2nd International Conference

Global Warming and the Human-Nature Dimension in Siberia

Social Adaptation to the Changes of the Terrestrial Ecosystem, with an Emphasis on Water Environments

to be held and co-organized with the

7th Annual International Workshop

C/H_2O/Energy balance and climate over boreal and arctic regions with special emphasis on eastern Eurasia

8-11 October, 2013

Lecture Hall, National Academy of Republic,Yakutsk,Russia

Organized by

Institute for Biological Problems of Cryolithozone (IBPC)

and

Research Institute for Humanity and Nature (RIHN)

PROCEEDINGS

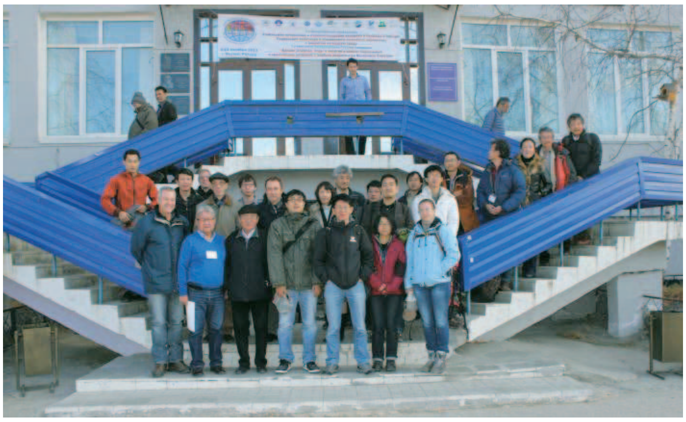
of 2nd International Conference

"Global Warming and the Human-Nature Dimension in Siberia: Social Adaptation to the Changes of the Terrestrial Ecosystem, with an Emphasis on Water Environments"

and the 7th Annual International Workshop

"C/H_2O/Energy balance and climate over boreal and arctic regions with special emphasis on eastern Eurasia"

8-11 October, 2013
Yakutsk, Russia



CONTENTS

III CLIMATIC RESPONSES OF CARBON, WATER AND ENERGY CYCLES IN NORTHERN ECOSYSTEMS

PREFACE

Let me, on behalf of the steering committee of the second international conference and the 7th international workshop, welcome you in Russia, in the Republic of Sakha (Yakutia), in our homeland - the Sacred Land of Olonkho!

I would like to take the liberty to say that this severe land of Olonkho became a second homeland for you, because you devoted almost half of your life to the study of this Land, where you are conducting your routine field and laboratory research, analyze and process the data obtained here.

We all know that creative workers, that all scientists are, have no rest. The scientific imagination and scientific interpretation do not give us free time to spend neither in the light of the day nor in the dark of the night. We are all familiar with the effect of adrenaline rush after obtaining valid and reliable research results, after well-articulated assumptions, concepts and hypotheses.

This scientific event is a remarkable and is timed to the 60th anniversary since starting field experimental studies on the forest station "Spasskaya Pad" of the Institute for Biological Problems of Cryolithozone of Siberian Branch of Russian Academy of Sciences (IBPC SB RAS). 60 years ago, scientists from Institute of Forest and Forestry, graduates and students from Moscow State University and Leningrad Forestry Academy established experimental plots in the forests of different formational and typological structure. Silviculture, hydroclimatological, zoological and forest resource studies have been commenced. At that time, the Institute of Forest and Forestry had been in Moscow and Director of these Institute was Vladimir Nikolayevich Sukachev. Forest Research Station for over 40 years operated under the above-mentioned institution, until 1991, when the station was transferred to IBPC SB RAS. And from that moment Spasskaya Pad got a second wind, well received by Russian academicians Alexandr Isaev, Evgeny Vaganov and other professors and heads of several departments from Institute of Forest. And we are very glad and cordially proud by that fact.

Dear colleagues, anniversaries have both altruistic and, its antonym, egoistical aspects. First, it is necessary to mark anniversaries, as a tribute to our predecessors, and it is our sacred duty. The second is egoistical. We stand on the shoulders of our predecessors and see what once had been and want to see what would happen in future. Here, I want to mention the names of our parents and teachers from the cohort of the great scientists. This Russian scientists - corresponding member of RAS, professor Nikita Solomonov, professors Boris Ivanov and Rostislav Kamensky, Japanese Professors Masami Fukuda, Kunihide Takahashi, Gen Inoue, Yoshihiro Fukushima, Tesuzo Yasunari, Tetsuo Ohata, European Professors Han Dolman, Martin Heimann, Terry Callaghan and Hans Hubberten. The English have a very good saying "We are all in the same boat ». We are inspired with ideas of our leaders embarked on a long-term independent voyage to the new and the unknown, where there is a friendly understanding and constructive cooperation. We shared together and share will all our joys and mishaps.

For more than 20 years of joint cooperation, We, together with the leaders of the second generation, Professors Takeshi Ota, Atsuko Sugimoto, Tetsuya Hiyama, with Doctors Ko van Huissteden and Eddy Moors done a great scientific and managing work. Under more than 30 international research projects on global climate change with 14 countries on the basis of forest research station "Spasskaya Pad" of IBPC RAS, a unique international system of monitoring changes in climate and biogeochemical parameters of permafrost ecosystems SakhaFluxNet has been established with additional three research stations in representative forest, tundra and permafrost tundra biomes. The Russian-Dutch tundra station "Chokurdakh" (Project PIN MATRA, since 2003), the Russian-Japanese research stations "Elgeeii" (project RIHN, since 2009) and "Kodac" (Grene Tea project, since 2012) in the highly productive forest and tundra ecosystems of eastern Siberia, respectively. These SakhaFluxNet stations are a part of a greater global networks Global Carbon, EuroFlux and AsiaFlux. It is encouraging that by the number of research stations, we are far ahead of other regions of Russia and have no analogues. All of these stations operate on the same common methodology and protocols. Currently, the network of SakhaFluxNet stations is expanding, as we speak, both in terms of coverage area and the number of parameters studied - cosmic, geological, physical, mathematical, biological and social.

Results of many years of our research are reflected in the four monographs issued in Russia and in Europe, over 60 articles published in peer reviewed journals with high impact factors of up to 14 (Nature Climate Change and Tree Physiology), released in the special issue of a top journal on Meteorology "Argicultural and Forest Meteorology», produced two special issues on Hydrology in EcoHydrology Journal and Arctic Research in Journal of Polar Sciences. We have organized more than 60 international conferences, symposia and meetings on climate change and biogeochemical cycles in different countries of the world.

The Russian liaison office of the Global Centre of Excellence (GCOE) of the University of Hokkaido at the Institute for Biological Problems of Cryolithozone of Siberian Branch of Russian Academy of Sciences and the International Center BEST (Biogeosciences Educational and Scientific Training) on climatology and biogeochemistry at the Institute for Natural Sciences of North Eastern Federal University have been created on the basis of the research station "Spasskaya Pad" for consolidation of world science and Russian education. As part of this, this innovation centers BEST conduct basic and special courses, short courses on research station "Spasskaya Pad" and laboratory biogeochemistry courses at the University of Hokkaido for senior students and young scientists. We thank Hokkaido University and namely Professor Atsuko Sugimoto for conceivable assistance and supporting in academic exchange and education field.

Dear colleagues, let me wish you fruitful work, wide-ranging discussion and lots of enjoy during your time in the city of Yakutsk. We wish you the new achievements and new discoveries! Be daring and go for it!

Trofim Maximov, Dr.Sci.
Chair of Steering Committee

PURPOSE

Global warming will likely transform Siberian environments. Early evidence indicates that carbon and hydrologic cycles are undergoing rapid change, with potentially severe impacts on Siberian flora and fauna. Human populations, which have adapted to great changes in social structure and environment in the past, will be forced to adapt again, but in this case to an unprecedented sequence of cascading environmental changes.

In 2013 we commemorate 60 years since starting field experimental works at the scientific station "Spasskaya Pad" of IBPC SD RAS. At present, the station is rightfully considered to be a regional research outpost on the study of environmental and global climate changes in the cryolithozone.

This conference will examine three aspects of climate-related environmental change:

1) Current and likely future variations in water and carbon cycles;
2) Ongoing field observations and modeling studies of the effects of carbon and hydrologic variability in Eastern Siberian landscapes, and key feedbacks, exchanges and driving forces associated with these effects;
3) The distinct social-economic impact of climate change on multi-ethnic Siberian societies, and their potential capabilities for adaptation to projected changes in climate and terrestrial ecosystems.

Key themes:

a) Physical and plant physiological processes of C/H2O/Energy cycles in Siberian ecosystems;
b) Forest and tundra ecosystem structure related to C/H2O/Energy cycles;
c) Permafrost / cold climate processes and their impacts on C/H2O/Energy cycles;
d) Usage of satellite remote sensing techniques and the development of C/H2O/Energy cycle models;
e) Interaction between wild/domesticated animals and terrestrial vegetation;
f) Vulnerabilities of landscapes, human subsistence systems, and infrastructures in permafrost areas;
g) Ethnographic accounts of human-nature relations in conjunction with climate change
h) Local knowledge of, adaptations to, and policies for responding to the changing climate;
i) Research status, cooperative arrangements, and plans for the future.

Sessions:

S1 – Plenary session – Global features of climate changes in the northern ecosystems
S2 – Human-nature interactions in a changing climate
S3 – Climatic responses of carbon, water and energy cycles in the northern ecosystems
S4 – Biological processes during climatic changes
S5 – Remote sensing & modeling for eco-climatic monitoring
S6 – Climatic vulnerabilities of permafrost

Organizing Committee:

Trofim MAXIMOV, IBPC & NEFU, RUSSIA
Takeshi OHTA, GSBS, NU, JAPAN
Tetsuya HIYAMA, RIHN, JAPAN
Atsuko SUGIMOTO, FEES, HU, JAPAN
Maxim TROFIMOV, SCSIP, RUSSIA
Evgeniya MIKHAYLOVA, NEFU, RUSSIA
Vanda IGNATIEVA, IHRNIPB, RUSSIA
Sardana BOYAKOVA, IHRNIPB, RUSSIA
Han DOLMAN, VUA, THE NETHERLANDS
Eddy MOORS, WUR, THE NETHERLANDS
Alexander KONONOV, IBPC & NEFU, RUSSIA
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- **Tuesday 8 October 2013**

► Lecture Hall, National Academy of Republic of Sakha (Yakutia).
2nd floor, Build. 33, Lenin Ave., Yakutsk

09:30 **[Opening ceremony]**
Trofim MAXIMOV (IBPC SB RAS, Leader of Projects from Russian side, Russia)
Opening speech
Mikhail LEBEDEV (Chairman of YSC SB RAS, Russia)
Welcoming speech
Tetsuya HIYAMA (RIHN, Project Leader, Japan)
Welcoming speech
Vasiliy VASILYEV (Vice-rector of NEFU, Russia)
Greetings from North-Eastern Federal University

[Session 1, Plenary]
GLOBAL FEATURES OF CLIMATE CHANGES IN THE NORTHERN ECOSYSTEMS
Chaired by Trofim MAXIMOV

10:00 Tetsuya HIYAMA (RIHN, Project Leader, Japan)
Global warming and changes in Siberian terrestrial environments

10:30 Andrey DEGERMENDZHI, Sergey BARTSEV (Institute of Biophysics, Russia)
Comparison of "biosphere-climate" global small-scale model and regional Siberian ecosystem models in studies of greenhouse effect mechanism

11:15 Nikita SOLOMONOV (IBPC, RAS Corresponding Member, Counsellor, Russia)
Global warming and bioecological effects in Yakutia – the coldest region of Siberia

11:45 Atsuko SUGIMOTO (Hokkaido University, RIHN Core Member, Japan)
Research activities on Arctic ecosystem of Indigirka lowland in eastern Siberia

12:15 Rikie SUZUKI (JAMSTEC, Japan)
Recent studies on vegetation in boreal regions by remote sensing

[Continuation of Session 1]

Chaired by Sergey BARTSEV

14:00 Trofim MAXIMOV (IBPC, Russia)
Permafrost-dominated ecosystems in a changing climate

14:30 Alexander FEDOROV (MPI SB RAS, Russia)
Features of cryogenic landscape's reactions on recent climate changes in Eastern Siberia

15:00 Pavel VORONIN (Plant Physiology Institute RAS, Russia)
Continental climate limitation for photosynthetic gas-exchange of main tree species in Siberia

[Keynote session]

Chaired by Tetsuya HIYAMA

15:45 Liliya VINOKUROVA, Sardana BOYAKOVA (IHRNIPB SB RAS, Russia)

Keynote speech for Session 2 [Human-nature interactions in a changing climate]

Climate change consequences in Yakutia: social and economic challenges for rural communities

16:10 Ayumi KOTANI (Nagoya University, Japan)

Keynote speech for Session 3 [Climatic responses of carbon, water and energy cycles in northern ecosystems]

Net ecosystem water use efficiency over two larch forest at eastern Siberia

16:35 Nikolay GERMOGENOV, Nikita SOLOMONOV, Zakhar BORISOV, Kirill SOLOMONOV (IBPC SB RAS, NEFU, Russia)

Keynote speech for Session 4 [Biological processes during climatic changes]

Dynamics of terrestrial vertebrate animal population in Central Yakutia in the last 150 years under climate change and increasing anthropogenic pressure

17:00 Takeshi YAMAZAKI (Tohoku University, Japan)

Keynote speech for Session 5 [Remote sensing & Modeling for eco-climatic monitoring]

Long-term simulation of soil condition and energy flux in eastern Siberian taiga forests

17:25 Yoshihiro IIJIMA (JAMSTEC, Japan)

Keynote speech for Session 6 [Climatic vulnerabilities of permafrost]

Spatio-temporal variations in permafrost and boreal forest degradations in Central Yakutia

19:00 **[Reception]**

@ Restaurant of Yakutian Food "Muus Khaya", Build. 16, Oyunskogo street, Yakutsk.

- **Wednesday 9 October 2013**

► Conference Hall of Mining Institute of the North SB RAS. 2nd floor, Build. 43, Lenin Avenue, Yakutsk.

[Session 2]

HUMAN-NATURE INTERACTIONS IN A CHANGING CLIMATE

Chaired by Liliya VINOKUROVA

09:00 Nikita SOLOMONOV, Roman DESYATKIN, Anatoly GOGOLEV, Viktor NOGOVITSIN (IBPC SB RAS, NEFU, Russia)

Dynamics of permafrost ecosystems and evolution of human populations in Central Yakutia during the Late Pleistocene and the Holocene

09:25 Sardana BOYAKOVA (IHRNIPB SB RAS, Russia)

Assessment of the impact of climate change on transport infrastructure Yakutia

09:50 Fuyuki EBATA (Niigata University, Japan)

The nature words in Sakha, compared with other Turkic languages

10:15 Viktoriya FILIPPOVA (IHRNIPB SB RAS, Russia)
Adaptation to extreme impacts of climate change: the experience of the villages of Yakutia

10:55 Tuyara GAVRILIEVA, Igor CHIKACHEV (NEFU, Russia)
Features of adaptation of the Russkoye Ustye community to the ecosystem of the Indigirka River estuary

11:20 Tohru IKEDA (Hokkaido University, Japan)
Transformation of furbearer hunting in Yakutia

11:45 Svetlana KNYAZEVA (UNESCO Institute for Information Technologies in Education, Russia)
UNESCO project: A Networked System of Open Indigenous Knowledge Resources for Climate Change Mitigation and Adaptation in Polar Regions

12:10 Yukari NAGAYAMA (Hokkaido University, Japan)
Indigenous Weather Knowledge in Kamchatka

12:35 Yuka OISHI (Tokyo Metropolitan University, Japan)
Reindeer herding of Northern Khanty and forest Nenets in the post-soviet era

[Continuation of Session 2]
Chaired by Sardana BOYAKOVA

14:00 Vyacheslav SHADRIN (IHRNIPB SB RAS, Russia)
The peoples of the North Yakutia: the historical experience of adaptation to climate change in the XVIII - XIX centuries (on historical and folkloric materials)

14:25 Mikhail VASILIEV (ICRA SB RAS, Russia)
Impact of human activity on forest fires

14:50 Atsushi YOSHIDA (Chiba University, Japan)
Reindeer herding and Environmental Change in the Kobyai and Olenek districts, Sakha Republic

15:15 Yuriy ZHEGUSOV (IHRNIPB SB RAS, Russia)
Yakutian residents' daily observations of aquatic environment changes in the context of global warming (according to the sociological survey)

15:40 **[General Discussion on the results of session 2]**
<closure at 16:30, move to IBPC for Poster Session>

- **<u>Wednesday 9 October 2013</u>**

► Conference Hall of IBPC SB RAS. 1st floor, Build. 41, Lenin Avenue, Yakutsk.
[Session 3]
CLIMATIC RESPONSES OF CARBON, WATER AND ENERGY CYCLES IN NORTHERN ECOSYSTEMS
Chaired by Atsuko SUGIMOTO

09:00 Tetsuzo YASUNARI (Director of RIHN, Japan)
Interannual variation of summer hydro-climate in East Asia

09:25 Sara LIVSHITS (IOGP SB RAS, Russia)

Flows of hydrocarbons in the northern ecosystems and their influence on the state of the contemporary climate

09:50 Ryuhei YOSHIDA, Masahiro SAWADA, Takeshi YAMAZAKI, Takeshi OHTA and Tetsuya HIYAMA (RIHN, Japan)

Estimation of regional water cycle changes by various land-cover-change scenarios in eastern Siberia

10:15 Taro NAKAI (Nagoya University, Japan)

Characteristics of energy balance within a permafrost black spruce forest in interior Alaska for the intercomparison study with a larch forest in eastern Siberia

10:55 Eddy MOORS et al. (Wageningen University, Netherlands)

Spatial patterns of precipitation in Siberia: Where does the snow comes from?

11:20 Yoshihiro TACHIBANA (JAMSTEC, Japan)

Climatological features of atmospheric and terrestrial water cycles in the three great Siberian rivers and their interannual variations

11:45 Aleksey DESYATKIN (IBPC SB RAS, Russia)

Carbon budget of thermokarst depression on example of Ulakhan-Sukkhan alas

12:10 Oleg MIKHAYLOV, Svetlana ZAGIROVA (Institute of Biology, Komi Science Centre, Russia)

The ecological factors impact on methane fluxes in the ecosystem of meso-oligotrophic peatland

12:35 Aytalina EFIMOVA (IBPC SB RAS, Russia)

Catastrophic floodings on the Alazeya River valley (North-East Yakutia) as a consequence of the air temperatures increasing

[Continuation of Session 3]

Chaired by Ayumi KOTANI

14:00 Alexander KONONOV (IBPC SB RAS, Russia)

Interannual variations of soil CO2-efflux in larch forests of Central and South-Eastern Yakutia

14:25 Kynney KIRILLINA (NEFU, Russia)

Climate change in Yakutia during XX-XXI centuries

14:50 Anastasiya TIMOKHINA (Institute of Forest SB RAS, Russia)

The temporal variability of atmospheric CO2 over middle taiga ecosystems in central Siberia from 2006 to 2012 years

15:15 Vadim STARODUBTSEV (ICRA SB RAS, Russia)

Methane concentration measurements in surface air (Polar Geocosmophysical Observatory – PGO Tiksi)

15:40 Roman PETROV (IBPC SB RAS, Russia)

Energy budget investigations of the Central Yakutian larch forests using eddy covariance technique

16:05 **[General Discussion on the results of session 3]**

16:45 **[Poster session] – Front Space of the IBPC Lecture Hall**

- **Thursday 10 October 2013**

► Conference Hall of IBPC SB RAS. 1st floor, Build. 41, Lenin Avenue, Yakutsk.

[Session 4]

BIOLOGICAL PROCESSES DURING CLIMATIC CHANGES

Chaired by Ayaal MAKSIMOV

09:00 Innokentiy OKHLOPKOV (IBPC SB RAS, Russia)
Mammal species in Yakutia as possible global climate change indicators

09:25 Alexandr ISAEV (IBPC SB RAS, Russia)
Aboveground biomass of sparse larch forests on tree line (North-East Siberia)

09:50 Yuri ROZHKOV (Olekminsky state nature reserve, Russia)
Features of biological activity of frozen soil Olyekmisky reserve (zapovednik)

10:15 Shirow TATSUZAWA (Hokkaido University, Japan)
5 years corporative study of reindeer migration: its result and prospect

10:55 Anatoliy NIKOLAEV (NEFU, Russia)
Features of trees radial growth in conditions of criolithozone

11:20 Valentina SOFRONOVA (IBPC SB RAS, Russia)
Down regulation of PSII efficiency in sun exposed assimilating branchlets of Ephedra monosperma during autumn cold hardening

11:45 Irina DRANAEVA (NEFU, Russia)
Steady and adaptive approach to the study of biodiversity and the preservation of the environment

12:10 Tatiana IVANOVA (IBPC SB RAS, Russia)
Effect of radioactive contamination of Yakutia over microflora of cryogenic soils

12:35 Marina TERENTYEVA (IBPC SB RAS, Russia)
Eco-physiological peculiarities of photosynthesis of Larix cajanderi in Siberian larch forest

[Continuation of Session 4]

Chaired by Alexander KONONOV

14:00 Tatiana TATARINOVA et al. (IBPC SB RAS, Russia)
Dehydrins associated with extreme frost hardiness of Betula platyphylla in Central Yakutia

14:25 Alexandra POPOVA, Atsuko SUGIMOTO, N. TOKUCHI, Trofim MAXIMOV (BEST Center, NEFU, Russia)
Study on N use by larch in the north-eastern Siberia boreal forest using tracer 15N

14:50 Ayaal MAKSIMOV (IBPC SB RAS, Russia)
Photosynthesis of larch at different permafrost areas: case study of Canada and Yakutia

15:15 Tatiana SIVTSEVA (NEFU, Russia)
The role of forest ecosystems and cultivated land of Yakutia in carbon budget in Kyoto protocol

15:40 Evgeniya VARLAMOVA et al. (ICRA SB RAS, Russia)
Research of multiannual dynamics of leaf area index in Eastern Siberia

16:05 Nadezhda DANILOVA (IBPC SB RAS, Russia), Polina PAVLOVA (IBPC SB RAS, Russia), Natalia IVANOVA (NEFU, Russia)
Introduction of Iris cetosa in Central Yakutia

17:00 **[General Discussion on the results of session 4]**

17:50 **[Closing ceremony]**
Tetsuya HIYAMA (concluding remarks)
Trofim MAXIMOV (closing address)
Tetsuzo YASUNARI (closing address)

- **Thursday 10 October 2013**

► Conference Hall of Mining Institute of the North SB RAS. 2nd floor, Build. 43, Lenin Avenue, Yakutsk.

[Session 5]
REMOTE SENSING & MODELING FOR ECO-CLIMATIC MONITORING
Chaired by Takeshi YAMAZAKI

09:00 Shamil MAKSYUTOV, V. SEDYKH (National Institute for Environmental Studies, Japan)
Forest mapping with remote sensing data in Laryegan basin

09:25 Victor BROVKIN (Max Planck Institute for Meteorology, Germany)
Climate-vegetation feedbacks in high latitudes in Earth System Models

09:50 Yasushi YAMAGUCHI (Nagoya University, Japan)
Comparison of vegetation changes in Siberia detected by SPOT-vgt and MODIS data

10:15 Vladimir SOLOVIEV (ICRA SB RAS, Russia)
Forest fire detection and monitoring system in Yakutia based on remote sensing data

10:55 Boris BORISOV (IBPC SB RAS, Russia)
Usage of DHI-index in mapping of biodiversity of terrestrial mammals in Yakutia

11:20 Thomas KLEINEN (Max Planck Institute for Meteorology, Germany)
Modelling organic soils and their role in the carbon cycle

11:45 Oleg TOMSHIN (ICRA SB RAS, Russia)
Studying of forest fires influence on lower atmosphere on remote sensing data

12:35 **[General Discussion on the results of Session 5]**

[Session 6]
CLIMATIC VULNERABILITIES OF PERMAFROST
Chaired by Yoshihiro IIJIMA

14:00 Alexander CHEVYCHELOV (IBPC SB RAS, Russia)
Pyrogenesis and evolution of frozen soils

14:25 Ho-Teak PARK (JAMSTEC, Japan)
Simulating the contribution of snow conditions to permafrost climate

14:50 Pavel KONSTANTINOV (MPI SB RAS, Russia)
Influence of soil moisture and snow cover on the thermal state of permafrost in Central Yakutia

15:15 Oleg TREGUBOV (NEISRI FEB RAS, Russia)
Seasonal thawing dynamics as tundra soil moisture regime changing factor and vegetation transformation factor

15:55 Makoto OKUMURA (IRIDeS, Tohoku University, Japan)
Vulnerability of Infrastructure based on Physical Characteristics of Ice

16:20 Go IWAHANA (University of Alaska, USA)
Cryostratigraphy and water stable isotope profiles of the active layers and the upper permafrost layers near Yakutsk, Eastern Siberia, Russia

16:45 Leonid GAGARIN (MPI SB RAS, Russia)
Dynamics of thermal-suffusion processes on the Bestyakhskaya terrace of the Lena river, Central Yakutia

17:10 Matrena OKONESHNIKOVA, Roman DESYATKIN (IBPC SB RAS, Russia)
Soil of Larch forests in "Spasskaya Pad" and "Elgeeyi" stations

<closure at 17:35 and move to IBPC for Closing ceremony>

- **Friday 11 October 2013**

[Excursion to Spasskaya Pad Scientific Station]

- **9 October 2013 at 16:45-18:00 and 10 October 2013 at lunch-time.**

[Poster presentations]

► Front Space of the IBPC Lecture Hall

P01 Sargylana BORISOVA (IBPC SB RAS, Russia)
Preservation and restitution of natural vegetation of Yakutia

P02 Zakhar BORISOV (IBPC SB RAS, Russia)
Condition of protection of flora of the Arctic Yakutia in protected territories

P03 Sardana BOYAKOVA, T. Maximova (IHRNIPB SB RAS, Russia)
Folk meteorology of Yakuts: history and modernity.

P04 Inga BYSYKATOVA (IBPC SB RAS, Russia)
Expansion of Sandhill Crane in Northeast Asia

P05 Lyudmila GABYSHEVA (IBPC SB RAS, Russia)
Changes of microclimatic and soil conditions after forest fires in Central Yakutia

P06 Angelina EGOROVA (IBPC SB RAS, Russia)
Flora of Kytalyk resource reserve (Arctic Yakutia)

P07 Vanda IGNATIEVA (IHRNIPB SB RAS, Russia)
The Evolution of Climate and Economy: the Presentation, Opinions and Estimates Horse Breeders of Yakutia

P08 Alexandra IVANOVA (IBPC SB RAS, Russia)
Degradation of permafrost soils of the Alaseya River valley due to flood inundation

P09 Masaru KAGATSUME (Kyoto University, Japan)
Effects of Global Warming on the Reindeer Nomads Economies and Their Adjustments after Restructuring of Government System - the approach by the System Dynamics model

P10 Yuji KODAMA (National Institute of Polar Research, Japan)
Recent Japanese activity in Arctic Environment Science.

P11 Stanislav KSENOFONTOV (IBPC SB RAS, Russia)
Climate change impacts to rural Yakutia

P12 Atsushi NAKADA (Hokkaido Museum of Northern Peoples, Japan)
Reindeer herders and Environmental Change in the Oimyakon district, Sakha Republic

P13 Takeshi OHTA (Nagoya University, Japan)
Interannual variations of water and carbon balances affected by the change in annual precipitation in an eastern Siberian larch forest during the 1998 – 2011 year.

P14 Atsushi SAITO (Nagoya University, Japan)
Interannual change of latent fluxes from overstory and understory with environmetal changes at the Larch forest in the East Siberia

P15 Toru SAKAI (RIHN, Japan)
The impact of flood over the Lena river

P16 Peter SOBAKIN (IBPC SB RAS, Russia)
The role of pyrogenic and cryogenic processes in 137Cs migration in cryotic soils of Central Yakutia

P17 Vera ZAKHAROVA, Nikolay KARPOV (IBPC SB RAS, Russia)
Monitoring of vegetation on mountain mining in Arctic Yakutia

P18 Ivan CHIKIDOV (IBPC SB RAS, Russia)
Change of vegetation in larch forest after mass outbreak of the Dendrolimus superans sibiricus Tschetv.

P19 Maya NIKOLAEVA (IBPC SB RAS, Russia)
Dynamics of spatial structure of alas at change of a climate

P20 A.I. KOLMOGOROV, A.N. NIKOLAEV (NEFU, Russia)
Dendrochronological research in the Nizhnekolymskiy region

Global warming and changes in Siberian terrestrial environments

Tetsuya HIYAMA[1], Toru SAKAI[1], Shamil MAKSYUTOV[2], Heonsook KIM[2], Takahiro SASAI[3], Yasushi YAMAGUCHI[3], Atsuko SUGIMOTO[4], Shunsuke TEI[4], Takeshi OHTA[5], Ayumi KOTANI[5], Kazukiyo YAMAMOTO[5], Takeshi YAMAZAKI[6], Kazuhiro OSHIMA[7], Hotaek PARK[7], Trofim C. MAXIMOV[8], and Alexander N. FEDOROV[9]

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9 Melnikov Permafrost Institute, Merzlotnaya street, 36, Yakutsk 677010, RUSSIA

Key words: water cycle, carbon cycle, Siberia, unsymmetrical pattern, annual maximum thawing depth (AMTD)

Introduction

Siberian environments are likely being transformed by global warming. Early evidence indicates that the water and carbon cycles in eastern Siberia are undergoing rapid change (e.g., Ohta *et al.*, 2008; Iijima *et al.*, 2010; Hiyama *et al.*, 2013b), as suggested by the high levels of precipitation from 2005 to 2008. The Lena River basin in eastern Siberia is covered with larch forest and generally receives little precipitation. However, the forest - permafrost symbiosis (Zhang *et al.*, 2011) was extremely susceptible to the abnormal variations in precipitation that occurred from 2005 to 2008. As natural science researchers of the RIHN Siberia (C-07) project, we have tried to reveal, with special emphasis on water environments, how the forest - permafrost symbiosis in eastern Siberia has responded to climate change. We have also attempted to explore the contrasts in climatology for eastern and western Siberia through the past few decades.

Approaches

Regional climate in Siberia is based on energy and water exchanges, and particularly on changes in the surface reflectance of snow, ice, and vegetative cover. Such changes need to be continuously monitored for as long as possible. We commenced monitoring of energy and water exchanges between larch forest and the atmosphere in 1998 at Yakutsk, in the middle region of the Lena River basin (Ohta *et al.*, 2001). This monitoring revealed that the region has suffered from extraordinarily high precipitation in late summer to winter from 2005 to 2008 (Ohta *et al.*, 2008; Iijima *et al.*, 2010; Hiyama *et al.*, 2013b).

For the purposes of the RIHN Siberia (C-07) project, we have used our own monitoring data (Ohta *et al.*, 2001; Ohta *et al.*, 2008), satellite remote sensing information, Global Precipitation Climatology Project (GPCP) one-degree daily resolution precipitation records (Huffman *et al.*, 2001), and atmospheric reanalysis JRA-25/JCDAS figures (Onogi *et al.*, 2007). We have also conducted dendro-climatological analysis of tree-ring widths and carbon isotope ratio ($\delta^{13}C$) studies of several larch trees taken from around eastern Siberia. Additionally, we have revised permafrost - ecosystem models (Yamazaki *et al.*, 2004, 2007; Sasai *et al.*, 2005, 2011; Park *et al.*, 2011) to better represent the energy, water, and carbon fluxes in permafrost ecosystems.

Major Results

High levels of precipitation in the Lena River basin, eastern Siberia, from 2005 to 2008 led to tremendous changes in the terrestrial environments. The increase in winter precipitation enhanced the probability of spring flood, and riparian regions experienced more extreme and unparalleled floods in 2007. The ecohydrological changes observed include a deepening and moistening of the active layer, hindrance of tree growth (Tei *et al.*, 2013), and expansion of water surfaces due to the melting of ground ice (Fedorov *et al.*, 2013). The anomalously wet condition of forest soils caused larch trees to wither at our forest monitoring site (Hiyama *et al.*, 2013b) in the middle part of the basin. However, an analysis of satellite data revealed that such tree withering occurred only at certain scales.

Based on our permafrost - ecosystem models (Yamazaki *et al.*, 2004, 2007; Park *et al.*, 2011), we have identified increases in thawing depth, surface soil moisture, and net primary production (NPP). The annual maximum thawing depth (AMTD) was revealed to have gradually increased (deepened) on a decadal scale. Increases in terrestrial water storage in the Lena River basin generated increases in river base flows during the open water (summer) season. Hydrological analysis indicated that between 1950 and 2008, the basin-scale AMTD in the region increased at an average rate of approximately 1 cm year^{-1} (Brutsaert and Hiyama, 2012). Because soil pore ice was found below the thawing depth around the region, melting ice could be contributing to summer river discharges (Hiyama *et al.*, 2013a). If recent global warming causes permafrost degradation in the region, it could produce changes in groundwater recharge - discharge relationships and the contribution from thawing permafrost to river low flows.

Moistening and warming of the surface soil could affect methane emissions from Siberian terrestrial ecosystems. Regional methane fluxes were estimated using an inversion model (Kim *et al.*, 2011) with data collected in Siberia from aircraft and tower measurements. In 2007 and 2008, enhanced methane fluxes from wetlands in western Siberia were estimated under relatively wet conditions and high temperatures. Remarkably, methane fluxes in western Siberia have gradually decreased since 2008; however, those in eastern Siberia have increased asymmetrically. Such an asymmetrical (seesaw) pattern between western and eastern Siberia has also been observed in carbon dioxide exchanges in terrestrial ecosystems. Gross primary production (GPP) and ecosystem respiration (ER) in the 2000s were estimated using our permafrost - ecosystem models (Sasai *et al.*, 2005, 2011), which showed a decreasing trend in western Siberia but an increasing trend in eastern Siberia. These differences were primarily due to differences in the trends of temperature and precipitation between the two regions.

Summary

One of the important research objectives of the RIHN Siberia (C-07) project is to reveal, with special emphasis on water environments, the climatological responses related to forest - permafrost symbiosis in Siberia. Because of the decadal variations in precipitation, the AMTD was revealed to have increased (deepened) gradually on a decadal scale. Such AMTD increase was detected as an increase in river base flows during the open water season.

Moistening and warming of surface soil has also affected methane emissions and carbon dioxide exchanges in Siberian ecosystems. An asymmetrical (seesaw) pattern of methane emissions and carbon dioxide exchanges between western and eastern Siberia in the 2000s was observed. Decadal climate change could mostly transform Siberian environments through such ecohydrological responses, which might result in feedbacks to global climate.

References

Brutsaert, W. and Hiyama, T., 2012. The determination of permafrost thawing trends from long-term streamflow measurements with an application in eastern Siberia. *Journal of Geophysical Research* **117**, D22110.

Fedorov, A.N., Gavriliev, P.P., Konstantinov, P.Y., Hiyama, T., Iijima, Y. and Iwahana, G., 2013. Estimating the water balance of a thermokarst lake in the middle of the Lena River basin, eastern Siberia. *Ecohydrology* doi:10.1002/eco.1378.

Hiyama, T., Asai, K., Kolesnikov, A.B., Gagarin, L.A. and Shepelev, V.V., 2013a. Estimation of residence time of permafrost groundwater in the middle of the Lena River basin, eastern Siberia. *Environmental Research Letters* **8**, 035040.

Hiyama, T., Ohta, T., Sugimoto, A., Yamazaki, T., Oshima, K., Yonenobu, H., Yamamoto, K., Kotani, A., Park, H., Kodama, Y., Hatta, S., Fedorov, A.N. and Maximov, T.C., 2013b. Changes in eco-hydrological systems under recent climate change in eastern Siberia. *IAHS Publication* **360**, 155-160.

Huffman, G.J., Adler, R.F., Morrissey, M., Bolvin, D.T., Curtis, S., Joyce, R., McGavock, B. and Susskind, J., 2001. Global precipitation at one-degree daily resolution from multi-satellite observations. *Journal of Hydrometeorology* **2**, 36-50.

Iijima, Y., Fedorov, A.N., Park, H., Suzuki, K., Yabuki, H., Maximov, T.C. and Ohata, T., 2010. Abrupt increases in soil temperatures following increased precipitation in a permafrost region, central Lena River Basin, Russia. *Permafrost and Periglacial Processes* **21**, 30-41.

Kim, H.-S., Maksyutov, S., Glagolev, M.V., Machida, T., Patra, P.K., Sudo, K. and Inoue, G., 2011. Evaluation of methane emissions from West Siberian wetlands based on inverse modeling. *Environmental Research Letters* **6**, 035201.

Ohta, T., Hiyama, T., Tanaka, H., Kuwada, T., Maximov, T.C., Ohata, T. and Fukushima, Y.,

2001. Seasonal variation in the energy and water exchanges above and below a larch forest in eastern Siberia. *Hydrological Processes* **15**, 1459-1476.

Ohta, T., Maximov, T.C., Dolman, A.J., Nakai, T., van der Molen, M.K., Kononov, A.V., Maximov, A.P., Hiyama, T., Iijima, Y., Moors, E.J., Tanaka, H., Toba, T. and Yabuki, H., 2008. Interannual variation of water balance and summer evapotranspiration in an eastern Siberian larch forest over a 7-year period (1998-2006). *Agricultural and Forest Meteorology* **148**, 1941-1953.

Onogi, K., Tsutsui, J., Koide, H., Sakamoto, M., Kobayashi, S., Hatsushika, H., Matsumoto, T., Yamazaki, N., Kamahori, H., Takahashi, K., Kadokura, S., Wada, K., Kato, K., Oyama, R., Ose, T., Mannoji, N. and Taira, R., 2007. The JRA-25 reanalysis. *Journal of the Meteorological Society of Japan* **85**, 369-432.

Park, H., Iijima, Y., Yabuki, H., Ohta, T., Walsh, J., Kodama, Y. and Ohata, T., 2011. The application of a coupled hydrological and biogeochemical model (CHANGE) for modeling of energy, water, and CO_2 exchanges over a larch forest in eastern Siberia. *Journal of Geophysical Research* **116**, D15102.

Sasai, T., Ichii, K., Nemani, R.R. and Yamaguchi, Y., 2005. Simulating terrestrial carbon fluxes using the new biosphere model "biosphere model integrating eco-physiological and mechanistic approaches using satellite data" (BEAMS). *Journal of Geophysical Research* **110**, G02014.

Sasai, T., Saigusa, N., Nasahara, K.N., Ito, A., Hashimoto, H., Nemani, R.R., Hirata, R., Ichii, K., Takagi, K., Saitoh, T.M., Ohta, T., Murakami, K., Yamaguchi, Y. and Oikawa, T., 2011. Satellite-driven estimation of terrestrial carbon flux over Far East Asia with 1-km grid resolution. *Remote Sensing of Environment* **115**, 1758-1771.

Tei, S., Sugimoto, A., Yonenobu, H., Hoshino, Y. and Maximov, T.C., 2013. Reconstruction of summer Palmer Drought Severity Index from $\delta^{13}C$ of larch tree rings in East Siberia. *Quaternary International* **290-291**, 275-281.

Yamazaki, T., Yabuki, H., Ishii, Y., Ohta, T. and Ohata, T., 2004. Water and energy exchanges at forests and a grassland in eastern Siberia evaluated using a one-dimensional land surface model. *Journal of Hydrometeorology* **5**, 504-515.

Yamazaki, T., Ohta, T., Suzuki R. and Ohata, T., 2007. Flux variation in a Siberian taiga forest near Yakutsk estimated by a one-dimensional model with routine data, 1986-2000. *Hydrological Processes* **21**, 2009-2015.

Zhang, N., Yasunari, T. and Ohta, T., 2011. Dynamics of the larch taiga-permafrost coupled system in Siberia under climate change. *Environmental Research Letters* **6**, 024003.

Comparison of "Biosphere-Climate" Global Small-Scale Model and Regional Siberian Ecosystem Models in Studies of Greenhouse Effect Mechanism

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Key words: small-scale biosphere model, ecosystem-climate feedbacks, permafrost bomb

Introduction

To forecast response of the biosphere and regional ecosystems to observed and expected climate change in different scenarios of man-made impact is a fundamental problem with obvious practical significance. Fundamental non-linearity of the climate system and biosphere focuses attention on feasibility of implementing multiple states and threshold processes in the biosphere-climate system (BCS) in response to impulse impact (volcano eruption, destructive logging, etc.) or uniformly growing disturbing impact, e.g. man-made carbon dioxide emission. As an example, presently observing pause in global temperature growth is considered as a result of switching the climate system (MetOffice, 2013). Another possible variant of non-linearity manifesting is threshold irreversible response to gradual increasing of global temperature. This effect was discovered caused by positive feedback: existence of an "irreversibility date" after which even if fuel combustion stops, the climate warming will persist because of the additional oxidation of soil organics (Bartsev, Degermendzhi, Erokhin, 2008). Special attention shall be paid to assessing the contribution into global dynamics of the tundra ecosystems because huge deposits of organic carbon in permafrost soils (~1000 Gt) together with increased rates of climate change in these regions can launch a potentially dangerous feedback that can cause a considerable influence on the rates of global changes. The aim of this work is to consider the most unfavorable possible consequences of the incorporation of processes occurring in permafrost ecosystems into global dynamics require.

Small-scale models description

In accordance with the principle of the worst scenario (Bartsev, Degermendzhi, Erokhin, 2008) two small-scale models were built. The original small-scale model of the biosphere-climate system (BCS) includes an integrated description of the contents dynamics of carbon forms in the terrestrial ecosystem, ocean and atmosphere. The small biological role of the ocean in the seasonal planetary dynamics of CO_2 was shown due to the high rates in "autotroph-heterotroph" ecological oceanic system at relatively small mass (~3 Gt) of plankton. The model was modified for evaluating aerosols contribution to temperature changes and accounting contribution of permafrost ecosystems. The basic (i.e. without permafrost part) model (Eq.1) consists of carbon circulation block and one equation on the increment of global temperature:

$$\begin{cases} \dfrac{dA}{dt} = v_s f_s(T)Y + m(T)c_{fU}B - p(X,A,T)X - c_{aD}A + e(t) \\ \dfrac{dX}{dt} = p(X,A,T)X - v_d X \\ \dfrac{dY}{dt} = v_d X - v_s f_s(T)Y \\ \dfrac{dB}{dt} = c_{aD}A + c_{dU}U - \left[c_{fD} + m(T)c_{fU}\right]B \\ \dfrac{dU}{dt} = c_{fD}B - c_{dU}U \\ \mu\dfrac{d(\Delta T)}{dt} = r(A) + k_A f_A(t) + f_B \Delta T \\ T = T_0 + \Delta T \end{cases} \qquad \text{(Eq.1)}$$

$$p(X,A,T) = v_p(X_{\max} - X) f_p(T)\frac{A}{K_{0.5} + A}$$

$$r(A) = r_0 \ln\left(\frac{A}{A_0}\right) \qquad f_i = \begin{cases} T^d(T_{\max} - T) \\ 0, T < 0 \\ 0, T > T_{\max} \end{cases}$$

$$m(T) = e^{k_s(T - T_0)}$$

where A – carbon in atmosphere; X – carbon in biomass of terrestrial plants; Y – carbon in soil organic matter; B – carbon in upper layer of ocean; U – carbon under thermo cline; T – global surface temperature; ΔT – equilibrium temperature increment; v_i and c_j – corresponding coefficients; $p(X,A,T)$ – biomass growth rate function; $r(A)$ – forcing; $m(T)$ – CO_2 release function; $e(t)$ – CO_2 emission; $f_A(t)$ – empirical and predicted aerosols concentration; f_B – temperature feed-back coefficient.

It is easy to see that total amount of carbon in the model is constant value unless external carbon emission into the system takes place.

To consider the worst possible consequences of tundra and boreal forest regions warming a simple model of permafrost soil with internal positive feedback is added to Eq.1:

$$\begin{cases} \dfrac{dY_S}{dt} = -p_S(T_S)Y_S + p_0 Y_{S0} \\ \mu_S \dfrac{dT_S}{dt} = h_S p_S(T_S) - \lambda(T_S - T_a) \end{cases} \quad \text{(Eq.2)}$$

$$p_S(T_S) = c_S e^{\alpha(T_S - T_{ref})}$$

where Y_S – carbon in permafrost soil; T_S – permafrost soil temperature; Y_{S0} – initial carbon in permafrost soil; μ_S – permafrost soil heat capacity; h_S – soil respiration heat production; λ - heat conductivity; T_{ref} – some reference (initial) soil temperature.

This model is taken with minor changes from (Luke, Cox, 2011).

For fitting the models to known experimental data BCS simulator was developed in SciLab 5.4.1 – open (GPL-2 compatible license) software medium. Well known Nelder-Mead optimization algorithm was used for the minimization of the sum of squared deviations from the experimental data.

For model parameters fitting the data on global temperature, atmospheric CO_2 concentration and net carbon dioxide uptake by land and oceans (Ballantyne et al., 2012; Brovkin et al., 2002, 2004; Gregory et al., 2009; Fung et al., 2005) dynamics were used. Empirical data on and forecast of future trends of anthropogenic CO_2 emission (http://cmip-pcmdi.llnl.gov/cmip5/) and atmospheric aerosols concentration (http://www.iiasa.ac.at/web-apps/tnt/RcpDb) were also used.

In the model the following parameters were fixed: A_0=592, X_0=550, Y_0=2000, B_0=267.5, U_0=36730 (all in GtC), r_0=5.3W/m^2, OceanDiffusion=4.3 GtC/year, μ=31.8 (J m^{-2} ◦C^{-1}), μ_S=12.5 (J m^{-2}◦C^{-1}), k_S=0.0423 (C^{-1}) . All coefficients associated with rates of matter transformation - v_i and c_i were calculated to provide stationary state of BCS variables and total NPP flow equal to 65 GtC/year at the initial 1850 year as if no anthropogenic CO_2 emission take place. By that simulated dynamics is the response of initially stable BCS to anthropogenic impact. Other parameters of models were adjusted by fitting procedure.

Results

To evaluate possible effect of permafrost region warming first of all possible dynamics of global model at different but allowable parameter values has to be considered.

Fitting basic (Eq.1) model to empirical data shows essential discrepancy between them (Fig.1). Any variations of the model parameters to improve the fit were failed.

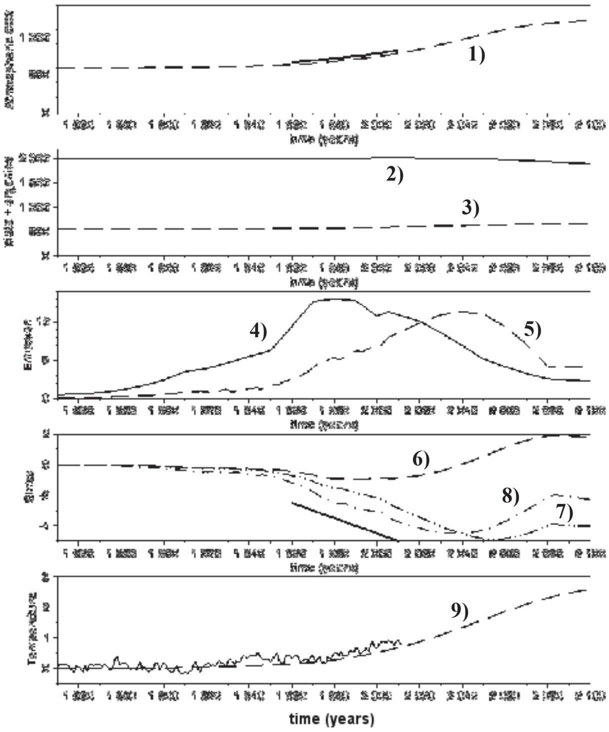

Fig.1. Discrepancy between the model and empirical data. Designations: 1 – atmospheric CO_2; 2 – soil carbon; 3 – carbon in vegetation; 4 – aerosols dynamics; 5 – CO_2 emissions (GtC/year); 6 – land carbon uptake (GtC/year); 7 – ocean carbon uptake (GtC/year); 8 – total carbon uptake (GtC/year); 9 – anomaly of global temperature. Solid lines near lines 1, 8, 9 represents empirical data. Recalculated climate sensitivity is 2.8^{o}C.

Analyses showed that there are some contradictions in the empirical data - the total carbon budget does not add up. To improve the balance we have suggested that data on CO_2 anthropogenic emission are under-estimated. Gradual increasing emission by additional 1.8 GtC allows balancing the flow of carbon.

In this case quite good agreement between the simulation and empirical data can be achieved (Fig.2 and Fig.3). These two figures demonstrate that observed empirical data can be described by models with essential difference in the key parameter – climate sensitivity to CO_2 doubling. It is possible due to very uncertain contribution of aerosols, and if shielding effect of aerosols is essential then high climate sensitivity can be masked.

However future BCS dynamics of these variants is dramatically different. On the figures the difference in the scenario looks like not essential, but the transformation of sinks into sources of carbon will lead to developing self sustain warming process described elsewhere (Bartsev, Degermendzhi, Belolipetsky, 2012).

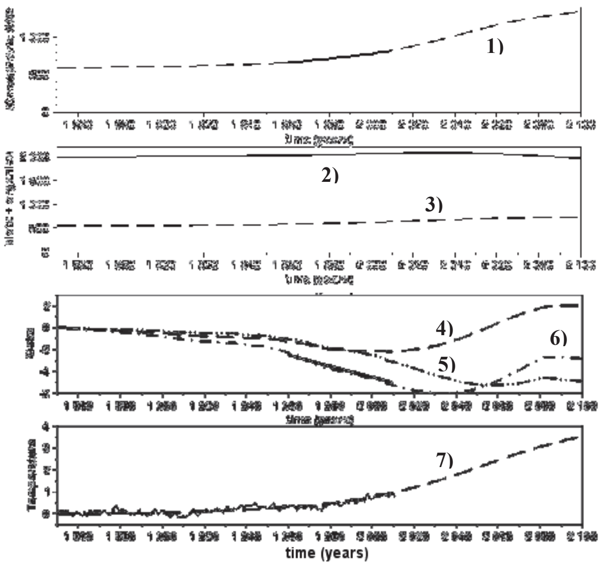

Fig.2. Fitting the model to the empirical data in the case of weak aerosols influence. Designations: 1 – atmospheric CO_2; 2 – soil carbon; 3 – carbon in vegetation; 4 – land carbon uptake (GtC/year); 5 – ocean carbon uptake (GtC/year); 6 – total carbon uptake (GtC/year); 7 – anomaly of global temperature. Solid lines near lines 1, 6, 7 represents empirical data. Recalculated climate sensitivity is 3.7^{o}C.

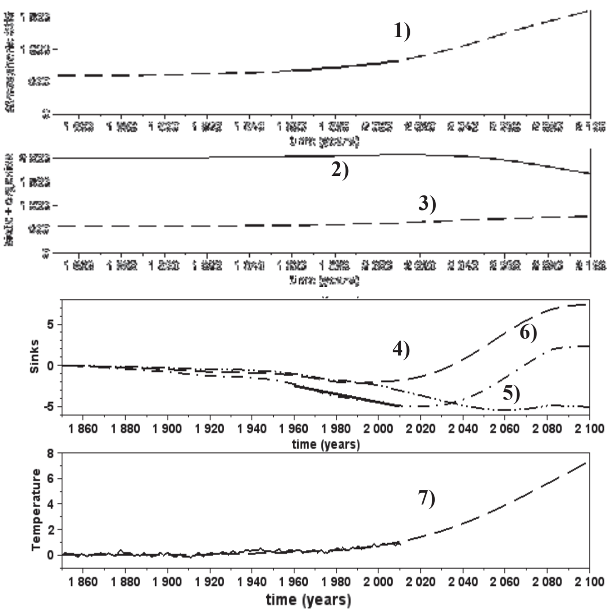

Fig.3. Fitting the model to the empirical data in the case of relatively strong aerosols influence. Designations are the same as on Fig.2. Recalculated climate sensitivity is 11^{o}C.

After considering possible BCS dynamics at the global level the possible impact of permafrost ecosystems on global dynamics can be considered.

In accordance with he principle of the worst scenario the most unfavorable variant of "compost bomb" (Luke, Cox, 2011) is considered (Eq.2).

Autonomous response of Eq.2 system to linear increasing of external temperature is shown on Fig.4.

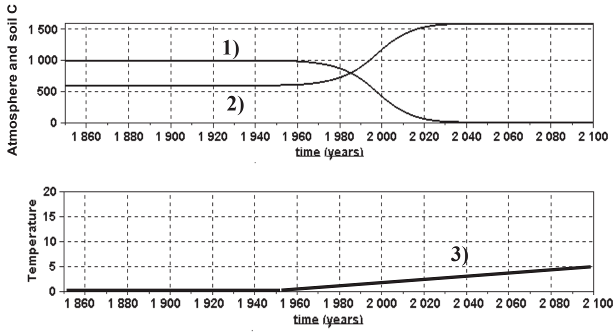

Fig.4. Illustration of possible "permafrost bomb" response to slow temperature increasing. Dates on axes are conventional. Designations: 1- permafrost soil; 2 - atmospheric CO_2; 3 – atmospheric temperature.

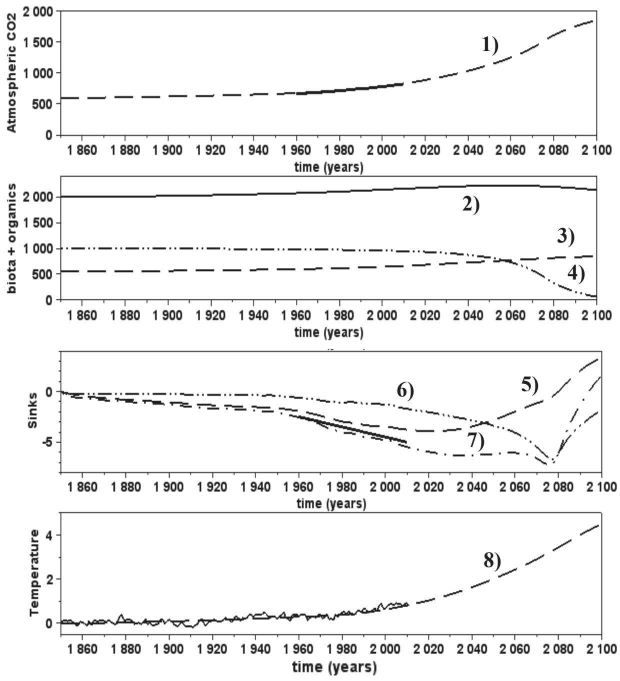

Fig.5. Fitting the combined model to the empirical data. Designations: 1 – atmospheric CO_2; 2 – soil carbon; 3 – carbon in vegetation; 4 – carbon in permafrost soil; 5 – land carbon uptake (GtC/year); 6 – ocean carbon uptake (GtC/year); 7 – total carbon uptake (GtC/year); 8 – anomaly of global temperature. Solid lines near lines 1, 7, 8 represents empirical data.

Combined global-permafrost soil model is built by addition Eq.2 to Eq.1. To demonstrate possible negative effect of polar region warming we have chosen quite favorable variant of the climate sensitivity value - 3.7^{o}C corresponding to rather soft effects of global warming. The results of simulation are shown on Fig.5. By the way in this model the balance of carbon blow is achieved without additional anthropogenic CO2 emission.

It can be seen that in spite of relatively low climate sensitivity future dynamics of BCS is not favorable – there is a transformation of sinks into sources and a tendency to further temperature growth.

Conclusion

The possibility of positive feedback between local temperature increase and the rate of carbon release processes (self-heating of soil) was estimated. The contribution of the permafrost zone and carbon cycle methane branch to the global dynamics for different values of the BCS model parameters inside evaluation intervals was also estimated. Observing intensive warming of Polar Regions poses a potential danger of autonomous positive feedback initialization and further activation global feedbacks. Further investigation of this possibility and searching for stabilizing mechanisms are required.

Acknowledgment

This work was supported by RFBR grant №13-04-98119.

References.

Ballantyne A.P., Alden C.B., Miller J.B., Tans P.P., White J.W.C., 2012. Increase in observed net carbon dioxide uptake by land and oceans during the past 50 years. *Nature*, **488**, 70-73.

Bartsev S.I., Degermendzhi A.G., Erokhin D.V., 2008. Principle of the worst scenario in the modelling past and future of biosphere dynamics. *Ecological Modelling*, **216** (2), 160-171.

Bartsev S.I., Degermendzhi A.G., Belolipetsky P.V., 2012. Carbon cycle modeling and principle of the worst scenario. *Models of ecological hierarchy*. Elsevier, 447–458.

Brovkin, V., Bendsen, J., Claussen, M., Ganapolski, A., Kubatzki, C., Petoukhov, V., Andreev, A., 2002. Carbon cycle, vegetation, and climate dynamics in Holocene: experiments with the CLIMBER-2 model. *Global Biogeochemical Cycles* 16 (4), 1139.

Brovkin, V., Sitch, S., Bloh von,W., Claussen, M., Bauer, E., Cramer, W., 2004. Role of land cover changes for atmospheric CO2 increase and climate change during the last 150 years. Global *Change Biol.* 10, 1253–1266.

Fung I.Y., Doney S.C., Lindsay K., John J., 2005, Evolution of carbon sinks in a changing climate. *Proc. Natl. Acad. Sci. USA,* **102**, 201–206.

Gregory J.M., Jones C.D., Cadule P., Friedlingstein P., 2009. Quantifying carbon cycle feedbacks. *J. Climate,* **22**, 5232–5250.

Luke C.M., Cox P.M., 2011.Soil carbon and climate change: from the Jenkinson effect to the compost-bomb instability. *European Journal of Soil Science*, **62**, 5–12.

MetOffice, 2013. The recent pause in global warming (1): What do observations of the climate system tell us? http://www.metoffice.gov.uk/media/pdf/q/s/Paper1_Observing_changes_in_the_climate_system.PDF

Global climate warming and its bioecological consequences in Yakutia – the coldest region of Siberia

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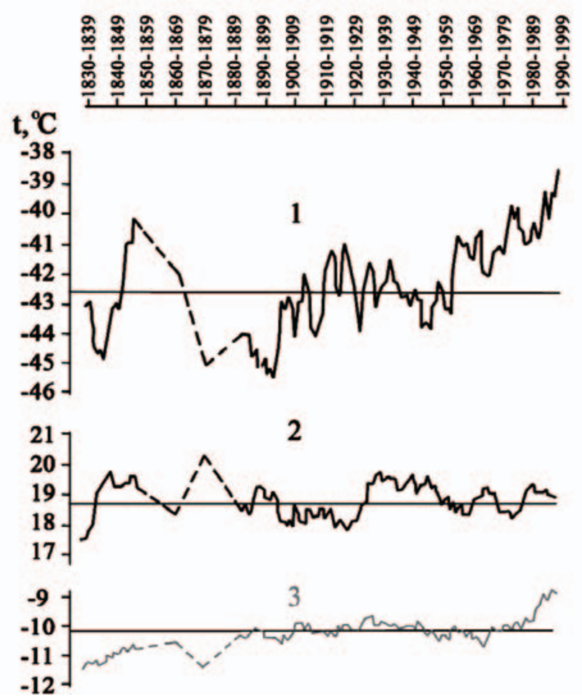
Keywords: climate change, Arctic Ocean, ecosystems, diseases.

It is generally recognized that during 20th and early in 21st the climate warming on a global and regional basis is under way. The performance data on the air temperature change from 1830 (the beginning of instrumental meteodata measurement) show the progress of the climate change in Yakutia (Fig.1). We can see that notable warmings were traced from 1910 to 1930 and from 1960 to 2000.



1 – January
2 – July
3 – year

Fig.1. Changes in air temperature according to the data of the Yakutsk meteorological station for the period of instrumental observations (10-year moving average) [1]

The climate warming resulted in the change of the natural environment and habitats for animals and the human himself. It concerns the basin of the Arctic Ocean and the regions of near-Arctic Yakutia (Fig.2).

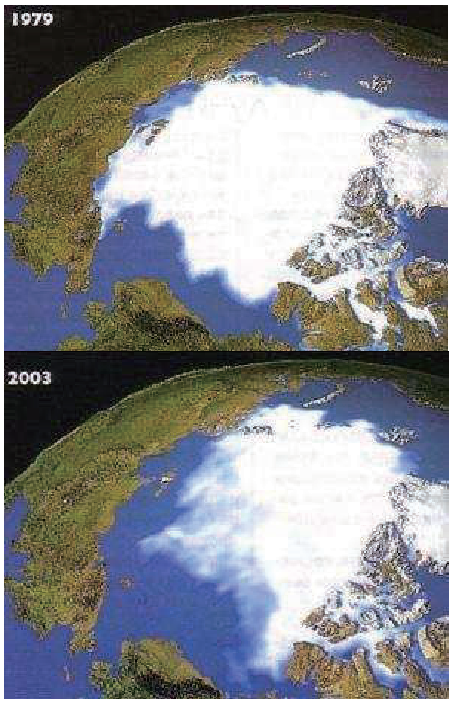


Fig.2. Reducing of sea ice. According to NASA new research continuous arctic sea ice gives a 9% reduction every 10 years since the 70s of the last century.

Fig.2 shows that there was a decrease of the ice - covered area and thinning-down of ice blanket in the Arctic in particular over recent 40 years. It contributes to worsening of white bear habitat including other ice-sea animals.

Ice breakup in the Arctic Ocean results in lanes where herds of marine animals – white whales and narwhales - enter. Sometimes ice-fields freeze together and animals found themselves entrapped. Prof. Savva Uspensky described the event when a 1000-herd of white whales (1985) were trapped in two small pools in Sinyavin Strait, east of Chukotka and were saved only owing to people’s assistance.

Active ice melting in the Antarctic and Arctic entails an ocean-level rise.

In the opinion of Academician R.I. Nigmatulin [2] the ocean level is up 3 mm/year over recent 20 years. Seemingly it is little. But this was enough to change the environment in many coastal countries and marine islands; enough to emerge many risks relating to floods, tsunami, hurricanes and other natural disasters. The size of such ocean currents as Gulf Stream and Labrador also changed. In this connection North East Atlantic washing and warming North Europe may endure not so much warming as cooling. However just northern regions of Eurasia and the basin of the Arctic Ocean experience the highest effect of warming. It concerns also the northern and continental Yakutia regions.

The change of animal and human habitat is in process in North Yakutia. It is established that soils of the Lena riv. delta for example in Bykovskaya channel contain 80-90% of ice, sometimes ice content attains even – 95%. It is natural that at the climate warming there will be active destruction of these soils. Banks of the delta and especially coastal islands suffer from intensive wearing away because of thermal abrasia and thermal denudation processes.

Over last 40 years a significant increase in watering of the Allaikha tundra that is the center of the nesting area for the Siberian white crane occurred causing a strong decrease of optimal habitats of this Red Book species. The bridges between lakes disappeared and the water surface area enlarged that also worsens the conditions for Siberian crane breeding.

Of even greater concern is the animal habitat change at simultaneous interference of human-induced pressure. Degradation of reindeer ranges in the northern uluses (regions) of the republic is a vivid example of such impact over the state of the northern ecosystems. Inventory of food stock of reindeer ranges made by the staff of the Institute of Biology YaF SD USSR AS in the 70-80s of the last century in Anabar, Allaikha, Ust-Yansk regions every 10-15 years showed that reindeer grazing capacity gave a 2-3% annual decrease because of delichenization.

The principal reason for delichenization is overgrazing of northern reindeer in the places of their main migratory routes and long stopovers. The destructive action becomes stronger because of the climate warming, northern recurrent fires, influence of wild reindeer populations and devastating effect of technological load. But over 20 recent years the tundra vegetation began renewing including the yagel stock because of depletion in domesticated reindeer number.

Owing to the climate warming new animal species enter to the north over recent dozen of years. There is also range expansion of the local species. Among them there is a set of epidemiologically dangerous species – carriers and keepers of pathogenic agents of hazardous diseases – tick-borne encephalitis [3], pseudotuberculosis, rabies and possibly avian flu [4]. The climate warming may ensure “awakening” of old nidi of infection – anthrax, smallpox, etc. Siberian silkmoth, dangerous forest pest, has become very active and abundant in recent years. Forest mortality including tree needle loss causes landslides, ravine development, increase in floods and area impounding. Strong climate warming may result in definite degradation of steppe and grassland ecosystems, in this case serious changes will occur in taiga-alas, subarctic and mountain ecosystems.

References

1. Gavrilova M.K. Klimaty kholodnykh regionov Zemli // Uchebnoye posobiye. - Yakutsk, Izd-vo SO RAN, 1998. - 206 s.
2. Nigmatulin R.I. Okean: klimat, resursy, prirodnyye katastrofy // Vestnik RAN, t.80, №8, 2010, s.675-687.
3. Opyt sozdaniya karty iksodovykh kleshchey Aziatskoy Rossii // Pod red. B.B. Prokhorova. - Irkutsk, 1974. - 84s.
4. Epidnadzor za osobo opasnymi i prirodoochagovymi infektsiyami v usloviyakh Kraynego Severa // Yakutsk: Kuduk, 2000. - 248s.

Research activities on Arctic ecosystems of Indigirka lowland in eastern Siberia

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Key words: taiga-tundra boundary ecosystem, Kodak station, larch growth, methane

Introduction

Taiga-tundra boundary ecosystem near Chokurdakh (70.4°N, 147.5°E) is one of main research sites of GRENE-TEA, formally entitled "Change in the terrestrial ecosystems of the pan-Arctic and effects on Climate", which is one of research projects under GRENE Arctic Climate Research Project funded by Ministry of Education, Culture, Sports, Science & Technology, Japan for the period from 2011 to March 2015. Four strategic research targets are set for GRENE projects. They are i) understanding the mechanism of warming amplification in the Arctic, ii) understanding the Arctic system for global climate and future change, iii) evaluation of the impacts of Arctic change on weather and climate in Japan, marine ecosystems and fisheries, and vi) projection of sea ice distribution and Arctic sea routes. GRENE-TEA project contributes the first and second targets.

Purposes of GRENE-TEA are to understand a role of terrestrial ecosystem of Arctic for polar amplification, understanding material cycle, and understanding current status of Arctic terrestrial ecosystem. Collaboration between observation and modeling is one of essential part of GRENE-TEA. For this purpose, GTMIP (GRENE-TEA Model Inter-comparison Project) has been initiated under cooperation between modelers and researchers conducting observations.

Observations

Taiga-tundra boundary ecosystem locates in the north of taiga. It is also called forest tundra, and its area is much larger than typical tundra (GRID Vegetation zone in the Arctic http://www.grida.no/publications/vg/ arctic). This ecosystem is so-called ecotone, which is sensitive to environmental change and potentially change to both directions forest and tundra. As tundra ecosystem is a source of CH_4, vegetation change of this ecotone may affect green house gas emission from the Arctic ecosystem (McGuire et al., 2009). Environmental change especially in eastern Siberia may greatly affect the green house gas emission, because permafrost degradation bring a change in soil moisture and an increase in soil temperature. Wetter condition may enhance CH_4 emission and higher soil temperature causes increase in a rate of decomposition of soil organic matter, resulting in higher rates of CO_2 and CH_4 emissions.

Five observational sites (B, F, K, A, V) which have different land scapes and tree densities were set near the village of

Chokurdakh. At site K (Kodak international observation station) which is our main observation site, automatic weather observation system and eddy covariance flux observation system were installed in July 2013. Observations on soil temperature have been also started from 2010. We also set up a plot (100 m x 120 m) for surveys for vegetation and micro-relief. Various manual observations are also going on in order to know controlling factors on larch growth and spatial distribution of vegetation, to understand processes of green house gas emissions, and to know the amount of organic matter and CH_4 stored in the soil including permafrost. Those are essential for better understanding of the future of this ecosystem.

Vegetation

One of the interesting points of the vegetation at the site K is that we found larch trees alive and dead at the site. Most larch trees are living on a place where elevation is relatively high (here called tree mound), and dead trees are found in depressions (wet area). However, we also found trees living in or near wet area. It is possible to investigate the effects of soil moisture on tree growth using these larch trees in the wet area at site K. We therefore conducted observations on photosynthesis, N availability for those trees comparing with those on the tree mounds.

There was a clear difference in moisture of the surface soil: it was obviously higher at the place where no tree grow than that with living trees (Liang et al., under review). In 2011, water level was extremely high during a whole growing season, and wet condition continued in the growing season in 2012. Effect of this wet event was revealed in the year 2012. Needles of some larch trees growing in the wet areas turned yellow soon after needle opening, indicating deadly effect of high soil moisture. Liang et al. (under review) also reported the importance of N for larch trees: tree size (height and DBH), needle mass and N content showed similar spatial variations, suggesting N availability affects the tree growth.

Methane dynamics

We also found a large year to year variations in CH_4 emission corresponding to the soil moisture (Shingubara et al., in preparation). However, it was not straightly depending on the soil moisture in the year. In 2012, soil moisture decreased after extreme wet event in 2011, while CH_4 flux was higher in 2012 than 2011. Methane flux is strongly depending on type of vegetation. We therefore preparing vegetation map for upscaling of CH_4 emission from the area. In 2013, we also conducted drilling down to 10 m, to observe the amounts of CH_4 and organic matter in it, Those results will be described in somewhere in the future.

Reference

McGuire, A. D., L. G. Anderson, T. R. Christensen, S. Dallimore, L. D. Guo, D. J. Hayes, M. Heimann, T. D. Lorenson, R. W. Macdonald, and N. Roulet (2009), Sensitivity of the carbon cycle in the Arctic to climate change, *Ecological Monographs*, ***79*** (4), 523-555.

Stomatal cavity water vapor deficit in intact leaves of some Siberian trees

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Key words: leaf, stomata, water regulation, Siberian trees

Modern commercial precise portable photosynthesis systems of Walz (Germany), Li-COR (USA), ADC (UK) corporations are complex of hardware based on IR-detection of CO_2 and H_2O and software computing some photosynthetic parameters and CO_2/H_2O gas exchange. The background for such calculations was described in a theoretical model of the photosynthetic leaf CO_2/H_2O gas exchange (Farquhar et al., 1980). One of the basic parameters of the model used to calculate photosynthetic carboxylation and intercellular CO_2 concentration is stomata conductivity, which in turn is based on *a priori* proposal that stomata cavity is water vapor saturated by definition. The proposal was an object for rapid discussion in 70-th years of the last century and has not been proved yet directly (Laisk, 1977). It was admitted that water vapor deficit in stomata cavity of intact leaf is absent or very close to zero. Most of available experimental data do not contradict the hypothesis of 100% relative humidity in stomata cavity while some data suggest indirectly that it's not the case [Laisk, 1977]. The formula used by any portable photosynthesis system to calculate air-to-leaf vapor pressure deficit (VPD) according to the model is as follows (Portable…, 2007):

$$VPD = (wi - wa) / (1 - (wi + wa) / 2)$$

where wi – H_2O molar fraction in stomata cavity,
wa – H_2O molar fraction in the cuvette;
wi is calculated from leaf temperature as wi = SVP(Tleaf)/Pcuv,
where SVP(Tleaf) – saturation vapor pressure at Tleaf calculated according to Goff-Gratch,
Pcuv – total pressure in the cuvette which is normally almost equal to atmosphere pressure.

Thus, calculation of VPD supposes the relative humidity in stomata cavity to equal 100% at any leaf temperature. The experimental examination of this proposal was a purpose of the current research.

Gas exchange measurements were conducted in summer period from July to August in 2010-2012 during day hours from 10:00 to 16:00 of solar time. In the experiments with 40- to 50-old woody species (*Larix sibirica* Ledeb., *Pinus sylvestris* L., *Betula pendula* Roth.), we used fully expanded leaves or the current year needles. The leaf VPD of trees in South Ural (Ekaterinburg) was measured with a GFS-3000 (Walz, Germany) and LI-6400 (LI-COR, USA) in Yakutia (Yakutsk and Ust-Maya) under conditions optimal for photosynthesis. Undetached leaves or needles were placed into a cuvette (a clip chamber) with an artificial light source (light-emitted diode providing photosynthetically active radiation of 1500-1800 µmol/(m^2 s) at desired temperature of 16-26 °C and relative humidity of 10-80%).

The measurement procedure consisted 15-min adaptation of an intact leaf to the conditions of the cuvette followed by measurements of the steady-state photosynthetic CO_2/H_2O gas exchange in the leaf. Samples for statistical treatment were represented by one to three leaves collected from three plants. Data in the figures provided show mean values.

The hypothesis, that water pressure in stomata cavity is equal or almost equal to saturation at leaf temperature, was tested by precise measurements of H_2O gas-exchange of leaves attached to shoot using two modern portable photosynthesis systems GFS-3000 (Walz, Germany) and LI-6400 (LI-COR, USA). The data were plotted as dependence of VPD on relative humidity (RH) in the cuvette. An example of such a plot in case of South Ural is presented in Fig. 1 (left column plots). The analogous graphs were plotted for the measurements made in Yakutia also (not presented). Extrapolation of temperature parameterized VPD-RH curves toward X-axis gave the VPD at 100% RH in the cuvette around the leaf. In all cases a non-zero value was received.

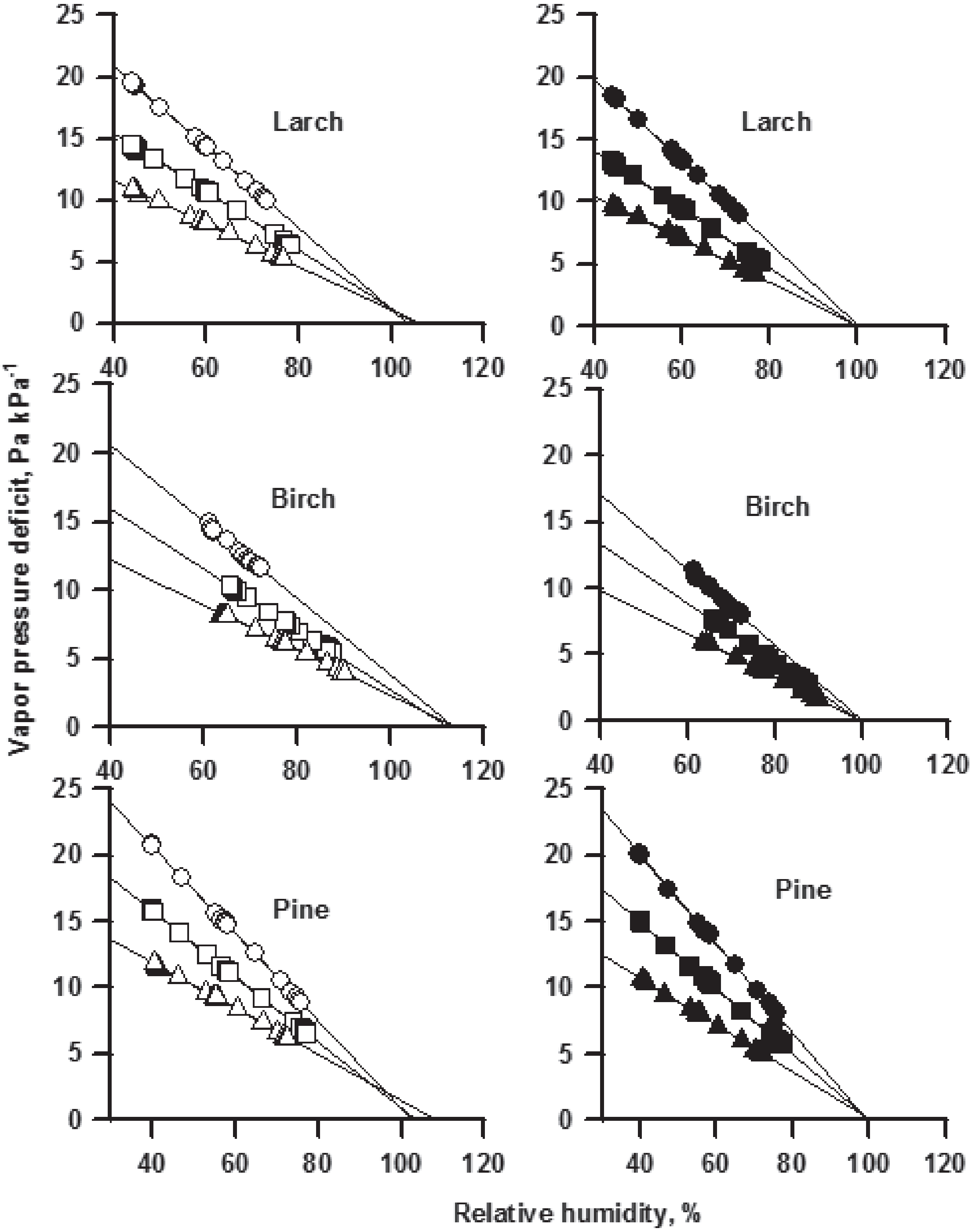

Fig. 1. Photosynthetic gas exchange measurements of the shoot attached leaves were made at saturated PPFD (1800 μmol s^{-1} m^{-2}) with GFS-3000 in Ekaterinburg (South Ural region). Leaf temperatures were 26 °C (circles), 21°C (squares) and 16 °C (triangles). Left plots column (light symbols) refers to calculation of VPD in assumption of 100% relative humidity in stomatal cavity according to Farquhar et al. (1980). Right plots column (dark symbols) refers to calculation of VPD in assumption that the relative humidity in stomatal cavity is less than 100%.

But such a result *a priori* contradicts the physics of H_2O gas exchange in case of orthodox proposal of saturated vapor pressure in stomatal cavity. To omit the obvious contradiction one can admit the presence of some unsaturation of water vapor in the leaf. The result of such a correction of RH in stomatal cavity towards its diminishing from 100% is presented on left column plot series in Fig. 1. Corrected values of RH in stomatal cavity of leaves from some Siberian trees species, that permit to overcome the contradiction, are shown in Fig. 2.

Thus, the direct measurements of photosynthetic transpiration in intact leaves of larch, birch and pine trees demonstrate significant unsaturation (2-12%) of water vapor in leaf stomatal cavity under continental climate in western (South Ural) and eastern (Yakutia) Siberia.

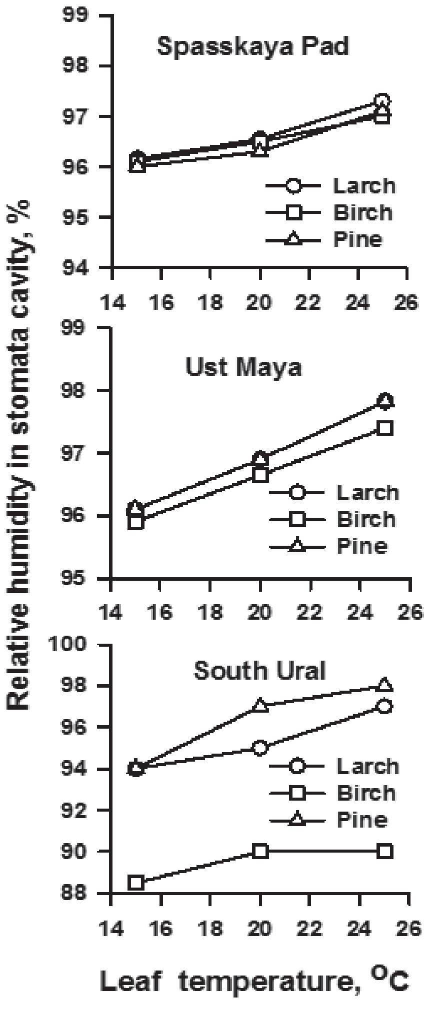

Fig. 2. Relative humidity in stomata cavity (%) in leaves and needles of larch, birch and pine in Siberia after correction of VPD dependence on RH (see Fig. 1).

References

Farquhar G.D., von Caemmerer S., Berry J.A. 1980. A biochemical model of photosynthetic CO2 assimilation in leaves of C_3 species. *Planta* **149**, 78-90.

Laisk A. X., 1977. *Kinetica fotosinthesa i fotodyhaniya (Kinetic of Photosynthesis and Photorespiration)* Nauka, Moscow, 156 p.

Portable Gas Exchange Fluorescence System GFS-3000. 2007. Handbook of Operation. Heinz Walz GmbH, Effeltrich, 197 p.

The consequences of climate change in Yakutia: the socio - economic challenges for rural communities

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Key words: climate changes, Yakutia, aboriginals, rural communities

In human studies, assessment of the effects of climate change are estimated at widest amplitude - from apocalyptic to deny the fact of global change. The report aims to outline the range of real - extreme and latent threats - for the life of rural communities in the Republic of Sakha (Yakutia). Reveals a list of the most visible and affect economic activity and the rural social environment of the natural processes of climate change. Analyzed the response of the rural population on the debated issue, including views, expectations, and develop strategies to adapt to changing environmental conditions.

Despite the traditional restraint of rural communities in the estimates of their representatives acknowledge that a great danger to the republic of agriculture are natural emergencies caused by floods, forest fires and prolonged drought. Experts in social processes are warning that a number of factors causing social tensions may soon trigger the following negatives:

- Aggravation of pre-existing socio -economic and environmental problems of the rural population;
- The increased threat to the security of rural livelihoods;
- The projected long-term poverty of rural residents;
- The probability of mass migrations due to the destruction of communications, residential areas in the countryside.

Despite the presence in the rural areas of individual groups with the opinion of the stability of its own existence and permanence and security of traditional occupations, there are facts that complicate the already traditional livestock management.

Of course, the difficulty in modern agricultural livelihoods are determined by a complex environment. But a component of natural changes in the socio - economic challenges recognizes the vast majority of respondents to our surveys in the central and northern regions of Yakutia in 2009 - 2012.

The village of Yakutia the main occupations of the indigenous peoples are cattle-breeding, reindeer-breeding, hunting and fishing. In the central and southern regions of Yakutia agriculture is developed, the unique fact that the territory of the republic is located in the permafrost zone. The eternal ice of land for indigenous peoples has always been the usual earth's expanse. The specificity of the nature of the North is also a weak ability to regenerate, increased vulnerability. In connection with the preservation of traditional occupations, status of rural ecology is a very important factor in the everyday life of the indigenous population of the republic. Known classic example of the vulnerability of the Arctic soil of Yakutia is when a grassy tundra after driving the tractor is not overgrown decades. In taiga zone also regenerative processes, slower than in the regions with more favorable climate.

Ecological problem of the indigenous peoples of Yakutia was still in the Soviet time. Industrial and transport development on the territory of the republic was accompanied by an expansion on the land of indigenous where they lived by the traditional land using.

All the soviet projects were implemented without consideration of the opinion of indigenous peoples, without ethnological and cultural expertise. Unfortunately, this negative trend in the industrial policy of passing away very slowly. For the rural indigenous population, is tied to the traditional nature management at the present time there are new challenges.

So, the threats related to the effects of climate change added to the total unfavorable ecological situation of the last decades.

The report's author had the opportunity to observe rural life of the indigenous peoples of Yakutia over the last twenty years. Working on research projects in the agricultural and social history, simultaneously collected field data on oral history, extensive interviews, especially valuable to the fact that part of the informants in the present there is no.

Prolonged contact with the residents of rural settlements, personal part in their daily life with work and everyday worries allows you to record and analyze what is not reflected in official publications and in the scientific literature.

In 2009-2010, the author participated in the polls of the rural population about the environmental situation, the climatic changes in the environment in the regions affected by major floods 2007 and 2010. Here is mainly inhabited by the indigenous peoples of Yakutia.

Analysis of materials of the project showed that in recent years the villagers have become visible changes in the environment, including weather regimes, the state of the fauna, water reservoirs and etc. If we compare these estimates with data collected by the author in the early 1990s, it is obvious how the villagers feel the changes of environment and climate in their daily life, in everyday reality.

First of all villagers concerned about environmental changes affecting economic activity. The villagers noted a change, first of all, in the temperature regime of the seasons, in the state of soils and in the local fauna.

So, my surveys 2009-2010 in the regions of central Yakutia have shown that more people worry the following facts: floods, melting of the ice layer in the ground, forests fires, silkworm invasion (sequence corresponds to a frequency of mentions).

The interviewed persons of older age often stress the «bundle» of these phenomena: the silkworm moth - the destruction of forests - the melting of soil – the excess water. Climate warming, thawing of permafrost in Yakutia are fixed all the scientists working with natural phenomena.

Heard and recorded by us - oral testimony rural inhabitants about the changes in the environment are confirmed documentary photo and video galleries. They do show in the recent years new bogs in forests damaged melting of ground roads and power lines.

For many of the Yakut villages located along the rivers and lakes are common phenomena collapse of banks of reservoirs; wetlands and water dangerously close to residential and commercial facilities.

Here it is necessary to dwell on one fact. Undoubtedly, that in the aspect of observations over the climate change increased attention to traditional knowledge. Therefore it is interesting phenomenon of how the attitude to traditional knowledge in rural societies. It had lost its former traditional significance.

First of all, due to the natural departure of representatives of older age groups disappears traditional knowledge. Next, we must admit that changed the very nature of the surrounding biosystem - under the influence of anthropogenic and technogenic processes. Last connoisseurs of natural phenomena - the carriers of the unique gift of foresight seasonal events are going away and already left us. Therefore, some algorithms perception and interaction with nature to just «do not work». As shown by personal communication with the residents of rural settlements, interviews and surveys, many are skeptical not only to the weather predictions for the near future or for the next season, but generally to traditional knowledge and norms of relationship to nature.

However, during the field work in the villages of Yakutia I interviewed as experts facial mature and older ages, permanently residing in the surveyed areas. Among them were respected people of both sexes, elders, are considered in the local societies, as keepers of the traditions. Interviewed have their own interesting evaluation and conclusions about the processes of climatic and environmental changes in rural areas of Yakutia and their impact on everyday life. They analyze the causes of changes in the environment, often indicating their causes. Among the opinions of rural experts most frequently encountered the following: «I believe that this is connected with the global «greenhouse effect», «ecological changes have been driven by large-scale anthropogenic load». In General, rural experts converge in the main умозаключении that «climate change, environment and landscape is the answer to the nature of the thoughtless man's attitude towards it».

Given that the traditional occupations of the Yakuts and other representatives of the indigenous peoples of Yakutia directly dependent on the stability of landscapes and natural state of a production network, it should be noted real threats to production routes and social, transport communications.

In the everyday life of the villages of Yakutia is actually there are difficulties associated with the increase in level of water in reservoirs, flood, frequent rains, thawing of the frozen layer of soil.

For rural communities, is important not only the production, the economic effect of climatic processes. Not less important to them-the social aspect. Thus, the destruction of habitual eco-landscape in the Yakut villages is perceived not only as painful invasion of everyday life, as a threat to community and family life and lifestyle, but also acutely experienced on a personal level. This is understandable, as literally in front of the villagers too quickly destroyed familiar since the childhood and youth of the surrounding world. It is connected not only with the economy and daily life, and is part of the emotional human wealth, part of the memories of past years.

Typically the statement of one of the residents of the Yakut village: «I look at their native places with pain. Those fields where we are in youth work and rest - dips from melting ice like a funnel after the war... To hay meadows are on the brink of wetlands, many of weeds and shrubs, trees are dying...».

Informants in ethnic villages concerned by current environmental changes, as reflected in their estimates of the environment «considerably changed in view of environmental change is a familiar sight of the coast, the sizes of water and forests, grasslands and pastures»; «it has become difficult to pass on the old paths pass through the forest roads and lots of water, lots of new ravines...», etc.

The poll showed that the perception of the natural-ecological threats differentiated according to the age groups of rural residents. Older respondents are experiencing the destruction of the surrounding natural objects almost as a personal loss and the social danger. Elderly people and people of middle ages very worried, listing specific components of the rural landscape as abandoned industrial sites with decaying reservoirs, line pipelines in the taiga laid excluding natural ecology and economic routes, impoverishment of the usual fauna.

While most young inhabitants of the villages of the greatest reaction causes only the threat of floods. Apparently, they appear to be the most real, as there is the personal experience of the experiences of such events. Young representatives of native peoples of Yakutia, who came to the polls and interviews, have an ambivalent attitude to the traditional knowledge. Some of them retain a deep respect for the ideas and norms of behavior in nature, preserved in ethnic consciousness. The other part of the young people demonstrates not only poor knowledge, but also a certain indifference to the traditions. Not only natural destruction, but anthropogenic negatives they are perceived almost as the norm.

In general, representatives of the indigenous peoples of all ages recognize changes in the temperature regime of the seasons, in the local flora and fauna. The respondents indicate the new bird species not previously wintering in Yakutia. Also there is evidence that appeared plant species not previously known in the local systems. Of those interviewed as a new phenomenon drastic temperature changes, unusual even for a sharply continental climate.

Among the most notable changes indicate warmer winter (temperature-November-December average annual). The most serious threatening changes recognized melting of eternal ice. So, even the young, the less observant, representatives of indigenous peoples, noted: everlasting ice melts under a layer of earth, bombarded the shores of large lakes. Decreased square visible surface outputs ice strata, in particular, in Kangalassky, Ust-Aldan regions of Yakutia.

