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Potential Contributions of IGBP-AIMES to the Future Earth Initiative

Introduction and Track-record

The IGBP "Analysis Integration and Modelling of the Earth System (AIMES)" project has championed and developed the notion of *System Science for Planet Earth*, or "*Earth System Science*" for short. Earth System Science (ESS) is the notion that the planet operates as a tightly coupled system of interacting components, which is capable of producing emergent behaviours over and beyond the dynamics of the individual components. This ESS perspective has been almost imperceptibly moving into the mainstream of global environmental change research over the last decade, in part because of the success of IGBP-AIMES, and its forerunner (IGBP-GAIM) and partner projects (e.g. WCRP-WGCM).

For example, many of the latest climate models to be used in the next Intergovernmental Panel on Climate Change (IPCC) report will include not just representations of the physical components of the climate system, but also couplings to the biological components of the land and ocean carbon cycle. AIMES has been instrumental in stimulating this advance (Friedlingstein *et al.*, 2006) , and also in encouraging dialogue between climate modellers and those producing socioeconomic scenarios in order to ensure greater consistency in the IPCC assessment process (Hibbard *et al.*, 2007).

However, this is just the starting point for a better representation of the coupling between humans and environment. In reality human well-being is sensitive to changes in the environment, just as much as the environment is sensitive to human actions. The new "*Future Earth*" agenda for global environmental research is to provide the information required for sustainable management of the Earth system. This requires perceiving humans as fully interacting components of the Earth System, rather than just as external drivers of environmental change. This note outlines the important roles that AIMES could play in the conceptual phase-change required to fulfil this *Future Earth* vision.

1 **Monitoring and Predicting Earth System Change : *Fusing Observations and Models***

Two of the grand-challenges of Future Earth are "Observing" and "Forecasting", but AIMES sees these as two sides of the same coin. Building-up a complete picture of the ES requires a fusion of models and observations, with observations providing process constraints and initial conditions for models, and models providing the means to interpolate observations in both space and time. Furthermore, whereas climate model projections have to-date focused on the century timescale, the forecasting required to inform adaptive management of the ES needs to provide information on annual to decadal timescales. Initialisation of models will be of paramount importance on these shorter timescales, requiring ES models to assimilate observations in the manner employed in Numerical Weather Prediction.

AIMES envisages using such ES forecast models to derive best estimates of the state of the Earth system (past, present and future) based-on the fusion of models and observations. The *Future Earth* drive to bring humans inside models of the ES also requires that observations span socioeconomic as well as biophysical data. AIMES is ideally-placed to be at the forefront in these syntheses, and has already proposed the development of an "Earth System Observatory" (Schimel *et al*., 2012).

AIMES Priorities:

1a. Model-data fusion for monitoring and forecasting the Earth System.

1b. Development of an ES system observatory for biophysical and socioeconomic data.

2 Human-Environment Coupling : *Humanity as part of the Earth System*

With few exceptions, global environmental change research has treated humans as external to the "natural" ES, in many cases being the cause of changes and in some cases experiencing the impact changes, but rarely being treated as an internal component of the ES. This distinction between the "natural" and "human" world has been useful for highlighting the environmental changes that human activities are causing (*i.e.* as part of a cautionary tale), but it is insufficient to inform active management of the ES for *Future Earth*. In reality humanity is deeply embedded in the ES, both dependent on the energy and ecosystem services that it provides, and transforming the ES through the use of these services and the development of technology. This tight human-environment coupling is capable of leading to new and rich behaviours in the ES, which are intellectually interesting and fundamentally important if we are to inform sustainable management of the ES.

AIMES is already working on two fronts to promote the notion of the coupled human-environment system. Firstly, through its sponsorship of the IGBP-IHDP "IHOPE" project it is stimulating cross-disciplinary research to identify the impacts of environmental change on human well-being in the past (Costanza *et al*., 2012). As part of *Future Earth*, AIMES wishes to use the understanding of human-environment interactions in the past to inform models of the future. Secondly, AIMES is now prioritizing the further development of the Integrated Assessment Models (IAMs) used to produce climate change scenarios for the 21st and 22nd centuries. IAMs typically model economic constraints on environmental policies, but rarely include either environmental constraints on economic growth or indeed human-beings as "irrational" agents in the Earth System. Overcoming these limitations is a top priority for the AIMES contribution to *Future Earth*.