International experts on social processes believe that the importance of climate change are not fully understood. The results of my field work are intermediate (not definitive) that require further in-depth studies. But even at this stage, they allow to make the following principal conclusions. First, the local examples of rural settlements of Yakutia are clearly identified, the problem of global climate change as a direct challenge to the established production cycle and way of life of the rural indigenous population.

Secondly, the impact of climatic factors associated with climate change, has a strong social aspect influencing the whole social sphere, functioning of social communications in rural settlements.

And, thirdly, among the members of the surveyed rural communities widespread perception of climate change on a personal level, especially for individuals of senior and middle age. For them the integrity and balance of the surrounding cultural landscape means safety, stability daily picture of the world, the welfare of the family, friends and of the whole society. Combination of these factors makes the impact of climate change in topical and socially significant phenomenon in Yakutia. So, events in this arctic region are therefore critical to understanding how our world is going to change.

References

1. Boyakova S.R., Vinokurova L.I., Ignatieva V.B., Filippova V.V. 2010. Yakutia in the conditions of global climate change: vulnerability, risks, social adaptation //*North-East Humanitarian Vestnik.* **1.** 22-25.

2. Field materials of the author. 1995 – 2013. Interviews, personal communication with residents of the Bulunsky, Verkhoyansky, Tattinsky, Churapchinsky, Megino - Kangalssky, Ust-Aldansky uluses of the Republic Sakha (Yakutia).

Net ecosystem water use efficiency over two larch forests at eastern Siberia

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Key words: evapotranspiration, photosynthesis, ecosystem water use efficiency

Introduction

The coupling of water and carbon exchange has been investigated in various forest ecosystems. Boreal forest is considered to play important roles in the global climate as well as water and carbon balances. Under a cool climate with a modest precipitation, boreal forest adapts to the harsh environment restricting growth and photosynthesis capacity, but surviving by using water effectively through the regulation of stomata closure (Baldocchi *et al*., 2000). Larch forests in eastern Siberia also survive such a precipitation-limited environment by using the water supply by seasonally thawing frozen soil (Kelliher *et al*., 1997).

To improve understanding of relation between water and carbon cycles over eastern Siberia boreal forest, two observation sites at a larch dominated forest in the middle and southern part of Lena basin were analysed in this study.

Methods

One is the Spasskaya Pad station (SP) at Yakutsk (62° 15´N, 129° 14´E). The other station named Elgeeii station (EG) (60° 0´N, 133° 49´E) is located at 300 km southeast of Yakutsk. Average of annual precipitation during 1986-2004 is 290mm and 230mm at Ust-Maya, which is the nearest station at a distance of 60km from Elgeeii, and Yakutsk, respectively, while difference of the other meteorological values such as air temperature and humidity is small (Dataset from Suzuki *et al*., 2007). The dominant species in the forest is larch (*Larix cajanderi*), mixed with birch (*Betula pendula*), willow (*Salix bebbiana*) and pine (*Pinus sylvesrtis*). The stand density of larch trees is 770 and 1090 trees ha^{-1} (1870 and 2600 trees ha^{-1} including birch, salix and pine) at SP and EG, respectively. The mean stand height of upper canopy, which is comprised of larch trees, is around 20m at SP and 25m at EG, and plant area index measured in August 2011 is 1.4 at SP and 2.1 at EG.

In these forests, meteorological measurements including radiation, wind, temperature, and humidity above and inside the canopy, ground temperature (0.1–5 m), and soil water content (0.1–1.2 m) were conducted. CO_2 and water vapour fluxes above the canopy were measured with the eddy covariance system. Observed CO_2 flux represents net ecosystem exchange NEE, which was divided into gross primary production GPP and ecosystem respiration and data gaps were complemented using empirical equation of flux and environmental variables. Water vapour flux, i.e., evapotranspiration ET, was also gap-filled by the multiple imputed methods. Details of data processing are written elsewhere (Kotani *et al*., 2013). These continuous flux data was used to derive daily cumulative sums. Data obtained during growing season (April through September) in 2010 and 2012 were used in this study.

Results and Discussion

The seasonal variations in meteorological conditions and evapotranspiration (ET) were generally similar at the two sites, whereas gross CO_2 uptake (GPP) and ecosystem respiration during the growing season varied between the sites and the years studied (Fig.1). An earlier onset and a later decline of GPP compared to ET at EG resulted in a seasonal time lag between ET and GPP and therefore a mid-summer depletion of ecosystem WUE (defined as the ratio of gross CO_2 uptake to ET in this paper), which is typical for an ecosystem in a broad climate, especially a relatively dry summer climate (Fig.2). However, a relatively seasonally stable WUE (GPP/ET) was observed at SP because of the synchronous seasonal variation in these fluxes. These two sites typically displayed a relatively non-conservative water use (low WUE) compared to other boreal forests (evergreen conifer).

The total amount of ET from May to September was almost identical at the two sites, whereas the components of CO_2 exchange (gross uptake and respiration) at EG were 1.31 and 1.21

times those recorded at SP. A possible reason for this is the difference not only in plant mass (represented by PAI) but also in the nitrogen concentration of larch needles (Tei, 2013), the species composition, and the forest age.

The higher CO_2 uptake at EG suggests that transpiration is likely to be higher at EG if WUE at the tree scale is at the same level as at SP. Assuming that the transpiration of plants, which contributes to CO_2 uptake, was larger at EG than at SP, the other components, such as floor ET including soil evaporation, would make up the deficit at SP. ET from the forest floor evaluated with the pan measurement at EG was 30–40%, and it is likely that 60–70% of water vapour flux and CO_2 uptake would be due to the upper canopy layer of trees. In contrast, the understory ET at SP would account for more than 50% of the water vapour flux of the whole ecosystem. Photosynthetic capacity parameters of the floor vegetation at SP were much lower than those for the larch leaves at this site (Maksimov *et al.*, 2007). Therefore, the contribution of the floor vegetation to CO_2 uptake is not expected to be as high as the ET of the whole canopy.

Conclusions

To improve our understanding of water and carbon exchange over eastern Siberian boreal forests, two forest sites in a larch-dominated forest in the southern Lena basin were analysed. Measurements during three years growing season at Elgeeii site showed that net CO_2 assimilation were higher than those at Yakutsk especially during June (the first half of the growing season), while evapotranspiration was not different. Difference in CO_2 assimilation would be due to difference in not only biomass but also photosynthetic capacity of plants. On the other hand, difference in contribution of evapotranspiration from forest floor resulted in similar magnitude and response to evaporative demand at both forests.

Acknowledgement

This study was supported by the Research institute for Humanity and Nature (RIHN, Kyoto) entitled ‘Global Warming and the Human-Nature Dimension in Siberia: Social Adaptation to the Changes of the TerrestrialEcosystem, with Emphasis on Water Environments’ (PI:Tetsuya Hiyama),and the Nagoya University Global COE Program "From Earth System Science to Basic and Clinical Environmental Studies".

References

Baldocchi D. *et al.*, 2004. Net ecosystem exchange of carbon dioxide and water of far eastern Siberian Larch (Larix cajanderii) on permafrost. *Biogeosciences* 1, 133-146.

Kelliher F.M. et al., 1997. Evaporation from an eastern Siberian larch forest. *Agric. For. Meteorol.* 85, 135-147.

Kotani A. *et al.*, 2013. Temporal variation in the linkage between the net ecosystem exchange of water vapour and CO_2 over boreal forests in eastern Siberia. *Ecohydro.ogy* DOI: 10.1002/eco.1449

Maksimov A. *et al.*, 2007. A/Ci curve analysis of larch forest subcanopy vegetation in Central Yakutia, Siberia. Proc. III Inter. Conf., 149-156.

Suzuki R.*et al.*, 2007. *Baseline Meteorological Data in Siberia Ver.4.1*, IORGC, JAMSTEC, Japan.

Tei S., 2013. Study on radial growth and carbon isotope ratio of larch in taiga of a northeastern Siberia. Ph.D thesis, Hokkaido University, Japan.

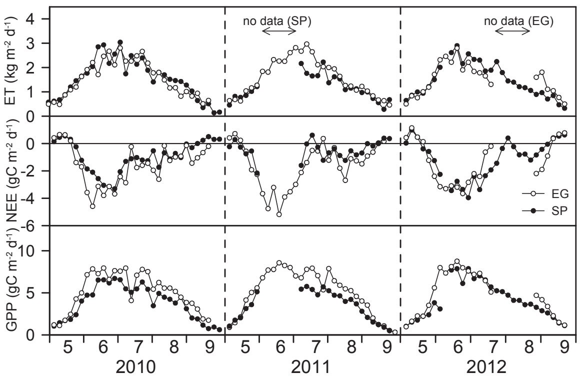

Fig.1. 5-days average fluxes; ET (top), NEE (middle), and GPP (bottom) at EG (open circles) and SP (closed circles).

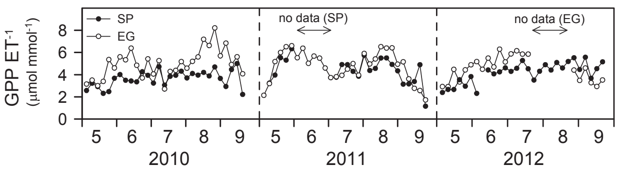

Fig.2. 5-days average water use efficiency at EG (open circles) and SP (closed circles).

Dynamics of vertebrate animal populations in Central Yakutia for the last 150 years in conditions of climate change and intensification of anthropogenic press

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Key words: climate change, anthropogenic press, birds, mammals

We present some our results of an attempt to characterize the bird and mammal populations and their dynamics for more than 150 year period of the study of them, on the base of many-years instrumental research of meteorological data from 1830 and analytical review of expeditions made by A.D. Middendorff (1848-1846), R.K. Maak (1854-1855), A. Kayander (1901), R. Holl (1903), Migration Management of Russia (1910-1914) and Yakutian Expedition of USSR Academy of Science (1925-1931), numerous publication of their participants and political convicts, and collaborators of local Scientific organization, especially Institute for Biological Problems of Cryolithozone SBRAS and Yakutian State University (North East Federal University at the present) in 20-50-es of the last century, about the state of nature conditions, soil and plant cover and animal world of the region.

Under the Central Yakutia we, after V.G. Zolnikov (1954), understand the territory of Central-Yakutia plain with adjacent parts of Middle-Siberian plateau.

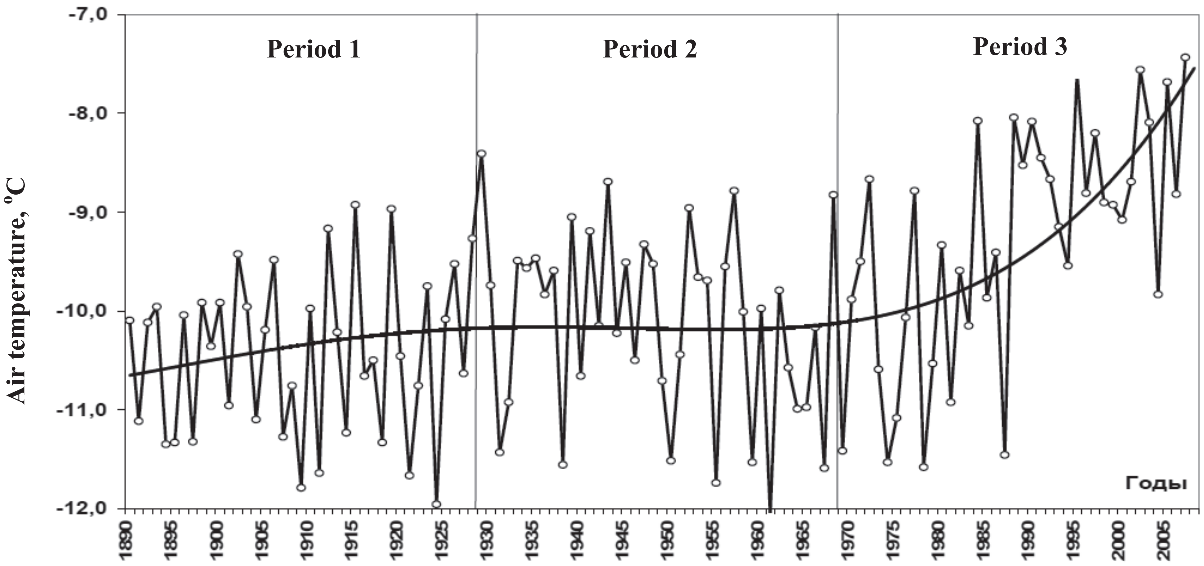

Fig. 1. Process of average air temperature. Data of meteo-station Yakutsk for the period 1890 - 2008 (by: Pavel Fedorov, 2012)

Fig. 1 shows the data on the average temperature of the year in Yakutsk for period 1890-

2008 subdivided for 3 periods. It can be seen that from 1890 to 1930 the conspicuous increasing of the average year temperature was occurred (the Arctic warming period), and some environmental temperature stabilization is reported from 1930 to 1970, and, finally, from 1970 the abrupt increasing average year air temperature.

These data witnessed about the significant climate change in Central Yakutia for the last 120 years. At the same time, the intensification of natural resource using of the region is going up. The people population growth appears to be an integral indicator of anthropogenic press on the nature (fig. 2).

Fig. 2. Population dynamics of Yakutia from the 17th to 21st centuries

During XIX and first half of XX century, the population of Yakutia had been growing mainly for the villages, mainly, Yakut people. In 1897, by census data, there were 269880 people, including 9182 in Yakutsk, in 1917 г. – 264136, including Yakut people living mainly in villages (220040), in 1926 - 289085, in 1939 - 413200 people. Yakutsk people population abrupt increasing occurred after 60-es of the last century in connection with appearance and development of industrial centers, energy t, transport and building development. Fast development of mining industry led to appearance of districts bad in ecological relation yet in 89-90 years of XX century in Yakutia. This is Vilyuiskii diamond-oil-mining work region.

Enlargement of villages in result of special settlement politic in 50-70 years led to discrepancy in development of economic capacity in meadow-taiga regions of Central Yakuia and fast ecological worsening of them. The fast population decreasing in some hunt animal species number in R.K. Maak expedition times in 1854-1855 already was reported in Middle Lena Valley and in group of Vilyui districts. The main animal species used as a tax, Sable, began to disappear in many sites yet in XVIII century, and Tsar Administration made several orders about permission to give skins of foxes, elks and deer instead of Sable skins, or even pay money. R.K. Maak reported that Sables were killed in some sites at all. Sable was conserved on Tyung, Tyukyan, Khappass, Markha rivers till 30-es of the XIX century. A hunter could have got till 150 Sables in Olenek River, but Sables begun to disappear in 30-40-es, and it disappeared absolutely to time of Maak's traveling. The same things Maak wrote about the Elk, as about the legend animal what could be sighted in some days in Vilyui district. Maak wrote that Brown Bear also disappeared along the Vilyui River. For example, near Suntar village the Bear disappeared in relation with deforestation and people population growth. In Prilenie district, between Yakutsk and Olekminsk, the Bear was reported as extremely rare.

Intensification of agricultural development, increasing of sowing territories, deforestation, construction of highways, wires led to ranges and population grows of ground squirrel, roe dear and raw of other mammals. Chipmunk and mouse-like rodents fast increased their number near agriculture field, meadows and pastures. In connection with mass bringing of animal feed in 70-80-es of the last century, серая крыса created several sustainable settlements in agriculture districts of Central Yakutia.

At the last tens, in relation with sawing territories contraction, grain farming and harsh decreasing of animal feed bringing, the reverse process is going up – shortening in number and even in ranges of species connected with agriculture. It relates to ground squirrel, common rat and mouse-like rodents, all the more, very active chemical attack against of these animals was conducted in 50-70-es. Roe dear, what actively settled Central Yakuia from 30-es of the last century, is under the press of changing climate factors and poaching. During low-snowing winters, especially with periodical warming, animal death from exhaustion and from predators is reported. Even more influence gives still existing poaching. Often cases of flooding in the last years also are fatal for the valley part of the species. Human activity on mammal acclimatization and re-acclimatization (Sable, Water Rat, etc.) promote the enrichment of biodiversity.

50 years has past from the time of Yakutia bird fauna inventory by K.A. Vorobiov (1963). At the present, the ornithology fauna here consists of 318 species (19 orders): 271 (including 43 sedentary species) breeding species, and 47 vagrants. Over the period under reviewing, the avifauna of the region increased by 68 new species (almost 1.3 times more), the number of breeding birds became more for 31 (1.2 species). Status of 3 species is changed because they started to breed here. 6 species considered by K.A. Vorobiov as subspecies appeared in result of re-systematic. Even more expressing the list of new vagrant birds -37, representing mainly group of watery birds (25) and passerine birds (12):

The most of these birds inhabit the researched region –they nest or can be seen as vagrants. For example, 284 bird species from 18 orders inhabit the most studied in ornithology Lena River basin comparing in size with the middle part of Central Yakutia. 28 new species (for Yakutia too) were revealed here, in comparison with 80-90-es of the last century. 19 from these species were found during last 10 years: 11 vagrants and 8 breeding species.

The breeding or migration number of the most geese, ducks, swans, large birds of prey (Golden eagle, White-edged eagle, Gyrfalcon, Peregrine falcon), Siberian spruce, Common crane, Coot и Ural owl. It accompanies with their ranges declining or fragmentation. In 1854, R.K. Maak reported thousands of whooper in mouth part of Vilyui and Lungha rivers. In 1925-1926, A.I. Ivanov in Middle Lena valley (1929) sighted this species as breeding very rare and in 1971, A.G.Degtyarev for all spring season registered just 780 individuals in mouth Vilyui district. By Maak data, fish hawk in was the most conspicuous bird in the middle of XIX century in Lungha River but at the present it stopped to breed along all Middle Lena.

The increasing of bird disturbance and persecution by human during their nesting is negatively affected on state of their populations, especially for anthropophobian species. By the way, chemical weed or pest killers were used and birds of prey were attacked as pest of agriculture in several central Yakutia districts in 60-es of the last century.

The range expansion filling of "empty places" in these, comparing with 60-es of the last century, is reported for 26 species: Red-necked grebe, Great Bittern, Grey heron, Lesser White-fronted Goose, Mallard, Gadwall, Water Rail, Gulls (4 species), European tern, Owles, (2), Eurasian Wryneck, corvids (2) и small Passerine birds (9). At the process, the clear number increasing is characterized just for few species- for Water Rail and for gulls.

At the present, intensive number repair can be watched in Baikal Teal almost disappeared in several districts of Central Yakutia in early 60-es of the last century and on wintering ground in China. It provided with birds wintering on the south of Korean semi-island.

So, the intensification of human activity and climate warming has the great effect at the last decades on species composition, number, distribution, inhabiting character and in-range distribution of many species of terrestrial vertebrate animals, birds and mammals firstly, of such great region of Siberia as Central Yakutia.

References

V.G. Zolnikov, 1954. Relief and parent rocks in the eastern half of the Central Yakutia // Proceedings of the natural environment and agriculture in Central Yakutia. - Moscow: Publishing House of the USSR Academy of Sciences. - P. 7-54

Fedorov P.P. Sovremennoye potepleniye klimata i rost listvennitsy v Tsentral'noy Yakutii // Biologicheskiye problemy kriolitozony: Mat. Vserossiyskoy konf., posv. 60-letiyu so dnya obrazovaniya IBPK SO RAN (30 iyulya-05 avgusta 2012 g., g. Yakutsk). - Yakutsk: Sfera, 2012.

A.F. Middendorf, 1869. Travel to North and East of Siberia. Dep. V, Siberian fauna. St. Petersburg., 1869. - ... P.

R.K. Maak, 886. Vertebrates // Viliuiski District of Yakutia Region. Part 2. St. Petersburg. - P. 16-197.

K.A. Vorobiov, 1963. Birds of Yakutia. Moscow: Publishing House of the USSR Academy of Sciences. - 336.

A.I. Ivanov, 1929. Birds of the Yakutia Region // Proceedings of the Commission for the Study of Productive Forces of the Socialist Republic of Yakutia. LA Publishing House of the USSR Academy of Sciences, 25 (1). - 205.

Long-term simulation of soil condition and energy flux in eastern Siberian taiga forests

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Key words:Soil moisture, Soil temperature, land-surface model, Soil thaw depth, Soil parameter

Introduction

Meteorological and hydrological observations continued in a larch taiga forest at Spasskaya Pad near Yakutsk of eastern Siberia on a permafrost zone since 1998 (Ohta et al., 2001). In addition, another site was constructed at Elgeeii near Ust-Maya located 300 km southeast of Yakutsk in 2010 (Kotani et al., 2013). Moreover, we have 40 years or more routinely observed meteorological data in Russia.

Soil moisture and temperature have been abruptly increased and active layer became deep since 2004 (Ohta et al., 2008; Iijima et al., 2010). Iijima et al. (2010) pointed out this soil warming caused by abnormally high pre-winter rainfall and snowfall rather than air temperature rising; Yamazaki (2012) suggested especially autumn snowfall affected the soil warming. In this study, we simulated long-term soil/snow condition and water/energy fluxes at the two forest sites before the start of tower observation by use of routine meteorological data. The effect of soil parameters on the soil simulation was discussed with observed soil parameters.

Method

The estimation method for Spasskaya Pad is same as Yamazaki et al. (2007):

1) The relationships of meteorological data between Yakutsk and the tower at Spasskaya Pad are established from 1998 to 2000.
2) Past meteorological conditions over the taiga forest are estimated using the equations obtained step 1). Diurnal variations are given with empirical equations.
3) The heat fluxes and soil/snow situations are estimated using a one-dimensional land surface model.

On the other hand, routine data itself is used at Ust-Maya for Elgeeii simulation because we do not have enough data to establish the relationship between Ust-Maya and Elgeeii.

Land-surface model

The land surface model (2LM) used in this study is a one-dimensional model described in Yamazaki et al. (2004). It is composed of three submodels; vegetation, snow cover, and soil. It can calculate water and energy fluxes above and within forest, if meteorological data over the forest are given as input (Fig. 1).

The snow submodel can consider depth hoar to adapt intensely cold regions Yamazaki (2001). The submodel is multi-layer, the number of snow layers depend on snow depth. It can calculate profiles of snow temperature, density, and liquid water content as well as snow depth.

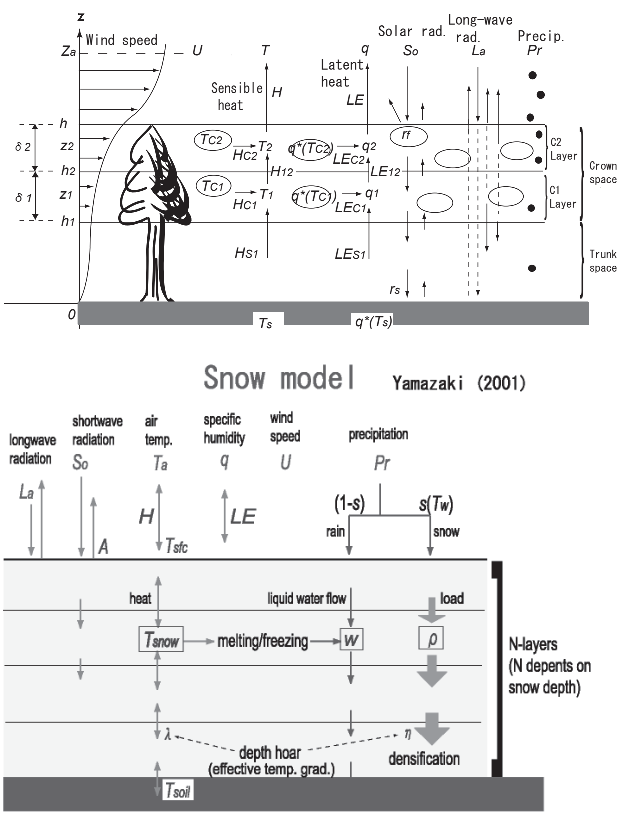

Fig.1. Schematic of the land surface model (2LM). Upper: vegetation submodel, Lower: Snow submodel.

The soil submodel is a multi-layer model having a thickness of 0.1 m except for the top layer (0.2 m). It can calculate profiles of soil temperature and water content. Heat of fusion of frozen soil is taken into account with a method in which heat capacity is regarded as larger in a small temperature range between -1 and 0 C.

Jarvis type parameterization is used for stomatal conductance, which controls transpiration from tree; common parameters (Yamazaki et al., 2013) are given according to a concept of potential response.

Data

The routine data used in this study is Baseline Meteorological Data in Siberia (BMDS) Version 5 (Yabuki et al., 2011). It consists of daily mean, maximum and minimum air temperature, precipitation amount, water vapor pressure, mean and maximum wind speed, duration of sunshine, snow depth, and other elements. BMDS includes no data of solar radiation and long-wave radiation, which are necessary for the model as input. Thus they are estimated from duration of sunshine etc. The periods of simulation were from 1966 to 2008 for Yakutsk and from 1960 to 2008 for Ust-Maya; in these periods, the all data including duration of sunshine are available. Wind speed data in 1983 are missing in Yakutsk, thus monthly mean obtained from the other year data is used instead of daily wind speed in this year.

The leaf-out date is parameterized as the date of 'soil temperature at 10 cm becomes greater than 5 C' and 'accumulated daily mean air temperature becomes greater than 100 Cday after daily mean air temperature is beyond 0 C'. The period until leaf-out finish is assumed as 16 days. It is assumed that the fallen leaf starts at 1 Sep. and finishes 30 Sep. in every year.

The initial soil temperature and water content are obtained as follows. At first, whole period simulation is carried out with tentative initial soil situation that are constant temperature of annual mean air temperature and constant water content of 0.2. Ten set of the soil temperature and water content of January 1 from 1999 to 2008 calculated by this tentative simulation are used as initial condition for regular simulation for the two sites. The reason ten member initial values are used is that uncertainty due to initial condition and length of influence of initial condition can be estimated.

Figure 2 shows warm season average or amount of meteorological data (from May to August). We can find slight increasing trend in air temperature in both sites, however there are no significant trends in solar radiation and precipitation. The difference of air temperature between the two sites is small (average for warm season

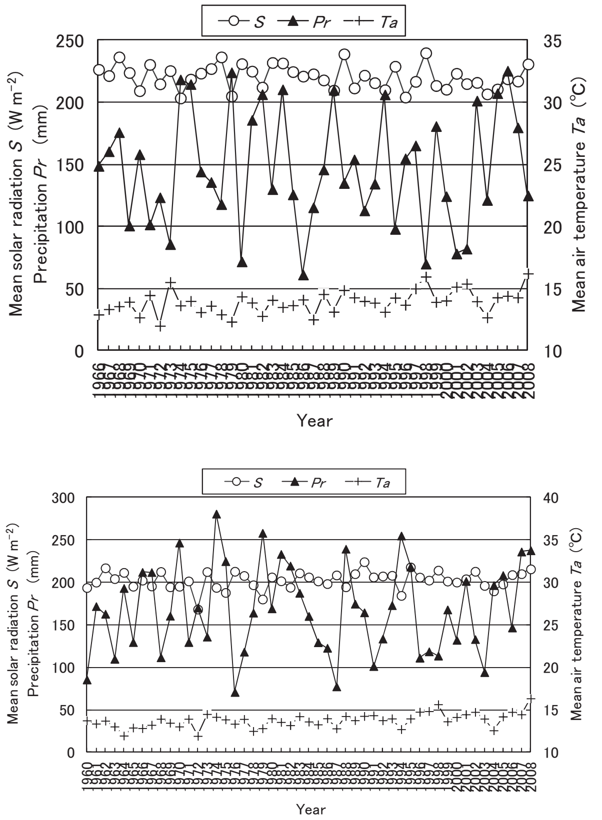

Fig. 2. Warm season averages of solar radiation and air temperature, and amount of precipitation (from May to August). Upper: Yakutsk, Lower: Ust-Maya.

of whole period is 13.9 C at Yakutsk and 13.8 C at Ust-Maya). The warm season averages of solar radiation are 221 W m^{-2} at Yakutsk and 203 W m^{-2} at Ust-Maya; on the other hand, the averages of precipitation amount for warm season are 147 mm at Yakutsk and 168 mm at Ust-Maya.

Results

< Yakutsk >

Figure 3 shows the relationship between volumetric water content and soil water potential at Spasskaya Pad. The marks indicate observation (Kotani et al., 2013); only both extremes are shown in the figure, other data are distributed between triangles and squares. Lines are fitting of formulae by Clapp and Hornberger (1978), the fitted parameters are listed in table 1.

Figure 4 shows interannual variation of calculated soil water content in the layer of 0 – 2 meters depth for three soil parameter sets listed in Table 1. Only the results for soil initial condition of 2004 is shown, which is close to average of ten initial conditions. It has been shown that

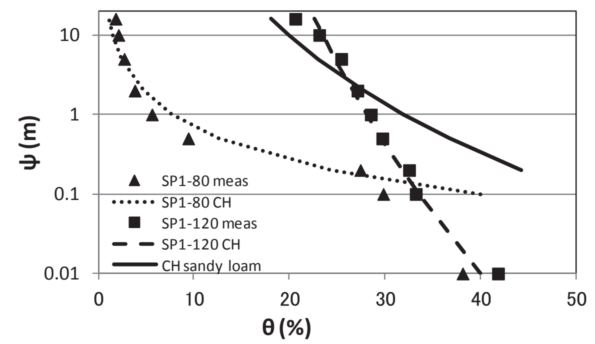

Fig. 3. The relationship between volumetric water content and soil water potential at Spasskaya Pad. Marks indicate observation (Kotani et al., 2013); Lines are fitting of formulae by Clapp and Hornberger (1978); solid line: sandy loam parameters.

the influence of initial soil condition disappeared after about 8 years (Yamazaki, 2012). The result with K2 parameters is similar to that with sandy loam parameters; the soil water from 2006 to 2008 is in highest level during 40 years. However, soil water is significantly low when K1 parameters, which correspond with sandy condition, are used; in particular recent abrupt increase of soil water does not reproduced.

Figure 5 shows simulated soil thaw depth and snow depth. The simulated thaw depth with sandy loam and K2 parameters tends to increase after 2004. In particular, it is estimated that the soil thawed deepest from 2006 to 2008 during this 40 years. On the other hand, the simulated soil thaw with K1 parameters has small variation in the range between 100 and 150 cm; abrupt increase of thaw depth after 2004 is not found.

Figure 6 indicates simulated energy fluxes. Here, simulated fluxes with sandy loam and K2 parameters are similar again; however, high sensible heat and low latent heat fluxes are simulated with K1 parameters.

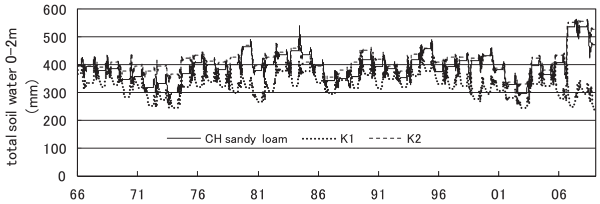

Fig. 4. Calculated total column soil water from 0 – 2 m depth. Solid line: sandy loam, dotted line: K1 and broken line: K2 parameters in Table 1.

Table 1. Soil parameters of formulae by Clapp and Hornberger (1978). K1: dotted line, K2: broken line, and Sandy loam: solid line in Fig. 3, respectively.

	ψ_{sat} (m)	θ_{sat} (%)	b
K1	0.1	40	1.4
K2	0.01	40	13
Sandy loam	0.218	43.5	4.9

< Ust-Maya >

Figure 7 shows the relationship between volumetric water content and soil water potential at Elgeeii; the fitted parameters are listed in table 2. Simulated soil water content is shown in Fig. 8; but simulation with K2 parameters is unstable thus the result is not shown.

Conclusion

Long-term soil conditions and energy fluxes were simulated with use of a one-dimensional land surface model. The results were sensitive to soil parameters; it is important not only to improve models but to determine effective soil parameters.

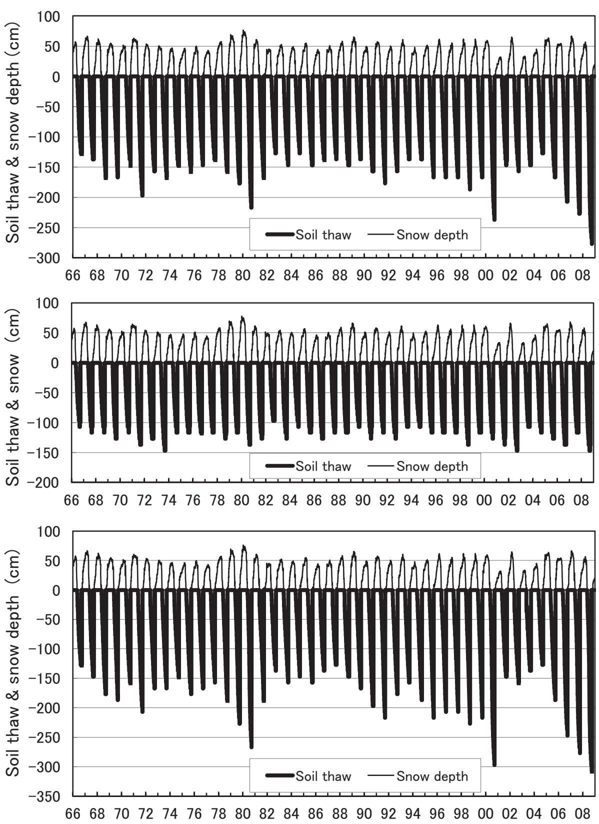

Fig. 5. Simulated soil thaw depth and snow depth. Upper: sandy loam, middle: K1 and lower: K2 parameters in Table 1.

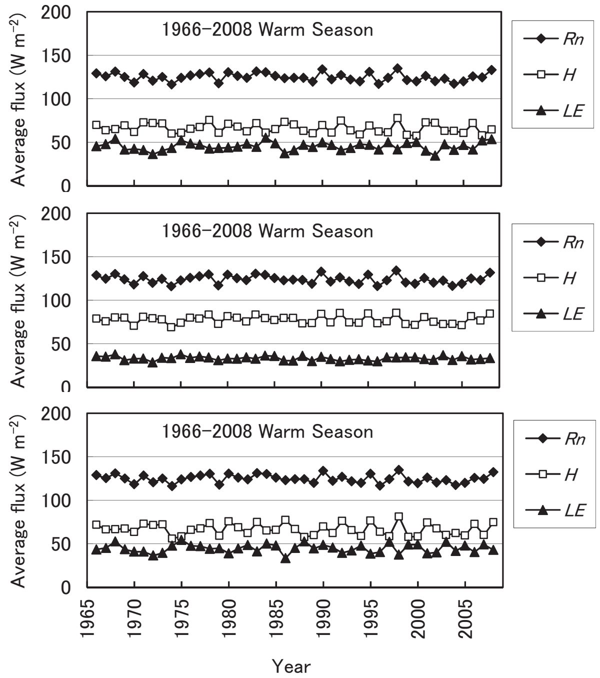

Fig. 6. Simulated energy fluxes. Upper: sandy loam, middle: K1 and lower: K2 parameters in Table 1.

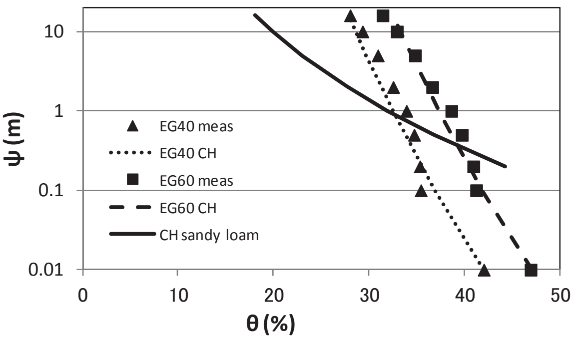

Fig. 7. Same as Fig.3 but at Elgeeii.

Table 2. Same as Table 1 but at Elgeeii.

	ψ_{sat} (m)	θ_{sat} (%)	b
K1	0.01	42	18
K2	0.01	47	20
Sandy loam	0.218	43.5	4.9

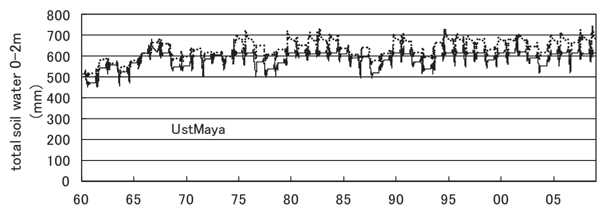

Fig. 8. Same as Fig.4 but at Elgeeii.

References

Clapp, R. B., and G. M. Hornberger, 1978: Empirical equations for some soil hydraulic properties. *Water Resour. Res.*, **14**, 601-604.

Iijima, Y., A.N. Fedorov, H. Park, K. Suzuki, H. Yabuki, T.C. Maximov and T. Ohata, 2010: Abrupt Increases in soil temperatures following increased precipitation in a permafrost region, central Lena River basin, Russia. *Permafrost Periglacial Processes*, **21**, 30-41.

Kotani, A., T. Ohta, A. Kononov and T. C. Maximov, 2013: Temporal variations in the linkage between the net ecosystem exchange of water vapour and CO_2 over boreal forests in eastern Siberia. *Ecohydrology*, (inpress).

Ohta, T., T. Hiyama, H. Tanaka, T. Kuwada, T.C. Maximov, T. Ohata and Y. Fukushima, 2001: Seasonal variation in the energy and water exchanges above and below a larch forest in eastern Siberia. *Hydrological Processes*, **15**, 1459–1476.

Ohta, T., T. C. Maximov, A. J. Dolman, T. Nakai, M. K. van der Molen, A. V. Kononov, A. P. Maximov, T. Hiyama, Y. Iijima, E. J. Moors, H. Tanaka, T. Toba and H. Yabuki, 2008: Interannual variation of water balance and summer evapotranspiration in an eastern Siberian larch forest over a 7-year period (1998–2006). *Agricul. Forest Meteor.,* 148, 1941-1953.

Yabuki, H., Park, H., Kawamoto, H., Suzuki, R., Razuvaev, V.N., Bulygina, O.N., and Ohata, T. (2011): Baseline Meteorological Data in Siberia (BMDS) Version 5.0, RIGC, JAMSTEC, Yokosuka, Japan, distributed by CrDAP, Digital media.

Yamazaki, T., 2001: A one-dimensional land surface model adaptable to intensely cold regions and its applications in Eastern Siberia. *J. Meteor. Soc. Japan*, **79**, 1107-1118.

Yamazaki, T., H. Yabuki, Y. Ishii, T. Ohta and T. Ohata, 2004: Water and energy exchanges at forests and a grassland in eastern Siberia evaluated using a one-dimensional land surface model. *J. Hydrometeorology* **5**, 504–515.

Yamazaki, T., T. Ohta, R. Suzuki and T. Ohata, 2007: Flux variation in a Siberian taiga forest near Yakutsk estimated by a one-dimensional model with routine data, 1986-2000. *Hydrological Processes*, **21**, 2009-2015.

Yamazaki, T, 2012: Simulation of soil water and temperature in eastern Siberian taiga forests by a one-dimensional land-surface model. *Proceedings of 1st International Conference on Global Warming and the Human-Nature Dimension in Siberia*, 20-23.

Yamazaki, T., K. Kato, T. Ito, T. Nakai, K. Matsumoto, N. Miki, H. Park and T. Ohta, 2013: A Common Stomatal Parameter Set to Simulate the Energy and Water Balance over Boreal and Temperate. *J. Meteor. Soc. Japan*, **91**, 273-285.

Spatio–temporal variations in permafrost and boreal forest degradations in central Yakutia

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Keywords: Permafrost degradation, ALOS, PALSAR, AVNIR2, GIS

Introduction

Large increase in precipitation during summer through winter had continued since 2004 winter in the central Yakutia. Soil moisture during following years had been increased corresponding with the precipitation increase accompanying with thawing permafrost near the surface (Iijima *et al.*, 2010). The perennially waterlogged conditions furthermore exacerbated the boreal forest habitat, namely withered and dead trees widely extended in this region.

Increases in active layer thickness caused rapid thermokarst subsidence, which has negatively impacted the growth of larch forest. According to multi-year sap flow measurements between 2006 and 2009, transpiration from larch trees was significantly reduced in conjunction with the deepening and moistening of the active layer (Iijima *et al.*, 2013). The perennially waterlogged conditions left mature trees withered and dead. The reduction ratio of seasonal average canopy stomatal conductance within damaged emergent trees between 2006 and 2009 had a significant positive correlation with the increase in active layer thickness.

The present study examined the relationship between permafrost degradation and ecohydrological change in this region due to the unexpected climate–driven damages. We have attempted to extract the degraded boreal forest based on satellite image analyses, along with expansion of the water surface area in relation to permafrost degradation in the central Yakutia.

Data and methods

We utilized ALOS (The Advanced Land Observing Satellite)–PALSAR (Phased Array type L-band Synthetic Aperture Radar) and AVNIR2 (Advanced Visible and Near Infrared Radiometer type 2) images taken during 2006 through 2009. After geocoding and noise reduction of PALSAR backscatter signal ((HH+HV)/2), classification of water surface area including water–logged ground was performed with supervised classification using the threshold of a microwave backscattering coefficient. Then, we compared the distribution of the water–logged area between multi–years. In addition, during the same period, supervised classification of grassland and boreal forest was conducted using AVNIR2 images. Then, both classifications were overlaid and the multi–years change in degraded boreal forest due to water–logged conditions was extracted as well (Fig. 1).

In order to detect the possible area of permafrost degradation in conjunction with forest degradation by overwet active layer, we determined a threshold range of backscatter coefficient representing vegetation change from forest to grassland by AVNIR2 images between 2007 and 2009 with wet surface in by PALSAR

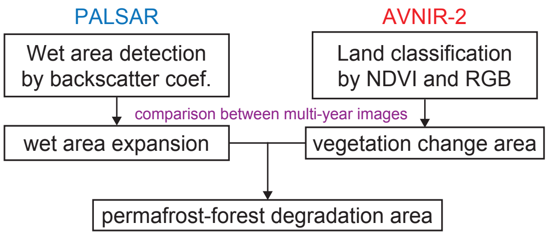

Fig. 1. The framework for the classification of permafrost & forest degradation area using ALOS–PALSAR and AVNIR2 data.

in 2007. Based on random sampling of 200 points in PALSAR image in 2007, which coincides with the landscape change from forest like surface in 2007 to grassland like surface in 2009 by AVNIR2 images, backscatter coefficients are distributed as shown in Fig. 2. The range between -11 to -17 dB of the backscatter coefficient is determined as the possible degraded area due to perennial wet stress. As demonstrated by Martinez and Toan (2007), the backscatter signal by J–ERS SAR images ranging from -9 to -14 dB is determined as occasionally flooded low vegetation areas. Thus, the range we defined here is comparable to the threshold of overwet surface under forested surface. Then, we applied the range to the PALSAR image in September 2009. The procedure detects further possible area of forest degradation by continuous wet surface in conjunction with perennial active layer change (permafrost degradation).

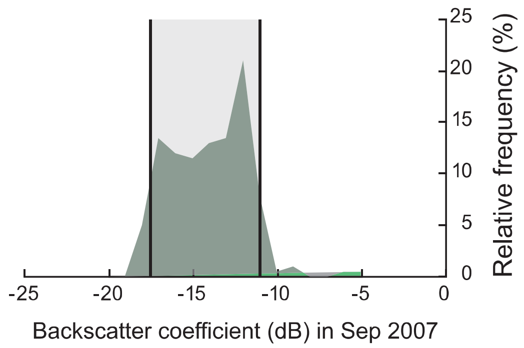

Fig. 2. The frequency distribution of backscatter coefficient in 2007 at 200 points sampled randamly which changes from forest to grassland and classified as wet surface in 2009.

Results

Boreal forest in the left bank of the Lena River distributes on river terrace where density of alas lakes is quite low due to consisting of sandy loam soil with underlying permafrost with less ground ice content. In this area, water surface area expanded in concaved terrain and along the valley year by year in conjunction with change from forest to grassland like landscape. By the classification using PALSAR image in September 2009 (Fig. 3), in total, 528.4 ha of Spasskayapad region (5.3% of 10 x 10 km) is detected as possible forest and permafrost degradation area. As mentioned above, the degradation area distributes mainly along valley in the higher terrace, and partially around alas lakes.

On the other hand, forest in the right bank of the Lena River distributed in the region with very high density of alas lakes due to underlying ice rich permafrost. During the same period, alas lakes expanded and boreal forest on the periphery of lakes turned to water surface and grassland. The possible degradation area in Yukechi region (Fig. 4) is remarkably larger than that in the Spaskayapad region, that is, 1217.5 ha (12.2%) in the analyzed area.

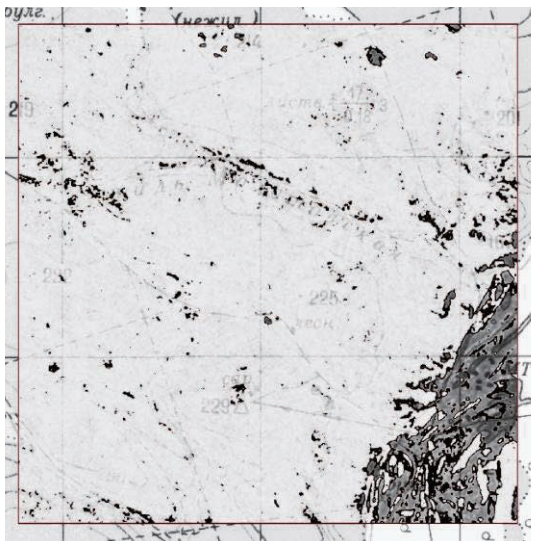

Fig. 3 Permafrost & forest possible degradation map in Spasskayapad area (10x10 km). Black area denotes possible area for degradation.

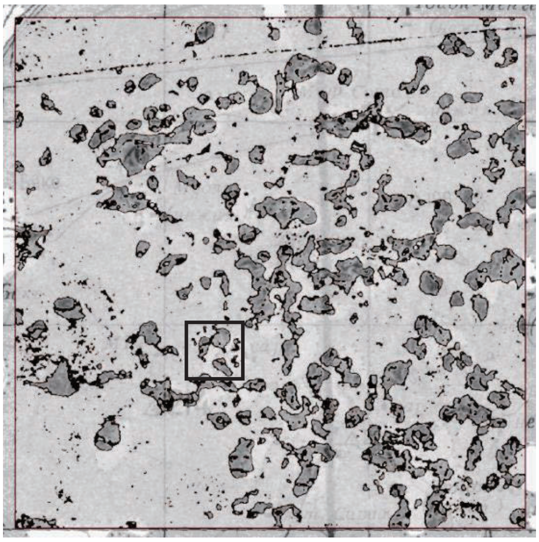

Fig. 4. Same as in Fig.3 except for in Yukechi area (10x10 km). The rectangle area denote intensive observation sites shown in Fig. 5.

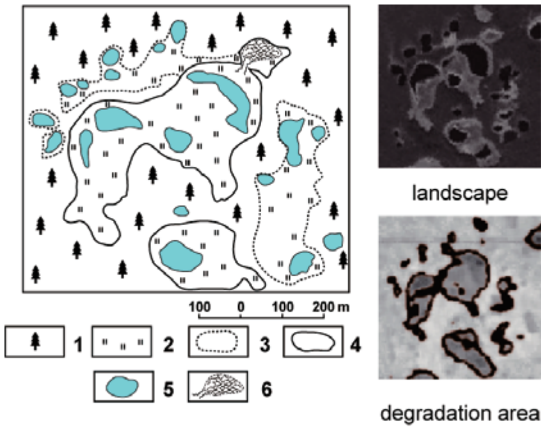

Fig. 5. Location map of Yukechi Experimental site (left) and landscape image by AVNIR2 (upper-right) and deradation area (lower-right)
1-larch forest; 2-meadow; 3-meadow contour in inter-alas; 4-alas contour; 5-lake; 6-collapsed lake

Based on the field survey at the intensive observation site in Yukechi (Fig. 5), we could found humidified and deepen active layer in side slope of alas lakes increased topographical instability and finally eroded forest surrounding lakes by largely increased water mass.

In addition, thermokarst depression was also accelerated during the wet years after 2005 (Fedorov et al., 2013), consequently causing expansion of alas lakes and infiltration of high soil moisture from lake side to forest interior. The process also induced the forest degradation accompanying with deepening and over–wetting active layer.

In brief, the method combining ALOS satellite analyses has great possibility to detect permafrost and forest degradation caused by wet climate in the central Lena river basin in the recent years.

Acknowledgement

This study was supported by the Research Institute for Global Change (RIGC), JAMSTEC and by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Young Scientists (A) No. 21680057.

Reference

Fedorov, A. N., P. P. Gavriliev, P. Y. Konstantinov, T. Hiyama, Y. Iijima, and G. Iwahana, 2013, Estimating the water balance of a thermokarst lake in the middle of the Lena River basin, eastern Siberia. *Ecohydrology*, in press.

Iijima, Y., A. N. Fedorov, H. Park, K. Suzuki, H. Yabuki, T. C. Maximov and T. Ohata, 2010. Abrupt Increases in Soil Temperatures following Increased Precipitation in a Permafrost Region, Central Lena River Basin, Russia. *Permafrost and Periglacial Processes*, **21**, 30–41.

Iijima, Y., T. Ohta, A. Kotani, A. N. Fedorov, Y. Kodama and T. C. Maximov, 2013. Sap flow changes in relation to permafrost degradation under increasing precipitation in an eastern Siberian larch forest. *Ecohydrology*, in press.

Martinez, J.–M., and T. L. Toan, 2007. Mapping of flood dynamics and spatial distribution of vegetation in the Amazon floodplain using multitemporal SAR data. Remote *Sensing of Environment*, **108**, 209–223.

Nature-human coevolution in the coldmost region of the planet

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Keywords :climate adaptation, human, society

Yakutia is the coldest [1] and at the same time one of the richest [2] in mineral resources regions of our planet. On this basis the scholars predict a considerable increase in population in these territories by the end of the century [3].So the study of nature-human coevolution becomes one of the principal grounds for the northern regions of the country to substantiate an ecological sustainability of natural ecosystems in general from the philosophical angle and successful well-being of northeastern community in particular.

In this context we have analyzed research data on the air temperature change, human population, plant and animal kingdom in the Holocene. Vegetation in late Sartan glaciation that foregone the Holocene is well-described on the map compiled by Skryabin and Karavayev [4, fig.1]. The map shows the territory of the present central, western and southern parts of Central Yakutia grown at that time with patchy birch-larch-pine forests in combination with grass-wormwood steppes.

It should be noted that there was no continuous glaciation in Yakutia as it happened in Europe. This phenomenon is also mapped as occurring island mountain glaciers coupled with mountain tundras. Matching the map by Skryabin and Karavayev with the map of present Yakutia it may be concluded that the flat tundra with short vegetation and the mountain one with participation of forests changed little for the last millenniums. The change concerns a slow forest movement northward. Main landscapes, plant species diversity of Yakutia, western and southern parts of Central Yakutia also did not change much as opposed to the animal kingdom.

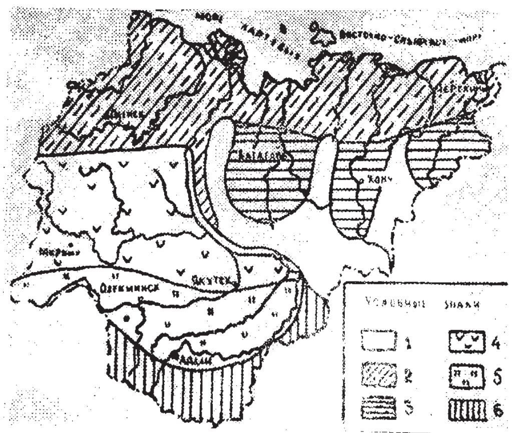

Fig.1. Vegetation of the end of late Sartan glaciation (according to S.Z. Skryabin, M.N. Karavayev, 1991)

1- island mountain glaciers with mountain tundras, subgoletz brushwood and patches of sparse forests

2 – vegetation of a plain tundra type.

3 – mountain forest-tundras with steppe sites

4 –forest-tundra with subarctic steppes near glaciers

5 – forest-steppes near glaciers island birch-larch-pine forests combined with grass-wormwood steppes);
6 - mountain tundra with participation of forests.

Late in Pleistocene – early Holocene there was a rapid and recurrent change of coolings and warmings causing significant change in the structure and functioning of ecosystems. Waves of warmings and the following coolings varied from – 8.5, 10.5 to – 12.0, 14.0°C. Therefore typical members of the mammoth fauna – mammoths, bison, woolly rhinoceros, muskoxen, cave lions found themselves poorly accommodated to rigid northern conditions. Animal adaptation to cold, skin thickening, increasing and lengthening of hair, metabolism change, etc began.

The following climate warming caused the larch taiga coming with participation of pine, birch and spruce forest on the one hand and an active development of thermokarst processes and appearance of many natural traps where mammoths and other representatives of the mammoth fauna died, on the other hand. Mammoths disappeared at the turn of Pleistocene-Holocene because their remains in the mainland Yakutia found in deposits were not younger than 9 thousand years.

It must be emphasized that death of the mammoth fauna concurred in time with further settlement of the Paleolithic man in Yakutia. Bifacial way of the arrowhead and spears treatment invented by the Dyuktai human made it possible to kill big animals for the Neolithic man. Among the kitchen wastes of people belonging to the Dyuktai culture (35-10.5 thou yr ago) there were bones of mammoths, bison, horses, muskoxen, etc.

In late Mesolithic the Paleoasians who were ancestors of Yukagirs lived over Yakutia territory; about 2 thousand years ago the Evenks settled there and during the last millennium the land of Yakutia accepted Sakha (Yakuts); the Russians came about 400 years ago. The ancestry of the modern Evens and Evenks tamed the northern reindeer, the Sakha people (Yakuts) brought horses and cattle, the Russians introduced farming. In the 20th century the dawning of the industrial development began.

Accommodation of different ethnoses to the conditions of the cold climate had their own features. Currently it is generally recognized that the Sakha ancestry who originally came to Central Yakutia somewhere late in the 13th century A.D. experienced the influence of extremely rigid cold climate.

Living under such conditions during many generations the northerners acquired a set of ecologo-physiological features of an adaptive origin, including:

- massive, relatively short-legged body;
- high level of metabolism
- high level of gamma-globulin fraction of blood;
- delayed blood coagulation;
- increase in oxygen blood index at physical exercise;
- better uptake of lipid-protein complexes in nutrition;
- delayed rhythms of vital functions.

We would like to say a few words relating to items of social adaptation - farming, Yakut balagan, clothes and food as the ground for adaptation to the coldest region on Earth. The

Sakha people (Yakuts) learned to use grasslands, hay-making meadows. Having learned from the Russians their technology of grain production they brought in much new in the way of tillage under permafrost conditions.

The architecture and design of the balagan were constructive because a wayfarer who could come to the cold house (balagan) and light a fire-place (at the ambient temperature 50-60^{0}C) was able to take off his overclothes (sheepskin coat or fur coat) in 8-10 min [5].

The proceedings of the All-Russian hygienic show (1913) indicate the advantages of traditional clothes of Sakha people. "The Yakut costume is made to wear it easily and move free on foot or ride a horse considering the least cost for dress or skin material at the greatest preservation of animal warmth of an organism. This idea is successfully implemented by all members of national minorities of the North and recognized by many experts of polar countries and travelers."

It should be emphasized that original ideas and technologies laid in the traditional manner of nutrition of the Yakuts: sour milk food, kumys, salt-free diet, raw-stuff eating, consumption of natural products, increased use of high-calorie food (fats) in the conditions of low temperatures, etc are recognized today rational and useful and popularized in the entire world [6].

In the North the Yakuts made a real food revolution that was a major outcome of their economic revolution. Before the Yakuts came many foodstuffs were not available in the North: milk, cream, sour cream, butter, curds, sour-milk products, kumys, whey, beef, colt meat, sapwood flour. Having upgraded fishing tools the Yakuts created a greater variety of fish products for their subsistence. As opposed to other North peoples the Yakuts always managed to store foodstuffs as thrifty people and planned their consumption.

Consequently, one of the major origins of phenomenal hygienic and demographic development of the people of Sakha is actually new revolutionary decision of their food problem in the archaic conditions of the North[7].

In this context the analysis of nature-society interaction for a relatively long time span displayed that the criterion for the increase in the human population in the definite territory and the change of the temperature behavior of this territory are the result of coevolutional nature-society interactions.

References

1. Gavrilova M.K., 2000. Climates of cold regions of Earth. Yakutsk, 206 p.

2. Tikhonov N.N., 2011. Yakutia as the last storeplace of the planet. Yakutsk, 312 p.

3. Tjerri Goden, 2000. By the end of the 21 century Yakutsk and Igarka towns will become the largest Russia cities. *In newspaper* "Yakutia" #12(40), 28.03.2000.

4. Skryabin S.Z., Karavayev M.N., 1991. Green cover of Yakutia, Yakutsk, 176 p.

5. Schukin N.S., 1854, Yakuts//*In* Journal of Ministry of Internal Affairs, 46 p.

6. Lvov L.A. 1984. Lifestyle and longevity in Yakutia, Yakutsk, 32 p.

7. Tyrylgin M.A., 2000. The origins of phenomenal vital capacity of Sakha people. Yakutsk, 304 p.

Assessment of the impact of climate change on transport infrastructure Yakutia

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Key words: transport, Yakutia, climate change, risks, vulnerability

Nowadays global climate changes have been recognized not only as an ecological problem but also as a problem of the economy and life safety of people. In the first place, changes in the environment will affect the functioning of those branches which are provided and limited by such components of ecosystems as agriculture, forestry, water management, recreation and leisure industry, energetics, construction, transport, mining industry. Of course, in these branches, the results of worldwide climate change tied to water ecosystems can be both positive and negative; however, extreme climate events and other abrupt changes that give lesser time for adaptation tend to more seriously effect all life support systems including transport. At the same time, it should be noted that for Siberia and especially its northeastern regions, the development of transport communications has always been crucially important, and any change in the conditions under which these communications are constructed and exploited can complicate the functioning of practically all branches of economy.

Transport is a relevant component of the contemporary economy of Yakutia as it ensures transfer of vitally essential cargo, goods, and people. It plays a significant role in safeguarding life quality and comfort living standards in the north, providing continuous supplies for such strategic sectors of the economy as mining and others. The transport network does not only satisfy human and economic needs in traffic; it also forms a material base for the socioeconomic development of the region.

Practically all kinds of transport are now functioning in Yakutia, i.e. railway, air, motor, water (sea and river), and pipeline traffic.

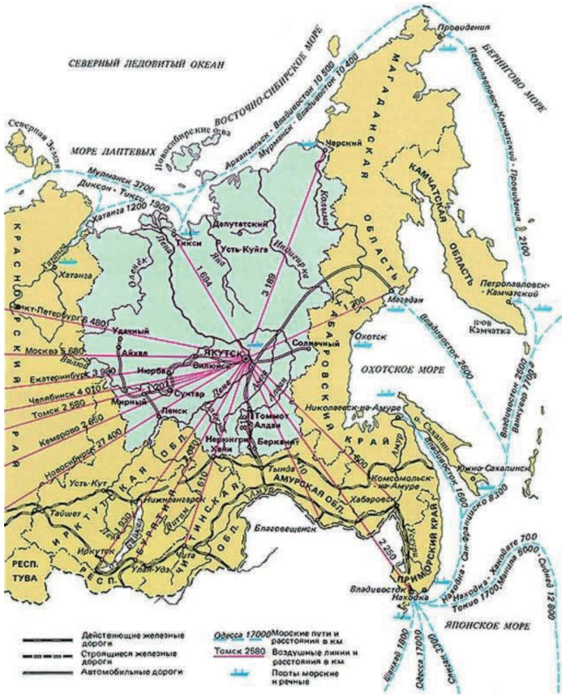

Fig. 1. Transport infrastructure in Yakutia

The railway transport is the youngest in Yakutia. Its development in the republic will generate opportunities for enhancing the economic development of the region, successful exploitation of mineral deposits in the southern Yakutia, expansion of the year-round transport access zone over the considerable part of the territory of the republic (with the substantial proportion of its population), and cost reduction for goods deliveries patterning.

The planned construction of the bridge across the Lena River will directly connect the capital of the republic, Yakutsk City, with the all-Russian railway network. In the southeastern Yakutia, the construction of the terminal Ulak-El’ga train track is almost finished, and it will tie Baykal-Amur Railroad with the El’ga coal deposit.

Yakutia is still among the Russian regions with the fairly developed air traffic. By early 2010s, twenty-three airports have been working in the republic. Air transport provides the major passenger traffic in the republic covering around 65% of entire passenger traffic. Besides long-haul passenger traffic, it services short-distance, communal and interregional, transportation. Air transport carries out air medical and other services, saving the diseased from remote localities, extinguishing forest fires, destroying ice blocks, aerosurveying and reconnaissance, and other air services.

Water transport is now the major kind in the Sakha Republic (Yakutia). It plays the main role in delivering supplies for the population of the region. It is during the short northern navigation, for four and a half months, from early June to mid-October, that the primary goods deliveries takes place, as well as from the outside and inside the republic.

In the Sakha Republic (Yakutia), exploited waterways extend for 21,800 km; operating waterways cover 13,600 km. Yakutia has a wide composite water transport network: the portion of the Northern Sea Route; the major waterway of the Lena River flowing across entire territory of the republic, with its tributaries of Aldan and Viliuy; navigable waterways of Anabar, Olenek, Yana, Indigirka, and Kolyma rivers in the northern Yakutia. The sea transport operates in twelve Arctic districts, from Khatanga Bay to the port of Pevek as well as Chukot regions.

Nowadays, the main part of the goods are transported to the republic through the combined railway/water route of the Trans-Siberian Railroad — Baykal-Amur Railway — Osetrovo port — Lena River. The port of Osetrovo (Ust'-Kut town, Irkutsk Oblast) makes 80% of cargo handling for the republic. This stable, decades old transport pattern can gradually change on condition that the Amur-Yakut Railroad is completed; then, it could reach the river port of Yakutsk and the railways would play the growing role in freight traffic in the republic [Karpov].

Water transport hauls oil and oil products, coal for housing and communal services, wood in rafts, dry cargo, construction materials, food etc. The water transport in Yakutia also is important for passenger traffic, as the underdeveloped road infrastructure actually makes it the suitable, if not the only, way to get to the desired destination.

The motor transport is more than significant for the republic, remaining the only means of road communication. The republic road network is 24050 km long; of these, 3616 km of common highways of the federal level and 11218 km of regional roads. Sixty-three percent, the main proportion of the republic motor roads, are winter roads (*zimniks*). Seasonal, low-duty, and limited capacity roads make 90% of all motor roads [Kharitonova].

The pipeline transport network in Yakutia is quite developed. The first gas-main pipeline Tas-Tumus — Yakutsk was built in 1967. Today, there are 4047 km of operating gas pipelines and 110 km of oil pipelines of the republic level. Besides, to exploit explored reserves of Yakutian Talakan, Srednebotuobinsk, Chayanda, Verkhnechonsk and other oil deposits, the East Siberia – Pacific Ocean (ES-PO) oil pipeline has been constructed and run since 2009. The 1105 km ES-PO portion is working, from Talakan deposit to Taishet, thus providing oil transport to the Angarsk petrochemical plant. In Yakutia, it passes Lenskii, Olekminskii, Aldanskii, and Neriungrinskii districts, and has eight oil-transfer pump stations. The oil pipeline is known to further reach Khabarovsk and Vladivostok, with subsequent delivery of oil and gas to the Asian-Pacific countries [Zotova].

Lifetime of main equipment, buildings, ships, boats and aircraft have exceeded their prescribed lifetime limits by many times. For Yakutia with its vast territories the most disastrous was the reduction of traffic volume by air and sea transport. Currently, regular air communication (once or several times a week) within the republic is only maintained with district centers. As for all other settlements, a rather stable connection is only possible in winter. In summer, travel is carried out by cutters and boats on rivers and streams or, as in the past, by horses and deer. In the arctic uluses, where average distance between neighboring settlements is around 300-500 kilometers, the republican government finances helicopter flights. However, these flights are subject to limitations and each nasleg (rural settlement) has an annual quota. Moreover, a flight is not made according to a schedule but becomes possible only if it is 65% full both ways which is by far not always possible given scarcity of population. Therefore it happens quite often that passengers have to wait for a flight to their place of destination for a month or even longer than that.

Thus, over 90% of the territory of the Sakha Republic (Yakutia) are accessible only seasonally. Almost 88% of products and services are situated in the regions with seasonal lines of communication and means of transport. Only 15% of the population live in

the zone of the year-round transport communications.
92% of the public motor roads comprise seasonal motor roads (automobile *zimniks*) and those with low carrying and bearing capacity (unpaved roads of the V technical category). Until now, 344 localities of the region of the total 522 have no year-round connection with the public net of paved motor roads. Practically all transportation in Yakutia is provided by river and automobile transport. The importance of the water transport and such specific road type as *zimnik* have considerably increased and will probably persist.
As the authors of the "Climate Change and Water Resources" working paper point out, traffic networks are affected by the changes in climate and such collateral events as floods, ice and permafrost thawing, higher precipotations, stronger winds, lower snow cover etc. The impact includes both direct damage from, for instance, disastrous floods or rainwash and effects upon functioning, price, and capability of objects not intended to conform with climate conditions predicted to dominate in the future [Baytes et al.].
The transport systems of Yakutia, so far dependent on natural resources and water ecosystems, are also under high risk caused by effects of worldwide and local climate changes.
The water transport of Yakutia, already in critical state, is under high pressure also. Significant damage to port buildings and equipment was caused by disastrous floods of 2001-2010. Also in the last decade, according to observations of old-timers, a more intensive erosion of river banks is taking place. Any environmental burdens, including global climate changes, given the current state of the republic's water transport will pose additional risks for the life safety of people.
Aftermath of the floods resulted in serious damage for other objects of the Yakutia transport infrastructure. Interruption of traffic caused by flooding and washout inflict losses both to business and people. Thus, only the 2010 flood led to breakdown of 7 bridges, 4 dams, 80 km of local roads, 11.8 km of interregional roads, 6.5 km of 7 republic roads [Departmental records]. High water of three (spring, summer, and autumn) 2013 floods resulted in destruction of already 203 portions of motor roads with 208 km total length: 27.24 km of the Kolyma federal road, 76.5 km of the regional roads, 105 km of the local roads. The floods led to partial or entire unfitness of 72 bridges along the republic and local roads and 13 bridges of the Kolyma federal route. The total damage to the road transportation has been about 2 billion roubles of 4.2 billion of the total republic damage [Andrianov]. Climate effects on changes in ice parameters and weather conditions have a significant impact on *zimniks* as the most popular kind of motor roads in Yakutia, generally following frozen river beds and lakes.
Permafrost thawing also has a negative effect on the road communication network in Yakutia.

Fig.2. Destruction of roads as a result of the thawing of frozen ground. Megino-Kangalasskii ulus (district), Suola village, 2010.

Recently, the people of the republic have become concerned with more and more frequent collapses of the portions of the roads, especially in the zones where the so-called *alas* systems prevail. Soil deformation due to permafrost thawing and washout caused by higher precipitation lead to breakage of traffic-bearing surfaces as well as other objects of the transport infrastructure as buildings, ports, berths, pipelines etc.
Another challenge to the transport system of the region is river shoaling. These days we can see the severe consequences of that at the Indigirka river.
In the first half of September, the depth of the bar section in the Indigirka river mouth was 100 to 135 cm, while in the second half — 90 to 120 cm (with necessary 200 cm). By September 27th, the consumers got only 14.4 thousand tons instead of the planned 57.3 thousand tons. In the main, these were the goods of high priority: oil products and coal. The danger became real for life support of three regions of the republic: Allaikhovsky, Abyisky, and Momsky [Ryzhov].

Thus, climate change has a serious influence upon the state and development of the transport infrastructure and consequently on the state of the economy and well-being of the people. Such an influence include, in particular,

- Destruction of roads, buildings, pipelines, and other objects of infrastructure caused by permafrost thawing.
- Changes in transportation patterns due to later freezing and earlier opening of the rivers.
- Higher cost of prevention and eliminating of consequences of natural disasters (damaged roads, bridges, port structure, and other objects of transport infrastructure).
- Higher mortality caused by more frequent accidents due to growing danger of transportation in changing ice parameters and weather conditions.

To lessen negative consequences of climate change effects on socioeconomic development of Yakutia, the complex measures on the government level are required aimed at prevention and diminution of all the problems mentioned above.

References

Andrianov V. 2013. Podschitan usch'erb ot yakutskih pavodkov [The damage of Yakutia floods has been calculated]. *Gazeta Yakutia,* October 3.

Baytes B.K., Kuntsevich Z.V., Paliutikoff S.U., Paliutikoff Z.P. (ed.). 2008. *Climate Change and Water Resources. Technical paper of Intergovernmental group of experts on climate change.* IGECC Secretariat, Geneve, 80.

Departmental archives of the SR(Y) Motor Roads Department.

Karpov Y. 2011. Bridge over Lena: pros and cons. *Gazeta Yakutia, February 25.*

Kharitonova T. 2012. Transportation Secretary of Yakutia Semen Vinokurov: "Unfortunately, problems are many". *Gazeta Zhizn' Yakutska*, July 19, 8-9.

Ry'jov I. 2013. Severny'y zavoz gruzov v Indigirskuyu gruppu rayonov - pod ugrozoy [Northern delivery to the Indirsky group of regions is endangered]. *Gazeta Novy'y region,* September 27.

Zotova E. 2008. First oil. *Gazeta Vedomosti*, October 6.

The nature words in Sakha, compared with other Turkic languages

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Key words: Sakha language, nature words, folklore, Olonkho

Introduction

In the present paper, particular interest is put on Sakha nature words, and those in Sakha folklores in particular. This paper has three main topics: the language profile of Sakha, nature words in Sakha and other Turkic languages, and nature words in the Sakha folklore.

The Sakha language as a member of the Turkic language family

The Sakha language is a member of the Turkic language family. About 30 individual languages in Eurasia belong to the Turkic language family, and they range from Anatolia to Eastern Siberia. According to the classification of Johanson (1998), Turkic languages are divided into four sub-groups: SW, SE, NW, and NE (Figure 1). Sakha is classified into the NE group. The Sakha language is spoken mainly in the Sakha Republic, which has the size of 3.1 million km^2, and the approximate number of the speakers is 450,000.

NW	NE
Kazakh, Kirghiz, Tatar, Bashkir, etc.	Sakha, Tyvan, Tofa, Khakass, Altay, etc.
SW	SE
Turkish, Azerbaijan, Turkmen, etc.	Uzbek, Uyghur

Figure 1. Four subgroups of Turkic languages

Originally, the Sakha people did not inhabit the current area of the Sakha republic. They are considered to have moved from around the Lake Baikal along the Lena River. The travel is not made in a short period. It is said that the Sakha people have moved from the Baikal area gradually, from 10th century up to 13th century. In the course of this travel, Sakha people experienced language contact with other peoples who speak Mongolic, Tungusic, or Yukaghir languages. Therefore, the Sakha language contains a large amount of foreign vocabulary, especially from Mongolic languages.

Sakha language also keeps their native Turkic words. What is particularly discussed here is some lexical items related with the nature, namely, nature words. Let us take a quick look at the table. As Table 1 shows, nature words of these Turkic languages are very similar. This linguistic evidence suggests that these languages share a common origin. The last item ‘sea’ is an exception. Turkish and Tatar, as well as many other Turkic languages have a similar word *deniz* or *deŋgiz* for ‘sea’, but the Tyvan form is *dalay*, which is borrowed from Mongolian and the Sakha form is *muora*, which is borrowed from Russian.

Table 1. Nature words in Turkic languages

	Turkish	Tatar	Tyvan	Sakha
water	su	su	sug	uu
snow	kar	qar	xar	xaar
ice	buz	boz	---	muus
land	yer	yir	čer	sir
lake	göl	kül	xöl	küöl
sea	deniz	diŋgez	***dalay***	***muora***

Sakha folklore and world view

In this section the Sakha folklore, especially Olonkho, is taken up. Folklore is traditionally contrasted with literature. Briefly speaking, literature is written work, and folklore is told by memory. Olonkho is a kind of Heroic Epic, and is the greatest genre of Sakha folklore. A storyteller and singer of Olonkho does not simply copy previous works of other storytellers, but he also changes and augments the story. Consequently new ideas or items can be introduced into the story in the long history of oral transmission of Olonkho.

The Sakha people has a tradition of their world view, and it is reflected in the world told in Olonkho. The world is divided into three parts: upper world, middle world, and lower world. In upper world live Gods. In middle world live we humans. In the lower world, ogres or devils. At the center of the middle world, there stands Аал Луук Мас, 'holy tree' with wide branches. The top of the holy tree reaches the upper world, and the roots of the holy tree stretches to the lower world.

A quick look on Olonkho

Most Olonkho stories have a common motif. That is, a Hero in the middle world fights devils in the lower world, and after that peace comes to the world. For instance, in *Ehe Xara Attaax Eles Bootur* 'Eles Bootur with a black horse', the Hero Eles Bootur lived with 3 sisters. But one day, the devil Üös Tardar came to the middle world and carried off 2 of the sisters and the youngest lost her consciousness. Eles Bootur came to know this kidnap afterward, and he went to the lower world in order to take back the sisters. Finally Eles Bootur managed to beat Üös Tardar, and peace came to the middle world again.

Let us take up one scene from *Eles Bootur* (told by Petr Ogotoev (1910-1977), published as Ogotoev (2002)). This is a dream of a nightmare the youngest sister had.

Үс балсыстарын үһүөннэрин
Субуллар суһуохтарыттан,
Эрчимнээх илиитигэр
Холбуу-хомуйа үс төгүл эрийэ тутта да,
(Üös Tardar) Snatching all the three sisters
By their long hair,
Winding it three times
Round his powerful hand,

Ытаппытынан-соҥоппутунан
Үктэнэр сирдэригэр үктэннэрбэккэ,
Биир да тылы быктарбакка,
Быһа ньимийэн тус хоту диэки хайыһа түһээт,
Хахай харбаабытынан халыаннык бара турда.
Taking no notice of their tears and shouts
Not letting them step the ground,
Letting them utter not a single word,
(Üös Tardar) Growling like a lion, rushed to the North.

Үс түүннээх күнү мэлдьи тохтоло суох түһэн,
Чэҥ түгэхтээх, уста сылдьар
Улуу муус хайалардаах,
Күннэри-түүннэри куугунуу ытыллар
Кулан буурҕалаах, мунурун булларбатах
Муус кудулу **байҕал** улуу дьаалга тиийээт,
Falling for three days and nights without a stop,
He got to an ***ocean*** *with huge icebergs and with snowstorm blowing day and night.*

Үс балсыстарын үһүөннэрин
Үс аҥы илгэн кэбиһээт,
Муус кудулу **байҕалга** төбөтүн оройунан түстэ,
Үс түүннээх күнү мэлдьи таастыы тимирдэ.
Throwing the three sisters to three directions,
(Üös Tardar) Dived into the ice-covered ***ocean*** *from the head, and he was under the water like a stone for three days.*

The word *байҕал* is an archaic word whose meaning is ‘ocean.’ In this scene, ice-covered ocean can be considered to be a kind of a symbol of the lower world. In my research on other folklore stories also, rivers and lakes are often described as dangerous places and should not be approached.

Concluding remarks

In this paper, the language profile of Sakha, nature words in Sakha and other Turkic languages, Sakha folklore, and the world view of Sakha people were discussed. At present, I am translating some Sakha folklore into Japanese, which will be published next year. In my research, both in Olonkho and in other folklore stories, rivers and lakes are often described as dangerous places and should not be approached, and sometimes witches are supposed to live in such places. Perhaps this can be considered to be an analogy to the lower world.

References

Johanson, Lars. (1998) The history of Turkic. Lars Johanson and Éva Ágnes Csató. (eds.) *The Turkic languages*. 81-125. London: Routledge.

Ogotoev, P.V. (2002) *Eles Bootur. Olonkho*. Yakutsk.

Adaptation to extreme impacts of Climate Change: the experience of the villages of Yakutia

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Keywords: climate change, indigenous peoples, socio-cultural problems, adaptation.

This report presents the results of an expedition to s.Kyllah undertaken in the course of the project RFBR № 09-06-98503 «Peoples of the Arctic in global climate change: stability, transformation, adaptation. During the expedition, in 2010, the project staff were able to view the history of flooding and the problems of social adaptation of the village's population to the new conditions.

One of the question a problem protecting settlements from catastrophic flooding is to move the village to a non-flooding terrace. One of the annual flooding of settlements on the territory of the Republic of Sakha (Yakutia) is an island village Kyllakh of Olekminsky district. Catastrophic floods in Kyllakh occurred in 1903, 1937, 1948, 1969, 1998 and 2001.

After the floods of 1998 and 2001 the issue of relocating the village Kyllakh was included in the decree of the Government of the Republic of Sakha (Yakutia) of 15 January 2002 «About the relocating the most affected by the floods of 1998 and 2001 the settlements of the Republic of Sakha (Yakutia)».

The decision to postpone the village on the right bank of Lena river on the village Dapparay, which located opposite village Kyllakh in 3 km to the high terrace was taken at the village meeting February 17, 2003.

Fig. 1. Village Kyllakh relocate to the Dapparay village

The organization works of relocate the village Kyllakh began with the publication of the decision of the Government of the Republic of Sakha (Yakutia) № 333 of June 9, 2005. These decision have led to the development of a «Feasibility Study of relocate the village Kyllakh of the Olekminsky district of the Republic of Sakha (Yakutia)» [1].

The official relocating of the village-island Kyllakh began in 2006. The general plan of arrangement of village include the management and organization of neighborhoods, service establishments, places of leisure, as well as the structural unity with old Dapparay.

Residential buildings in the new Dapparay are mostly one-story single-family wooden houses with homestead area of 0.15-0.20 ha.

120 houses will build in plan. Not the entire population was included in the state program of relocating. The Govenment of the Republic of Sakha (Yakutia) will build social, cultural and the entire infrastructure building.

Houses in village Dapparay built of these three programs [2]:

1. Program «Milk rain». According to this program the first 30 homes were built in the spring of 2009, including 15 homes designed for young professionals, and 15 - for the population of the village. Under this program, people could pay 30% of the equity of the value of a house. Feature of this program is that the payment of credit through the proceeds from the sale of milk.
2. Federal target program "Social development of village." Construction is under co-financing: 30% of the federal budget, 40% - republican, 30% - means population). The first direction of construction - to improve housing conditions, and the second - providing housing for young families and young professionals.
3. The program of the Ministry of Agriculture of the Republic of Sakha (Yakutia).

The relocate of the whole of the village, especially to the non-flooding terrace of Dapparay village requires a lot of cost, effort, there are a lot of issues, problems. The main issues keeping the residents on the island despite continued and increasing flooding are the huge expense, energy and the many difficulties in moving as well as the problem of psycho-social adaptation to a new place.

The main problem of the population, despite the introduction of residential buildings is the provision of housing low-income families. Actual residents of the village did not have the financial and material opportunities to make any kind of credit for housing. Therefore, people are in limbo, which enters them into position of hopelessness, depression, loss of hope for a better future.

There were also problems with the entered houses. The villagers complained that built houses was very cold.
Socio downside is risk of bursting of family ties, as well as artificially created gender tension.
The mother with the children move to village Dapparay and husbands are stayed in village Kyllakh to look after the cattle during the school year. Financial and organizational problems to the families who have school children connect with building new school in Dapparay. Those who do not have their own house in Dapparay, forced to seek house with relatives or rent a room. The problem is exacerbated in spring and autumn. Children whose families are do not have house in Dapparay, autumn and winter are coming to school from Kyllakh.
The big drawback master plan for the village is a small area of homestead, which does not provide space for for livestock. It is keenly aware of the local population, the main occupation is cattle breeding. Family where all family members work at the school forced to move to Dapparay without livestock.
The reason by which the local population of the Kyllakh not to move in Dapparay is the lack of native grasslands on the bank. The island is rich by grasslands and pastures for livestock from olden times.
Some residents of Kyllakh also do not like the fact that everyone has to build a house, following the master plan: roofs of houses should be red-tiled and the house should be yellow.
Among the residents were willing to move the house in other villages inside Olekminsky district. Unfortunately, the program provides one-time assistance to move or construction of individual houses from the flooded village Kyllakh only to Dapparay.
During our research, the main focus was to identify the measures taken to prevent the adverse effects of Climate Change, particularly in relation of Kyllakh - measures taken during the flood.
Compared with other districts, population of Kyllakh of Olekminsky district is generally satisfied with the work of governing bodies in the area of prevention and protection of the settlements and their inhabitants from natural emergencies at the local level (65.0%) and at districts level (77.5%) and republic (72.5%) levels.
The population of Kyllakh, according to our study, the least appreciated the work of the local authority - Administration of Kyllakh village. The work of the republic and district authorities rated highly, since the measures were taken to prepare for floods and were decided to relocate to the village Dapparay. But on the other hand, the transfer of the village was made possible thanks to the efforts of the employees of the administration of Kyllakh village, which in time have collected the required number of required material, which contributed to the fact that Kyllakh was one of the first village was included in the program for the transfer of the flooded villages
The study revealed a lack of coordination between different structures of power and control in the practical implementation of measures for relocate of the village.
Relocate of Kyllakh to the Dapparai village is a historic event not only for Kyllakh population, but for all residents of the Oleknisky district and also the republic in general. The experience gained from relocate of the Kyllakh village, will be an invaluable lesson for the rest of the population the most affected flooded villages of republic, which waiting for their turn.

Reference:
1. «Feasibility Study of relocate the village Kyllakh of the Olekminsky district of the Republic of Sakha (Yakutia)». / The current archive of the Office of Economic Development and Finance, MO "Olekminsky district" of the Republic of Sakha (Yakutia).
2. The current archive of the Municipal Institution "Administration of Kyllakh village (nasleg)".

Features of adaptation of the Russkoye Ustye community to the ecosystem of the Indigirka River estuary

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Key words: local communities, natives, traditional economy, Indigirka River

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The community of Russian Ustie was formed in the area of the Indigirka river estuary more than 400 years ago. There are three main hypotheses in relation to its formation:

1. The citizens of Novgorod, who escaped from political repressions of Ivan the Terrible,

2. Descendants of Cossacks and craftsmen.

3. Migrants from Zashiversk-city which was liquidated pursuant to the Tsar decree in 1805.

Probably, we should bear in mind all three versions as they are not mutually exclusive. The Russian Ustie people up to the present day categorize their names as follows: «Doselnye» which are the first settlers (Kiselevs, Shkulevs, Chihachjovs and others), «Cossacks» (Soldatovs, Kochevshhikovs), «Peasants» (Portnjagins), «Verhovskie» - that is, the people who arrived from the upper reaches of the Indigirka river (Banshikovs).

The first hypothesis is based on an old legend. After the massacre raised by Oprichniks of Ivan the Terrible in Great Novgorod in 1570, a large group of people fled by sea. They sailed on 14 ships (“kochi”) and settled at the mouth of the Indigirka River. The number of refugees was about 300 people. Each boat held up to 25 people. Only in the 40-s of the 17th century the Russian Ustie community was rediscovered by the Cossacks, who were coming over from Yakutsk to Kolyma.

If the first hypothesis is correct, then perhaps, the Northern Sea Route at the end of the 16th century was relatively devoid of ice. And this means that perhaps long-term temperature cycles are typical of the Arctic. So, warming periods interchange with cooling periods cyclically through the centuries. Perhaps the proof of this hypothesis can be acquired in the course of genetic research of the members of this community, population of which currently makes about 1 thousand people.

Community settled in a remote place, it had to adapt to living conditions of the Arctic, using the previously gained experience life in the North-West of Russia. It has mothballed for a long time their language, customs, culture and religion. Their religion is Orthodoxy. According to legend, the first settlers built a Church, a bath and a tavern. They were free people and for a long time had not been paying taxes to the Russian Empire neither had they been liable to involuntary military service.

Throughout four centuries the settlers created an exogenous economic culture of a small

Russian community living within the boundaries of a geographically limited habitat, which beside the Indigirka river estuary swept away from the lower reaches of the river Khroma (from the West) to the river Alazeya (from the East) (Fig.1).

Living and economic activities in this region due to rigorous climate, remoteness and inaccessibility of the territory were strongly weather-dependent, at the same time dependent on the means of providing oneself with food and other life necessities. The rivers fed all the community. They were giving people fish for food and wood for heating. In consequence of the above mentioned a specific small Russian Arctic civilization of primitive ichthyophagi-fishermen there was formed.

A similar way of existence of the local settled population Yukagirs whose fishing was even on a much more primitive level, allowed rapprochement with this tribe and its gradual assimilation. This ensured community quantity growth up to the 18th century (Fig. 2.).

Accepting the assimilating the indigenous population, the community continued to maintain their native Old Russian Language. But concurrently inclusion of particular terms from the Yukagir, Chukch and Yakut languages into the language was taking place. Some primitive tools were adopted (for example, kozhemjalki - kydaran, scrapers for removal of excessive adipose layer etc), items of household and clothing (for example, pants of Chuckch tailoring for fishery and Yukagir fur caps (*malahai*)), some techniques and elements of fishing activities.

Limited fishing base resulted in decentralization of the community. People were forced to resettle to small zaimkas located 15-20 kilometers away from one another. Resettlement ensured sufficient catches volumes of fish (which served as a staple food), but also saved people's lives in the periods of frequent epidemics of black smallpox or measles. Several hundred people wouldn't have survived in a major settlement by reason of low intensity of work.

Zaimka is a small settlement, consisting of 2-3 houses (cabins) with a complete set of necessary household outbuildings including: ice-cellar for storage of frozen fish, pits for pickling fish, barns or granaries for storage of food products, semi-basement for storing utensils, numerous hangers for drying nets, seines, dry-salting fish, small hangers - «benches» for chaining dogs (Fig. 3.).

Among the mandatory attributes of *zaimkas* was the stock of chopped driftwood - e.g. dried logs stored in pyramid-like pile. The above-listed set of buildings and constructions allowed to preserve and store food (fish or even meat) and live through long and severe winters. Fish-tackles normally included hair nets, seines, karbass boats, *vetka-kayak (a kayak made of three boards)*. For winter fishing and digging holes in the ice icepicks were used. There were iron axes and knives, shovels, spears, bows and arrows and as well as a lot of other tools and devices. For catching Arctic foxes snares and traps were used.

Fig. 1. Russian Ustie Community Natural Habitat

P. 2. Dynamics of the population in Russian Ustie in 16-21 centuries, people

Formed set of household buildings and accessories allowed zaimka to lead self-sufficient lifestyle in the capacity of an independent economic unit.

Careful attitude towards natural resources allowed them to adequately distribute the load on the fragile ecological system of the Estuary of Indigirka River. The community was using all that nature could provide: the primitiveness of tools and, as a consequence, the extensive character of labor prevented from taking too much. The region inaccessibility and actual absence of commodity-money relations excluded the possibilities of surplus products realization, thus allowing nature to fully recover itself.

According to the population census of the year 1750 the population rate numbered 493 persons. In the period from 1822 to the late 19th century, this number ranged from 200 to 400 people, due to epidemics. In the early 20th century the population of the community, about 500 people lived in 28 zaimkas, not more than six of which were the so-called «dyms», i.e. winter cabins or yurts, in which people could overwinter. Usually, each «dym» was occupied by a single family. Sometimes several families lived in the same cabin or *yurt*. 10 of those *zaimkas* were located near the Russian Ustie channel, 7 of them were situated near the Kolyma channel, 2 of them were not far from Medial channel, 1 of them was on Alazeya River, 8 zaimkas were located upstream of the estuary of the river.

Great contribution in studying of Russian Ustie community was made by Vladimir Zenzinov, a revolutionary, economist and ethnographer, who served sentence in a forced-labor camp. In 1913 and 1914 two editions of his book «Old people near a cold ocean» describing the life and culture of the community were published.

In the period of Soviet collectivization several communal farms were established: one of them is «Pioneer» named after C.U Voroshilov and some other farms; subsequently their amalgamation was carried out. The village of Russian Ustie became the center of agricultural community which comprised only 6 *dyms* prior to the revolution. Due to the bank caving onset in 1941 the village Russian Ustie was relocated to a new, higher area, at the same time it was renamed into «Polarnoe». A club, a school with affiliated foster home, a post office, a radio station, a diesel power plant, and a centralized boiler-house were built.

In the postwar period a branch of the state-owned farm «Allayhivskyi» was established in the Russian Ustie; fishing and fur-trapping were the main activities of this farm. In the best years 25

P. 3. Zaimka (cabin).

hunters, i.e. 5% of the community population were professionally engaged in Arctic fox hunting. By the end of the 80s, due to the development of cage cattle-breeding Arctic fox hunting had reached the vanishing point. The introduction of track-laying rough-terrain vehicles, Motorsledges and Motorboats into practice led to elimination of the sledge dog breeding. Thus, primitive economy based on a fragile balance with the surrounding environment faced the new realities.