AIMES Priorities:

2a. Identifying the impacts of past environmental changes on human well-being.

2b. Development of Integrated Assessment Models to include "irrational" agents and market failures.

3 **Planet Earth as a Complex System :** ***Organisational principles and Tipping Points***

The paradigm shift brought about by ESS is the notion that "the whole is more than the sum of the parts". The behaviours of the ES are richer than the behaviours of its components, because new emergent behaviours arise from the coupling between the components. For example, the dominant mode of interannual variability in the climate system is the El Nino Southern Oscillation (ENSO) – a coupled ocean-atmosphere phenomenon. Similarly ice-ages are a consequence of coupling between temperature, ice-sheets and atmospheric CO_2, with no single component able to account alone for the changes between glacial and interglacial periods. As a result, it makes no more sense to try to understand ES dynamics from a purely reductionist perspective than to try to understand the human body by studying each cell in isolation.

Of particular current concern are the prospect of tipping points arising as emergent behaviours in the Earth System. IGBP-AIMES, and its forerunner IGBP-GAIM, has been instrumental in the identification of climate "tipping points" that could result in abrupt and/or irreversible changes (Lenton *et al*. , 2008). Such tipping points were originally assumed to be inherently unpredictable, but recent work arising from the mathematics of dynamical systems suggests that there may well be detectable precursors prior to a tipping point or "bifurcation". AIMES plans to promote this exciting research on *early warnings of global environmental risks,* with the goal of providing techniques that could be used across the whole-range of disciplines that will contribute to *Future Earth* - from the economics of market crashes to the dynamics of human migration.

AIMES Priorities:

3a. Understanding and characterisation of tipping points in the ES.

3b. Development of early warning indicators for tipping points in environment and society.

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GLP position on the Future Earth and transitioning process

Giovana Espindola[1] and Peter Verburg[2] on behalf of the Global Land Project Scientific Steering Committee (GLP SSC)

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The Global Land Project (GLP) is a joint core project of the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP) to improve the understanding of land system change in the context of Earth system functioning. GLP, being one of the core projects of both the IGBP and IHDP, has emerged as a follow-up of the LUCC and GCTE projects.

GLP goal is ***to measure, model and understand the coupled socio-environmental terrestrial system***, and the project coordinates science on land system change under three thematic areas: (i) the dynamics of land system change; (ii) the consequences of land system change; and (iii) integrating analysis and modelling for land sustainability.

GLP started its activities in 2006 with a former International Project Office (IPO) hosted by the University of Copenhagen until 2011. Since January 2012, a new IPO is placed in Brazil, being hosted by the Brazilian National Institute for Space Research (INPE). INPE has agreed to host the current GLP IPO until at least December 2015. Currently, GLP activities are also supported by two regional nodal offices in Japan and China.

GLP has organized many activities with the 2010 Open Science Meeting (OSM) in Arizona as the major highlight. During this event, it became clear the GLP science community has been matured and, although coming from different disciplinary backgrounds, has been able to successfully establish the observation, analysis and forecasting of land system change as an interdisciplinary science. In that sense, land system science has become a particular example of truly interdisciplinary collaboration between the social and physical sciences, with an increasingly more smooth communication across the disciplines and a focus on the interface of social and ecological systems.

Since its last annual meeting in May 2011, the Scientific Steering Committee and the International Project Office of the Global Land Project have closely followed the developments of the Future Earth framework. Overall, we are very much pleased with the ongoing developments towards a more integrative structure that brings forward many of the achievements of the land science community with:

- a strong focus on the further integration of human and natural science aspects of global environmental change (GEC) with the main challenges in reconciling the different perspectives;
- a central focus on the 'grand challenges' driven from ICSU global consultation on emerging environmental issues. The GLP community has always been addressing the multiple challenges of GEC as by bringing different communities and perspectives under the same umbrella[1];
- a high level of interaction across GEC themes: GLP is actively interacting with other current core projects, including UGEC (urbanization), ESG (earth system governance) and iLEAPS (land-atmosphere interactions).

Looking at the development of global environmental change in recent years, we believe the Global Land Project has become more relevant as a key component of Earth system research. Land system change is both a cause and effect of the interactions of humans with their environment. The way in which we modify and manage the land has major impacts on climate, water availability and quality, and biodiversity. At the same time, land system change and the management of the land resources offer the opportunity to adapt to environmental changes. Land science, therefore, provides an important platform for integrating global change research and policy. This requires reconciling our understanding of the human dimensions of environmental change including governance, economy and behavior with its physical and ecological dimensions. Linking human dimensions research to physical and ecological dimensions has always been one of the grand challenges of Earth system research. It is especially land science that has the tradition of integrating the different disciplinary insights into a consistent analysis of the land system as a whole. Land systems are at the interface of human, ecologic and physical dimensions of global change and therefore are of prime importance to many of the other core projects of IGBP and IHDP. A strong collaboration and the organization of joint activities with the other core projects is therefore one of the GLP priorities for the coming period.

The following points reflect the main GLP perspectives for consideration by the Transition Team in response to the information that was provided:

1. Goal and objectives of Future Earth

As mentioned above, GLP is deeply involved with the ICSU Grand Challenges and has been addressed critical land system change problems at the local and regional scale, and to and from the global scale. GLP research approach provides a framework to study the vulnerability and sustainability of the coupled system in

[1]The following groups of the GLP community strongly contribute to the five priorities identified by the Future Earth Transition Team. (A) **Observing**: the land change observation community, especially remote sensing community. (B) **Forecasting**: the land use modelling community. (C) **Innovating**: the recent work on land architecture to 'design' land systems that best use synergies between ecosystem services. (D) **Responding**: much climate adaptation takes place through modified land use. (D) **Confining**: the work on large transition in land use such as the forest transition.

different regions of the world. Delivery systems (website, reports and workshops) that accelerate transfer of knowledge to all levels of society are the basis of the GLP research strategy, and efforts made to improve communication among researchers and between researches and stakeholders. GLP is in the unique opportunity to engage with research communities that have, historically, a strong connection to practice, such as land use planning. Also, the GLP community has a lot of members that have a long expertise of engaging stakeholders in their research throughout the whole process. Land is often owned by stakeholders, which has made the need to involve stakeholders throughout the research process a pre-requisite. However, at the same time, we are happy with the strong focus on further stakeholder engagement in the Future Earth initiative. Also for GLP, there are many remaining challenges in this field of which we are convinced that further emphasis is needed.

2. Institutional design elements

GLP has a strong interest in the Future Earth initiative, and already works on many of the challenges addressed by the framework document. GLP looks forward to continually engage with the initiative and aims at a constructive dialogue and cooperation. The strategy for Future Earth should make sure that the emerging initiative is aware and make use of existing results, networks and ongoing research driven by GLP and other ICSU core projects. Future Earth should avoid damage to existing networks and research cooperation that took years of personal contacts and efforts to build. Those networks are built on trust and long-term cooperation. It should be noted that the core projects normally hardly receive any funding but are fully based on the enthusiasm and dedication of the research communities. Given their enormous importance to engage the whole community (including young scientists) it is important to appreciate this community engagement as the core of the existence and success of these initiatives. We are very happy that the documents clearly acknowledge this and do want to build on the current core projects. However, more clarification and discussion on the integration of existing projects is needed. Will the new architecture for the international coordination of Earth system research integrate existing projects across activities or the architecture will decide if individual projects nested within research programs should be continued or discontinued?

3. Transition Team activities

The Transition Team should enable constructive input by core-projects (such as GLP) in the process of facilitating the design of a research and implementation plan on global change research. Core projects such as GLP have years of professional experience in dealing with initiating, organizing and summarizing global change research. They have also first-hand experience in dealing with the challenges and shortcomings (as well as the advantages) of the current system, as identified in the visioning process, and they may therefore contribute with experience, lessons-learned and new ideas.

Finally, a list of current GLP SSC members is enclosed.

March 8, 2012

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Future Earth: Research for Global Sustainability Initiative

IGAC's Vision

December 2011

In order to effectively address global change and meet economic and social goals, an evolution of earth system science is essential. Humans are at the center of the earth system both as the key forcer of change and as the recipient of its feedbacks. In recognition of this, the International Council for Science (ICSU), the International Social Science Council (ISSC), and the Belmont Forum established the Future Earth: Research for Global Sustainability Initiative that aims to deliver the environmental science-derived solutions that society needs.