From the 20th century climatic changes in the Arctic became prominent. Such landscape changes as ravines formation and crumbling of the coast from the side of the Indigirka River occurred on the territory of the village resulting in significant changes of the riverbed. A massive glacier formerly used for storage of frozen fish crumbled being washed down by the river; Thereby the most important productive and economic component was shattered. Currently *zaimkas* have been reduced to summer hunting-and-fishing areas almost completely abandoned in winters. According to the official statistics, at the beginning of the year 2013 139 people lived on the territory of the Russian Estuary, the majority of which were pensioners and budget-funded institutions employees. But this is most likely a consequence of urbanization, the youth leaves the Russian Ustie.

Thus, during the last century a number of factors caused significant changes in the community life. Among these factors are: change of the social and economic model, the consolidation of the villages, technological progress, climatic changes as well as the technogenic impact on the environmental conditions. The old balance is broken now, the production process has suffered a sizeable decline; The Russian Ustie as well as the other Arctic settlements in Yakutia are financed solely from the government budget.

What's the next step to be taken in the studying of this community?

1. It seems interesting to study the influence of different factors on the life and economy of local communities. Over the last 100 years their life has been differentially modified by new technologies, climate and economic formations. It's important to build more accurate ranks of the population rates, economic base and climate. Perhaps such scientific survey will provide interesting results including the ones in the field of «demo-capacity» determination (maximum possible population rate) under extreme living conditions, the state influence on the life of these communities and some other results.

2. A group of NEFU researchers has submitted a grant application to RFBR for the project «Forgotten natural disasters and catastrophes in the North-East of Russia and Alaska during 18-19 centuries: an archival study based on the Russian-American company archives and other historical sources». Within the framework of this project we're also planning to conduct a comparative analysis between the economies of local communities Yakutia and Alaska. Now the economic models are very diverse, and it's far from certain that the model which works well for the US indigenous peoples better than the Russian. Money received by the natives from corporations is hardly a lesser problem than the level of welfare benefits in Russia.

3. New approaches are needed with regard to the model of sustainable development in the Russian and foreign Arctic. Perhaps one of the new projects is the creation of a National Park in the Estuary of Indigirka River.

References

Zenzinov V.M., 2001. Ancient people at cold ocean. Yakutsky kray. Yakutsk, 133 p.

Chikachev A.G., 2010. Russian heart of the Arctic. Lit. fund. 496 p.

Reindeer Herding of Northern Khanty and Forest Nenets in the Post- soviet Era

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key words: reindeer herding, multiple livelihood, Khanty, Forest Nenets, Siberia

1. Introduction

The aim of research is how the Khanty and Forest Nenets in the northern part of the taiga of western Siberia have adapted to changes in the politico-economic system after the Soviet period. First, I look at the spreading placement of these peoples' residences. Second, I show the actual conditions surrounding their multiple livelihoods: reindeer herding, fishing, and hunting. Finally, I demonstrate that their individualized herding nowadays is different from either of the two previous models they followed: "nomadism as a way of life" and "production nomadism." I also show that the form of livelihood has been transformed from "production nomadism" to more individualized herding in a border area in the northern part of the taiga in western Siberia.

2. Studies on Reindeer Herding in Siberia in the Post-Soviet Era

Two models of reindeer herding in Siberia are proposed by Vitevsky to characterize collectivized reindeer herding in the Soviet era [Vitebsky 1989: 215]. The first model is called "nomadism as a way of life," in which entire families lived and moved together with the reindeer. This way of life disappeared in the collectivization of the society of indigenous people between the 1930s and the 1960s.

The second model is "production nomadism" which was established during Soviet collectivization. In this herding method, herders consisted of brigades with professional herders and meal attendants, who lived in camps and grazed the reindeer in a large productive division apart from human settlements [高倉 2010: 149]. After the Soviet era, the *sovkhoz* were restructured and came to be run by the villages, with both public and private management. Researchers used these two models in their fieldwork analysis, paying attention to the remaining features of production nomadism. However, little research has been done on more individualized herding, especially in terms of ethnographical materials for the region where the Forest Nenets live [cf. Zeniko-nemchinova 2006].

3. Field work

The data was collected through ethnographic fieldwork around the Num-to Lake in the Khanty-Mansi autonomous region of northwestern Siberia during the winter of 2011 to 2012. The Khanty and Forest Nenets live there. The boundary between them is inhabited by a regional and administrative people. Almost all my fieldwork was done during the winter, so I am limiting my discussion of reindeer herding to the winter period. Moreover, I did intensive interviews with five families, considering the ethnic balance in those I chose to interview.

4. Outline of the area around the lake Num-to

Num-to Lake is located in the northwestern part of the Khanty-Mansi autonomous region, and it abuts the Yamal-Nenets autonomous region. It is located at 63° latitude north, in the northern part of the taiga where there is a large number of lakes and swamps. The perimeter of the lake is 60 km and the depth is 4 m. About 200(Krikov 2008: 131) to 250(Zeniko-Nemtinova 2006: 5) people live around the lake. The Num-to settlement is located at the south shore of the lake. There are about 50 houses, but almost all the inhabitants live in the taiga and herd reindeer, fish, hunt, and gather food.

5. Historical process

5-1. Reindeer Herding in the Sovkhoz

In the area around the Kazym River and Lake Num-to, the civil war continued until the 1920s, after that, the Khanty protested Soviet rule from the first half of the 1930s, so collectivization was implemented full-scale after the 1950s[Balzer 1999].

The people in this area worked in the Kazym sovkhoz as professional reindeer herders, fishers, and hunters. The Kazym sovkhoz had 17 brigades. One brigade consisted of 3-4 breeders, a few women and 200-300 reindeers. Except of this, it was permitted to hold 50 individual reindeers a herder. They moved and camped in tents in a provided range of pasture. For fishing, one fishery group consisted of four to five fishers who would run a 10-fish-trap point on the Kazym River.

5-2. Changes in reindeer herding from the politico-economic transformation

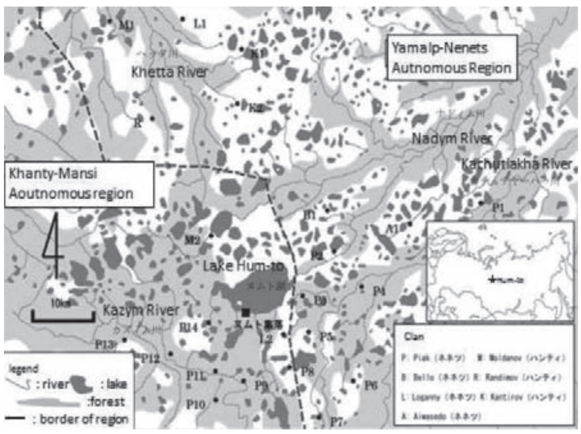
In the second half of the 1980s, the herders increased individual reindeers, such that "nobody exactly counted reindeer" (as a Khanty man born in the 1960s said). In the fishery sovkhoz, the fishermen also began to work individually.

After the Soviet period, the Kazym sovkhoz began to be managed by Kazym village and the number of brigades was reduced to three. Herders who left the sovkhoz began to live and carry out multiple livelihoods—including reindeer herding, fishing, hunting, and gathering in the forest—with their family and reindeer. They had already built houses to live around Lake Num-to when they had worked in the brigade.

5-3. The occupations of the people in Num-to today

After the Soviet Era, the Khanty and Forest Nenets around Num-to began engaging in multiple livelihoods. In fact, only one household continues to work in the Kazym sovkhoz, whereas 15 households are registered as under individual agricultural farm management. Some people are employed like this, but many young people depend on their parents' pensions.

6. Placement of houses



Map.1. the placement of homes around Lake Num-to.
Drawn by Author

Their residences consist of a wooden house, pasture fence, raised granary, fish storage, houses for dogs, a soil oven for bread, and a garbage pit. A household is composed of a nuclear family, and every household herds only its own animals.

There are about 50 households around the lake. The black points indicate the winter residences. The alphabetical letters show their clans. Twenty-three families are shown on this map. Others live in the settlement, or have been omitted, because they are outside the boundaries of this map. Households live from 4 to 20 km from each other.

7. Actual conditions of multiple livelihoods

7-1 Reindeer herding

The people in Num-to do not herd or fish with neighbors and relatives, but in household units. I will explain next how they derive their livelihood in the forest.

Ilustration1: Seasonal grazing and placement of houses on P1 household

A household has about 60–120 reindeer, on average. To carry out their seasonal grazing, one household has from two to eight fixed houses with pasture, moving the reindeer back and forth from house to house annually. The houses are from one to 12 km apart. This illustration shows how they move among their houses. For example, from December to February, a family stays at house number 1. From March to May, they stay at number 2, and from June to August they live in number 3. Then they go back to number 1 again and stay from September to October.

For their everyday grazing schedule, the reindeer are first released from their fence in the evening. The next morning, someone searches for the reindeer and drives them home on foot with the help of a dog. After driving the reindeer into the fence, they capture some of the reindeer and prepare some sleds. Then members of the family go fishing, hunting, or wood-cutting in the afternoon, using sleds drawn by reindeer.

7-2. Fishing

Fish is a very important food in the taiga of western Siberia. Freshwater fish are a big part of the diet in this area, and they are also used as feed for reindeer and dogs. The people fish in both lakes and rivers in one of two ways. The first way is to use a fish weir, which is done in all seasons. The second way is fishing with a rod, which they do especially in autumn. Fish weirs are set in the lakes and rivers, usually around 4 to 5 km from the house, and a household usually has several weirs. A weir is set at the place where a stream goes from the lake. Thus, one household will occupy several lakes or streams.

7-3. Hunting

The Khanty and Forest Nenets in this area capture such mammals as the glutton, otter, fox, weasel and squirrel, and such birds as swan, duck, and snow grouse. Wild reindeer do not live there, but on rare occasions, youths who like hunting go several kilometers to the north to hunt them. All of these types of prey are used as meat or as fur or feathers for clothes. Sometimes, the furs are sold for cash.

There are two ways to capture animals: one is to use such hunting gear as stones, branch, axes, and guns, and the other is to trap them. Traps are usually set around the house or near the fishing place. Hunting is also an important livelihood, but its priority is lower than that of herding and fishing. For example, when a man goes to look for his reindeer, if he finds footprints from a certain kind of animal, he will not follow them at that time but will go back later to look for the animal when he has the time. Moreover, if he goes somewhere and meets an animal by chance, he might be able to kill it with an axe on the spot and get it that way.

8. Conclusion

Based on this report from my fieldwork, I have used the concepts of production nomadism and nomadism as a way of life to compare the labor in the Soviet production system with the actual conditions of livelihood in the post-Soviet Era.

In the Soviet period, the Khanty and Forest Nenets practiced herding in the form of production nomadism, grazing reindeer as professional herders in a large production division established apart from the settlement in order to produce meat, holding individual reindeer partially. However, when the Soviet system collapsed, the people quit working in brigades and started to live individually around Lake Num-to. Now they do not live and graze together, but each household is individually managed and herds, fishes, and hunts independently. Moreover, each household in the Num-to society has several houses, and they herd reindeer by moving in a cyclical fashion among those houses. This form is also different from nomadism as a way of life because the people do have fixed houses as opposed to tents.

Reference

高倉浩樹 2010「生活様式としての遊動定住連続体：定住化政策後の森林ネネツにおける社会組織と居住」『東北アジア研究』14: 174-187。

福田正巳 1996『極北シベリア』岩波新書。

山田孝子 2007「文化復興から読む宗教と自然の意味：ハンティ、サハの事例から」煎本孝・山岸俊男編『現代文化人類学の課題：北方研究からみる』世界思想社、pp. 203-230。

Balzer, M.M. 1999 *The Tenacity of Ethnicity: A Siberian Saga in Global Perspective*. Princeton University Press.

Krikov, V. M. 2008 *Ot Kazymskoi Volosti do Beloiarskogo Roiona.* XMAO.

Pravintel'stvo khanty-mansii'skogo okruga-yugra 2008 *Infopmatsionnyi' demograficheskii' Byulleten'*. Khanty- Mansii'sk Poligrafist.

Sokolova, Z. P. 2009 *Khanty i Mansi: Vzgliad iz ＸＸＩ Veka.* Moskva: Nauka.

Vitebsky, P 1989 "Reindeer Herders of Northern Yakutia: a Report from the Field." *Polar Record* 25(154): 213-218.

Zeniko-nemchinova, M. A. 2006 *Sibirskoe Lecnye Nenty: istopiko-Etnograficheskie ocherki*. Ekaterinburg: Basko.

Web site of Khanty-Mansi autonomous region http://www2.admhmao.ru/index.htm(30/8/2013 final look)

The influence of human activities on forest fires

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Key words: forest fires, thunderstorms discharges, satellite monitoring.

Introduction

It is known that main reasons of the origin of forest fires (FF) in boreal forest are divided into natural (thunderstorm discharges) and anthropogenic ones. Depending on factors forming the climate, a degree of developing of territories and density of population living on it, one of two these reasons can prevail. For example, by the opinion of many scientists (Vakurov, 1975; Korovin, 2003; Suvorov et. al., 2008) a human is guilty of 95 % of cases. For separate regions (for example, northern parts of Krasnoyarsk region) a proportion of fires caused by thunder-storms may account for 90 % (Ivanov et. al., 2004).

The influence of technological pressure on the environment is quite often manifested in the form of variations of some natural indices whose maximum values are developed during days off (Saturday, Sunday). Such periodicity, in many respects, is connected with a rhythm of human activity. This phenomenon bears the name of the «weekend effect» (WE) (Zotov, 2007; de Forester, Solomon, 2003; Fraser-Smith, 1979; Karinen et. al., 2002).

In this work the results of studies of short-period (weekly) variations of FF in the Western and Central Yakutia by the long-term data of satellite monitoring are given.

Input data

In the work the NOAA series satellite data obtained with a receiving complex «ScanEx» (ICRA SB RAS) for the period of May-September 1998-2012 (Solovyev, Vasilyeva, 2000; Solovyev, 2001; Solovyev et. al., 2008a; Solovyev et. al., 2008b) are used. The FF was detected by the multi-channel AVHRR radiometer and was recorded into the digital data archive. To study the influence of anthropogenic activity on FF sections in the central and western Yakutia (Fig. 1), respectively, the test sections «C» and «W» were chosen. The sections are approximately identical in square, natural - climatic indices, features of a vegetative cover etc. On the average in both sections the number of thunderstorm discharges accounts for ~ 150-200 (Kozlov, Mullayarov, 2004), and the annual average level of precipitations is ~ 250-350 mm (Atlas, 1989). However, the test sections strongly differ from the point of view of the quantity of population living in their territory. The average index of population density ρ [per/sq. km] living in the section «C» is ~ 2.5, whereas this index for the section «W» is ~ 0.06.

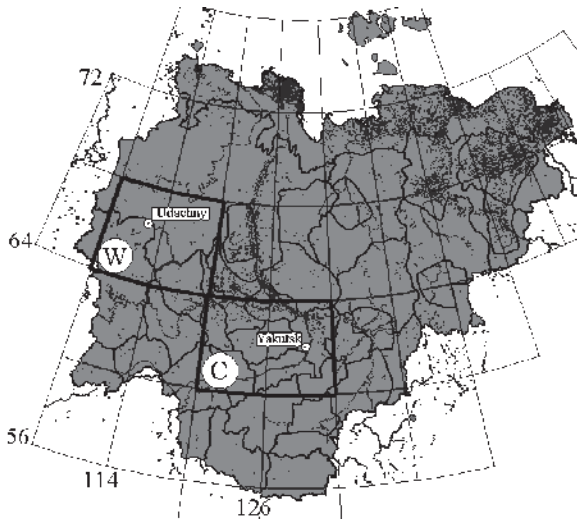

Fig.1. Location of sections «C» and «W» on the territory of Yakutia.

Discussion of results

Earlier in papers (Solovyev, Kozlov, 2005; Solovyev et. al. 2009) devoted to studies of spatial-temporal variations of cloudiness, FF and thunderstorm activity, it was shown that the fire-dangerous period on the territory of Yakutia (Fig. 2) falls on the period from May till September. The main peak of FF activity is observed in July-August. The seasonal change of cloudiness has an opposite character i.e. from May till July the percent of cloud cover noticeably decreases, the minimum of cloudiness falls on July, by September the index of cloudiness slightly increases. The thunderstorm activity is mainly manifested from June till August with a maximum in July.

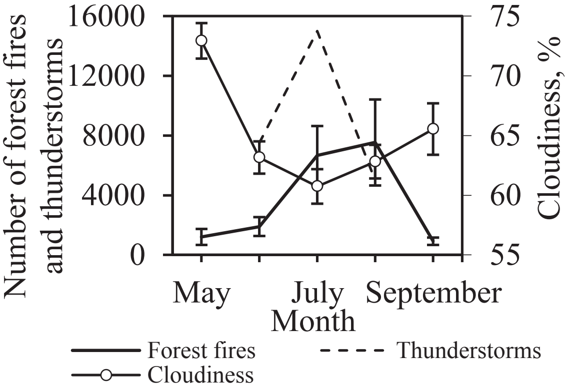

Fig.2. Seasonal variations of the cloudiness, forest fire and thunderstorm activity in Yakutia for the period of May-September 1998-2012.

In the tested sections the study of temporary variations of forest fire activity for the phase of beginning (May-June), maximum (July-August) and decrease (September) of a fire-dangerous season were carried out. As a whole, in the section «C» there was considerably more sources of fire than in the section «W». In the variations of FF activity in the western section it was not possible to detect the temporal rhythms reliable statistically which are related to a week cycle of anthropogenic activity. The similar pattern of temporary dynamics of FF was also observed in the central section except the decrease phase of FF season (Fig. 3).

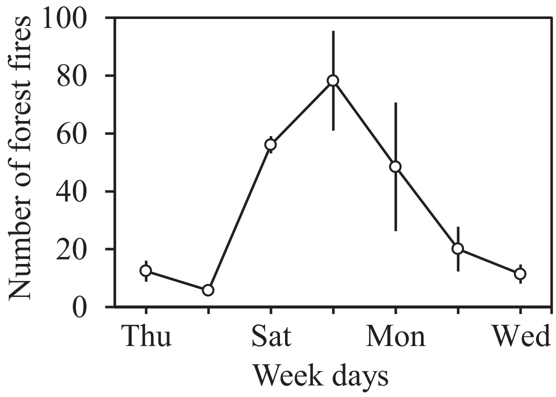

Fig.3. Week variations of forest fires in the section «C» in September for the 1998 to 2012 period.

From Fig. 3 it is seen that the maximum of week FF variations is observed at the end - beginning of the week, the minimum falls on Friday. Thus, one can suppose that in the section «C» under the conditions of absence of thunderstorm activity (in September) the weekend effect is observed.

Conclusions

It is shown that in the Central Yakutia at the end of fire-dangerous season the week dependences of FF activity with a maximum at the end-beginning of the week and a minimum on Friday is observed. Taking into account the absence of thunderstorm activity at that time, relatively a high density of population and a temporal character of FF variations one can suppose that the observable week dependence of quantity of sources of fire detected by data of satellite monitoring is explained by WE, i.e. it is of anthropogenic origin.

References

Vakurov, A.D. Forest fires in the North. - M., 1975. - P.10.

Korovin G.N., The impact of climate change on forest fires in Russia // Climate change: a view from Russia / ed. V.I. Danilov-Daniljan. TEIS, 2003. - P. 69-98.

Suvorov E.G., Novitskaya I.N., Kitov A.D., Maksyutova E.V. The manifestation of the pyrogenic factor, are established in the dynamics of the geosystems of the South-Western Baikal region // Geography and natural resources. - 2008. - № 2. - P.66-73.

Ivanov V.A, Korshunov N.A., Matveyev P.M. Fires because of lightings in forests of Krasnoyarsk region near the river Angara. Krasnoyarsk: SSTU, 2004. P. 132.

Zotov O. D. Weekend effect in the seismic activity // Physics of the Earth, 2007, № 12. P. 27-34.

de Forster P.M., Solomon S. Observation of a “weekend effect” in diurnal temperature range//Proc. Natl. Acad. Sci. USA. 2003 V. 100. P. 11225-11230.

Fraser-Smith A.C. Weekend increase in geomagnetic activity // J. Geophys. Res. 1979 V. 84. №A5. P. 2089-2096.

Karinen A., Mursula K., Utich Th., Manninen J. Does the magnetosphere behave differently on weekends? // Ann. Geophys. 2002 V. 20. P. 1137-1142.

Solovyev V.S., Vasilyeva E.K. Satellite monitoring of forest fires and an estimation of their consequences // Science and education. Publishing house of the Academy of Sciences of Republic of Sakha (Yakutia), 2000. № 4 (20). P. 24-27.

Solovyev V.S. Satellite monitoring in Yakutia / Coll. of papers. Space research in Yakutia. - Yakutsk: Publishing house of the Yakut Detachment of Siberian Branch of the Russian Academy of Science, 2001. P. 302-308.

Solovyev V.S., Kozlov V.I., Mullayarov V.A., Vasiliev M.S. Characteristics of forest fires in Yakutia, caused by thunder-storms / XV International Symposium "Atmospheric and Ocean Optics": Abstracts. - Tomsk: Institute of Atmospheric Optics SB RAS, 2008a. P. 162.

Solovyev V.S., Kozlov V.I., Vasiliev M.S., Varlamova E.V. Weekly variations of forest fires area in Yakutia / XV International Symposium "Atmospheric and Ocean Optics": Abstracts. - Tomsk: Institute of Atmospheric Optics SB RAS, 2008b. P. 158.

Kozlov V.I., Mullayarov V. A. Thunderstorm activity in Yakutia. - Yakutsk: Publishing houses of the Yakut Detachment of Siberian Branch of the Russian Academy of Science, 2004. 103 C.

Atlas of Agriculture of Yakut ASSR. M: GUGK, 1989. 116 p.

Solovyev V.S., Kozlov V.I. Studies of spatial-temporal dynamics of forest fires and cloudiness in the North Asian region by data of NOAA // Optics of the atmosphere and ocean. 2005. V. 18. № 01-02. P. 146-149.

Solovyev V.S., Kozlov V.I., Mullayarov V. A. Distant monitoring of forest fires and thunder-storms in Yakutia. Yakutsk: Publishing house of Yakut Detachment of the Siberian Branch of the Russian Academy of Science, 2009. 108 p.

Folk Meteorology of the Yakuts: History and the Present

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Key words: Yakuts, folk meteorology, traditions, preservation

The folk meteorology of the Yakuts has been formed on the basis of their experience in economic activities in the nature and climate conditions of the North: determining desired productivity of forage grasses crop for the present and the next year, the number of cattle and horses left for the next winter, later — placement and volume of grain crops etc. Their meteorological knowledge can be divided into groups based on observations over the sky and connected to astrometeorology (the Sun, the Moon, planets and constellations), earth (soil, permafrost), atmospheric conditions (snow, hail, rain, thunder, draught, frosts, temperature change etc.), habits and behavior of animals and plants etc. [Yakuty, 2012, pp.263-264].

Their meteorological knowledge combined both rational views and mythological elements in life of the Yakuts. Many of these have common grounds with other Turkic peoples, but they have significantly transformed while the ancestors of the Yakuts explored the northern territories, adapted to the new nature and climate conditions.

The observations conducted for years, decades, and centuries have resulted in conventional folk omens and signs (*kun-d'yl bilgelere*) used to forecast weather. For example, clouds reddening at the sunset mean raining. If the sun sets not hiding in clouds, there will be serene weather tomorrow, if the rising sun is scarlet, there will draught. The moon and the sun decorated with side beams of refracted rays predict cloudy days without rain and snow in the future. If they are surrounded by the halo of such rays, it means bad weather ahead, if the halo is small and dark — this or next day, if it is large and persistent — in two or three days. If the halo is large but thin and appears in the evening, it will be windy. Looking at those halos, the Yakuts used to say, "there is great wind on the sea". The bad weather, as the Yakuts have noticed, is forerun by cyclonic winds blowing mainly from the eats, west or southwest.

Short- and long-term weather forecasts have been also made by the behavior of some animals. In spring, when bullfinches come early and fly around the yards, the snow will stay for long. If geese fly low in autumn, snow is coming, if high — autumn will be long and dry. For the long-term weather forecasts the following signs were used: October winds blowing leaves off the trees and March snowstorms with heavy snowfalls, much snow on tree branches in winter, and large snow lumps on them in spring meant much floodwaters in spring. Strong winds in December and January in central Yakutia let quite precisely forecast frosts in June and July. In autumn, by the Lena river freezing, they predicted the day of its opening in spring at the same place. Thick ice cover and sand drifts also helped to predict ice jams and flood in spring. The folk meteorology, in its daily practice, has defined the weather "key points" in Yakutia. They are heavy clouds (*Sis bylyt*, "cloud ridge") and snow in late January or early February, lessening winter frost, rains in early summer, at the start of haymaking, at its height etc. [Makarov 1983, pp.61-63].

Every family used the Yakut folk weather signs. The most prominent were *bilgestchyts* — weather foretellers — for their keen watchfulness, retentive memory, generalizing and analyzing skills. The *bilgestchyts* able to predict the harvest of the year and make long-tern weather forecasts were called *d'yllyts*. I.M.Sosin supposes there were one-two *d'yllyts* in every *nasleg* (district) [Sosin 2010, p.6].

The *d'yllyts* lived in every Yakut naslegs. The most popular were Mas Khalandaar (name unknown; died late 19th century) from the Kyllakh nasleg of the Olekminskii okrug, Afanassii Danilovich Fedorov (late 1870s-lane 1920s) from the Nemyuginskii nasleg of the West Kangalasskii ulus, Gavril Nikolaevich Zolotarev (about 1857-1958) from the Kharbalakhskii nasleg of the Verkhneviliuyskii ulus, Vassilii Yadreev (died early 1930s) from the 1st Edey nasleg of the Namskii ulus, Afanassii Semenovich Poryadin (avout 1870-1957) from the Moorukskii nasleg of the Megino-Kangalasskii ulus, and others.

Mas Khalandaar, for instance, Mas Халандаар could, on the basis of his forecasts of the spring and summer weather, advice on where (wet lowlands or dry highlands) and what (wheat, rye, barley) to sow. In summer, he warned sowmakers of the coming rain two or three days beforehand. A.D.Fedorov (Onoosku) paid serious attention not to miss the moment of the start of the spring sowing. He said, "one day late in spring sowing — ten days late in bread ripe", meaning the danger of August colds for the crop. Fedorov has predicted spring frosts, summer colds, rains etc. He warned the people and showed himself how to save cattle from starving and death by extra fodder and how to protect grain harvest (e.g. he made fires around the ploughland the night before the frost etc.). People came to him from far naslegs or even from other uluses to know the spring and summer weather. As old residents recall, A.D.Fedorov was especially successful in his prediction of the draught of the first half of the 20th century, seeing its start in lean years of 1905 and 1906 in some east uluses of the Yakut okrug. The he made peasants to prepare additional forage (berch branches, reeds, canes) for cattle in advance, thus saving many families from ruin. In early 1900s, Kirill Ksenofontov, a *d'yllyt* from the 2nd Tyllyminslii nasleg of the Meginskii ulus was among those who warned the people of "fifty years of draught", i.e. of 50-year dry period. He advised cattlemen to drain lakes and turn these new free areas into grasslands not subject to draughts.

One of the last generation of the Yakut *d'yllyts* with 30-year experience, Ilya Fedorovich Platonov (1894-1975) successfully forecast weather changes, the Lena river opening in spring, summer colds etc. Living in the Central Yakutia, he tried, by the time and character of the winter frost onset, forecasting weather not only in the region but also in the north of the republic, in Oymiakonye, Allaikha, Abyi, Verkhoyanye [Makarov 1983, pp.79-80].

To make notches to mark the weather conditions of every year, the *d'yllyts* used tetra- and hexagonal sticks (*d'yl maha*) 28 in. long. Some of them had up to 80-100 such sticks. They all made a kind of a "wooden book" recording the weather in Yakutia for decades.

The *d'yllyts* have always followed folk signs to make short- and long-term weather forecasts. Some used a primitive "device" with a grass leave as a "sensor", winding in dry and unwinding in wet weather.

The *d'yllyts* were sure all meteorological events of the given physical year repeat every six months. They took the so-called "year joint", December 25th, the shortest day in the Yakut folk calendar, for the starting point. It means all meteorological events occurring before and after that date will repeat as follows: November-May, December-June, January-July, February-August. If, for instance, there were no heavy frosts in the first half of December, it will be cool in the first half of June. If it was snowy in the second half of January, it will rain in the second half of July etc.

Another way the Yakut folk meteorology used to forecast spring weather was the convergence of celestial bodies. Such a convergence, or *altyy*, meant the Moon passing near or along the Pleiades constellation in its actual eastward movement, of what the *d'yllyts* knew. They tried to forecast spring weather by such a convergence and especially by the Moon approaching the Pleiades: if it happened in May, it meant cold and long spring, unfavorable for the end of cattle wintering, and if not — the next spring would come in time, i.e. would be neither early nor late, and warm and favorable for the end of cattle wintering in late spring.

Spring weather was also forecast by rare convergence of the Moon and the Sun. It was defined by the shadows an object cast from the moon and the sun. The measurement was done when an object shadow from the sun equaled its height. In this prediction the sun meant dryness, the moon — wetness. If an object shadow from the sun was shorter than that from the moon, they said, "the Sun has won, summer will be dry". If an object shadow from the moon was shorter than that from the sun, they said, "the Moon has won, summer will be wet, with good crop".

On January 1st (14th), the day marked as the "top of winter" (*d'yl baha*), the Venus "coupling" with the Pleiades predicted windy weather. If it passed under the Pleiades in winter months, starting from December, good summer harvest was awaited. In the second half of summer, when it was possible to watch the starry sky, they followed the movement of the Venus and the Pleiades. At this, if they noticed the Venus "coming into" the Pleiades, they forecast rainy weather in near future.

Phenological forecasts were made by the first snow: if it stuck to tree branches and grass by large lumps and thawed abundantly in the daytime, it was considered harvest would be good the next summer.

If snow was blown off the trees early in spring, summer would be cold. In winter people tried to notice when trees and grass far from rivers covered with hoarfrost. From the moment on, in six months sharp, there would be colds in summer.

The Yakuts have also made weather forecasts by the “habits” of spring thunder. Early thunders promised good summer. It was thought that if the first spring thunder was heard from west, there would be good summer rich with hay [Gogolev 1999, pp.30-35].

The Yakut *d’yllyts* did not make short- and long-term weather forecasts only, but could do much longer predictions. At this, they followed the rules of the Yakut folk meteorology elaborated through many centuries of observations and summarization. According to them, in Yakutia there coexist wet and dry periods alternating as inevitably as seasons change, as winter comes after summer. That was thought to be an objective law of nature itself. Any period does not lasts less than 40 and more than 60 years. Besides, these periods are never completely wet or dry; there can happen very dry years in a wet period, and wet — in a dry one. Those are the so called “flaws” of a year (*d’yl ardaya*) that do not change the character of the periods themselves.

In total, the Yakut folk meteorology postulates that there is a certain trend in multiannual draughts and long wet years (i.e. dry and wet periods) as they are directed westward [Makarov 1983, pp.64-69].

In modern life, the Yakut folk meteorology, as many other elements of their traditional culture, is going to the past. New generations prefer to fins weather forecasts in mass media (newspapers, radio, TV, and Internet).

In 2009-2011 we conducted s questionnaire survey among the rural population of the Megino-Kangalasskii and Ust’-Aldanskii uluses (central Yakutia), the Verkhoyanskii ulus (northern Yakutia) and the Olekminskii region (western Yakutia) on the problems of preservation of the Yakut folk knowledge of weather and climate.

Table 1. *What notions, beliefs and signs of your nation do you know?*

	Megino-Kangalasskii ulus,%	Verkhoyanskii ulus, %	Ust’-Aldanskii ulus, %	Olekminskii region, %
Connected with:	17.6	16.1	14.8	15.0
Earth				
Astrometeorological	7.1	15.2	12.8	35.0
Fire	13.5	12.1	23.2	7.,5
Water	12.4	27.3	16.8	40.0
Weather	8.8	12.1	18.4	45.0
Seasons of the year	7.1	6.1	15.2	37.5

As seen from Table 1, the folk meteorological knowledge has better preserved in the northern and western parts of Yakutia, where integration processes have been less and thus more of the traditional culture has persisted. Analogous results are characteristic of the answers to the questions dealing with the folk and ceremonial aspects of ethnic meteorology (Table 2).

Table 2. *What elements of the popular culture connected with climate and weather do you know?*

	Megino-Kangalasskii ulus,%	Verkhoyanskii ulus, %	Ust’-Aldanskii ulus,%	Olekminskii region, %
Proverbs, sayings	15.9	9/1	13.6	12.5
Customs, rituals	20.6	36.4	34.4	55.0

As expected, the better awareness of the traditional climate and weather observations have been shown in senior age category with obvious men prevalence. This is understandable, as exactly these groups, despite the socioeconomic transformations of recent decades, are still committed to such traditional activities as cattle breeding, hunting, and fishery. Women care for the weather to forecast harvest of berries and mushrooms. Recently, as floods become more frequent, people worry about possible high floods.

Initial knowledge and concepts of the majority of respondents have been formed mainly through mass media — 84.8% and informal contacts (other people’s stories and talks) – 6.1%. Only 15.2% of respondents had their own observations as the source of the initial information on the changing climate.

At the same time, folk methods of definition and prediction of the weather events become the matter of the past: as a rule, most of the observers use thermometers and barometers. However, old people say that the recent climate change has influenced many parameters of the folk meteorology that no longer correspond to the modern reality.

Thus, the data of sociological surveillance show the critical state of the traditional knowledge that becomes less and less demanded. Phenological and climatic knowledge is going to the past for two reasons:
1) traditional folk meteorology and information on climate are not confirmed by the recent ecoclimatic situation;
2) as real bearers of the traditional knowledge leave us, there appears a "generation gap" in this sphere. The Yakut rural villages face the time of climate challenges "hanging and confused", deprived of ane information but general, impersonal, alien to the local peculiarity. Taking in mind that the daily "temperature map" of Yakutia gives variations of 10 to 20^{0}C between uluses and towns, one can judge of the state of awareness of the rural population [Vinokurova 2011, pp.9-10].
All this makes traditional economic activities even more difficult in the republic the entire territory of which enters the zone of risky agriculture and difficult and complicated cattle breeding.

References

Vinokurova L.I. 2011. *Otchet o vy'polnenii granta RFFI №09-06-98503-r- vostok-a Narody' Arktiki v usloviyah global'ny'h klimaticheskih izmeneniy: ustoychivost', transformacii, adaptaciya (Report on implementation of the grant RFFI №09-06-98503-r- East- a Peoples of Arctic in conditions of global climate change: stability, transformation, adaptation) –* 14 pp.

Gogolev A.I. 1999. *Tradicionny'y kalendar' yakutov (The Yakuts' traditional calendar).* Yakutsk, 72 pp.

Makarov D.S. 1983. *Narodnaya mudrost': znaniya i predstavleniya (People wisdom: knowledge and concepts).* Yakutsk, 120 pp.

Sosin I.M. 2010*. Kyun-d'y'l bilge`te` [narodny'e primety' o pogode] (Folk weather signs).* Yakutsk: Bichik, 64 pp.

Yakuty' (sakha) / Ed. N.A. Alekseev, E.N. Romanova, Z.P. Sokolova. 2012. Moscow: Nauka, 599 pp.

The Evolution of Climate and Economy: the Presentation, Opinions and Estimates of Horse Breeders of Yakutia

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Key words: Key words: climate change, traditional economy, vulnerability of indigenous peoples

Introduction. Recently, almost everywhere in the world there has been a noticeable growth of scientific interest in the safety of life of modern society, ethnic and local communities that are closely associated with the problem of global climate change [1].

Note that the results of the international monitoring of the state of the Earth cryosphere and global ecosystems indicate that the most significant climate change in the near future are expected to occur in its Northern and Arctic regions. Currently, there are three main factors that make us pay serious attention to the problems of sustainable development of the most vulnerable areas of the planet and the indigenous peoples living there:

- The Arctic and the North are the largest biosphere reserve of the Earth, first of all, as one of its climate regulators and thereby provide ecological services on a global scale;

- The gradual increase in the extraction and processing of mineral resources in the Arctic and Northern areas like never before actualize the issues of ecologization of the existing and newly discovered industries;

- The experience in adaptation of indigenous peoples to the geographic and climatic conditions of the Arctic and the North, gained in an incredible struggle for survival in the permafrost zone has a universal value. Local knowledge of the mechanisms of life support in a changing environment is very important for the understanding of the risks produced by climatic processes of modernity.

All of the above factors are highly relevant in relation to the Republic of Sakha (Yakutia), including its indigenous peoples that are highly dependent on their traditional occupations. Several thousand years ago in the coldest part of the planet, they formed a unique human environment, having mastered its economy and creating a model of civilization, characterized by a lifestyle in harmony with nature. The unique structure of the northern productive economy and a variety of historical local cultures have no analogies elsewhere in the world: reindeer herding, hunting and reindeer herding, hunting and fishing, fishing, ranching and farming, established as a result of progression of the culture of cattle, horses and farming of southern origin to the high-latitude zone of the Earth.

In this research, I discuss the topic of changes in global climate and its impact on society, realized from the standpoint of social sciences. At the center of scientific thought is the problem of studying the cultural aspects of climate evolution in the context of economic instability and socio-economic vulnerability of the regions, population, peoples, both tangible and intangible heritage and traditions of the Arctic and the North.

Horse breeding in Yakutia: historical and contemporary discourse. Topics related to the role of the horse in the various spheres of life of the Sakha people, can be very wide in terms of in the historical chronology and geographical space. For centuries, the territory of Yakutia has seen the formation and development of the original form of horse-breeding culture. After a long, hard and painstaking work the people managed to get a hardy and unpretentious breed of Yakut horses adapted to the extreme natural and climatic conditions of the North and create a special and unique economic-cultural type, lifestyle and spiritual world of the most northern horse breeders in the world.

The Yakut mythology associated with the traditional world view and dating back to the cult of the horse as an animal of divine origin, reflects the priceless heritage of horse-breeding culture, its philosophical, religious and folkloric traditions. The Olonkho recognized by the UNESCO as Masterpiece of the Oral and Intangible Heritage of Humanity, one of the archaic stories of ancient heroic epic, describes the birth by a horse of the first ancestor of the Sakha people, and the very sunny tribe aiyy - Yakuts are described as owners of “so many white horses, which they had more than there were stars in the vast hollow-jangling sky.” In the traditional Yakut society horses were the greatest value, and the wealth and nobility of the owner, as well as the prestige of his family, were determined by the number of his herds, the horses were the measure of all transactions, in fact, the sacred horses were addressed while swearing the most important oaths, concluding truces, conducting ritual ceremonies.

The basis of the specific “polar” type of food are ethnic victuals and national food traditions that are inextricably linked with the horse culture, which is *kumys*, young horse meat, horse sausage, cheese made from fermented mare's milk, etc. The national cuisine, organically adapted to the local ecological system and based on dishes having a high protein content and the saturated animal fat, facilitate the production and conservation of heat, and are now a daily reality.

The Yakut horse holds a special place in the history of the region. As it is known from historical sources of the 17th century, the Lena region appeared before the eyes of the first European travelers as an ancient center of horse breeding and an amazing island of equestrian culture. It is impossible to imagine the development of the vast territory of Yakutia, the coasts of the Okhotsk Sea, Pacific Ocean, Kamchatka, Chukotka, Alaska without the Yakut horse. Thus, only in 1736-1785 and 1796-1830 for the transportation of state-owned cargo, military crews, various expeditions and their equipment along the routes from Yakutsk to Okhotsk, Yakutsk to Verkhoyansk, Zashiversk, Srednekolymsk, Udsky fortress a total of 373,800 horses was involved. The establishment of transportation along the Irkutsk, Okhotsk and Ayan tracts facilitated the entry of the North-East Asia and North-West of America in the orbit of the Russian and international political, economic and cultural space [2].

The historical merit of the Sakha people to the humanity is the introduction of the horse-breeding civilization into the world of in the Arctic and the North, the formation of the northern area of world horse breeding and the creation of a unique variant of the northern horse farming. It is no accident that the rider on a horse became the national symbol of the Republic of Sakha (Yakutia).

At present, in the Republic of Sakha (Yakutia), horse breeding is regarded not only as a narrow sector of the regional economy, but also as a paradigm of the existence of the Sakha people. Ecology, economy and ideology - an inseparable triad, based on experience, knowledge and philosophy of the horse culture, should make the foundation of the modern horse breeding as the most important resource of living arrangement (habitat), life support (food production) and reproduction of the national culture and mentality.

Arctic horse breeding in the context of climate change: vulnerability, risks and adaptation issues in public opinion. The collective experience of adapting traditional occupations to the geographical, natural and climatic conditions of the North is associated with the accumulation of a variety of empirical indigenous knowledge of the Yakuts. Careful observation of the features of the world around them, the knowledge of their interrelationships and interdependencies allowed them to find practical application in their everyday life. In particular, long-term monitoring of the rhythms of nature and habitat weather conditions, economic skills acquisition and dissemination of knowledge about food resources, diet, housing conditions, anatomy and diseases, treatments and specifics of the care of horses led to the development of the best forms and methods of horse-breeding. [3]

Modern Arctic horse breeding, as in the past, is the recipient of nature and is based on the use of its biological resources, as well as small technologies and closed circle of exchange, which allows us to consider this type of farming the basis of livelihoods and the sustainable development of the Sakha people. Consequently, the direct dependence of the northern horse breeders on the state of the environment is a pivotal issue around which other equally important issues of their activities are grouped.

Table 1. Dynamics of horse population in the 15 Arctic and Northern Districts of Yakutia (all types of farms, heads, as of the year end). [4]

Uluses (districts)	1985	1990	1995	2000	2005	2010
Abyisky	2638	3778	3318	3033	2276	1839
Allaikhovsky	168	201	203	249	173	217
Anabarsky	25	28	5	11	37	17
Bulunsky	184	348	219	304	306	500
Verkhnekolymsky	1372	1291	1278	739	592	715
Verkhoyansky	15017	12453	10573	8625	7012	7617
Zhigansky	20	22	-	19	3	14
Momsky	3258	3220	3014	2057	1559	1697
Nizhnekolymsky	187	336	361	168	351	225
Oymyakonsky	4049	4044	3767	3217	3655	3447
Olenyoksky	182	132	123	88	143	176
Srednekolymsky	4421	5197	6898	3809	4601	3734
Tomponsky	2335	2421	2058	1579	1070	1667
Ust-Yansky	1080	1212	927	757	482	555
Eveno-Bytantaysky	-	2502	1787	1311	1538	1801
Total for the RS (Y)	-	199.5	158.5	129.5	130.8	159.8

The number of horse population is a determining factor in the assessment of the economic situation of both individual breeders and agricultural enterprises and cooperatives of any form of property. Counting the number of horses as their main wealth is conducted in the modern system of economic performance and reflected in official statistics.

As it can be seen from the table, the 15 Arctic and Northern districts of Yakutia, as the whole of the Republic of Sakha (Yakutia), in the past 25 years there has been a marked decline in the number of horses. The decline in population has mainly been caused by the poor working conditions, low yields, the outflow of young people from rural areas, the impact of spring flooding, etc. The decline of horse breeding, as an agricultural sector, has identified urgent problems of modern agricultural policy of the Republic of Sakha (Yakutia). Priority funding from the national budget has been used to preserve the unique Yakut horse and support stud farms. The state systems of credit and leasing, construction and reconstruction of feedlots and model stud farms, the redemption of young animals, collateral feed helped to stabilize the number of horses and even provide some growth in their numbers. As a result of many years of work of scientists and horse breeders in Yakutia two new breeds of Yakut horses have been developed and included in the register of breeding achievements of the Russian Federation: Prilenskaya and Megezhekskaya. The Government of the Republic note that the development of the agricultural sector has not only economic, but also social significance, since it helps “maintain the traditional way of life and economy of rural workers, and at the same time, improve the quality of their lives.”

The main goal of my research is to study the impact of climate change on the peoples and societies, first of all, on their farms, and cultural traditions in their entirety. The views, opinions and estimates of Yakutia’s breeders identified using the methods of questioning and personal communications, helped to more clearly consider the manifestations of climate change, the environment, local ecosystems, which are closely intertwined with the local economic production (the increase of infested land, dead or dying forests, reduction of areas designated for agriculture, etc.). For example, as a result of warming quickly replaced by cold snap, snow, beneath which horses get their grass, turns into an impenetrable ice shell. Many horse-breeding farms have suffered heavy losses in young animal population and sustain losses by buying additional hay for the horses left without food. Thus, the abrupt changes in weather and temperature have the worst impact on the stability of horse breeding.

So the present climate processes that change the working and living conditions of rural people, actualize the importance of a scientific discussion of the problems of conservation of ethnoeconomics and cultural values of the world's northernmost horse breeders and pastoralists.

Conclusion. One of the key factors for sustainable development in the Arctic and the North, characterized by the highest sensitivity to changes in global climate, is the preservation and protection of ethnic and cultural diversity of this unique part of the Earth. This global problem calls for identifying and assessing the vulnerability of indigenous peoples in the process of climate-driven changes in the ecological system, and the collection and annotation of local experience and knowledge of indigenous people about the sustainable life support system in a changing habitat, respectively, about the adaptation to the changing conditions of life and economic activities. In this regard, it is important to conduct these studies on a quantifiable scale and reflect on the strategies to reduce the risks associated with climate change.

References

1. Anthropology and Climate Change: from Encounters to Action. –Walnut Creek, 2009.
2. Международный конгресс «Проблемы устойчивого развития табунного коневодства». Секция: «Социальное значение исторических и культурных традиций народов в развитии табунногог коневодства». –Якутск, 2006. (The International Congress "Sustainability of horse breeding." Workshop: "The social significance of the historical and cultural traditions of the peoples in the development of horse breeding." - Yakutsk, 2006.
3. Атласов С.В. История развития скотоводства и коневодства в Якутии (1917-1928 гг.). –Якутск, 1992. (S. V. Atlasov. The history of cattle and horse breeding in Yakutia (1917-1928) - Yakutsk, 1992.
4. Таблица составлена по: Экономика улусов и городов РС (Я) в 1985-1999 гг. –Якутск, 2000; Республика Саха (Якутия) за годы суверенитета (1990-2000 гг.). –Якутск, 2000. –С.27; Экономика районов и городов РС (Я). – Якутск, 2002; Основные показатели агропромышленного комплекса РС (Я) за 1999-2004 гг. –Якутск, 2005. – С.66; Сельское хозяйство Республики Саха (Якутия): статистический сборник. –Якутск, 2010. –132. (The table compiled on the basis of: The economy of the regions and cities of the Republic of Sakha (Yakutia) in 1985-1999. - Yakutsk, 2000; the Republic of Sakha (Yakutia) during the years of independence (1990-2000). - Yakutsk, 2000. - p.27; The economy of the regions and cities of the Republic of Sakha (Yakutia). - Yakutsk, 2002; The key indicators of the agroindustrial complex of the Republic of Sakha (Yakutia) in 1999-2004. - Yakutsk, 2005. - p.66 ; Agriculture of the Republic of Sakha (Yakutia): statistical yearbook. - Yakutsk, 2010. -132.

Effects of Global Warming On Reindeer Husbandry and Resource Dynamics
—a simulation analysis by System Dynamics Model—

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Key words: global warming, reindeer husbandry, resource dynamics, system dynamics, ancestral commons

1. Introduction

Global warming affects vegetation of grassland and animal husbandries. In this paper, we deal with dynamic relation in animal resources and the human life utilizing them. As variables of economic aspects of human life, we use reindeer nomad number, domesticated (reared) reindeer number, and per capita income. As variables of resource dynamic, we use moss (lichens), wild reindeer and carnivorous animal number.

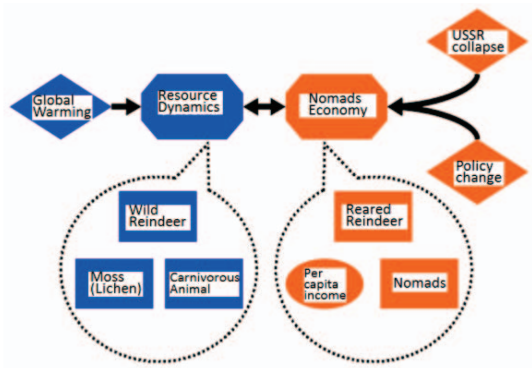

Fig 1 Concept of System Dynamic Model for Reindeer Husbandry

2. Outline of the System Dynamics methodology.

In case of System Dynamics model, future situations are predicted each time by solving recurrence equation system which consists of simultaneous differential equations over 3 time points of previous (J), present (K) and next (L) times. This method can be applied even in case that there are no actual data for some variables in the system. For variables which have actual data, relations among variables are estimated in the way that these variables are replicated by best fitting to actual data and for variables which do not have actual data, data are generated so as to be most consistent to whole equations system.

Here, variables with notations J, K or L show levels of the variable (the stock variable) at time points J (previous), K (present) or L (next), respectively. Variables with notations JK or KL show flows of the variables (the rate variable) between J and K or between K and L time points. DT means time duration in which rate variables flow into. Using these notations of each variables and parameters, dynamic relations among major variables can be described in Fig 2.

(reindeer no).K = (reindeer no).J + DT*(reindeer birth).JK−DT*(reindeer death).JK
(reindeer birth).KL = (reindeer no).K * (reindeer birth rate).K
(reindeer death).KL = (reindeer no).K * (reindeer death rate).K
<Initial value for parameters > (reindeer no) = 10000, (reindeer birth_rate)=0.3, (reindeer mortal_rate)=0.25
(carnivorous animal).K
= (carnivorous animal).J + DT*(max(carniv inflow.JK, 0)−max (carniv outflow.JK, 0))
(wild reindeer).K
= (wild reindeer).J + DT*(max(wild reindeer_inflow.JK, 0)−max(wild reindeer_outflow.JK, 0) + reverting rate to wild.JK)
(reared reindeer).K
= (reared reindeer).J + DT*(max(reared reindeer_inflow.JK, 0)−max(reared reindeer_outflow.JK, 0)−reverting rate to wild.JK)
(moss).K = (moss).J + DT*(max(moss_inflow.JK, 0)−max(moss_outflow.JK, 0))
For example, the module related to the global warming is shown as follows.
(wild reindeer birthrate).K = C(wild reindeer birthrate) + α(wild reindeer birthrate) *(warming).K [1]
(growth state).K = (per reindeer moss eating).K +α(growth state)*(warming).K [2]
(moss recovery).K= C(moss recovery) + α(moss recovery) *(warming).K [3]
(edible moss rate).K= 1 − α (edible moss rate)*(warming).K [4]
The formula [1] shows that reindeer birth rate is lowered by the effects of global warming. The formula [2] shows that growth state is affected by the moss quantity eaten and deterioration due to the global warming. The formula [3] shows that moss recovery rate declined due to the global warming. The formula [4] shows the situation that permanent frozen soil has melted due to the warming and then froze again. In this process, the moss is locked into the ice, which cannot be eaten by the reindeers.

Fig 2 One parts of Simultaneous Differential Equations in System Dynamics model

3. Model analysis

1) Baseline simulation for validation

Actual and estimated numbers of reindeers are shown in Figure 3. Reindeer numbers are predicted by running baseline model for 120 years from 1963.

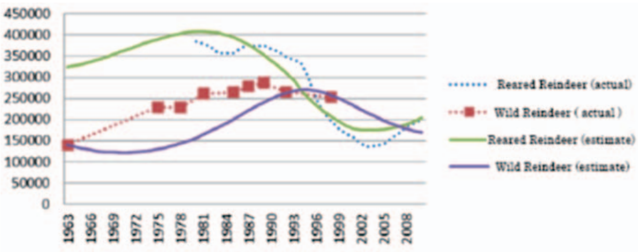

Fig 3 Reindeer Number (actual and estimated)

Both domesticated and wild reindeer numbers have fluctuated widely. The fluctuating factor of domesticated reindeer is reverting to wild. Following birth rate fluctuation of domesticated reindeer, number reverting to wild changes with time lags, which causes flow of domesticated reindeer, resulted in their number fluctuation.

2) Scenario analysis

(a) USSR non-collapse scenario

The USSR regime collapse affected nomads in Siberia drastically. As shown in Fig 4, in case of regime collapse (the baseline scenario), per capita income has been recovering gradually with fluctuation, following drastic decline just after the regime collapse. On the other hand, in case of no regime collapse, per capita income would have decreased moderately with fluctuation and take

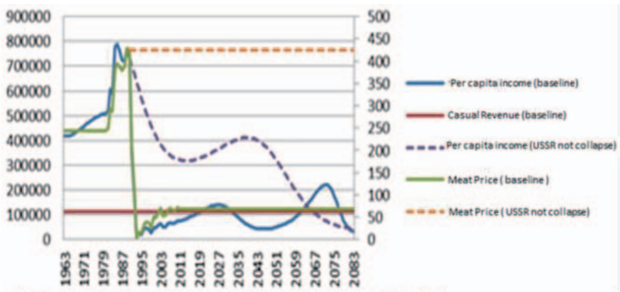

Fig 4 Per Capita Income (Regime Change Scenario)

similar process to the former case after several decades. In Fig 4, per capita income declined to level less than casual (provisional) revenues from fringe work such as slaughtering or distributing of domesticated reindeers after USSR collapsed

(b) Global warming acceleration scenario

In period after 2014, two cases of global warming are simulated, i.e. moderate warming case and drastic warming case. It was shown that as temperature goes up, domesticated reindeer number would decrease although wild reindeer number would increase after 2060s. The birth rate will decline and the death rate will rise for both domesticated and wild reindeers as temperature goes up. However, weight loss of reindeers due to decreased availability of moss and its growth deterioration caused by global warming is more important factor and common to both domesticated and wild reindeers. However, this causes opposite changes in each of reindeers. Weight loss of domesticated reindeers causes nomads to increase slaughtering to maintain the income, which result in decrease of domesticated reindeer number. On the other hand, weight loss of wild reindeers means the shortage of food for carnivorous animals which eat them, followed by the increased death rate of carnivorous animals. As the results of decreased natural enemy, wild reindeer number increases.

The increase of wild reindeer number causes the increased taking away of domesticated reindeers by wild reindeers. This process raises rate of reverting to wild. In addition, the decrease of domesticated reindeer number tends to decrease per capita income for nomads.

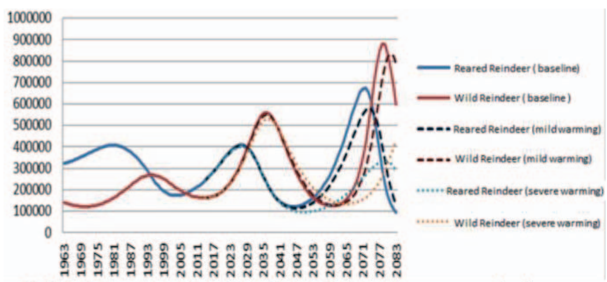

Fig 5 Reindeer Number (baseline, mild and severe warming)

(c) Subsidy increase scenario

Assume that subsidy is increased to the level where per capita income recovers to the level of USSR era (mild increase case) and increased drastically to much higher level (upsurge case) in Sakha (Yakutia) Republic. As shown in Fig 6, in case of mild increase in subsidy, fluctuations of both domesticated and wild reindeer numbers are reduced. On the other hand, both domesticated and wild reindeer numbers are decreased drastically in case of subsidy upsurge scenario. This shows that excessive subsidy causes resource reduction. At first, per capita income increases by subsidy. If subsidy is excessive, nomad number increases, followed by increase of domesticated reindeer slaughtering and wild reindeer hunting, which cause decrease of both domesticated and wild reindeer numbers.

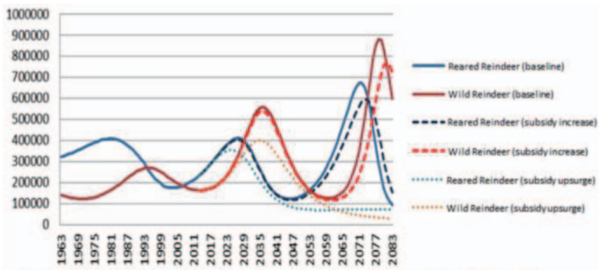

Fig 6 Reindeer Number (base, subsidy increase, subsidy upsurge)

(d) Meat price support scenario

Reindeer meat market is not well developed and meat prices are kept depressed. Here, we assume that government improves the reindeer meat market system, which raises meat prices. Under this scenario, although reindeer number has been stabilized similarly as the case of subsidy scenario, the effects are not so much as the increased subsidy scenario. As shown in Fig 7, per capita income fluctuates widely, following fluctuating domesticated reindeer number. It is contrastive to subsidy case where per capita income recovered to level of USSR era. For per capita income stabilization, measures to raise meat price through market system improvement is not so effective as subsidy policy.

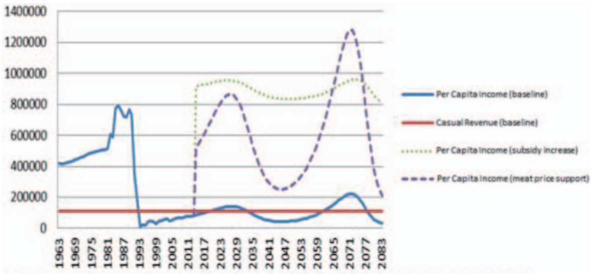

Fig 7 Per Capita Income (baseline, subsidy increase and price support)

4. Concluding remarks

(4.1) Effects of USSR regime collapse

Several subsidies to nomads and hunters were stopped after collapse of USSR regime. Also, state farms such as sovkhozes or group of reindeer husbandry specialists were dismantled, which damaged soviet style reindeer husbandries seriously. However, it was shown that this style of reindeer husbandries was not sustainable even if USSR regime had not collapsed. Although temporary shock seems to be mitigated gradually over time, unstable resource dynamics caused by USSR collapse have made husbandry economy unstable afterwards.

(4.2) Effects of global warming

Global warming does not affect reindeer's birth rate or death rate so much in spite of moss growth deterioration. Reindeer can live on not only moss but also fish etc. and adapts to climate change. It is mainly through reindeer weight loss due to poor moss growth that global warming affects nomad economies substantially. Domesticated reindeer number hardly decreases through poor moss growth but their weights actually decrease, which decrease the income. To maintain the income, nomads increase slaughtering. So, their numbers decrease, which cause their income decrease again.

(4.3) Toward sustainable reindeer husbandry

Domesticated reindeer number declined to the bottom at 2001 and recovered gradually afterwards. Wild reindeer increase is harmful for both reasons of taking away domesticated reindeer and exploiting moss. Domesticated reindeer decrease lowers the income, which discourages management motivation. This increases reverting rate to wild. Birth rates and number of domesticated reindeer decreases. To maintain reindeer husbandry, it is necessary to prevent domesticated reindeer number from decreasing. However, subsidy tends to be burden to government and to make nomads more dependent on government assistance.

Carnivorous animals are increasing. Sakha republic subsidized fox hunting without effect so far. Reindeer number decrease is caused by taking away by wild reindeers as well as attack by fox. To control fox, it is important to control wild reindeer number eaten by fox. To control wild reindeer, the hunting should be promoted through reindeer meat price increase.

Recently, per capita incomes of nomads are lower than the sustainable level. To solve this problem, subsidy should be applied in the first place. In the next stage, fluctuation of domesticated reindeer number should be mitigated in order to stabilize the income. Reindeer number fluctuation is caused by number fluctuation of wild reindeers which take away domesticated reindeer. In addition, wild reindeer number fluctuation has been causing fox number fluctuation as well. To solve these situations, government should give incentives to control wild reindeer number. Once wild and domesticated reindeer numbers are stabilized, subsidy should be phased out. Instead, by improving reindeer meat system, meat price and then per capita income can be raised to the sustainable level, eventually.

In the period before Soviet regime, ancestral commons had existed and nomad society had been maintained efficiently. When USSR regime started, the ancestral commons had been destroyed and replaced by the state farms (sovkhozes). After USSR regime had collapsed and set up the new law accepting the ancestral commons in the nomad areas, in some republics such as Tyva Republic, the ancestral commons revived and began to work as the successful management organization of natural resources. Some researchers have argued that the ancestral commons system seems to be suitable to the traditional society of the reindeer husbandry and should be resumed in order to make the reindeer husbandry economies more sustainable like the previous period before USSR era.

References

Kagatsume M. and Nakashoya E., 2013. ”Impacts of Global Warming on Reindeer Husbandry Economies and Their Responds After USSR Regime Collapsed, in Nature and People in Siberia under the Global Warming,, (RIHN FR4 C-07), 32-41

(note) SD model estimation is assisted by E. Nakashoya, student of Kyoto University.

Murota T. and Litvinenko T. V., 2012. "Recent Emergence of Ancestral Commons in Southern Siberia: A Case Study of Reindeer Husbandry in Todzhinskii County, Tyva Republic”. The Doshisha University Economic Review, Vol.64 No.1, 1-15

Reindeer Herders and Environmental Change in the Oimyakon District, Sakha Republic

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Key words: reindeer herders, awareness, environmental change, Oimyakon District, Sakha Republic

Introduction

The aim of this study is to estimate influences of environmental change induced by global warming to reindeer pastoralism in the Oimyakon District, Sakha Republic in eastern Siberia.

Reindeer pastoralism has been managed for about 3000 years (Vainshtein 1980), and is engaged by more than 20 ethnic groups in the circum-polar region (Oskal *et al.* eds. 2009). It is important subsistence activity for indigenous peoples living in northern Eurasia area, not only economically to meat production (Baskin 2000; Jernsletten & Klokov 2002: 31-34; Klokov 2012), but culturally to preserve traditional way of life (Ulvevadet & Klokov eds. 2004; Muller-Wille *et al.* 2006; Oskal *et al.* eds. 2009). However, global warming and related environmental changes are considered to influence reindeer pastoralism directly and indirectly through reindeer health, quality of pasture, forage availability and so forth (Oskal 2008).

In eastern Siberia, including Sakha Republic, the effects of environmental changes to reindeer pastoralism have not been fully investigated yet. Since the research project "Global Warming and the Human-Nature Dimension in Siberia" has started by RIHN (Research Institute for Humanity and Nature) in 2009, members of the project have studied this subject in some areas in Sakha Republic. In this article, the Oimyakon District is focused on, and influences of environmental change to reindeer pastoralism are estimated.

Study Site and Method

Research was performed in Oimyakon District, eastern part of Sakha Republic (Fig. 1). The Capital of the district is Ust' Nera, and the gross area of the district is 92,000 km^2. Oimyakon District is well-known for its severe cold in winter, and it is called "pole of coldness" (poljus kholoda). The coldest air temperature in the northern hemisphere were measured in this district; -71.2C. in 1926 and -67.7 C. in 1933.

It has a population of 14,700, including ethnic groups of Russian (56.8%), Sakha (22.8%), Ukrainian (10.2%), Even (2.7%), Evenki (0.4%) and others (7.1%) (Pravitel'stvo Respubliki Sahka (Yakutia) i institut gumanitarnykh issledovanij AN Respubliki Sakha (Yakutia) 2007). There are 14,787 head of domesticated reindeer, 72 reindeer herders and 26 tent workers in the district (Osipova *et al.* 2010).

Fig.1. Study Site.

To investigate environmental change and its influence to reindeer pastoralism, 3 types of indicators were focused; fluctuation of domestic reindeer number in statistics as an indicator of herding success in the district, awareness of local residents, including reindeer herders, to environmental change and its impact to reindeer pastoralism, and fluctuations of meteorological variables (air temperature and precipitation). They were examined individually, and their relationships and interactions were considered.

First, to confirm situation of reindeer pastoralism in Oimyakon District, statistical data (number of the domesticated reindeer in 1980-2010, presented by the Ministry of Agriculture of Sakha Republic from

Osipova *et al.* 2010) were checked out.
Second, from 24 February to 8 March in 2013 semi-structured interviews were conducted by using open-ended question at Uchugei Town and Sordnnokh Town in Oimyakon District. The questions include changes of climatic variables, topography, fauna and flora, for about past 20 years in their neighboring area. In addition current problems about general livelihood including reindeer pastoralism were also asked.
Third, climate change was estimated by fluctuations of meteorological variables (air temperature and precipitation in the district) from 1960 to 2010. These data sets were acquired from NOAA (National Oceanic and Atmospheric Administration).

Results

Number of Domesticated Reindeer

Statistical data shows that numbers of domestic reindeer in Oimyakon District dropped sharply after Soviet regime had collapsed, as same as whole Sakha Republic, however they are recovering gradually in recent years (Fig.2). The maximum number of domestic reindeer in Oimyakon from 1980 to 2010 is 19,648 head in 1988. After that, it decreased to 7,858 head in 2005, and then increased consistently to 14,787 head in 2010. In this tendency harmful influences of environmental change to reindeer herding is not detected in Oimyakon District at least in recent years.

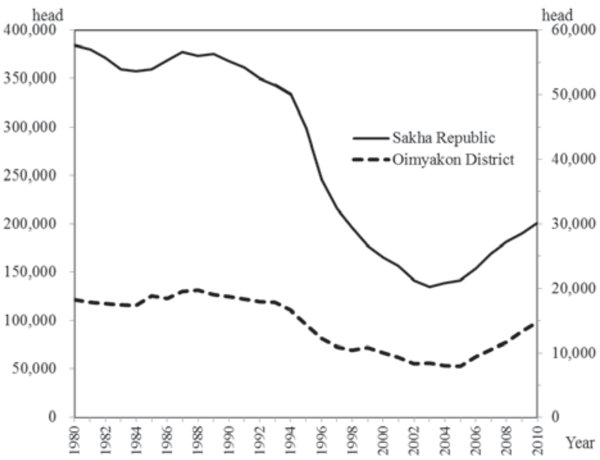

Fig. 2. Reindeer Number in Sakha Republic and Oimyakon District (1980-2010).

Semi-structured Interviews

Six interviewees were selected among local residents, including reindeer herders, from 25 to 68 years old (Table 1). Each interview required from 30 minutes to 1 hour.

Table 1. Interviewee for Semi-structured Interview.

	Age	Sex	Ethnicity	Residence	Occupation
A	25	M	Even	Uchugei	Reindeer Herder
B	56	M	Even	Uchugei	Reindeer Herder
C	57	M	Even	Sordnnokh	Horse Herder
D	49	M	Sakha	Uchugei	FGUP* Director
E	53	M	Sakha	Uchugei	Painter / Guide
F	68	M	Even	Uchugei	Reindeer Herder

*Federal'noe Gosudarstvennoe Unitarnoe Predpriiatie

All of them are aware of climate changes in their neighboring area to a greater or lesser extent. That is, as follows:
- Warming in summer
- Cooling in winter
- Increasing of precipitation in summer
- Decreasing of snow in winter.

And in connection with the increasing of precipitation, it was said that floods also increasing in summer.
About changes of fauna and flora in this district, interviewees state as follows:
- Increasing of wolves and bears
- Appearing newcomers of birds and animals: a king of gulls, ducks, minks, otters
- Decreasing of fishes: grayling, Dolly Varden
- Decreasing of parasitic flies and mosquitos
- Growing trees in the former bare land

About impacts of environmental changes to reindeer pastoralism, awareness of reindeer herders (A, B, F) and FGUP director (D) are as follows:
- Decreasing of pastures by floods and change of streams
- Increasing of predation by wolves and bears

However, at present they do not recognize serious impact of environmental changes to reindeer pastoralism. Meanwhile they think that problems for reindeer pastoralism are as follows:
- Low salary
- Difficulty for transportation of commodities to camp site
- Short of young reindeer herders

Fluctuation of Meteorological Variables
Meteorological data sets acquired from NOAA, indicate that annual average temperature is almost invariable, and seasonal average temperature is increasing in spring, summer and autumn, but decreasing in winter (Fig. 3.).

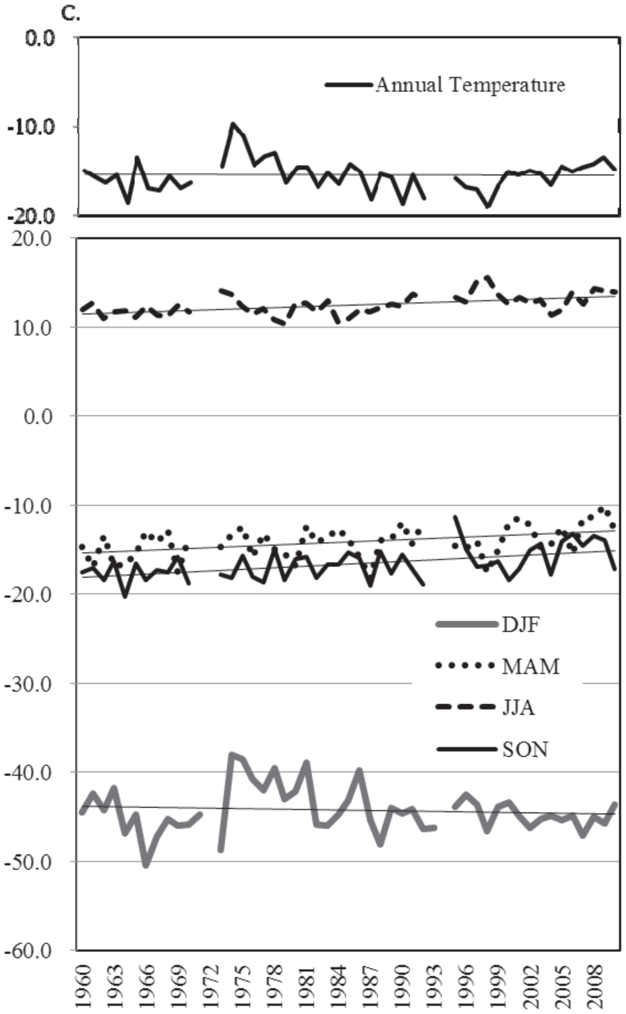

Fig.3. Annual and Seasonal Variation of Average Temperature in Oimyakon District (1960-2010). Source: National Oceanic and Atmospheric Administration

In the case of precipitation, annual and seasonal averages of precipitation are gradually increasing in Oiymakon (Fig. 4.).

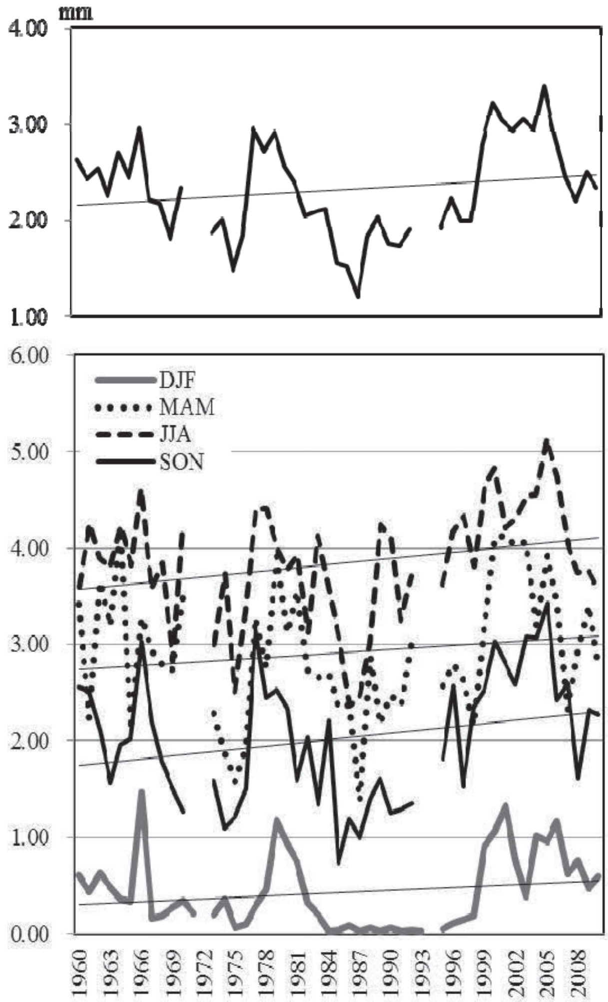

Fig.4. Annual and Seasonal Variation of Average Precipitation in Oimyakon District (1960-2010). Source: National Oceanic and Atmospheric Administration

Conclusion
From the fluctuation of domesticate reindeer numbers, reindeer pastoralism in Oimyakon district seems to be managed successfully in recent years.
Climate and environmental change are recognized by local residents to greater or lesser degrees, such as warming in summer, cooling in winter, increasing of precipitation and floods, decreasing of snow, some changes of fauna and flora.
Some of these climatic changes felt by local residents are confirmed from meteorological data set. Air temperature is increasing in spring, summer and autumn, but decreasing in winter. Precipitation is increasing in all season.
About impacts of environmental changes to reindeer pastoralism, reindeer herders and FGUP director recognize some problems, such as decreasing of pastures by floods and change of streams, and increasing of predation by wolves and bears. However, it seems that local reindeer herders do not think these impacts as serious difficulties to reindeer pastoralism. They think that more serious problems

are low salary of reindeer herders, difficulty of transportation to camp site, and short of young reindeer herders.

Judging from these 3 indicators, even though meteorological variables are gradually changing, environmental changes and their serious impacts are not generally recognized by local residents, and also they do not exert intense harmful influences on reindeer pastoralism in Oimyakon District at this stage.

One of the possible causes of this seems to be extremely cold climate in this region. Ice layers in the snow block the reindeer's access to winter food on the ground, and they are reported to be major difficulty for reindeer pastoralism (Oskal 2008, Oskal *et al.* 2009). However, in Oimyakon District, air temperature is not increasing in winter, but is mostly - 40 C. or below, therefore it seems that ice layers are hardly formed in the snow.

Then it is pointed out that overwhelming influences of social and economic environments may prevail against slight changes of natural environment. Previous studies indicate that socio-economic environment has played an important role in reindeer pastoralism in northern Europe and Russia (Tyler *et al.* 2007; Rees *et al.* 2008; Forbes & Stammler 2009; Klokov 2012). Similarly in this semi-structured interview, although local reindeer herders feel some impact of environmental changes to reindeer pastoralism, they consider that low salary, difficulty of transportation and shortage of workers are major problems for reindeer pastoralism.

References

Baskin, L.M., 2005. Number of wild and domestic reindeer in Russia in the late 20th century. *Rangifer* 25(1):51-57

Forbes, B.C. and Stammler, F., 2009. Arctic climate change discourse: the contrasting politics of research agendas in the West and Russia. *Polar Research* 28: 28-42.

Jernsletten, Johnny-Leo L. and Klokov, K., 2002. *Sustainable reindeer husbandry.* Arctic Council 2000-2002: Centre for Saami Studies, University Tromso, 157p.

Klein, D.R., 1991. Limiting factors in caribou population ecology. *Rangifer*, Special Issue No.7: 30-35.

Klokov, K.B., 2012. Changes in reindeer population numbers in Russia: an effect of the political context or of climate? *Rangifer* 32(1): 19-33.

Muller-Wille, L., Heinrich, D., Lehtola, V.-P., Aikio, P., Konstantinov, Y. and Vladimirova, V., 2006. Dynamics in human-reindeer relations: reflections on prehistoric, historic and contemporary practices in northernmost Europe. In: Forbes, B. C., Bolter, M., Muller-Wille, L., Hukkinen, J., Muller, F., Gunslay, N. and Konstatinov, Y. (eds.) *Reindeer Management in Northernmost Europe.* pp. 27-45. Ecological Studies 184, Springer-Verlag: Berlin Heidelberg.

Osipova, G.N., Balanov, I.M., Pavlov, I.P., Nikolaev, P.P., Borisova, M.V., Semenov, I.I., 2010. *Domaschnee Olenevodstvo Respybliki Sakha (Yakutia).* Ministerstvo sel'skogo khopzjaistva Respubliki Sakha (Yakutia) Departament traditsionnykh otraslei Severa i rybokhozjaistvennoi dejatel'nosti: Yakutsk, 56p.

Oskal, A., 2008. Old livelihoods in new weather: Arctic indigenous reindeer herders face the challenges of climate change. *Development Outreach* 10(1): 22-25. World Bank Institute

Oskal, A., Turi, J.M., Mathiesen S.D. and Burgess, P. eds., 2009. *Ealat Reindeer Herders' Voice: Reindeer herding, Traditional Knowledge and Adaptation to Climate Change and Loss of Grazing Land.* International Centre for Reindeer Husbandry, 131p.

Pravitel'stvo Respubliki Sahka (Yakutia) i institut gumanitarnykh issledovanij AN Respubliki Sakha (Yakutia), 2007. *Yaketia. Istoriko-kul'turnyi Atlas.* Izdatel'stvo Feoria: Moskva, 869p.

Rees, W.G., Stammler, F.M., Danks, F.S. and Vitebsky, P., 2008. Vulnerability of European reindeer husbandry to global change. *Climatic Change* 87: 100-217.

Tyler, N.J.C., Turi, J.M., Sundset, M.A., Strom Bull, K., Sara, M.N., Reinert, E., Oskal, N., Nellemann, C., McCarthy, J.J., Mathiesen, S.D., Martello, M.L., Magga, O.H., Hovelsrud, G.K., Hanssen-Bauer, I., Eira, N.I., Eira, I.M. G. and Corell, R.W., 2007. Saami reindeer pastoralism under climate change: applying a generalized framework for vulnerability studies to a sub-arctic social-ecological system. *Global Environmental Change* 17:191-206.

Ulvevadet, B. and Klokov, K. eds., 2004. *Family-Based Reindeer Herding and Hunting Economies, and the Status and Management of Wild Reindeer/Caribou Populations.* Arctic Council 2002-2004: Centre for Saami Studies, University Tromso, 170p.

Vainshtein, S., 1980. *Nomads of South Siberia: The Pastoral Economies of Tuva.* translated by Michael Colenso, Cambridge: Cambridge University Press, 289p.

Weladji, R.B., Klein, D.R., Holand, O. and Mysterud, A., 2002. Comparative response of Rangifer tarandus and other northern ungulates to climatic variability. *Rangifer* 22(1): 33-50.

Weladji, R.B. and Holand, O., 2006. Influences of large-scale climatic variability on reindeer population dynamics: implications for reindeer husbandry in Norway. *Climate Research* 32: 119-127.

FLOWS OF HYDROCARBONS IN THE NORTHERN ECOSYSTEMS AND THEIR INFLUENCE ON THE STATE OF THE CONTEMPORARY CLIMATE

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Key words:_decomposition of arctic methane hydrates, planetary climatic system, biospheric catastrophes.

Introduction

Many scientists have linked the current climate warming with an increase in the greenhouse effect. Enrichment of atmospheric trace gases is due to the different sources of natural and anthropogenic origin. The alternation of relatively warm and cold periods in Earth's history is well known in the geological, geochemical and paleoclimatic data. Highest temperatures and significant increase in the concentration of greenhouse gases marked about 420 thousand years, 320, 235, 130 and 10 thousand years ago, that is, at intervals of 90-120 thousand years, the concentration of CO_2 and CH_4 rapidly increased from about 180 to 280 ppmv and 300 to 650-750 ppbv, respectively (Figure 1), and the amplitude of changes in mean annual temperature reached about 8-10 ^oC.

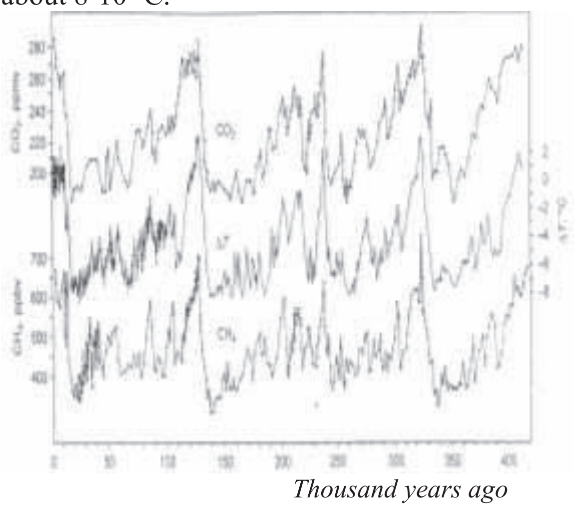

Figure 1. Correlation of CO_2 and CH_4 concentrations in the atmosphere with changes of air temperature in the Antarctica during glacial and interglacial periods for 420,000 years (Adushkin V.V. et. al.).

Climatic fluctuations of greenhouse gases occur due to natural causes, while anthropogenic effect on the environment, including the flow of greenhouse gases in the atmosphere was negligible. The contribution of anthropogenic sources in the greenhouse effect was significant only in the last 200 years. By purely anthropogenic factors it is impossible to explain the observed over the last 420 thousand years oscillatory regime change in global climate.

Discussion

In the paper (Spector V.B. et. al.) it was shown that the climatic mechanism can be viewed as a self-regulating system, and climate autooscillations are a total result of many different factors, among of which the leading role is played by carbonate-methane system. At present time, our planet remains at the turn of the ascending and descending branches of the last Holocene climatic planetary cycle ("climate crisis"). It means that the self-organizing climatic mechanism functions in the "deterministic chaos", and during this period, even relatively weak impact of biosphere and technosphere on carbonate-methane mechanism of self-regulation may have a decisive influence on the choice of the further trajectory of its evolution.

In this respect, particularly the role of anthropogenic factor and its contribution to greenhouse gas fluxes in the atmosphere is increasing. Estimation of CO_2 fluxes to the atmosphere is a complex task because their amount can vary considerably depending on the temperature of the Earth's surface and water in oceans, on the volcanic activity and other factors.

The contribution of anthropogenic factor in flow of CO_2 in the atmosphere is estimated to 21.3-27 billion tons/year (Table 1). Anthropogenic methane sources include agricultural activities, losses of methane during the mining of organic fuels and their industrial emissions, which give the average annual flow estimates vary from 1.1 billion tons / year (Table 1) to 0.35 billion tons / year (Table 2).

Table 1. Global flow of gases in the atmosphere (Adushkin V.V. et. al.)

Source	Gas	
	CO_2 billion t/ year	CH_4 billion t/ year
Natural	700	1.9
Anthropogenic	21.3-27	1.1
Total	721.3-727	3.0

As seen from the Table 1 anthropogenic flow of CO_2 is about 3.7% of the total flux of carbon dioxide, for CH_4, this value is about 37%.

Table 2. Power of natural and anthropogenic sources of methane (Bazhin N.M. et.al.)

Natural sources	**mln.t/year**
Swamps	50-70
Lakes	1-25
Oceans	1-17
Tundra	15-35
Insects	20
Total powder	**130±40**
Anthropogenic sources	**mln.t/year**
Rice fields	120±50
Animals	80
Dumps	50±20
Coal mining,	35±10
Losses in the natural gas production	34±5
Biomass burning	30±15
Total powder	**350±100**
Total	**480±140**

According to Bazhin N.M. et.al., anthropogenic methane stream in the atmosphere is already about 73% of the total flow, i.e. exceeds the natural approximately 2.7 times.

The authors did not take into account the contribution of light hydrocarbons that evaporate at numerous spills and leaks of oil and petroleum products in the processes of production, transportation, storage and processing. The oil industry is the danger of environmental impact in third place among the 130 branches of modern production (Solntseva N.P. et.al.). Total world oil losses are about 3% of its global production (Goldberg V.M. et. al.). 2% of the oil produced is lost during transportation and storage of petroleum products, about 75% of these losses occurring in the evaporation of hydrocarbons from tanks and tanker vessels. By evaporation of the removed soil from 20 to 40% of a light fraction oil spilled. That is, nearly half of the loss of oil and petroleum products to the atmosphere, increasing the greenhouse effect.

The concentration of the main greenhouse gases CO_2 and CH_4 in the atmosphere over the past 200 years has increased by 30 and 145%. At present, their concentration continues to increase, and the rate of growth of CO_2 for 0,42-0,5% a year for CH_4 - 0.6-1% per year (Adushkin V.V. et.al.). It is clear that the impact of anthropogenic sources of CO_2 modern (360 ppmv) and especially CH_4 (1720 ppbv) are significantly higher than the concentrations of these gases on the eve of the industrial period (280 ppmv and 700 ppbv, respectively, in 1800) and, most importantly, the content of these gases in the previous climatic maxima, i.e. 420, 320, 235, 130 and 10 thousand years ago (see Figure).

Carbon dioxide is one of the major greenhouse gases, which contribute to global warming and the highest is 60%. The share of anthropogenic sources of 2-2.5%, as the ratio of anthropogenic and natural fluxes of 1: (25-30). For methane, whose contribution to the greenhouse effect is estimated at 15%, anthropogenic stream may range from 1/3 or more, therefore, the proportion of man-made sources of methane have 5% or more of global warming. To this must be added the flow of hydrocarbons into the air by evaporation of crude oil and petroleum products.

The methane concentration in the atmosphere is about 200 times lower than carbon dioxide, but its radiation activity is 21 times higher. Increase the concentration of methane has recently unprecedented and may lead to the fact that over the next 50-60 years will doubling its content in the atmosphere (Adushkin V.V. et.al., Dyadin J.A. et.al.).

It is possible that one of the sources of methane in the atmosphere and observed are hidden methane emissions decomposition of natural gas hydrates. Accoding to Dyadin J.A. et.al. the amount of methane that is fraught with natural gas hydrates, is 3,000 times greater than the amount in the atmosphere ((6-7) * 1012 m^3). The release of this greenhouse building would have dire consequences for humanity. Warming can cause decomposition of hydrates, and thus make a methane increasing the greenhouse effect, in a positive feedback will further warming, i.e. begin the process of self-acceleration.

In the Earth's history of such events have occurred. This catastrophic Mesozoic and Cenozoic warming, so-called "methane catastrophe", accompanied by global oceanic anoxic events (OAE). The last such rapid warming (over several millennia) is fixed at the boundary of the Paleozoic and Eocene 55 million years ago (Yudovich Ya.E.; Golitsin G.S. et.al.). For that is used the name of climate - PETM, which means the Paleocene-Eocene Thermal Maximum. The mechanism of catastrophe is shown in the form of the following causal chain: in the first stage, for whatever reason (most likely volcanic) dramatically increased the amount of CO_2 in the atmosphere. The accumulation of greenhouse gases in the atmosphere has led to a warming of the atmosphere and hydrosphere, which in turn, according to many scientists, prompted the expansion of virtually all available at the time of oceanic gas hydrates (about 1200 GTonns, it is about 1/10 of the current storage), which has further increased the greenhouse effect. The temperature of the surface layers of the ocean has increased to 12-13^{o}C, and deep - up to 6 ^{o}C.

The sudden warming, melting glaciers, desalination of surface water are posing the density stratification of the ocean: the deep waters no longer supplied with oxygen, which killed most of the benthos. Anoxia prevents the aerobic oxidation of organic matter sinks to the bottom. Coefficient of its fossilization (not exceeding in the modern ocean 0.05% of the initial content of organic carbon in living matter), abruptly jumps. So instead of precipitation with organic carbon contents at 0.1-0.5% carbon precipitates are formed (future black shales) with much higher contents of organic carbon, sometimes exceeding 10% (Yudovich Ya.E.).

Thus, according to Yudovich Y.E. black shale episodes associated with the OAE, are "black pages of the chronicle of the biosphere." Given that the black shale formations are potential oil source, it can be assumed that climate-caused disaster biosphere initiates the process of forming caustobiolites, including oil formation. Accumulation of black shales meant leaving large masses of supergene carbon cycle "atmosphere-biosphere-atmosphere."

Empowered burial organic carbon for 200 thousand years has led to a decrease in atmospheric pCO_2, decreased greenhouse effect, come chill, anomalous black shale sedimentation was replaced normal.

The rate of increase of methane concentration in the atmosphere is now so great that it can not but cause concern among many scientists. According to Yudovich Yu.E. review, 19-th Annual International Goldshmid geochemical conference held in Davos in 2009, about one-third of all the papers were devoted to this issue.

According to the Novosibirsk scientists (Dyadin J.A., et.al.), available today simplistic assessment of changes in the temperature profiles of the crust leads to the following conclusions. The submarine gas hydrates located in the world's oceans, inland seas and lakes do not cause concern. In any event they will remain stable in the next thousand years.

The most dangerous are hydrates, which are already in a metastable state (zone of permafrost). Particularly, gas hydrate deposits affected by climate change in the Arctic continental shelf. Due to the rising sea level, they experience an increase of surface temperatures. Amount of methane released from this source today is about 5.6 x 10^9 m^3 per year, or about 1% of all known sources of atmospheric methane. Critical for this source is the temperature of -2 ÷ 0°C, above which the effect of self-preservation is no longer valid, and starts a landslide decomposition of gas hydrates.

On the territory of one of the coldest regions of the planet, north-east Asia, for example, over the past 50 years, the growth in average annual temperatures has a trend 0.06-0.09 ° C / year (Gavrilova M.K.).

While maintaining the modern trend of the temperature, permafrost layer on the bottom of the annual heat exchange (-8 ÷-6C) in this region can rise to a critical level for 60-80 years.

From the bottom of the Arctic Ocean (Beaufort Sea) is now showing signs of awakening of the masses of methane (Paull C.K., et.al.).

Conclusion

From the above it follows that in a "climate crisis", which our planet is currently going through, anthropogenic factor can make permanent effects on the choice of a self-regulating climate system in a further trajectory of its development. Do not want to see human activity provoking a new "methane catastrophe" in the Earth's history and modern biota has become a source of accumulation of caustobiolites for perhaps the next civilizations.

References

Adushkin V.V., Solov'yev S.P., Turuntayev S.B. 2001. Sootnosheniye antropogennoy i prirodnoy sostavlyayushchikh v potoke gazov v atmosferu. *Global'nye izmeneniya prirodnoy sredy.* SO RAN «GEO», Novosibirsk, 249-264.

Bazhin N.M., 2000. Metan v atmosphere. *Sorovskiy obrazovatel'nyy zhurnal. Khimiya.* **6 (**3), 52-57.

Dyadin Y.A., Gushchin A.L., 1998. Gazovyye gidraty. *Sorovskiy obrazovatel'nyy zhurnal. Khimiya.* **4** (3), 55-64.

Gavrilova M.K., 2007. *Rayonirovaniye (zonirovaniye) Severa Rossiyskoy Federatsii.* izd - vo Instituta merzlotovedeniya SO RAN, Yakutsk, 64-98.

Gol'dberg V.M., Zverev V.P., Arbuzov A.I., Kazennov S.M., Kovalevskiy Y.V., Putilina V.S., 2001. *Tekhnogennoye zagryazneniye prirodnykh vod uglevodorodami i yego ekologicheskiye posledstviya.* Nauka, M, 125 p.

Golitsyn G.S., Ginzburg A.S., 2007. Otsenka vozmozhnosti «bystrogo» metanovogo potepleniya 55 mln let nazad. *DAN. Geofizika.* **413** (6), 816-819.

Paull C. K., Ussler W., Dallimore S. R., Blasco S.M., Lorenson T. D., Melling H., Medioli B.E., Nixon F.M., McLaughlin F.A., 2007. Origin of pingo-like features on the Beaufort Sea shelf and their possible relationship to decomposing methane gas hydrates. *Geophysical Research Letters.* **34** (1).

Solntseva N.P., 1998. *Dobycha nefti i geokhimiya prirodnykh landshaftov*. Izd - vo MGU, M, 376p.

Spektor V.B., Kershengolts B.M., Lifshits S.H., Spektor V.V., 2007. Karbonatno - metanovaya sistema samoregulyatsii planetarnogo klimata. *Izvestiya RAN. Seriya geograficheskaya.* **6,** 1-12.

Yudovich Y.E., 2009. Davosskaya geokhimicheskaya moda – 2009. *Vestnik instituta geologii Komi nauchnogo tsentra Ural'skogo otdeleniya RAN*. **7,** 25-33.

Estimation of regional water cycle changes by various land-cover-change scenarios in eastern Siberia

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Key words: land cover change, water cycle, eastern Siberia

This extended abstract is the short summary of Yoshida et al. (2013)

1. Introduction

The land surface strongly affects the lower atmosphere in eastern Siberia in the summer. The relationship between precipitation originated from land surface evaporation P_m and total precipitation P at the local scale has been investigated on the basis of the recycling ratio (P_m/P). For example, Dirmeyer and Brubaker (2007) demonstrated that eastern Siberia has a higher local recycling ratio than other regions in the summer. Van der Ent and Savenije (2011) defined local moisture feedback in terms of length and time scales. Land cover change was recently reported in eastern Siberia, and it was found that the forest area is decreasing because of increasingly frequent forest fires. Moreover, the water surface of alas has expanded (Iijima et al. 2010). This type of land cover change affects the lower atmosphere in eastern Siberia.

The aim of this study was to determine how the lower atmosphere would change with land cover changes in summer when evaporation is enhanced. We considered parameter changes through land cover changes, such as forest area decreases or water surface expansion, with the exception of permafrost change.

2. Model and experimental design

We used the Japan Meteorological Agency Non- hydrostatic model (JMA-NHM; Saito et al. 2007). The model includes atmospheric physical processes and land surface processes. The calculation domain is shown in Fig. 1. The domain center was taken as 66º00' N, 126º30' E. We used Global Land Cover Characterization (GLCC) from the U.S. Geological Survey (USGS) for the land surface type distribution and a global digital elevation model with horizontal grid spacing of 30 arc (GTOPO30) for the topography and water surface distribution. This downscaling was conducted as one-way nesting. The domain size was 4200 km x 4200 km for the 30-km grid and 2000 km x 2000 km for the 5-km grid. Data from the Japanese 25-year Reanalysis (JRA-25; Onogi et al. 2007), were used for the initial and boundary conditions in the 30-km grid-size calculations. The results were used as the initial and boundary conditions for the 5-km grid-size calculation. The results for the 5-km grid size were used as data for analyses. The calculation period was from 0000 UTC 21 June 2000 to 0000 UTC 1 August 2000.

We designed an experiment to clarify which land surface parameters are significant for the lower atmosphere when they change independently. Land cover changes associated with an increase in forest fires occurred in the low elevation area (Potapov et al. 2008). Moreover, considering that water surfaces are primarily located below 250 m above mean sea level (MSL) (Fig. 1), the change in land surface parameters was determined for the area below 250 m MSL in the 5-km grid-size domain. Land surface parameters did not change for the 30-km grid-size domain. We examined five land surface parameters that describe the land surface state: surface albedo α, evaporative efficiency β, roughness length z_0, heat capacity $c\rho$, and thermal conductivity λ. The lower-atmospheric response was examined with respect to the independent changes in each parameter.

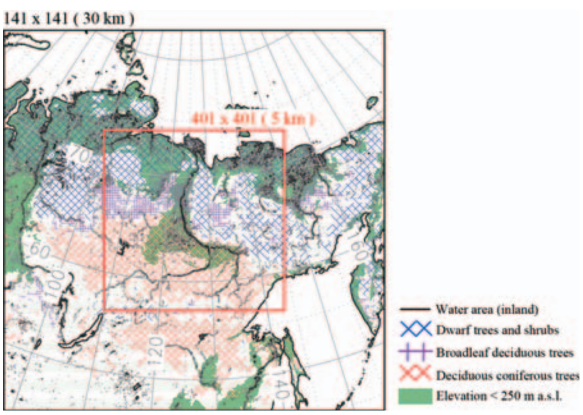

Fig. 1. Calculation domain and distribution of water surfaces and vegetation.

3. Result

Figure 2 shows the area-averaged meteorological quantities for each change in the land surface parameters below 250 m MSL. A similar trend was observed between the latent heat flux and precipitation (Figs. 2a,b), with a monotone increase or decrease corresponding to the changes in the land surface parameters under observation.

The sensible heat flux exhibited an opposite tendency of that of latent heat flux. From a heat-balance relationship, sensible heat flux decreased with increases in the latent heat flux (Fig. 2c). A negative tendency was calculated between downward shortwave radiation α and β, whereas an unclear relationship was derived for z_0, $c\rho$, and λ (Fig. 2d).

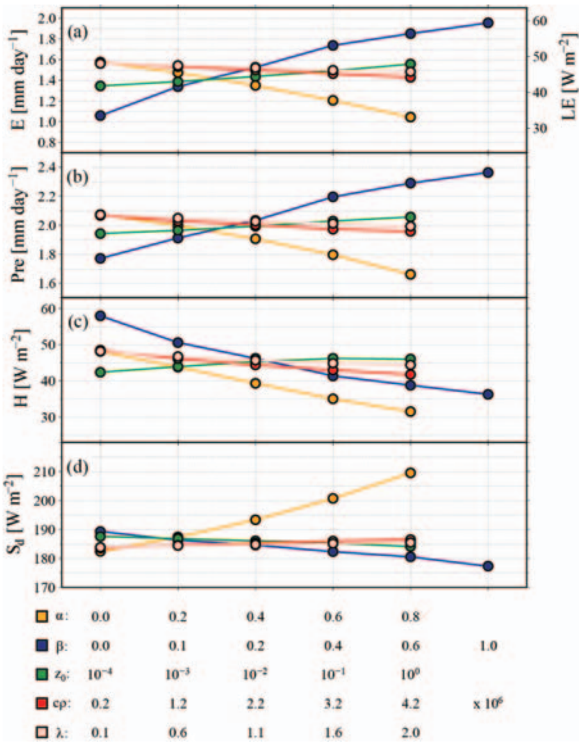

Fig. 2. The area-averaged quantities for each of the land surface parameter settings: (a) evaporation (left axis) and latent heat flux (right axis), (b) precipitation, (c) sensible heat flux, and (d) downward shortwave radiation.

Presuming linearity between the latent heat flux and the changes in the five land surface parameters, the latent heat flux change can be written as the product of parameter impact (PI) and the changes in the parameters with land cover change as follows:

$$
\begin{aligned}
\Delta \mathrm{LE} = {} & \frac{\partial \mathrm{LE}}{\partial \alpha}\Delta\alpha + \frac{\partial \mathrm{LE}}{\partial \beta}\Delta\beta + \frac{\partial \mathrm{LE}}{\partial \log(z_0)}\Delta\log(z_0) \\
& + \frac{\partial \mathrm{LE}}{\partial c\rho}\Delta c\rho + \frac{\partial \mathrm{LE}}{\partial \lambda}\Delta\lambda ,
\end{aligned}
$$

where ΔLE is the latent heat flux difference from the control run (G, W, O) = (0.2, 0.0, 0.8). The partial derivative coefficients, *LE*/para, where 'para' denotes surface albedo, evaporative efficiency, roughness length, heat capacity, and thermal conductivity, are given based on the PIs.

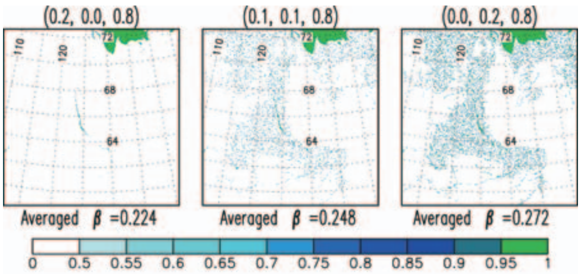

Fig. 3. Distribution of the evaporative efficiency for (left to right) three land surface distribution ratios: (grassland, water surface, original) = (0.2, 0.0, 0.8), (0.1, 0.1, 0.8), and (0.0, 0.2, 0.8).

The sum of all the effects on latent heat flux change was 1.2 W m^{-2} in the water surface expansion experiment (Fig. 3), indicating a 0.4 W m^{-2} overestimation with the JMA-NHM method. Similarly, the calculated daily precipitation of 0.026 mm day^{-1} represented a 0.01 mm day^{-1} overestimation by the JMA-NHM method. Although we used a simple estimation method for the calculations, a similar order of magnitude was derived via the JMA-NHM method.

4. Discussion

On the basis of previous results, the area-averaged latent heat flux and precipitation can be calculated using the parameter impact method and various land surface data. Figure 4 presents a schematic diagram of the land surface distribution ratio below 250 m MSL. 'Original' signifies forest in the southern area and bare soil in the northern area. The land cover changes from original to grassland or a water surface. For simplicity, the land cover change from original was designated as 'deforestation' in this study. 'WF' denotes the water fraction of the sum of the water surface area and the grassland area.

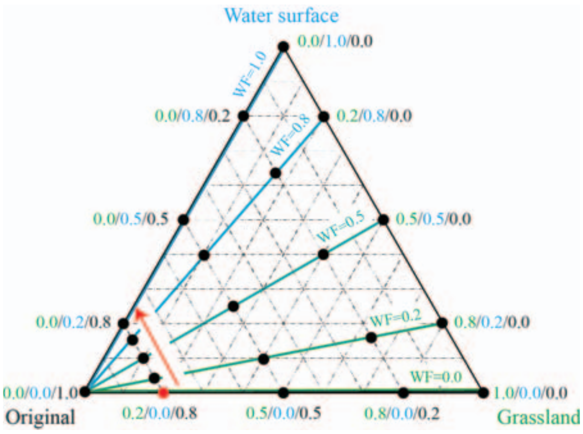

Fig. 4. Schematic diagram of the land cover change. The land surface takes values of (grassland, water surface, original)=(0.0, 0.0, 1.0) if there is no land cover change.

The land cover change to grassland had no significant impact on the area-averaged latent heat flux; however, land cover change involving a water surface enhances the latent heat flux intensely. In particular, the ratio ΔPre/ΔE increased strongly for small WF, indicating that water surface expansion in a small water area enhances the water cycle, in contrast to expansion in a large water surface area. Figure 5 shows the lower atmosphere response caused by land cover changes under the present climate.

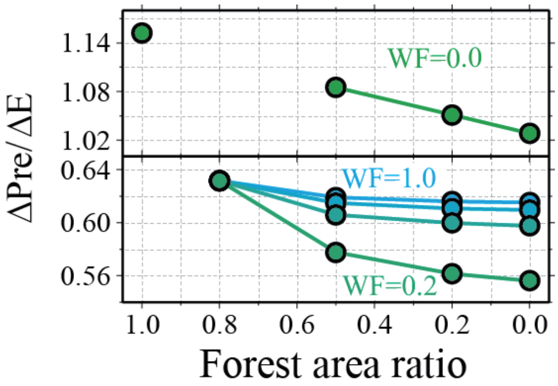

Fig. 5. Area-averaged precipitation/latent heat flux change from the control run (grassland, water surface, original) = (0.2, 0.0, 0.8).

5. Conclusion

The impact of land cover changes on the lower atmosphere was discussed in this study. On the basis of the results of the parameter sensitivity experiment, the lower atmosphere response associated with land cover change was also evaluated. The increase in the rate of ΔPre/ΔE was weak for large expanding water surface areas. By contrast, the rate was intense for small expanding water surface areas in eastern Siberia. Land surface change such as grassland formation from forest through forest fire yielded little enhancement of evaporation and precipitation; however, if water surface formation was caused by an increase in incoming downward shortwave radiation to the land surface because of the disappearance of the forest shading effect and the melting of permafrost, the water cycle would be enhanced intensely. Moreover, the calculation of the latent heat flux with the parameter impact method yielded a similar value to that obtained when using the JMA-NHM method, implying that parameter impact method could be used to estimate the latent heat flux change caused by a given land cover change.

References

Dirmeyer P. A. and K. L. Brubacker 2007: Characterization of the global hydrologic cycle from a back-trajectory analysis of atmospheric water vapor, *J. Hydrometeor.*, **8**, 20-37.

van der Ent R. J. and H. H. G. Savenije 2011: Length and time scales of atmpsheric moisture recycling. *Atmos. Chem. Phys.*, **11**, 1853-1863.

Iijima Y, A. N. Fedorov, H. Park, K. Suzuki, H. Yabuki, T. C. Maximov and T. Ohata 2010: Abrupt increases in soil temperatures following increased precipitation in a permafrost region, central Lena River basin, Russia. *Permafrost Periglacial Processes*, **21**, 30-41.

Onogi K. and Coauthors, 2007: The JRA-25 reanalysis. *J. Meteor. Soc. Japan*, **85**, 369-432.

Potapov P., M. C. Hansen, S. V. Stephan, T. R. Loveland and K. Pitman, 2008: Combining MODIS and Landsat imagery to estimate and map global forest cover loss. *Remote Sens. Environ.*, **112**, 3708-3719.

Saito K., J. Ishida, K. Aramami, T. Hara, T. Segawa, M. Narita and Y. Honda 2007: Nonhydrostatic atmospheric models and operational development at JMA, *J. Meteorol. Soc. Japan.*, **85B**, 271-304.

Yoshida R, M. Sawada, T. Yamazaki, T. Ohta and T. Hiyama 2013: Influence of land cover change on regional water cycles in eastern Siberia, *J. Appl. Meteorol. Climatol.*, **52**, 484-497.

Characteristics of energy balance within a permafrost black spruce forest in interior Alaska, for intercomparison study with a larch forest in eastern Siberia

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Key words: permafrost black spruce, energy balance, ground heat flux, energy balance deficit, latent heat of fusion

Introduction

Larch forest in eastern Siberia and black spruce forest in interior Alaska are the representative species for these two permafrost regions, respectively. The soil underneath the larch forest in eastern Siberia is old fluvial deposit with sandy texture, whereas black spruce in Alaska usually grows on a wet organic soil, covered by a thick moss layer. Such forests are strongly dependent on the state of permafrost, and are thus considered vulnerable to future climate change.

Since boreal forests occupy about 17 % of the vegetated surface of the globe (e.g., Whittaker, 1975), and these two species are dominant in their respective regions, an intercomparison study between the two forest sites will be important for a better understanding of the characteristics of the boreal forest biome, with respect to energy, water, and carbon cycling; it will also contribute to reducing uncertainty in future climate change prediction. For future intercomparison study with larch forest in eastern Siberia, we report here the year-round (2011) observed energy balance components within a black spruce forest underlain by permafrost in interior Alaska.

Study site

Observations were conducted at the site of a black spruce forest at the Poker Flat Research Range (PFRR) of the University of Alaska Fairbanks (65° 07' 24.4" N, 147°29' 15.2" W), located in interior Alaska (Fig. 1) (Nakai et al., 2013). The dominant overstory tree species in this forest was black spruce (*Picea mariana*), with the forest floor nearly completely covered by a moss layer of rusty peat moss (*Sphagnum fuscum*) and splendid feather moss (*Hylocomium splendens*) and partly covered by tussock with cotton-grass (*Eriophorum vaginatum*). The understory was dominated by low shrubs and herbs, such as Labrador tea (*Ledum groenlandicum*), bog bilberry (*Vaccinium uliginosum*), dwarf birch (*Betula nana*), and cloudberry (*Rubus chamaemorus*). At the time, this lowland black spruce forest was considered a bog forest.

According to our tree survey conducted in July 2010 within a 30 m by 30 m plot, this site represented a nearly pure stand of black spruce. Stand density of this forest was 3,967 trees ha^{-1}, arithmetic mean height of trees was 2.44 m, and maximum tree height was 6.4 m. The leaf area index (LAI) of overstory black spruce was 0.73 (measured on September 24, 2011, using a LAI-2000 (LI-COR)); the effect of leaf clumping was considered.

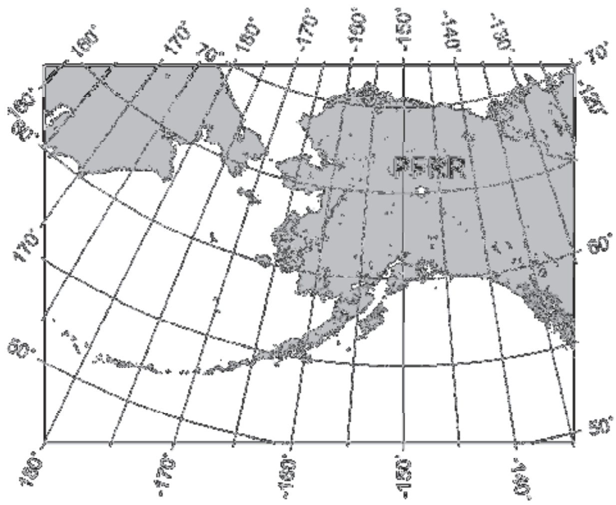

Figure 1. Map of the study site at the Poker Flat Research Range (PFRR), University of Alaska Fairbanks.

Measurements

A 17-m tower was built within the black spruce forest of the PFRR supersite. Net radiation R_n (W m^{-2}) was observed at the top of the tower (16.0 m above the ground) by CNR4 (Kipp & Zonen, the Netherlands), which observes downward/upward short-wave and long-wave radiation independently. Ground heat flux G (W m^{-2}) was measured using a heat flux plate (HFP01SC, Hukseflux, the Netherlands) at 8-cm depth in the moss layer at two points, and the average of these measurements was used.

Sensible heat flux H (W m^{-2}) and latent heat flux λE (W m^{-2}) were measured by eddy covariance technique, using a WindMaster Pro ultrasonic anemometer (Gill Instruments, Lymington, UK) and a LI-7200 enclosed infrared gas analyzer (LI-COR, Lincoln, Nebraska, USA) on the tower at 11.0-m height above the ground (Fig. 2). When calculating H and λE, the angle of attack errors on the measurements of WindMaster Pro were corrected, in accordance with Nakai et al. (2012).

In addition, other meteorological data, including precipitation, snow depth, and vertical profiles of air temperature, relative humidity, wind speed, soil temperature, and soil moisture, were also measured in this site (see Nakai et al., 2013).

Data used in this study spanned from January 1 to December 31 of 2011. According to the downward phonological fisheye images taken from the top of the tower (Nagai et al., 2013), the day of complete snow disappearance in 2011 was May 5, and the snow-free period that followed was May 5 to October 12 (Fig. 3).

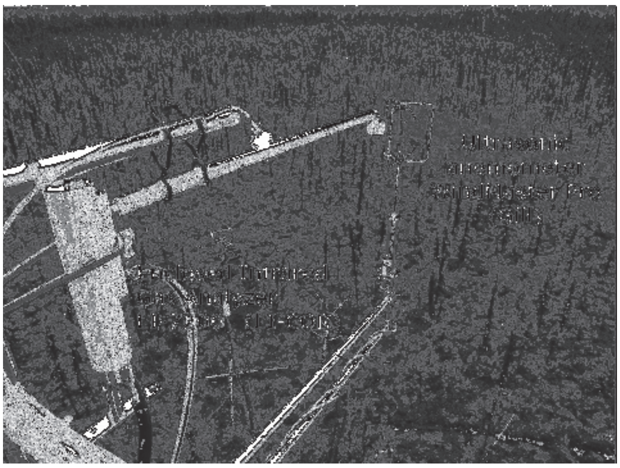
Figure 2. Photo of the eddy covariance flux measurement system on the tower, 11.0 m above the ground.

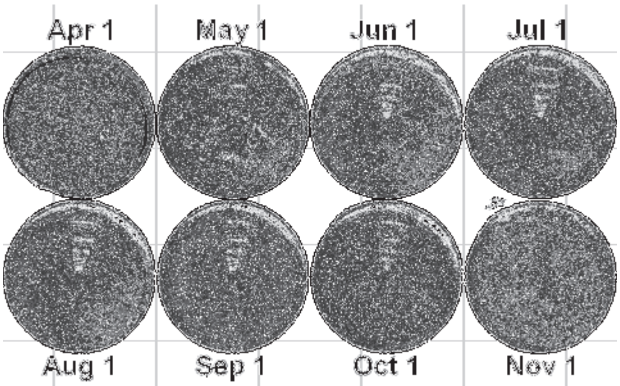

Figure 3. Downward fisheye images of a black spruce forest at PFRR supersite, taken from the top of the tower. Images from 2011.

Energy balance

The energy balance of this forest is expressed as follows:

$$R_{\mathrm{n}} - G - J_{\mathrm{H}} - J_{\mathrm{E}} = H + \lambda E\,, \qquad (1)$$

where J_{H} and J_{E} (W m^{-2}) are the sensible heat storage and latent heat storage of the air between the ground surface and the eddy covariance system, respectively. As has been pointed out in the literature, Eq. (1) is not usually closed. To check energy balance closure, energy balance deficit (EBD) (Hendricks Franssen et al., 2010) was used in this study, defined as follows:

$$\mathrm{EBD} = R_{\mathrm{n}} - G - H - \lambda E - J_{\mathrm{H}} - J_{\mathrm{E}}\,. \qquad (2)$$

In addition, energy balance ratio (EBR) was also used, and is represented as follows:

$$\mathrm{EBR} = \frac{H + \lambda E}{R_{\mathrm{n}} - G - J_{\mathrm{H}} - J_{\mathrm{E}}}\,. \qquad (3)$$

Results and discussion

Usually, the right-hand side of Eq. (1) is reported to be smaller than the left-hand side, and EBD is positive as a result. Figure 4(a) shows seasonal variation in EBD, which was calculated from daily-averaged components of Eq. (1). EBD showed large positive values from the end of April to mid-May, a feature partially accounted for by the effect of snowmelt, as discussed later. After mid-May, EBD showed negative values until mid-August, which was considered erroneous.

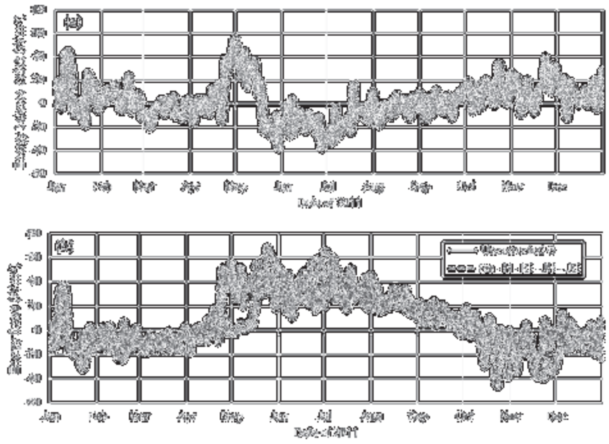
Figure 4. Seasonal variations in (a) EBD and (b) G and $R_{\mathrm{n}} - H - \lambda E - J_{\mathrm{H}} - J_{\mathrm{E}}$ (i.e., EBD – G).

When G and $R_{\mathrm{n}} - H - \lambda E - J_{\mathrm{H}} - J_{\mathrm{E}}$ (i.e., EBD + G) were compared (Fig. 4(b)), G was larger than EBD + G during the corresponding period of when EBD was negative. Overestimation of G

during summer was thus suspected as the cause of negative EBD.

The heat flux plate HFP01SC adopted the value of thermal conductivity, $k = 0.8$ W m^{-1} K^{-1}. O'Donnel et al. (2009), however, showed that the thermal conductivity k of living *Sphagnum* varied with volumetric water content θ (%), and the maximum value of k ranged from 0.5 to 0.6 W m^{-1} K^{-1} at high volumetric water content θ. Also according to O'Donnel et al. (2009), the linear regression relationship between θ and k is provided as follows:

$$k = 0.0047\theta + 0.0233\,. \tag{4}$$

By this relationship, we corrected summer G. Since the heat flux plates were installed at 8-cm depth, the average value of volumetric water content data at 5-cm and 10-cm depths was used. G data from May 15 to September 27 were corrected since G was positive during this period, and volumetric water content data of before May 15 was considered doubtful.

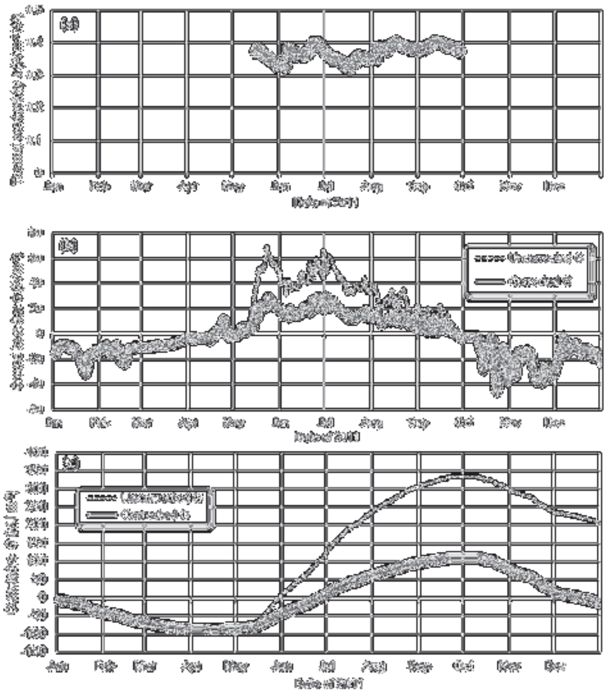

Figure 5. Temporal variation in (a) thermal conductivity k calculated by Eq. (4); seasonal variations in (b) uncorrected G and corrected G using calculated k; and (c) cumulative value of uncorrected and corrected G.

Figure 5(a) shows the variation in thermal conductivity k calculated using Eq. (4). Clearly, the calculated k was smaller than 0.8, the default value of HFP01SC. The mean value of k during this period was 0.38. By using calculated k, summer G was corrected during the corresponding period. Corrected G was nearly half when compared with uncorrected G (Fig. 5b). When the cumulative value of G was calculated, the annual value of uncorrected G resulted in a large positive value, whereas annual corrected G was close to zero (Fig. 5c). The overestimation of G, therefore, was considered as caused by an invalid k., and the correction of G by using Eq. (4).

By using corrected G, the energy balance during summer (June 1 to August 31, 2011) was evaluated (Fig. 6). The pie graph in Fig. 6 shows the partitioning of net radiation. The storage terms of sensible and latent heat were negligibly small. Obviously, ground heat flux G accounted for a large portion (16.7 %) of summer energy balance, which was considered consumed by thawing frozen soil.

Contributions of sensible heat flux H (35.2 %) and latent heat flux λE (37.2 %) to summer energy balance were nearly the same. On the other hand, EBD accounted for 10.9 % of net radiation; i.e., the energy balance was not closed during this period. EBR in summer was calculated as 0.869.

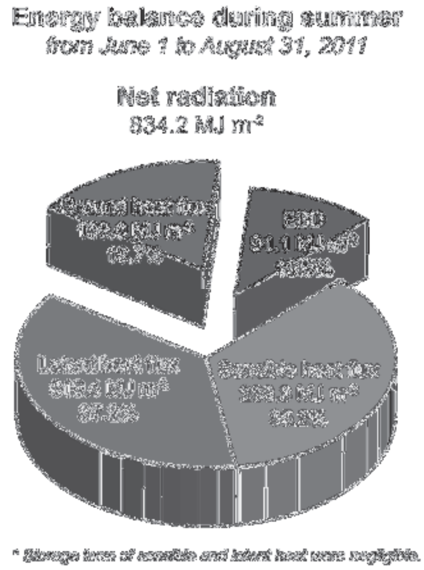

Figure 6. Summer (JJA) energy balance components over black spruce forest in PFRR.

Figure 7 shows the annual energy balance (partitioning of net radiation) in 2011. As pointed out above, annual ground heat flux was close to zero after applying corrections of Eq. (4) (Fig. 5c). EBD occupied 30.0 % of the annual energy balance, and EBR was calculated as 0.703. This may be partially explained by snowmelt (as described later), though a large part of EBD is still unknown. This should be clarified in the near future. Contribution of latent heat flux λE to annual energy balance

(44.4 %) was much larger than that of sensible heat flux H (26.6 %). This is because daily H was negative in winter whereas the daily λE was positive year-round.

Figure 8 shows energy balance during snowmelt period. Since we conducted our snow survey in March 23, and the snow-covered portion of the ground surface reached less than 50 % on May 1, the energy balance was evaluated for the period of March 23-May 1. EBD during this period was 37.9 MJ m^{-2} (34.2 %), which was the largest for the year (see Fig. 4a). This large EBD was expected as used for snow melting. Snow water equivalent at this site, measured on March 23, was 110.8 mm, and latent heat of fusion to melt this snow was calculated as 37.0 MJ m^{-2}, which accounted for most of the EBD. As a result, the energy balance during this period was nearly closed, which might support the validity of eddy covariance measurement in this site.

Conclusions

We conducted year-round observation of energy balance components within a permafrost black spruce forest in interior Alaska in 2011. The findings in this study are as follows:

1. Annual ground heat flux was close to zero, by correcting ground heat flux in summer.
2. Ground heat flux played an important role in energy balance in summer, which accounted for 16.7 % of net radiation.
3. Sensible heat flux and latent heat flux were nearly the same in magnitude in summer, whereas latent heat flux was larger than sensible heat flux in annual heat balance.
4. Energy balance deficit was very large in annual energy balance, which accounted for 30 % of net radiation.
5. The large energy balance deficit during the snowmelt period was explained by energy consumed by snowmelt.

Acknowledgment

This research was conducted under the JAMSTEC-IARC Collaboration Study, with funding provided by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) under a grant to the International Arctic Research Center (IARC).

References

Nagai, S., Nakai, T., Saitoh, T.M., Busey, R.C., Kobayashi, H., Suzuki, R., Muraoka, H., Kim, Y., 2013. Seasonal changes in camera-based indices from an open canopy black spruce forest in Alaska, and comparison with indices from a closed canopy evergreen coniferous forest in Japan. *Polar Sci.*, **7**, 125-135.

Nakai, T., Shimoyama, K., 2012. Ultrasonic anemometer angle of attack errors under turbulent conditions. *Agric. For. Meteorol.* **162-163**, 14-26.

Nakai, T., Kim, Y., Busey, R.C., Suzuki, R., Nagai, S., Kobayashi, H., Park, H., Sugiura, K., Ito, A., 2013. Characteristics of evapotranspiration from a permafrost black spruce forest in interior Alaska. *Polar Sci.* **7**, 136-148.

Whittaker, R.H., 1975. Communities and Ecosystems, second ed. Macmillan, New York, 385p.

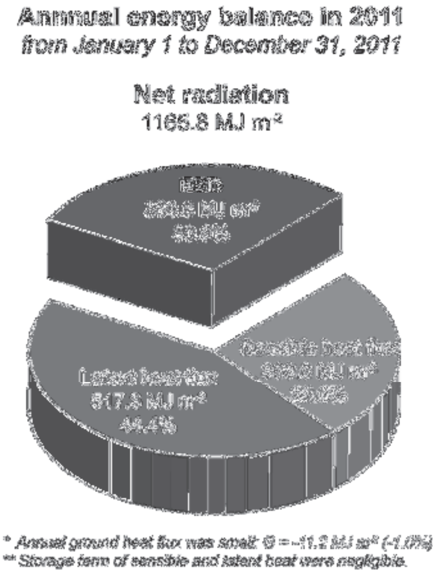

Figure 7. Annual energy balance components over a black spruce forest in PFRR.

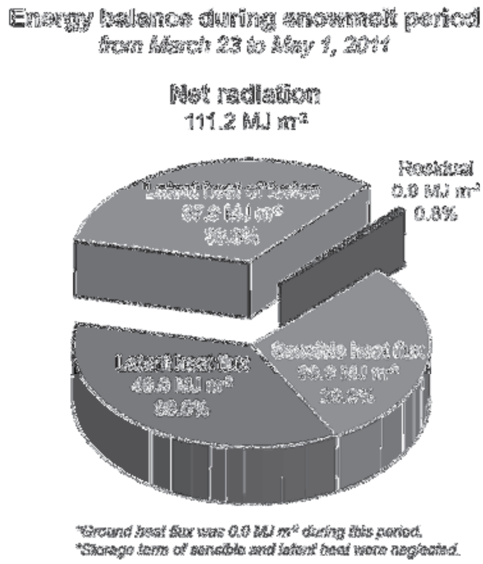

Figure 8. Energy balance components over a black spruce forest in PFRR during the snowmelt period, from March 23 to May 1, 2011. Latent heat of fusion to melt the snow cover is also included.

Spatial patterns of precipitation in Siberia: Where does the snow come from?

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Key words: Climate change, vapour source, precipitation, feedback

Introduction

At the conference "Global Warming and the Human-Nature Dimension in Siberia: Social Adaptation to the Changes of the Terrestrial Ecosystem, with an Emphasis on Water Environments" in Kyoto of 2012, four open research questions where recognised:

- How will land cover change affect precipitation, and will this have an impact on vegetation, will this change species composition? Will this have an effect on the timing of the first snow cover?
- Is there a trend, natural variability or an increase in the tail ends of the frequency distributions (i.e. more extremes)?
- How do extreme events (drought, heat, excess precipitation) change surface controls (e.g. temperature and soil moisture) affecting landscape scale atmospheric concentrations and surface-atmosphere GHG fluxes?
- Is present warming and precipitation change part of a positive feedback loop and changing vegetation and snow cover?

To answer these questions, it is important to understand the water cycle, both at the local as well as at the larger scale. Here we will focus on the precipitation and more specifically the location and timing of the water vapour source and how this water vapour contributes to snow and rainfall in the area near Yakutsk.

Based on a comparison by Yasunari et al. (2012) of NDVI and moisture divergence data it shows, that for the Siberian region NDVI corresponds well with moisture divergence, i.e. $P<E$, in the summer months June, July and August. This correspondence suggests role of the boreal forest in this region as a moisture source by evapotranspiration.

Using and Empirical Orthogonal Function (EOF) analysis on the years 1979 – 2007 Yasunari et al. (2012) concluded that the main moisture source for all the summer rainfall patterns can be attributed to the zonally-oriented boreal forest zone along 60 N. These results suggest that a change of the boreal forest ecosystem, either anthropogenically or naturally, may, at least partly, induce a change in precipitation pattern, by changing the moisture source pattern. Better understanding of potential changes in the precipitation patterns is of great importance to know the river discharge, as e.g. in the Lena River, the autumn discharge is provided by the summer net precipitation and the spring discharge is provided by the winter net precipitation. Knowing where the water vapour contributing to the precipitation comes from and how it is changing, will help us to better understand possible changes in vegetation composition, flooding events and greenhouse gas emissions.

The summer rains contribute most to the water balance. However, as the winter precipitation is accumulated as snow over a period of more than 6 months and melts in a relatively short period, the contribution to the runoff in spring time is very important. In addition to these hydrological events, also the timing of melt and onset of snow is important because of the insulation properties of a snow cover. Insolation by snow cover prevents rapid freezing at the beginning of winter, and at the end of the winter the snow cover keeps the soil frozen for a prolonged period. Therefore these phenomena play an important role in the development of the active layer and thus the stability of the permafrost. The insulation capacity of snow depend more on the presence of a snow over than on the depth of snow. This implies that it is important to know how temperature and precipitation will change in the spring and in the autumn (see Fig. 1).

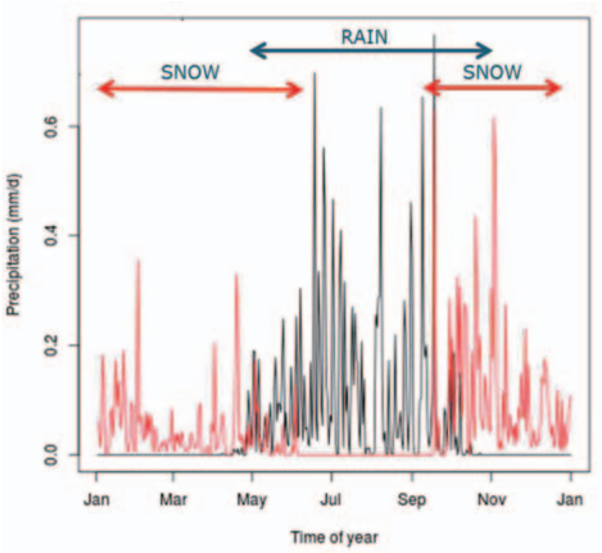

Fig 1.: Average precipitation falling as snow and as rain for 2002 over the area marked with the red square in Fig. 2.

Evaporation source analysis method

The relation between precipitation and its previous surface evaporation source are determined using an atmospheric moisture tracking model (Tuinenburg et al., 2012, Tuinenburg, 2013), which is forced with MERRA atmospheric reanalysis (). This model traces parcels of precipitation backward in time through the atmosphere. During each time step, the moisture balance of the parcel is made, using only surface evaporation (entering the parcel) and precipitation (leaving the parcel) as loss/gain terms. For each time step, a part of the precipitation the is tracked back is allocated to the evaporation into the parcel. Figs 2 and 3 show the monthly aggregation of these evaporation contributions to the precipitation in the area marked with the red rectangle. For more details see Tuinenburg, 2013.

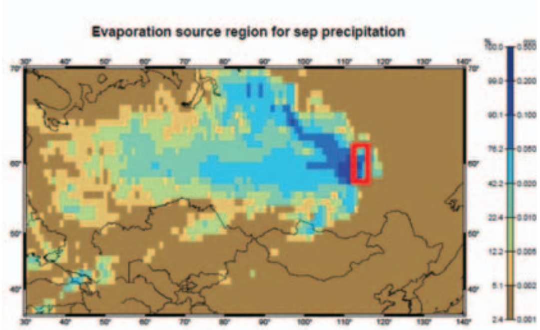

Fig 2.: Vapour source analysis showing the source and strength of the water vapour signal that contributes to the precipitation in the study area, marked by the rectangle.

Results

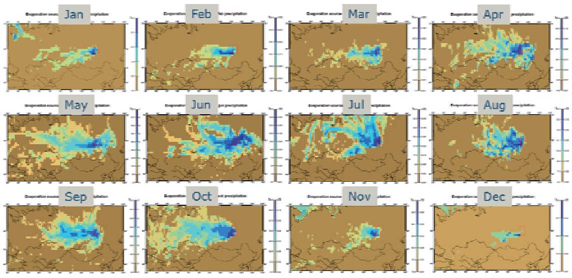

Fig. 3.: Vapour source contribution for each month in 2007.

Fig. 3. shows the strong westerly winds guiding the pathways of the water vapour, consequently the main source area for our study area is in the west. In summer (JJA) the contribution of locale evaporation to the precipitation is relatively large. The latter confirms the findings by Yasunari et al., (2012). Warming of the land surface and melting the snow end March and beginning April and subsequent increase in evaporation is clearly seen in the source area. The same can be seen for the start of the winter in end of October. In the winter, i.e. in the months November, January and December, the contribution of evaporation to the precipitation is larger by the Arctic sea area than from the land surface.

Differences between "wet" and "dry" years

The East-Siberia area has always been seen as a dry area, sometimes called a "cold dessert". However, the years 2007 to 2010 have been so wet, that there is more and more proof coming available that these extreme wet conditions are causing significant mortality of the larch trees (see e.g. Ohta et al., this conference). This raised the question if there are differences in the source area contributions of water vapour for "wet" and "dry" years. Comparing Fig. 3. depicting the vapour source areas in the "wet" year 2007 with a similar figure for the "dry" year 2002, revealed that in 2007 a larger part of the water vapour for the summer precipitation originated from northern region (i.e. Arctic Sea). In 2002 the "dry" year a larger part originated from local sources, i.e. the boreal forest in the region. In the September month of 2002, the "dry" year, a larger part of the water vapour originated from the North-West region.

Discussion

Our results show that the summer precipitation of the East Siberian region is for a large part depending on the water vapour released by the land surface in the region. In winter the contribution of the local land surface is much less and the water vapour originating from the Arctic Sea plays a more important role. Among others Cohen et al. (2013) showed that regressions between autumnal sea ice extent and Eurasian snow cover extent and Northern Hemisphere temperatures yield the characteristic "warm Arctic/cold continents" pattern. Although our vapour source analysis showed the importance of the Arctic Seas vapour sources in the winter, it is not clear how this influences the snowfall and snow melt taking place in spring and autumn in the East-Siberian region. Coupling our source area analysis with the temperature patterns will be a next step to further unravel the driving processes and possible feedbacks. Cohen et al. (2013) conclude that simulated widespread warming may be due to incorrect sea ice-atmosphere coupling, including an incorrect triggering of positive feedback between low sea ice and atmospheric convection (Cohen et al., 2013). This is another good example of the need to improve our understanding of the processes driving the conditions and therefore the existence and change of the sensitive East Siberian eco-system.

Feedback hypothesis

Next to the well-known snow-albedo positive feedback loop we hypothesis that based on the discussion above, there are two other feedback loops at different scales that may play an important role in the precipitation distribution in East-Siberia:

- At the regional scale there seems to be a positive feedback loop especially in summer: more evaporation, more rain. Land use change (i.e. change in species composition) reducing evaporation will therefor reduce precipitation.
- At the larger scale there may be a negative feedback loop: i.e. warmer summer (i.e. warmer Arctic Sea), larger snow cover, less warming of the air, but also less cooling of the soil.

As there are also a number of other feedback mechanisms at even larger scales (e.g. the thermo-heline circulation and the GHG feedback) it is difficult to know the integrated results of these feedback loops.

Conclusions

Our main conclusions are:

- The summer precipitation especially during dry years originates from evaporation of the boreal forest area;
- In winter the contribution of evaporation to the precipitation is larger by the Arctic sea than from the regional land surface;
- In the "wet" year 2007 a larger part of the water vapour for the summer precipitation originated from northern region (i.e. Arctic Sea) if compared to the "dry" year 2002.
- In the 2002 "dry" year a larger part of the water vapour originated from local sources, i.e. the boreal forest in the region.
- Extending the vapour source analysis with temperature patterns is needed to improve our understanding of the impact of precipitation on the freezing and thawing of the active layer above the permafrost.

Our study demonstrated that to further our understanding of the impacts of climate change on the carbon and water cycle of the eastern Siberian region, an improved understanding of the different regional and local processes and feedbacks is needed. But also larger scale feed-backs mechanisms may play an important role.

References

Cohen, J., J. Jones, J.C. Furtado, and E. Tziperman. 2013. Warm Arctic, cold continents: A common pattern related to Arctic sea ice melt, snow advance, and extreme winter weather. *Oceanography* **26**(4)

Rienecker, M.M., M.J. Suarez, R. Gelaro, R. Todling, J. Bacmeister, E. Liu, M.G. Bosilovich, S.D. Schubert, L. Takacs, G.-K. Kim, S. Bloom, J. Chen, D. Collins, A. Conaty, A. da Silva, et al., 2011. MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications. *J. Climate*, **24**, 3624-3648.

Tuinenburg, O. A., R. W. A. Hutjes, and P. Kabat, 2012. The fate of evaporated water from the Ganges basin, *J. Geophys. Res.,* ***117*****,** *D01107*

Tuinenburg, O.A., 2013. PhD Thesis, Wageningen UR, available at http://library.wur.nl/WebQuery/wda/2027147

Carbon budget of thermokarst depression on example of Ulakhan-Sukkhan alas

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Key words: carbon cycle, thermokarst depression, alas, Central Yakutia

Introduction

Permafrost region occupy about 25% of the terrestrial surface in the Northern Hemisphere, and more than 60% of it is in Russia (Kudrjavtsev *et al*. 1978; Brown and Grave 1981). Changes in permafrost have important implications for natural ecosystems. The permafrost degradation and human settlement due to thermokarst process may lead to a drastic distortion of terrain and to changes in hydrology and vegetation, and may lead ultimately to transformation of the existing landforms. The fluctuation of thermal conditions during the early Holocene led to thermokarst degradation of ice complex in Central Yakutia (Bosikov 1991). Bosikov estimated around 16,000 thermokarst depressions, also known as "Alas", located in Central Yakutia lowland within the boreal forest region with a total area of 440,000 ha, and it covers up to 17% of the total land area of Central Yakutia. Grasslands are widely distributed on these formations replacing boreal forests during the Alas development. The accumulation of organic deposits at the bottom of periodically appearing and disappearing thermokarst lakes and formation of peat on the lower parts of the depression thus lead to the accumulation of organic material in thermokarst depressions. Fast dynamics of thermokarst depression relief promote redeposition of grounds and occurrence of buried humus, peat, and sapropelic horizons in a soil structure (Gavriliev *et al*. 1983; Bakulina *et al*. 2000). As a result, stocks of C in Alas soils considerably exceed the content of C in boreal forest soils (Matsuura *et al*. 1994). Carbon stocks in Alas soils are 7-10 times larger than that in forest soils (Desyatkin and Desyatkin 2006). One of the most likely and important feedbacks from sustained warming in high-latitude ecosystems is the thawing of permafrost soils and the release of soil C to the atmosphere by microbial organic matter decomposition as carbon dioxide (CO_2) and methane (CH_4) (Oechel *et al*. 1993; Goulden *et al*. 1997; Melillo *et al*. 2002), or by leaching out as dissolved organic C (Freeman *et al*. 2004; Frey and Smith 2005). The soil organic matter is among the largest global reservoirs that exchanges C with the atmosphere at time scales ranging from a few years to several hundreds of years (Trumbore *et al*. 1996).

The main purpose of this work is to evaluate the influence of human activities on C balance in grasslands of thermokarst depression in Central Yakutia. C budget of these thermokarst depressions is completely not studied that is why this topic is very important under the present climate change.

Materials and methods

An Alas located on the east bank of the Lena River, around 50 km to the east from Yakutsk city, was selected for this study. The area of studied Alas (Ulakhan Sukkahan Alas, 62º08'49"N, 130º30'49"E, Fig. 1) is 64 ha, which consists of grassland and lake in its center. The grassland in the Alas was divided into three plots (dry, middle and wet grasslands) according to the difference in soil moisture and vegetation type.

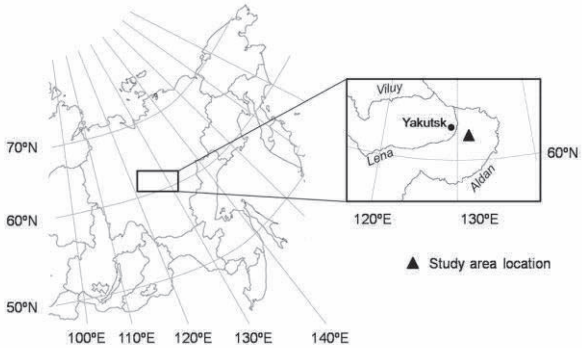

Figure 1. Location of study site.

The management of Alas grassland includes grazing and hay harvest. Cattle grazing take place only in early June and end of September, for around two weeks each time. The season for hay harvest is the end of July or early August during one week depending on highest above-ground biomass at the time.

Soil CO_2 flux (soil respiration) consists of root and microbial respirations. For microbial respiration measurements, bare soil plots were made in dry, middle and wet grasslands. For this, a soil column of 1 m^2 area and 40 cm depth was made and was protected by a nylon sheet to prevent root penetration inside the column. Roots were completely removed from the bare soil plots. Measurement and estimation of microbial respiration was conducted by the closed chamber method. All measurements were made in three replications.

The NPP was estimated using a harvest method. After grass harvesting, we divided the biomass into above and below-ground. The samples of above-ground biomass were taken at three replications of 50x50 cm^2 every month, four times during the growing season. The below-ground biomass was taken at 3 replications of 50x25 cm^2 with a depth of 40 cm three times during the growing season. The NPP is defined as the total new organic matter produced during a specified interval (Clark *et al*. 2001). The local farmers were interviewed for getting information on harvest of hay.

C budget as a Net ecosystem production (NEP) and net biome production (NBP) were calculated as follows:

NEP = NPP – microbial respiration;

NBP = NEP – yield.

The positive values of NEP and NBP indicated the net C loss from the ecosystem.

This instrumental measurement of C budget was carried out during the snow free period (86 days) in 2006-2008. And using extrapolation of these 3 years MR, NPP, NEP, NBP and climatic data, the estimation was done for the period of the missing 1999-2011.

Results and discussion

MR of 2006-2008 is perfectly correlating with the sum of active temperatures and this exponential correlation we used for approximate estimation of MR for all period (1999-2011) (Fig. 2). In years with high monthly and active temperature sum the MR increases significantly despite of precipitation amount, and can reach up to 6 Mg C ha. In years with low temperature and relatively high amount of precipitations MR decreases up to 1 Mg C ha only. All grasslands NPP except of Middle grassland have small but positive correlation (R^2=0.21 to 0.42) with the May and June monthly precipitations and temperature. Middle grassland has no positive correlations with the monthly air temperature but only have small positive correlation (R^2=0.16) with June precipitations. NPP amount is more stable and have a small differences between estimated years. But values is quite low than MR. The net ecosystem production (NEP) of all grasslands is mostly negative, that shows C loss from this Alas ecosystem (Fig. 2).

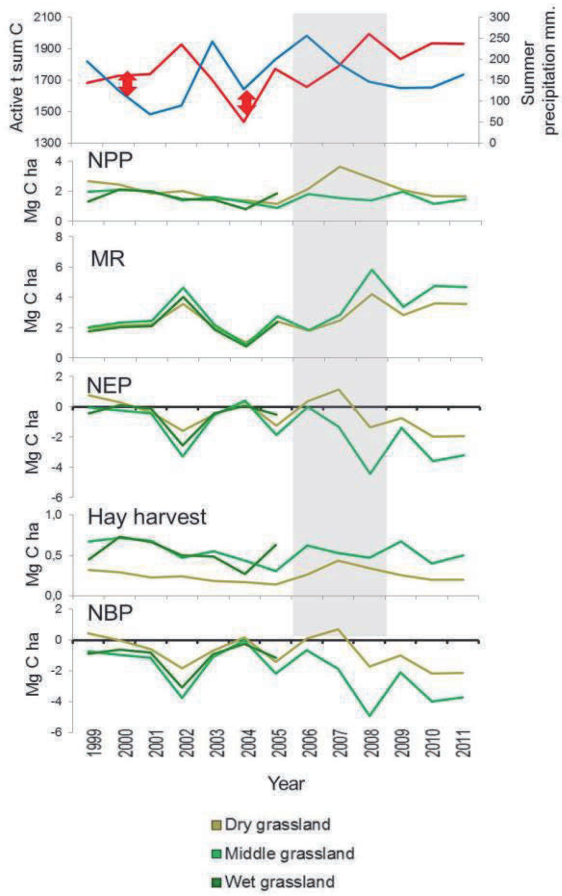

Figure 2. Climatic parameters, NPP, MR and NEP of measured and estimated years.

NEP has higher positive values in dry grassland and on the middle and wet grasslands it is near zero. We noted that there is some optimum conditions of climatic parameters (red arrow, Fig. 2) which makes Alases to C sequester or reduce the C loss to atmosphere. But the hay harvest in thermokarst depressions is strong factor in increasing of C loss (Fig. 2).

Thus, grasslands of Alas ecosystem are mainly source of C to atmosphere, even without human affect. Also utilization of thermokarst depressions as grazing and hay harvest place may reduce Alas soil C stock significantly.

References

Bakulina N.T., Spektor V.B., Novikov N.I., Kurchatova A.N. and Spektor V.V., 2000. The cut of ground deposits of Small Chabyda lake. *In:* The materials of international conference «Lakes of cold regions », Part 4. The Yakutsk State University, Yakutsk, Russia, 29-41. (in Russian).

Brown J. and Garve N.A., 1981. The disturbance of surface and its protection at development of the North. Nauka, Novosibirsk, Russia, pp. 88 (in Russian).

Bosikov N.P., 1991. Alas evolution in Central Yakutia. Permafrost Institute, Siberian Division, Russian Academy of Science, Yakutsk, Russia, pp. 128 (in Russian).

Clark D.A., Brown S., Kicklighter D.W., Chambers J.Q., Thomlinson J.R. and Ni J., 2001. Measuring net primary production in forests: concepts and field methods. Ecol. Appl., 11: 356-370.

Desyatkin R.V. and Desyatkin A.R., 2006. Thermokarst transformation of soil cover on cryolithozone flat territories. *In:* Hatano, R. and Guggenberger, G. (eds.) Symptom of Environmental Change in Siberian Permafrost Region. Hokkaido University Press, Sapporo, Japan, 213-223.

Freeman C., Fenner N., Ostle N.J., Kang H.,Dowrick D.J., Reynolds B., Lock M.A., Sleep D., Hughes S. and Hudson J., 2004. Export of dissolved organic carbon from peatlands under elevated carbon dioxide levels. Nature, 430: 195-198.

Frey K.E. and Smith L.C., 2005. Amplified carbon release from vast West Siberian peatlands by 2100. Geophys. Res. Lett., 32: L09401.

Gavriliev K.A., Dmitriev A.I., Ivanov K.P., 1983. Sapropele resources of Central Yakutia lakes. *In:* Question of rational use and protection of natural resources of cryolithozone lakes (on example of Central Yakutia). Publishing house of Yakutsk University, Yakutsk, Russia, 47-58.

Kudrjavtsev V.A., Kondratjeva K.A. and Romanovskii N.N., 1978. The zonal and regional laws of formation of cryolithozone in the USSR. *In:* Works of Ш International conference on permafrost studies. Edmonton, Albert, Canada. vol. 1, Ottawa, Canada, 419-426.

Matsuura Y., Ohta S., Sanada M. and Desyatkin R.V., 1994. Carbon and nitrogen storage in soil developed on two different toposequences of the Lena River terrain. *In:* Inoue, G. (ed.) Proceedings of the Second Symposium on the Joint Siberian Permafrost Studies between Japan and Russia in 1993, 13-14 January 1994, Tsukuba, Japan, 177-182.

Melillo J.M., Steudler P.A., Aber J.D., Newkirk K., Lux H., Bowles F.P., Catricala C., Magill A., Ahrens T. and Morrisseau S., 2002. Soil warming and carbon-cycle feedbacks to the climate system. Science, 298: 2173-2176.

Oechel W., Hastings S., Vourlitis G., Jenkins M., Riechers G. and Grulke N., 1993. Recent change of arctic tundra ecosystem from a carbon sink to a source. Nature, 361: 520-523.

Trumbore S., Chadwick O. and Amundson R., 1996. Rapid exchange between soil carbon and atmospheric CO_2 driven by temperature changes. Science, 272: 393-396.

The ecological factors impact on methane fluxes in the ecosystem of meso-oligotrophic peatland

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Key words: methane fluxes, meso-oligotrophic peatland, eddy covariance

Introduction

Methane has about 30 % from carbon dioxide contribution to greenhouse effect (Bazhin, 2000). 70−80 % of atmospheric methane is of biological origin. The humidified soils, including marsh landscapes are characterized by high methane generation potential (Zadorozhny et al., 2010). The average size of global emission of methane from a surface of marsh ecosystems can make 143 Mt in a year (Mohov et al., 2007). The vertical flux of methane in atmosphere represents result of two processes: production of this gas by archaea microorganisms and its oxidation by methanotrophic bacteria. In the conditions of climate change strengthening of methane emission in the north as a result of thawing of permafrost and flooding of soils is expected (Denisov et al., 2010). However there are not enough scientific data to estimate quantitatively the contribution of different types of bogs to this process. The aim of the work was to study a vertical flux of methane on meso-oligotrophic peatland in a taiga zone.

Materials and methods

The study was conducted from 1st April till 11th September 2013 in meso-oligotrophic peatland Medla-Pev-Nur located in 40 km on the northwest from Syktyvkar (Komi Republic, Russia, 61° 56' N, 56° 13' E, fig. 1).

The peatland was covered by three dominate plant communities: 1) oligotrophic Pinus-Andromeda-Eriophorum-Sphagnum communities; 2) mesotrophic Andromeda-Carex-Sphagnum communities; 3) mezo-eutrophic Carex-Scheuchzeria-Sphagnum flowing bog.

The maintenance of the dissolved organic carbon in peatland waters fluctuated from 18.9 to 54.5 mg l^{-1} depending on water level table, pH in waters varied from 3.3 to 5.7 depending on vegetation and microlandscape.

Researches of vertical fluxes of methane were executed by eddy covariance system. The measuring system included ultrasonic anemometer (CSAT3, Campbell Scientific Inc, USA) and an open-path infra-red gas analyzer (Li-7700, Li-Cor Inc., USA). Data recording occurred to frequency 20 Hz. Processing of the received results made in program EddyPro (Li-Cor Inc., USA).

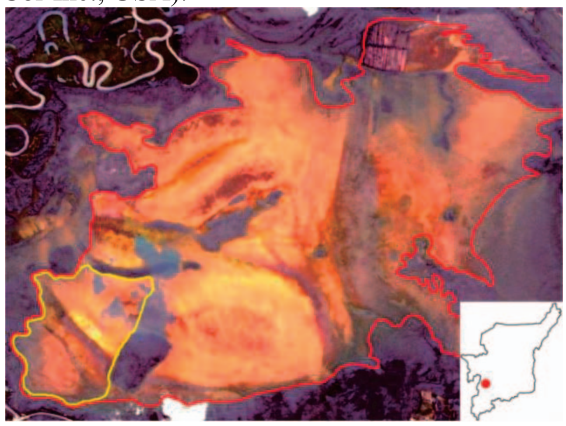

Fig. 1. Scheme of meso-oligotrophic peatland Medla-Pev-Nur. The light line notes border of an investigated site

The program analysis included mathematical and statistical processing of the primary data. For correct calculation specified the information on height of an arrangement of devices over a surface of a bog and distance between the central part of anemometer working space and working space of a gas analyzer. At the analysis such indicators, as speed and a wind direction in three projections, the temperature of air measured by anemometer, average value of concentration CH_4 during measurements, atmospheric pressure were considered. Data processing included also the analysis and leveling of a time difference between measurements of speed of a wind and concentration CH_4 for each 30-minute time period.

Statistical processing of the primary data was spent according to a technique (Vickers, Mahrt, 1997). It included a finding of physically significant limits of variability of data, revealing and removal of the data caused by casual electronic hindrances, arising owing to water congestion on converters ultrasonic anemometer. From the general file also deleted the data with the weak dispersion arising owing to low turbulence of atmosphere or technical problems.

As a result received average methane flux for the 30-minute periods, and also the information, allowing to estimate turbulence conditions in boundary with a surface of a bog an atmosphere layer (u*), stability of atmospheric conditions at the moment of measurement (z/L) and time for which the portion of air in working space of a gas analyzer (τ) is replaced. For definition of the footprint area used the model described in the literature (Kljun et al., 2004).

Statistical processing of values of methane emission was done in program STATISTICA 10 (the license of Institute biology of Komi SC UB RAS).

Results and discussion

In a year of carrying out of measurements active thawing of a snow cover observed in 14-21th April (fig. 2) and it followed by rising of soil temperature on depth of 0-5 cm above zero (fig. 3).

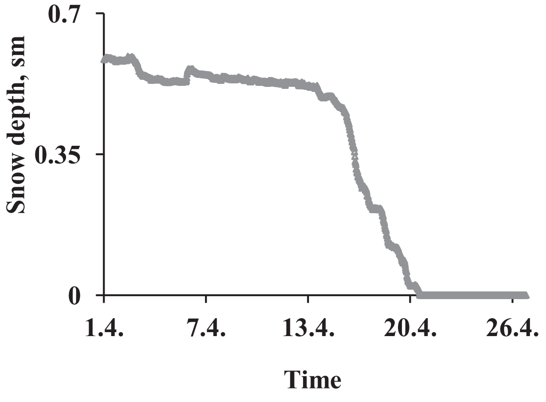

Fig. 2. Change of a thickness of a snow cover on a peatland in the spring of 2013.

The vegetative period has begun in the middle of May when the soil temperature has exceeded +5 °C. In the conditions of an average taiga in Komi Republic the vegetation period proceeds about 158 days (Lesa…, 1999).

During the vegetation season methane emission varied largely. So, in April methane flux was 22.1 μg $m^{-2}d^{-1}$ (table). Short-term splash of methane emission to 72.7 μg $m^{-2}d^{-1}$ observed on 21st April, that can be result of thawing of lenses of ice in a peat deposit and emissions of the gases saved up for a winter in atmosphere (fig. 4).

Emission of CH_4 increased during vegetation period, maximum value was observed in July (fig. 4, table). The next months it gradually decreased.

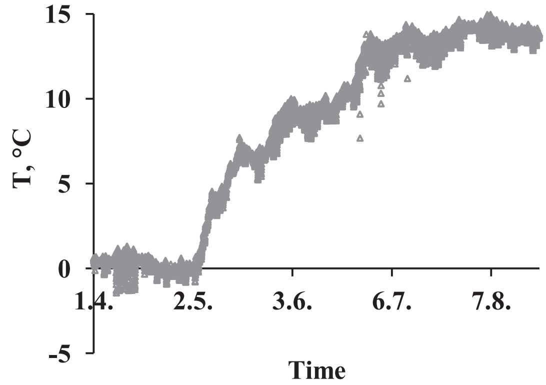

Fig. 3. Dynamics of temperature of soil on depth of 0-5 cm in April – August 2013.

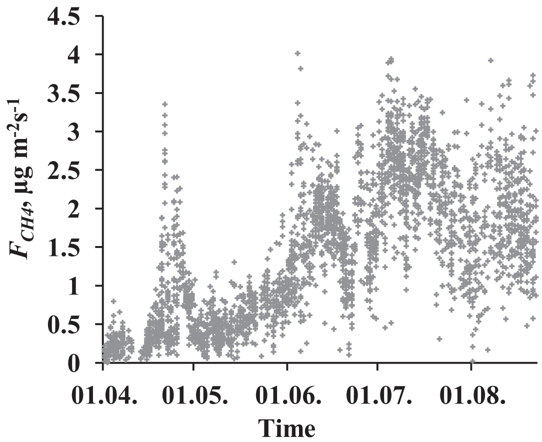

Fig. 4. Seasonal dynamics of methane fluxes from a surface of meso-oligotrophic peatland in atmosphere in 2013.

In seasonal dynamics vertical flux of methane has been related with change of water level table (fig. 5). The regression model for median flux data analysis has shown high dependence of methane emission on water level (r=0.76, p=0.049, n=7).

Table Methane emission in meso-oligotrophic peatland

Month	Average methane flux (μg $m^{-2}d^{-1}$)
April	22.1±18.85
May	24.6±12.94
June	66.7±14.09
July	86.3±20.60
August	56.9±14.55
September	22.0±6.03

Methane emission also correlated with soil temperature on depth of 0-5 centimeters ($r=0.69$, $p=0.000$, $n=2831$) during the vegetation period. This dependence is described by exponential function (fig. 6).

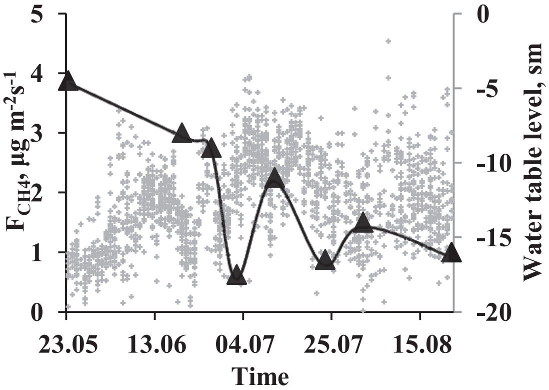

Fig.5. Seasonal dynamics of methane emission (gray pluses) and level of ground water (black triangles) in 2013.

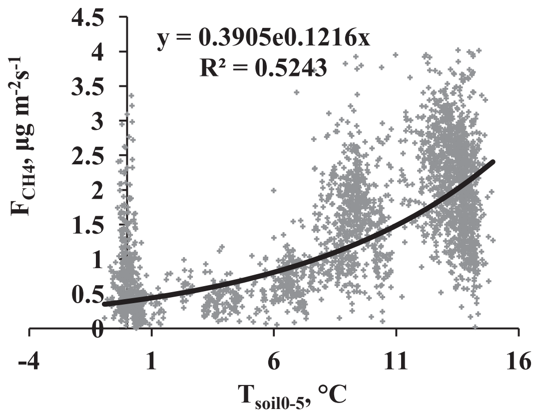

Fig.6. Dependence of methane emission (F_{CH4}) from soil temperature on depth of 0-5 cm ($T_{soil0-5}$) in 2013.

Proceeding from the received data, it is possible to make following conclusions:

1) methane emission from peatland to atmosphere increased from April (22.1±18.85 µg $m^{-2}d^{-1}$) to July (86.3±20.60 µg $m^{-2}d^{-1}$) and then decreased to 22.0±6.03 µg $m^{-2}d^{-1}$ in September;

2) high correlation of methane emission with soil temperature at the depth of 0-5 cm and water table level was observed in the seasonal dynamics.

References

Bazhin N.M. Metan v atmosphere // Sorosovskiy obrazovatelniy jurnal. 2000. Vip. 6(3). S.52-57.

Denisov S.N., Eliseev A.V., Mokchov I.I. Otsenka izmeneniy emisii metana bolotnymi ecosistemami Severnoy Evrazii s ispolzovaniem rezultatov raschetov s regionalnoy modeljy klimata // Meteorologija I gidrologija. 2010. № 2. C. 55-62.

Zadorozhniy A.N., Semenov M.V., Kchotzhaev A.K., Semenov V.M. Pochvennye processi produksii, potreblenia i emissii parnicovikch gazov // Agrochimija. 2010. №10. S. 75-92.

Mokchov I.I., Eliseev A.V., Denisov S. N. Modelnaja diagnostika emissii metana bolotnymi ekosistemami vo vtoroy polovine XX veka s ispolsovaniem dannikch reanaliza // Doklady akademii nauk. 2007. Vol. 417. № 2. S. 258-262.

Lesa Respubliki Komi / Pod redakciey G.M. Kozubova i A.I. Taskaeva. - M., 1999. - 332 s.

Kljun N., Calanca P., Rotach M.W., Schmid H.P. A simple parameterization for flux footprint prediction // Boundary layer meteorology. 2004. №112. P. 503-523.

Vickers D., Mahrt L. Quality control and flux sampling problems for tower and aircraft data // Journal of atmospheric and oceanic technology. 1997. Vol. 14. P. 512-526.

Catastrophic floodings on the Alazeya River valley (North-East Yakutia) as a consequence of the air temperatures increasing

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Key words: Alazeya, Larix cajanderi, postfluvial dynamics

Catastrophic floods that wreaked havoc in natural complexes and agricultural sector took place since 2006 up to 2008 on the territory of The Alazeya River valley.

The Alazeya River basin is situated on the territory of Kolyma-Alazeyskaya lowland presented as lake-grass plain with conformed surface covered with quaternary deposits. The climate of the region is extremely continental with low winter (monthly mean January temperature is about -30 °C, bare temperature minimum is about – 60 °C) and high summer (monthly mean July temperature is about +10 °C, absolute temperature maximum is about +32 °C) temperatures, with minor cloudiness, and insignificant annual average precipitation (about 150 mm). The Pacific Ocean weak softening action is more shown on thermic regime than on precipitation level (Agricultural…, 1989). The Alazeya River nourishment is carried out due to streams issuing from glaciers, surface waters, permafrost thawing, and lake runoffs. Spring floods commence in May-June period, and floods caused by lake melt water and permafrost thawing commence in June-July period.

Due to geobotanical subdivision the observable region is included as a compound of: Alazeysko-Nizhnekolymskii subarctic tundra district of Yano-Kolymskii subarctic subprovince, Kolymskii district of north-eastern subtundra subprovince, and Abyisko-Kolymskii district of north-eastern northtaiga subprovince (Andreev etc., 1987). The river middle-course (from Svatay up to Andrushkino) is located in Abyisko-Kolymskii district of north-eastern northtaiga subprovince. Northtaiga open larch forests of *Larix cajanderi* Mayr, alternate with shrubby osiers of *Salix pulchra* A.K. Skvortsov, different mesophytic and wet meadows, sphagnum bogs, and dwarf birches *Betula exilis* Sukacz. prevail on this territory. The valley vegetation cover is differentiated mostly by meso- and microclimatic conditions, regime of river, and bottom, soil, and permafrost spatial variations.

We conducted floristic-geobotanical researches of middle and lower Alazeya River reaches valley to estimate postfluvial changes in forest and shrubby vegetation cover. Field works were held with the help of en-route observation of typical viewpoints – geobotanical divisions that were selected by the imagery spectral analyses results and model en-route plant communities by longitudinal and transverse transects. The floral-geobotanical descriptions were made as on methodological instructive regulations (Sukachev, Zonn, 1961; Aleksandrova, 1964; Neshataev, 1987; Ipatov, 1998). The Latin names cited by S.K.Cherepanov (1995).

The main reasons of catastrophic floods on the Alazeya River valley are spontaneous natural lake water discharges into the valley caused by lake areas overflow, and general permafrost thawing caused by average annual air temperatures increasing (Report…, 2009).

Floristic-geobotanical researches showed that on the Middle and Lower Alazeya River longstanding floods caused destruction or considerable changes of various meadows, shrub and forest communities of the first terrace above flood-plain from several meters to several kilometers strip. The geographical information system maps of Alazeya River valley vegetation were created in association with E.I. Troeva (IBPC SB RAS) (Report…, 2009). 2007 satellite imagery spectral analysis showed that on the first terrace above flood-plain of the Middle Alazeya River from the Kumah lot up to Argahtah village the most catastrophic floods happened. The most suffered areas were wet meadows of *Arctophila fulva* (Trin.) Anderss., *Calamagrostis langsdorffii* (Link) Trin., of *Carex* species (*Carex vesicaria* L., *C. vesicata* Mench., *C. rhynchophysa* C. A. Mey., *C. aquatilis* Wahlenb.), that are very important as all-year pastures for horses and cattle. Communities of *Salix pulchra* were also flooded. Next position is for larch forests and light forests of moss group that is predominant formation of the valley and divide spaces of Alazeya basin. The mid-wet meadows flood part of the whole is insignificant but about one third of this kind of meadows, being the main mowing grounds and pastures for cattle, are in the flood zone. Flood-plain cenoses of *Salix udensis* Trautv. et C.A. Mey. suffered the least losses. Dwarf birches and light forests, open forests of sphagnous group that are evolved on the second above flood-plain have been short-termly flooded in lakeside depressions and on hollows, linked with the first above flood-plain terrace.

As it follows from the outdoor route explorations of 2008-2009 on the Kumah-Argahtah section on the Sloboda inflow and on the Andrushkino village surroundings the largest part of completely perished larch forests (*Larix cajanderi -Calamagrostis langsdorffii* – green mosses) and open forests of the first above flood-plain terrace (up to 90% of total flooded forests). Considerable scale of meadow loss that grew on the depressed areas of the first above flood-plain terrace. In 2007-2008 during almost whole vegetation season lots of meadows of *Calamagrostis langsdorffii* and *Arctophila fulva* were under considerable water column (about some meters) and were covered with intense silt-loamy alluvium layer (up to 20-40 cm). All this caused oxygen hunger and long-term cereal and ling underground bodies decay, photosynthesis limitation, growth and development delay, that caused meadows mass mortality (up to 50-90 %).

In plant communities altogether one can mark lowering of stability, biological production, sharp worsening of plants vitality both edificators and assectators. In larch and osier forests mass mortality of main surface cover edificators is a common presentation sign (up to 90-100%) – *Vaccinium uliginosum* L., *Ledum palustre* L., *Empetrum nigrum* L., *Vaccinium vitis-idaea* L., mosses and lichen.

Postfluvial changes of mostly damaged osiers and larch forests of ecocenomorphic structure show in appearance, increase of hygrophilous, mesohygrophilous coastal-watery, pratal and marsh species (fig. 1). In both formations *Rorippa palustris* (L.) Bess., *Tephroseris palustris* (L.) Reichenb. Were registered, that is explerent primary and secondary successioned hygrophilic species, ordinary to river, lake shore, grass bog, and mosses. Demonstrative examples of foreign species invasion in victim forests are *Stellaria crassifolia* Ehrh., *Ranunculus gmelinii* DC., *Epilobium palustre* L., *Hippuris vulgaris* L., *Comarum palustre* L. etc. It is also necessary to mark the leafy and hepatic pioneer hygrophilous mosses number appearance and/or increase. In the osier-beds *Marchantia polymorpha* L., *Funaria hygrometrica* Hedw. were more active (fig. 1A), in the larch forests - *Leptobryum pyriforme* (Hedw.) Wilson.

The analysis of communities changing further to the long floods impact and communities stability after the manner of A.A. Titlyanova (2009) that comes from the point of view that specific structure variability with the influence of one of another factors denotes ecosystem general resistance. Researches have shown, that after a cycle of flooding the greatest variability observed in low floodplain meadows of *Arctophila fulva* and the first above floodplain terrace osier-beds of *Salix pulchra*. The greatest average amount of the alien and lost species are registered in these communities, i.e., these meadows have the least resistibility to flooding.

We have also investigated vegetative communities stability to floodings. Herewith ecosystem stability was analyzed as a measure of species composition resistibility in return to external stress factor (Titlyanova, 2009). Researches showed that above flood-plain bushy osier-beds are least stable against long floodings, that is explained by alluviophobic features of the dominant - *Salix pulchra*, that is unable to maintain long watering and alluvium. Besides lower aboveground layers of these communities are also less tolerant to being long under the water and to soil aeration lowering. Such common sylva species of grass-fruticulose cover as *Ledum palustre, Vaccinium uliginosum, V. vitis-idaea*, also such mosses as *Aulacomnium turgidum* (Wahlenb.) Schwägr., *A. palustris* (Hedw.) Schwägr., and species of *Polytrichastrum* genus have suffered most of all.

The highest stability to floodings showed low flood-plain osier-beds, main edificatory of which - alluviophilous *S. udensis* is biologically adapted for long floodings and alluvial accumulation. All species of these communities subordinated layers – hygrophilous nature with long creeping (quite often with respiratory functions by the rhizomes) tillering zones moving upwards as the alluvium accumulation process. It is natural and expected that these communities have sustained catastrophic floods in whole.

Larch forests are also show sufficiently high stability in spite of the fact that dead stand of trees are not so rare and in many cases lower layer species loss is observed. It should be noted that the floristic structure in whole appeared to be rather steady because of rather high range of larch forests – 20 species average, that in 2-3 times higher than in other formations. Considerable role here played the fact that almost all lower layer species in these radical forests are creeper with ligneous offshoots and with vegetative renewal ability. Strongly marked roughness of nano- and microrelief promoted the plants survival. That enabled to preserve lots of species on the heights particularly around trunks. Moreover it is necessary to note that these forests complete horizontal structure (shown in close vicinity species groups that are distinguished in ecological, and biological way) promoted plants survival. That striking examples are *Carex + Eriophorum* group with sphagnum cover, meeting among typically forest environment with arctoboreal silvan dwarf shrub and medium shrubs. In these groups with mesohygrophilous species all plants survived. It is also necessary to note that larch forests growing basically at higher levels of the first above flood-plain terrace and on transition to the second terrace were flooded for less prolonged time than osier-beds of *S. pulchra*. Besides these woods soil surface frost split intensify drainage in a varying degree that promotes earlier descent of water than in osier-beds with the smooth microrelief of thixotropic soil.

We compiled short- and long-term prognoses of vegetation development after flooding period. The demutation-regenerative process of larch forests and light forests outside of frost-thaw processes development territory will be slowed down because of live seed trees absence on vast areas, significant seed production decrease in whole and larch germinative quality because of shrub forest floor spread pessimal conditions. Larch stand recovery is not expecting on the territories where on the vast area there is no a single seed tree. Sizeable wood areas would transform to long functioning shrubby thickets. In cases when seed trees are partially kept, both frost-thaw sink and contraction processes will not develop, through some intermediate stages larch, and light forests can be restored in a big time interval. As permafrost degrades and massive wedge ice thaws sink and contraction processes will take place under the lifeless forests that, in turn, will cause a number of specific changes down to ponds and bogs formation. With this course of events wood areas would disappear. Stands of perished trees that perished standing will determine numerous fires that can cause irreversible changes of permafrost landscapes and considerably increase of above permafrost layer flow that in whole will raise water balance of all river system. For that matter the organization of a complex monitoring station is necessary. This station will estimate the influence degree of natural and anthropogenous factors on catastrophic floodings development on the rivers of the Vostochno-Sibirskoe Sea basin (Report …, 2009).

The author it is sincerely grateful for the organization of expeditionary works to S.P. Gotovtsev, P.S. Zabolotnik, L.I. Kopyrina, to guides M.K. Sozonov, A.A. Sozonov, K.M. Sozonov, V.V. Sleptsov, E. E.Tirilgin, D.V. Fedorov; to A.Z. Ivanova for consultations on soils, E.I. Ivanova for definition of mosses, L.N. Poryadina for definition of lichens, V.I. Zakharova – for identification of species of the supreme vascular plants, E.I.Troeva – for GIS-maps, to A.P. Isaev – for edition of the article.

References

Agricultural Atlas of Yakut ASSR. Moscow, 1989, 115 p. *(In Russian)*

Aleksandrova V. D., 1964. *The vegetation cover dynamics. Field geobotanics.* Lavrenko E.M., Korchsgin A.A. Science, Moskow-Leningrad, **3.** 300-447. *(In Russian)*

Andreev V.N., Galaktionova T.F., Perfil'eva V.I., Sherbakov I.P., 1987. *Main features of Yakut ASSR vegetation cover.* NP SB AS USSR, Yakutsk, 156p. *(In Russian)*

Ipatov V.S., 1998. *The phytocenosis descritpion. Methodological recommendations.* Sankt-Petersburg, 93p. *(In Russian)*

Neshataev U. N., 1987. *Methods of geobotanical materials analysis.* Leningrad, 192p. *(In Russian)*

Report on research work «Development of the scientifically-grounded recommendations on protection of settlements in Alazeya River basin from negative influence of freshet waters», 2009. Archive of IBPC SD RAS, Yakutsk, 50 p. *(In Russian)*

Sukachev V.N., Zonn S.V., 1961*Forest types study manuals.* USSR Academy of Sciences Press. Moscow, 144p. *(In Russian)*

Interannual variations of soil CO_2-efflux in larch forests of Central and South-Eastern Yakutia

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Key words: carbon cycle, soil carbon dioxide emission, permafrost, boreal forest

Introduction

Forecasted air temperature rise in north-eastern Russia may reach 3-5°C by 2050; a valuable increasing of summer precipitation amount is expected together with other environmental and social changes as well.

Soil respiration (carbon dioxide emission from soils) is one of the most intense carbon flux components in the global carbon cycle, almost equal to net primary production. Even very small variations of soil respiration due to climate changes will cause considerable changes in annual carbon emission into the atmosphere. High sensitivity of soil respiration to variations in soil temperature and moisture is also a problem.

Thus, to understand more clearly the carbon balance characteristics of permafrost larch forest ecosystems, we investigated the response of permafrost soil CO_2-efflux processes in the dominant larch forests to changing climatic conditions, by comparing two sites with different forest, ambient and edaphic environment in Yakutia, North-Eastern Russia.

The main tasks were to find the differences between the sites, to study inter-annual variability at the sites, to detect the dependency on environmental factors and to estimate the accumulated fluxes of carbon from permafrost soils at the sites. This article briefly describes the main results of the studies made in 2010-2012.

Observation sites and methods

Spasskaya Pad site (**SPA**) is located on the left valley side in the middle reaches of the Lena River in Central Yakutia, Russia (62°15'N, 129°14'E; 250 m a.s.l.). A 180-year-old cowberry Larch forest (Laricetum vacciniosum) stands on permafrost pale-solodic soil based on light old-alluvial sandy loam. Full-automated soil respiration system (ASRS, Alterra, Netherlands) including CIRAS-SC CO_2 IRGA (PP Systems, UK) was used to measure CO_2 samples taken every 1 hour by 4 auto-operated soil chambers with complementary soil temperature and moisture measurements at 10 cm depth; April to October.

Elgeeii site (**ELG**) is located on the 3rd terrace of left bank of the Aldan River in South-Eastern Yakutia, Russia (60°00'N, 133°49'E; 220 m a.s.l.) in a 150-year-old cowberry Larch forest (Laricetum vacciniosum) on permafrost dark-humus pale lightly solodic soils based on carbonated loam base ground. An automatic soil respiration system ACE-001/L based on ADC CO_2 IRGA (ADC Bioscientific Ltd.) with soil temperature, moisture and PAR sensors was used to measure CO_2 samples taken every 2 hours by auto-operated soil chamber; April to October.

The main understory plant species at both sites were almost same: *Vaccinium vitis-ideae*, *Betula sp.*, *Salix sp.*, herbs.

Tree stand and soil properties at the sites are given in Table 1, and environmental factors are provided in Table 2.

Table 1. Parameters of Larch forest tree stands and soils in Spasskaya Pad and Elgeeii sites, 2010.

Parameter		SPA	ELG
Average tree height, m		20.0	25.0
Stand density, trees ha^{-1}		1870	2600
Basal area, m^{-2} ha^{-1}		24.1	35.3
DBH, cm		18.8	21.4
Plant Area Index		1.4	2.1
Floor Leaf Area Index		1.5	0.8
Soil porosity, %		40.9	48.8
Small roots density at 0-20 cm depth, kg/m^3	2 mm >	4.0	10.0
	2-5 mm	0.6	1.6

Table 2. Environmental factors in Spasskaya Pad and Elgeeii sites, summer (Jun-Aug) mean values.

Parameter (2010-2012)	SPA	ELG
Air temperature, T_a, °C,	17.5	16.9
Soil temperature, T_s, °C	9.2	9.4
Soil moisture, η, %	22.0	41.9
Precipitations, PP, mm	85.9	102.5

Results and discussion

Our comparative study of soil properties and hydrothermal regime of soils at Spasskaya Pad and Elgeeii stations have shown that the mean seasonal moisture values of both the upper and lower above-permafrost soil horizons in the active layer of soil in ELG exceeds that of SPA by 2.1 times on average (Fig. 1, A). This fact can be explained not only by relatively higher precipitation level in ELG, but also by more developed soil porosity in ELG compared with SPA (around 49 and 41, respectively), as well as by elevated water retention capacity of clay soils in ELG versus sandy soils in SPA, and also by a considerable supply of soil water in ELG, accumulated in the soil column during autumn rains of the previous year. The average seasonal soil temperature during the vegetation season in ELG is slightly higher than at SPA (Fig. 1, B). However, due to the presence of thick organic and humus upper layers in ELG soils, the temperature of the upper 5-cm soil layer is significantly (by 5-7 °C) warmer than in SPA, where the thickness of litter and humus layers does not exceed 5-10 cm. Thus, hydrothermal soil conditions of the sites are significantly different due to distinct soil types and structure.

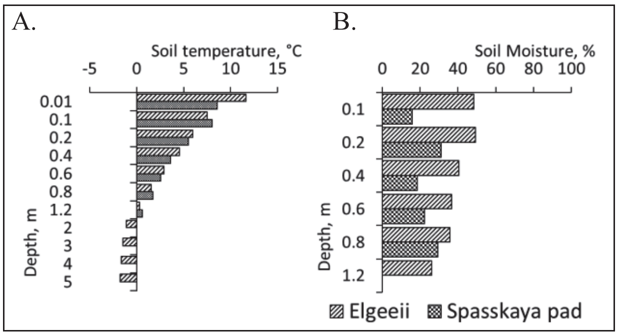

Fig. 1. Distribution of temperature (A) and moisture content (B) along soil profile at Spasskaya Pad and Elgeeii sites, seasonal (May-Sep) means, 2010-2012.

Diurnal variations of soil respiration at both sites have a bell-shaped form and depend mostly on soil temperature, and highly correlate with temperatures at 10-40 cm depth, which means that most soil biological activity is originated from those depths that could be proved by root density and microbial activity studies ("Spasskaya Pad…", 2006; Ivanova et al., 2006). During soil drought with contemporary high soil temperatures at mid-summer period, even very small precipitation (2-3 mm day^{-1}) causes much higher soil respiration rate increase (by 24-30%) in comparison with much stronger storm-rains (15-20 mm day^{-1}) during wet periods (by 10-15%). At the same time, considerable amounts of precipitation during the cold period of late summer and early autumn do not affect much the soil respiration course, because low soil temperatures inhibit respiratory metabolism of roots and soil organisms despite sufficient soil moisture condition.

Seasonal course of soil CO_2-efflux has a dome-like form at both sites (Fig. 2). Minor observable soil CO_2 release starts immediately after snow cover melt, around the end of April-early May. Marked soil carbon dioxide emission begins at almost same time at both sites, in the second decade of May, but in ELG it starts a few days earlier (DOY 125-135).

Maximum soil CO_2 emission in SPA was usually observed in late July - early August (DOY 199-232), reaching an average of 6.8 μmol CO_2 m^{-2} s^{-1}. In ELG site the highest CO_2 emission (interannual mean: 12.5 μmol CO_2 m^{-2} s^{-1}) was recorded at the end of second decade of July (DOY 188 ± 3), which is 2-3 weeks earlier than at SPA site. This fact indicates the early occurrence of optimal conditions for the soil biota in the south-eastern site, and can be explained by the physical properties of soils in South-Eastern Yakutia (e.g. fast soil warming and higher soil porosity, 48.8% versus 40.9% in Central Yakutia).

Soil CO_2-efflux at SPA usually stopped in the middle of October (DOY 285-290). At ELG we measured soil respiration only until early October, but based on soil temperature trends we can consider the activity ending date to be similar – around the end of October.

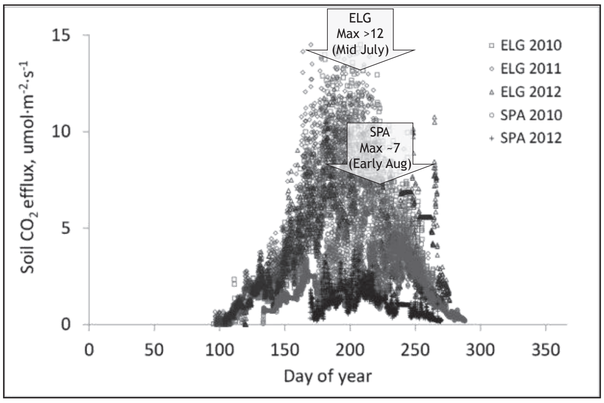

Fig.2. Seasonal curves of soil CO_2-efflux at Spasskaya Pad (SPA) and Elgeeii (ELG) sites, half-hourly average values, 2010-2012.

Environmental dependencies of soil respiration were discovered using a simple regression analysis. The soil CO_2-efflux values during the season (F_s) have strong positive correlation with the trend of soil temperature (T_s) at both sites (r^2=0.74 for SPA and r^2=0.79 for ELG).

Temperature response of F_s (many-years average Q10 values) at SPA equals 4.89 and is almost identical to that one at ELG (4.85), but base respiration (T_0) is by one third higher at ELG (1.53 vs 0.99 at SPA). It probably means that bigger CO_2 flux at Elgeeii site is explained not only by relatively higher T_s, but also by some endogenous reasons, for example, more massive microbial and fungi community. Analysis of other environmental factor dependencies showed that there are no essential soil CO_2-efflux correlations with net radiation, PAR, soil heat flux etc. A soil physics study indicates that the soils at ELG are also heavier with higher porosity and water retention capacity (see Table 1) comparing to SPA. So, soil moisture content at ELG is relatively stable during the whole season as well. Due to these facts the soil condition at ELG is much more comfortable for soil biota and therefore the higher annual soil carbon release (cumulative CO_2-flux) was observed at ELG site.