The International Global Atmospheric Chemistry (IGAC) Project, a Core Project under the umbrella of the International Geosphere Biosphere Programme (IGBP) and co-sponsored by the international Commission on Atmospheric Composition and Global Pollution (iCACGP) will play a key role in responding to the challenge of the Future Earth Initiative by;

- ***Recognizing the linkages and benefits of both disciplinary and multi-disciplinary aspects of this challenge.***
- ***Seeking to nurture and evolve fundamental science to address the duality of disciplinary and multi-disciplinary work.***
- ***Underpinning scientific research on the impacts of changing atmospheric composition (e.g. climate, air quality) for evidence-based policy within a global sustainability framework.***
- ***Acknowledging a need for national/international funding and organizational structures that accelerate the development of a multi-disciplinary approach.***
- ***Accepting the need for IGAC to evolve within a new structure.***

IGAC was formed in 1990 to address growing international concern over rapid changes observed in the Earth's atmosphere and has evolved over the decades to respond to the scientific needs of the earth system science research community. The first phase of IGAC, 1990-1999, focused on quantifying the pre- and post-industrial distributions of reactive trace species and determining the chemical, physical, and optical properties of aerosols. The first phase of IGAC culminated with the publications of *Atmospheric Chemistry in a Changing World, Brasseur et al.* (2003), which summarizes and integrates more than a decade of atmospheric chemistry research. In its second phase, 2000-2010, IGAC initiated and coordinated international research that greatly increased our understanding of the chemical composition of the troposphere, the fluxes of chemical species into and out of the troposphere, and the processes controlling the transport and transformation of chemical species within the troposphere.

As IGAC enters into its third phase as part of the Future Earth Initiative, its mission is ***to coordinate and foster atmospheric chemistry research towards a sustainable world.*** This is achieved by integrating, synthesizing, guiding, and adding value to research undertaken by individual scientists through initiating new activities, acting as a hub of communication for the international atmospheric chemistry research community, and through building scientific capacity. More specifically, IGAC's core activities focusing on emissions, atmospheric processes, and atmospheric composition will integrate more closely with sustainability issues such as climate, human health, ecosystems, and how individual and societal responses feed

back onto the core research-led activities of IGAC (Figure 1). IGAC believes by viewing the environment as a resource and one of the bases of energy and economic activities, human well-being can be sustained.

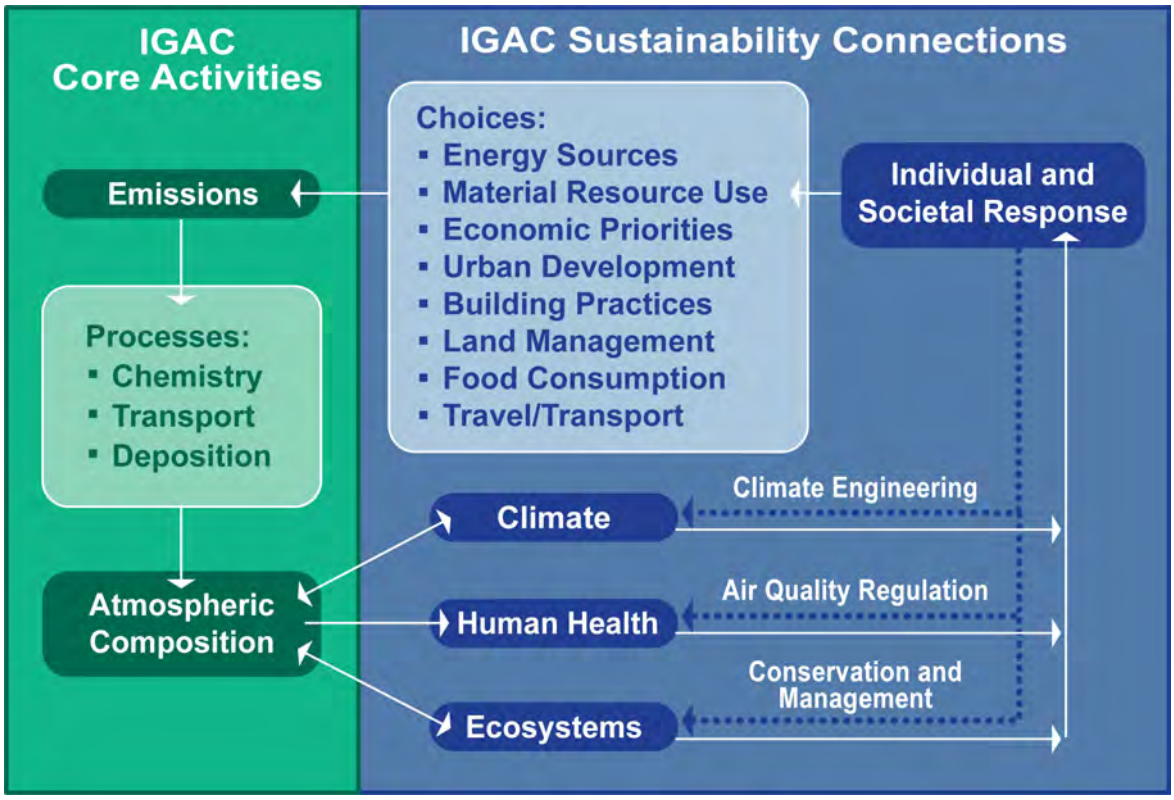

Figure 1: IGAC's role in the Future Earth Initiative is to coordinate and facilitate both fundamental research and multi-disciplinary studies on interactions between atmospheric composition and climate, human health, and ecosystems.

IGAC embraces the challenge of developing a multi-disciplinary approach to address global sustainability. This is evident in IGAC's already established multi-disciplinary activities such as the Atmospheric Chemistry & Health initiative that is linking the atmospheric chemistry community and the toxicology and epidemiology communities, the IGBP Air Pollution & Climate initiative being lead by IGAC that seeks to create a science-policy dialogue in order to address air pollution and climate simultaneously, and the Atmospheric Chemistry & Climate initiative that focuses on how atmospheric composition change influences climate and vice versa. In addition, many research questions necessitate a multi-disciplinary approach within the earth system science community. Therefore IGAC has, and will continue to, collaborate with other IGBP core projects such as SOLAS (Surface Ocean Lower Atmosphere Study), iLEAPS (Integrated Land Ecosystem Atmosphere Process Study), and AIMES (Analysis Integration and Modeling of Earth Systems) projects as well with the World Climate Research Program's SPARC project (Stratospheric Processes and their Role in Climate). Through joint workshops and research projects, IGAC, SPARC, AIMES, iLEAPS, and SOLAS have increasingly been working towards an integrated study of earth system research for global sustainability.

IGAC is meeting the challenges of the Future Earth initiative by recognizing the need to evolve in a transitioning landscape of global environmental change science. Under the strong and clear umbrella of the Future Earth initiative, the aggregate impacts of IGAC and other core projects will deliver the environmental science-derived solutions that society needs.

1. iLEAPS perspective on Future Earth

The land-atmosphere interface is where humans primarily operate. Humans modify the land surface in many ways that influence the fluxes of energy and trace gases between land and atmosphere. Their emissions change the chemical composition of the atmosphere and anthropogenic aerosols change the radiative balance of the globe directly by scattering sunlight back to space and indirectly by changing the properties of clouds. Feedback loops among all these processes, land, the atmosphere, and biogeochemical cycles of nutrients and trace gases extend the human influence even further. iLEAPS (integrated Land Ecosystem – Atmosphere Processes Study), a core project of IGBP, is the land-atmosphere component of the Earth System Science Partnership, focussing on the **basic biogeochemical processes that link land-atmosphere exchange, climate, the water cycle and tropospheric chemistry (Fig. 1).** This document outlines the added value iLEAPS (2004-2014) and the planned iLEAPS Phase II (2014 – 2024) will bring to the Future Earth Initiative.