We also found that in SPA the cumulative soil carbon efflux in early summer was highly dependent on previous year autumn precipitation levels (Fig.3). If, for example, there was a big precipitation registered in autumn of 2009, then in the early season of 2010 the soil CO_2-efflux will be also high. But in late summer the CO_2-efflux mainly correlates with current precipitation levels. There are no enough data for ELG available yet but it seems that the same dependencies also exist there.

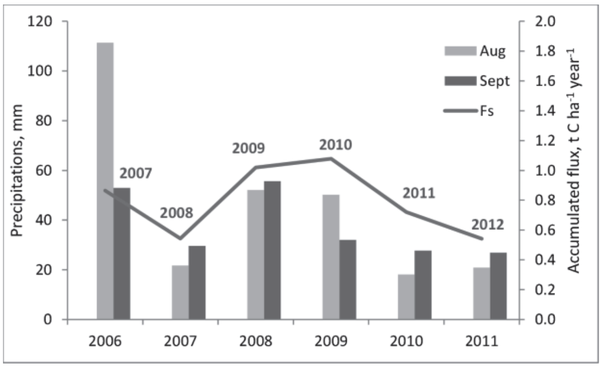

Fig. 3. Dependency of cumulative soil flux during June of current year on previous year autumn precipitation levels, Spasskaya Pad, 2006-2012.

Seasonal accumulated CO_2 fluxes (F_a) were calculated for both sites. It is clearly shown that the cumulative soil carbon emission during the season at ELG is 2.2 times higher than at SPA (Fig. 4). The average seasonal sum of soil carbon release at ELG for 2010-2012 reached 7.99 t C ha^{-1} per season compared to 3.54 t C ha^{-1} of a many-years average of F_a at SPA. F_a at ELG starts to exceed that of SPA already in June and keeps high level until the end of August, while CO_2-flux at SPA decreases after mid-August. Maximum F_a at both SPA and ELG was observed in July, being about 35% of the total seasonal sum. Early summer soil carbon efflux is usually smaller than that in late summer.

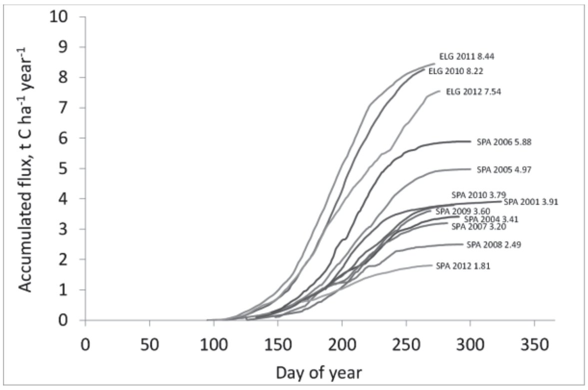

Fig. 4. Accumulated soil carbon efflux, Spasskaya Pad (2001-2012) and Elgeeii (2010-2012).

Conclusion

The main environmental factor, affecting soil CO_2 flux, is soil temperature at both sites. Precipitation (and, accordingly, soil moisture) plays an important role not only in the daily CO_2-efflux course but in the seasonal scale as well. Early summer soil CO_2 efflux shows high correlation with the previous year's autumn precipitations. Soil respiration in the second half of summer is mainly correlated with the current year's late summer rains.

Accumulated soil carbon efflux at the south-eastern site (ELG) was more than twice higher than in Central Yakutia (SPA), being on average 7.99 t C ha^{-1} and 3.54 t C ha^{-1}, respectively. The main reasons of this difference were probably the following: soils at ELG are heavier, with higher porosity and water retention potential than at SPA; higher soil moisture together with slightly higher precipitation at ELG; a longer no-frost period (with higher soil biota activity) at ELG – 156±14 days vs. 145±12 days at SPA; a higher soil biota activity (including roots, fungi etc.) at the south-eastern site (but this fact is not proved yet).

References

Fedorov A.N., Maximov T.C., Gavriliev P.P. et al. 2006. *«Spasskaya Pad»: complex studies of permafrost landscapes*. Yakutsk, PI Publish. House, 210 p.

Ivanova T.I., Kononova N.P., Nikolaeva N.V., Chevychelov A.P., 2006. Microorganisms in forest soils of Central Yakutia. *Pochvovedenie* **6**, 735-740 (in Russian).

The temporal variability of atmospheric CO_2 over middle taiga ecosystems in central Siberia from 2006 to 2012 years

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Key words: atmospheric CO_2, ZOTTO, central Siberia.

Introduction

The changes in concentration of atmospheric carbon dioxide (CO_2) are attributed to an interaction of climate change and global carbon cycle [1]. For a better understanding of the global carbon cycle, the long-term monitoring atmospheric CO_2 to quantify the sources and sinks are vitally important. The continuous tower based CO_2 mole fraction measurement density is increasing in the World, with the goal of using the data in inversion models to diagnose CO_2 fluxes [2]. However, greenhouses gases monitoring system in Russia is not developed sufficiently and significant forest areas still have not enough studied in terms of their ability to sequester atmospheric CO_2 [3]. While the Siberian ecosystems are very important for the future climate as 30% of the boreal forest is concentrated in Siberia. Therefore, a scientific platform ZOTTO (the Zotino Tall Tower Observation) has been constructed in 2006 to enable the continuous monitoring of trace gases on a regional scale.

In the previously studies (Kozlova et al. (2008) and J. Winderlich et al. (2010)) reported the CO_2 linear trends at ZOTTO are about 2.02 and 2.62 ppm/yr in the year 2007 and 2009-2010, respectively [1,4]. However, these estimates were based on short-term CO_2 mixing ratios observations carried out during 1.5 - 2.5 years. Therefore, they cannot be considered accurate for long period because of the CO_2 concentration has the high inter-annual fluctuations and CO_2 trend strongly varies over time (e.g. Mauna Loa).

The aim of our study was to analyze annual rate of CO_2 increment at ZOTTO in base of fragmentary ZOTTO measurements for long period (2005 – 2013 гг.) and comparison with global CO_2 growth.

Materials and methods

The ZOTTO site is situated in the boreal forest of central Siberia at 60° N, 89° E, (Zotino, Krasnoyarsk region) and characterized by a strong continental climate (Table 1) [5]. The Yenisei River divides the ZOTTO footprint into two distinct parts, with pine forest and bogs on the west, and dark coniferous taiga on the east [4].

Table 1. Climatic conditions at the ZOTTO station

MAAT, C^o	-3.8
MAP, mm	536
Growing season >10 C^o (days)	91
> 0 C^o (days)	173
Snow cover period (days)	207

The CO_2 mixing ratio was measured by different measurement systems:

1. The NDIR analyzer (Siemens AG, Ultramat 6F) from November 2005 to September 2006 (52 m) and October 2006 to June 2007 (4, 52, 92, 227, and 302 m);
2. The EnviroSense 3000i analyzer (Picarro Inc., USA) from May 2009 to December 2012 (4, 52, 92, 156, 227, 301 m);
3. 1-l glass flasks (1.6 bar) taken weekly or bi-weekly during comprehensive flask sampling program from 2008 to 2010 on 301m for laboratory analyzes in the MPI for Biogeochemistry).

Result of regression analysis for fragmentary measurements CO_2 mixing ratio in quasi-continuous mode and analysis of flasks in the laboratory shows the ability to use the fragmentary measurements to estimate the long-term CO_2 trend. In order to get the trend at annual time scales of the CO_2 seasonal variation from the all ZOTTO dataset, fitting model was used. In this model, CO_2 data were filtered by taking afternoon means of the observations during overall mixing of atmospheric boundary layer. Then a function is fitted through the monthly mean of afternoon data consisting of four harmonics and a linear trend with time, where x is time (day of year), a and a_0 – linear trend coefficients, b_n and c_n – fitting coefficients:

$$F(x) = a_0 + a_1 x + \sum_{n=1}^{4} (b_n \sin(\frac{2\pi}{365} nx) + c_n \cdot \cos(\frac{2\pi}{365} nx)) \quad (1)$$

The annual mean rate of growth of CO_2 in a given year is the difference in concentration between the end of December and the start of January of that year. There is a small amount of month-to-month variability in the CO_2 concentration that may be caused by anomalies of the winds or weather systems arriving at ZOTTO. This variability would not be representative of the underlying trend. Therefore, estimate for the annual mean growth rate was done, by using the average of the most recent September-December months, corrected for the average seasonal cycle, as the trend value for January 1 and then subtracted the same four-month average centered on the previous January 1 [3].

Result

Annual rate of CO_2 increment at ZOTTO during the study period (January 2006 to December 2012) varied from negative to positive values (-0.47 to 4.33 ppm/yr.) (Table 2). The main reasons of considerable inter-annual variability of CO_2 growth at ZOTTO footprint are high sensitivity of carbon balance in inland terrestrial ecosystem to regional weather conditions and forest fires in the region. It results in significant inter-annual fluctuations of atmospheric CO_2.

Table 2. The annual rate of CO_2 growth at "ZOTTO"

Year	The seasonally adjusted atmospheric CO_2	Annual rate of CO_2 increment	
		"ZOTTO"	Mauna Loa**
2006	387.23±0.75		1.76
2007	387.50±0.53*	0.27	2.22
2008	388.99±0.58	1.49	1.21
2009	388.53±0.99	-0.47	1.90
2010	392.16±0.45	3.63	2.42
2011	394.64±0.56	2.49	1.86
2012	398.99±0.92	4.33	2.65

*modeled month averaged CO_2 .
**CO_2 data from NOAA Web [3]

A mean 1.41 ppm/yr increase rate of temporal trend was obtained for ZOTTO area. It is significantly lower compared to the increments estimated for 2006-2007 (2.02 ppm/year) [4] and 2009 - 2011 (2.62 ppm/year) [1].

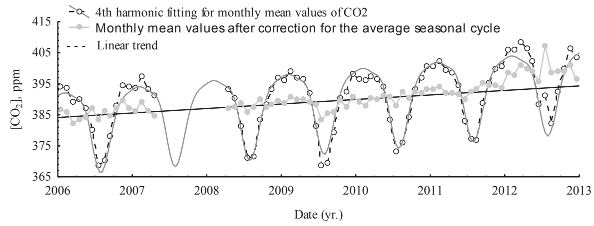

Fig. 1 CO_2 time series of monthly mean on 301 m level with 4th harmonic fitting and linear and seasonally trends.

However, ZOTTO CO_2 trend would increase by 0.68 ppm if the 2012 growth season with anomaly high level of atmospheric CO_2 included (Fig.1). Therefore, only long-term observations of greenhouses gases provide the reliable forecasts of CO_2 changes in Central Siberia.

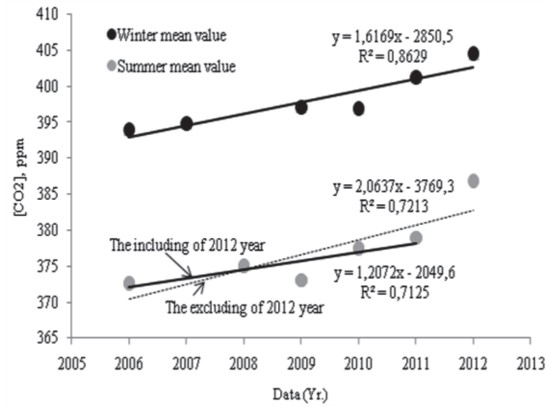

Fig.2 Winter and summer CO_2 linear trend at ZOTTO

The ZOTTO growth rate characterized by 1.41 ppm/yr averaged for 2006-2011, that lower of 0.54 ppm/yr than globally representative Mauna Loa record (1.95 ppm/year) for the same period. The low growth rate of atmospheric CO_2 might be due to the high uptake of terrestrial ecosystems in Central Siberia. It was showed that the summer growth of atmospheric CO_2 during the study period was 24% below than the winter (Fig. 2) (with the exception of summer 2012 with extreme fires). This suggests that absorption of atmospheric CO_2 by forest ecosystems of Central Siberia has not changed during the study period at the present level of CO_2 growth rate/year. It reflects an ability of terrestrial ecosystems of Central Siberia compensate in some extent the current global increase in atmospheric CO_2.

Conclusion:

1. There is high inter-annual variability of atmospheric CO_2 at ZOTTO region that might be due to the strong changes in net productivity (e.g. growth season in 2009) and CO_2 emissions (e.g.

nature fires in summer 2012) of inland forest ecosystems.

2. The linear CO_2 trend at ZOTTO for longer period (2006-2012) is significantly lower compared to the increments estimated for 2006-2007 (2.02 ppm/year) [4] and 2009 - 2011 (2.62 ppm/year) [1].

3. The ZOTTO growth rate characterized averaged for 2006-2011 by 0.54 ppm lower than globally representative Mauna Loa record (1.95 ppm/year) for the same period. It is the result of lower increase in summer atmospheric CO_2 at ZOTTO, but with excluding the period of large wildfires.

References:

1. Winderlich et al., Continuous low-maintenance $CO_2/CH_4/H_2O$ measurements at the Zotino Tall Tower Observatory (ZOTTO) in Central Siberia // Atmospheric Measurement Techniques. – 2010. – №3. – pp. 1113–1128. doi:10.5194/amt-3-1113-2010;

2. Miles et al., Large amplitude spatial and temporal gradients in atmospheric boundary layer CO_2 mole ractions detected with a tower-based network in the U.S. upper Midwest // Journal of geophysical research. – 2012. – №117. G01019, doi:10.1029/2011JG001781;

3. Esrl noaa Web. NOAA Earth System Research Laboratory;

4. Kozlova E. A., Seasonal, synoptic, and di-urnal-scale variability of biogeochemical trace gases and O_2 from a 300-m tall tower in central Siberia // Global Biogeochemical Cycles. – 2008. – № 22. – pp. 1–16;

5. E.-D. Schulze et. al., The Eurosiberian transect: an introduction to the experimental region // Tellus. – 2002. –№ 54B. –pp. 421-428.

Methane measurements at Polar Geocosmophysical Observatory “Tixie”

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Key words: methane, gas analyzer, permafrost, remote sensing, Arctic

Introduction

Global warming is the one of actual problem of today. Disturbances of natural fluctuations of the climate system components, can lead to catastrophic, irreversible changes in the environment. The main mechanism of global warming is the “greenhouse effect” caused by the high content of trace gases, which efficiently absorbing thermal radiation in the atmosphere.

About 65% of the Russian territory is occupied by permafrost. Most of it is located in Eastern Siberia and northern part of the Far East. Huge amount of methane and other greenhouse gases contain in type of frozen bubbles in permafrost. According to rough estimates (Shakhova 2008) the mass of the trapped methane is about 1400 Gt. It is known, that the methane molecules 21 times efficiently produces the “greenhouse effect” than the carbon dioxide molecules (IPCC 1995). Permafrost melting could lead to a sharp rise the emission of methane into the atmosphere and appropriate stimulation of “greenhouse effect”. Also, the global warming will lead to the rise of world ocean temperature, which may cause an increase in methane emissions from the bottom sediments (Semiletov 2010). Thus, monitoring and research of methane variations in the atmosphere is one of the most important targets of modern science.

Polar Geocosmophysical Observatory “Tixie” (PGO “Tixie”, ICRA SB RAS) was founded in 1957.Its geographical location is unique and there is no similar observatory in Russian Arctic. The main purpose of the observatory is the continuous geophysical study of geomagnetic field variations, auroral absorption of radio waves, the characteristics of the ionosphere and cosmic ray intensity.

Data

Fast Methane Analyzer DLT-100 was installed at the Polar Geocosmophysical Observatory “Tixie” in 2011 in the framework of cooperation between Yu. G. Shafer Institute of Cosmophysical Research and Aeronomy SB RAS and V. I. Il`ichev Pacific Oceanological Institute FEB RAS. DLT-100 is operating on the principle of laser spectroscopy. The range of measured values of methane concentration is 10 ppbv – 25 ppmv. Measurements are made automatically with a period of 5 sec. Accuracy of methane measurements is not less than 1%.

In addition to ground-based measurements, remote sensing data (instrument AIRS/Aqua) were used. AIRX3STD.005 product is the daily average maps of CH_4 concentration at altitude of ~7 km (359 hPa). Resolution of the data is 1°x1°.

Also, weather station (Russian Hydrometeorological Centre) data were used.

Results and Discussion

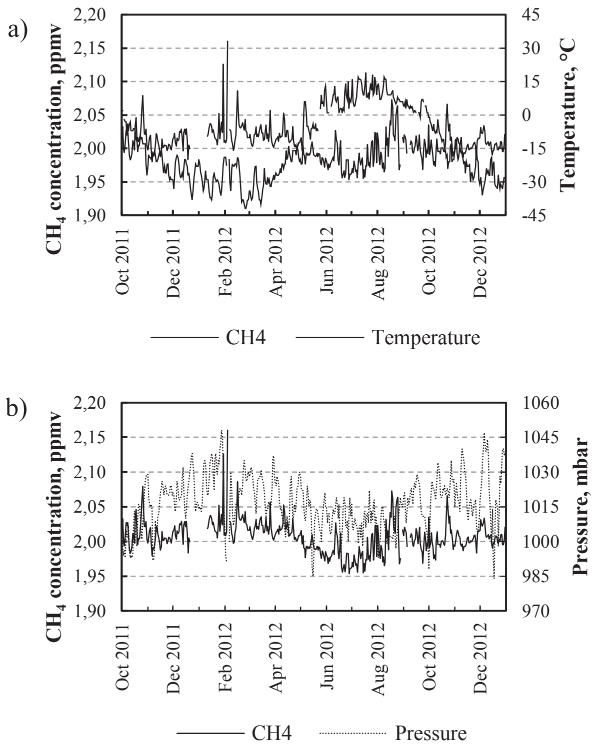

Fig.1. Variations of CH_4 concentration and a) temperature, b) air pressure during 01.10.11 - 31.12.12.

On Figure 1, the seasonal variations of CH_4 concentration, temperature and air pressure during 01.10.11–31.12.12 are presented. As shown in Figure 1a, high methane concentrations are observed during January–February and September.

An increase of CH_4 concentration during January–February coincides with decrease of air temperature at the PGO “Tixie”. Maximum values of methane concentrations during this period was ~2.16 ppmv. In summer, there was growth of temperature values and decrease of CH_4 concentration to ~1.94 ppmv. Decrease of methane concentration was replaced by the growth in September, with maximum values in this period ~2.08 ppmv. The correlation between CH_4 concentration and air temperature during whole period is -0.73. The correlation between CH_4 concentration and air pressure is 0.53. This behavior of methane corresponds to common seasonal variations presented in several works. (Adushkin 2010; Belan 2009; Makarova 2006).

a)

b)

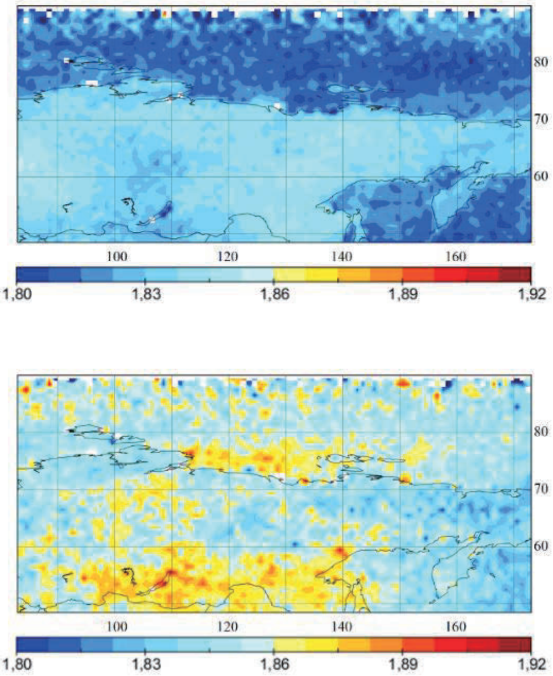

Fig.2. Distribution of methane at altitude ~7 km (AIRS) for a) June 2012, b) December 2012.

The observed decrease of concentration during the summer can be explained by a chemical reaction with the hydroxyl (OH) and by the sink of methane on the surface (Belan 2012). Methane sink to the surface is terminated in winter, as well as its emission from the soils. Increase of methane concentration in September may be due to the contribution of the Arctic region sources: the emission from sediments and geological faults (Adushkin 2010).

Monthly CH_4 distribution at the altitude of ~7 km (359 hPa) for June 2012 and December 2012, obtained by the Atmospheric Infrared Sounder (AIRS) on – board Aqua satellite are shown in Figure 2. Methane concentration in the winter (Fig. 2b) was higher compared to the summer (Fig. 2a). Differences in the distribution of methane over the ocean and land in the summer are clearly visible. In the winter, there is a region of high CH_4 concentration values that begins at 95° longitude, in the area of mountain ranges of the South Siberia and the Far East.

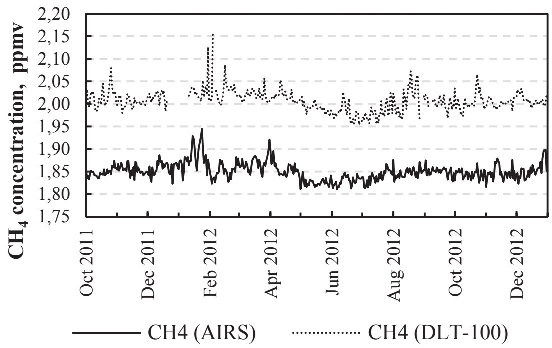

Fig.3. Variations of methane concentration at altitude ~7 km (AIRS, solid line) and at surface (DLT-100, dashed line) during 01.10.11 – 31.12.12.

Figure 3 shows seasonal variations of methane obtained from AIRSo (solid line) and DLT-100 (dashed line) data during 01.10.11–31.12.12. AIRS CH_4 concentrations is daily average values for the study area (69°-75° lat. and 122°-133° lon.). As can be seen in Fig. 3, seasonal variations of methane at ~7 km, in general, similar to the seasonal variations obtained from the ground-based observations. There are similar periods of increased concentration in January and February and decrease in the summer. The maximum value in February reached ~1.95 ppmv and the minimum value in June was 1.81 ppmv.

Conclusions

The results of methane measurements on the ground obtained by the Fast Methane Analyzer DLT-100 on PGO “Tixie” are presented. The seasonal variations of CH_4 obtained by ground-based measurements are in agreement with remote sensing data (AIRS / Aqua). The seasonal behavior of methane represented in this paper matches the current understanding of methane variations.

Polar Geocosmophysical Observatory “Tixie” has a broad range of scientific equipment, huge data archive, which in combination with the developed infrastructure makes it a unique place for research in the Arctic.

References

Adushkin V.V., Kudryavtsev V.P., 2010. Global flow of methane into the atmosphere and its seasonal

variations. *Physics of the Earth.* **4**. 78-85. (In Russian)
Shakhova N., Semiletov I., Salyuk A., Kosmach D., 2008. Anomalies of methane in the atmosphere over the East Siberian shelf: Is there any sign of methane leakage from shallow shelf hydrates?. *Gephysical Research Abstracts.* **10**.
Semiletov I., Shakhova N., Salyuk A., Yusupov V., Kosmach D., 2010. Extensive methane venting to the atmosphere from sediments of the east Siberian arctic shelf. *Science.* **327** (**5970**). 1246-1250.
Makarova M.V., Poberovskii A.V., Yagovkina S.V., Karol I.L., Lagun V.E., Paramonov N.N., Reshetnikov A.I., Privalov V.I., 2006. Investigation of formation of a field of methane in the atmosphere of the north- western region of the Russian Federation. *Izvestiya RAN*, *Fizika atmosferi i okeana.* **42(2)**. 1-13. (In Russian)
Belan B.D., 2009. Tropospheric ozone.5.Gases – precursors of ozone. *Atmospheric and Oceanic Optics*. **22 (3)**. 230 -268. (In Russian)
Belan B.D., Krekov G.M., 2012. Human impact on the content of greenhouse gases in the troposphere. 1. Methane. *Atmospheric and Oceanic Optics*. **25 (4)**. 361-373. (In Russian)
IPCC, Intergovernmental Panel on Climate Change, Second Assessment Report: Climate Change, 1995. *Cambridge University Press.* 21-23.

Impacts of water and carbon dioxide fluxes on waterlogging in an eastern Siberia larch forest during 1998 – 2011

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Key word: wet stress, Siberian larch forest, water and carbon exchanges, overstory vegetation, understory vegetation

1. Introduction

Recently, changes of water/energy/carbon dioxide fluxes caused by vegetation resulting from climate change attracted a great deal of attention. For example, drought weakened the water and carbon dioxide exchanges in Amazon, and the plant physiology and local occupancies were influenced (Betts et al., 2008). Exponential hot wave and drought attacked over Europe in 2003, and the volumes of carbon exchanges were significantly changed (Ciais et al., 2005).

In high latitude region of northern hemisphere, drought damaged forest vegetation in Canadian boreal forests (Peng et al., 2011), whereas waterlogging damages occurred in a forest in eastern Siberia (Ohta et al., 2008; Iijima et al., 2013).

This paper reported the forest recent changes and the changes in water and carbon dioxide fluxes through the vegetation changes.

2. Site and Method

The observation site is located in the left side of the middle reaches of the Lana River (62º15' N, 129º14' E. 220 m a.s.l.), approximately 20 km north of the city of Yakutsk. This forest is named "Spasskaya Pad" experimental forest of IBPC. Overstory vegetation was larch (*Larix cajanderi*), and the average tree height of larch was 20 m. Tree density was 844 trees ha^{-1} in 1998, but it decreased 740 trees ha^{-1} in 2011. Understory vegetation was dense cowberry (*Vaccinium vitis-idaea*) in 1998, which turned to shrubs and water-tolerance grasses during the wet period in 2005 and 2006.

The 32-m observation tower was installed in 1996, and measured meteorological elements. Downward and upward short-wave radiation, downward and upward long-wave radiation, net all-wave radiation, wind speed and direction, air temperature and relative humidity were observed at the top of tower. Soil temperature was measured at seven depths, and soil water content was observed at five depths. These elements were measured around the basilaris tower. Precipitation was measured in an open place location about 1 km south of tower using the tipping bucket of 0.13 mm accuracy. The data obtained by the above instruments were logged every 1 min until June 2005 and every 5 sec after June 2005.

Latent heat, sensible heat and net ecosystem exchange were measured by an eddy correlation method using a three-dimensional sonic anemothermometer (3D-SAT) and an infrared gas analyzer (IRGA). Evapotranspiration was calculated by latent heat flux, and gross primary productivity was calculated by net ecosystem exchange and ecosystem respiration.

3. Results and Discussions

3.1. Meteorological condition

Meteorological condition at Spasskaya Pad was changeable during 1998 – 2011. Precipitation represented three period; normal years were 1998 – 2000 and 2009 – 2011; dry years were 2001 – 2004 and wet years were 2005 – 2008. Atmospheric components such as net all-wave radiation, air temperature and water vapour deficit were steady values, and do not suffer a change of precipitation. Underground conditions such as soil temperature and soil water content were changeable to the amount of precipitation. Soil water content, especially, reflected drought in 2001 – 2004 but waterlogged in 2005 – 2009. These values were normal years in 1998 -2000 and 2010 – 2011.

3.2. Vegetation condition

Vegetation condition of overstory and understory were variable to the soil water content.

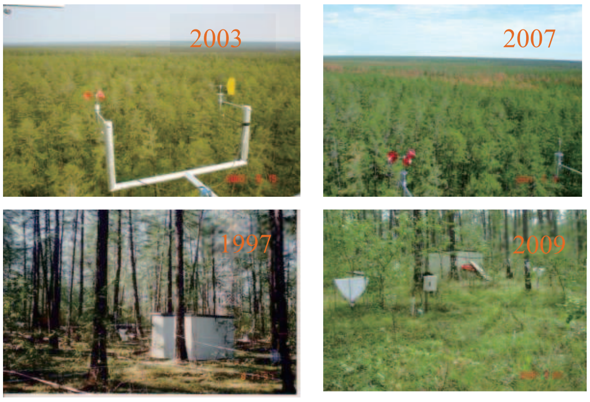

Figure 1 Changes of overstory and understory vegetation

Overstory was green before the foliating season in 2007, but some trees died in the early summer in that year. Understory vegetation was dense cowberry (Vacusinimu) in 2004, but it intruded on shrubs and high water-tolerance grasses.

3.3. Evapotranspiratio

The relationships of surface conductance (*Gs*) with downward short-wave radiation (*Sd*), air temperatire (*Ta*), atmospheric water pressure deficit (*VPD*) and soil water content (*SWC*) in June, July and August (JJA) in 1998 - 2011. *Sd* had no relationship to *Gs*. The relationships of

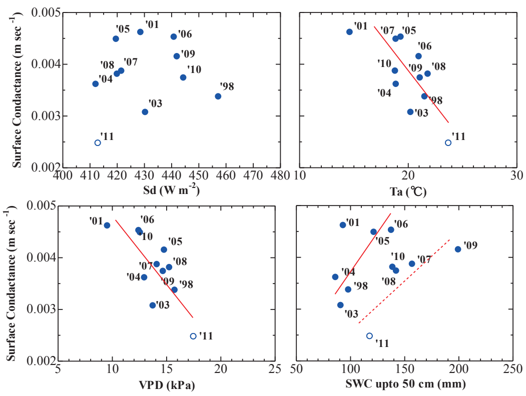

Figure 2 The relationships between *Sd*, *Ta*, *VPD*, *SWC* and *Gs*

Gs with *Ta* and *VPD* had negative relations but did not have same tendency in two relationships. *SWC* had different tendency in 1998 – 2006 compared to 2007 – 2011. The points of 1998 –

2006 were bigger than 2007 – 2011.

Evaporation rate (*Ev*/*Ep*. *Ev* was the actual evapotranspiration and *Ep* was the potential evaporation) and *SWC* was examined in the observed period in Spasskaya Pad. *Ev*/*Ep* was linearly correlated in 1998 – 2006, and the points of 1998 – 2006 were larger compared to those of 2007 – 2011. The relationships of *SWC* with *Ev*/*Ep* during 1998 – 2006 were different from those of 2007 – 2011. The basic trend of the relationship between *Ev*/*Ep* and *SWC* was same as that between *Gs* and *SWC*.

3.4. Photosynthesis

The time series of gross primary production (*GPP*) was investigated in JJA in 2004 – 2010. In 2004 – 2009, *GPP* increased with the year, whereas *GPP* in 2008 – 2010 was constant with lower values. It was found that *GPP* in 2004 – 2007 were different from those of 2008 – 2010.

The relationships of *GPP* with photosynthesis active radiation (*PAR*), *Ta*, *VPD* and *SWC* were researched in this forest. The tendencies of *PAR*, *Ta* and *VPD* were not found to be significant like evapotranspiration. The relationship between *SWC* and *GPP* was different tendency in 2004 – 2007 compared to 2008 – 2010. The points of 2004 were bigger than those of 2008 – 2010.

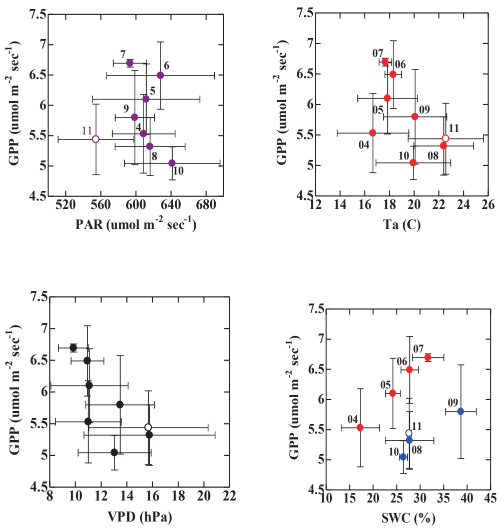

Figure 3 The relationships between PAR, Ta, VPD, SWC and GPP

The relationship between *SWC* and *Gs* changed in 2007, whereas the change in photosysthesis was occurred in 2008. The time series of changes in evapotranspiration and in photosysthsis was around one year.

3.5. Water use efficiency

Water use efficiency (*WUE*. *WUE* was the ratio of gross primary production to evapotranspiration) was calculated in JJA in 2004 – 2010. The time series of *WUE* decreased during the observation period. *WUE* decided the magnitude of *Ev* in 2004 – 2006, and the magnitude of *GPP* influenced *WUE* during 2008 – 2010. The time series of *WUE* were different from 2004 – 2007 and from 2008 – 2010.

4. Conclusion

The water and carbon dioxide fluxes were measured over an eastern Siberian larch forest from 1998 to 2011. As the results, drought attacked this forest during 2001 – 2004, but the damages of drought were concealed damages. For 2005 – 2009, waterlogging was significantly suffered for overstory and understory vegetation. The water and carbon dioxide fluxes were affected by waterlogging, and the relationships between surface conductance and soil water content as well as gross primary production and soil water content were damaged clearly by wet condition. The change in evapotranspiration was roughly one year earlier than in photosynthesis. From now on, not only drought but also waterlogging is targets of the researches.

References

Betts R.A., Malhi Y., Roberts J.T., 2008. The future of the Amazon: new perspectives from climate, ecosystem and social sciences. Phil. Trans. R. Soc. 363, 1729-1735. DOI:10.1098/rstb.2008.001

Ciais Ph., Reichstein M., Viovy N., Granier A., Ogee J., Allard V., Aubinet M., Buchmann N., Bernhofer CHR., Carrara A., Chevallier F., Noblet N.De., Friend A.D., Friedlingstein P., Grunwald T., Heinesch B., Keronen P., Knohl A., Krinner G., Loustau D., Manca G., Matteucci G., Miglietta F., Ourcival J.M., Papale D., Pilegaard K., Rambal S., Seufert G., Soussana J.F., Sanz M.J., Schulze E.D., Vesala T., Valentini R. 2005. Europe-wide reduction in primary productivity caused by the heat and drought in 2003. Nature, 437, 529-533. Doi:10.1038/nature03972

IijimaY., Ohta T., KotaniA., Fedorov A.N., Kodama Y., Maximov T.C., 2013. Sap flow changes in relation to permafrost degradation under increasing precipitation in an eastern Siberian larch forest. Ecohydrol., DOI:10.1002/eco.1366

Ohta T., Maximov T.C., Dolman A.J., Nakai T., van der Molen M.K., Kononov A.V., Maximov A.P., Hiyama T., Iijima Y., Moors E., Tanaka H., Toba T., Yabuki H., 2008. Interannual variation of water balance and summer evapotranspiration in an eastern Siberian larch forest over a 7-year period (1998-2006). Agric. For. Meteorol., 148, 1941-1953.

Peng C., Ma Z., Lei X., Zhu Q., Chen H., Wang W., Liu S., Fang X., Zhou X., 2011. A drought-induced pervasive increase in tree mortality across Canada’s boreal forests. Nature Ckimate Change. 1, 467-471. DOI:10.1038/NCLIMATE129

Contribution of LAI and stomatal conductance to canopy conductance in eastern Siberian larch forest

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Key words: canopy conductance, leaf area index(LAI), stomatal conductance

Introduction

Boreal forest comprises approximately 25% of global forest area, and approximately 76% of the boreal forest is in Russia (FAO, 2005). Siberia (especially eastern Siberia) is characterised by low precipitation, a short growing season, and extensive permafrost. The permafrost creates an impermeable underground layer that causes surface soils to remain wet despite low amounts of precipitation.

Anomalous conditions occurred from 2005 to 2007, during which pre-winter (July–September) precipitation was high and soil water content in the central Lena River basin increased (Iijima *et al*., 2010). The continuously saturated conditions led to the occurrence of yellowing and browning in larch leaves in 2007 at Spasskaya Pad near Yakutsk (Iwasaki *et al*., 2010). Iijima *et al*. (2013) showed that transmittance, the proportion of solar radiation that penetrates through the forest canopy, has increased since 2008 as a result of decreasing leaf coverage. These researchers also reported a decrease in total transpiration of 15 larch trees in 2009 compared to 2006 (Iijima *et al*., 2013). It is assumed that recent changes in forest canopy conditions (the quantity and health of leaves) have occurred. Clarifying the influence of leaf cover and activity (H_2O and CO_2 fluxes) is important to understanding the terrestrial circulation of H_2O and CO_2. In this study, we show interannual variation in H_2O and CO_2 fluxes from the upper canopy and the contributions of leaf area index and stomatal conductance to canopy conductance at Spasskaya Pad during the years immediately before and after the extremely wet conditions.

Observation

The observation site is located on the west bank of the middle reaches of the Lena River in eastern Siberia (62°12′18″N, 129°14′29″E), approximately 20 km north of Yakutsk City, in the Spasskaya Pad experimental forest. The mean annual air temperature and mean annual precipitation (1961–1990) at the site are –10.4ºC and 236.9 mm, respectively. The dominant species of the upper canopy are larch (*Larix cajanderi*) and birch (*Betula platyphyila*). We measured fluxes of H_2O (latent heat, λE) and CO_2 (net ecosystem production, *NEP*) using an eddy covariance system, and environmental variables (air temperature, relative humidity, downward shortwave radiation, net radiation, and wind speed) at the top of the observation tower (32.0 m) and on the forest floor (3.3 m) from 2005 to 2012.

Data processing

In this study, we define “flux from the upper canopy” as the difference between the fluxes at top of the tower and those on the forest floor. We calculated canopy conductance (g_c, m s^{-1}, degree of stomatal opening at the canopy scale) using the Penman-Monteith equation (Montieth, 1965):

$$gc = \frac{\lambda E \gamma g_a}{\Delta(Rn_T - Rn_U) + \rho c_p g_a (e_{SAT}(T) - e) - \lambda E(\Delta + \gamma)}$$

$$ga = \frac{u{*}^2}{U}$$

where λE is latent heat flux from the upper canopy, γ is the psychrometric constant, g_a is aerodynamic conductance, Δ is the rate of change in saturation water vapour pressure with temperature, R_{nT} is net radiation at top of the tower (32 m), R_{nU} is net radiation on the forest floor (1.2 m), ρ is the density of moist air, c_p is the specific heat of air at constant pressure, e_{SAT} is saturation water vapour pressure with temperature, T is temperature, e is water vapour pressure, u_* is friction velocity, and U is wind speed.

We calculated leaf area index (LAI, m^2 m^{-2}, leaf area per unit area) using radiative transmittance (the ratio of downward shortwave radiation) and the Lambert-Beer equation (Monsi and Saeki, 1953). We determined the extinction coefficient "K" in the Lambert-Beer equation using LAI = 0.64, which was calculated from the difference between values during the period with foliage and the dormant period in 2005 measured by LAI-2000; and average radiative transmittance (0.46), which was the ratio of downward shortwave radiation at the top of the tower (32.0 m) to that on the forest floor (1.2 m) during the period with foliage in 2005:

$$LAI = \frac{\log(\frac{1}{Tr})}{K}$$

Where Tr is radiative transmittance and K is the extinction coefficient (1.21 in this study). We show only annual average LAI values during the foliage period.

Stomatal conductance (g_s, m s^{-1}, degree of opening of stomata per unit leaf area) was calculated using g_c and LAI:

$$gs = \frac{gc}{LAI}$$

Where g_c is the average mid-day (10:00–14:00) value and LAI is the average annual value during the foliage period in each year.

Results

Interannual changes in fluxes

Figure 1 shows interannual variation in the mid-day (10:00–14:00) mean λE (W m^{-2}), NEP (μmol m^{-2} s^{-1}), and g_c, (m s^{-1}) of the upper canopy during the foliage period (DOY 160–230). Both λE and NEP decreased after 2007, and g_c showed a decreasing trend from 2005 to 2012. Yellowing and browning leaves appeared on larch trees in 2007 at Spasskaya Pad. We infer that the decreasing trend in latent heat flux and ecosystem production was caused by the loss of leaves, reduced stomatal activity, or both. The factors responsible for reduced canopy conductance are not clear.

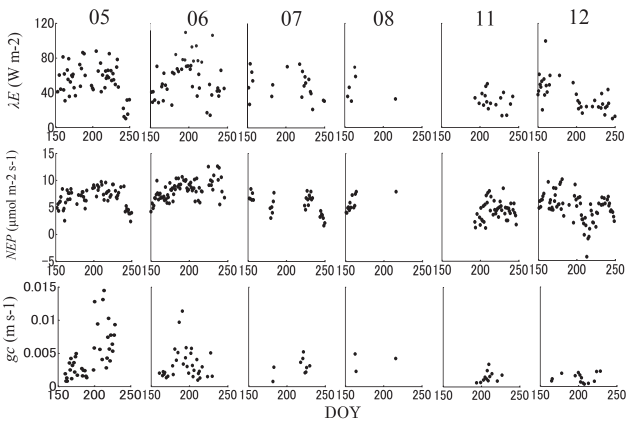

Figure 1. Interannual variation from 2005 to 2012 (excluding 2009 and 2010) in λE, NEP, and g_c of the upper canopy. Each dot represents the mid-day (10:00–14:00) mean.

Contribution of *LAI* and stomatal conductance to canopy conductance

Interannual variation was observed in LAI and g_s of the upper canopy during the foliage period (Fig. 2).

The values of *LAI* decreased from 0.66 to 0.57 (13% reduction) from 2007 to 2012. At Spasskaya Pad, damage to larch trees (i.e. lack of foliage production in summer) appeared in 2008 and the quantity of leaves in the canopy decreased thereafter. Prior to this, in 2007, yellowing and browning occurred in canopy leaves; thus, *LAI* as calculated by radiative transmittance would overestimate leaf activity in 2007. We assumed that all yellowing and browning trees died in the following year. Therefore, the value of "active *LAI*" in 2007, which excludes yellowing and browning leaves, was the same as that in 2008. The grey line in Figure 2 shows the active *LAI* value in 2007; we used this value to calculate the contribution of *LAI* to g_c. Stomatal conductance also showed a decreasing trend from 2005 to 2012, indicating that the reduction in g_c was due not only to dead trees but also to reduced activity of living trees.

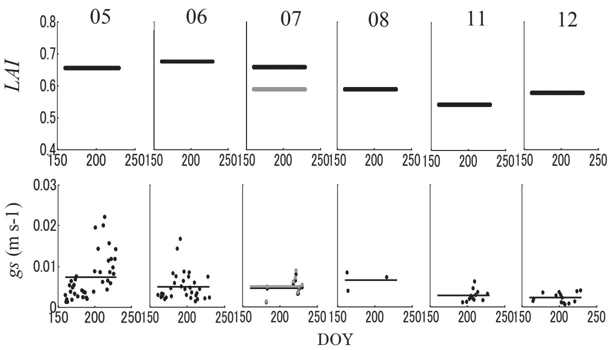

Figure 2. Interannual variation in *LAI* and g_s of the canopy from 2005 to 2012 (horizontal lines show average annual values during the foliage period, grey lines show active *LAI* and g_s values (excluding yellowing and browning leaves in 2007)

Finally, we calculated the contribution of interannual variation in *LAI* and g_s to interannual variation in g_c, and determined that the respective contributions were 16.5% and 83.5%. This result indicates that interannual changes in g_s had a greater influence than those of *LAI* to interannual changes in λE and *NEP* from the upper canopy at Spasskaya Pad.

Conclusion

In this study, we showed that latent heat flux and net ecosystem production in the upper canopy at Spasskaya Pad have decreased since 2007, and we conclude that this decreasing trend was caused mainly by decreasing stomatal conductance. This result indicates that clarifying changes in g_s under extreme wet or dry conditions is important not just at the leaf scale, but for the whole-canopy scale. When analysing changes in ecosystem fluxes after 2007 at Spasskaya Pad using models or satellite data, it will be critical to account for stomatal activity.

References

FAO, 2005. *State of the World's Forests 2005.* 166p

IijimaY., Fedorov.A.N., Park H.,Suzuki K.,Yabuki.H., Maximov,T.C.,Ohata T., 2010. Abrupt increases in Soil Temperature following increased precipitation in a permafrost region, central Lena river basin, Russia. *Permafrost and periglacial processes* 21, 30-41

Iijima Y., Ohta T., Kotani A., Fedorov. A. N., Kodama Y and Maximov T. C., 2013. Sap flow changes in relation to permafrost degradation under increasing precipitation in an eastern Siberian larch forest. *ECOHYDROLOGY*

Iwasaki, H.,Saito, H., Kuwao, K., Maximov, T. C., Hasegawa, S., 2010. Forest decline caused by high soil water conditions in a permafrost region. *Hydrology and Earth System Sciences.* 14, 301-307

Monsi, M. and Saeki, T., 1953. Über den Lichtfaktor in den Pflanzen-gesellschaften und seine Beteutung für die Stoffproduktion. *Jap. J. Bot.* 14, 22-52

Montieth, J.L., 1965. Evaporation and environment. In: 19th symposium of the society for experimental Biology. *Cambridge University Press*, 205-234

Mammal species in Yakutia as possible global climate change indicators

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Key words: climate, mammals, arctic ecosystems, range

Global warming started in the second half of the 60-s in the most parts of the northern hemisphere and affected the territory of Yakutia. Global warming is observed in Yakutia during the last decade. The greatest increase in air temperature in the region occurred in the 1980s. Since the mid - 1990s warming in some regions of Yakutia clearly stalled but the average annual air temperature remained at the same high level. Therefore, elongation of warm season occurs. Spring began coming 10-15 days earlier and autumn lengthened by 15-20 days than it was in the middle of the last century. The long-term tree-ring analysis revealed that growing period of trees shifted earlier in Central Yakutia (the average age of the studied material is 140-150 years). The main reason for the earlier growing period of trees is a date shift of average daily air temperature at 0°C at the beginning of the third decade of April with a simultaneous increase in mean daily air temperatures by 1-2°C higher than in previous periods.[1]
Changes in bioclimatic conditions influence the distribution and status of animal populations. Consequently some mammal species of Yakutia may be indirect indicators of climate change in the direction of warming. In this paper we present observation results of 2000-2013 in this direction in comparative aspect with the data from the book "Mammals of Yakutia"[2].
First of all, significant changes in distribution and ecology of Arctic region mammals of Yakutia are marked. So, recently every year since 2005 increased occurrence of polar bear (*Ursus maritimus*) is noted for the first time on the mainland of Yakutia - in the Lower Kolyma tundra.
Beginning from September, about 20-30 polar bears come ashore each year and remain for the period until middle and late November (Fig. 1).

Fig 1. Polar bear (*Ursus maritimus*) walking ashore. The Lower Kolyma, 2012. Photo by F.G. Yakovlev

With the formation of the ice cover bears leave the land and go into the large expanses of the East Siberian Sea.
Another noteworthy and require special research feature of the tundra mammals is disruption of established and earlier identified regular cycles of lemming and Arctic fox number dynamics. In recent years significant decrease in population size and density of Arctic fox in tundra ecosystems is recorded. The same situation is observed in the collared lemming population. Also changes in the wild reindeer population size may be related to the global warming. It is almost catastrophic decline in number of some populations as well as changes in traditional migratory routes from the forest zone to tundra and back. These points are studied in another report presented in this volume.
At the same time active penetration of the taiga (boreal) mammal species in the Arctic tundra ecosystem is observed. And it does not accidental occurrence but a statement that there is a species' habitat which was earlier located further south.

This species is a brown bear (Ursus arctos) which began permanently inhabit tundra zone in the lower reaches of the Indigirka and Kolyma rivers. During the period of research a considerable number of facts of brown bear den sites occurrence in these areas have already collected (Fig. 2).

Fig. 2. Bear's den with two cubs in the tundra discovered in May 2011, The lower reaches of Indigirka river. Photo by E.A. Nikolaev

During the active period bears began to create problems for indigenous peoples often attacking reindeer or entering the territory of human habitation (towns, villages, fishing grounds). People in tundra do not have experience of interaction with such a large predator and very often people's lives are in serious danger.

Another non characteristic for the tundra species is a sable (Martes zibellina) which began actively inhabits tundra during the last 10 years. Analysis of fur trade data showed that since 2000 about 10-15 sable skins were procured from tundra zone. During our work in the Arctic regions (lower reaches of Anabar, Olenek, Yana, Indigirka, Kolyma rivers; Lena Delta) we regularly observed sables and the traces of their activity (Fig. 3). Also evidences of hunters confirm these facts. Hunting Department of the Sakha Republic (Yakutia) in 2008 began to issue licence for sable hunters in tundra.

Fig. 3. Sable (*Martes Zibellina)* in tundra. Lower Kolyma, October, 2011. Trail camera photo.

In recent years expansion of many other boreal species to the north is observed. It can be connected to global warming. One of these species is a red deer (*Cervus elaphus*) which is actively moving to the north. The range of the red deer in Yakutia has increased almost four-fold over the last half century. It expanded its area to the north-east for more than 200,000 km² (Fig.4).

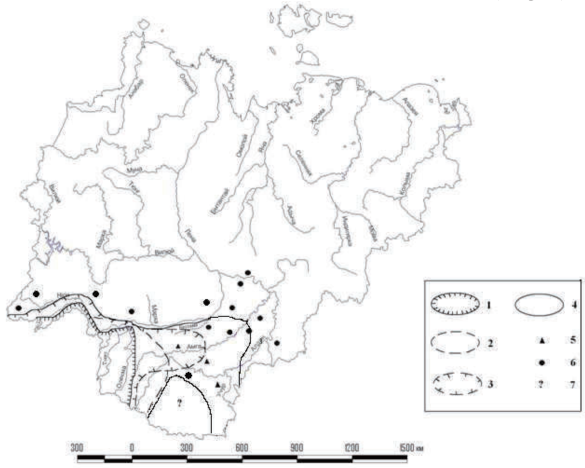

Fig. 4. Dynamics of the red deer range in Yakutia: 1 – range in 1960s [3, 4, 2]; 2 – range in 1980s [5]; 3 – range in 1990s [6]; 4 – current range [7]; 5 – occurrence in 1980s [5]; 6– occurrence in 1990s and nowadays [our data]; 7 – unexplored area.

Since the late 1970s - early 1980s the red deer began to occur in the northern part of Central Yakutia and more intensively distributed since the mid-1990s. This tendency continues to the present. Northern border of the range reaches lower course of the river Aldan. Some individuals occur on the right bank of the river in the Predverhoyansky fore deep area.

The next indicator of climate warming may be shift of shedding (changing of fur cover of many fur-bearing animals) to a later date from summer to winter in Yakutia. As many hunters note shedding period of squirrel, ermine, sable and other species completed by mid-October earlier. Now it depends on the year conditions and can be completed to mid-late November. This fact causes a shortening of the fur production period with qualitative fur and reduces the income of hunters.

Another species-indicators of climate warming may be hibernating rodents of Yakutia. There are two species of ground squirrels - *Spermophilus undulatus* (Fig. 5) and *S.parry*, siberian chipmunk (*Tamias sibiricus*) and black-capped marmot *(Marmota camtschatica).*

Fig. 5. *Spermophilus undulatus* in hibernation. Photo by A.I. Anufriev

Years of observations showed that these species went into hibernation later than in previous years. Thus in 2012 we observed active ground-squirrels in late October and early November. In 2013 they were on the surface in the second decade of November. We relate this fact with the anomalous warming in this period. Deeper study of hypothermia duration, hibernation bouts may reveal more interesting facts.

Thus, a lot of facts on distribution change and life cycle of mammals related to climate change were collected in Yakutia. Based on these facts we can highlight the model mammalian species as indicators of climate change in Yakutia. They could be an essential addition to research of the physical nature of climate change. Investigation of these change mechanisms in mammal populations could become the new joint research projects with our Japanese and other foreign colleagues in the near future.

References

1. Grigoriev M.N., Skuchkov Y.B., Fedorov A.N., Desyatkin R.V., Maximov T.C., 2010 . An overview of current climate change and the environment in the Republic of Sakha (Yakutia). Preprint. - Yakutsk, 24p.
2. Mammals Yakutia / Tavrovsky V.A., Egorov O.V., Krivocheev V.G. et al, Moscow, 1971. - 660.
3. Belyk V.I. Composition and distribution of game fauna of Yakutia / / Game fauna and hunting management in Yakutia. Yakutsk. 1953. Issue 1. p. 15-19.
4 . Egorov O.V. Wild ungulates in Yakutia. Moscow: Nauka, 1965. 259 p.
5 . Revin Y.V. Mammals of South Yakutia . - Novosibirsk,1989. 321p.
6. Mordosov I.I. The mammalian fauna of the taiga in Western Yakutia//Fauna and ecology of terrestrial vertebrates of Yakutia taiga zone. Yakutsk, 1980. p. 3-27.
7. Stepanova V.V., Okhlopkov I.M., Ecology of the red deer in Yakutia. Novosibirsk, 2009. - 136.

Aboveground biomass of sparse larch forests on tree line (North-East Siberia)

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Key words: North-East Siberia, tree line, larch forest, aboveground biomass

At the beginning of the 20th century, the expedition headed by A.K. Cajander (1903, 1904) discovered the northern outpost of a larch forest in the lower reaches of the Lena River, on a polar island Tit-Ary. In 1942-1943, the forest was cut. Since 1950s, the island was regularly surveyed by scientists (Tikhomirov and Shtepa, 1956; Polozova, 1961; Sherbakov, 1965, 1975; Andreev et al, 1987; Perfiljeva, Teterina, Karpov, 1991; Isaev et al, 2012). Later on, the island ecosystems were investigated by specialists from Yakutsk Institute of Biology: in 1972, 1977, 1982, 1984, 1989, and 1994.

In 2009-2012 our investigation on the island ecosystems has been conducted with revealed the following parameters of the forest: 2750 trees/ha, canopy density – 0.3, height – 1.5-3.2 (6.5) m, DBH – 1.7-6.2 (12) m (table 1).

Table 1. Stands characteristics of larch ecosystems on Tit-Ary island

Type of larch forest	Number of trees per 1 ha		H, m		DBH, cm		Average age
	total	≥ 1,3 m	average	max	average	max	
TA-5. *Betula exilis + Sphagnum*	2300	850	1.45	2.9	2.03	5.5	40
TA-6. *Ledum decumbens + Aulacomnium turgidum*	4400	2250	2.11	3.4	1.74	4.1	44
TA-9. *Ledum decumbens*	3200	2750	3.15	6	3.4	8.8	62
TA-10. *Cassiope tetragona + Sphagnum*	1150	800	2.73	5.3	6.17	12	43
TA-13. *Eryophorum vaginatum + Sphagnum*	1350	700	2.15	3.55	2.06	4.7	41

Forest stands have 4 generations of a larch – more than 80, 40-50, 25-30, less than 20 years. To a half of all trees appeared before 1942. After World War II were 3 main waves of regeneration - in the 60th, 70th and 80th years of the XX century (Fig. 1).

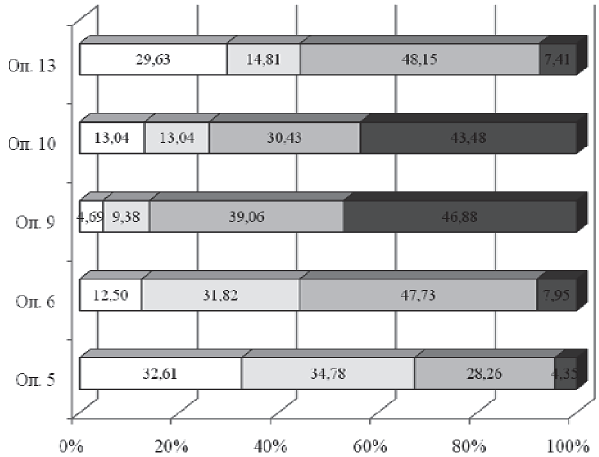

Fig. 1. Age structure of larch stands on Tit-Ary island: □ – 0-20; □ – 25-30; □ – 40-50; ■ – >80 year old

The aboveground biomass of a forest stand in different conditions is 557.1–3383.9 kg per 1 ha (table 2).

Table 2. Aboveground biomass of larch ecosystems on Tit-Ary island

Type of forest	Biomass, kg / ha		
	timber	needles	total
TA-5. *Betula exilis + Sphagnum*	603.2	64.5	667.7
TA-6. *Ledum decumbens + Aulacomnium turgidum*	3089.4	294.5	3383.9
TA-9. *Ledum decumbens*	879.5	83.5	963.0
TA-10. *Cassiope tetragona + Sphagnum*	1722.9	182.9	1905.8
TA-13. *Eryophorum vaginatum + Sphagnum*	502.9	54.2	557.1

Biomass of needles of the sparse larch forest on Tit-Ary island is very low (54.2-294.5 kg per hectare), but the relation of a biomass of needles to the total aboveground biomass is higher, than in the larch forest of more southern areas (Fig. 2).

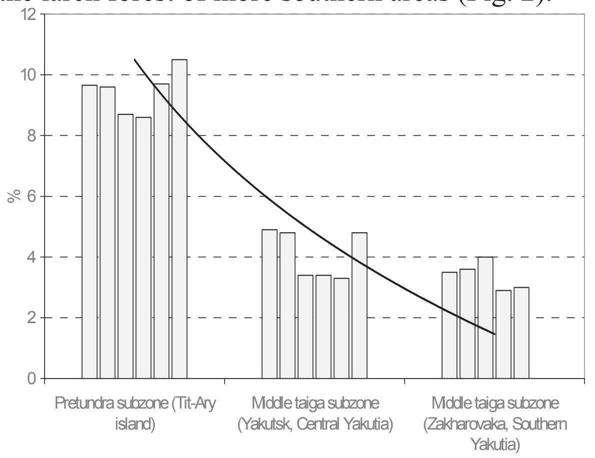

Fig. 2. Ratio of the needles biomass and the aboveground biomass in larch forests on different regions of Yakutia. Age of stands – 40–100

Climatic conditions of the beginning of the XXI century favor to larch growth on a northern tree line. Since 2002 increase axial shoot length of larch stems (Fig. 3). At the larches growing in the stand the average increment of axial shoot length increased more than by 2 times and reached 7.66 cm. At the larches growing on southern slopes the average increment of axial shoot length increased by 5 times (15.6 cm), at single stems of larch in the tundra – twice (4.88 cm).

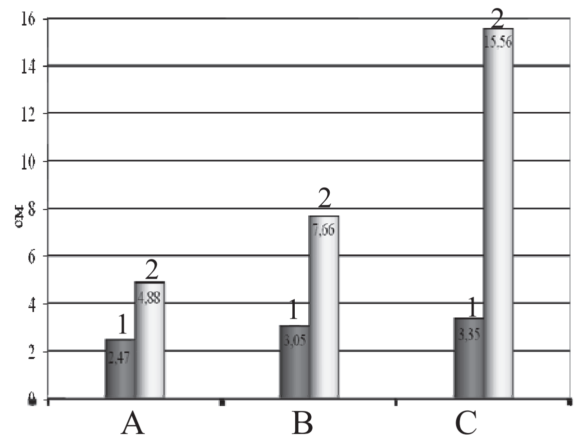

Fig. 3. Axial length of larch stems growing on different ecotops: A – single trees in tundra; B – trees in the sparse larch forest; C – trees in the sparse larch forest on the southern slope. 1 – 1991-2002; 2 – 2001-2009

Air temperature is an important for growth of larch trees (table 3). Precipitation influences to growth of larch trees lesser extent, especially on the trees growing in the forest.

Table 3. Correlation (r) between axial length of larch stems on Tit-Ary island and climatic condition

Parameters of climate	axial shoot length of larch stems	
	single trees	trees in the stand
Summer precipitation	0.60	0.14
Annual precipitation	0.52	0.20
Summer average temperature	0.66	0.63
Annual average temperatureгод	0.59	0.82

Acknowledgements

The study was partially supported by projects RFFI (13-06-93939-J8_a, 13-05-01015A, 12-06-98504-p_vostok_a) and grant of Ministry of Education and Science of Russian Federation (4.5133.2011).

References

Cajander A.K. Beiträge zur Kenntniss der Vegetation der Alluvionen des nordlichen Eurasiens. I. Die Alluvionen des unteren Lena-Thales. Acta Societatis Scientiarum Fennicae 32 (1). 1903. P. 1-182.

Cajander A.K. Studien uber die Vegetation des Urwaldes am Lena-Fluss //Acta Soc. Sci. Fennical. Helsingfors. 1904. T.32. N 3.

Polozova T.G. About northern location of larch (Larix dahurica Turcz.) and alder shrub (Alnaster fruticosus Ldb.) in lower reaches of the Lena River // Materials about vegetation of Yakutia. Leningrad, 1961. P. 291-294 (in Russian)

Tikhomirov B.A., Shtepa V.S. Characteristic of forest outposts in lower reaches of the Lena River // Botanical journal, 1956. Volume 41. № 8. P. 1107-112 (in Russian)

Sherbakov I.P. About forest regeneration on far north tree line in Eurasia // News of Siberian Division of Academy of Science of USSR. Biological & medical science series. 1965. №8. Release 2. P. 54-61 (in Russian)

Andreev et al. Main peculiarities of vegetation cover of Yakutia. Yakutsk: Publishing Center of Yakutian Branch of Siberian Division of Academy of Science of USSR, 1987. 156 p. (in Russian)

Perfiljeva V.I., Teterina L.V., Karpov N.S. Vegetation of tundra zone of Yakutia. Yakutsk: Publishing Center of Yakutian science center of Siberian Division of Academy of Science of USSR, 1991. 194 p. (in Russian)

Isaev A.P., Mikhalyova L.G., Solomonov N.G. et al. Age-old changes in ecosystems of Tit–Ary, the polar island in the lower reaches of the Lena river (north-east Asia) // Cryobiology. Volume 65. Issue 3, December 2012. P. 352–353.

Features of the biological activity of permafrost soils in the Olekminsky Nature Reserve

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Key words: the biological activity of soil, the quantity of microorganisms, the balance of carbon in soils

Introduction

One of the most important components of the biological activity of the soil is the composition and abundance of microorganisms and their functional activity.

Such indicators as the fertility of the soil and the rate of circulation of chemicals into the soil from the waste products of plants and animals depend on the state of soil biota.

The integral indicator of soil biological activity - “The intensity of gaseous metabolites, carbon dioxide”, which characterizes the "breath" of soil is the most important element of the environmental monitoring of soil. This indicator, classical microbiological method of sowing on the environment, the results of chemical analysis of soil allows you to give a comprehensive assessment of the state of the soil.

The purpose of the study is to identify the characteristics of the biological activity of permafrost soils of different habitats in the area of scientific station “Dzhikimda” in the Olekminsky reserve.

The objectives:

1. To evaluate the biological activity of different permafrost soils;
2. To determine the composition and abundance of the dominant soil microorganisms of different habitats.

Methodology, data.

The studies were conducted in the Olekminsky reserve.

For the duration of the research work on the subject it has been investigated 10 habitats in duplicate at two different depths.

48 microbial cultivation and 56 measurements of soil biological activity was done.

The modification of the Shtatnov’s method [1] was used in determining the biological activity of soils.

Hach Paddle testers (USA) were used to determine the number of microorganisms in soil. It were testers, on which both sides the ready microbiological culture was applied to determine the number of aerobic bacteria and fungi (yeasts and actinomycetes). For example For the detection of bacteria it were Tryptone Glucose Agar, for yeast and fungi it were Sabouraud-dextrose agar.

The main results and conclusions.

1. The maximum number of bacteria was 10^7 cells / g of soil in the lichen pine forest, the minimum number of bacteria was 10^3 cells / g of soil in the cowberry-larch forest (Tabl.1). The maximum number of fungi (yeasts and actinomycetes) was 10^5 cells / g of soil in the lichen pine forest and the pine grass forest, the minimum number of fungi was 10^3 cells /g of soil in the spruce forest.

Table 1. The comparison of the number of bacteria and fungi in different habitats

The name of the biotope	Amount of microorganisms (cells/g of soil)	
	bacteria	fungi
Herb-pine forest	10^4	10^5
Non-grass-birch forest	10^5	10^4
Dry forb meadow	10^4	10^4
Lichen-pine forest	10^7	10^5
Green-moss spruce forest	10^4	10^3
Cowberry-larch forest	10^3	10^4
Wet forb meadow	10^4	10^4

2. The biological activity of soil at the depth of 20 cm in all biotopes is higher than on the surface. (the herb-pine forest- of 1.09 times; the forb meadow - by 1.07 times; the non-grass birch forest - 1.07 times; dry meadow - 1.12 times). This is due to the fact that the biological activity (respiration) of soils is more dependent on the humidity of soil than the temperature [2]. At a depth of 20 cm the soil temperature is lower by 5-7 degrees, but the soil moisture is higher (Table 2).

Table 2. Characterization of the soil biological activity at different depths

The name of the biotope	Amount of CO_2 g/m^2 per day	
	on the ground	at 20 sm depth
Herb-pine forest	3,91	4,25
Wet forb meadow	3,49	3,83
Non-grass birch forest	3,91	4,17
Dry forb meadow	3,49	3,90

3. The soil biological activity (respiration) is depending on the soil habitat composition, that varies from 3.40 g of CO_2 /m^2 per day to 4.58 g of CO_2/m^2 per day.With increasing soil biological activity habitats can be arranged in the following series: moist meadow and forb meadow <Spruce forest< Moss-herb-pine forest and herb-pine forest < non-grass birch forest < Lichen-pine forest < cowberry-larch forest <willow-forest (Tabl.3).

Table 3. The comparison of biological activity in different habitats

The name of biotope	Amount of CO_2 g/m^2 per day
Moist meadow	3,40
Dry forb meadow	3,49
Spruce forest	3,57
Moss-herb-pine forest	3,74
Herb-pine forest	3,91
Non-grass birch forest	3,91
Lichen-pine forest	4,08
Cowberry-larch forest	4,17
Willow-forest	4,59

4. With increasing soil biological activity for 2006 habitats are located in the following series: forb meadow < non-grass birch forest < Lichen-pine forest < cowberry-larch forest. This proves that the distribution of the biological activity of habitats from 2006 to 2012, remained unchanged (Table 4).

5.The number of bacteria on the surface of the ground is greater on the order than the depth of 20 cm in four habitats. (Pine herb, herb meadow (dry), lichen pine, birch dead-cover). This is due to a higher content of organic carbon in the surface layer, and as a consequence a greater biomass of microorganisms (Table 5).

Table 4. Comparative characteristics of biological activity in 2006 and 2012

The name of the biotope	Amount of CO_2 g/m^2 per day	
	2006 y.	2012 y.
Wet forb meadow	2,84	3,49
Non-grass birch forest	3,63	3,91
Lichen-pine forest	4,04	4,08
Cowberry-larch forest	4,12	4,17

Table 5. Comparing the total number of bacteria on the surface and on the depths of 20 cm.

The name of biotope	Total amount of aerobic bacteria (cells / g of soil)	
	on the ground	at 20 sm depth
Herb-pine forest	10^4	10^3
Dry forb meadow	10^4	10^3
Wet forb meadow	10^6	10^5
Lichen-pine forest	10^7	10^6
Non-grass birch forest	10^5	10^5

6. The fungi (yeasts and actinomycetes) enter the largest contribution to the biological activity (respiration) of soils. It is typical for permafrost soils in the region of investigation [3] In habitats where the maximum biological activity registered, the highest number of fungi (yeasts and actinomycetes) - 10^5 cells / g of soil was recorded also (Table 6). The correlation coefficient (r) between the index of the biological activity of the soil and fungi amount (yeasts and actinomycetes) is 0,78.

7. Evaluation of soil biological activity in Olekminsky ulus showed that the rate of decomposition of soil organic matter is very low. According to experts [4], 1 hectare of arable layer black soil of the European part of Russia produces 10-15 tonnes of CO_2 per year, whereas the soil of Olekminsky ulus produce at least three times less carbon dioxide. Low biological activity of the soil is the reason that many types of permafrost soils is the annual accumulation not had a time to decompose organic matter. The peat formation and gleification occur.

Table 6. Comparison between the biological activity of the different habitats' soils and the amount of fungi

The name of biotope	Amount of CO_2 g/m^2 per day	Amount of fungi (cells/g of soil)
Herb-pine forest	4,25	10^5
Non-grass birch forest	4,17	10^5
Lichen-pine forest	4,08	10^5
Dry forb meadow	3,49	10^4
Green-moss spruce forest	3,57	10^2

8. We have attempted to estimate what part of the soil organic matter decomposes in the year. According to experts [1], one hectare of permafrost soils in Olekminsky ulus was contained 99 tons of organic matter in the layer of 0-20 cm depth. If we assume that during the frost-free period of the decomposition rate remained the same and amounted to3.5 g of CO2 per m^2 / day in average we can find that for the month seceded at 1.08 tons of CO_2 , and for the entire period could degrade about 3 - 3.5 tons of organic matter , or about 2.5 % of the organic matter contained in the soil in an area of one hectare.

References

1. Mazilkin I. A., 1956. The microbiological characteristics of sod -forest and humus - calcareous soils in the Olekminsky region of the Yakutia. Proceedings of the Yakutia's affiliate of SB RAS, Vol. 1, P. 134-175.
2. Anderson J.P.E. and Domsch K.H., 1980. Quantities of plant nutrients in the microbial biomass of selected soils. *Soil. sci*. 130, 211- 216.
3. Kuzmina N. P., 2010. Microbiocenoses of alas- and anthropogenic - transformed soils of Central Yakutia. Ulan-Ude, 22 p.
4. Mishustin E. N., 1953. Microorganisms and the soil fertility. Nature, Vol. 10.

Down Regulation of PSII Efficiency in Sun Exposed Assimilating Shoots of *Ephedra monosperma* During Autumn Cold Hardening

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Key words: low temperatures, chlorophyll fluorescence, NPQ

Introduction

Cold hardening in evergreen plants in East Siberia at early autumn is triggered by decreasing photoperiod and potentiated by moderate cool daily average temperatures +4 – +8 °C. This process is accompanied with deep rearrangements of the photosynthetic machinery, including acclimation in the energy partitioning in PS II (Ottander et al.; 1995; Savitch et al., 2002; Öquist & Huner, 2003; Adams III et al., 2004; Ensminger, 2004; Zarter, 2006; Buch et al., 2007). Harmless thermal dissipation of light energy absorbed during cold periods becomes of fundamental importance for photoprotection of the photosynthetic apparatus when photosynthetic activity is low or inhibited fully.

In the present study we characterized the down-regulation of maximal photochemical efficiency of photosystem II (PSII) in sun exposed assimilating shoots of *Ephedra monosperma*, measured as the ratio of variable to maximal chlorophyll fluorescence $F_V/F_M = (F_M - F_O)/F_M$ (Bilger and Björkman, 1990) at longer time-scale (from July until Janiary) under natural field condition. Cold adaptive energy dissipation in the PS2 antenna was characterized via evaluation of (a) *qE*, energy dependent quenching component of NPQ; (b) the quantum yield of regulated ΔpH- and/or xanthophyll-dependent NPQ (Φ_{NPQ}); (c) the quantum yield of non-regulated energy losses ($\Phi_{f,D}$).

Materials and methods

Ephedra monosperma ex C.A. Meyer (division Gnetophyta, class Gnetopsida, order Gnetales, family Ephedraceae) is a perennial evergreen small subshrub, over-wintering under a snow mantle. Its height typically varies between 20 and 25 cm. *E. monosperma* is *a* heliophilous and xerophilous plant with long subterranean trunks or creeping runners. We monitored 10–15-year-old plants, growing in the Botanical Garden of the Institute of Biological Problems of Cryolithozone located on the second terrace of the Lena river (62°15′ N, 129°37′ E). Experiments were carried out during 2010–2012. In summer plant-watering was performed once a week, excluding rainy days. Annual changes of weather characteristics were approximately the same during three years. In May–September an average air temperature was 13.5-14.2°C, the sum of precipitations was 142-161 mm. Winter temperatures drop down to –46… –48°C. In December-January snow height was typically 44–48 cm, temperature at a depth of 15 cm from snow surface ranged between –20 and –24ºC.

Air temperature and photosynthetic photon flux density (PPFD) were recorded with a DS 1922L iBitton thermograph (Dallas Semiconductor, United States) and a LI-190 (LI-COR, USA), respectively. Temperatures were taken from the values measured every hour (from 1:00 to 24 h). PPFD was measured every half hour during daylight period and average value was calculated. Pigments were extracted from the shoots in acetone (100%) at 8°C in the dark. Total chlorophyll and total carotenoids were estimated spectrophotometrically (Lichtenthaler 1987). Pigments were separated on a reversed phase Nucleosil C18 column (Teknokroma, Spain) by HPLC (Gilmore and Yamamoto, 1991).

To determine fluorescence quenching parameters, a field-portable pulse modulation fluorometer PAM-2500 (Walz, Effeltrich, Germany) was used. During July - September F_V/F_M was measured in the field before sunrise. During October – January this parameter was estimated in the laboratory at room temperature. For this shoots were cut before sunrise, placed in a thermostat at air temperature, and brought to the laboratory. Thereafter, shoots were kept for 30 min in the dark at room temperature, followed by fluorescence measurements. F_o and F_M values are normalized to F_o value recorded on the 10th August at temperature 13.1°C and Chl content (Kornyeyev, 2002). The energy dependent quenching *qE*, was estimated from kinetics, using a formulae (F_M/F_M' - F_M/F_M''), where F_m' is the maximal fluorescence yield at the end of illumination period, F_M'' is the maximal fluorescence yield after 10 min of dark relaxation period. The quantum yields of loss processes of absorbed excitation energy in PS II were calculated as $\Phi_{NPQ} = F/F_M' - F/F_M$ and $\Phi_{f,D} = F/F_M$ according to Klughammer and Schreiber (2008). Tables and graphs show mean values with their standard deviation from 8-16 replications.

Results and Discussion

During cold acclimation Chl *(a+b)* levels decreased by 25-27% from breaking of September to mid October, while total carotenoids increased less than 13% in shoots (table). Ratio Chl *a*/Chl *b* was constant (4.1±0.1) in all year seasons. In general, the share of neoxanthin and lutein made up approximately half of the carotenoid pool and did not vary much between seasons. In contrast, the fractions of the remaining carotenoids were more variable. This indicated by a decrease in β-carotene and violaxanthin (Fig. 4) reaching only about half of the values observed in the summer and beginning of September. In turn, at zero and subzero temperatures the highest amount of zeaxanthin but less increased content of antheraxanthin were observed. As a result, the deepoxidation state of xanthophyll cycle was considerably higher (0.8) since mid October, when daily average temperatures were approximately zero and subsequently from -10 to -25°C. Should be noted that deepoxidation state was equal to 0.35 and 0.6 at the beginning and the end of September at daily average temperatures 9±2°C and 1±2°C.

Table. The content of photosynthetic pigments (mg/g DW) in shoots of Ephedra monosperma in 2010-2012. Values are means of ±SD (n=9-12).

Months	Chl (a+ b)	Total carotenoids	Chl / Car
July – August	2.82±0.23	0.62±0.04	4.6±0.3
September	2.46±0.17	0.70±0.06	3.7±0.3
October – January	2.07±0.24	0.69±0.04	3.0±0.3

We characterized the down-regulation of maximal photochemical efficiency of photosystem II (PSII) in sun exposed assimilating shoots of *E. monosperma*, measured as the ratio of variable to maximal chlorophyll fluorescence ($F_V/F_M = (F_M - F_O)/F_M$) at longer time-scale (from July until January) under natural field condition. F_V/F_M decreased to 54% in comparison with summer values at temperature range from +8.0 to -10.4°C (Fig. 1). Correlation coefficients have been calculated for F_V/F_M with daily average temperatures and PPFD. The correlations have been tested using a *t*-test. The maximal quantum yield of photochemical energy conversion show high positive correlation with daily average temperatures: $F_V/F_M = 0{,}620+0{,}025{*}T$ ($t = 7{,}899$; $P \le 0.05$). The correlation with photosynthetic photon flux density under natural field condition is insignificant.

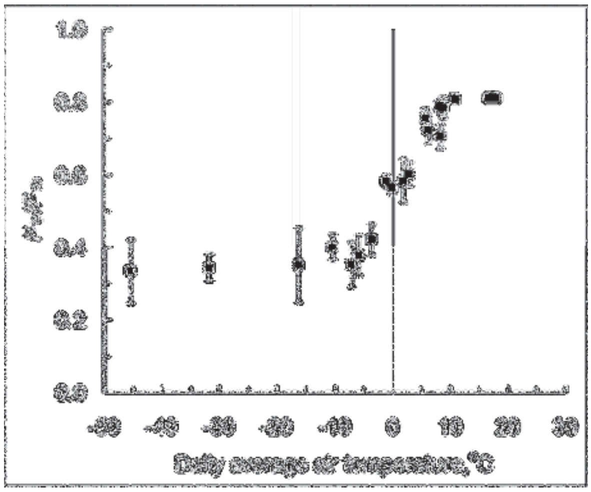

Fig. 1. Distribution of F_v/F_m parameter versus air temperature in *E. monosperma*. Measurements were carried out under field conditions during 2010-2012. Temperature values are average for 3 days. Fluorescence was recorded every third day one hour before sunrise. Values are means of 7-16 measurements ±SD.

The long-term response of F_V/F_M to low temperatures consists of two major phases: decrease only of F_M (maximal chlorophyll fluorescence yield), which occurs at temperatures slightly above zero and simultaneous suppression of F_M and F_o (basic chlorophyll fluorescence yield) which occurs at zero and subzero temperatures (Fig. 2). The energy dependent quenching *qE* gradually decreased since the beginning of September (Fig. 3), and could not ensure safely energy partitioning in photosynthetic apparatus. The development of sustained thermal dissipation of absorbed light in PSII core became seasonal acclimation process. Under moderate environmental stress at temperatures slightly above zero it may be correlated with sustained phosphorylation of all PSII core proteins D1, D2, CP43 and PsbH (Ebbert *et al.*, 2005, Demmig-Adams and Adams III, 2006; Verhoeven et al., 2009) or partial loss of photosystem II reaction-center D1 protein (Ottander et al.; 1995; Savitch et al., 2002; Öquist & Huner, 2003) in concert with early process of

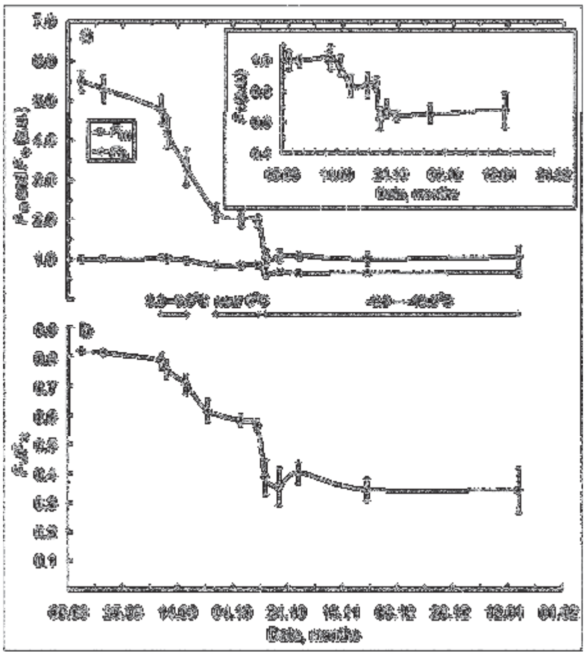

Fig. 2. Seasonal changes of Chl fluorescence parameters in shoots ts of *E. monosperma* measured *in situ* in 2011. Values are average of 7-9 measurements. Vertical bars show standard deviations, and horizontal bars represent temperature intervals for the given periods of measurements.

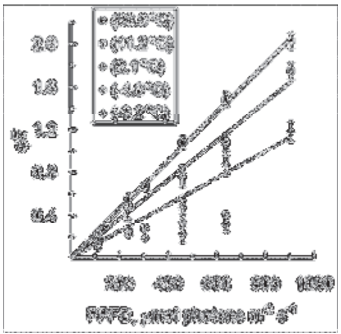

Fig. 3. The influence of daily average temperatures on light curves of the energy dependent quenching component of NPQ (*qE*) in *E. monosperma*. For each measurement shoots were cut from field plants then incubated 60 min at room temperature in the dark, followed by fluorescence measurement. Values are mean ± SD, n = 4.

frost hardening when a shortened photoperiod is combined with lowering of the temperature to a day/night temperature regime of 6.2 ± 2.1/3.2 ± 2.6^{o}C. In steady state photosynthesis conditions the D1 protein is continuously degraded but also continuously resynthesized (Trebst, 2003). Under low temperature the Q_A, Q_B and the PQ pool change their redox state, so more P680 triplet and singlet oxygen are formed. Enhanced D1 protein degradation by singlet oxygen, the low rate of translation and assembly of new D1 protein may no longer compensate the degradation rate. Subsequently under severe environmental conditions at around zero and subzero temperatures we observed simultaneous increase in $\phi_{f,\,D}$ (the 'constitutive losses', corresponding to the sum of non-regulated heat dissipation and fluorescence emission) and zeaxanthin.

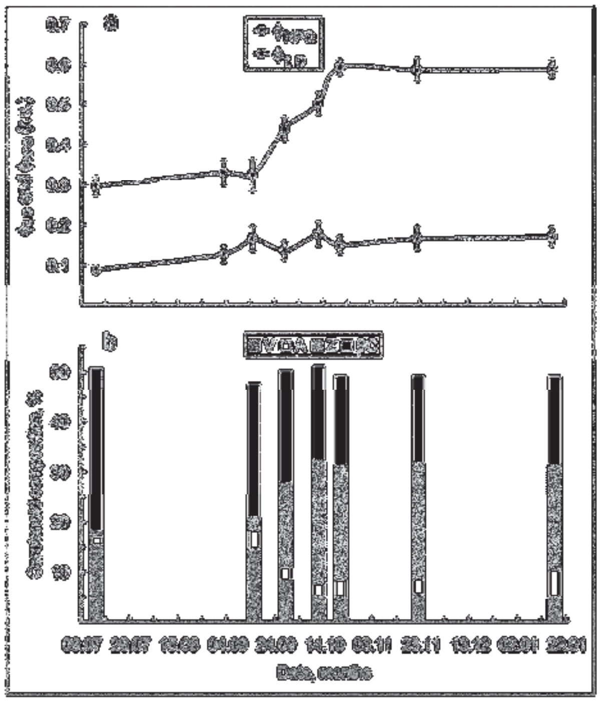

Fig. 4. Seasonal changes in non-phothochemical quenching parameters (a) and carotenoid composition(b) in branchlets of *E. monosperma*. For each measurement branchlets were cut from field plants then incubated 60 min at room temperature in the dark, followed by fluorescence measurement. Non-photochemical quenching was induced by light of PPFD=305 µmol photons m^{-2} s^{-1} (see details in Material and Methods). Values are mean ± SD, n = 4-6.

The degree of photoinhibition determined as the percentage of decrease of the initial F_V/F_M values, was increased to 44.6 ± 3.2%. So the slowly relaxing components qI of NPQ (non photochemical quenching), attributed to photoinhibition, is also enhanced. It is persistent in the dark and maintained not only within the reaction centers but also in the antenna pigment–protein complexes and not dependent on low lumenal pH. The accumulation of zeaxanthin contributes to qI, a component of NPQ whose origin was until now poorly understood. The switch between the different CP 24, CP26, CP29 and LHCII proteins conformations as a result deep rearrangements of the photosynthetic machinery may be activated by the binding of zeaxanthin to the allosteric site L2, which display pH- independent fluorescence quenching (Dall Osto et al., 2005).

References

Adams W.W. III, Zarter C.R., Ebbert V., Demmig-Adams B., 2004. Photoprotective strategies of overwintering evergreens. *Bioscience* **54**, 41–49.

Bilger E., Björkman O., 1990. Role of the xanthophyll cycle in photoprotection elucidated by measurements of light-induced absorbance changes, fluorescence and photosynthesis in leaves of *Hedera canariensis*. *Photosynth Res*. **25**,173–185.

Busch F., Huner NPA., Ensminger I., 2007. Increased air temperature during simulated autumn conditions does not increase photosynthetic carbon gain but affects the dissipation of excess energy in seedlings of the evergreen conifer Jack pine. *Plant Physiol.* **143**, 1242–1251.

Dall'Osto L., Caffarri S., Bassi R. 2005. A Mechanism of Nonphotochemical Energy Dissipation, Independent from PsbS, Revealed by a Conformational Change in the Antenna Protein CP26. *The Plant Cell*, **17**, 1217–1232.

Demmig-Adams B., Adams W.W., 2006. Photoprotection in an ecological context: the remarkable complexity of thermal energy dissipation. *New Phytol.* 172:11–21.

Ebbert V., Adams W.W. III., Mattoo A. K., Sokolenko A. Demmig-Adams B., 2005 Upregulation of a PSII core protein phosphatase inhibitor and sustained D1 phosphorylation in zexanthin-retaining, photoinhibited needles of overwintering Douglas fir. *Plant Cell Environ.* **28**, 232 – 240.

Ensminger I, Busch F, Huner NPA., 2006. Photostasis and cold acclimation: sensing low temperature through photosynthesis. *Physiol Plant* **126**, 28–44.

Gilmore, A.M. and Yamamoto, H.Y., 1991. Resolution of Lutein and Zeaxanthin Using a Non-Endcapped, Lightly Carbon Loaded C18 High-Performance Liquid Chromatographic Column. *J. Chromatogr.* **35**, 67–78.

Klughammer C., Schreiber U., 2008. Complementary PS II quantum yields calculated from simple fluorescence parameters measured by PAM fluorometry and the Saturation Pulse method. *PAM Application Notes*, **1**, 27-35.

Kornyeyev D. Yu. 2002. *Chlorophyll fluorescence induction method: information potentialities.* K.: «Alt-Press». 188 p. (in Russian).

Lichtenthaler H. K., 1987. Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. *Methods Enzymol*. **148**, 350–382.

Öquist G., Huner N.P.A., 2003. Photosynthesis of overwintering evergreen plants. *Annual Review of Plant Biology* **54**, 329–355.

Ottander C., Campbell D., Öquist G., 1995. Seasonal changes in photosystem II organization and pigment composition in Pinus sylvestris. *Planta* **197**, 176–183.

Savitch L. V., Leonardos E. D.,, Krol M., Jansson S., Grodzinski B., Huner N.P.A., Öquist G., 2002. Two different strategies for light utilization in photosynthesis in relation to growth and cold acclimation. *Plant Cell Environ.* **25**, 761–771.

Trebst A., 2003. Function of β-carotene and tocopherol in photosystem II. Z. Naturforsch. 58c, 609-620.

Verhoeven A., Osmolak A., Morales P., Crow J., 2009. Seasonal changes in abundance and phosphorylation status of photosynthetic proteins in eastern white pine and balsam fir. *Tree Physiol* **29**, 361 – 374.

Zarter, C.R, Adams W. W. III, Ebbert V., Adamska I., Jansson S,, Demmig-Adams B. 2006. Winter acclimation of PsbS and related proteins in the evergreen *Arctostaphylos uvaursi* as influenced by altitude and light environment. *Plant Cell Environ.* **29**, 869–878.

Radioactive pollution effect over microflora of cryogenic soils of Yakutia

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Key words: permafrost, cesium, thorium, soil, microorganisms, filamentous fungi, cellulolytic organisms, stability

Introduction

Principal contribution to formation of radioactive pollution over the territory of Yakutia has been made by natural radioactive elements (uranium, thorium, radon) containing in rocks. The regions of uranium and thorium production and zones of emergency underground nuclear explosions (UNE) are characterized with increased values of radiation. In fact 12 UNEs were set off over the territory of the Republic of Sakha (Yakutia) during 1974-1987, two of them "Crystal" and "Kraton-3" sites got the status of radiation accidents [1].

Investigation of microbial communities of soils in radioactive polluted zones and importance of microorganisms in their evolution was particularly considered after the Chernobyl accident and recently after "Fukushima-1".

Objects and methods

Radioecological and microbiological research was conducted in two zones of radioactive pollution of Yakutia. The first zone is in the upper reaches of the Markha River where in the summer 1978 an accidental underground nuclear explosion (AUNE) of plutonium charge code-named "Kraton-3" occurred for peaceful purposes (40 km east of Aikhal settlement). The nuclear yeild of 22 kt, which was put at the depth of 577m, belched radioactive products of explosion on the ground surface and into the atmosphere because of bad sealing of the hole. Powerful emergency emission of radiation turned the woodland in the direction of the radioactive cloud distribution into a "dead" area, embracing the area about 600 m x 2000 m.

In 2012 in the progress of summer field work, three soil sections were made: at the edge of the dead wood; across the radioactive track axis; and approx 200 m far from the hole mouth. The soil cover of these areas is distinguished with sod-carbonate typical and sod-carbonate destructive soils. The content of ^{137}Cs in the examined soils makes from 1.1 to 29903 Bq/kg of air-dry weight decreasing its concetration with soil profile depth. The highest ^{137}Cs concentration is found in the topsoil horizons where it exceeded its background level by 2 and 230 times.

The second zone is located in the upper part of the divide of the Vasilievka stream (Aldan Highlands). From 1949 to 1953 the USSR Dal'stroy performed mining of the thorium mineral (turnerite) in the placer deposit in this region.

Sands of primary dressing are stored near the the dressing enterprise. Now the exposure rate of gamma-radiation varies within 120-400 mR/h on the sand dump surface. And the thorium concentration (^{232}Th) in sands makes 1445-1612 Bq/kg.

Resulting from wind scattering and atmospheric precipitation washout part of sand was disseminated round the dump and grown with vegetation.

Soil sections were put in the prevailing direction of the wind at a 25-m (section 1) and 85-m (section 2) distance from sand dumps.

In the studied soil sections ^{232}Th concentration changes from 34 to 1536 Bq/kg of the air dry weight of soil. The highest ^{232}Th concentrations are found in the top soil sections. In this part of soils ^{232}Th accumulation exceeded its background values ranging from 1.6 to 34 times.

Results and discussion

Abudance of microorganisms in sod-carbonate soils of "Kraton-3" site fluctuated from 3 thousand to 542 mln CFU/g [2]. In polluted section 1 the pool of ammonifiers sharply changed on a profile, at a 20-30-cm depth it made 451 mln CFU/g that is 4 times more of their number in the topsoil- 127 mln CFU/g with the value of cesium content there 230 times greater. Polluted stction 1 showed the following values: oligonitrophil bacteria twice as little; micelial fungi – 1 order less; actinomycete -2 orders less as compared to conditionally "clean" section 3. Distribution of actinomycete on profiles of the studied soil sections also strongly differed from each other: s. 2 ($1.92x10^8$) and s.1 ($8.25x10^7$) and maximum number of actinomycete ($4.54x10^8$ CFU/g) was noted in clean s.3 (fig.1).

Dependence of microorganisms abundance on humidity wasn't detected in the studied soils. The radioactive cesium was the

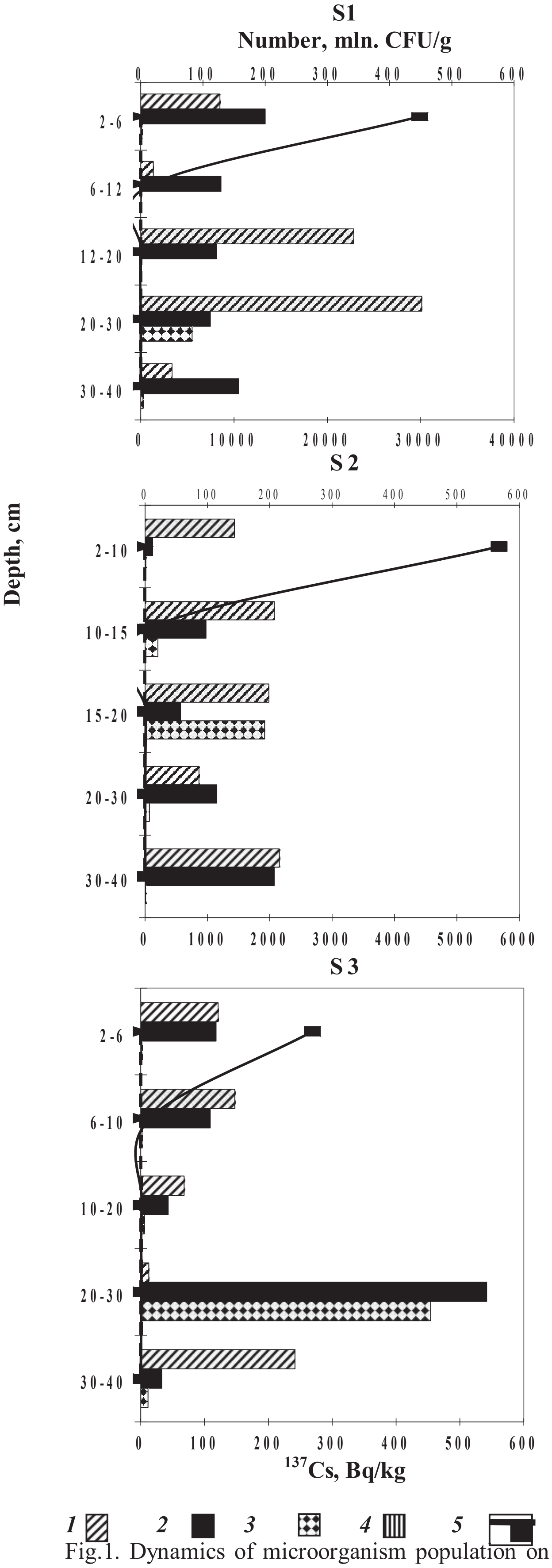

Fig.1. Dynamics of microorganism population on cesium content (*5*) sod-calcareous soils on the Kraton-3 site Microorganisms: *1* – ammonifiers, *2* – oligonitrophils, *3* – actinomycetes, *4* – filamentous fungi

major factor which regulated the size of microorganisms population. With increase in cesium content a 2-3-order drop in the number of microorganisms in the soil was observed, dependence is strictly negative in all studied soil sections (fig.1). With depth and reduction of the cesium content the pool of ammonifiers, antinomycete, oligonytrophils increases.

Filamentous fungi and cellulosolytic bacteria showed resistance to the higher content of radio-cesium: 20 ths filamentous fungi in humic horizon A s.1 with the radiocesium content 29903 Bq/kg; 7 ths CFU/g of cellulosolytics. Section 2 produced its maximum - 17 ths CFU/g, of cellulosolytic bacteria at the depths of 2-10 cm with radiocesium concentration 5676 Bq/kg.

Such stability of microorganisms to ^{137}Cs can be explained by this radionuclide unique chemical nature. Radiocesium has a long half-life period (almost 30 yrs), high solubility of its salts in the water, similarity to physical and chemical properties with potassium cause high bioavailability of cesium within many decades after emission in the environment [3]. Recently a few works appeared on cesium ions accumulation by actinobacteria of genus Rhodococcus and use of these bacteria when developing a biotechnological way of purification of the industrial waters polluted by radionuclides and oil products. Only single works on the use of bacteria from genus Rhodococcus are known [4].

Cesium is a rare element. Apparently, it is reasonable to agree with S. Avery's opinion (1995b) that in view of rare cesium occurrence in the environment, there are no adaptations in the living organisms interfering penetration of cesium ions in cells [5]. It once again emphasizes high biological availability of cesium.

One of the 10 brightest scientific news of 2011 was the discovery of Japanese scientists who found a way of radiation washout from water and soil.

The team of scientists from university Hiroshima Kokusai Gakuin headed by professor Ken Sasaki found a solution for microbes using which eat radioactive materials. If they are put in the water or in soil containing cesium, every other day microbes reduce the level of radioactive materials to

1/12 and completely remove these elements in three days.

Microorganisms population in typical sub-bur soils of the Vasilievka stream according to solid medium inoculation ranged from 10^3 to 10^9 CFU/g of soil, i.e. made from one thousand to billion cells in 1 g of soil ACB. Oligonitrophil microorganisms totalling 4.67 billion CFU/g of soil in hor.B s.2 at a 85-m distance from the dump of radioactive sand made the greatest populatioan in the microbial pool in the sub-bur soils, the background content of thorium here was 38 Bq/kg of the air dry weight (fig.2).

Other physiological groups of microorganisms investigated by us, showed their direct dependence on concentration of thorium. The higher thorium content in the sub-bur soils was registered, the more microorganisms were detected. For example, cellulosolytic bacteria and actynomycete making 34 ths and 2.89 billion CFU/g, correspondingly, were found in the same conditionally "clean" section 2, but topsoil horizon of A1A2 containing ^{232}Th - 60 Bq/kg of air and dry weight exhibited the indices that by 1,6 times exceed its background values (fig.2).

The most unusual thing was distribution of ammoniphiers, their greatest population totalling 666 mln CFU/g, was found in the topsoil of s.1 at the depths of 7-11 cm. In this soil part ^{232}Th concentration was 1535 Bq/kg of the air and dry weight, that exceeds the background values by 34 times.

Microorganisms distribution on profiles of the soils under examination gave a direct correlation with thorium content and did not depend on humidity of these soils (fig. 2). The more thorium is, the more oligonitrophils, actinomycete and ammonifiers are found. Thereby long action of radioactive cesium on soil microorganisms differed from the effect of radioactive thorium.

It may be associated both with different types of cryogenic soils in these radioactive zones, and the effect of the studied radionuclides. Radioactive cesium is one of the principal components of technogenic radioactive pollution of the biosphere. Its action is most destructive on the living organisms.

Thorium is a slightly radioactive chemical element, its action can be compared with the action of low doses of radiation [6].

Low doses of ionizing radiation often stimulate the development of some microorganisms, and with increase in a dose, a specific effect that is expressed first of all, in the change of the total population of soil microorganisms is noted. Occasionally there is an increase in the bundance of

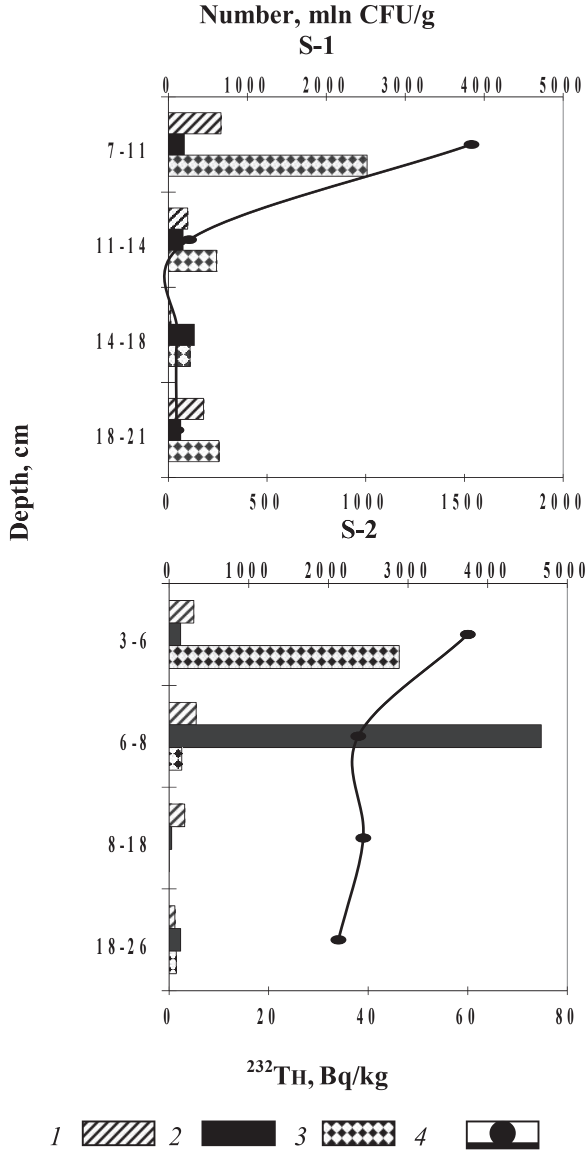

Fig. 2. Abundance of microorganisms – thorium content dependence (*4*) in soils at the Vasilievka stream, 2012. Microorganisms: *1* – ammonifiers, *2* – oligonitrophils, *3* – actinomycetes.

microflora, not decrease as it develops at lead contamination. Some researchers explain it because of sensible microorganisms death and an active development of form stability using an energy potential of died cells [7,8].

Lately, it became known, that Microorganisms found at the International Space Station, were recognized as dangerous because they can cause faulty operation of all station's equipment. Vice-president of the Russian Academy of Sciences - Anatoly Grigoriev - reported about it in mass media.

"Earlier, we had already faced with a problem of a disastrous impact of microflora on "Mir" station and now we faced it on the ISS. These microbes negatively influence on the ISS construction affecting not only metal, but also polymers. Microbes are likely to be the main reason of the engineering equipment failure" – reported Grigoriev at the scientific conference held in Moscow.

Vice-president also reported that the experiment providing exhibiting of biological objects , which are on the outer side of the ISS proved high viability of microorganisms in the conditions of the outer space for 18, 31 and even more months. This information was presented by the "Interfax" agency. The filamentous fungi and cellulosolytic bacteria resistant to radiocesium found by us and those from the ISS are likely related to each other.

The population of microorganisms inhabiting cryogenic soils of the Elkon uranium-ore area in South Yakutia fluctuated from 10^3 to 10^7 CFU/g (study of 2006-2009). The maximum population of microorganisms in alluvial soils (76 million C/g) of the Elkon zone, studied earlier, was 2 order less, than in pale-yellow forest soils of Central Yakutia (3-8.5 billion C/g [14] and 3 order less, than in soils of the middle and southern taiga (28-50 billion C/g) in the European territory of Russia [15].

Conclusions

1. Soil microorganisms in the radioactive zones of Yakutia under study that experienced radiation action over a long period of time are characterized with high resistance to anthropogenic radioactive contamination.
2. Total population of microorganisms in thorium sands of the Vasilievka stream amounted to billions of cells/1 g of soil, and this by an order is greater than in soils on the Kraton-3 site, where hundreds of millions of cells/1g of soil were found.
3. Dependence of microorganism abundance on radiocesium proves to be negative while positive on thorium.
4. Filamentous fungi and cellulosolytic bacteria showed resistance to higher-than average radocesium concentration: abundance of filamentous fungi made 20 000 and cellulosolytic bacteria 7 000 CFU/g in hor. A s. 1 with ^{137}Cs - 29903 Bq/kg content.

References

1. Gedeonov, A.D., Petrov, E.R., Alexeev, V.G., Kuleshova, I.N., Savopulo, M.L., Burtsev, I.S., Shkroev, V.Yu., Arkhipov. Residual radioactive contamination at the peaceful underground nuclear explosion sites "Craton-3" and "Crystal" in the Republic of Sakha (Yakutia)// J. Environmental Radioactivity. – 2002. - V. 60. - N. 1-2. - pp. 221-234.
2. D. G. Zvyagintsev (Ed.), Methods of Soil Microbiology and Biochemistry (Mosk. Gos. Univ., Moscow, 1991) [in Russian].
3. De Rome L., Gadd G.M. Use of pelleted and immobilized yeast and fungal biomass for heavy metal and radionuclide recovery//! Ind. Microbiol. -1991.-V. 123.-P. 447-453.
4. Tomioka N., Uchiyama H., Yagi O. Caesium accumulation and growth characteristics of Rhodococcus erythropolis CS98 and Rhodococcus sp. strain CS402//Appl. Environ. Microbiol. 1994. - V. 60, N. 7. - P. 2227-2231.
5. Avery S.V. Microbial interaction with caesium implication for biotechnology//! Chem. Technol. Biotechnol. - 1995b. - V. 62. - P. 3-16.
6. G. Audi, A.H. Wapstra, and C. Thibault (2003). «The AME2003 atomic mass evaluation (II). Tables, graphs, and references». *Nuclear Physics A* 729: P.337-676.
7. T. Doolotkeldieva and Ch. M. Omurgazieva, in *Science of Kyrgyzstan in the 21th Century, Collected Papers Dedicated to the First Congress of Scientists of the Kirghiz Republic*, (Bishkek, 2001), Issue 3, p. 218.
8. S. V. Letunov and V. V. Kovalskii, *Geochemical Ecology of Microorganisms* (Nauka, Moscow, 1978) [in Russian]
9. T. I. Ivanova, N. P. Kononova, N. V. Nikolaeva, and A. P. Chevychelov, "Microorganisms in Forest Soils of the Central Yakutia," Pochvovedenie, No. 6, 735–740 (2006) [Eur. Soil Sci. **39** (6), 661–666 (2006)].
10. A.V. Golovchenko and L. M. Polyanskaya, "Peculiaritiesof the Annual Dynamics of Microorganisms in Southern Taiga Soils," Pochvovedenie, No. 4, 471–477 (2000) [Eur. Soil Sci. **33** (4), 411–416 (2000)].

Dehydrins associated with extreme frost hardiness of *Betula platyphylla* in Central Yakutia

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Key words: Central Yakutia, Betula platyphylla, frost hardiness, dehydrins

Introduction

Under the influence of sharply continental climate of Yakutia unique species and varieties of plants adapted to extreme frosts and summer droughts were formed. This region has a relatively small diversity of higher vascular plants comprising about 2000 species, 27 of them are trees (Timofeev, 2003).

Betula platyphylla Sukacz. is the main deciduous, forest-forming species in Central Yakutia. It occupies approximately 2% of the forest covering 300 000 km^2 and with the conifers stabilizes perennially frozen grounds. In connection with global climate change displacement of forest areas further to the Arctic is possible. Under this scenario an increasing role of deciduous species is possible in the taiga ecosystems. Moderate requirements in climatic, edaphic factors and other features define a high birch potential in the pioneer settling of free spaces because of forest felling, fires and technogenic pollution. Birch significance may be greater with its ability to reclaim territories damaged by anthropogenic effect.

Its ecological plasticity is directly related to genetic polymorphism found in the pattern of protein polymorphism (Vetchinnikova, 2002). Birch is well suited as a model species to study plant adaptation to unfavorable environmental factors including frost.

The ability to cold acclimation is known to be associated with massive reprogramming of gene expression. Among the several hundred genes that are modified in response to cold, the most abundant group of long-term up-regulated genes is encoding dehydrins or other late embryogenesis-abundant-proteins (LEA) (Fowler, Thomashow, 2002). They accumulate during dehydrative stresses caused by or associated with low/freezing temperature, drought, salinity, embryo desiccation and abscisic acid (ABA) (Close, 1996; Svensson et al., 2002; Kosova et al., 2010).

It is assumed that dehydrins participate in protection of cells when water is moving from the cytoplasm to form extracellular ice during the overwintering process (Welling, Palva, 2006). Several studies have demonstrated seasonal variation in dehydrin gene expression and protein content in various woody plants, the level being high during the winter and low during the active growth period (Wisniewski et al., 1996; Rinne et al., 1998; Kontunen-Soppela, Laine, 2001; Karlson et al., 2003; Welling, 2004).

We have identified several dehydrins in separate birch organs in Central Yakutia (Bubyakina et al., 2011; Petrov et al., 2011). Here we reveal characteristics of the unique frost hardiness of *B. platyphylla* under the extreme climatic conditions of Eastern Siberia through immunological detection of bud dehydrins to determine the following questions: (i) is there intraspecific polymorphism of dehydrins in birches (ii) what are the peculiarities of the annual variation of dehydrins during seasonal temperature changes and how are these associated with the water content in plants?

Materials and methods

Mature birches (*Betula platyphylla* Sukacz.) approximately 40-50 years old, growing at the Botanical Garden of the Institute of Biological Problems of Cryolithozone (Siberian Branch of Russian Academy of Sciences), located on the second Lena river terrace, 7 km west of Yakutsk (62°15′ N, 129°37′ E), were used for sampling. Samples were collected for analyses monthly from January to December 2009-2012. The weather characteristics during plant growth and development were typical.

Samples from 14 individual birches were analyzed separately. For isolation of total proteins, birch buds (1.5 g) were ground in liquid nitrogen with a mortar and pestle and homogenized in the extraction buffer (20 ml) in the presence of insoluble polyvinylpyrrolidone (Serva, Germany; 2.5 % of the volume of the extraction buffer). The extraction buffer contained 0.1 M Tris–HCl, pH 7.5, 12 mM 2-mercaptoethanol, 1% SDS, 10 mM EDTA, and 3 mM phenylmethylsulfonyl fluoride (Korotaeva et al., 2011). The homogenate was centrifuged at 50 000 x g for 30 min. All procedures were performed at 4°C. Proteins were sedimented with 5 volumes of acetone at –20°C during 1 h. The content of protein was determined by the method of Lowry using the kit from Bio-Rad (USA). Electrophoresis was conducted on a mini-Protean tetra cell (Bio-Rad, USA) in 12.5% SDS-PAGE (Laemmli, 1970), using molecular weight markers from Fermentas (Lithuania). Proteins were stained with Coomassie R 250. Equal amount of protein (15 µg) was loaded on each lane.

Proteins were transferred from the gel to the polyvinylidene fluoride membranes (Bio-Rad, USA) using a mini trans-blot electrophoretic transfer cell (Bio-Rad, USA). Dehydrins were identified using polyclonal antibody raised against dehydrin conserved K-segment (Close et al., 1993) (Agrisera, Sweden) at a dilution 1 : 500. Control immunoassays were also performed with the dehydrin K-segment specific antibody blocked with the same peptide (Close et al., 1993) according to the manufacturer's instructions (Agrisera, Sweden). Dehydrins were visualized by rabbit antibody conjugated with alkaline phosphatase at a dilution of 1 : 2 500 (Sigma, USA). Nitro blue tetrazolium and 5-bromo-4-chloro-3-indolyl phosphate (AppliChem, Germany) were used as chromogenic substrates.

The water content of buds from field-grown trees was measured by weighing the samples immediately after collection (fresh weight, FW). The dry weight (DW) was measured after drying in an oven at 105°C to a constant weight. Water content was calculated from the formula [(FW-DW)/FW] X 100%. Mean values and their standard error are presented.

All data were processed with Microsoft Excel 2010 software using the macro complement Excel 4.0 (XLM).

Results and Discussion

The profile of the total proteins was analyzed at the example of birch Ya3 (Fig. 1). The profiles of the total proteins of other birches are not brought in this article because they are actually similar to the considered. We identified about 60 bands of polypeptides with different molecular masses. Binary bands of proteins with molecular masses 26-27 and 49-51 kDa are specific features of the profile of the total proteins. The proteins of 26-27 kDa display an annual variation with the greatest content during dormancy and disappearance in the middle of vegetation (July), whereas proteins of 49-51 kDa are observed all year round. There is a band of 17 kDa with a prominent seasonal variation. The dehydrin of 17 kDa is supposed to be in this region. A 42-kDa polypeptide is a major protein with a higher content during dormancy. Some polypeptides of 60, 68 and 79 kDa are the most represented in the summer and we assume them to be associated with the growth and development of plants.

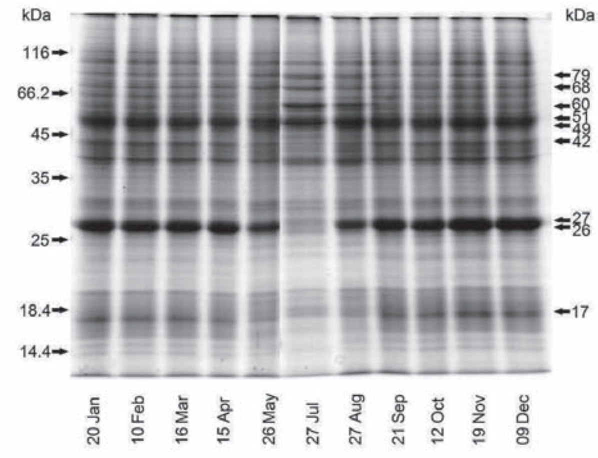

Fig. 1. SDS-PAGE profile of total proteins in buds of birch Ya3 from January to December 2009. Molecular masses of protein markers are shown on the left. The apparent molecular masses of selected proteins are indicated on the right.

Two groups of dehydrins were identified. The first group unites dehydrins with low molecular masses (15-21 kDa). Dehydrins with molecular masses in the range of 56-73 kDa are attributed to the second group. A dehydrin of 17 kDa is abundant in all investigated birches. Dehydrins of 15, 18 and 21 kDa are detected with lower frequency. Relatively high molecular dehydrins have many forms (15 at least). Dehydrins of 66 and 69 kDa are major proteins in many birches, others are abundant in some plants.

The annual variation of dehydrins was measured to determine their relationship with the frost hardiness of plants. Common features of the seasonal variation are: decrease in the dehydrin level after coming from dormancy, their minimum or absence during vegetation and further increase in late summer (August) (Fig. 2). Dehydrins reach a relatively constant level in the end of phenological autumn in Central Yakutia

(October). The seasonal production pattern of dehydrins with higher molecular mass (56-73 kDa) is somewhat different from that of low molecular dehydrins (15-21 kDa). Dehydrins of 56-73 kDa are observed in all seasons and do not disappear completely in the summer though their amount decreases during vegetation. Low molecular dehydrins show an annual variation, disappearing completely in the spring (April-May). They are not found in the summer months and are observed again early in the cycle of dormancy preparation. There are individual displacements in appearance and disappearance of low molecular dehydrins.

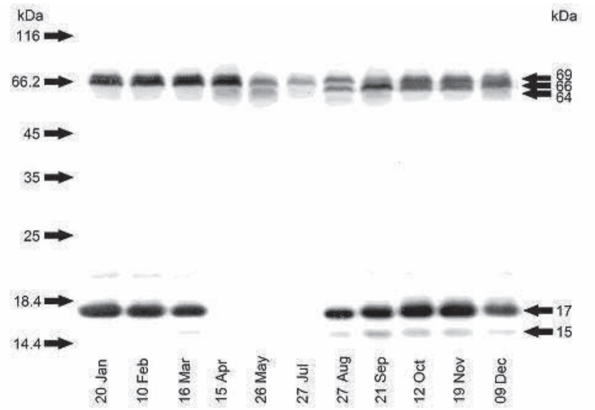

Fig. 2. Western-blot of proteins from buds of individual birch Ya6 *B. platyphylla* from January to December 2009. Molecular masses of standards are indicated on the left. The apparent molecular masses of dehydrins are shown on the right.

The climatic features of the regions define the phenological rhythm of plants. According to average long-term observation, sap circulation in the Yakutian birches, fixing the beginning of the plant vegetation period, occurs differently in May (in early, middle and late month) and is connected with the definite sum of positive temperatures. A short vegetation season in plants of the North is balanced by their intensive growth in the first half of the summer.

Among dehydrins the major one of 17 kDa is the most interesting. It is found in all investigated individual plants and shows the specific accumulation pattern during the annual cycle. The coloration intensity of the 17-kDa dehydrin in the three different birches is similar, differing only in quantitative values (Fig. 3). Short day length and low non-freezing temperatures lead to a cessation of plant growth. The appearance of the dehydrin of 17 kDa correlates with dehydration and coincides with the beginning of the autumn coloring of leaves in late August. Starting at the time of permanent snowfall cover in Central Yakutia (mid-October) the amount of dehydrin of 17 kDa attains its stationary level and remains high throughout the winter months disappearing in April-May.

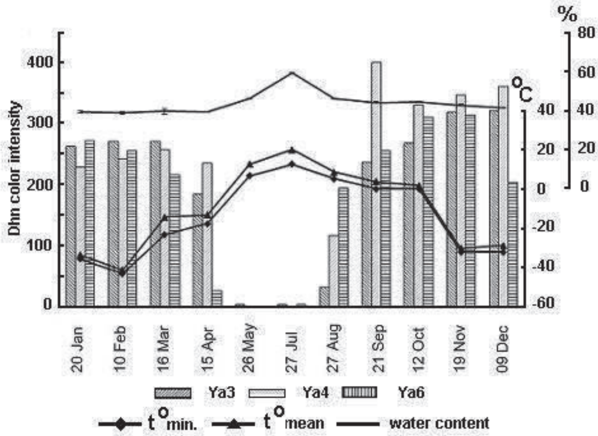

Fig. 3. Variations in water content, the level of 17-kDa dehydrin in the buds of three birches (Ya3, Ya4, Ya6) and air temperature from January to December 2009. The coloration intensity of 17-kDa dehydrin in birch Ya4 in July was taken to be 0% coloration.

Conclusions

The level of several polypeptides of the protein profile including the proposed storage proteins was higher during the winter than in the growing season. Polymorphism of birch winter dehydrins was found. Two groups of dehydrins were identified. Dehydrins of 56-73 kDa were found all year round, decreasing in the summer. Dehydrins of 15-21 kDa have high stability levels in the winter and are not identified in the vegetation period. Maximum content of dehydrins coincides with small water content in buds and the lowest winter temperatures when frost hardiness is considered at its greatest. Dehydrins of 15-21 kDa are supposedly associated with the frost hardiness of birch. The abundant dehydrin of 17 kDa is of particular interest occurring in all birches. The supposition is made that this dehydrin may serve as a biochemical marker for frost tolerance.

References

Bubyakina V.V., Tatarinova T.D., Ponomarev A.G., Perk A.A., Solomonov N.G., 2011. Characteristics of seasonal dynamics of *Betula platyphylla* Sukacz. dehydrins associated with frost hardiness development under the cryolitic zone conditions. *Doklady Biological Sciences.* **439**, 258-261.

Close T.J., 1996. Dehydrins: emergence of a biochemical role of a family of plant dehydration proteins. *Physiol. Plant.* **97**, 795–803.

Close T.J., Fenton R.D., Moonan F., 1993. A view of plant dehydrins using antibodies specific to the carboxy terminal peptide. *Plant Molecular Biology.* **23**(2), 279-286.

Fowler S., Thomashow M., 2002. Arabidopsis transcriptome profiling indicates that multiple regulatory pathways are activated during cold acclimation in addition to the CBF cold response pathway. *The Plant Cell.* **14**, 1675-1690.

Karlson D.T., Fujino T., Kimura S., Baba K., Itoh T., Ashworth E.N., 2003. Novel plasmodesmata association of dehydrinlike proteins in cold-acclimated red-osier dogwood (*Cornus sericea*). *Tree Physiol.* **23**, 759-767.

Kontunen-Soppela S., Laine K., 2001. Seasonal fluctuations of dehydrins is related to osmotic status in scots pine seedlings. *Trees.* **15**, 425-430.

Korotaeva N.E., Oskorbina M.V., Kopytova L.D., Suvorova G.G., Borovskii G.B., Voinikov V.K., 2011. Variations in the content of stress proteins in the needles of common pine (*Pinus sylvestris* L.) within an annual cycle. *J. Forestry Research.* doi 10.1007/s10310-011-0260-y.

Kosova K., Prasil I.T., Vitamvas P., 2010. Role of dehydrins in plant stress response. *Handbook of plant and crop stress.* 3nd ed. Edited by Mohammad Pessarakli. CRC Press, Tucson. pp. 239-285.

Laemmli U.K., 1970. Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature.* **227**, 680-685.

Petrov K.A., Sofronova V.E., Bubyakina V.V., Perk A.A., Tatarinova T.D., Ponomarev A.G., Chepalov V.A., Okhlopkova Zh.M., Vasilieva I.V., Maximov T.Ch., 2011. Woody plants of Yakutia and low temperature stress. *Russian Journal of Plant Physiology.* **58**(6), 1011-1019.

Rinne P., Welling A., Kaikuranta P., 1998. Onset of freezing tolerance in birch (*Betula pubescens* Ehrh.) involves LEA proteins and osmoregulation and is impaired in an ABA deficient genotype. *Plant Cell Environ.* **21**, 601-611.

Svensson J., Ismail A.M., Palva E.T., Close T.J., 2002. *Dehydrins. In Cell and molecular responses to stress.* Edited by K.B. Storey and J.M. Storey. Elsevier Press, Amsterdam, 155-171.

Timofeev P.A., 2003. *Trees and shrubs of Yakutia.* Bichik, Yakutsk. 64 p. (In Russian).

Vetchinnikova L.V., 2004. *Birch variability: morphological, physiological, and biochemical aspects.* Nauka. Moscow. 183 p. (In Russian).

Welling A., Palva E.T., 2006. Molecular control of cold acclimation in trees. *Physiologia Plantarum.* **127**, 167–181.

Wisniewski M., Close T.J., Artlip T.A., Arora R., 1996. Seasonal patterns of dehydrins and 70-kDa heatshock proteins in bark tissues of eight species of woody plants. *Physiol. Plant.* **96**, 496-505.

Photosynthesis of larch at different permafrost areas: case study of Canada and Yakutia

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Keywords: larch photosynthesis, Larix laricina, Larix cajanderi, Canada, Yakutia

Introduction

Photosynthesis of the larch as of the dominant tree species in the boreal forest of Yakutia was characterized as having up to three times higher CO_2-assimilation rate (A_{net}) compared to relative abroad species, with averaged field maximum (A_{max}) of 10 µmoles m^{-2} s^{-1} due to higher conductances and transpiration rate (Vygodskaya et al., 1997). Multiyear seasonal observations of *L. cajanderi* revealed high variability of diurnal A_{net} depending on hydroclimatic conditions of the growing season, with an average field A_{max} range of 6.3-13.5 µmoles m^{-2} s^{-1} (Maximov et al., 2005).

Of relative abroad species, most relevant to *L. cajanderi* larch species of *L. laricina* (or tamarack) growing in permafrost areas of Northern Canada, was reported to show A_{max} only up to 1-2.6 µmoles m^{-2} s^{-1} (Dang et al., 1991; Macdonald and Lieffers, 1990; Whitehead and Gower, 2001), which seems to be underestimated because of the research sites representing flooded peatlands and much higher A_{max} of up to 14 µmoles m^{-2} s^{-1} reported for tamarack seedlings in experiments with flooding, elevated CO_2 and temperature (Calvo-Polanco et al., 2012; Islam et al., 2003; Islam and Macdonald, 2004; Tjoelker et al., 1998).

To re-assess field A_{max} and related photosynthetic parameters of tamarack under as similar as possible with *L. cajanderi* growing conditions, photosynthesis of tamarack was measured in a permafrost forest subzone of the forest tundra of Canada, the results of which are presented here in a comparison with *L. cajanderi*, with the emphasis on A_{net} as an integrative parameter of plant photosynthetic activity.

Sites, objects and methods

The fieldwork in Canada was carried out as a part of a project between "Spasskaya Pad" forest station, IBPC, Yakutsk, Russia, and a research station of Centre for Northern Studies of Laval University (CEN) located at Whapmagoostui-Kuujjuarapik (W-K) settlement on the eastern shore of Hudson Bay at the maritime limit of James Bay (55°16' N, 77°45' E), Quebec, Canada. The CEN site characteristics are in detail described in a comprehensive review by Bhiry et al. (2011). The site in Yakutia is a typical boreal taiga larch forest at "Spasskaya Pad" station (62°14' N, 129°37' E) described in Maximov et al. (2005) and Ohta et al. (2001).

The research object was *Larix laricina* (Du Roi) K. Koch, or tamarack, in general morphology and in needle anatomy toughly different from Yakutian *Larix cajanderi* Mayr under comparing (Vygodskaya et al., 1997; Zwieniecki et al., 2007). The measurements of photosynthesis were done on 20-26 June 2012, which is the beginning of the growing season at W-K area. Retrospective data for *L. cajanderi* in Yakutia are those of second half of June 2001-2010 obtained at "Spasskaya Pad" larch forest site. All the measurements were performed with an infrared H_2O/CO_2 gas analyzer LI-6400 (LI-COR, USA) using standard techniques and requirements.

Time of day for W-K and Yakutsk is given in 24 hours format for both; Eastern Daylight Time (EDT) with GMT/UTC offset -4 for W-K, and Yakutsk Standard Time (YST) with GMT/UTC offset +10 for Yakutsk.

Results

Larix laricina, W-K, Canada

The daily courses of the main parameters of interest are shown in the left column of Fig. 1. A_{net} of tamarack was in good coincidence with those of essential inner factors for photosynthesis – stomatal conductance *gs* and transpiration *E* that is proven by Pearson's linear correlation coefficient of >90%. Mean A_{max} for all days made 5.6 µmoles m^{-2} s^{-1} with highest absolute A_{max} of 7.1 and an overall daily mean A_{net} of 2.8; mean maxima for *gs* and *E* made 92.6 and 0.8 mmole m^{-2} s^{-1}, respectively.

Important environmental factors appearing to regulate A_{net} were photosynthetically active radiation *PAR*, air temperature T_{air} and vapor pressure deficit at the leaf level *VpdL* with >80% of the correlation with A_{net} for all. The effects of the environment on gas exchange showed that saturation levels for A_{net}, *gs* and *E* were reached at high irradiances of 720 to 1500 µmole m^{-2} s^{-1} (not shown).

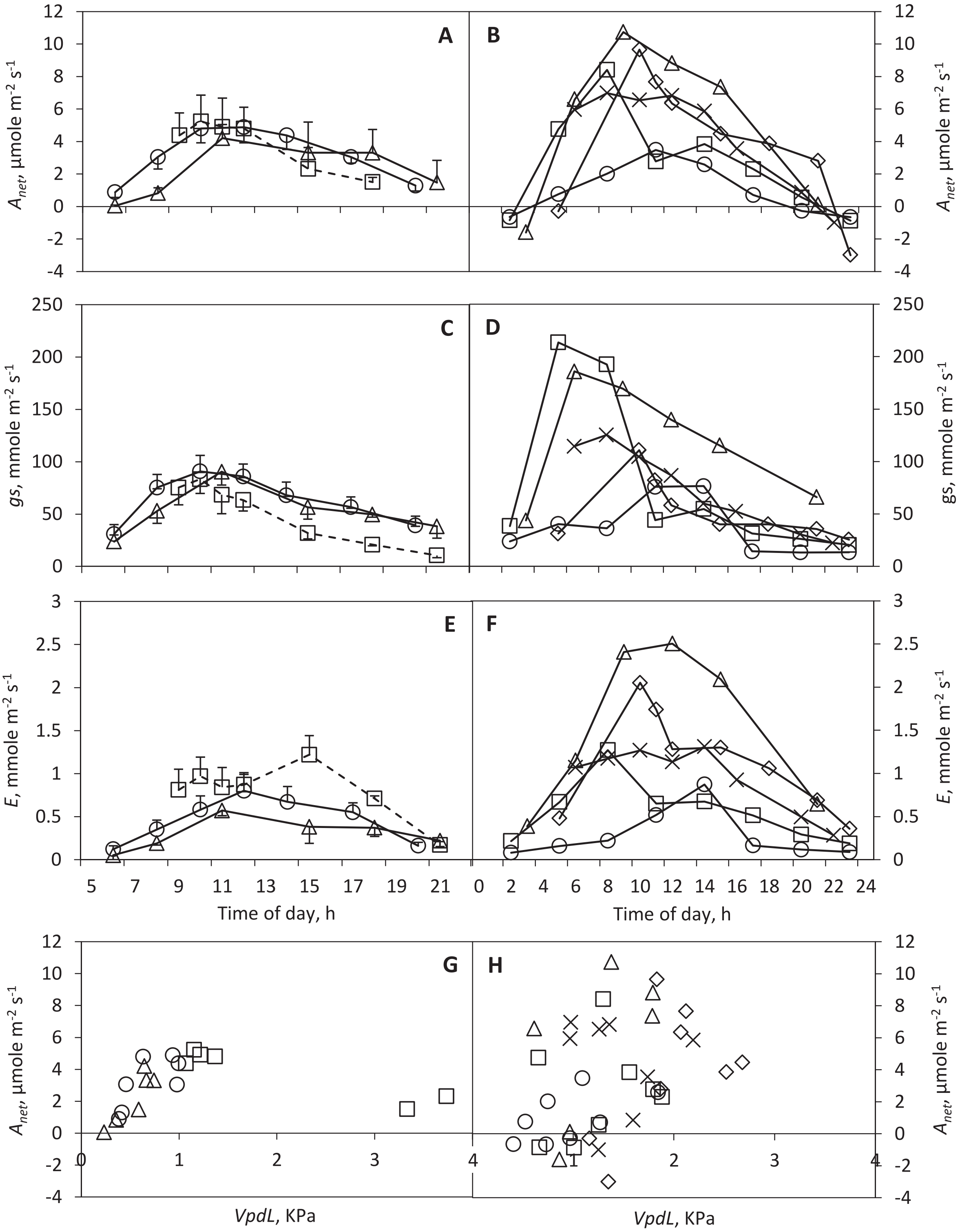

Fig. 1. *Left column*: diurnal gas exchange parameters of *Larix laricina*, W-K, Canada, 2012. **A** – net-photosynthesis, **C** – stomatal conductance, **E** – transpiration, **G** – effect of vapour pressure deficit on net-photosynthesis (typical for *gs* and *E* as well). Bar indicates standard deviation. Symbols: ○ – 20 June, □ – 23 June, Δ – 26 June. *Right column*: diurnal gas exchange parameters of *Larix cajanderi*, Spasskaya Pad, Yakutsk, Russia, 2001-2010. **B** – net-photosynthesis, **D** – stomatal conductance, **F** – transpiration, **H** – effect of vapour pressure deficit on net-photosynthesis (typical for *gs* and *E* as well). Symbols: ○ – 17 June 2001, □ – 20 June 2002, Δ – 23 June 2003, × – 30 June 2004, ◊ – 17 June 2010. Time of day in 24 h format is EDT, UTC-4 for W-K, Canada, and YST, UTC+10 for Yakutsk, Russia

All three parameters almost linearly increased in values with increasing *VpdL* up to 1 KPa (Fig. 1: G as an example) and T_{air} up to 20 °C. At light saturation and *VpdL*< 1, A_{net} ranged insignificantly, from 3.3 to 5.2 µmole m^{-2} s^{-1} indicating that climate accounted for, at least, most of the variation.

Larix cajanderi, Yakutsk, Russia

The daily courses are presented in the right column of Fig. 1, from which one can see that *L. cajanderi* was in general much higher in corresponding magnitudes compared to tamarack. Mean A_{max} for all the dates made 6.5 µmoles m^{-2} s^{-1} at a range of 2.7-8.4 µmoles m^{-2} s^{-1}, with highest absolute A_{max} of 13.7 µmoles m^{-2} s^{-1} and a daily mean of about 5; averaged maxima for *gs* and *E* were 128.6 and 1.2 mmole m^{-2} s^{-1}, respectively.

Correlations of A_{net} with other measured parameters were really high (>90%) only for transpiration, being 70-80% for the rest, with weakest links to leaf temperature T_{leaf} (30-60%) and *VpdL* (-10 to 50%).

Environmental effects on gas exchange parameters showed that saturation levels of A_{net}, *gs* and *E* were reached at *PAR* of 500-700 µmoles m^{-2} s^{-1} and T_{leaf} of around 23 °C, with no clear linear relationships between the parameters (not shown) unlike tamarack; the impact of *VpdL* was not regular at all, chaotically scattered within basically 2 KPa (Fig. 1: H).

Discussion

The mean field A_{max} value of tamarack of 5.6 µmoles m^{-2} s^{-1} is much higher of reported earlier 1-2.6 µmoles m^{-2} s^{-1} for boreal forests of Canada, which we attribute primarily to different conditions of growing as previous studies of *L. laricina* were conducted in continental areas of Western Canada, and mostly in flooded peatlands that naturally suppress physiological processes of the vegetation. The effect of the habitat condition is supported by results of the examination of *PAR*, T_{air} (T_{leaf}) and *VpdL* influence on A_{net} that show good dependence of A_{net} variation on climate, which is evidenced by high corresponding correlation coefficients as well. In terms of leaf physiology, high A_{max} of tamarack in 2012 was a result of higher *gs* compared to earlier studies (92.6 vs. 28-35 mmole m^{-2} s^{-1}, respectively).

Data on *L. cajanderi* show similar patterns with tamarack but the magnitudes are consistently higher for all the parameters (A_{net}, *gs*, *E*). However, *L. cajanderi*, observed over years, in some cases presents the same values as tamarack (e.g. 20 June 2002), and even lower (17 June 2001). Thus, we may state that the magnitudes for *L. laricina*'s are generally in well accordance with the data on *L. cajanderi* though tending to be at the lower boundary of the magnitudes in most cases. On the whole, Yakutian larch shows 1.4 times higher values that are a result of higher leaf conductances in terms of physiology; the role of different permafrost habitats leading to different climates is of importance as well.

The effect of climate on photosynthesis is strict and pronounced for tamarack that could not be said about *L. cajanderi*. Tamarack showed stronger correlation of A_{net} with conductances and environmental factors, while CO_2 assimilation and stomatal conductance of *L. cajanderi* in general were not affected by the environment testifying to better accommodation of Yakutian larch to harsh arid conditions of East Siberia.

However, as three day measurements of Canadian larch are hardly relevant to compare with a decade dataset for Yakutian larch, at least a seasonal observation is needed for tamarack to get reliable estimates.

Acknowledgements

The research leading to these results has received funding from INTERACT (grant agreement No 262693), under the European Union's Seventh Framework Programme.

References

Bhiry N., Delwaide A., Allard M., Begin Y., Filion L., Lavoie M., Nozais C., Payette S., Pienitz R., Saulnier-Talbot E., Vincent W.F., 2011. Environmental change in the Great Whale River region, Hudson Bay: Five decades of multidisciplinary research by Centre d'études nordiques (CEN). *Ecoscience* **18**, 182-203.

Calvo-Polanco M., Señorans J., Zwiazek J., 2012. Role of adventitious roots in water relations of tamarack (*Larix laricina*) seedlings exposed to flooding. *BMC Plant Biology* **12**:99.

Dang Q.L., Lieffers V.J., Rothwell R.L., Macdonald S.E., 1991. Diurnal variation and interrelations of ecophysiological parameters in three peatland woody species under different weather and soil moisture conditions. *Oecologia* **88**, 317-324.

Islam M.A., Macdonald S.E., 2004. Ecophysiological adaptations of black spruce (*Picea mariana*) and tamarack (*Larix laricina*) seedlings to flooding. *Trees* **18**, 35-42.

Islam M.A., Macdonald S.E., Zwiazek J.J., 2003. Responses of black spruce (*Picea mariana*) and tamarack (*Larix laricina*) to flooding and ethylene. *Tree Physiology* **23**, 545-552.

Macdonald S.E., Lieffers V.J., 1990. Photosynthesis, water relations, and foliar nitrogen of *Picea mariana* and *Larix laricina* from drained and undrained peatlands. *Can. J. For. Res*. **20**, 995-1000.

Maximov T.C., Maksimov A.P., Kononov A.V., Sugimoto A., Dolman A.J., Moors E.J., van der Molen M., Ivanov B.I., 2005. Ecophysiological peculiarities of photosynthesis of Cajanderi larch in cryolithozone. *Lesovedenie* **6**, 3-10 (in Russian).

Ohta T., Hiyama T., Tanaka H., Kuwada T., Maximov T. C., Ohata T., Fukushima Y., 2001. Seasonal variation in the energy and water exchanges above and below a larch forest in eastern Siberia. *Hydrol. Process*. **15**, 1459-1476.

Tjoelker M.G., Oleksyn J., Reich P.B., 1998. Seedlings of five boreal tree species differ in acclimation of net photosynthesis to elevated CO_2 and temperature. *Tree Physiology* **18**, 715-726.

Vygodskaya N.N., Milyukova I., Varlagin A., Tatarinov F., Sogachev A., Kobak K.I., Desyatkin R., Bauer G., Hollinger D.Y., Kelliher F.M., Schulze E.-D., 1997. Leaf conductance and CO_2 assimilation of *Larix gmelinii* growing in an eastern Siberian boreal forest. *Tree Physiology* **17**, 607-615.

Whitehead D., Gower S.T., 2001. Photosynthesis and light-use efficiency by plants in a Canadian boreal forest ecosystem. *Tree Physiology* **21**, 925-929.

Zwieniecki M.A., Brodribb T.J., Holbrook M.N., 2007. Hydraulic design of leaves: insights from rehydration kinetics. *Plant, Cell and Environment* **30**, 910-921.

Ecological and economic conditions of preservation of unique forest ecosystems of Yakutia in the implementation of the Kyoto Protocol

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Key words: climate change, the Economy, Kyoto Protocol

Introduction

The functions of terrestrial ecosystems as sources or sinks, carbon dioxide are determined by the balance between two powerful biospheric processes of photosynthetic production of organic carbon and abjection of CO2 during respiration and decomposition of organic substance. Russia plays an important role in the global carbon cycle, primarily due to large areas of forest, reserves and bog muck - and wetlands, as well as a huge carbon content of the soil. According to the results of years of research, the annual carbon budget of major biomes of the Russian Federation is 0.7 Gt C per year, taking into account the influence of land-use management, forest fires, insects impact, waste-land, etc.. [1]. Where the contribution of forests is about 90-95%. These data were strongly supported by four independent methods, such as the Land Ecosystem Assessment, the result from eddy covariance estimates, presenting NEE and NEP, and the modeling results from the inversion schemes (NBP) and DGVMs (NBP). Russia annually submits a report on the state of forests and carbon sequestration to the Secretariat of Framework Convention of the UN on Climate Change. The presentation of these verified figures to the international community on climate conferences can enable to take into account adequately the ecological services provided by the Russian forests in a global dimension. These numbers become more relevant when there is their monetary value that occurs with the development of a new global carbon market, one of the fastest growing international markets.[2]

Eastern Russia has great potential in the area of trading of greenhouse gases. Huge permafrost territory of the Republic of Sakha (Yakutia) is one of the largest regions of Russia on the forested area. The forests of Yakutia, covering 80 percent of the territory of the Republic and one fifth of Russian forests take 20% of the world's forests. Forest area of the Republic of Sakha (Yakutia) is 252 million hectares, or 82% of the total area of the republic [3]

Currently, the Institute of Biological Problems of cryolithic zone of the Russian Academy of Sciences within 30th international and intergovernmental climate change projects, established a comprehensive system for the study of regional, continental and global cycles of energy, water and carbon, which includes series of 30-meter high observation towers TOWER FLUX NETWORK in Central Yakutia, Research study area «Spasskaya Pad» - the only one in Russia, uniting projects of Asia (AsiaFlux) and Europe (CarboEurope). According to years of research using the Eddy Covariance annual flow of the dominant larch forests are estimated to be within 2 ± 0,5 tonnes of carbon per hectare per year [1 - 4].

Table 1. Estimate of the cost of carbon in permafrost forests of Yakutia.

№	Name of The forestry of the Republic of Sakha (Yakutia)	The Forest Fund, million ha	Lands covered with forest vegetation, million hectares	Lands covered with larch, million hectares	Carbon sequestration(annual sink of carbon in the larch forest _ 2.0 0.5 t C ha-1 year-1)	The price of the quota, million euros *
1	Aldansky forestry	15.57	13.07	2.33	5.83	233.2
2	Amginsky forestry	2.83	2.5	1.52	3.80	152
3	Verkhneviluisky forestry	3.80	3.08	0.14	0.36	14.4
4	Viluisky forestry	5.11	3.50	0.33	0.82	32.8
5	Gornuy forestry	4.37	3.99	2.66	6.67	266.8
6	Zhiganskyforestry	5.25	3.26	2.11	5.28	211.2
7	Indigirsky forestry	49.02	17.67	12.54	3.13	125.2
8	Lensky forestry	7.46	6.80	1.62	4.04	161.6
9	Megino-Kangalassky forestry	3.69	3.45	2.73	6.83	273.2
1	Mirninsky	16.0	11.23	2.16	5.41	216.

0	forestry	3				4
11	Neruingrinsky forestry	11.18	8.52	7.22	18.05	72.4
12	Nurbinsky forestry	4.89	4.42	0.73	1.83	73.2
13	Olekminsky forestry	12.11	11.2	3.86	9.65	386
14	Suntarsky forestry	5.30	5.01	2.45	6.12	244.8
15	Tomponsky forestry	45.40	17	12.54	31.35	1254
16	Ust-Aldansky forestry	1.61	1.5	0.8	2	80
17	Ust-Maisky forestry	9.33	7.2	2.5	6.25	250
18	Khangalassky forestry	2.81	2.7	2.1	5.25	210
19	Yakutsky forestry	1.12	1.03	0.5	1.25	50

* conditional unit per tonne is taken according to the experts (2013) in the amount of 1 euro per tonne fixed carbon [5]

As can you see from table 1 contribution to the boreal forest remains far undervalued at international climate negotiations, especially in comparison to the political activities of tropical countries where there are special arrangements for REDD - enable developing countries not to cut their forests and get paid for it investments from «the carbon market.

Under the Kyoto Protocol, countries can invest in joint implementation projects either directly or through international funds. In addition, they can also develop rules for investment in projects of companies. The state projects increasingly the EU countries, and private projects increasingly used in Canada and Japan.

Prior to the entry into force of the Protocol, most of the projects carried out by international or public funds and in the framework of various international and national programs.

Carbon funds were established in the early 2000s, to purchase quota or investing in projects to reduce greenhouse gas emissions. Obtained as a result of the implementation of emission permits deals comes at the expense of funds that give investors the guarantees commitments under the Kyoto Protocol. Countries, in which projects can be undertaken to reduce emissions, the funds offer a set of sample result of such projects, as well as providing technical and advisory assistance for their development.

The world Bank is the Manager of the nine carbon funds, the participants of which are public and private organizations: Prototype carbon Fund (PCF); Netherlands Fund projects joint implementation and the Dutch Fund clean development Mechanism; Carbon Fund for local development; Biocarbon Fund, the Italian carbon Fund; Spanish carbon Fund; the Danish carbon Fund;

Listed funds are state-owned or operate as public-private partnerships, stewards of the world Bank, as the trustee. Funds to buy greenhouse gas emission reductions from projects in developing countries with economies in transition, on behalf of the funds and make payments over reducing emissions.

Emission reductions can be used to meet obligations under the Kyoto Protocol or another regulated or voluntary greenhouse gas emissions reduction regime. All emission reduction are purchased on behalf of Funs, provide public and private sector. The world Bank performs the function of an honest broker, ensuring that the benefits of carbon Finance received and developing countries and countries with economies in transition. The World Bank plays the role of an honest broker, to benefit from carbon finance were both developing countries and countries with economies in transition, on behalf of the funds and make payments when the emission reduction. [6]

For the permafrost zone of Eastern Siberia, ecological and economic prospects of the Kyoto agreement may be associated with a flexible mechanism of qouta trading of Article 17, which is also called green investment schemes. A new product which was formed by the Kyoto Protocol is a kind of equivalent of gold and forex reserves in the environmental field. The assignment of quotas can enable to implement in practice international cooperation in solving problems of soften results of global climate changes. Funds from the sale of quotas come into the state budget or special non-budgetary fund, and then can be passed to enterprises as special-purpose funding or special-purpose investments. Upon that the purchaser disposes quotas regardless of the results of these projects.

References

[1] A.J Dolman, A. Shvidenko, D. Schepaschenko, P. Ciais, N Tchebakova, T. Chen, M.K. Van Der Molen, L. Belelli Marchesini, T. C Maximov, S. Maksyutov, E.-D Schulze. An estimate of the terrestrial carbon budget of Russia An estimate of the terrestrial carbon budget of Russia using inventory based, eddy covariance and inversion methods // Biogeosciences. 2012. DOI:10.5194/bgd-9-6579-2012.

[2] Sivtceva T.V. Environmental and economic aspects of participation of the Republic of Sakha

(Yakutia) in the implementation of the Kyoto Protocol report on the II International scientific conference "Humanitarian Sciences and contemporaneity (Moscow, 10 October 2011) European journal of social science. -2011.-№7. - C32-39.
[3] State report on the state and protection of environment of the Republic of Sakha (Yakutia)... Г72; the Government of the Republic. Sakha (Yakutia), Ministry of nature protection REP. Sakha Yakutia.-Yakutsk: Company "Dani Almas", 2003 in ... 2012 :/ [Amounted to AI. Olesov,I.I. кычкина; scientific editor V.A. Grigoriev] -2012, -216 S. Agency CIP NBR of Sakha.
[4] Maximov T.Chr, Dolman A.J., Moors E.J., et. al (2005a) Parametry uglerodnogo i vodnogo obmena v lesnykh ekosistemakh. Doklady RAN 408(8): 684-686 - Parameters of carbon
[5] Price of CO_2 quotas on the European energy exchange (EEX). Information: http://www. eex. De [6] Piskulova N. A. / Kyoto Protocol: opportunities for Russia.: Training kit for program of the course" State control of nature management". - M:MGIMO, WWF-Russia, 2006. 88

Research of long-term dynamics of vegetation index in Eastern Siberia

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Key words: NDVI, Eastern Siberia, NOAA/AVHRR, Spot/VGT, GIMMS.

Introduction

The monitoring of changes in Arctic environment and the surrounding area is one of the actual problems in a warming climate. As an essential component of the biosphere and source of resources, land cover is sensitive "indicator" of changes of the biosphere and climate. The aim of this work is research of vegetation index variations in Eastern Siberia on satellite data.

Data and Methods

Due to the difficulties with access to large parts of Arctic zone, the remote sensing is an invaluable source of information about the environment, providing a high level of reliability, efficiency and regularity of general parameters of measurement.

There are a number of different vegetation indices, which calculated from spectral characteristics of the vegetation obtained by remote sensing. The most widely used index is NDVI (Normalized Difference Vegetation Index): NDVI = NIR-RED/NIR + RED, where NIR and RED – the Earth's surface albedo in the near infrared and red bands of the spectrum, respectively. NDVI has a wide dynamic range and high sensitivity to changes in land cover.

NOAA satellites data obtained on ScanEx station (ICRA SB RAS) was used in this study. Also GIMMS, Spot Vegetation, and Hydromet weather stations (st. Saskylah, Chokurdakh, Shelagontsy, Srednekolymsk, Aldan, Yakutsk) data were used. The study period is May-September 1982-2012. (Varlamova, Solovyev, 2010a; Varlamova, Solovyev, 2010b; Varlamova, Solovyev, 2012a; Varlamova, Solovyev, 2012b).

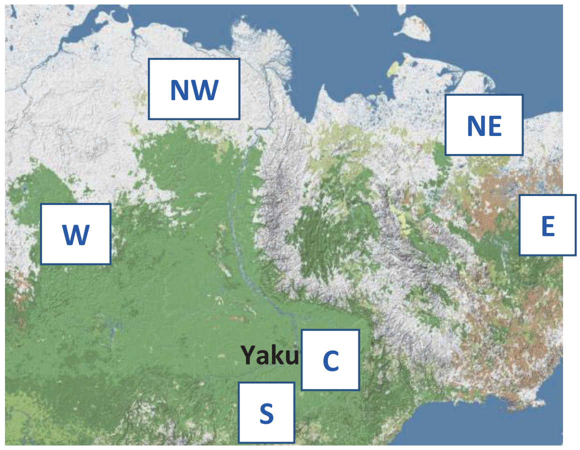

Fig.1. Test sites locations: NW, NE, W, E, C and S.

To study variations of vegetation index, test sites (TS) of ~50*50 km were selected on the territory of Yakutia (Fig. 1). As seen from Fig. 1 TS are located on different latitudes: the northern group of sites (NW, NE), central (W, E) and southern (S, C). There are no large water bodies on the TS and the type of vegetation by species composition is homogenous.

Results and discussion

Interannual NDVI variations for all sites for the period 1982-2012 are shown on figure 2. NDVI variations of northern group (NW, NE) are presented by solid and dashed lines with square markers; NDVI of central group (W, E) with diamond-shaped markers; NDVI of southern group of sites (C, S) with round markers.

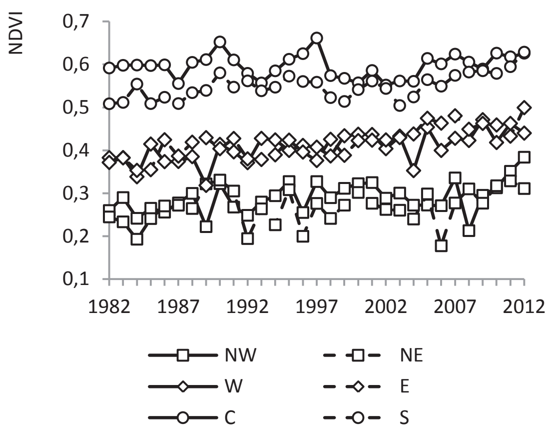

Fig. 2. Interannual (May-September) NDVI variations for test sites.

As shown on figure 2, the NDVI values of vegetation cover of all sites is sufficient changeable for the whole period. As well it is show the difference in absolute values of vegetation index specific groups of sites is observed. The sites that is located to the south has higher values of NDVI. This is due to the differences in types of vegetation - from the sub-arctic tundra's to middle taiga forests. In addition, differences of climatic zones, which are typical for particular geographic latitudes.

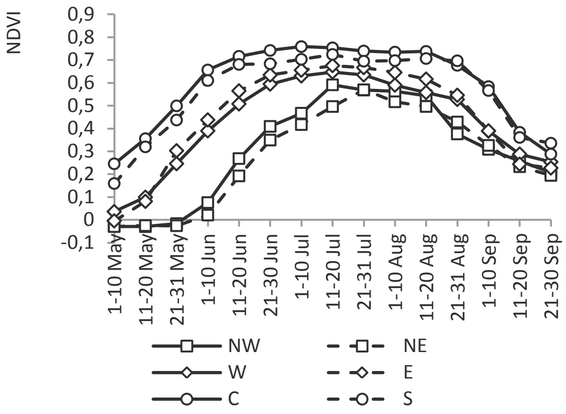

Fig. 3. Seasonal NDVI variations for test sites (average for 1998-2012).

A similar latitudinal dependence of vegetation cover is well see and over the growing season since May to September. At Fig. 3 it shows the averaged for 15 years of NDVI seasons variation sites. The designations are same to Fig. 2.

It shown on Fig. 3 that sites located to the north has much shorter length of growing season. Increase of NDVI values on the S and C sites begins in the beginning of May. On the W and E sites - in the end of May. On the NW and NE sites – in the middle of June.

NDVI trends (solid lines) of all sites and surface air temperature (dashed line) and precipitation (dash-dot line) by the period 1982-2012 are presented on figure 4. The increasing trends of NDVI values and air temperature are observed on all sites. Increase of NDVI values on all sites is from 4 to 10 percent, except C site. The precipitation trends are different: on E, S and C sites – positive trend, and on other sites – negative. Increase of NDVI on C site was noticeably lower than on other sites - trend of NDVI was 1 percent. It is connected with particular qualities of microclimate, which was formed by orography (mountain massifs on the North, East and South). The results of many foreign and Russian authors are shown similar results and point out a tendency of NDVI growth at Northern latitudes (Tucker et al., 2001; Eastman et al., 2013).

The analysis showed a good positive correlation between NDVI and temperature values on all sites (R = 0,67-0,54) except the C site (R = 0,29). Link between NDVI values and precipitation amount is not sufficient.

The Yakutia belongs to zone of semi deserts with according annual amount of precipitation. The average annual precipitation is 200-250 mm. Groundwater is the main additional source of moisture for vegetation.

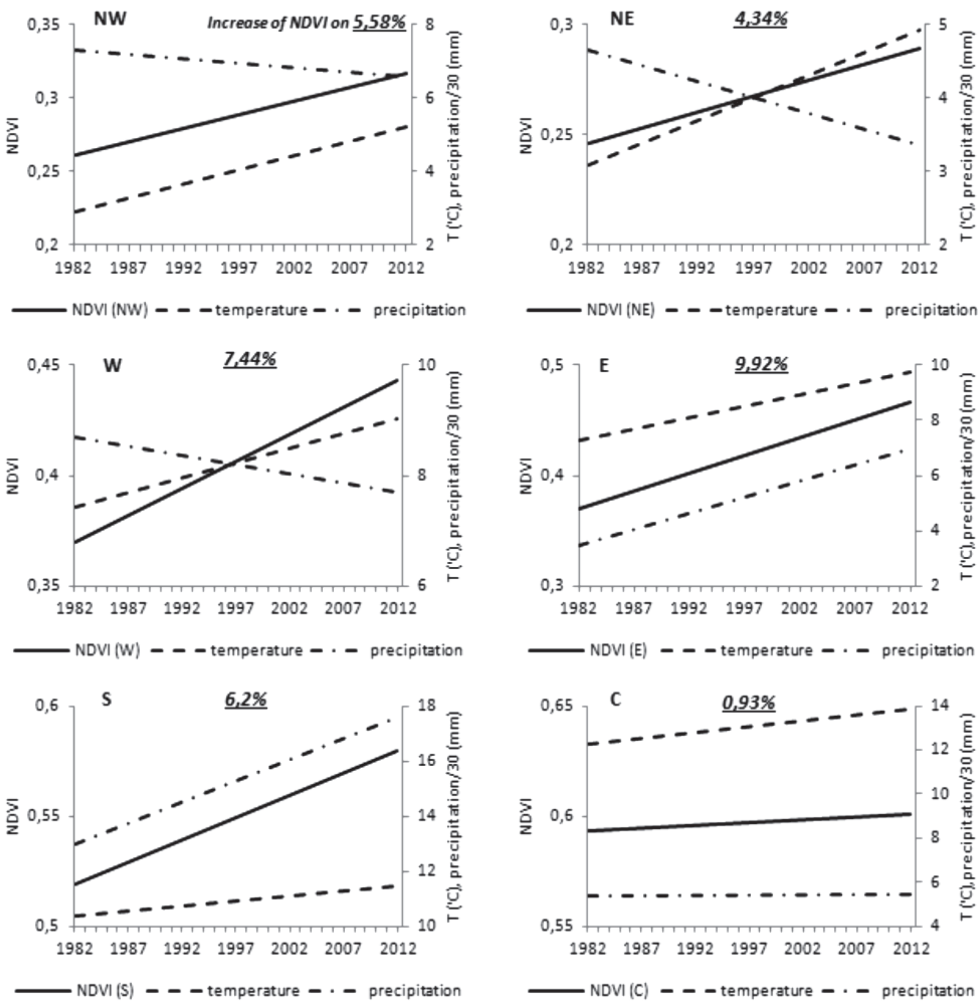

Fig.4. NDVI trends, air temperature and precipitations (weather stations are located near the sites).

In Northern latitudes, the water-saturated soils freeze through in winter, so the growth and development of plants in spring and early summer depends mostly on the temperature of the surface air.

The annual variations of NDVI (solid lines with circle markers) and air temperature values (lines without markers) in May for S and C sites are presented on Figure 5. The fluctuations of temperature and NDVI in May are varying quite similar on both sites. The correlation on S site is 0.78 and on C site is 0.77. It can be noted that NDVI relationship with temperature at the C site is observed only in May. On the rest sites especially in northern areas, NDVI correlates with the temperature during the whole vegetation period.

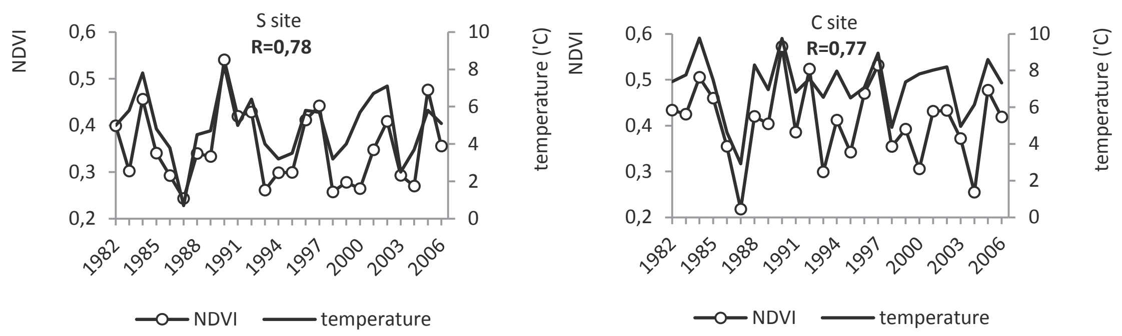

Fig.5. Interannual (May) NDVI and air temperature variations of S and C sites.

Conclusions

1. Vegetation index on the test sites have expected latitudunal dependence caused by features of climatic zones and types of vegetation cover of study region. Sites that located to the south have higher absolute values of NDVI.
2. A similar dependence is noticeable in the length of the growing season of the sites. Increase of NDVI values on the S and C sites begins in the beginning of May. On the W and E sites - in the end of May. On the NW and NE sites – in the middle of June.
3. Over the last decades (1982-2012) there is increasing trend of NDVI values and season averaged (May-September) air temperature values on all sites.
4. The analysis showed a good positive correlation between NDVI and temperature values on all sites (R = 0,67-0,54) except the C site (R = 0,29). Link between NDVI values and precipitation amount is not sufficient.

References

Compton J. Tucker, Daniel A. Slayback, Jorge E. Pinzon, Sietse O. Los, Ranga B. Myneni, Malinda G. Taylor., 2001. Higher northern latitude normalized difference vegetation index and growing season trends from 1982 to 1999. *International Journal Biometeorology*. 2001. 45. P. 184-190.

Eastman J. Ronald, Florencia Sangermano, Elia A. Machado, John Rogan, Assaf Anyamba., 2013.Global Trends in Seasonality of Normalized Difference Vegetation Index (NDVI), 1982–2011. *Remote Sensing.* 2013. 5. P. 4799-4818.

Varlamova E.V., Solovyev V.S., Vasil'ev M.S., Budishchev A.A., 2010. Research of Variations of NDVI Vegetation Index of Yakutia On AVHRR/NOAA Data. *Materials of The IX International Symposium on Cold Regions Development «The application of technologies for the conservation of nature in Cold Regions».* Yakutsk, 1-5 June, 2010. – P. 233.

Varlamova E.V., Solovyev V.S., 2010. Research of variations of the vegetation index NDVI of the Arctic zone of Yakutia. *Contemporary problems in remote sensing of the Earth from space*. 2010. V. 7. №4. P. 226-230, (*in Russian*).

Varlamova E.V., Solovyev V.S., 2012. Study of vegetation index variations of the Arctic zone of Eastern Siberia based on satellite data. *Contemporary problems in remote sensing of the Earth from space*. 2012. V. 9. №1. P. 65-70, (*in Russian*).

Varlamova E.V., Solovyev V.S., 2012.Monitoring of vegetation cover of the Arctic zone of Eastern Siberia based on satellite data. *Science and Education*. 2012. №2(66). P. 58-62, (*in Russian*).

The dynamics of the phenological development of Iris setosa in connection with climate change

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Key words: Iris setosa, phonological development, climate warming

Iris setosa Rall. ex Link (Iridaceae) - one of the recognized ornamental plants that are widely used in landscaping. East Asian-North American species is found in all areas in Yakutia. This is the only one kind of iris growing far to the north.

Meadow species. It grows in a wide range of environmental conditions. It grows in damp marshy meadows, often in middle-humid zone of sandy alasses, where it grows abundantly among the motley grass. *I. setosa* can be found in versions of halophytic motley grass meadows, under the canopy of birch forests in the floodplain terraces on the frozen turf-forest soils, aspen forests, among willow.

Despite the fact that *I. setosa* grows on moistly wealthy soil, species can grow on harsher conditions, as evidenced by its use in planting of greenery of cities. *I. setosa* are tolerant to moderate anthropogenic influence, but it does not tolerate trampling by cattle.

I. setosa is undoubtedly heliophyte regarding to light but nevertheless it tolerates to little shade because it is possible to find it in the grassy vegetation tier of light woods. The wide range of habitats indicates about the ecological plasticity of the species, which is based on the wide variability of plants.

It is cultivated in Yakutsk botanical garden in Yakutsk since 1966. The natural conditions are typical for the Central Yakutia, which is characterized by sharp continental: low winter and high summer temperature and high dryness.

There is global warming in Yakutia as at other regions at recent decades, which is reflected in the seasonal timing of plant development. Table 1 shows the average temperature of the growing season from 1964.

Table 1. Medium temperature (Yakutsk), ^{0}C

Years	May	June	July	August	September
1964-1973	6,3	15,1	19,1	14,7	5,7
1974-1983	7,4	15,4	18,2	14,9	5,7
1984-1993	7,1	15,8	19,2	15,0	5,6
1994-2003	7,3	16,7	20,0	15,5	5,8
2004-2013	8,6	17,3	19,9	15,7	6,6

Let's consider the example of 46 - year phenological observations of *I. setosa* (table 2). Seasonal spring growth and budding are the most turning-point in the life of plants. At this period the transition of plants goes from one qualitative state to another. The analysis of phenological information shows that budding of iris steadily starts 6-7 days earlier because of the increase in the average temperature of spring in the last 30 years and the timing of spring regrowth. At the same time a warm and long autumn, which is observed in the last decade, creates the conditions for more complete development of underground embryonic shoots of next year.

Table 2. Phenological development of *Iris setosa* (mean)

The period	Regrowth	Budding	Flowering		
			start	mass	end
1968-1973	12.05	19.06	25.06	30.06	8.07
1974-1983	12.05	17.06	20.06	25.06	8.07
1984-1993	12.05	19.06	24.06	27.06	7.07
1994-2003	7.05	13.06	25.06	1.07	9.07
2004-2013	5.05	13.06	20.06	23.06	5.07

This extension of the boundaries of the growing season opens new prospects for resettlement and use in landscaping ornamental plants.

Conservation and restoration of biological diversity in flora of Yakutia

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Key words: flora, biodiversity, recovery of cenopopulations, Yakutia

The varied landscape of Yakutia forms the diversity of vegetation cover. Large plant vegetation types are arctic and boreal, in which combine different plant communities. Arctic type includes arctic deserts and semi-deserts, arctic and subarctic tundra, tundra bogs, rocky deserts and mountain tundra. Over large areas of boreal vegetation there are various kinds of meadows and woods, which form a unique landscape combined with steppe communities. Steppe vegetation is an interesting nature object of Yakutia and the relict of the past geological epochs.

The development of industry, extraction of natural resources has significantly transformed the landscape of Yakutia. Traditional agriculture in the Central and southern regions of Yakutia also led to the degradation of vegetation cover. It is the well-known fact, that biological diversity is a condition for the sustainability of natural ecosystems. At present, it is considered as the main parameter for the assessment of the state of overorganismic systems on different levels.

Now in Yakutia is quite topical problem of restoration and conservation of biological diversity of nature. One of the applied measures for the conservation of biological diversity can serve as a study of the state of populations of the rare and endangered species of plants, and solving for the ways to restore them.

There are two approaches to conservation of the rare and endangered species of plants: «in situ» and «ex situ».

«In situ» conservation of the species in natural communities is the most effective and natural way of protection of plants. The advantage of this way is undoubtedly, because in the natural conditions remain the plants active components cenoses. Development of a network of especially protected natural territories, reserves, organization of natural parks, etc. is a promising environmental protection measure, especially on the vast territory of the Republic of Sakha (Yakutia). Unlike to highly-urbanized regions of the European part of Russia and foreign countries Yakutia has great advantages for the conservation of species in their natural habitats. However, it would be unjustified to refuse the second way - «ex situ» - conservation of plants in artificial conditions, in particular in the Botanical gardens. These two paths should be combined harmoniously, cultivation should be additional and effective measure for the conservation and reproduction of the genetic stock of plants and vice versa.

Fig. 1. *Adonis sibirica* L. in the Botanical Garden of the NEFU

One of the techniques of restore of productivity of the natural vegetation cover is the reintroduction of plants. In present in Yakutia developed methodological aspects reintroductional works. In the framework of this problem are held monitoring of natural populations of rare and endangered species of Yakutia, in order to determine the expediency of restoration measures. The first introduction population of a number of protected species created in the Botanical garden of the NEFU. Work on the restoration of disturbed populations began, the adaptive capabilities of exotic species studied for their transferred in natural communities. Preliminary data, obtained in the result of these activities, provide an opportunity to optimistically evaluate the prospects for resolving this problem.

Fig. 2. *Gagea pauciflora* (Turcz. ex Trautv.)

Carried out by us for several years, monitoring of populations of rare species in the vicinity, Yakutsk showed that the number of species on the verge of extinction (*Thermopsis lanceolata* subsp. *jacutica* (Czefr.) Schreter, *Gagea pauciflora* (Turcz. ex Trautv.), *Iris laevigata* Fisch. et Mey., *Lilium pensylvanicum* Ker-Gawl.), completely gone population *Adonis sibirica* L. In recent decades ceased to exist 16 of cenopopulations of the species. Their disappearance occurred for several reasons. In many cases radically changed the habitat of the species. In recent years significantly widened the boundaries of urban development.

Research on the reintroduction of rare species in the immediate vicinity of Yakutsk helped identify the following regularities. Survival of reintroductional species depends on the method of transfer and the age of transplanted plants. In respect of *Delphinium grandiflorum* L. is recommended to planted with sowing seeds. For bulbous plants successful transplantation of uneven-aged plants, which are equally well adapted in the new environment; transfer can be carried out sowing seeds. Promising combined method of transplantation is a simultaneous seeding and transplanting of bulbs. For *Iris laevigata* optimal is the transplantation of vegetative species. Comparative testing of methods of transfer of plant material in conditions of culture (seeds, living plants) created within the framework of introduction populations reserve Fund of plants, which can to be planted in the damaged natural communities and develop private methods reintroduction of 4 of rare species of Yakutia.

Monitoring reintroductional populations, located on the guarded territory or at a distance from settlements, showed the prospects of this works. It is marked a very high acclimatization of plants in the new conditions, increasing the area cenopopulation, revealed a positive dynamics of the population number and density of populations.

The status of the territorial protection of flora of the Arctic region of Yakutia

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Key words: Protected areas, GAP-analyst, Artic flora

Introduction

Currently in the Arctic region of Yakutia has an extensive network of protected areas, which is regarded as a preventive measure to protect highly vulnerable nature of the Arctic. However, studies evaluating the representation of the protected territories of components of the ecosystems of the Arctic natural areas still not started. This applies to the higher taxa of vegetation and all Botanical objects worthy of protection. In this regard, we conducted a GIS research that is actually a pioneer in this field.

Materials and Methodic:

We present the result of the «GAP - analysis» of the spatial distribution of protected areas, contours, geobotanical districts (GD's), the contours of vegetation and habitat of unique plant communities (UPC).

For the compilation of GIS data, we used the following materials:

• The geobotanical map from the book "The Main features of the vegetation cover of the Yakut ASSR" (Andreev at all., 1987), the boundaries of paths, areas and districts) which have been adjusted on the basis of satellite images Landsat-7 ETM+ (Borisov, 2010);

• Habitats of unique plant communities of the book "Green book of Siberia…" (1996);

• The boundaries of the protected areas of Yakutia were taken from the map provided by the Department of Nature Protection of Yakutia.

All cartographic material was created and calculated in SHP-files in the software ESRI ArcView 3.3.®.

Observation:

Arctic region of the territory of Yakutia have been allocated 10 GD's (Andreev at all., 1987), of which 7 have large areas and are covered by territorial protection in varying degrees. Almost entirely (80-100 %) fall within the territorial protection area GD's Novosibirsk Islands and Delta of the Lena river, Indigirka-Kolymskiy, almost half of the area (40-60%) – Anabaro-Nignelenskiy, Indigirskiy (tundra), Alazeisko-Nizhnekolymskiy district. Area of the County Chekanovskogo-Kharaulahskiy covered territorial protection of the quarter. District Island D'Long, Khatanga-Olenekskiy and the Coast of the Lena Delta, occupying the smallest square and simultaneously characterized by the most vulnerable plant-soil cover is completely covered territorial protection. The data show that almost all GD's Arctic sector of Yakutia sufficiently represented in the Protected Area (PA) network. Completely: district Coast of the R. Lena, Delta County R. Lena and Chekanovskiy-Yaraulahskiy partly included in the reserve. Some districts are covered by several protected areas of different status. So, in the GD Indigirsko-Kolymskiy placed State Nature Reserve and 3 Republican Resource Reserve, areas GD Chekanovsky-Haraulahskiy are part of the reserve, 2 resource reserves (republic and local).

Vegetation map of the territory of Yakutia (Atlas…,1989) are the 30 plots Arctic vegetation, each of which represents a different from all the rest on a number of grounds set of contours devoted phitocoenology criteria. They occupy area is very different - from 0.25 to 250,1 thousand sq. km Most plots (n = 22) takes more than 5 thousand sq. km and are assessed as potentially stable to negative natural and anthropogenic factors of higher taxa of vegetation cover. In size from 1 to 5 thousand sq. km has every fifth private. 2 separation of the Northern Sub-Arctic tundra wetland complexes and Arctic rivers valleys have an area of just 1.4 and 2.9 thousand sq km, respectively. Very limited area (0,25 thousand sq. km) is the Arctic deserts and semi-deserts. All these 3 compartments, vulnerable because of their small areas, almost completely covered by the territorial protection.

At the present stage of Botanical studies in Yakutia found 48 UPC, which were included in the summary of the «Green book of Siberia» (the editor RAS academic Koropachiskiy). Their membership includes the zonal (typical) community and phytocenosis, located on the border area, as well as selected by the criteria of scientific and resource importance and as a habitat of endemic and relict plants. These community certainly require special attention scientific organizations, but especially from the Republican and local bodies of nature protection. To the tundra UPC are 10 communities, i.e. 21 % of the total number of UPC. Every second of them described as a model of the indigenous vegetation of exceptional scientific value. As habitats of endemic, rare vascular and spore plants allocated 2 community. As a very rare community composition UPC joined one community found only in the Arctic part of the North-Western Yakutia (the basin of lower reaches R. Anabar). Also in the list included: one community as being under threat of disappearance and one community, as being located on the most Northern Yakut sector of the Arctic border area.

Territorial protection should primarily be provided Botanical objects, vulnerable due to limited occupied territories and in danger of extinction under the influence of adverse natural (fire, flooding when changing river courses, extensive thermokarst phenomena and other) and anthropogenic factors (technogenic impact on the soil cover, delichen pastures, as a result of overgrazing). To those of the number of tundra UPS should be attributed plot moss-lichen tundra *“Lichenum – Muscum – Luzula confuse + L.nivalis”,* found in the Arctic sector of Yakutia only on the island of Chetyrekhstolbovoy (in other regions found on the Islands of the East Siberian sea, Chukotka and Alaska). Local areas have spotted tundra *“Ditrichum flexicaule – Salix Polaris + Saxifraga oppositifolia»* found on the upper levels of the Paleozoic plateau Kotelnyy Island (Novosibirsk archipelago) and a rare combination of tundra *“Aulacomnium turgidum + Cetraria cucullata – Salix nummularia + Diapensia obovata – Cassiope tetragona”* and tundra *“Stigonema sp – rupestris”* on spots, is described on the island Erge-Muora-Sise in the Lena Delta. The remaining 7 UPC have larger areas of subregional up polyregional. Habitats of all tundra UPC, including local, covered by existing network of protected areas.

Results:

Analysis of the spatial distribution of the PA network, geobotanical districts, vegetable plots of the Arctic region of Yakutia has shown that the representation of higher taxa of the vegetable world of high latitudes of the protected areas is estimated as high. Besides all these plant communities in tundra area to be studied, as well as requiring particular attention when using tundra pastures and pre-tundra forests covered by protected areas.

The creation of a large, ecologically-based network in the Arctic zone of Yakutia is of great practical importance in protecting its highly vulnerable nature. After two decades of relative environmental «peace» in Yakutsk sector of the Arctic due to the economic crisis, in the nearest future one should expect a considerable increase in the anthropogenic load. Right now is the resuscitation of the Northern sea route, resumes exploration of mineral deposits. Thus, the existing network of Arctic protected areas of Yakutia, if not radically, it will greatly facilitate the solution of environmental problems of the North, resulting from its economic development.

Reference:

Andreev V.N., Galakyionova T.F., Perfil’eva V.I., Sherbakov I.P. The Main features of the vegetation cover of the Yakut ASSR. Yakutsk: Ya.F.SD RAS, USSR, 1987.156 p. (in Russian).

Atlas of Agriculture of the Yakutian ASSR. – Moscow, 1989. P. 40-41.

Borisov B.Z. Use space imagery to clarify the boundaries of geobotanical districts Arctic region of Yakutia // In: Collection of articles “Geobotanical and resource research in the Arctic”, 2010. – P. 185-189 (in Russian).

Green book of Siberia. Rare and in need of protection vegetative communities. –Novosibirsk, 1996. – 397 p.

Reimers N.F., Shtilmark F.R. Especially protected natural territories. Moscow, 1978. 295 p.

Distribution of the Sandhill Cranes (G. canadensis canadensis) in Northeast Asia

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Key words: Sandhill crane, Siberian crane, population, Yakutia, subarctic tundra, expansion

Global warming, which began in the second half of the 60s in most of the northern hemisphere, also affected territory of Yakutia. The strongest increase in temperature occurred here in the last 40 years. This is mainly due to increase winter temperatures. There is a lengthening of the warm period of the year. Spring comes to 10-15 days earlier and an end later in the autumn 15-20 days than it was in the middle of the last century. Maximum rate of temperature change was noted in Central Yakutia , the minimum - in areas north of latitude 69^{o} . In the Arctic regions of Yakutia (with the exception of the Kotelnii iceland, the village of Chokurdakh and the village of Verhojansk) the global warming is minimal.

The ongoing climate change contributes to expand the boundaries of animal ranges to the north and the emergence of the new species. Since the beginning of the 60s avifauna of Yakutia enriched by 21 breeding and 27 stray bird species.

Only two out of the four crane species breeding in Yakutia – the Siberian crane *Grus leucogeranus* and Sandhill crane *Grus canadensis canadensis* inhabit the northernmost regions of the subarctic tundra in the Yana – Kolyma Lowland.

One of the possible threats to the eastern population of the Siberian Crane - a rare species of fauna of the world, may come from the Sandhill Crane, which continuing trend of his expansion to the west. Currently, their breeding ranges are overlapping. The density of the population of Sandhill Cranes in the lower river of Indigirka, where he appeared in the 1990s, sometimes exceeds density of the Siberian Crane. In a seasonal shortage of feed, this is may lead to increased competition for the food resources, the more that these species diets largely overlaps.

As is known, in the presence of suitable habitats, the latitudinal distribution of the species limits exclusively by the climatic factors. The boundaries of the breeding range bounded by the extreme values of the Siberian Crane interval his preferred latitude and climatic conditions - its main nesting sites are within the parallel contours of air temperature 2 - 8 ° C in May, 4 - 8 - in June. The boundaries of the breeding range of the mid-continental population of the Sandhill Cranes are within 2 - 8 in Yakutia, 1 - 7 in Chukotka and Koryakia, -1 - 9 in Alaska, 10 - 11 in Canada.

Sandhill cranes continue to settle in the western tundra region and increase their numbers. At present, the range of this species is almost completely coincides with that of the Siberian crane (approximately 82 sq. km). Active penetration of Sandhill Cranes in Western Yakutia tundra, apparently began in the early 90s of the last century. The Sandhill cranes did not sighted during aerial surveys and ground-based field studies of the Siberian Crane, held in Lower Indidgirka tundra in the 60-80s. On the left bank of the river Indigirka (lower reaches of the river Berelekh) the breeding of this species for the first time established in 1998 - on 150 km from the previously known on the western border of the area along the river Sundrun. In July and August of 2009 6 sandhill cranes has been sighted in Chondon - Chroma rivers interfluve (lower reaches of the Sellyakh river), 250 kilometers west of the river Indigirka. And in August 2012 the breeding of the sandhill crane was sighted in the 50 km from the east coast of the Sellyahskaya bay. Thus, it is now possible to say with confidence that Sandhill crane actively resettled in the western, northern, perhaps, in the southern areas of the North -East of Russia.

References

Germogenov N.I., 2006. Changes in the avifauna of Yakutia in the last 45 years. *Modern Problems of the Ornithology of Siberia and Central Asia.* III International Ornithological Conference. Part 1. Ulan-Ude, 31-34.

Krapu G.L., Bysykatova I.P., 2010. New Western Breeding Limits for Siberian Cranes and Sandhill Cranes in Yakutia. *Unison Call*, newsletter of North american Crane Working Group. http://www.nacwg.org/news.html

Flora of vascular plants of the Resource Reserve "Kytalyk" (Northeastern Yakutia)

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Key words: flora, vegetation, rare species, tundra, Arctic

Data on the flora and vegetation of the RR Kytalyk are laid in the works by B.A. Sheludyakova [1938, 1948], M.S. Boch, V.T Tsareva [1974], V.I. Perfilyeva, A.A. Egorova, N.A. Stepanova [1991], A.A. Egorova, et al [1991], V.I. Perfilieva, L.V. Teterina, N.S. Karpov [1991]. Since 1976 the research on the impact of the crawler vehicles over the vegetative cover of the subarctic tundras have been conducted near Chokurdakh village [Andreyev, Perfilyeva 1979] as well as pasturing of domestic and wild reindeer [Karpov 1989].

The Resource Reserve Kytalyk (RRK) was established by the RS(Ya) Government Decree of August 12, 1996, No.337

Vegetation of the RR combines the features typical for the subzone of hypoarctic tundras. In the region under survey polygonal-ridged formations, raised-pool or sometimes hillocky-hollow microcomplexes are widespread. Development of plant groupings similar to plakor are typical on the positive relief elements, that enables to determine the latitudinal strike and excludes their recognition as bogs [Boch, Masing, 1979]. This is one of the features pertaining to the reserve's vegetation just as the whole tundra area of Yakutia.

According to the geobotanic zoning the area of the RR joins in the northern and southern belts of hypoarctic tundras and the Yana-Indigirka Okrug of the Yana-Kolyma hypoarctic subprovince [Andreyev, Galaktionova, Perfilyeva, Scherbakov, 1987]. The RR area is distinguished with tundras with participation of hypoarctic hemi-prostrating shrubs *(Betula exilis, Salix pulchra, S. glauca, S. reptans)* in the plakor and other locations close to them. Cotton grass hillocky tundras, occasionally combined with lichen or hypoarctic-low bush hillocky tundras occupying more elevated levels. Extensive polygonal-ridged and flat-hillock and hollow tundra-boggy microcomplexes with cotton grass and thin-birch tundras on the hummocks are developed in the lake-alas plains. Flat-hillock-ridged microcomplexes with the touch of lichen tundra occur over extensive areas together with polygonal-ridged tundra bogs.

The List of vascular plants given below is arranged according to A.L. Takhtadzhyan [1987], genera and species are brought in the alphabetical order. The names of taxons are cited as specified in the summary by S.K. Cherepanova [1995].