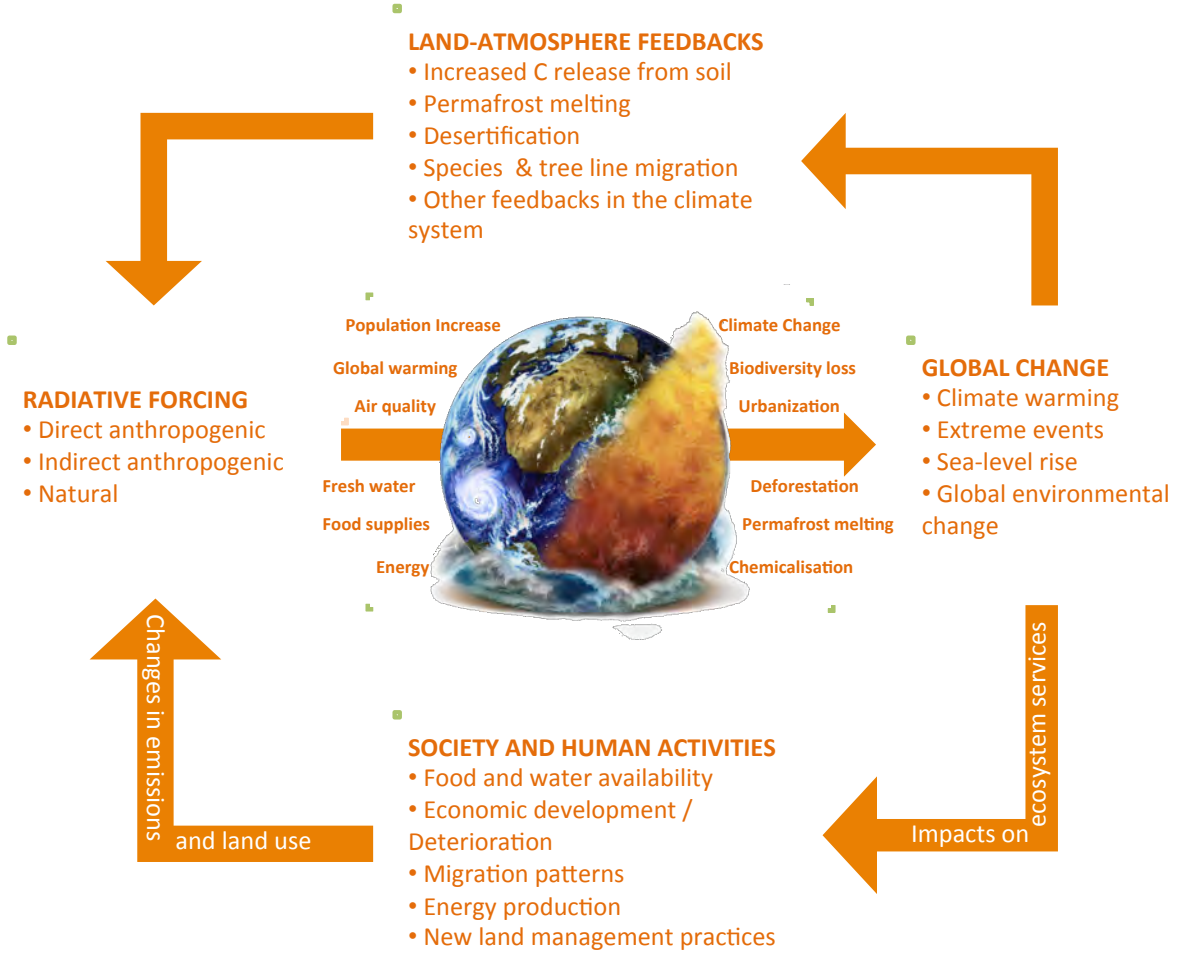

Figure 1. The land-atmosphere-society processes under global change that are the focus of iLEAPS.

iLEAPS SSC is happy to see ICSU and the Belmont Forum working together with high-level partners towards a new approach to global change research. The problems are global and international and so should the scientific and funding approaches be. iLEAPS is ready and willing to contribute to global sustainability and we trust that Future Earth will provide new funding opportunities to support these new activities.

As input for the Transition Team's work, iLEAPS offers the following points for consideration:

1. **iLEAPS is a powerful source of indispensable knowledge of land-atmosphere interactions** that is absolutely necessary to back up any technical and political mitigation solutions addressing the burning global sustainability issues. iLEAPS is well equipped, experienced, and willing to assess mitigation & adaptation solutions such as land-use management to mitigate climate change, biofuels, or atmospheric engineering. For instance, reforestation does much more than just store carbon; it changes energy and water cycles and iLEAPS has a crucial role in conveying such information to policymakers.