Selaginellaceae: *Lycopodioides sibirica* (Milde) Tzvel.;

Equisetaceae: *Equisetum arvense* L., *E. fluviatile* L., *E. scirpoides* Michx., *E. variegatum* Schleich. ex Web. et Mohr;

Ranunculaceae: *Caltha arctica* R. Br., *Delphinium chamissonis* G. Pritz. ex Walp., *D. chelianthum* Fisch., *D. middendorffii* Trautv., *Ranunculus gmelinii* DC., *R. jacuticus* Ovcz., *R. lapponicus* L., *R. nivalis* L., *R. pallasii* Schlecht., *R. pedatifidus* subsp. *affinis* (R. Br.) Hult., *R. propinquus* C.A. Mey., *R. pygmaeus* Wahlenb., *R. sabinii* R. Br., *Thalictrum alpinum* L.;

Papaveraceae: *Papaver lapponicum* subsp. *orientale* Tolm., *P. pulvinatum* subsp. l*enaense* Tolm.;

Portulacaceae: *Claytonia arctica* Adams;

Caryophyllaceae: *Cerastium jenisejense* Hult., *C. maximum* L., *Gastrolychnis furcata* (Raf.) Hult., *G. uniflora* (Ledeb.) Tzvel., *Minuartia arctica* (Stev. ex Ser.) Graebn., *M. macrocarpa* (Pursh) Ostenf., *M. rubella* (Wahlenb.) Hiern, *M. stricta* (Sw.) Hiern, *Moehringia lateriflora* (L.) Fenzl, *Sagina nodosa (L.) Fenzl, Silene repens* Patrin, *S. stenophylla* Ledeb., *Stellaria ciliatosephala* Trautv., *S. crassifolia* Ehrh., *S. edwardsii* R. Br., *S. peduncularis* Bunge, *Wilhelmsia physodes* (Ser.) McNeill;

Chenopodiaceae: *Monolepis asiatica* Fisch. et C.A. Mey.;

Polygonaceae: *Aconogonon tripterocarpum* (A. Gray) Hara, *Bistorta elliptica* (Willd. ex Spreng.) Kom., *B. vivipara* (L.) S.F. Gray, *Koenigia islandica* L., *Oxyria digyna* (L.) Hill., *Persicaria lapati*flora (L.) S.F. Gray, *Rumex arcticus* Trautv.;

Betulaceae: *Betula exilis* Sukacz., *Duschekia fruticosa* (Rupr.) Pouzar;

Pyrolaceae: *Orthilia obtusata* (Turcz.) Jurtz., *Pyrola rotundifolia* L.;

Ericaceae: *Andromeda polifolia* L., *Arctous alpina* (L.) Niedenzu, *A. alpina* subsp. *erytrocarpa* (Small) M. Ivanova, *Cassiope tetragona* (L.) D. Don., *Ledum palustre* subsp. *decumbens* (Aiton) Hill., *Vaccinium uliginosum* L., *V. vitis-idaea* L.;

Empetraceae: *Empetrum nigrum* L.;

Diapensiaceae: *Diapensia lapponica* subsp. *obovata* (Fr. Schmidt) Hult.;

Primulaceae: *Androsace bungeana* Schischk. et Bobrov, *A. septentrionalis* L., *A. triflora* Adams., *Douglasia ochotensis* (Willd. ex Roem. et Schult.) Hult.;

Salicaceae: *Salix alaxensis* Cov., *S. boganidensis* Trautv., *S. glauca* L., *S. fuscescens* Anderss., *S. hastata* L., *S. krylovii* E. Wolf, *S. lanata* L., *S. myrtilloides* L., *S. polaris* Wahlenb., *S. pulchra* Cham., *S. reptans* Rupr., *S. reticulata* L., *S. saxatilis* Turcz. ex Ledeb., *S. sphenophylla* A. Skvorts.;

Brassicaceae: *Achoriphragma nudicaule* (L.) Sojàk., *Arabidopsis petraea* (L.) V.I. Gorof., *Cardamine bellidifolia* L., *C. dentata* Schult., *C. pratensis* L., *Cochlearia arctica* Schlecht. ex DC., *Descurania sophioides* (Fisch. ex Hook.) O.E. Schulz, *Draba alpina* L., *D. cinerea* Adams, *D. fladnizensis* Wulf., *D. hirta* L., *D. juvenilis* Kom., *D. lactea* Adams, *D. nivalis* Liljebl., *D. oblongata* R. Br., *D. parvisiliquosa* Tolm., *D. pauciflora* R. Br., *D. pseudopilosa* Pohle, *D. subcapitata* Simm., *Eutrema edwardsii* R. Br., *Neotorularia* humilis (C. A. Mey.) Hedge et Leonard, *Spaerotorrhiza trifida* (Poir.ex Lam.) A. Khokhr.;

Crassulaceae: *Rhodiola borealis* Boriss.;

Saxifragaceae: *Chrysosplenium sibiricum* (Ser.) Charkev., *C. tetrandrum* (Lund ex Malmgr.) Th. Fries, *Saxifraga cernua* L., *S. caespitosa* L., *S. foliolosa* R. Br., *S. funstonii* (Small) Fedde, *S. hieracifolia* Waldst. et Kit., *S. hirculis* L., *S. hyperborea* R. Br., *S. nelsoniana* D. Don, *S. nivalis* L., *S. radiata* Small, *S. redofskyi* Adams, *S. spinulosa* Adams;

Grossulariaceae: *Ribes triste* Pall.;

Parnassiaceae: *Parnassia kotzebueiu* Cham. et Schlecht., *P. palustris* subsp. *neogaea* (Fer.) Hult.; **Rosaceae:** *Comarum palustre* L., *Dryas punctata* Juz., *Rubus arcticus* L., *R. chamaemorus* L., *Potentilla hyparctica* Malte, *P. nivea* L., *P. stipularis* L., *P. uniflora* Ledeb., *Sanguisorba officinalis* L., *Rosa acicularis* Lindl.;

Onagraceae: *Chamerion angustifolium* (L.) Holub, *C. latifolium* (L.) Holub, *Epilobium davuricum* Fisch. ex Hornem, *E. palustre* L.;

Fabaceae: *Astragalus alpinus* L., *A. frigidus* subsp. *parviflorus* (Turcz.) Hult., *A. tugarinovii* Basil., *Hedysarum arcticum* B. Fedtsch., *H.* dasycarpum Turcz., *Lathyrus palustris* subsp. p*ilosus* (Cham.) Hult., *Oxytropis adamsiana* (Trautv.) Jurtz., *O. deflexa* (Pall.) DC., *O. leucantha* subsp. *subarctica Jurtz*., *O. mertensiana* Turcz., *O. nigrescens* (Pall.) Fisch.;

Apiaceae: *Angelica decurrens* (Ledeb.) B. Fedtsch., *Cnidium cnidiifolium* (Turcz.) Schischk., *Phlojodicarpus villosus* (Turcz. ex Fisch. et C.A. Mey.) Ledeb.;

Adoxaceae: *Adoxa moschatellina* L.;

Valerianaceae: *Valeriana cap*itata Pall. ex Link.;

Gentianaceae: *Comastoma tenellum* (Rottb.) Toyokuni, *Dasystephana algida* (Pall.) Borkh.;

Menyanthaceae: *Menyanthes trifoliata* L.;

Polemoniaceae: *Polemonium acutiflorum* Willd. ex Roem. et Schult., *P. boreale* Adams;

Boraginaceae: *Eritrichium villosum* (Ledeb.) Bunge, *Myosotis asiatica* (Vest.) Schischk. et Serg.;

Scrophulariaceae: *Lagotis minor* (Willd.) Stand., *Pedicularis amoena* Adams ex Stev., *P. capitata* Adams, *P. hirsuta* L., *P. labradorica* Wirsing, *P. langsdorffii* Fisch. ex Stev., *P. lapponica* L., *P. pennellii* Hult., *P. sceptrum-caolinum* L., *P. sudetica* subsp. *albolabiata* Hult., *P. sudetica* subsp. *interioides* Hult., *P. tristis* L.;

Lentibulariaceae: *Utricularia vulgaris L.;*

Hippuridaceae: *Hippuris tetraphylla* L., *H. vulgaris* L.;

Campanulaceae: *Campanula rotundifolia* subsp. *langsdorfii* (Fisch. ex Trautv. et C.A. Mey.) Vodop.;

Asteraceae: *Antennaria friesana* (Trautv.) Ekman, *Arnica iljinii* (Maguire) Iljin, *Artemisia borealis* Pall., *A. dracunculus* L., *A. furcata* Bieb., *A. glomerata* Ledeb., *Crepis chrysantha* subsp. *minor* (Ledeb.) Lomonosova, *Erigeron elongates* Ledeb., *Petasites frigidus* (L.) Fries, *P. glacialis* (Ledeb.) Polun., *Saussurea alpina* (L.) DC., *S. tilesii* (Ledeb.) Ledeb., *Tanacetum bipinnatum* (L.) Sch. Bip., *Taraxacum lateritum* Dahlst., *T. longicorne* Dahlst., *T. macroceras* Dahlst., *T. sibiricum* Dahlst., *Tephroseris atropurpurea* (Ledeb.) Holub, *T. jacutica* (Schischk.) Holub, *T. palustris* (L.) Reichenb., *T. tundricola* (Tolm.) Holub., *Tripleurospermum hookeri* Sch. Bip., *T. subpolare* Pobed.;

Juncaginaceae: *Triglochin maritimum* L.;

Potamogetonaceae: *Potamogeton perfoliatus* L., *P. vaginatus* Turcz.;

Melanthiaceae: *Tofieldia coccinea* Richards., *Veratrum lobelianum* Bernh.;

Liliaceae: *Lloydia serotina* (L.) Reichenb.;

Alliaceae: *Allium schoenoprasum* L.;

Convallariaceae: *Smilacina trifolia* (L.) Desf.;

Juncaceae: *Juncus biglumis* L., *J. castaneus* Smith, *J. castaneus* subsp. *leucochlamys* (Zing. ex V. Krecz.) Hult., *J. triglumis* L., *Luzula confusa* Lindeb., *L. nivalis* (Laest.) Spreng., *L. parviflora* (Ehrh.) Desv., *L. rufescens* Fisch. ex E. Mey., *L. sibirica* V. Krecz., *L. tundricola* Gorodk. ex V. Vassil., *L. wahlenbergii* Rupr.;

Cyperaceae: *Carex aguatilis* Wahlenb., *Carex aguatilis* subsp. *stans* (Drej.) Hult., *C. appendiculata* (Trautv.) Kűk., *C. bigelowii* subsp. *arctisibirica* (Jurtz.) A. et D. Löve, *C. bigelowii* subsp. *rigidioides* (Gorodk.) Egor., *C. chordorrhiza* Ehrh., *C. fuscidula* V. Krecz. ex Egorova, *C. fuliginosa* subsp. *misandra* (R. Br.) W. Dietr., *C. glacialis* Mackenz., *C. glareosa* Wahlenb., *C. lachenalii* Schkuhr, *C. maritima* Gunn., *C. marina* Dew., *C. rariflora* (Wahlenb.) Smith, *C. rotundata* Wahlenb., *C. saxatilis* subsp. *laxa* (Trautv.) Kalela, *C. subspathacea* Wormsk. ex Hornem., *C. ursina* Dew., *C. vaginata* Tausch, *Eriophorum angustifolium* Honck., *E. brachyantherum* Trautv. et C. A. Mey., *E. medium* Anderss., *E. russeolum* subsp. l*eiocarpum* Novosselova, *E. scheuchzeri* Hoppe, *E. vaginatum* L.;

Poaceae: *Alopecurus alpinus* Smith, *A. rosheitzianus* Ovcz., *Arctagrostis arundinacea* (Trin.) Beal, *A. latifolia* (R. Br.) Griseb., *Arctophila fulva* Anderss., *Beckmannia syzigachne* (Steud.) Fern., *Calamagrostis holmii* Lange, *C. lapponica* (Wahlenb.) C. Hartm., *C. neglecta* (Ehrh.) Gaertn., *C. purpurascens* R. Br., *Deschampsia borealis* (Trautv.) Roschev., *D. glauca* C. Hartm., *D. submutica* (Trautv.) Nikiforova, *Dupontia fisheri* R.Br., *D. psilosantha* Rupr., *Elymus macrourus* (Turcz.) Tzvel., *E. vassilijevii* Czer., *Festuca auriculata* Drob., *F. brachyphylla* Shult. et Schult., *F. rubra* L., *Hierochloe alpina* (Sw.) Roem. et Schult., *H. pauciflora* R. Br., *Hordeum jubatum* L., *Phippsia algida* (Soland.) R. Br., *P. concinna* (Th. Fries) Lindeb., *Pleuropogon sabinii* R. Br., *Poa alpigena* (Blytt.) Lindm., *P. alpigena* subsp. c*olpodea* (Fries) Jurtz. et Petrovsky, *P. arcica* R. Br., *P. glauca* Vahl, *P. paucispicula* Scribn. et Merr., *P. tolmatchevii* Roshev., *Puccinellia borealis* Swall., *P. hauptiana* V. Krecz., *P. phryganodes* (Trin.) Scribn. et Merr., *Trisetum sibiricum* Rupr.;

Sparganiaceae: *Sparganium hyperboreum* Laest. ex Beurl.

Currently 275 species and subspecies of vascular plants from 45 families and 117 genera have been recorded over the area of the RR and this correlates with the certain number for the plain hypoarctic Yakutia tundras.

The principal ten families comprise 67.0% from the total flora composition of vascular plants including 32% of genera. The most species abundance is represented by families *Poaceae* (36 sp and subsp), *Cyperaceae* (24), *Asteraceae* (23), *Brassicaceae* (22), *Caryophyllaceae* (17), *Salicaceae* and *Ranunculaceae* (14 each). The richest in species diversity are genera *Carex* (19 sp and subsp.), *Salix* (14), *Draba* (12), *Saxifraga* and *Pedicularis* (11 each), *Luzula* (7). The families with one and two species make 57.8% from the total number of families.

By the ratio of latitudinal-zonal elements the flora is a model of the plain hypoarctic one. The arctic, arctoalpine, hypoarctic and boreal species do not differentiate much in their number. But among dominant and active species arctoboreal, arctoboreal-montane and hypoarctic are mostly prevalent. The hypoarctic pattern of the flora is expressed mainly in high percentage of the last mentioned sp (to 30%). These are shrubs: *Betula exilis, Salix pulchra, S. glauca, s. reptans, Duschekia fruticosa*, undershrubs: *Vaccinium uliginosum, V. vitis-idaea, Ledum palustre ssp. decumbens*, grasses: sedge family (*Carex concolor, C. arctisibirica, Eriophorum polystachyon, E. vaginatum)*.

Among longitudinal groups the prevalence of circumpolar species that is typical for many northern floras is observed. The species characteristic of Chukotka such as *Androsace ochotensis, Parnassia kotzebuei*, et al. also occur here. Notable participation of the American species (over 20%) is registered as well.

Only 9 taxa (spp and taxa) are endemic among vascular plants: *Ranunulus jacuticus, Papaver lapponicum ssp. orientale, P. pulvinatum ssp. lenaense, Hedysarum dasycarpum, Oxytropis leucantha ssp. subarctica, Androsace triflora, Thymus oxyodonthus, Campanula rotundifolia ssp. langsdorffiana, Tephoseris jacutica.*

6 rare and endangered species joining the Red Book of Yakutia [2000] are specified: *Rhodiola borealis, Parnassia kotzebuei, Phlojodicarpus villosus, Androsace ochotensis, Pedicularis pennellii, Artemisia glomerata.* Medicinal herbs (25 spp) grow within the limits of the RR Kytalyk and 10 of them are used as medicinal and food raw material by local residents.

References

Andreyev VN, Galaktionova TF, Perfilyeva VI, Csherbakov IP (1987) Osnovnye osonennosti rastitelnogo pokrova Yakutskoy ASSR. Izd-vo Yaf SO AN SSSR, Yakutsk – *Dasic features of vegetation cover of the Yakutian ASSR* (in Russian)

Andreyev VN, Perfilyeva VI (1979) Vliyaniye dvizheniya gusenichnogo transporta na rastitelnost subarktichecheskoy tundry. In: Prooceeding of 7th All-Union Symposium @Biological problems of the North@/ Apapity: 22-24. – *Impact of caterpillar transport on the3 Subarctic tundra vegetation* (in Russian)

Boch MS, Tsareva VT (1974) K flore nizovyev Indigirkii (v predelakh tundrovoy zony). Botanichesky zhurnal 59 (6): 839 – 849 – *On the flora of the Lower Indigirka (on the tundra zone)* (in Russian)

Boch MS, Mazing VV (1979) Ekosistemy bolot SSSR. Nauka, Leningrad – *Bog ecosystems in the USSR* (in Russian)

Egorova AA, Vasilyeva II, Stepanova NA, Fesko NN (1991) Flora tundrovoy zony Yakutii. Izd-vo YaNTs SO RAN, Yakutsk – *The flora the tundra of Yakutia* (in Russian)

Karpov NS (1989) Dinamika rstitelnosti subarktichecheskoy tundry Yakutii pod vliyaniem vypasa severnykh oleney. Abstract of Thesis for a Candidate Degree. Moscow – *Vegetation dynamics of the subarctic tundra affected by reindeer grazing* (in Russian)

Perfilyeva VI, Egorova AA, Stepanova NA (1981) K flore Kondakovskogo ploskogorya (Severo-Vostochnayaq Yakutia). In: Andreyev VN (ed) Rastitelnost Yakutii I eyo okhrana. Izd-vo YaF SO AS SSSR, Yakursk – *On the flora of the Kondakovskoye Plateau (north-eastern Yakutia)* (in Russian)

Perfilyeva VI, Teterina LV, Karpov NS (1991) Rastitelny pokrov tundrovoy zony Yakutii. Izd-vo YaNTs SO RAN, Yakutsk – *Vegetation cover of the tundra zone of Yakutia* (in Russian)

Shheludyakova VA (1938) Rastirelnost basseynaq reki Indigirki. Sovetskaya botanica 4 – 5^ 43-79 – *Vegetation of the Indigirka River basin* (in Riussian)

Shheludyakova VA (1948) Rastitelnost severo-vostoka Yakutii. In: Loklaly naq pervoy nauchnoy sessii Yakutskoy basy AN SSSR. Gosisdat, Yakytsk – *Vegetation 0f the North-eastern Yakutia* (in Russian)

Monitoring of vegetation on mountain mining areas in the Arctic Yakutia

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Key words: restoration of vegetation, macroanthropogenous sites, monitoring, Arctic, Yakutia.

Results of monitoring researches of technogenic landscapes are given in a subband the pretundra sparse forests. In mine vicinities Kular we considered restoration of a vegetation cover on meso- and macroanthropogenous sites. At monitoring researches it is established that big changes happened on macroanthropogenous sites. In the Arctic influence of an anthropogenous factor on processes of a thermokarst differs considerable intensity.

In our republic of one of leading industries is gold mining, developed from the middle of the 20th years of last century. 3 large-scale deposits are operated: Aldan, Upper-Indigirsky and Kularsky. The two first fields are in a forest zone, and Kularsky – in a subband the pretundra of sparse forests. After mountain development the natural landscape completely changes and represents heaps of dumps with various substratum, a different bias and drying settlers with loamy soil.

In 1994-1996 and 2000 dynamics of natural restoration of a vegetation cover of the broken sites under the influence of mountain development in a subband the pretundra of sparse forests in a neighborhood of the settlement Kular (the Yana River lower reach) was studied. Industrial development of the Kularsky gold deposit was begun in 1963.

The valleys of the rivers turned to the North, are subject to influence of the Arctic air, in hollows and hollows close cold air collects. In the winter fogs, low overcast, calms are often observed, the Arctic cyclones with strong winds (speed of 20-30 m/s). Average annual air temperature is about -16 °C, the average monthly temperature of January –29-38 °C, July 12 °C, an annual amount of precipitation – 150-250 mm (a settlement meteorological station. Kazachye).

On geobotanical division into districts the settlement territory Kular enters the Omoloy-Indigirsky district of the Northeast pretundra subprovintion with the mountain and flat forests of a subband the pretundra of sparse forests (The main features …, 1987). For this district alternation the treecovering and the treeless areas is characteristic. Sparse forests occupy 35% of the area, the tundra – 40%, bogs – 15-20%, bushes and meadows – small sites (Nosova, 1964).

On technogenic landscapes with completely destroyed soil and vegetation the speed of restoration of a vegetation depends on mechanical structure of a substratum, age of technogenic substratum, moistening and activity of this or that species of plants. On dumps with a big stone material without fine soil (no more than 2-3% of the total area of technogenic landscapes) process of natural planting by vegetation goes very poorly or in general is absent. Process of a natural planting of the bottoms of settlers and dumps with a fine soil has different stages of restoration of vegetation. Restoration of vegetation of the bottoms of settlers and dumps in the conditions of the forest-tundra goes by primary successions, generally at the expense of local grassy flora and pioneer mosses.

In the bottoms of settlers restoration of a vegetation begins after the termination of its functioning. The flooded and remoistened soil of settlers grows with *Tephroseris palustris*. The initial stage of formation of *Tephroseris* group is presented by vegetative escapes, for the second year sockets, and then a generation stage.

The following stage – the sockets buried by old generative stalks, then the second generation of *Tephroseris palustris* and so proceeds to a site drying. Violation of a mode of continuous remoistening of communities of *Tephroseris palustris* gives rise to changes. Level of the majority of settlers is higher, than at a number of proceeding streams therefore water often finds a drain and follows. Then on a being formed bog there are *Eriophorum medium, Beckmannia syzigachne* and *Puccinellia hauptiana*. Cruder sites are occupied by *Arctophila fulva*. To 3-4-year age open not close groups with participation one-biannual mix herb, cereals both sedge and close communities of biennials develop. By 10 years in the bottoms of settlers of group disappear. *Tephroseris palustris* and *Eriophorum* communities on the remoistened soil, *Puccinellia* and open mix herb-cereals of different structure of community – on soil drying the middle humid prevail. Further at strong drying anthropogenous *Arctagrostis* and *Puccinellia* meadows with transition to a *Poa* meadow are formed.

On dumps characteristic primary group is anthropogenous group from *Descurainia* *sophioides* occupying middle humid fine earth substrata which is capable to renew on one place long time. The moss circle is developed poorly, pioneer mosses of *Ceratodon purpureus, Leptobryum pyriforme, Bryum pseudotriquetrum* (to 25%) prevail. At herbage in small abundance there is *Puccinellia hauptiana*, its presence is a sign of outlined change of *Descurainia* community to *Puccinellia* communities, the most widespread on a stage of restoration of vegetation on technogenic soil. Occupies the greatest spaces, *Arctagrostis latifolia* take part in herbage, *Epilobium davuricum, Eriophorum medium, Tephroseris palustris, Descurainia sophioides, Matricaria tetragonosperma*, from mosses *Leptobryum pyriforme* prevails, *Bryum pallescens, Pottia heimii var. obtusifolia*. One of the last stages of formation of vegetation on technogenic soil are anthropogenous *Arctagrostis* meadows, they occupy tops and gentle slopes of dumps and develop on a place of mix herba-cereals and the *Equisetum arvense* of groups. In damp falls at top of dumps plentifully grows *Marchantia polymorpha*.

In 2000, in 5 years on monitoring sites of the settlement Kular (MK), we made observations over vegetation changes on them. Noted vegetation change on 8 sites from 15. It, generally those sites which were at the settlement, ranging from 200 m to 1,5 km. On some of them already began a repeated mining of scatterings since the place where there was a settlement Kular, was rich with a deposit of loose gold.

The bottom of a settler of MK-3 (age of 10 years) in 1994 was occupied with almost pure thicket from *Tephroseris palustris*. From mosses *Leptobryum pyriforme, Bryum pseudotriquetrum* most plentifully met. In the forecast there was a moving of a *Tephroseris palustris* on condition of an drying of the coast of the lake. In a year of monitoring supervision the *Tephroseris palustris* group was replaced by the mix herb-*Marchantia polymorpha*. *Epilobium davuricum* participated in addition of herbage, *Chamerion angustifolium, Descurainia sophioides, Puccinellia hauptiana*, they together made to 20% of a covering. In a surface cover of *Marchantia polymorpha* formed a continuous cover (80-100%), its presence testifies to periodic redundancy of moistening.

MK-15 settler (age of 20 years). Groups were described: mix herb-cereals-scum liken-pioneer mosses and mix herb-*Puccinellia*-pioneer mosses. In the future it was supposed that the *Deskurainia* group will pass into the *Puccinellia* group. But it was replaced by a *Poa-Eriophorum*-moss meadow where a projective covering of types was: at *Poa alpigena* – 15%, *Eriophorum medium* – 25%, *Equisetum arvense* – 30%, a moss cover continuous: *Ceratodon purpureum* – 50%, *Marchantia polymorpha* – 45%.

MK-16 settler (age of 5 years) with mix herb-*Puccinellia*-pioneer mosses group on the lake coast. Herbage rarefied (25%). *Puccinellia hauptiana* (15%) was the most plentiful, it is a lot of *Equisetum arvense, Eriophorum medium, Tephroseris palustris, Matricaria tetragonosperma*, together cover 10 %. The moss cover is well developed (80%) and *Leptobryum pyriforme*, by *Bryum pseudotriquetrium, Funaria hygrometrica, Ceratodom purpureum* is educated. In the forecast was that *Puccinellia hauptiana* will dominate in the long term. In 5 years the settler surface completely grew with *Tephroseris palustris, Puccinellia hauptiana, Matricaria tetragonosperma.* Though the abundance of *Puccinellia hauptiana* increased to 30%, it on height (average height of 40 cm) in herbage was in the second circle in impurity with *Matricaria tetragonosperma.* In the first circle *Tephroseris palustris* which was in a generative phase with the average height of 80 cm and a projective covering of 40% therefore from far away it seemed dominated that all surface of a settler is occupied only by a *Tephroseris palustris*. Mosses occupied 70% of the area.

MK-17 settler (age about 25 years). *Bekmannia-Eriophorum* bog. Uniform herbage (the general covering of 40%) from *Eriophorum medium, Beckmannia syzigachne, Arctagrostis latifolia* with impurity *Arctophila fulva, Poa alpigena, Puccinellia hauptiana, Hordeum jubatum*. It isn't enough mosses, only 5%. When monitoring it is revealed that the abundance of *Arctagrostis latifolia* increased to 25%, *Eriophorum medium* to 15-20%, *Poa alpigena* – 10-15%, *Epilobium davuricum* – 10%, in a surface cover there were many vegetative escapes of *Rorippa palustris* up to 20 cm high with a projective covering of 20%. General covering of herbage is 95%. The next year the site became dry. In 4 years the bog dried and turned into an *Arctagrostis*-mix herb meadow. Under this site there was an intensive melting of repeated and vein ices, the small river with a strong current was formed. Because of it the way which was paved near a site, failed. The ravine up to 10 m long was formed.

MK-1 dumps (age of 10 years). In 1994 it was described *Descurainia* and *Descurainia-Puccinellia*-moss groups where *Descurainia sophioides* and *Puccinellia hauptiana* prevailed. 5 years of group later *Equisetum arvense* – 55% were replaced Po*a-Equisetum arvense-Marchantia polymorpha* where 25% of a covering fell to the share of *Poa alpigena*, in a surface cover *Marchantia polymorpha* (95%) dominated.

On MK-7 dumps (age of 10 years) *Arctagrostis latifolia* with a projective covering to 60% dominated, the rags occupied it to 30% of the place. In the next years dense *Arctagrostis latifolia* herbage was rarefied the mix herbs: *Descurainia sophiifolia, Equisetum arvense, Epilobium davuricum, Matricaria tetragonosperma, Poa alpigena*. The *Arctagrostis anthropogenous* meadow was replaced by a mix herb-*Arctagrostis* meadow. As a result of thermokarst processes at top of sites of MK-7 and MK-8 at first were formed bajdzharakh hillocks, under which intensively melt repeated and vein ices. Over time sites collapsed, on their place there were huge deep holes.

MK-8 dumps (age of 10 years) were covered with mix herb-cereals group. Herbage was formed by *Arctagrostis latifolia, Festuca brachyphylla, Trisetum spicatum, Puccinellia hauptiana, Hordeum jubatum, Matricaria tetragonosperma, Taraxacum ceratophorum, Descurainia sophioides, Chamerion angustifolium*, etc. which together made to 25% of a covering. The rags of cereals made: *Arctagrostis arundinaceus* – 25-30%, *Festuca brachyphylla* – 10%, *Critesion jubatum* – 30%. The covering of mosses was to 40%: *Ceratodom purpureum, Bryum pseudotriquetrium, Hylocomium splendens var. alascanum, Marchantia polymorpha*. Over time the abundance of types changed and the group was replaced with the *Arctagrostis*-mix herb-moss: *Arctagrostis arundinaceus* – 15%, *Petasites frigidus* – 10-15%, *Chamerion angustifolium* – 15%, *Taraxacum ceratophorum* – 3%, etc. It is a lot of rags of *Arctagrostis* – 20%. Covering mosses of 60% (*Bryum pseudotriquetrium*).

MK-11 dumps (age of 10 years) were occupied by a anthropogenous *Puccinellia* meadow (80%) and the rarefied *Puccinellia*-pioneer mosses group (20%). In a year of monitoring supervision the *Epilodium-Equisetum*-moss association where 10-15% fall to the share of *Epilobium davuricum*, by *Equisetum arvense* – 25%, mosses – 80% is noted: *Ceratodom purpureum* of-40%, *Marchantia polymorpha* – 35%.

In the Arctic influence of an anthropogenous factor on thermocarst processes very strong also differs considerable intensity since permafrost soil lies very close from a soil surface (Gordeyev, 1971). On sites of development of loose fields there is a sag of the soil, being accompanied a current of soil masses on slopes. If in the thickness of loams powerful repeated and vein ices lie, at their intensive melting fields of baidzharakh are formed. In a neighborhood of the settlement Kular the proximity of the settlement had a great impact on intensity of a melting of repeated and vein ices of dumps and settlers. Sites with intensive manifestation of thermocarst processes were from the settlement ranging from 200 m to 1,5 km.

References

Influence of the mining industry on ecosystems of the Northeast of Yakutia // V. I. Zakharova, N. K. Potapov, N. S, Karpov, etc. – Novosibirsk: Science, 2010. – 208 p.

Gordeyev P. P. Ancient and modern thermokarst on Yano-Omoloysky Entre Rios // Geocryologic researches. – Yakutsk: Yak. book publishing house, 1971. – P. 135-140.

Main features of a vegetable cover Yakut Autonomous Soviet Socialist Republic. – Yakutsk: YaF SD Academy of Sciences of the USSR, 1987. – 156 p.

Change of vegetation in larch forest after mass outbreak of the *Dendrolimus superans sibiricus Tschetv.*

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Key words: Dendrolimus superans sibiricus, larch forest, Central Yakutia, change of vegetation

Introduction

The main changes of microclimatic conditions on the larch forest after mass outbreak of the *Dendrolimus superans sibiricus Tschetv*., concerned factors of lighting, a temperature mode, conditions of moistening, manifestation of biogene influence of worms. The death of a forest stand and the related strong clarification of the struck sites, change of microclimatic conditions, increase of a seasonal thawed layer lead to sharp change of specific structure and abundance of present species.

Results and discussions

Dendrolimus superans sibiricus mass outbreak periodically were registered in Lensk, Olyokma, Hangalassky, Namsky regions of Yakutia. The last mass outbreak of its number concerns to the largest in Yakutia. At the beginning of summer of 1999 on Central Yakutia regions emergence of the centers of mass outbreak of the *Dendrolimus superans sibiricus* was recorded. In the 2000 the high number of the wrecker on the area over 5 million hectares is noted. From them on 500 thousand hectares the centers of mass outbreak are noted. In them it was recorded strong damage - degree from 20 to 100% from several tens to tens of thousands hectares (Fig.1.).

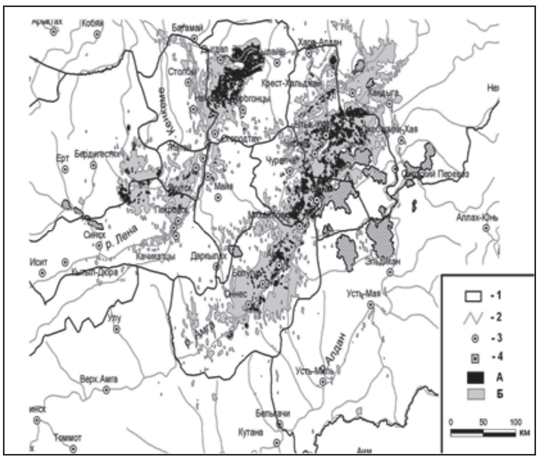

Fig.1. Map of distributions of the *Dendrolimus superans sibiricus Tschetv.* in the Central Yakutia in 2000-2001 according to SPOT4-Vegetation satellite images (Chikidov, Borisov, Isaev, 2010)

Forest defoliation, decrease in the root competition and sharp increase in quantity of humus in the soil processed by caterpillars from needles of a larch, gives an impetus to development in a cover of fast-growing plants, such as a *Vicia cracca, Artemisia tanacetifolia, Rosa acicularis* (Fig.2.).

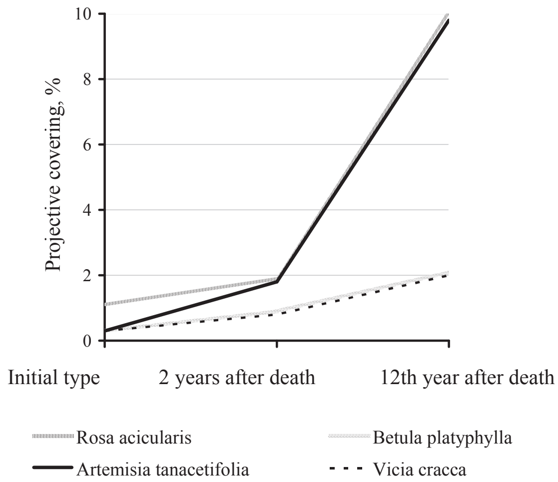

Fig.2. Species increasing the cover

Part of forest plants gradually reduce the cover, remaining by 12th year after mass outbreak of the *Dendrolimus superans sibiricus* in the form of small spots of vegetation. These are such species, as *Vaccinium vitis-idaea, Linnea borealis* and *Limnas stelleri*, and also mosses *Aulacomnium turgidum* and *Dicranum sp*. (Fig.3.).

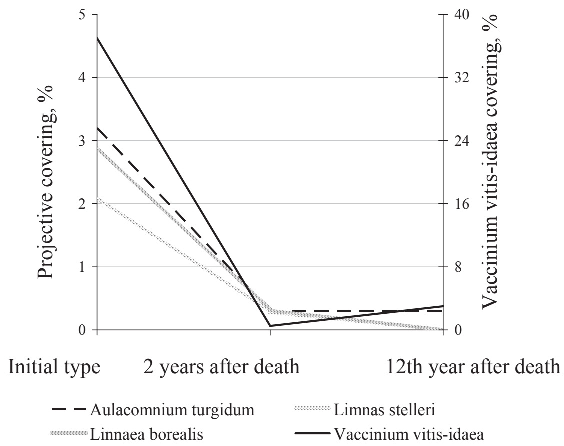

Fig.3. Species reducing the cover

Some forest plants, such as *Orthilia obtusata, Aquilegia parviflora, Carex vancheurkii, Equisetum scirpoides, Pyrola incarnata, Arctous erythrocarpa,* species of lichens, completely drop out of cover (Fig.4.).

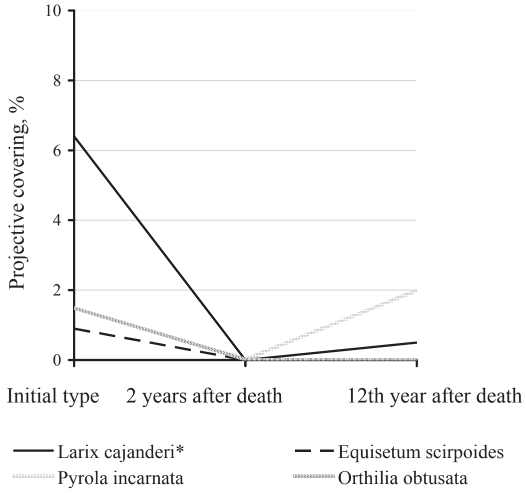

Fig.4. Species disappearing from cover

In a cover appear and such species as *Ribes parviflorum, Calamagrostis langsdorfii, Fragaria orientalis* and a *Achillea millifolium* start increasing a projective covering (Fig.5.).

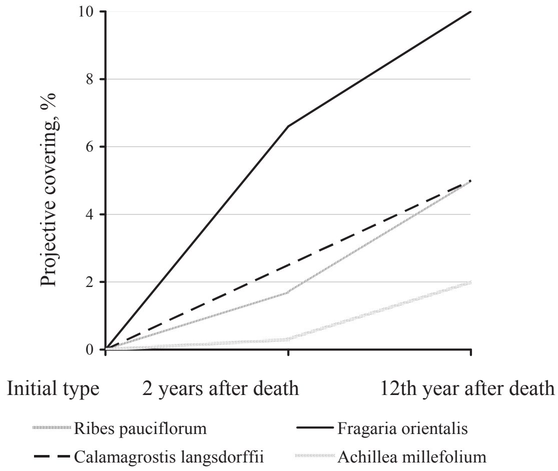

Fig.5. Species appearing in cover

Conclusions

The changes happening in a projective covering of the main components of a vegetation cover in larch forest after mass outbreak of the *Dendrolimus superans* generally are similar to vegetation change on fire burning larch forest. Dynamics of restoration of vegetation gives similar peaks of growth of covering of vegetation components (Fig.6.).

The emergence of peaks caused by such factors as death of a forest stand, the increase in a sun radiation, soil quality, excrement of caterpillars, etc., at the identical scheme of development, goes little different rates. In larch forest post mass outbreak of the *Dendrolimus superans*, the vegetation allows for shorter term than on fire burning larch forest. By 2-3 year after death of trees, these species reach a maximum of covering. In turn, on fire burning larch forest, peaks of a covering are reached by 4-6 year, with higher rates.

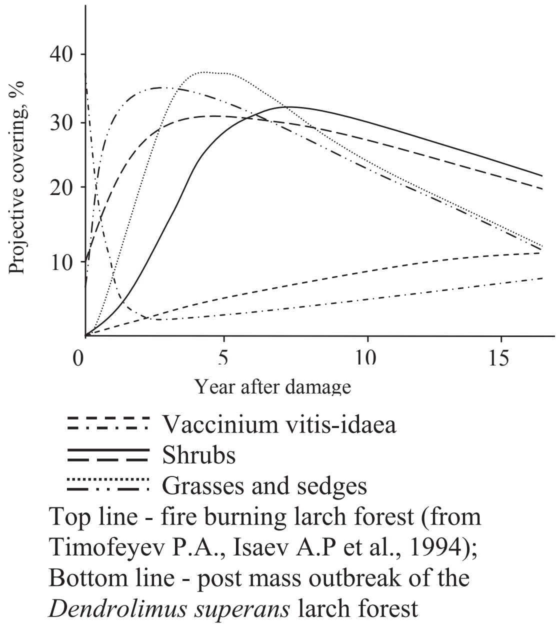

Fig.6. Dynamics of a projective covering of vegetation components on post fire and post mass outbreak of *Dendrolimus superans sibiricus* larch forests

References

Chikidov I.I., Borisov B.Z., Isaev A.P., 2010. Otcenka ploshadi ochagov massovogo razmnojenia sibirskogo shelkoprjada v 1999-2000 gg. v Centralnoi Yakutii po dannym SPOT-Vegetation // Nauka i obrazovanie №4 (60), Yakutsk, P. 76-82.

Timofeyev P.A., Isaev A.P., Scherbakov LP., et al., 1994. Lesa srednetaejnoi podzony Yakutii. Yakutsk, 140 p.

Dynamics alas spatial structure under the climate change

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Key words: dynamics, spatial structure, alas, climate change

Introduction

Last decades increased interest to researches on climate change and related changes of an environment. One of fast changing component of alas ecosystem is the spatial structure.

Field site

Studying of alas spatial structure dynamics was carried out on model alas «Ulakhan Sykkhan», located in 45 km north-east from Yakutsk in central part of the Lena - Amga interfluve during from 1999 to 2012. Absolute altitude of geodetic point located in the west part of alas is 133,3 meters, i.e. the depth of depression in this outskirts of alas makes 9-12,7 meters (Desyatkin et al., 2001). The shape of alas is oval and the long side is oriented from west to east. The maximum length of alas is 1545 meters, the greatest width - 725 meters. Total area of alas is 63,7 hectare.

Results

The weather conditions of vegetation period during the research had significant fluctuations and followed natural rhythms. Temperature of the summer season (May - September) of 2000 and 2004, were close to long-term average (Fig.1). Temperature records of 2001-2003 and 2005–2012 periods were higher than long-term average. During the warm season of 2000-2002, 2004, 2008-2010, 2012 fell 1,5-2 times lower precipitations than long-term average value. In 1999, 2003, 2005-2007, 2011 fell 1,2-1,6 times higher summer precipitation than long-term average. Thus, by agrometeorological conditions 1999, 2003, 2005-2007 and 2011 are favorable, and 2000-2002, 2004, 2008-2010 and 2012 are arid years.

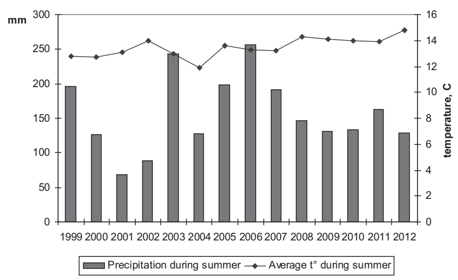

Fig.1. Meteorological conditions for st. Yakutsk.

The spatial structure of alas consist water surface of the lake, belts of wet, real, steppe meadows, and also a narrow strip of mesophytic meadows on the edge of larch forest under the slope of northern exposition and birch-larch - under the slope of a southern exposition.

In the beginning of observation the lake area was 5,2 hectare or 8,2% of all area of the alas. From 2000, under influence of a droughty climate the period of gradual drying of alas lakes was observed (Fig.2). Smallest area of the lake was observed in 2004 and was only 0,3 hectare. During the subsequent wet periods with positive water balance the area of lake has expanded up to 46,5 hectare or 72,9 % of total alas area in 2008. In the following years there was a gradual shrinking of the lake area up to 37,0 hectares.

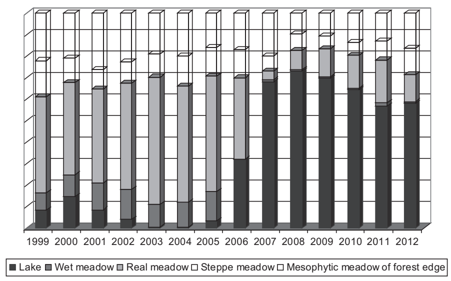

Fig.2. Dynamics alas spatial structure.

In 1999, the area of wet meadow was 5,1 hectares. In connection with the lake area shrinkage, the borders of wet meadows gradually expanded. The maximum area of wet meadow in 2002 was 8,9 hectare, but in 2006 have completely disappeared due to expansion of the lake water mirror. In 2007, the area of wet meadow was 0,6 ha and the next 3 years it almost has no change. Only in 2011 increased up to 1,0 ha. The area of the real meadow has increased from 28,5 in 1999 up to 37,8 ha in 2003.Further expansion of the lake in 2007 has affected reduction of the real meadow area to the minimum (2,7 hectare). In subsequent years there has been a gradual expansion of the area of these meadows up to 12,6 ha in 2011.

If in 1999 the steppe meadow occupied 10,8 hectare or 17 % of the total alas area after few years its area was reduced up to 3,9 hectare or 6,2 % of the total alas area in 2010. The same tendency was observed on mesophytic meadows of forest edge. Its area has decreased from 16,8 hectare in 2001 to 6,1 hectare in 2008. In general, during the period of observation is clearly visible a correlation between the dynamics of the alas spatial structure and climate variations. In wet years there is an expansion of the lake area and the reduction in the area of vegetation belts.

References

Desyatkin R., Nikolaeva M., Desyatkin A., Stepanova M., Ishii Y., Yabuki H. 2001. Geobotanical map of “Ulakhan Sykkhan” alas. Activity Report of GAME-Siberia 2000, GAME Publication No. 26, 131-141.

Comparison of Vegetation Changes in Siberia Detected by SPOT-vgt and MODIS Data

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Key words: remote sensing, vegetation, NDVI, Siberia

1. Introduction

In Siberia, vegetation is changing not only by climate variation (Suzuki et al., 2001) but also human activities such as cattle grazing, urban expansion, and natural resource exploration. Recently the issue of reindeer overgrazing in the tundra area in Siberia has received attentions (Golovatin et al., 2012). However, it is impractical to monitor vegetation and grazing status in a wide area by field investigation because of large labor and cost required. Satellite remote sensing is an effective tool to monitor vegetation in a large area. The purpose of this paper is to try to detect vegetation change in Siberia particularly induced by non-climate factors such as reindeer grazing.

2. NDVI and LST trends in 2001-2012

The decadal vegetation change in Siberia was analyzed. The following MODIS data products were used for the trend analysis from 2001 to 2012; Normalized Difference Vegetation Index (NDVI) (MOD13A2; 1km spatial resolution and 16 days time interval) and Land Surface Temperature (LST) (MOD11A2; 1km spatial resolution and 8 days time interval).

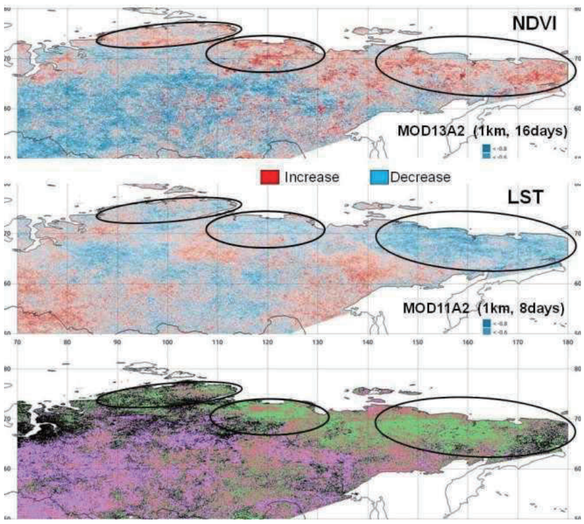

Fig.1. Trends of the yearly maximum NDVI (top) and LST (middle) from 2001 to 2012 derived from MODIS data. The bottom figure shows the areas with NDVI increase and LST decrease in green color.

The trends of the yearly maximum NDVI and LST were shown in Fig. 1. We chose the yearly maximum to avoid the cloud contamination problem. We can recognize that NDVI increased in the east Siberia and Arctic regions during this period, while LST decreased in the similar areas probably due to evapotranspiration increase caused by vegetation increase.

3. Correlation analysis between NDVI and climate factors

We chose the tundra areas in Siberia (45°N~80°N, 60°E~180°E) as the target of correlation analysis, because reindeers are commonly grazed in the tundra areas and it would be difficult to detect vegetation change in forest floor of the taiga areas. The tundra areas are derived from Global Land Cover 2000 (GLC2000) dataset as shown in Fig. 2 (http://bioval.jrc.ec.europa.eu/).

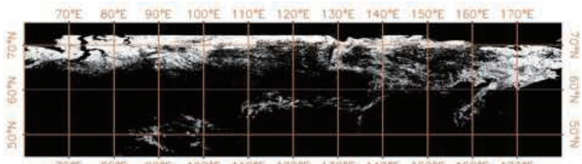

Fig. 2. Tundra areas in white color from GLC2000.

The NDVI dataset of SPOT-vegetation from 1999 to 2009 was used for monitoring the vegetation change in this area. Fig.3 shows the eleven-year average NDVI. The high NDVI areas correspond to the taiga forest, while the tundra areas show a relatively low NDVI. The grid meteorological data sets of the monthly surface air temperature (SAT) with 1.25° resolution from JRA25/JCDAS (Onogi et al., 2007) and the monthly precipitation with 2.5° resolution from GPCP (Gruber and Levizzani, 2008) were collected for our analysis.

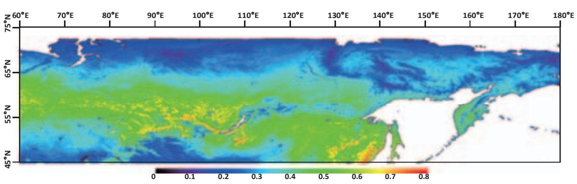

Fig. 3. Average NDVI of SPOT-vgt in 1999-2010.

As shown in Fig. 4, the methodology consists of two parts. Firstly pre-processing was conducted for reducing the cloud contamination in the NDVI data by using the Savitzky-Golay (Chen et al., 2004) (Fig. 5), and the NDVI and meteorological data were resampled to the same spatial resolution of 5 km. Secondly, the method of Evans and Geerken (2004) was applied to extract the tundra degradation areas induced by non-climate factors.

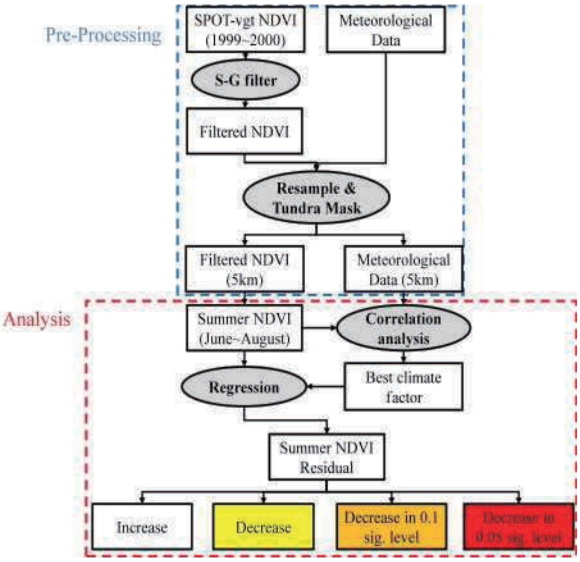

Fig. 4. Flowchart of the methodology.

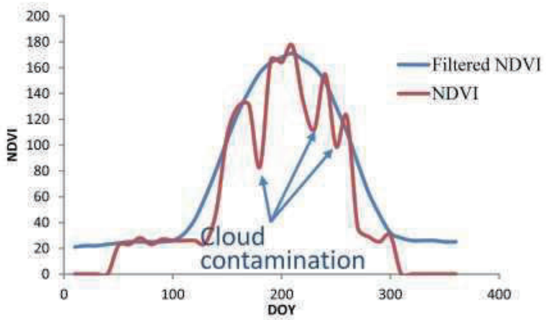

Fig. 5. An example of Savitzky-Golay filter.

As the grazing season is from June to August, the summer NDVI in the same seasonal period was picked up. The trend of summer NDVI is shown in Fig. 6. Considering that there might be a lag and accumulate effect in the relationship between climate factors and NDVI, we calculated correlation coefficients between the annual summer NDVI and SAT/precipitation in different periods. There were nearly no correlations between summer NDVI and precipitation in any periods. The best climate factor correlated with the summer NDVI most strongly was SAT from May to August, which means that the lag effect of SAT is around one month. Based on this result, SAT from May to August was selected for subsequent analysis

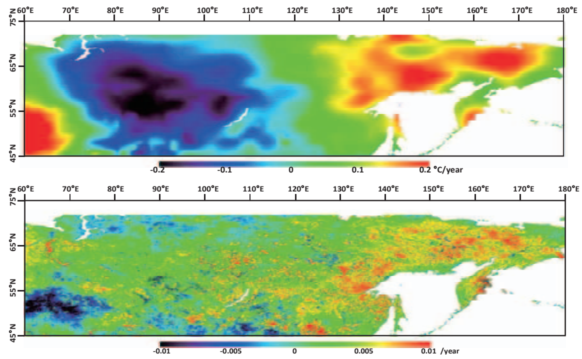

Fig. 6. Trends of the summer SAT (upper) and summer NDVI (lower) in 1999-2010.

In order to address the mixing effect of the climate variation and non-climate factors such as cattle grazing, Evans and Geerken (2004) proposed a discrimination method by combing the remote sensing data and meteorological data. The idea is illustrated in Fig. 7.

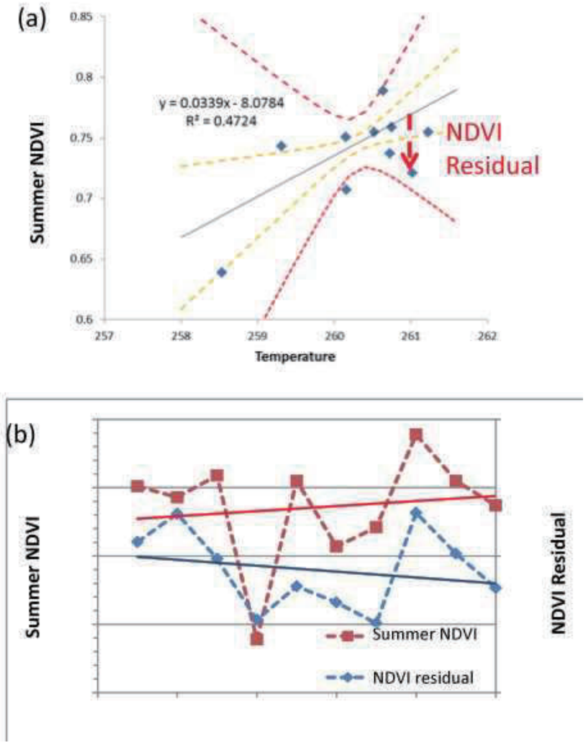

Fig. 7. Illustration of Evans and Geerken (2004)'s method. Regressions between (a) the summer NDVI and SAT, and (b) the NDVI residual and years.

Firstly, regression was conducted between the summer NDVI and summer SAT. Then, NDVI residual (difference between the actual NDVI and predicted NDVI) was calculated based on the regression model. As the climate effect was removed by the regression, the change of annual NDVI residual can be regarded as the changes induced by non-climate factors. Finally, trend of the NDVI residual from 1999 to 2010 was calculated, and the decreasing trend was classified into three grades: decrease without significance, decrease significantly with the level of 0.1 (p<0.1), and decrease significantly with the level of 0.05 (p<0.05).

Based on the method mentioned above, the tundra degradation pixels induced by non-climate factors were picked up as shown in Fig. 8. The reindeer camp locations were also marked as plus in the same figure. The picked up areas seemed to be generally consistent with the camp locations, which could reflect the grazing areas to some extents. However, as the camp locations are too few to confirm the effectiveness of this method, further careful confirmation is still needed.

Fig. 8. Detected tundra degradation areas possibly by non-climate factors.

4. NDVI analysis at the selected test sites

The inter-annual surface changes from 2001 to 2012 were analyzed at the selected test sites; Olenek Brigade and Sebyan Kyuelj in Sakha. The MODIS data sets used were NDVI (MOD13Q1), Normalized Difference Snow Index (NDSI) (MCD43A3), surface temperature (MOD11A2), and snow cover (MCD43A2). Fig. 9 and Fig. 10 show their inter-annual changes. We can recognize that year 2004 was a significant year at the both sites; snow melting and spring NDVI onset were later and summer (June to August) surface temperature was lower compared with those of the other years.

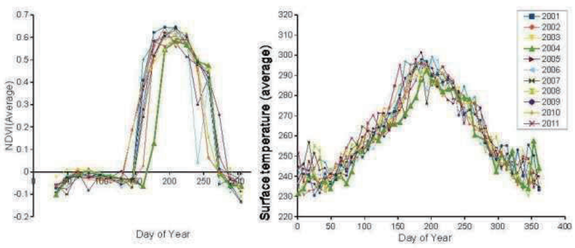

Fig. 9. NDVI and surface temperature changes from 2001 to 2012 at Olenek Brigade in Sakha.

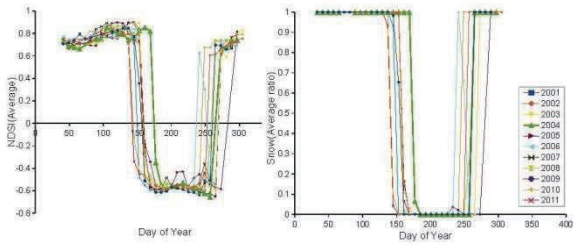

Fig. 10. NDSI and snow cover changes from 2001 to 2012 at Olenek Brigade in Sakha.

No long-term systematic NDVI decreasing trends were observed at the both sites. We could not confirm the vegetation changes induced by reindeer grazing either at these sites.

5. Concluding remarks

NDVI in the east Siberia and Arctic regions was increasing from 2001 to 2012, while surface temperature was decreasing probably due to evapotranspiration increase. Some of the NDVI decreasing areas seem to be consistent with the reindeer grazing camp locations, but further confirmation is needed. Future works include to check the vegetation decrease areas by wild fires, correlation analysis between NDVI and precipitation with 1-year time lag, and trend analysis with shorter time periods.

Acknowledgement: The authors would like to thank Dr. Kazuhiro Oshima of JAMSTEC for providing the meteorological dataset.

References

Chen J. et al., 2004. A simple method for reconstructing a high-quality NDVI time- series data set based on the Savitzky-Golay filter. *Remote Sens. Environ.* **91**, 332-344.

Evans J. and Geerken R., 2004. Discrimination between climate and human-induced dryland degradation. *J. Arid Environ.* **57**, 535-554.

Golovatin M. et al., 2012. Effect of reindeer overgrazing on vegetation and tundra ecosystems of the Yamal peninsula. *Czech Polar Reports*, **2**(2), 80-91.

Gruber A. and Levizzani V., 2008. Assessment of global precipitation product. *World Climate Research Programme Report*, (website: http://www.gewex.org/ reports/2008AssessmentGlobalPrecipReport.pdf)

Onogi, K. et al., 2007. The JRA-25 Reanalysis. *J. Meteorol. Soc. Japan*, **85**, 369-432.

Suzuki R. et al., 2001. Spatial distribution and its seasonality of satellite-derived vegetation index (NDVI) and climate in Siberia. *Inter. J. Climatol.*, **21**, 1321-1335.

Forest fire detection and monitoring system in Yakutia based on remote sensing data

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Key words: remote sensing, forest fire, satellite data, monitoring system

Introduction

Forest fires are a part of environment system. They play an important role in renewal and change of forests, nature ecosystem biodiversity, species and age structure of forests, and their resource and ecological potential. But fires can have a positive or negative effect on the environment. Unfortunately, negative effects of forest fires often dominate the positive impacts, especially where the thechogenic pressure on the environment is high.

The major causes of forest fires in Russia are the thunderstorm activity and the human factor. Increase of industrial impacts on the environment (extensive industrial development, expansion of the transport infrastructure, agricultural activity, etc.) leads to imbalance in the natural forest life cycles due to the man-made increase of the pyrogenic factor.

In addition to direct economic damage to forest resources, fires also cause significant damage to forest ecosystems and pollute the atmosphere with combustion products (a mixture of various gases, aerosol and smoke particles), affecting physical and chemical processes in the atmosphere.

Wild fires constitute special danger to regions with big territories and huge forests, such as Siberia and Yakutia. Only on the territory of Eastern Siberia annually forest fires burn up to 140 thousand hectares of woods. In the separate fire-dangerous years, the burned area increases many times. So, in Yakutia in 2002, the total burned area was about 500 thousand hectares.

The purpose of article is to show the possibilities of regional system of forest fire detection and monitoring based on remote sensing data.

Forest fire detection and monitoring system

In the Institute of Cosmophysical Research and Aeronomy SB RAS (ICRA SB RAS) the monitoring system was created in 1995 for “in real-time mode” monitoring of forest fires and a flood in Yakutia on base of direct readout satellite station “Scanor”. Scanor station was designed and made by the SCANEX Research and Development Center (SCANEX R&D Center) in Moscow, Russia. Station “Scanor” provides reception the data from NOAA satellites in HRPT (High Resolution Picture Transmission) telemetric format. Owing to a favorable geographical location (62N, 129L), the receiving station has wide field of the view: from Yenisei in the west up to Alaska in the east, and from North Pole up to Japan in the south. Simultaneously there are a several operating NOAA satellites on Earth orbits and they provide the full review of Yakutia several times a day.

On the base of satellite data there are conducted the researches of influence of solar-terrestrial relationships on cloud cover over Siberia, studies of NDVI-index variations of vegetation in northern, central and southern regions of Yakutia, researches of forest fires activity and so on (Solovyev, Shuts 1997; Solovyev, Kozlov 2005, 2009; Solovyev et al. 2006; Solovyev 2009; Solovyev, Budishchev 2010; Vasil’ev, Vasilieva, Solovyev et al. 2010).

In real-time mode monitoring of a flood, forest fires and cloudiness on NOAA data are conducted annually during May-September. Results of monitoring (satellite images of a flood, maps of forest fire, and maps of cloudiness) are posted online on web-server (lgi.ysn.ru).

The architecture of the user web-interface of information resource based on satellite monitoring data is presented in fig. 1. The main page has corresponding links to thematic web-pages («Cloudiness», «Forest fires», «Flood», etc.) which contain the current results of satellite monitoring. Also there is a possibility to access to archives of satellite data. Updating of contents of thematic pages happens 5-7 times per day. Results of forest fire monitoring are presented as distribution of «hotspots» on Yakutia map in raster formats (jpg, png) and in format of shape-file for GIS system. Through the corresponding links on the main page of information resource the registered users have possibility of access to databases «Cloudiness» and «Forest Fires» that contain data since 1997.

Resume

The exploitation of ICRA SB RAS satellite system (since 1998) based on NOAA data showed its utility and necessity for monitoring and detection of forest fires in Yakutia. Main users of forest fire monitoring system of IKFIA are the some regional ministries, the federal organizations, the enterprise of various forms of ownership and interested people. The advantages of regional monitoring system are fast delivery of information to consumers and the possibility of feedback «consumer-supplier».

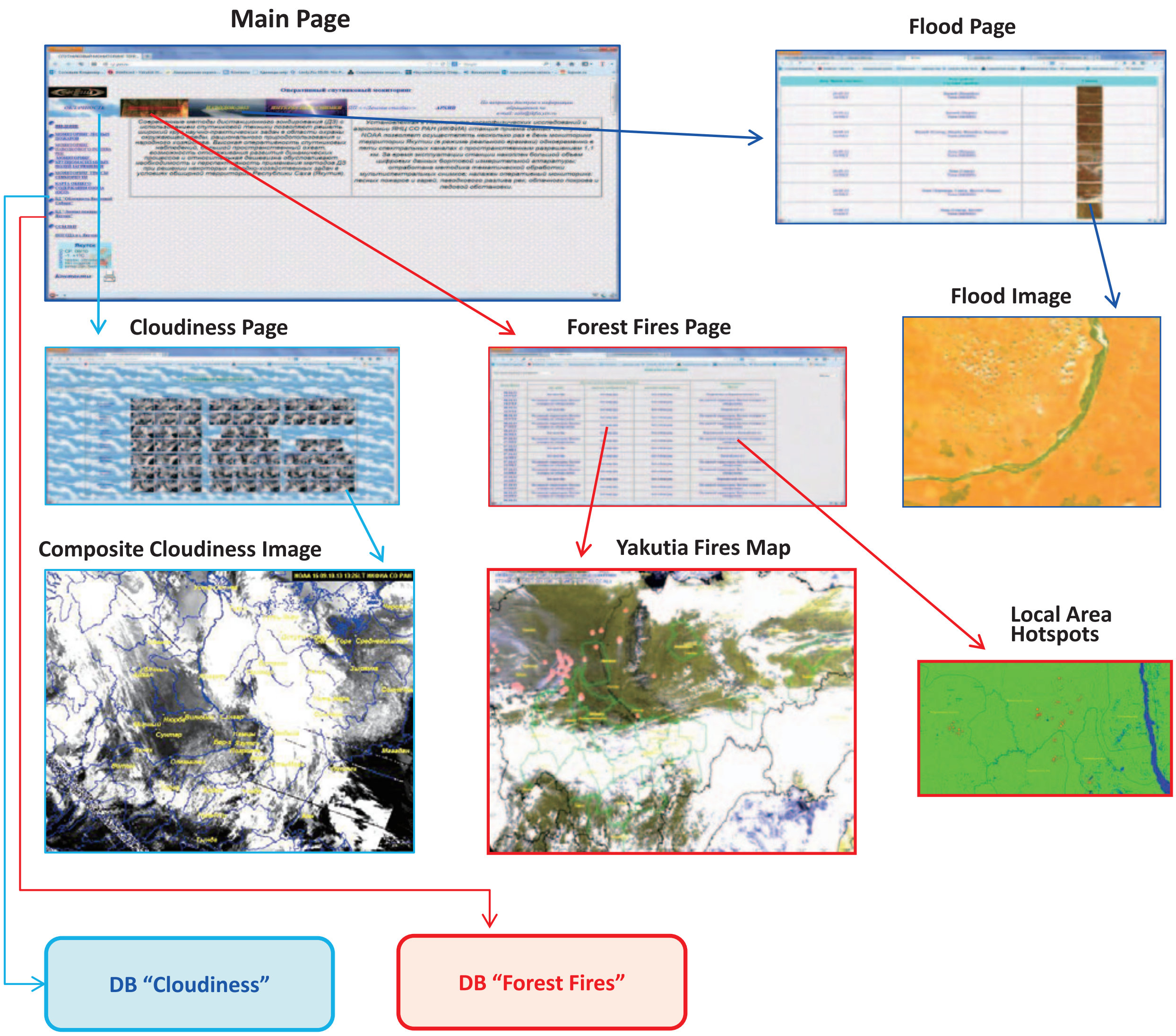

Fig. 1. The structure of information resource based on satellite monitoring system of Institute of Cosmophysical Research and Aeronomy SB RAS.

References

Solovyev V.S., Shuts M.M., 1997. Remote sensing of the environment in Northern Siberia. *Research Reports of IHOS*, Nagoya, Japan, March 1997, N3, p.82-84.

Solovyev V.S., Kozlov V.I., 2005. Research of spatial-temporal dynamics of forest fires in Eastern Siberia. *Proceedings of International Symposium on Remote Sensing of Environment «Global Monitoring for Sustainability and Security»*, Saint-Petersburg, June 20-24 2005, Section « Disasters and Hazards» ID:465.

Solovyev V.S., Kozlov V.I., Vasil'ev M.S., Andreev N.B., Belov V.V., Afonin S.V., Angel M.V., 2006. Investigation of Forest Fires in Yakutia (1998-2005) on Data of Remote Sensing. *Proceedings of International Workshop on "Tropical Rain Forest and Boreal Forest Disturbance and Their Affects on Global Warming"*, University of Palangka Raya, Indonesia, 16-18 September 2006, pp. 8-14.

Solovyev V.S., 2008. The influence of human activity on forest fires in Yakutia. *Proceedings of 4th International WS on C/H2O/Energy balance and climate over boreal regions with special emphasis on eastern Eurasia*. 14-16 July, 2008.

Yakutsk, Russia. Published in Nagoya University, Japan. 2009. P.113-114.

Solovyev V.S., Kozlov V.I., 2009. Influence of cosmic ray variations on cloudiness distribution over Northern Asia. *Russian Physics Journal*, Vol. 52, No. 2, 2009, P. 127-131.

Solovyev V. S., Budishchev A. A., 2010. Disturbances of Aerosol Optical Thickness of the Atmosphere Caused by Forest Fires in Yakutia. *Atm. and Ocean. Optics.* 2010. Vol. 23. №6. P. 538-541.

Vasiliev M.S., Vasilieva S.A., Solovyev V.S., Budischev A.A., 2010. Study of Effects of Natural And Tehnogenic Factor On Pirogenic Activity. *Materials of the IX International Symposium on Cold Regions Development «The application of technologies for the conservation of nature in Cold Regions»*. Yakutsk, 1-5 June, 2010. – P. 235.

Usage of the DHI-index in mapping of biodiversity of terrestrial mammals in Yakutia

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Key words: Biodiversity, Protected areas, GAP-analyst, Artic flora

Introduction

Monitoring patterns of fauna diversity across the landscape, both spatially and temporally, presents special challenges due to the dynamic nature of populations and complex interactions with the local and regional environment. One area where progress is being made is the development of relationships between regional biodiversity with indirect indicators or surrogates, such as vegetative production. In this report we discuss implementation of a dynamic habitat index, originally developed in Australia to Yakutian conditions. The index, based on the fraction of photosynthetically active radiation (fPAR) absorbed by vegetation, a variable which is analogous to green vegetation cover, is derived solely from satellite data. The index utilizes time series of satellite observations of greenness to derive three indicators of the underlying vegetation dynamics; the cumulative annual greenness, the minimum level of perennial cover, and the degree of vegetation seasonality (Coops et al. 2008).

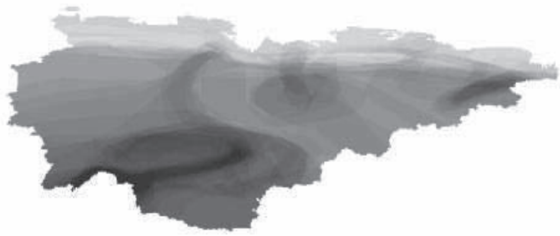

Fig.1. Raster map "Biodiversity Yakutian mammals"

This methodology can provide an initial stratification of large areas for biodiversity monitoring and can be used to focus finer scale approaches to specific regions of interest or monitor regions too remote for comprehensive field surveys.

Materials and Methodic:

To create a map of mammal diversity of Yakutia were used ranges from the book «Terrestrial animals of Russia» (2002). Using the GIS software ArcGIS 10.1 these maps were converted to vector format SHP. The resulting raster map (Fig.1) was used in the comparison with the data of DHI to check the results of the articles Mackey et al. (2004), Nilsen et al (2005), Berry et al. (2007). The basic idea is that the biodiversity of terrestrial mammals depends strongly on the primary productivity of ecosystems. Primary productivity can be calculated using satellite images (in our case MODIS) through vegetation index DHI (Dynamic Habitat Index), as did Mackey et al. (2004) and updated for the conditions in the Canadian North N.Coops et al. (2008). In this work we used the data of DHI received in the period from 2010 to 2012 (Fig. 2).

Fig.2. Map of the Dynamic Habitat Index

Observation:

For work were used 54 cards ranges of mammals Yakutia who had polygon view. In the future, these maps were vectorized in SHP format. The next step was to convert these vectors in bitmap format. Part of the habitat where species of animal is present received the numeric value of «1», where the species is absent - «0». The next step is costing all rasters maps habitats in a single raster map by simple arithmetic addition. The resulting raster - this is the Map of the biological diversity of terrestrial mammals Yakutia (Fig. 1). Then we have compared the obtained maps of the mammals biodiversity data DHI. To do this in ArcGIS 10, we have created 10 000 random points on the entire territory of Yakutia. By certain functions we have transferred these points card information of the biological diversity of mammals and index data DHI (Fig.2). Data DHI were used in one decade, from 2002 to 2012, as was the difference in received data was very small. Variability of the data was only 2-4%. Apparently difference arises due to climatic conditions and forest fires.

Analysis of the data card biodiversity terrestrial mammals Yakutia data DHI showed a high level of correlation - 0,78 (Fig. 3). This indicator is very high and therefore we believe that the data DHI very successfully can be used as a surrogate in studying the spatial distribution of the biological diversity of terrestrial mammals not only Yakutia, but also on the territory of Siberia.

Results:

The comparison of these data: Yakutian mammals biodiversity maps and DHI data, showed a high correlation (k=0.78) (Fig. 3). Index DHI strongly depends on the sum of positive temperatures, latitude and altitude. Thus biodiversity Yakutia depends heavily on climate change. Using remote-sensing, we can prediction the change in animal biodiversity.

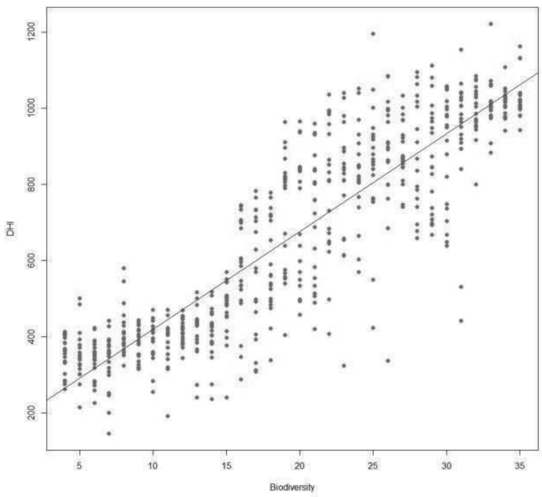

Fig.3. The correlation between the data card of the biological diversity of mammals Yakutia and data DHI

(R-squared: 0.7844, p-value: < 2.2e-16)

Reference:

Berry S., Mackey B., Brown T. Potential applications of remotely sensed vegetation greenness to habitat analysis and the conservation of dispersive fauna. Pacific Conservation Biology. 2007. P. 120-127.

Coops N.C., Wulder M.A., Duro D.C., Han T., Berry S. The Development of a Canadian Dynamic Habitat Index using multi-Temporal satellite estimates of canopy light Absorbance. Ecological Indicators 8(5): 2008. P. 754-766

Mackey B.G., Bryan J. and Randall L. Australia's Dynamic Habitat Template 2003. 'MODIS Vegetation Workshop II' which is hosted by the 'Numerical Terradynamic Simulation Group (NTSG)' (a part of the School of Forestry, University of Montana) and NASA. 2005.

Nilsen E.B., Herfindal I., Linnell J.D.C. Can intra-specific variation in carnivore homrange size be explained using remote-sensing estimates of environmental productivity? Ecoscince 12(1): 2005. P. 68-75

Pavlinov I.Y., Kruskop S.V., Varshavskiy A.A., Borisenko A.V. Terrestrial animals of Russia. Moscow: KMK. 2002. 298 p. (In Russian)

Studying of forest fires influence on lower atmosphere on remote sensing data

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Key words: forest fires, aerosol, emission, combustion products

Introduction

Forest fires have impacts on the environment, nature ecosystem biodiversity, species and age structure of forests, and their resource and ecological potential. The major causes of forest fires in the Asian part of Russia are the thunderstorm activity and the human interference. Increase of industrial impacts on the environment (extensive industrial development, expansion of the transport infrastructure, agricultural activity, etc.) leads to imbalance in the natural forest life cycles due to man-made increase of the pyrogenic factor.

In addition to direct economic damage to forest resources, fires also cause significant damage to forest ecosystems and pollute the atmosphere with combustion products (a mixture of various gases, aerosol and smoke particles), affecting physical and chemical processes in the atmosphere. Powerful convection currents of air, developed above large-scale forest fires, emit combustion products into high altitudes, where they can be carried by wind over long distances from the fire source.

There are a number of works on monitoring and study of forest fires, aerosol optical properties based on remote sensing data (Afonin 2008; Giglio 2006; Solovyev 2006, 2009, 2010).

Yakutia is one of the most fire vulnerable regions of the Russian Federation; according to the data of the Yakutia forest protection organization, more than 500 fires are recorded annually in an area of about 140 000 ha. Forest fires in Yakutia occur from May to September, with a peak in late summer.

This work is on study of impacts of large-scale forest fires (central Yakutia, 2002) on aerosol characteristics of the lower atmosphere based on the remote sensing data.

Study area

Yakutia is located in Far-Eastern Siberia and covers an area of $\sim 3.1 \cdot 10^6$ km^2 of which $\sim 1.5 \cdot 10^6$ km^2 are covered by forest. The climate of Yakutia is markedly continental; the amplitude of annual temperature fluctuations can exceed 100° C. The seasonal precipitation of central Yakutia in May-September is about 160 mm.

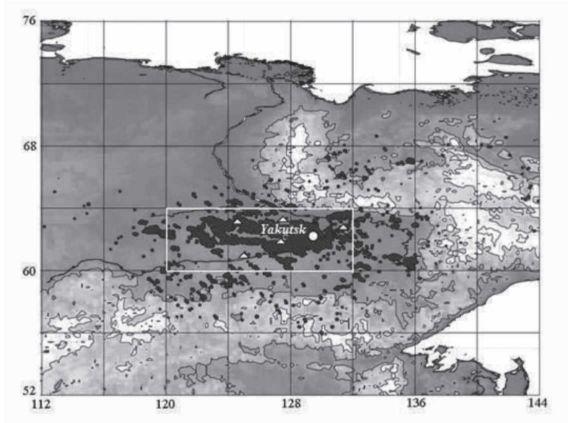

Fig. 1. General map of forest fires (black dots) registered in 2002 in Yakutia according to the data of satellite observations. Rectangle – area under study, triangles – meteostations, circle – Yakutsk.

Fig. 1 shows a map of Eastern Siberia with the study area (60^0–64^0 N, 120^0–132^0 E) marked as a rectangle, locations of the weather stations being marked by triangles, the city of Yakutsk marked by a circle and the identified forest fires in 2002 – marked by black dots. The region under study is surrounded by massifs of the Verkhoyansk and Stanovoi from the north (partly), east and south, which hampers the horizontal carryover of injected smoke particles out of the region. Vegetation of the study area is dominated by boreal forests of larch dahurian with varying degrees of crown density.

Averaged for the fire season (May-September) values of aerosol optical thickness (AOT) of the test site for 2000-2012 makes 0.13. In years with low fire activity (2000, 2004-2010), the value is 0.096, and in years with high fire activity (2001-2003, 2011-2012) – 0.17.

Data

The level of forest fire activity was estimated by the number of hotspots (N_{fire}), identified according to the data of the Moderate-resolution

Imaging Spectroradiometer (MODIS) observations (product MOD14A1). Only high confidence hotspots were taken into account. Burned area was identified by MCD45A1 product.

MOD08_D3 data are daily averaged AOT values gridded on 1 x 1° (lat. x lon.) map. The average AOT values of the studied area were calculated only for those days, when at least a half of the area was covered by the data. This condition was used due to limitations of AOT retrieval methods in the presence of heavy cloud cover and / or smoke.

Total Ozone Mapping Spectromenter (TOMS) data (product TOMSEPL3.008) are daily average aerosol index (AI) values gridded on 1 x 1.25° map. Data from 3 to 12 August are not available for technical reasons.

MODIS and TOMS data were obtained from the Giovanni online data system, developed and maintained by the NASA GES DISC (Acker 2007).

The surface air temperature was estimated based on Advanced TIROS Operational Vertical Sounder (ATOVS / NOAA 15, 16) data, obtained at Direct Readout Ground Station at Yakutsk. To assess the behavior of temperature variations we calculated deviations (ΔT) of daily average temperatures in 2002 from daily averages for 2004-2012 (years with low fire activity).

An average rainfall in the area was estimated according to weather stations data, marked by triangles in Fig. 1.

Emission of trace gases was estimated by Seiler-Crutzen model (Seiler 1980):

$$E = A \cdot B \cdot C \cdot D,$$

where A – burned area [m^2], B – density of the burned biomass [kg/m^2], C – proportion of biomass burned [%], D – mass of the material ejected from the combustion of 1 kg of biomass[g/kg], E – total mass of the material ejected by fire [g]. The values of the coefficients B, C and D were taken from Wiedinmyer (2006), taking into account the characteristics of the vegetation (type, crown closure) at the test site.

Forward trajectories of aerosol plumes movement were calculated by Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT / NOAA, Draxler 1998). Daily mean wind patterns at 850 mb were obtained from NCEP Reanalysis.

Results and Discussion

Summer 2002 was extremely fire-dangerous in Yakutia. Figure 2 shows the daily variations of the number of hotspots N_{fire} (solid line), temperature deviations ΔT (dashed line) and the amount of rainfall (vertical columns). There are two main periods of increased fire activity – 18-24 July and 14-21 August.

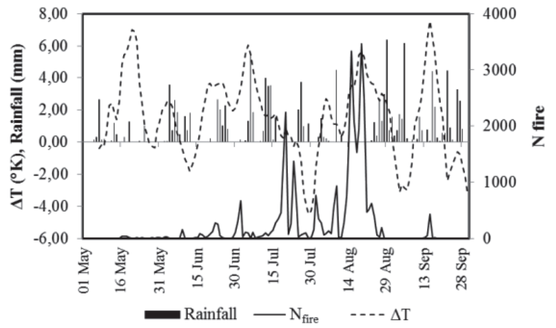

Fig. 2. Daily average variations of the number of «fire» pixels (solid line), rainfall (vertical columns) and smoothed ΔT (dashed line) in May-September 2002.

As it can be seen in Fig. 2, from early May to mid-July, daily temperature is generally a few degrees above the average, while the rainfall is very low. These conditions led to a high level of forest fire risk in central Yakutia and resulted in increased forest fire number on July 18-24 with maximum values of $N_{fire} > 2000$.

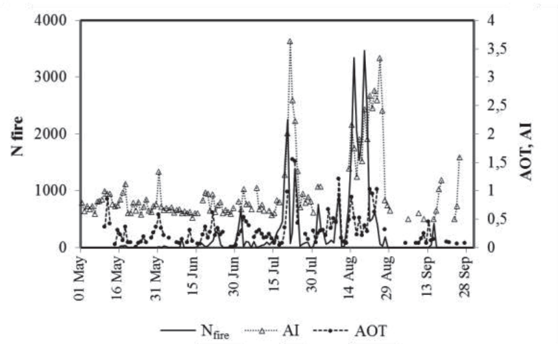

Fig. 3. Daily average variations of the number of «fire» pixels (solid line), AI (dotted line) and AOT (dashed line) in May-September 2002.

From late July to mid-August there was a decrease of ΔT and the corresponding decrease in forest fires activity.

The growth of ΔT and decrease in rainfall developed next period of increased fire activity observed on 14-21 August with the maximum number of $N_{fire} > 3000$. The autumn rains in late August caused a decrease of the forest fire number to a minimum. However, on September

14-15, there was a small outbreak of pyrogenic activity coincided with the September peak of ΔT.

Figure 3 shows the daily variations of the number of hotspots N_{fire} (solid line), AI (dotted line) and AOT (dashed line). In the first period of increased fire activity, maximal values of AOT and AI reached ~1.5 and ~3.6, respectively. High values of AI indicate the presence of a large number of highly UV absorbing aerosols in the atmosphere produced as a result of forest fires.

Maximum AI values during the second period of increased fire activity reaches ~3.3, while maximum AOT values did not exceed ~1. Insignificant growth of AOT values, in comparison with the first period, can be caused by underestimation due to the limitations of AOT retrieval over heavy cloud cover and/or smoke.

As shown in Fig. 3, AI values falls simultaneously with the number of hotspots. However, after the second period of increased fire activity AI values remain high during six days (21-27 August). This is explained by the different dynamics of air masses in these cases. The analysis of daily average wind patterns at 850 mb shows, that during the first period, there was an intense removal of combustion products from the study area. In the second case, there was a stagnation region formed over the study area by low wind speeds, which led to accumulation of injected combustion products in the atmosphere over the study area.

High values of AI on 23-25 September were caused by the transfer of aerosol plumes from severe forest fires outside the study area.

Total emissions of combustion products presented in Table 1.

Table 1. Total emissions of combustion products in central Yakutia in 2002.

	Emission, Tg	Rate of global fire emissions, %
CO_2	68 – 171	0,9 – 2,4
CO	3,5 – 9,7	0,9 – 2,5
CH_4	0,13 – 0,52	0,6 – 2,4
NH_3	0,025 – 0,098	0,3 – 1,4
SO_2	0,021 – 0,087	0,8 – 3,5

The contribution of considered forest fires in the study area in global fire emissions in 2002 (Van der Werf 2010) was ~1%.

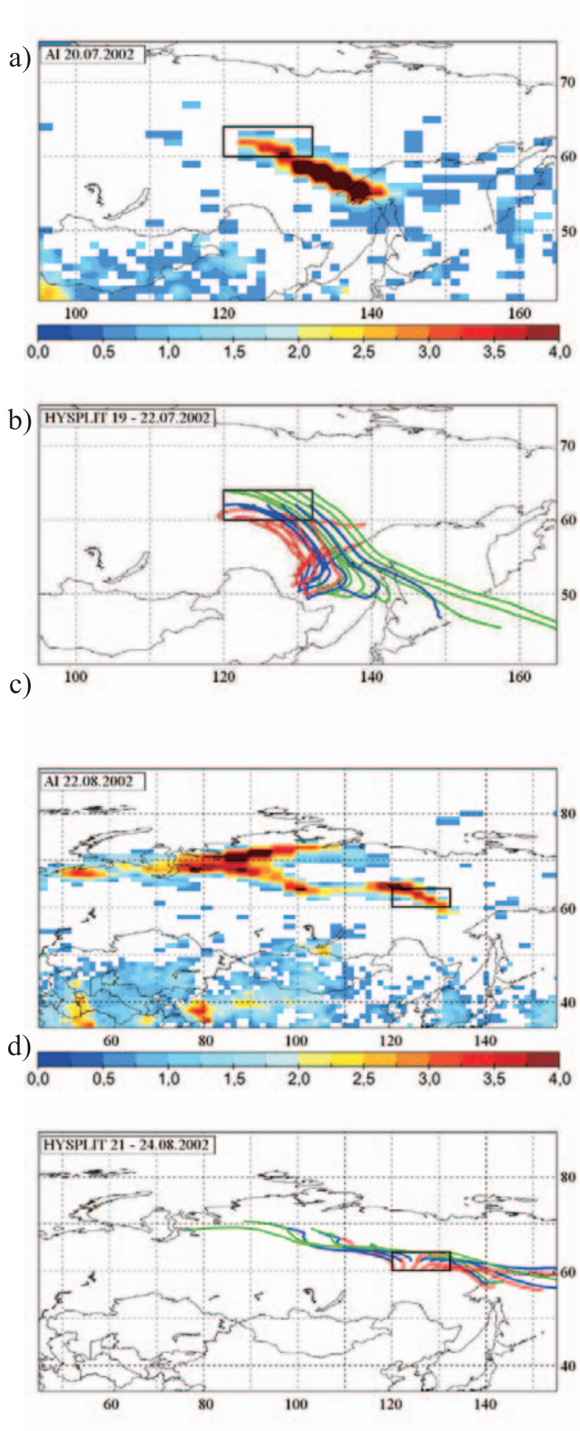

Fig. 4. Spatial distribution of daily average AI and HYSPLIT forward trajectories.

The daily AI distributions (a. 20.07.2002; c. 22.08.2002) and HYSPLIT forward trajectories (b. 19-22.07.2002; d. 21-24.08.2002) are presented on the Fig. 4. Trajectories were calculated for 21 points over the study area. The comparison of daily average distributions of AI and the forward trajectories indicates that forest fires in the study area were the source of perturbation of aerosol parameters.

During July 19-22, smoke particles were carried away in the south-east direction, towards the Sea of Okhotsk. The transport distance in this case was ~1000 km. During the second (main) period of increased forest fire activity (21-24 August), the removal of combustion products occurred mainly in the north-west and slightly – in the west directions. In this case, smoke particles spread down to the coast of the Barents Sea with overall transport distance of ~3000 km. In all the cases, the aerosol cloud moved fairly compact, keeping high values of AI.

Summary and conclusions

The analysis of satellite data for the period from May to September 2002 shows that on days with high level of fires activity (18-24 July, 14-20 August), the area average values of AOT are several times higher than the background values (~0.13) and can reach ~1.5. The maximum values of the aerosol index reach ~3.6. The perturbations in the AI distribution, caused by forest fires, have been traced to a distance of ~3000 km and the amplitude of the perturbation at the maximum distance is comparable with the amplitude above the fire.

Total emissions of combustion products from forest fires in central Yakutia amounted to about 1% of the annual global emissions from fires. CO_2 emissions were quantitatively comparable to the average annual emissions from global volcanic activity (Gerlach 2011).

References

Acker, J.G. and Leptoukh, G., 2007, Online Analysis Enhances Use of NASA Earth Science Data. *Eos, Transactions, AGU*, **88 (2)**, pp. 14–17, doi:10.1029/2007EO020003.

Afonin, S.V., Belov, V.V., Panchenko, M.V., Sakerin, S.M., Engel, M.V., 2008, Correlation Analysis of Spatial Fields of Aerosol Optical Thickness Based on the MODIS Satellite Data. *Atmospheric and Oceanic Optics*, **21 (6)**, pp. 510–515.

Draxler, R.R. and Hess, G.D., 1998, An overview of the HYSPLIT_4 modeling system of trajectories, dispersion, and deposition. *Australian Meteorological Magazine*, **47**, pp. 295–308.

Gerlach, T., 2011, Volcanic versus anthropogenic carbon dioxide. *Eos, Transactions, AGU*, **92 (24)**, pp. 201–202, doi:10.1029/2011EO240001.

Giglio, L., Csiszar, I., Justice, C.O., 2006, Global distribution and seasonality of active fires as observed with the Terra and Aqua MODIS sensors. *Journal of Geophysical Research – Biogeosciences*, **111 (G2)**, doi:10.1029/2005JG000142.

Seiler, W., Crutzen, P.J., 1980, Estimates of gross and net fluxes of carbon between the biosphere and atmosphere from biomass burning. *Climate Change*, **2 (3)**, pp. 207–247. doi:10.1007/BF00137988.

Solovyev, V.S., 2009, The influence of human activity on forest fires in Yakutia. In *Proceedings of 4th International WS on C/H2O/Energy balance and climate over boreal regions with special emphasis on eastern Eurasia,* pp. 113–114, Japan: Nagoya University.

Solovyev, V.S., Budishchev, A.A., 2010, Disturbances of Aerosol Optical Thickness of the Atmosphere Caused by Forest Fires in Yakutia. *Atmospheric and Oceanic Optics*, **23 (6)**, pp. 538–541, doi: 10.1134/S102485601006014X.

Solovyev, V.S., Kozlov, V.I., Vasilev, M.S., Andreev, N.B., Belov, V.V., Afonin, S.V., Angel, M.V., 2006, Investigation of Forest Fires in Yakutia (1998-2005) on Data of Remote Sensing. In *Proceedings of International Workshop on "Tropical Rain Forest and Boreal Forest Disturbance and Their Affects on Global Warming"*, pp. 8–14, Indonesia: University of Palangka Raya.

Van der Werf, G.R., Randerson, J.T., Giglio, L., Collatz, G.J., 2010, Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009). *Atmosperic Chemestry and Physics*, **10**, pp. 11707–11735, doi:10.5194/acp-10-11707-2010.

Wiedinmyer, C., Quayle, B., Geron, C., Belote, A., McKenzie, D., Zhang, X., O'Neill, S., Wynne, K.K., 2006, Estimating emissions from fires in North America for air quality modeling. *Atmospheric Environment*, **40**, pp. 3419–3432, doi:10.1016/j.atmosenv.2006.02.010.

Pyrogenesis and evolution of frozen soils

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Key words: pyrogenes, frozen soils, evolution, composition, properties

Introduction

It was once and again noted in literature (Melekhov, 1981; Furyaev, 1996; Valendik, 1996; Matveyev, 2006; Chevychelov, 2011 et al.) that forest fires have a great impact on the forest cover state in the permafrost region of North-East Russia. I.P. Scherbakov (1975) justly believes the forest fires to be a regular catastrophic factor.

Meanwhile up to the last time scientists have not spared due attention to fire especially under frozen mountain taiga territory conditions. In our opinion first of all it deals with the existing concept of fires as a primarily anthropogenic factor, which is mostly connected with human activity. Yet forest fires for millenia accompanied soil forming on the continental part of North-East Asia and exerted decisive influence on the trend of soil-building processes.

Discussion

According to O.V. Makeev (1981) who proposed to determine permafrost as a subfactor of soil forming, i. e. «combining in itself in the indissoluble unity a peculiarity of two or several individual factors of the soil forming», we propose to value the fire influence on soil-building processes in the same manner. According to that we suggest the term «pyrogenesis» which means the totality of fire-induced processes and phenomenae in nature landscape. The pyrogenesis influence on the soil forming is particularly perceptible in humid mountain taiga regions of permafrost zone when there high intensive undertrees fires arise, which result in total destruction of zonal vegetation and formation of intermediate stages of its restoration. Thereby the organic topsoil completely or partially burns out and then it partly is destroyed due to erosion processes. The development of intensive shut erosion with considerable surface slope and heavy showers lead to losing the bared surface mineral soil horizons. The re-establishment of the initial vegetation in such case proceeds through the temporary phytocenosises which to a considerable degree differs from the strata and soil cover. It is obvious that in initial ones by the composition of forest strata and soil cover. It is obvious that in such case the character (capacity and chemistry) of biology circulation radically changes in the soil-phytocenosis system and consequently the composition of surface soil horizons changes too.

The erosion of soil silt from the soil surface leads to involvement into the new weathering – soil forming cycles of the «fresh» portions of the parent rock, i.e. there present periodic renewal of soil eluvium composition. It leads to a change in the trend and the rate of soil forming. It is especially obvious in erosion destruction of the residual carbonate soils silt enleached from alkali carbonates. Here the process of podzol-formation is buffered by initially rich composition of the parent rock. Perhaps, it is the only reason for low spreading of the thick weathering crusts and soils differentiated morphologically and physico-chemically by podzol type in South Yakutia territory characterized by cold humid climate and predominance in the cover of taiga vegetation on the ancient calcareous watersheds.

When the forest crown cover is destroyed by fire the thermal flow towards soil increases 1,5-2 times relatively the initial one, it leads both to analogous increasing of the seasonal thawing depth of the soil and evaporation (Tarabukina, Savvinov, 1990). The penetrating depth and temperature difference on burning and in forests are determined by initial soil state. They are larger in heavy soils with icy permafrost than in pine burnings on frozen soil (Savvinov, 1976). The volume weight considerably increases due to the loss of postcryogenic structure and as a result water capacity and filtration ability of soil decrease. The moisture of lower horizons is involved in active circulation. This water earlier was conservated in the segregated ice form. In general it leads to developing processes of gleyification and bogging and as a result leads to change of their oxidation- reduction potential.

The loss of postcryogenic structure in lower horizons due to strong low burning leads to thermal subsidence of soils. Thus, after the vegetation cover destruction on the frozen chalk humus soil in the Aldan river valley the seasonal thawing depth increases from 80 cm to 145 cm, i.e. by 1,8 time. The maximal change of volume weight in lower mineral (50-80 cm) soil thickness is equal to 0,85 g/cm^3 (increases from 0,75 to 1,60 g/cm^3). The total water supply in 1 metre thickness during the forest years increases from 216 to 392 mm. According to our calculations based on the volume weight increase the subsidence of soils is equal to 45 cm per 145 cm seasonally thawing thickness or 80 %. In our opinion this circumstance is very important because it allows to estimate the soil subsidence in root thickness which is as a rule equal to 40 cm for the frozen soil. It is equal approximately to 13 cm for heavy and icy varieties of soils. Larch roots are mainly concentrated in the surface 20 cm thickness and after strong fires the soil loses the coupling with silt and looks like «hanging in the air». It sharply increases larch falls on the burnings after storms. In our context the fact (Scherbakov et al., 1979) of total forest destruction during 1-3 years after the humus-ground lithosol fires when green mosses burn is mostly connected to the soil silt thermal subsidence than to the direct burning of the forest vegetation roots or to their interaction. In this case after the fires the surface of heavy and icy frozen soils characterized by high hydromorphism exposes.

This subfactorial influence is mostly obvious in humid continental sectors of North-East Asia boreal vertical zone. The climate and natural conditions of this territory are specific for frequent fires and the large scale effect of pyrogenesis on soils. The irregularity of atmospheric moistening during seasonal, annual and perennial cycles leads to mass fires during dry years and mass silt destroying from fire bared forest landscape during humud years. Heavy erosion takes place not only in normal and very humud zones but also in dry and drought zones during transitory periods of heavy rains. The fire analyses in Yakutia showed that common annual number of fires during last 10 years have changed from 100 to 300, i.e. the everage number – 200.

Some years differed in maximal fire events, e.g. it was 455 in 1985 and 699 in 1986. Such couples of dry and the most fire dangerous years when surface organic horizons of soils get dry and ready to burn, repeat very often – once every 33 years or three times a century.

The analysis of fires causes show that only 23 % of fires appeared through human fault (16 % agricultural burning, 7 % - careless fire handling) and 75 % of fires were caused by lightning.

Thus, forest fires in Yakutia like in all territory of continental North-East Asia are regular active factor. The forest stands of arid growth places burn out as often as once in 10-15 years, forest stands in middle moistening zones burn out 2-3 times in one forest generation, i.e. once in 60-70 years. As for forest stands in damp zones, they burn out as often as once in 100-150 years. Therefore even if fires are very few the pyrogenesis is worth studying as a most active nature soil forming subfactor especially in humud continental regions of permafrost zone. In this context the pyrogenesis is considered to be a primary factor in the common system (Koposov, 1983) of exogenic geomorphological processes.

The influence of pyrogenesis on structure and properties of automorphic soils during its evolution results in two forms: hidden and evident. Frozen soils of South Yakutia differ from other soils in their accumulative type of humus-clay-silt distribution without any visible buried humus horizons in the profile. Detailed analysis of these soils has showed the number of essential micromorphological features clearly indicating that the BC horizons of these soils had formerly passed the stage of surface humus horizons in their evolution.

The above soil peculiarities are:

1.Clear microaggregation, i.e. «sponge consistence» (Fig. 1);

2.Presence of iron-humus-clay microagregates and inclusions of organic matter decomposed to a different degree on clay plazma (Fig. 1);

3.Presence of thin biogenic pores (poot channels).

Therefore Yakut automorphic soils have low thickness due to intensive pyrogenic destruction of soils with normal, i.e. monocyclic profile. These are the soils with no visual buried humus horizons.

So the soils with polycyclic profile where the pyrogenesis signs are found in evident forms are of more interest for us (Table 1).

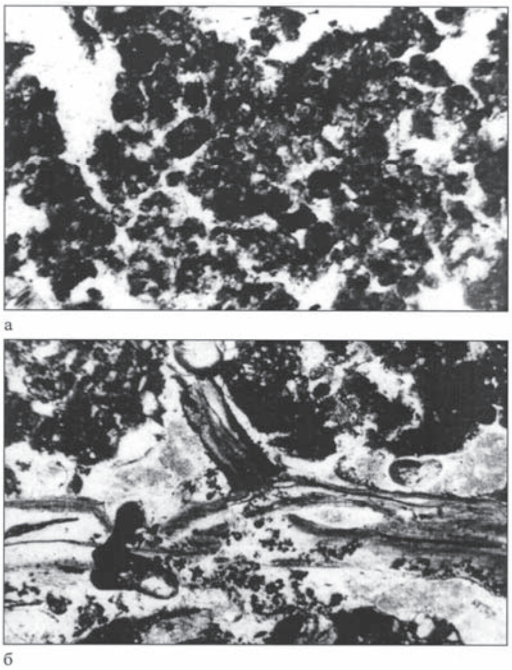

Fig. 1. Microphotographs of sections of typical pale-brown soil (section 5Э). a) Humus-clay microaggregates in horizon BC, x 112, ник. II;
б) large plant residue with excrements of soil fauna (horizon BC, x 28, ник. II).

Table 1. Chemical properties and physical-chemical indices of brown soil
(section 16-89 TU).

Hori-zon	Hu-mus, %	Gross N, %	Water pH	Fractions, %	
				< 0,01 mm	< 0,001 mm
A	17.3	0.54	5.1	27.4	13.6
B	7.5	0.28	5.4	34.0	16.9
[A]	14.7*	0.40	5.2	28.6	13.8
[B]	3.8	0.10	5.6	15.3	9.3
[A]	32.2*	0.90	5.2	20.7	10.3
BC	8.7	0.29	5.7	33.9	17.3

References

Chevychelov A.P., 2011. *Pyrogenesis and taiga soil-forming*. Saarbrücken: LAP LAMBERT Academic Publishing, 245 p.

Furyaev V.V., 1996. *Fire role in the process of forest development*. Novosibirsk: Nauka, 252 p.

Koposov G.F., 1983. *Soil genesises of Prebaikal mountains*. Novosibirsk: Nauka, 255 p.

Makeev O.V., 1981. *Facies of soil cryogenesis and peculiarities of soil profiles organization in them*. M.: Nauka, 86 p.

Matveyev P.M., 2006. *Post-fire effects in larch biogeocenoses on permafrost*. Krasnoyarsk: Izd-vo RITS, SibTGU, 268 p.

Melekhov I.S., 1981. *Fire effects on the forest*. L.: Nauka, 159 p.

Savvinov D.D., 1976. *Waterthermal regime of soils in permafrost zone*. Novosibirsk: Nauka, 255 p.

Scherbakov I.P., 1975. *Forest cover of the NE USSR*. Novosibirsk: Nauka, 306 p.

Scherbakov I.P., Zabelin O.F., Karpel B.A. et al., 1979. *Forest fires and their impact on the forest nature*. Novosibirsk: Nauka, 224 p.

Tarabukina V.G., Savvinov D.D., 1990. *The fire impact on frozen soils*. Novosibirsk: Nauka, 120 p.

Valendik E.N., 1996. Ecological aspects of forest fires in Siberia. *Sib. ecol. journ*. **1**, 1-8.

Dynamics of the seasonal thaw depth as a factor of change in water regime of soil and of vegetation change

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Key words: geocryological monitoring, surface eluvial landscapes, transeluvial landscapes, active layer

Studies of the environmental changes driven by climate fluctuations, have not lost their relevance. The reasons for this are ambiguous interpretation of the data of current measurements, complexity of the environments and, as a consequence of the multiplicity of scenarios of change of its components. Increasing mean annual air temperature and atmospheric precipitation in autumn and winter results in increasing of the seasonal thaw depth (STD) of permafrost and temperature of permafrost.

The present work is devoted to modeling of the restructuring of Chukotka tundra landscapes driven by the changing active layer thickness according to the long-term observations. Measuring of STD were carried out at three sites of geocryological monitoring (100x100 m), representing a variety of Anadyr lowland landscape (Tregubov, 2012 a). From the standpoint of geochemistry landscape this sites correspond to surficialeluvial, superaqualand transsuperakval landscape.

The average STD vary in different years, in "Onemen" site it is 38-58 cm, in "Kruglaya" site – 35-44 cm, and in "Dionisiya" site – 45-67 cm. Soil types are mostly moist typical tundra gley and gleyic, peat and peat-humus (Tregubov, 2010 a). Parent rocks are the frozen ice-rich loam, with admixture of gravel and fine gravel of basic and intermediate rocks on the "Dionisiya" site. The soil profile is poorly developed, morphological boundaries between the horizons are fuzzy, especially the organogenic-mineral boundary. Plant litter in the soil profile changes to uniform peat horizon, where with the depth the degree of decomposition of plant debris and silt fraction components gradually increase. On the border with permafrost proportion of mineral substances with characteristic dark gray and gray color sharply increase.

Degree of water content at sites is seasonal and depends on weather of specific years, though in summertime depressions between tussocks are almost always moist. The major factor regulating the distribution of moisture throughout the soil profile and the landscape are the surficial meso- and microrelief, STD, and the composition and the structure of tundra vegetation. All the factors and the level of supra permafrost groundwater (SPGW) are interrelated including feedbacks. Well-known examples of such relations are hummock-ridge, hillocky, tussock micro-relief of the lowland tundra, where the dwarfshrub-grass vegetation is the cause and effect of features ofsurface micro-relief. Less frequently mentioned are interconnections of water content and STD with the distribution of sphagnum-sedge and moss-dwarf shrub vegetation. The proximity of permafrosthere determines waterlogging of soils and favorable conditions of mossy turf , which in turn provides thermal insulation and stability of permafrost landscapes to mechanical stress through the dwarfshrub and herb component (Tregubov, 2012 b).

The radial distribution of moisture is poorly studied. According to our observations in the dry season (August - September) SPGW thickness is: in the surficialtranseluvial landscape of 7-12 cm, in the eluvial - 15-20 cm, in superaqual - 25-35 cm, which is 5 to 75 % of STD. In the dry season in transeluvial and eluvial landscapes the water supply is due to defrost of frozen soils. In superaqual – due to runoff and water exchange with swamps and lakes. In the case of minor precipitation upper organic horizons of the autonomous landscape are waterlogged without moisture migration down the profile. That is, in fact, two supra permafrost aquifer us layers exist simultaneously. For the beginning of infiltration, i.e. exceeding the critical limit the moisture retention by the moss layer, it takes up to 2 days of drizzling rain (> 30 mm) and the STD more than 35 cm.

Thus, knowledge of the dynamics of the STD in the particular tundra landscape allows to evaluate the dynamics of the level of SPGW, to predict the development of soil processes and, finally, to predict changes in vegetation cover and landscape as a whole.

Long-term observations (1994-2013) of the seasonal thawing showed a slight but steady increase in the STD with significant periodic fluctuations in the value of defrost (Fig. 1).

The explanation for this may be the seasonal dynamics of the permafrost defrost, which is a non-linear trend, and the combination both in space and timeof a sine harmonic oscillations with periods of 3-4, 12-16, 20 and 36

years (Tregubov, 2012, Velikotsky, 2003, Pavlov, 1997). Thus, the minimum variation of STD is on the "Onemen" site (9%), and the maximum variation is on "Dionisiya" (21%) and "Kruglaya" (19%) sites (Tregubov, 2013).

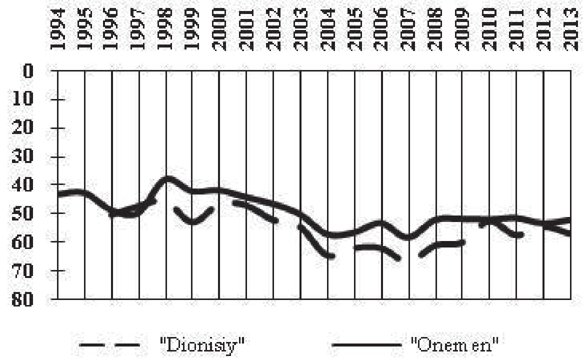

Fig. 1. Change of active layer at sites "Onemen" и "Dionisiy"

It should be noted that differences in the magnitude and variations of seasonal defrost on the "Onemen" site is due to its special landscape position. Surficialeluvial landscapes of “plakors” with dwarfshrub-moss-cottongrass tussock vegetation and monotonous mesorelief are the most stable in time and space natural tundra landscapes (Tregubov, 2010 c). Thus tussock vegetation of flat watersheds is the standard ofinvariability, the starting point for prediction of transformation of tundra landscapes.

Results of the study allow to consider two scenarios for the transformation of the tundra landscapesunder global warming: the long-term evolution, which is currently under way and the critical short-term, when the change will occur in the short time as a result of resonant growth of STD in a few (6-8) years. Thus, we can speak of two common, yet different processes of consistent and dramatic changes in hydrothermal regimes of lowland tundra.

At the example of the Anadyr Lowland it can be the following scenarios. In the first scenario, we expect an evolutionary transformation of the tundra landscape as a result of the gradual increase of STD, which will be reflected in changes in the structure of active layer and the regime supra permafrost waters. The second model proposes a sharp increase of STD for several years due to the resonance oscillations (Tregubov, 2012, 2010 b).

The surface eluvial landscapes of the gentle slopes will be replaced by the eluvial landscapes with increasing of STD. It will be accompanied by an increase of the proportion of peat-humus and humic-podzolic soils, and with the replacement of dwarfshrub-moss-cottongrass vegetation by mainly lichen-moss-dwarfshrub and dwarfbirch-herb vegetation. Locally, in the areas of development of thermokarst, moss-sedge-sphagnum bogs will be formed or expand existing area. In transeluvial landscapes increase of STD and improving of drainage of ground waters will be accompanied by increase of intensity of cryogenic erosion. In soil formation will increase the intensity of the decomposition of organic matter, podsolization, and sod process. Vegetation cover will be more mosaic. Lichen-dwarfshrub, grass-forb-dwarfbirch communities will bemore prevalent.Sparse alder shrubs andsolid alder and willow thicketswill be formed on the slopes and in thermoerosion gullies. Changes of superaqual landscapes will be largely determinedby the degree of flowage of lake and wetland basins. In closed basins rise of supra permafrostwater level is expected, lake-bog equilibrium will shift towards the flooding of an area. Under these conditions, bog vegetation will be differentiated into hummock-ridge bog with dwarfshrub-moss vegetation and sedge-peatbogvegetation of flooded depressions. In flow-through basins and floodplains dwarf birch-moss-forb and grass- forb plant communities with sparse willow and alder shrubs,and peat, peat- humus soils. Common to superaqual landscape of lake-bog basins will be strengthen of processes of permafrost heaving.An intensification of the processes of formation of lowered lakes and related dramatic restructuring of local hydrological conditions can be expected. The evolutionary changes will very little affect eluvialice-poor autonomous landscapes and transakval landscapes of rivers, for which changes in the water regime and channel dynamics is common.

In case of transient increase of STD in a few years we should expect a catastrophic scenario of transformation of landscapes. The sharp increase of STD lead to global melting of ice in a various kinds of the upper permafrost layer. It is estimated that an increase of STD at 60-150%, which is commonfor the local anthropogenic and pyrogenic effect, will provide about 500000-750000 m3/m2 additional water in the landscape. For the 2-3 years long period it is 60-90% of the annual average precipitation, i.e. it is 1.5-2 times higher than average precipitation in the warm season. Melting of ground ice will necessarily lead to change in the relief. Alas, hollow, thermal erosion gullies and ravines, thermokarst depressions, lumpy solifluxion relief will be widespread. Cryogenic erosion will occur in the disturbed habitatsaccompanied by the degradation of soil and vegetation cover. Changes in the groundwater regime will lead to increased level of SPGWin lakes and wetlands and to reduced level in the vast tundra slopes. This in turn will create the preconditions for the revitalization of tundra peat fires of watershed and to catastrophic descent of lakes in flow basins.

To summarize, we note that these scenarios are ongoing. In the dry summers (1997, 2000, 2004, 2007) in time of STD maximum (September), there was an increase of river runoff and the rise of the water level in the lakes. In abnormal years of STD maximum increase oftundra fires on watershedswas registered, whichresulted inthermokarst and thermal erosion, atmospheric smoke, pollution of waters by powders. Another observation is the formation of the sparse alder shrubs in 2007 at the "Dionisiya” site, according to the static scenario of respond of biotic components on increase of STD and changes in hydrothermal conditions of the landscape.

References

Pavlov, A.V., 1997, Permafrost-climatic monitoring of Russia: methodology, the results of monitoring, forecast / Earth Cryosphere. Vol. 1, N 1, p. 47-59. (in Russian)

Tregubov, O.D., 2010a , Global warming as a driverof change in the chemical properties of permafrost tundra soils / Math. III Int. scientific conference "Modern problems of soil contamination" (Moscow, 24-28 May 2010, Department of Soil Science). – Moscow: Moscow State University, p. 294-297. (in Russian)

Tregubov, O.D., 2010b, Transformation of the tundra landscapesunder climate change / Sat Reports. III Sun Scientific. Conf. with int. participation "Ecological problems of the northern regions and their solutions" (Apatity, 4-8 October, 2010). – Apatity,. - Part 2. P. 95-99. (in Russian)

Tregubov, O.D., 2010c, On the resistance of tundra to human impact and global environmental changes / Bulletin of FEB RAS. N 4, p. 79-89. (in Russian)

Tregubov, O.D., 2012a, Environmental threats of catastrophic resonance defrost of permafrost in climate fluctuations (Chukotka) / Proc. III All-Russia. Scientific. Conf. with int. participation "Environmental risk and environmental security" (Irkutsk, 24-27 April 2012) – Irkutsk: Publishing House of the V.B.Sochava Institute of Geography SB RAS, Vol 1,. p. 269-271. (in Russian)

Tregubov, O.D., 2013, Geochemical indication ofilluvial process tundra soils / / Modern problems of soil contamination. Collection of materials (IV Int. Scientific. Conf. 27-31 May 2013). M: Moscow State University, Department of Soil Science, p. 181-185. (in Russian)

Tregubov, O.D., Taysaev, T.T., 2012b, Introduction to the geochemistry of allelopathy on the example of tundra plant communities / Bulletin of the Northern (Arctic) University. Series: NaturalSciences. N 4, p. 28-40.(I nRussian)

Velikotsky, M.A., Fedorov, V.M., 2003, Short-term fluctuations in climate of Bolshezemelskaya tundra and forecasting of changes in permafrost conditions / Earth Cryosphere. Vol. VII, N 3, p. 85-93.(in Russian)

Cryostratigraphy and water stable isotope profiles of the active layers and the upper permafrost layers near Yakutsk, Eastern Siberia, Russia

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Key words: cryostratigraphy, water stable isotope, permafrost, active layer, Yakutsk

Introduction

Information about geocryological characteristics of frozen sediment, such as ice content, cryostructure, or stable isotope ratio of included water is essential for predicting consequences of the projected permafrost thaw in response to the global warming. This information determines the extent of thermokarst and controls the hydrological regime, and hence vegetation growth, especially in areas of high latitude. It also yields knowledge about the history of changes in the hydrological regime. To obtain the fundamental information, near-surface frozen sediments from 19 boreholes down to 2 - 5.7m depth at 7 sites near Yakutsk were sampled and analyzed.

Study sites and Methods

Sampling sites (Neleger, Spasskaya Pad, and Yukechi) are located on both banks of the Lena Liver near Yakutsk city (Figure 1). This region is underlain by highly ice-rich late Pleistocene permafrost (Yedoma). The total ground ice volume of Yedoma exceeds 50 % and can reach over 90 %; hence, it induces destructive thermokarst subsidence of the landscape.

Yukechi site was selected as an example of the results and discussion from whole study for this extended abstract. The site is located on the right bank of the Lena River (Figure 1). Some areas of the Yukechi site have been experiencing obvious thermokarst mainly because of removal of surface vegetation due to cultivation activity. Two sampling points were selected in a forest (Y7/Y7a) and other two points in an open subsiding area (Y10/Y11).

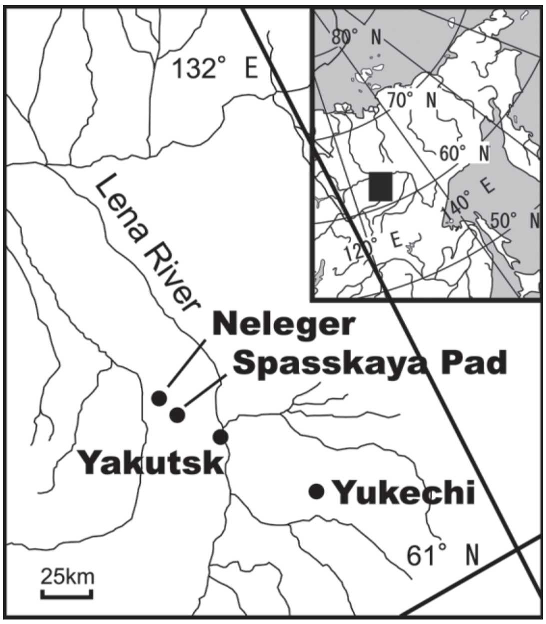

Figure 1 Location of study sites

Near-surface soil cores were sampled in 2009 and 2010 using an engine auger (Tanaka TIA-350S), with core samples of φ 2-3 inches. Sampled cores were truncated to remove contaminations, cut to 2-15 cm long, wrapped with polyethylene stretch film, and double sealed with polyethylene packs. Lengths and circumference of columnar cores were measured in the field to calculate the volume of the samples. Frozen samples were then thawed in the sealed packs, and supernatant water was stored in vial bottles for isotope analyses. Water was extracted using centrifuge from samples containing inadequate amounts of water.

The electrical conductivities (EC) of the extracted water samples were measured by B-173 Twin Cond (Horiba, Japan).

The isotopic compositions of water (hydrogen and oxygen) were analyzed by the $CO_2/H_2/H_2O$ equilibration method using a Delta V (Thermo Fisher Scientific, USA, manufactured in Germany) attached to a Gas Bench (Thermo Fisher Scientific, USA) at Hokkaido University, Japan (Ueta et al., 2013). These data were expressed as δD or $\delta^{18}O$ values, defined as δ_{Sample} (‰) = (R_{Sample}/R_{VSMOW} - 1) x 1000, where R is the isotope ratio of water (D/H or $^{18}O/^{16}O$), and subscripts Sample and VSMOW refer to samples and standard (i.e. Vienna Standard Mean Ocean Water), respectively. The analytical errors for the whole procedure were within 2 % and 0.2 % for δD and $\delta^{18}O$, respectively. Deuterium excess (d-excess) was calculated as d-excess = δD – 8 x $\delta^{18}O$ (Dansgaard, 1964), which is an indicator of non-equilibrium processes such as evaporation (e.g., Merlivat and Jouzel, 1979).

Selected soil samples were well mixed, and the mechanical composition of the sampled soils was determined by the Kachinsky method (1958). Cryostructures of frozen samples were classified based on Murton and French (1994).

Results and discussion

The profiles of $\delta^{18}O$, d-excess, volumetric ice content, electrical conductivity, and grain size distribution are shown in Figure 2.

We found clear ice at both forest and open subsiding areas (from 2.2 and 2.4 m depth down at point Y7 and Y10, respectively). This clear ice were safely determined to be a part of wedge ice judging by obvious vertical foliation structure and occasional occurrences of polygonal differential surface subsidence around the sampling points. The $\delta^{18}O$ of wedge ice were significantly lower than those of upper soil horizons, and the values changed from around -25 to -29 ‰ stepwise. The volumetric ice content of wedge ice samples was set to 99 %, though there was a certain volume amount of air bubbles and a little contaminant of soil or organic materials in the samples.

$\delta^{18}O$ is an indicator of air temperature when the meteoric water was precipitated. Its profiles showed gradual decrease with depth toward the depth of around 1.5-2.0 m (from -15 to -25 ‰), and at the lower soil layers, the $\delta^{18}O$ stayed somewhat stable values of around -25 ‰ except for the case of wedge ice. Sugimoto et al. (2002) reported values from -11.3 to -15.5 ‰ for $\delta^{18}O$ values of summer precipitation (July – September) at a site near Yakutsk on the left bank of the Lena River. The higher $\delta^{18}O$ values for the soil water in the upper horizons obviously indicate intrusion of recent heavier water into the lower horizons, which probably contain older meteoric water infiltrated when climate was colder in a certain past period.

Unconformities of the values of d-excess and volumetric ice content in the profile at around 1.0 m depth were observed at Yukechi site profiles. Smaller d-excess values from the upper horizons indicate influence of evaporation on the soil water. Value of d-excess tells us how the precipitated water experienced phase changes like evaporation and freezing before the water fixed into the frozen ground profile. Together with the increases in volumetric ice content from 1.0 m depth and lower, it can be assume that at least the upper 1.0 m was within the active layer in the previous relatively dry summer.

Upper-most part of permafrost is often ice-rich because of the presence of segregated ice lenses. In this layer, aggradational freezing or freeze-back from the permafrost table gives ideal freezing condition for the ice lens creation. So, usually this layer contains high ice content or excessive ice content. The uppermost permafrost layer, which is subject to episodic thaw at sub-decadal to multi-centennial scales, is known as the transition zone (Shur et al., 2005). At the Yukechi site, the transition zone can be assigned to from around 1.2 m to 2.2 m depth knowing the high ice content zone and the depth of the wedge ice top. The volumetric ice contents of the transition zones at the forest and open area showed a marked difference (the values were about 10 % higher at forest sampling points). Cryostructure of the transition zone at the open area often had structureless structure, while that at the forest area showed wavy non-parallel layered or lenticular structure with ice lenses. This difference in the cryostratigraphy in the transition zones indicates former degradation of permafrost in the open subsiding area. The witnesses of the surface subsidence support the permafrost degradation,

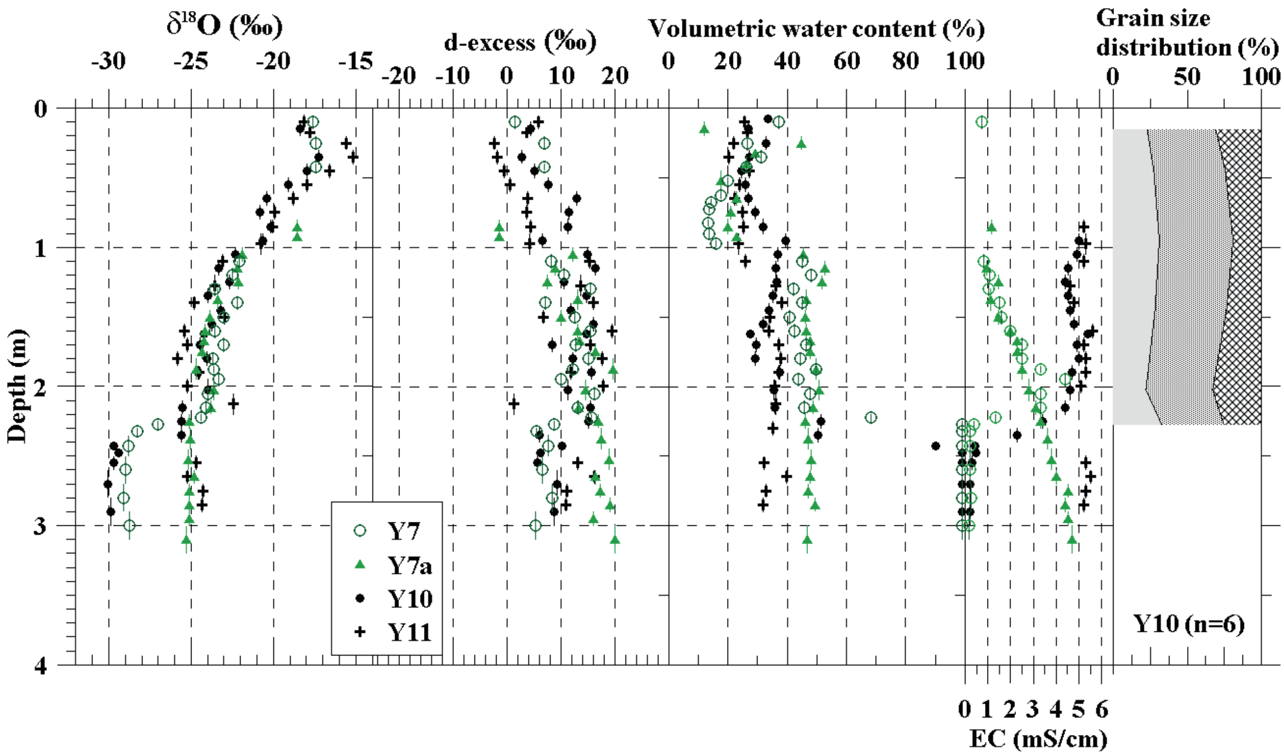

Figure 2 Profiles of oxygen stable isotope ratio (δ^{18}O), d-excess, volumetric ice content, electrical conductivity (EC), and grain size distribution at sampling points in a forest (Y7/Y7a) and in an open subsiding area (Y10/Y11) at Yukechi site.

which means that the active layer had reached to the depth of Yedoma ice table in the past.

EC profiles of the extracted water showed distinct difference between the two sampling areas. The values in the transition zones at the forest area showed gradual increase in the EC, while those at the open area stayed around 5 mS/cm. The EC values of wedge ice were much smaller than those of soil water. The much higher EC at open area is due to typical salinization of Alas.

Summary

We conducted the same analysis for frozen soil samples also from Neleger and Spasskaya Pad sites, in which sampling points contain different soil texture, water content, surface vegetation, and disturbance history. The cryostratigraphy in the active layer and the upper permafrost reflected the difference in site specific conditions. It was inferred that geocryological analysis of frozen ground can offer additional basic information for reconstruction of paleo-environment in permafrost regions.

Despite of the difference in the site specific conditions, we found some common features in water stable isotope among a variety of study sites. Ground ice takes the form of ice lenses or veins, mainly due to ice segregation during the frost heave of the water- saturated and frost-susceptible sediment. Profiles of water stable isotope ratio in the active layer and upper permafrost showed decrease from -15 to -25 ‰ at 2-3 m depth regardless of sampled locations. It is suggested that a part of history of permafrost development may be reconstructed by the analysis of the water stable isotope and cryostructure of the upper permafrost.

Acknowledgements

This work was supported by Grant-in-Aids, the Global COE Program “Establishment of Center for Integrated Field Environmental Science” (IFES-GCOE) from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the JSPS Institutional Program for Young Researcher Overseas Visits, and the JSPS KAKENHI Grant Number.

References

Kachinsky, N. A. (1958), Mechanical and microagregate composition of soils, Methods of Analysis, 192 pp., Moscow Academy of Sciences, Moscow.

Merlivat, L., and J. Jouzel (1979), Global climatic interpretation of the Deuterium-Oxygen 18 Relationship for precipitation, Journal of Geophysical Research, 84(C8), 5029-5033.

Murton, J. B., and H. M. French (1994), Cryostructures in permafrost, Tuktoyaktuk coastlands, western Arctic Canada, Canadian Journal of Earth Sciences, 31(4), 737-747.

Shur, Y., K. M. Hinkel, and F. E. Nelson (2005), The transient layer: implication for geocryology and climate-change science, Permafrost and Periglacial Processes, 16, 5-17.

Sugimoto, A., N. Yanagisawa, D. Naito, N. Fujita, and T. C. Maximov (2002), Importance of permafrost as a source of water for plants in east Siberian taiga, Ecol Res, 17(4), 493-503.

Ueta, A., A. Sugimoto, Y. Iijima, H. Yabuki, T. C. Maximov, T. A. Velivetskaya, and A. V. Ignatiev (2013), Factors controlling diurnal variation in the isotopic composition of atmospheric water vapour observed in the taiga, eastern Siberia, Hydrological Processes, 27(16), 2295-2305.

Dynamics of Thermosuffosional Processes on the Bestyakh Terrace of the Lena River, Central Yakutia

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Key words: thermal suffosion, permafrost, intrapermafrost water, ravine formation, climate change

Introduction

Thermal suffosion plays an important role in landscape modification in natural and disturbed areas of the permafrost zone. This process creates a potential hazard to roads and railroads on permafrost; its occurrences have been reported in a number of towns and villages.

Geodetic monitoring was performed starting from 2009 at the key sites, Cirques B and E of Ulakhan-Tarin spring, in order to understand the dynamics of thermosuffosional failure development. Thermosuffosional failures occur as depressions with no visible cracks at the surface or as funnel- or cylinder-shaped sinkholes. Tension cracks may form on the sand-terrace surface at some distance from these features.

Study sites

The study sites are located within the fourth, Bestyakh, terrace of the Lena River (Fig. 1). The terrace has a relatively level surface; it is dissected by the Ulakhan-Taryn Creek valley incised to a depth of about 30 m. The terrace deposits consist of fine to medium sands containing a gravel layer in the lower part of the profile. The alluvium, 50 to 80 m in thickness, is of Middle Pleistocene age. The Quaternary deposits are underlain by limestone, fissured in its upper part, of Middle Cambrian age.

Permafrost in the study area is continuous in areal extent and is generally more than 200 m in thickness. Permafrost temperatures at the depth of zero annual amplitude are high in level areas of the terrace, with values close to 0˚C. In the Ulakhan-Taryn Creek valley, the temperatures lower down to –2.5˚C. The characteristic feature of the Bestyakh terrace is the widespread occurrence of open and closed taliks maintained predominantly by the thermal effects of solar radiation, snow cover, surface water bodies and groundwater (Gagarin, Kolesnikov, Hiyama, 2012).

Suprapermafrost, intrapermafrost and subpermafrost types of groundwater occur within the study area. Five localized groups of significant groundwater discharge, A, B, C, D and E, are observed along the Ulakhan-Taryn valley slopes. In terms of recharge and movement conditions, the groundwater is classified as suprapermafrost-intrapermafrost type. The water is under confined pressure. The depth to the piezometric level near the discharge sites varies from 16.0 m in summer to 17.2 m in winter, while the depth to the intrapermafrost aquifer is 27 m in the northern part of the study area. Long-term observations indicate that the total discharge of the Ulakhan-Taryn springs is approximately 220–280 l/s (Gagarin, Kolesnikov, Hiyama, 2012). Groundwater flow removes large amounts of sand, resulting in thermosuffosional sinkholes on the terrace surface, a few meters to 30 m in diameter and 1 to 15 m in depth. Such sinkholes are topographically manifested as linear depressions with lengths of up to 300 m.

Fig. 1 Study area.

Methods

Groundwater monitoring studies, geodetic measurements, remote sensing, laboratory analysis and numerical modeling were employed in this study to develop an understanding of the mechanism and dynamics of thermosuffosional processes in permafrost terrain. For this paper, historical and published data were also used.

Two key sites were selected based on the analysis of available information from previous and recent investigations. One was located in

Cirque B in the Ulakhan-Taryn Springs area, firstly, because of intensive thermosuffosional activity. Secondly, similar studies were conducted at this site in the 1960s. The latter consideration was important for understanding the dynamics of thermosuffosional processes on a longer time scale (half a century).

The second site was located in a recently formed cirque, which was found during the field work in 2008 and designated as Cirque E. No groundwater discharge had been observed before.

Benchmark networks were installed at both key sites. Tacheometric surveys were performed with an electronic theodolite once or twice annually. Geodetic data obtained were used to produce 3D surfaces of thermosuffosional features in Surfer software, Golden Software Inc. (Fig. 2).

Using the Surfer's function that enables calculation of volumes between 3D surfaces and a horizontal plane, the volume changes in thermosuffosional features over the period from 2009 to 2012 were determined.

Results

In general, the results indicate intensification of thermosuffosional activity during the period from 2009 to 2012. For example, the volume of Cirque E was 1378 m^3 in 2009-2010, 4063 m^3 in 2010-2011, and 3363 m^3 in 2011-2012. Thermosuffosional sinkholes at Cirque E deepened annually by 1.5–2.0 m on average. The volume of Cirque B varied from year to year: 1605 m^3 in 2010, 3586 m^3 in 2011 and 2849 m^3 in 2012.

Shepelev reported that in 1966–1967 the volume of thermosuffosion-related terrain changes in Cirque B was 1820 m^3/yr, and the cirque measured 103 m in diameter and 15 m in slope height (Shepelev, 1972). Based on these data, he estimated the time of Cirque B formation due to thermal suffosion to be 80 years. Similar estimates have been made in the present study using data obtained in 2009–2012. The average rate of thermal suffosion in Cirque B was estimated with Surfer software to be 2934 m^3/yr over the period from 2009 to 2012. In 2012, the area of Cirque B was 10,459 m^2, while the height of the slopes increased to 20 m. This yielded the Cirque B age of 71 years.

The difference of 9 years in age estimate from the Shepelev's study is believed not to be essential, because the present study assumed that the volume of surface subsidence on the sand terrace was constant throughout the year. In reality, intensity of surface failure processes depends on the rates at which the springs discharge.

Comparison of the thermal suffosion rates between 1967 and 2012 indicates that they have increased by 1.6 times.

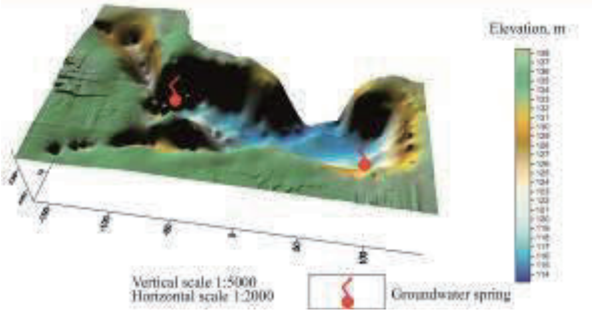

Fig. 2. 3D surface of thermosuffosional depressions in Cirque B, Ulakhan-Taryn Springs, September 2011.

Data from the on-going groundwater observation program performed at the Bestyakh terrace by the Melnikov Permafrost Institute show a considerable increase in discharge rate of springs in 2007–2011. This change in the hydrodynamic regime of the intrapermafrost aquifer could not but affect the intensity of thermosuffosional processes. Analysis of the available data has demonstrated that increased amounts of precipitation and changes in the precipitation regime were the primary causes for the increased discharge rates of springs.

Anomalously high precipitation amounts were recorded in 2006–2008. The annual precipitation during this period was 324-333 mm, or 28–31% higher than the long-term average of 253 mm. Of this amount, 65–80% occurred in the second half of the thaw season. The maximum daily rainfall, 44 mm, was recorded by the Pokrovsk weather station on 21 August 2006.

In 2005–2010, changes in the landscape were observed all over the area of the Bestyakh intrapermafrost aquifer, such as emergence of new groundwater discharge points, flooding of formerly dry topographic lows, and expansion of lakes. The author believes that the spring which appeared in 2008 in the Ulakhan-Taryn Creek valley (Cirque E) resulted from increased waterlogging caused by higher precipitation in 2005–2007. The observed hydroclimatic extremes caused significant changes to the hydrodynamic regime of the suprapermafrost-intrapermafrost aquifer. This increased the discharge of springs and intensified the thermal suffosion processes on the Bestyakh terrace.

Fig. 3 presents a plot of the estimated rates of thermal suffusion and summer rainfall. It is evident from the plot that the two parameters are in a direct relationship.

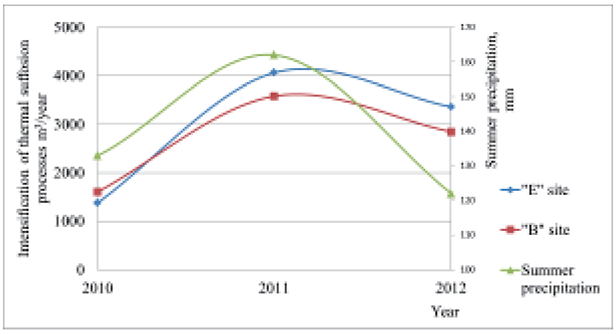

Fig. 3 Relationship between thermal suffosion rate and rainfall.

Conclusion

High thermosuffosional activity is observed in the Ulakhan-Taryn Springs area on the Bestyakh terrace of the Lena River. The rate of thermal suffosion averaged 2934 m^3/yr in Cirque E and 2680 m^3/yr in Cirque B during the observation period from 2009 to 2012. The results indicate a 1.6-fold intensification of thermosuffosional processes in the area compared to the earlier estimate for 1966-1967.

The study has shown that successive years (3-4 years) with precipitation considerably higher than normal can result in enhanced thermal suffosion.

References

1. Gagarin L., Kolesnikov A., Hiyama T., 2012. Effect of extreme hydroclimatic conditions on groundwater systems in permafrost, Central Yakutia. Proceedings of the 1st International Conference on Global warming and the Human-Nature dimension in Siberia. 59–61.
2. Shepelev V.V., 1972. Ocenka erosionno-suffosionnoy deyatelnosti istochnikov Centralnoy Yakutii. Izv. Visshikh uchebn. zavedeniy: Geologiya i razvedka. **9**, 88-92. (in Russian)

Soils of larch forests in “Spasskaya pad” and “Elgeeyi” stations

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Key words: larch forest, soil, composition, property, cryolithozone

Introduction

By the physical-geographical zoning, the area of stations is below of the Central Yakutia plain, formed by Mesozoic and Cenozoic sediments. Geomorphological structure of the territory associated with the history of the Lena River basin formation, landscapes – with the evolution of permafrost. All surface part of this territory is composed by the Quaternary sediments, indigenous Mesozoic and Tertiary grounds occur at the depths ranging from 30 to 100-120 m. From the soil-geographical zoning point of view, the study area is located within the Central Yakutian Province of mid-taiga subzone of the permafrost-taiga and pale soils of the boreal belt of East Siberian permafrost taiga region (National atlas of Russian Federation soils, 2011).

Conditions of soil formation and genesis of the soil forming grounds of stations are different: Spasskaya Pad (1) located within lacustrine-alluvial and Elgeeyi (2) – within erosional plains. For this reason, the parent grounds under the larch forests of the Spasskaya station are sandy-loamy alluvial-lacustrine sediments, and Elgeeyi - loamy eluvial and deluvial deposits.

Climatic factors of soil formation of both stations are similar by the temperature characteristics. The difference in mean air temperature of the year, in the warmest and coldest months is only 0.2-0.7°C (Scientific and applied climate handbook of USSR, 1989). By the amount of precipitations Elgeeyi station provided by significantly more moisture than the Spasskaya Pad. Annual precipitation of Elgeeyi is over 300 mm, which is higher than the Spasskaya Pag by almost 30%. Summer precipitations of the warm period in Elgeeyi station are higher than Spasskaya Pad for 27% and winter precipitations for 35%. The number of days of frost-free period for long term average in Spasskaya Pad is 97 days, Elgeeyi - 112 days, or 15 days longer. The difference in precipitations amount and the length of the frost-free period of these stations leads to the location of stations in different agro-climatic regions (Agroclimatic resources of the Yakut ASSR, 1973). Spasskaya Pad is located in an area with moderately warm, dry climate, with the sum of active temperatures 1400-1500°C and a humidity module <0.20 by Shashko D.I., and the station Elgeeyi - in an area with moderately warm, but with weakly dry climate with humidification module from 0.20 to 0.30.

Results

Soil investigations were carried out in larch forests: 1 – “Spasskaya Pad” station in Central Yakutia, 62º15’N, 129º37’E. (40 km east of Yakutsk); 2 – “Elgeeyi” station in South-East Yakutia, 60°00’N., 133°49’E. (60 km south of Ust-Maya).

Under the larch forests of Spasskaya Pad station the dominant position takes coarse humified permafrost sod-pale solodic soils on heterogeneous sandy-loamy carbonate grounds. The genetic profile is: **O-AYao-BPL**hi-**BPL**cr-**BCA**gcr. At the time of the soil description and sampling 22.08.2007 the permafrost table was at the depth of 124 cm.

Based on the classification (Classification and diagnosis of Russian soils2004), this soil is named by us as the type of sod-pale soil (Desyatkin R. V. et al, 2011). The dominant soil type in Elgeeyi station larch forests is typical sod-pale soil, developed on medium and heavy loam carbonated grounds. The genetic profile is: **O1/O3-AY-BPL-BCA-BCca,** which is subtype of sod-pale typical soils. At the time of the soil description and sampling 28.07.2011 the permafrost table was at the depth of 88 cm.

The studied soils have difference in granulometric composition (Table 1). Coarse humified sod-pale solodic soil (profile 2-07) is characterized by heterogeneous and light composition. Melkozem of this soil is dominated by coarse and medium grained sandy particles. Content of silt particles in the profile is variable, the lowest amount of silt found at a depth of 19-44 cm. Unevenness in distribution of size fractions has predominantly lithogenic nature that may be related to the genesis of deposits. Mineral horizons of typical sod-pale soil (profile 01-11) have poorly differentiated medium and heavy granulometric composition within horizons. In melkozem dominated fine grained sand and coarse silt particles. The content of the medium and fine silt particles in the soil 2-3 times more than in the coarse humified sod-pale solodic soil. By the quantity of clay particles, this soil is also significantly higher than coarse humified sod-pale solodic soil. Presence of heavy granulometric composition of the soil at the depth of 25-56 cm, apparently not related to soil processes, as evidenced by the lack of a clear pattern of all factions distribution in profile. As in the previous case, here in the uneven distribution of the granulometric fractions has predominantly lithogenic nature.

Table 1. Granulometric composition of studied soils.

Depth, cm	Fraction content, %, particles size, mm			
	1-0,05	0,05-0,001	<0,001	<0,01
Profile 2-07				
9-19	64,0	24,9	11,1	20,1
19-44	79,9	12,3	7,8	11,1
44-64	72,6	16,3	11,1	17,2
64-114	56,2	28,2	15,6	24,6
114-124	70,1	17,6	12,3	16,4
Profile 01-11				
11-25	38,3	43,3	18,4	38,9
25-56	30,9	50,7	18,4	41,3
56-88	36,5	46,3	17,2	39,7

Because of the light granulometric composition, on the surface of the sod-pale solodic soil the polygonal fractured micro-relief is poorly defined, and the soil profile more clearly differentiated into genetic horizons, both in color and content of silt fraction.

Soils are characterized by the slightly acidic and acidic pH values in the upper horizons and alkaline pH in lower horizons, by the low organic carbon content in mineral horizons and high proportion of weakly decomposed organic matter in the litter-biogenic horizons (Table 2). Despite the overall similar patterns of these indicators, the content of organic matter in the typical sod-pale soil almost two times more than in the coarse humified sod-pale solodic soil. In the surface organic layers of the typical sod-pale soil the ignition loss is up to 75-80%, in contrast to 49% in solodic soil. Almost twofold carbon excess in the mineral pale metamorphic and accumulative-carbonaceous horizons of typical sod-pale soil may have determined by the more heavy granulometic composition and related with high cation exchange capacity.

Table 2. Some physical and chemical properties of studied soils.

Horizon, depth, cm	C, %	pH water	Sum of salts %	CEC	Absorbed bases, mg eqiv/100 g of soil		
					Ca	Mg	Na
Coarse humified sod-pale solodic soil, Profile 2-07							
Litter 0-4	49,4*	5,0	ND				
AYaoe 4-9	13,8	4,4	1,63	25,6	11,3	6,7	6,9
BPLhi 9-19	1,9	6,3	0,54	18,9	9,6	5,2	3,8
BPLcr1 9-44	0,3	7,7	0,06	13,1	6,6	3,8	2,6
BCAgcr 44-114	0,3	8,0	0,11	14,3	7,2	4,4	2,6
BCAgcr 114-124	0,2	8,2	0,10	10,2	5,6	2,4	2,1
Typical sod-pale soil, Profile 01-11							
Litter 4-0	65,9*	5,1	0,74	11,6	4,8	4,8	0,6
0-10	75,8*	4,3	0,50	8,6	3,6	3,6	0,3
10-20	80,1*	4,4	0,28	9,3	4,4	3,6	0,3
AY 6-11	7,2	4,9	0,39	14,3	7,8	6,1	0,2
BPL 11-25	0,9	6,7	0,10	18,2	11,5	6,4	0,2
BCA 25-56	0,7	7,8	0,08	17,8	13,3	4,2	0,1
BCca 56-88	0,5	7,9	0,07	17,0	13,4	3,2	0,2

* Ignition loss

Cation exchange capacity of both soils is low. In the sod-pale soils with light granulometric composition this parameter depends on organic matter content and decreasing with the depth. In the absorbed bases composition a significant proportion of sodium, which is one of the reasons for appearance in the upper organic horizons solodization signs at slightly acidic environment. The highest content of absorbed sodium (20-37% of the absorbed bases) found in the horizons AYaoe and BPLhi. A large proportion of sodium in absorbed bases in the humus-accumulative horizon of sod-pale soil makes it different from the "typical" grey humus horizon AY, that, in our opinion, reflects the specificity of its formation in seasonally thawing soils under extracontinental climate.

In a typical sod-pale soil of Elgeeyi station the value of cation exchange capacity has a stronger correlation with the granulometric composition. In organogenic layers the cation exchange capacity is low, in lower mineral horizons increases up to 2 times in comparison with the overlying. In the absorbed bases composition Ca^{2+} ions is dominates, second is the Mg^{2+} ions. The proportion of sodium in the mineral layers is less than 1%. Such significant differences of absorbed cations composition in studied soils may depend not only on the granulometric characteristics, but also the mineralogy of parent grounds (Desyatkin R. V. et al, 2013).

Both soils in natural condition contains a small amount of water-soluble salts, mainly calcium bicarbonate, magnesium and sodium. Content of water-soluble salts in the coarse humified sod-pale solodic soil, despite its lighter granulometric composition, higher than the typical soil formed on the medium and heavy loams, which once again confirms the possibility of significant differences in the mineralogical composition of the parent grounds of the compared sites.

Conclusions

1. Soils of stations differ in particle size: melkozem of loamy-sandy loamy coarse humified sod-pale solodic soil (profile 2-07) is dominated by sandy particles. Loamy soils of typical pale soil (profile 01-11) dominated by fine sand and coarse-particle.

2. Soils are characterized by slightly acidic-acidic pH values in the upper horizons and by the alkaline in lower horizons; low content of organic carbon in mineral horizons and high proportion of weakly decomposed organic matter in the litter-organogenic horizons. Despite the overall similar patterns of these indicators, the organic carbon content in the mineral part of the typical pale soil almost 2 times more than in the coarse humified sod-pale solodic soil.

3. CEC of these soils is low. In the absorbed bases of coarse humified sod-pale solodic soil the main part takes sodium ions, which is one of the reasons for solodization of upper organic horizons under acidic condition.

References

Agroclimatic resources of the Yakut ASSR. L.: Gidrometeoizdat, 1973. -111 p.

Desyatkin R. V., S. N. Lesovaya, M. V. Okoneshnikova, and T. S. Zaitseva. Palevye (Pale) Soils of Central Yakutia: Genetic Specificity,Properties, and Classification // Eurasian Soil Science, 2011, Vol. 44, No. 12, pp. 1304–1314.

Desyatkin R. V., Goryachkin S.V., Konyushkov D.E., Krasilnikov P.V., Lebedeva M.P., Bronnikova M.A., Desyatkin A.R., Fedorov A.N., Khokhlov S.F., Lapteva E.M., Mergelov N.S., Okoneshnikova M. V., Shishkov V.A., Turova I.V., Zazovskaya E.P. Diversity of Soils of Cold Ultra-Continental Climate. Guidebook-monograph for the “Mammoth” ultra-continental WRB field workshop. Sakha (Yakutia). August 17-23, 2013 – Moscow – Yakutsk, 2013. - 95 p.

Classification and diagnosis of Russian soils. Smolensk.: Oikumena, 2004. - 342 p.

National atlas of Russian Federation soils. – M.:Astrel:ACT, 2011 – 632 p.

Scientific and applied climate handbook of USSR. Issue 24. Yakut ASSR, book 1. – L.: Gidrometeoizdat, 1989. – 607 p

Changes of microclimatic and soil conditions after forest fires in Central Yakutia

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Key words: Central Yakutia, forest fires, burned out areas, seasonally thawed layer

Introduction

One of the most common and destructive factors in the forests of a boreal zone are forest fires (Sherbakov e*t al*, 1979; Abaimov e*t al,* 1996 and *et al*). Over 8.2 thousand fires were recorded in Yakutia during the last 10 years, covering 1.3 million ha and resulting in 20 million m^3 of burned out timber (Lytkina and Isaev, 2010).

Materials and methods

We studied the burned out areas of different age: 1-2, 10-12, 20-23, and 58-60 for three years. The cowberry larch forest was chosen as a control area – the most prevalent type of the forest of Central Yakutia in East Siberia. The air and soil temperature (at different depths), field soil moisture, thickness of a seasonally thawed layer (STL) were measured by standard meteorological devices. The temperature condition observations were carried out early in June, mid July and late in August. The soil moisture and the depth of the STL were measured once a month.

Results

Fire effect on the ambient temperature. Temperature observations in the fire sites showed that the ambient temperature is slightly higher as compared to the one in the control area in the cowberry larch (hereinafter-in the forest). Thus, in 2002-2003, the surface layer of air on burned out areas was warmer than in the forest, by 1.2-1.4°C in July, by 0.6-1.1°C in August. In the middle of the vegetative period it was warmer in the fire sites at night, the difference of minimum temperatures in the burned out sites and in the forest varied within 0.4-0.9°C. At the end of the vegetative period the average temperature at the sites of observation was almost similar by the daytime temperature reducing.

Fire effect on the soil temperature. During the whole vegetative period the soil temperature in the burned out sites was much higher than in the forest. And the highest temperature was noted at a 1-2-year old burn site (Table 1). Maximum rising of soil temperature was observed in the middle of the vegetative period. A significant heating of soil temperature on the newly burned out areas is primarily determined by good absorption of sunlight by black surface (Gavrilova, 1969). It is known that in Central Yakutia the temperature of the open soil surface is two times higher than in the forest (Gavrilova, 1967). Shading of the soil surface by plants increases as the burning grows over in process of succession and thus reduces penetration of direct sunlight resulting in a gradual soil temperature decrease.

Table 1

Temperature difference in soils (Δt°) of burned out areas at different depths, ºC

Time	Site	Depth, cm								
		5	10	15	20	30	40	50	80	100
I decade of June 2004	(Δt°) 2-year-old burned area – cowberry larch	5.5	4.2	4.6	4.1	3.2	2.8	1.7	1.4	0.0
	(Δt°) 12-year-ld burned area - cowberry larch	3.1	2.4	3.0	2.4	1.4	1.4	1.4	2.2	-3.3
	(Δt°) 60-years-old burned area - cowberry larch	1.0	0.3	-0.7	0.2	-1.0	-0.2	0.7	1.6	0.0
II decade of July 2004	(Δt°) 2-year-old burned area - cowberry larch	5.6	5.0	4.2	2.6	4.3	5.9	7.8	6.3	0.3
	(Δt°) 12-year-old burned area - cowberry larch	5.2	4.8	6.3	4.7	6.2	7.1	8.4	3.9	0.6
	(Δt°) 60-year-old burned area - cowberry larch	1.3	-0.8	-0.4	0.8	-1.9	-0.4	0.2	0.1	0.0
III decade of August 2004	(Δt°) 2-year-old burned area - cowberry larch	1.9	2.1	2.3	1.5	1.3	2.5	5.0	2.9	2.7
	(Δt°) 12-year-old burned area - cowberry larch	1.9	2.4	3.0	2.2	2.0	2.9	5.5	2.6	2.6
	(Δt°) 60-year-old burned area - cowberry larch	1.0	0.4	-0.2	0.7	-1.4	-0.2	-0.1	-0.4	0.0

Fire effect on the soil moisture. Changes in temperature and freezing conditions of soils in the post-fire periods also affect soil moisture. Calculations showed that it increases mainly in the beginning of succession: in the 1-2-year-old burned out areas - by 1.1-2.3 times, and in the 10-12-year-olds - by 1.1-1.7 times as compared to the soil moisture in the forest (Fig. 1, Table 2). This is due to rise of water from the lower water-saturated horizons of the soil with increasing thickness of the seasonally thawed layer and reduced consumption of water by transpiration to disturbed surface cover of the burning (Pozdnyakov, 1963, Tarabukina and Savvinov, 1990).

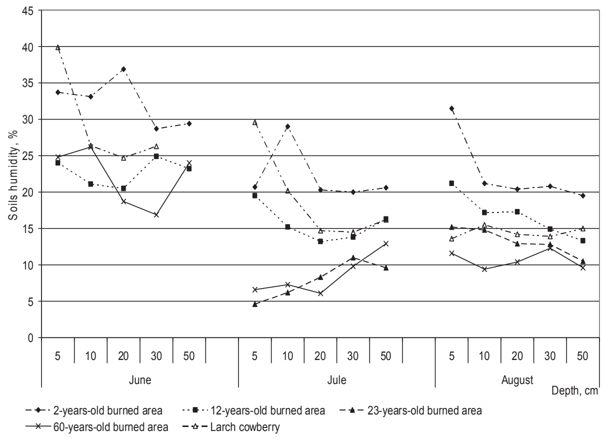

Fig. 1. Field soil moisture at different depths in the burned areas and in cowberry larch (as of 09.06.2004, 17.07.2004, 29.08.2004.)

Distribution of moisture in the soil profile at different depths is quite even under the forest canopy, but humidity in the upper horizons is often raised. It is explained by the ability of litter and humus horizon of the soil to retain moisture. There is over-moistened soil in the all burned areas and in the forest at the beginning of the vegetative period (the 1st decade of June). In July-August humidity becomes stable and generally slightly changes. A relative soil drying up is observed due to the consumption of water by trees and grass-shrub cover in a 20-30-cm layer in the cowberry larch and a 58-60-year-old burned area. In the middle of the vegetative period the lowest soil moisture is noted: in the fresh burned areas - due to greater evaporation from the exposed surface and in 10-12, 21-23 and 58-60-year-old

Table 2

Field soil moisture at different depths in the burned areas and in the control forest in 2004, % of dry weight

Depth, cm	June					July					August				
	The age of burned area				Forest	The age of burned area				Forest	The age of burned area				Forest
	2	12	23	60		2	12	23	60		2	12	23	60	
5cm	33.7	24	-	24.8	39.9	20.7	19.5	4.6	6.6	29.6	31.5	21.2	15.2	11.6	13.6
10cm	33.1	21.1	-	26.2	26.4	29.0	15.2	6.2	7.3	20.2	21.2	17.2	14.8	9.4	15.5
20cm	36.9	20.5	-	18.7	24.7	20.3	13.2	8.3	6.1	14.7	20.4	17.3	12.9	10.4	14.2
30cm	28.7	24.9	-	16.9	26.3	20.0	13.8	11	9.8	14.5	20.8	14.9	12.8	12.3	13.9
50cm	29.4	23.2	-	24	-	20.6	16.3	9.6	12.9	16.2	19.5	13.3	10.5	9.6	15

burned areas - due to absorption of water by roots of larch undergrowth and grass-shrub plants, which grow rapidly especially at this time. The highest water consumption and, consequently, low soil moisture is observed in 21-23-year-old burned out sites with dominant birch-larch young growth in the cover. The birch is known as one of the species which intensively consumes soil moisture, thus partially soil drying up may be associated with this property of plants.

Plant transpiration and soil moisture consumption become lower late in the vegetative season, respectively, soil moisture increases, especially in the burned out areas (Savvinov, 1971, 1976). Soil remains waterlogged until the age of 15-20 of the fire site, down to the age of 20 soil moisture becomes stable.

Fire effect on the permafrost conditions. Permafrost conditions of soils at the burned out areas are significantly different from those in the wooded areas. A thawed soil layer in the burned out sites on the average is 0.3-0.8 m thicker (0.3-0.6 m in Jul and 0.4-0.8 m in Aug) than in the forest (Fig. 2). The greatest thickness of the thawed layer is observed at the forbs-grasses phase in a 10-12-year-old fire site when the vegetation - mainly small grasses - does not prevent the penetration of heat into the ground, the minimum - in the larch forest, where there is the most developed heat insulating layer consisting of thick grass-shrub and moss-lichen cover and litter. The highest rate of soil thawing is typical for a young fire site (10-12 year old). In early June, the difference in the STL thickness between the burned out site and forest was 20-38 cm, late in August it reached 56-78 cm.

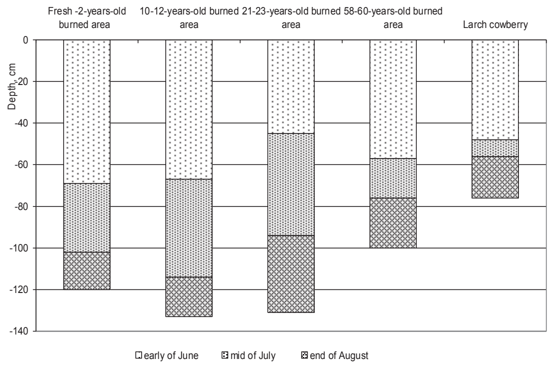

Fig. 2. Depth of seasonal thawing of the soil at different stages of succession of burned out areas (averages for 2002-2004)

It should be noted that vegetation regenerates almost completely within 50 years after the fire, and the thickness of permafrost, according to our observation becomes stabilized much slower. The process of the soil cooling and freezing begins in 20 year's time after the fire. According to A.P. Abaimov and his co-authors (Abaimov *et al*, 1996;

Prokushkin e*t al*, 2002) in the forests of Central Siberia it occurs in about 16 years after the fire. The difference in the depth location of STL on a 16-year-old burning and larch forest with a wild rosemary-cowberry green moss-lichen carpet is 10-15 cm, while in Central Yakutia it is approximately 55 cm (30-80 cm) in a 22-year-old fire site and cowberry larch forest, which is directly dependent on climatic differences, patterns of the permafrost spread and vegetation and fire intensity.

The research carried out showed that significant changes in microclimatic and soil conditions in the burned out areas occur in the first 10 years after the fire. And it is clearly seen especially in the young fire site. All parameters of microclimatic and soil conditions (temperature and soil moisture, STL thickness) depend on the stages of the fire site overgrowing. At the young burned out site soil temperature in average increases in comparison with the forest at a depth of 5 cm in 5.2 ... 5.6°C, at a depth of 30 cm - in 4.3 ... 6.2°C, soil moisture - by 1.1-2.3 times in a 1-2-year –fire site, by 1.1-1.7 times in a 10-12-year-old one; STL thickness is 0.3-0.8 m greater in the burned out areas than in the forest. There is stabilization of the modified conditions in the post-fire period in the course of succession.

References:

Abaimov A.P., Prokushkin S. G. & Zyryanova O.A., 1996. Ecological phytocenological assessment of fire impacts on forest of cryolithic zone of Central Siberia. *Sib. Ecol. Zh.* 1, 51-60. [In Russian].

Gavrilova M.K., 1967. Thermal balance of larch forests in the Lena and Amga interfluve. In: Molchanov A.A. (eds.), *Hydroclimatic research in the forests of Siberia,* Nauka, Moscow, pp. 28-33. [In Russian].

Gavrilova M.K., 1969. Radiation regime in larch forests of South-West Yakutia. *Lesovedenie* 1, 16-23. [In Russian].

Lytkina (Gabysheva) L.P., Isaev A.P., 2010. Forest fires. In: Troeva E.I., Isaev A.P. (eds.) *The Far North: Plant biodiversity and ecology of Yakutia. Plant and Vegetation 3,* DOI 10.1007/978-90-481-3774-9. Springer Science + Business Media B.V., 265-269.

Pozdnyakov L.K., 1963. *Hydroclimatic regime of larch forests of Central Yakutia,* AN USSR, Moscow, 146 p. [In Russian].

Prokushkin S.G., Abaimov A.P. & Prokushkin A.S., 2002. Conditions of temperature in the larch forests on permafrost soils. In: Pleshikov F.I., Vaganov E.A. & Vedrova E.F. (eds.), *Forest Ecosystems of the Yenisei meridian,* SD RAS, Novosibirsk, 34-45. [In Russian with an English summary].

Savvinov D.D., 1971. Conditions of temperature and water schedule of forest soils of Yakutia. In: Sherbakov I.P., Michaleva V.M., Karpel B.A. *Studies of vegetation and soil in the forests of the North-East of the USSR,* Yakutknigoizdat, Yakutsk, 118-175. [In Russian].

Savvinov D.D., 1976. *The hydrothermic conditions of soil in the permafrost zone*. Nauka, Sib. Division, Novosibirsk, 254 p. [In Russian].

Sherbakov I.P., Zabelin O.F., Karpel B.A. et al., 1979. *Forest fires in Yakutia and its influence on the forest's nature.* Nauka, Novosibirsk, 224 p. [In Russian].

Tarabukina B.G. and Savvinov D.D., 1990. *Influence of fire on permafrost soils*. Nauka, Sib. Division, Novosibirsk, 120 p. [In Russian].

Degradation of permafrost soils of the Alaseya River valley due to flood inundation

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Key words: flood, permafrost, disturbed soil

Introduction

Detailed soil research connecting with investigation of consequences of catastrophic flood flows on Alaseya River valley in 2008-2009 years was originally made. In recent years, high water level detected on the Alaseya river valley during prolonged seasonal flooding [1]. The reason for this was a disturbance of the hydrological regime of the river. A drastic change of the hydrological regime due to the disturbance of water balance is caused by discharge of water from a lakes to the river system and increase of precipitations. During research of the morphology and chemical properties of disturbed soils were identified several levels of soil degradation.

Materials and methods

Geographically the Alaseya River disposes in the North-East of Yakutia and flows into the East-Siberian Sea. The river has a length of 1590 km (basin area of 74700 sq. km) and is characterized mainly by atmospheric nutrition [2]. The plain territory of Northern Yakutia is completely formed by the Pleistocene quarternary deposits having thickness achieving several tens of meters. The researched region divides into three phytogeographical zones: tundra, forest tundra and taiga represented by northern taiga subzone in this case. Yakutia is most typical region of permafrost soil development. In this paper, it was used a classification of permafrost soil made by Elovskaya L. G.[3]. Zonal types of soil are cryozem and gleyzem. We compared the morphological and chemical properties of natural and disturbed soil. Morphological and chemical studies of soils were carried out by conventional methods.

Results

In northern taiga subzone and forest tundra a zonal type of soil is a typical cryozem, homogeneous non-gley and thixotropic, developing on diverse well drained relief elements (terraces, watersheds) mainly. The most characteristic morphological features of cryozems of this region are oversaturation, gleying, weak profile differentiation, brownish-grey homogeneous color of mineral horizon, characterized by lack of structure and homogeneity[4].

In tundra zone a permafrost tundra gley and gleyish soils (gleyzems) are spread. Thickness of soil active layer varies from 25 to 75 sm. Soil profile of all zonal soils on this area are divided into a organic and mineral layers. Organic horizons have different thickness and decomposition level, and mineral horizons are subdivided by expressiveness level of gleying. Soil granulometric composition analysis showed that the Alaseya River mean stream valley soils is dominated by loam with impurity of sandy loam and sand, and during downstream motion granulometric composition is replaced with loam with impurity of adherent sandy-slimy deposits. Explored region soils had taken or are taking hydromorphic developing phase.

The soils of Alaseya River valley have subacidic (less often close to neutral) pH level, relatively low humus content of mineral layer (0,7-2,9%), and these soils is characterized by high hydrolytic acidity in organic layers (up to 151 mmol/100g) and low hydrolytic acidity in mineral layers (up to 5,6 mmol/100g). All soils were weakly saturated by bases or non-saturated by bases, and this appearance is characteristic for acidic soils.

A significant degradation of vegetation and soil cover is observed in ecosystems damaged by flood waters. Because of permafrost table the soil rapidly reaches full saturation. On large flat areas with numerous depressions that have a minimum lateral subsurface flow, water output occurs only as evaporation and this process takes a long time. Soils keep wet for a long time, resulting in a limited supply of oxygen in the soil, death of plant roots, structural damage, increasing of thawing depth and waterlogging in subsequent years. In flooded soils under of oxygen depletion and excessive moisture conditions, established unfavorable redox conditions and significantly reduces the level of soil fertility.

During the research were identified several levels of soil degradation: 1. Weak degree: the soil profile is characterized by increased water-logged, thixotropy and partial homogenization;

2. Average degree: the upper part of the profile partially degraded; 3. Strong degree: on the surface layer of soil accumulated silt-loam river alluvium (about 6-10 cm). Mineral strata may be moist and devoid of structure.

When compared with the baseline values it was observed following chemical properties of the soil:

- Soils are similar in pH value (4-5,6), but there was a tendency to decrease of acidity in the upper part of profiles because of bringing alluvium.
- Hydrolytic acidity decreased due to the partial degradation of the upper organic horizon.
- In the northern soils humus has fulvic composition, therefore very mobile. The content of soil organic matter increases in lower mineral levels (from 0.75 to 4.85%) under the influence of the flood waters and homogenisation processes.
- It is observed a slight increase in the extent of saturation in the upper organic horizons, and it indicates a increasing influence of flood waters.

Conclusions

Prolonged flooding causes degradation of surface organic horizon, permafrost, impairment of soil structure and thermo-physical properties.

Productivity of plant mass changes because of change of physical indicators of permafrost soil such as moisture, structure, density and thawing depth.

Disturbed soils are characterized by reduction of biomass production, biological activity and fertility, transformation of living organisms decomposition processes, disturbance of buffer system.

From an environmental point of view, these territories are now very vulnerable and susceptible to various external factors (degradation of permafrost complex, climate, etc.), and in extreme conditions of the north the recovery of sustainable balance can take long time.

References

Grigoriev M.N., Kunitsky V.V., Zhang R.V., Shepelyov V.V. On the change of permafrost, landscape and hydrological conditions in the Arctic region of Eastern Siberia due to climate warming. Permafrost Institute SB RAS, Yakutsk. 2009, p. 5-11

Rivers and lakes in Yakutia. Quick Reference / Ed. Agueyev V.I. - Yakutsk: Bichik, 2007 - 136 p.

Elovskaya L.G. Classification and diagnosis of permafrost soils of Yakutia. Yakutsk, Academy of Sciences of the USSR, 1987.- p172.

Ivanova A.Z., Desyatkin R.V. Cryozems of Alaseya River valley / / Science and education. - Yakutsk, 2011. - № 2 (62.) - P.70-73.

Role of pyrogenic and cryogenic processes in ^{137}Cs migration in frozen soils of central Yakutia

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Key words: frozen soils, pyrogenic and cryogenic processes, ^{137}Cs migration

Introduction

During last years, the frequency of wildfires in the territory of Yakutia has significantly increased because of thunderstorms and unauthorized controlled fires. Only during the fire season of 2011, 265062.7 hectares of forest have been destroyed by fire[1]. Nowadays, many sites of burnt forest, which were formed in different years, are often found near cities and villages. One of such burnt sites is located on elevated, slightly inclined (0-2°) fluvial terrace of the Lena River near the city of Yakutsk. Here, 11 years ago a large piece of pine forest (300 meters in width and 1000 meters in length) was subjected to a wildfire. The fire completely destroyed the litter layer and humus horizon of this taiga cryogenic sandy soil. The profile sections were made on selected site and soil samples were taken from each layer for further gamma-ray spectroscopy analysis. The samples were harvested in the top-bottom manner to the depth of 30-60 cm and were equally spaced from each other. The total volume content of ice in sandy deposits of pine forest was around 0.3, thus, terrain forming cryogenic processes in this soil were relatively weak.

Discussion

The results of this study have shown that the increased concentration of ^{137}Cs was observed in the surface layer (0-4 cm) of the soil (Table 1).

Thus, in all studied profile sections the greater amount of ^{137}Cs (79.7 – 88.5 % of its total amount in a profile) was concentrated in the upper 4-cm layer of soil. However, it was still detectable until the depth of 8-9 cm.

In unaffected by fire cryogenic taiga soils the maximum concentration of ^{137}Cs was registered under the litter layer in the upper part of the humus horizon, usually in the depth of 2-6 cm. More than 70 % of total ^{137}Cs found in the profile section was concentrated within this interval.

Regarding vertical distribution of ^{137}Cs within

Table 1. Vertical distribution of ^{137}Cs in cryogenic taiga soil in burnt forest.

N	Horizon; Depth, cm	Bq /kg	Bq/m^2	%
The beginning of the burnt area				
1	Ao, 0-2	28.3	70	10.6
2	AoA$_1$, 2-4	29.9	457	69.1
3	A$_1$A$_2$, 4-6	2.7	65	9.8
4	A$_1$A$_2$, 6-8	2.6	69	10.5
5	A$_1$A$_2$, 8-10		∑ 661	∑ 100
The middle of the burnt area				
6	Ao, 0-2	30.1	75	11.9
7	AoA$_1$, 2-4	28.4	434	68.9
8	A$_1$A$_2$, 4-6	2.8	65	10.3
9	A$_1$A$_2$, 6-8	2.2	56	8.9
10	A$_1$A$_2$, 8-10		∑ 630	∑ 100
The end of the burnt area				
11	Ao, 0-2	96.4	260	37.0
12	AoA$_1$, 2-4	28.3	362	51.5
13	A$_1$A$_2$, 4-6	1.6	33	4.7
14	A$_1$A$_2$, 6-9	1.2	48	6.8
15	A$_1$A$_2$, 9-12		∑ 703	∑ 100

soil profiles it should be noted that it was detected in lower horizons in the unburned territories as compared to that in the burnt ones (Fig. 1).

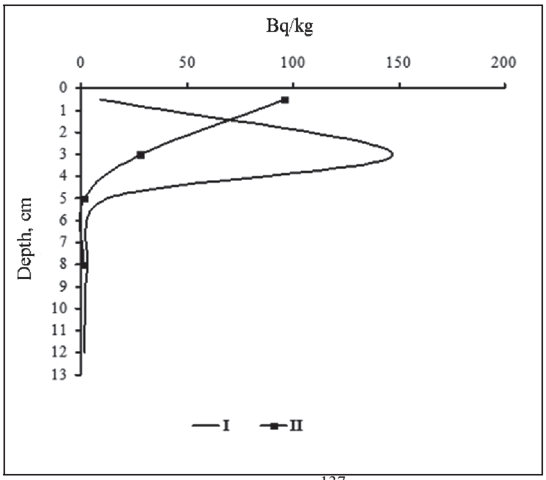

Fig. 1. The distribution of ^{137}Cs in profile of cryogenic taiga soil.
I – in unburned forest, II – in burned forest.

Within the studied territory, ^{137}Cs pollution density of 9-cm soil layer varied between 620 and 661 Bq/m^2 with average value of 642±16 Bq/m^2. At the same time, its average stock in soil measured in 5 different sites within 6 kilometers of the windward side of the burnt area, was 667±8 Bq/m^2.

The comparison of average amount of ^{137}C in soils of burnt and unburned forest revealed its average decrease by 3.7%. We believe that such decrease is primarily caused by escaping of ^{137}Cs with smoke during fire. Due to little incline of the watershed surface the influence of water erosion processes on lateral migration of ^{137}Cs in taiga soil during post-fire period in conditions of cryo-arid climate is minimal.

The second site of burned forest was located in the watershed of the Amga River near Myryla village in Churapcha region. Here, 11 years ago a massif of larch forest (650 meters in width and 1500 meters in length) was destroyed by wildfire. The site represents the beginning of the watershed surface with 2-3° incline towards the river valley. In loamy deposits of the soil the total volume content of ice varied between 0.4-0.8. The high ice content of soil-forming rock significantly affects the relief formation. Here one may observe highly developed specific forms of cryogenic micro- and mezorelief, such as baigerakhs (conical thermokarst structures), thermokarst depressions, frost fissures etc.

The maximum influence of cryotic processes on post-pyrogenic redistribution of ^{137}C is observed in pale yellow soils. In post-fire period, during the formation of new baigerakhs, thermokarst failures and/or expanding of hollows lead to partial removal of ^{137}C from the surface with soil. The redistribution of ^{137}C in permafrost soils during the post-pyrogenic period also increased. So, in frost fissure soils, where ash accumulated after fire, ^{137}C pollution density increased 1.5 fold as compared to control soils of testing sites. Similar situation was observed in mezorelief soils (baigerakh-hollow). All in all, the overall loss of ^{137}C in soil after a fire, because of its volatilization with smoke, influence of cryogenic processes and water erosion, varied between 17.8 – 42.4 % of its total amount, sometimes reaching even higher percentage.

Thus, forest fires greatly affect redistribution of ^{137}C in soils of Central Yakutian plain. Moreover, the influence of cryogenic processes on redistribution of the radionuclide in soil during the post-fire period depends on volume content of ice in cryogenic soil.

Reference

National report on status and protection of the environment of the Republic of Sakha (Yakutia) in 2011. The Ministry of Nature Protection of the Republic of Sakha (Yakutia), Dani-Almaz Inc., Yakutsk, 2012.

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2nd International Conference on “Global Warming and the Human-Nature Dimension in Siberia: Social Adaptation to the Changes of the Terrestrial Ecosystem, with an Emphasis on Water Environments”
7th Annual International WorkshopC/H2O/Energy balance and climate over boreal and arctic regions with special emphasis on eastern Eurasia

PROGRAM

Tue, 8 October

09:00 Registration
09:30 **Opening Ceremony**
Trofim Maximov (IBPC SB RAS, Leader of Projects from Russian side, Russia)
Mikhail Lebedev (Chairman of YSC SB RAS, Russia)
Tetsuya Hiyama (RIHN, Project Leader, Japan)
Vasiliy Vasilyev (Vice-director of NEFU, Russia)

Session 1 — *Plenary* —

Global Features of Climate Changes in the Northern Ecosystems

(chaired by Trofim Maximov, Sergey Bartsev)

10:00 Tetsuya Hiyama (RIHN, Japan)
10:30 Andrey Degermendzhi, Sergey Bartsev (Institute of Biophysics, Russia)
11:15 Nikita Solomonov (IBPC RAS Corresponding member, Counsellor, Russia)
11:45 Atsuko Sugimoto(Hokkaido Univ, Japan)
12:15 Rikie Suzuki (JAMSTEC, Japan)
12:45 Lunch
14:00 Trofim Maximov (IBPC RAS SB,Russia)
14:30 Alexander Fedorov (MPI SB RAS,Russia)
15:00 Pavel Voronin (Plant Physiology Institute RAS,Russia)

Session 1 — *Keynote* —

(chaired by Tetsuya Hiyama)

15:45 Liliya Vinokurova, Sardana Boyakova (IHRNIPB SB RAS, Russia)
Climate change consequences in Yakutia: Social and economic challenges for rural communities
16:10 Ayumi Kotani (Nagoya Univ, Japan)
Net ecosystem water use efficiency over two larch forest at eastern Siberia
16:35 Nikolay Germogenov et al.(IBPC SB RAS, NEFU, Russia)
Dynamics of terrestrial vertebrate animal population in Central Yakutia in the last 150 years under climate change and increasing anthropogenic pressure
17:00 Takeshi Yamazaki (Tohoku Univ, Japan)
Long-term simulation of soil condition and energy flux in eastern Siberian taiga forests
17:25 Yoshihiro Iijima (JAMSTEC, Japan)
Spatio-temporal variations in permafrost and boreal forest degradations in Central Yakutia
19:00 **Reception**

ISBN-978-4-906888-01-6

Wed, 9 October

Session 2

Human-Nature Interactions in a Changing Climate

(chaired by Liliya Vinokurova, Sardana Boyakova)

09:00 Nikita Solomonov et al. (IBPC SB RAS, NEFU,Russia)
09:25 Sardana Boyakova (IHRNIPB SB RAS, Russia)
09:50 Fuyuki Ebata (Niigata Univ, Japan)
10:15 Viktoriya Filippova (IHRNIPB SB RAS, Russia)
10:55 Tuyara Gavrilieva, Igor Chikachev (NEFU, Russia)
11:20 Tohru Ikeda (Hokkaido Univ, Japan)
11:45 Svetlana Knyazeva (UNESCO, Russia)
12:10 Yukari Nagayama (Hokkaido Univ,Japan)
12:35 Yuka Oishi (Tokyo MU, Japan)
14:00 Vyacheslav Shadrin (IHRNIPB SB RAS, Russia)
14:25 Mikhail Vasiliev (ICRA SB RAS, Russia)
14:50 Atsushi Yoshida (Chiba Univ, Japan)
15:15 Yuriy Zhegusov (IHRNIPB SB RAS, Russia)
15:40 General Discussion on the results of Session 2

Session 3

Climatic Responses of Carbon, Water and Energy Cycles in Northern Ecosystems

(chaired by Atsuko Sugimoto, Ayumi Kotani)

09:00 Tetsuzo Yasunari (Director of RIHN, Japan)
09:25 Sara Livshits (IOGP SB RAS, Russia)
09:50 Ryuhei Yoshida et al. (Tohoku Univ, JPN)
10:15 Taro Nakai (Nagoya Univ, Japan)
10:55 Eddy Moors et al. (Wageningen Univ, Netherlands)
11:20 Yoshihiro Tachibana (Mie Univ, Japan)
11:45 Aleksey Desyatkin (IBPC SB RAS, Russia)
12:10 Oleg Mikhaylov, Svetlana Zagirova (Institute of Biology,Komi Science Centre Russia)
12:35 Aytalina Efimova (IBPC SB RAS, Russia)
14:00 Alexander Kononov (IBPC SB RAS, Russia)
14:25 Kynney Kirillina (NEFU, Russia)
14:50 Anastasiya Timokhina (Institute of Forest SB RAS, Russia)
15:15 Vadim Starodubtsev (ICRA SB RAS, Russia)
15:40 Roman Petrov (IBPC SB RAS, Russia)
16:05 General discussion on the results of Session 3
16:45 **Poster session**
Poster presentations 9 Oct. 16:45-18:00 and 10 Oct. at Lunch time

Thu, 10 October

Session 4

Biological Processes during Climatic Changes

(chaired by Ayaal Maksimov, Alexander Kononov)

09:00 Innokentiy Okhlopkov (IBPC SB RAS, Russia)
09:25 Alexander Isaev (IBPC SB RAS, Russia)
09:50 Yuri Rozhkov(Olekminsky state nature reserve, Russia)
10:15 Shirow Tatsuzawa(Hokkaido Univ, JPN)
10:55 Anatoliy Nikolaev (NEFU, Russia)
11:20 Valentina Sofronova(IBPC SB RAS,Russia)
11:45 Irina Dranaeva (NEFU, Russia)
12:10 Tatiana Ivanova (IBPC SB RAS, Russia)
12:35 Marina Terentyeva (IBPC SB RAS,Russia)
14:00 Tatiana Tatarinova et al. (IBPC SB RAS, Russia)
14:25 Alexandra Popova et al. (BEST Center, NEFU, Russia)
14:50 Ayaal Maksimov (IBPC SB RAS, Russia)
15:15 Tatiana Sivtseva (NEFU, Russia)
15:40 Evgeniya Varlamova et al.(ICRA SB RAS Russia)
16:05 Nadezhda Danilova (IBPC SB RAS,Russia)
17:00 General Discussion on the results of Session 4

Session 5

Remote Sensing & Modeling for Eco-Climatic Monitoring

(chaired by Takeshi Yamazaki)

09:00 Shamil Maksyutov, V.Sedykh (NIES,JPN)
09:25 Victor Brovkin (Max Planck Institute for Meteorology, Germany)
09:50 Yasushi Yamaguchi (Nagoya Univ, JPN)
10:15 Vladimir Soloviev (ICRA SB RAS, Russia)
10:55 Boris Borisov (IBPC SB RAS, Russia)
11:20 Thomas Kleinen (Max Planck Institute for Meteorology, Germany)
11:45 Oleg Tomshin (ICRA SB RAS, Russia)
12:35 General Discussion on the results of Session 5

Session 6

Climatic Vulnerabilities of Permafrost

(chaired by Yoshihiro Iijima)

14:00 Alexander Chevychelov (IBPC SB RAS, Russia)
14:25 HoTaek Park (JAMSTEC, Japan)
14:50 Pavel Konstantinov (MPI SB RAS,Russia)
15:15 Oleg Tregubov (NEISRI FEB RAS, Russia)
15:55 Makoto Okumura (Tohoku Univ, Japan)
16:20 Go Iwahana (Univ of Alaska, USA)
16:45 Leonid Gagarin (MPI SB RAS, Russia)
17:10 Matrena Okoneshnikova, Roman Desyatkin (IBPC SB RAS, Russia)
17:50 **Closing Ceremony**
Tetsuya Hiyama (Concluding remarks)
Trofim Maximov (Closing address)
Tetsuzo Yasunari (Closing address)