2. **Integrating natural and social sciences has multiple benefits once applied.** The integration of social science methodologies with natural sciences creates the conditions where interdisciplinarity can be used as a tool for forging action towards global sustainability. Under the Future Earth umbrella, the task of the core projects is to provide the knowledge necessary for political and societal decisions hand in hand with social sciences that need to be deeply involved not only in the adaptation and mitigation strategies but also in the scientific research efforts.

3. **The social and natural science communities have to find paths to communicate in a meaningful way.** The successful implementation of Future Earth's integrative research plan requires people who can work at the interface and speak the language of both the natural and the social scientists. In order to succeed, an educational system is necessary where integration of these disciplines is taught from the very beginning. iLEAPS already has significant experience in educating new scientists to work at the interface of different disciplines and could provide useful examples.

4. **Interdisciplinary research requires a strong funding base.** The most effective way to encourage new integration between social sciences and natural sciences is to provide financial incentives in the form of new funding opportunities. Future Earth has the opportunity to make this happen. Stakeholder-driven funding has an important role in creating global sustainability and will inspire new core science. In parallel with this development, many crucial detail questions still have to be solved with basic natural sciences (physics-chemistry-biology), and specific projects such as iLEAPS with their long expertise must continue to set the main priorities of future research in their field independently of stakeholder interests.

5. **The main priorities of iLEAPS in the coming years** are *to establish a continuation for the period 2014-2024 with a focus on interactions among land ecosystems, atmosphere, and societies,* with special emphasis on new observation networks incorporating remote sensing techniques with ground-based observations; basic boundary-layer dynamics; the role of land-cover changes in modulating carbon, nitrogen, and hydrological cycles and, consequently, atmospheric chemistry, aerosol dynamics, and climate; regional (high-latitude) processes and their influence on global simulations; integrative model evaluation and development on many levels in collaboration with WCRP (evaluating land-surface models with/without land-use change and with a biogeochemical/physical approach to land surface; evaluation of climate models); extreme events vs. gradual change and adaptation; interactions and exchange between managed ecosystems and atmosphere; impact studies of land management practices and recommendations on best practices; societal-relevant indicators of land surface together with WCRP (biomass, water stress, soil moisture, soil fertility, pollution, phenology); and interactions among anthropogenic and biogenic aerosols, clouds, and climate. Many of the above priorities require collaboration and synthesis efforts with other IGBP core projects (especially AIMES for modelling efforts, PAGES and GLP for land cover change studies, and IGAC for aerosol and atmospheric chemistry studies) and with WCRP (land-surface modelling, soil & energy & thermal processes) and IHDP (land-use, societal influence).

2. iLEAPS contribution to ICSU Grand Challenges

iLEAPS II will be well equipped to address the five Grand Challenges outlined by ICSU. Especially the **Observing** and **Forecasting** challenges are well covered by the existing networks of observation platforms and their future development and by the modelling efforts from local scale to regional, global, and Earth System Modelling. The basic and applied science conducted within iLEAPS is essential for any **Confining** and **Responding** efforts. **Innovations** are central in iLEAPS research from conceptual thinking to observations, modelling, and capacity building: the multiscale, multidisciplinary approach of iLEAPS is manifested, for instance, in the studies of the anthropogenic and natural processes in the Amazon basin; in the studies of the interactions between soil and atmospheric chemistry; in the use of Earth Observation satellites in aerosol, methane, and smoke plume studies in the land-atmosphere interface over the extremely wide and often unreachable northern areas of boreal Eurasia (ESA-iLEAPS collaboration ALANIS); in the use of remote sensing and geospatial data in a predictive modelling technique for human population distribution and abundance estimation in rural mountainous area in East Africa; and in the hierarchical observational platform structure proposed by iLEAPS. These are all crucial innovations in Earth System Science and will develop under Phase II with the deeper collaboration with social scientists and new ways of doing research.

IMBER Inputs to the Earth System Sustainability Initiative

Example contributions from ongoing and planned IMBER research to the sustainability themes and meta-questions posed for the Earth System Sustainability Initiative are given below. Each has aspects that contribute to observations in support of forecasts of future states. The last section outlines challenges to IMBER posed by the ICSU visioning process.

Question 1: What is happening to the global environment?

All IMBER regional programs have aspects that address indicators of change in the environment and human societies. Two regional programs, Ecosystems Studies of Sub-Arctic Seas (ESSAS) and Integrating Climate and Ecosystem Dynamics (ICED) in the Southern Ocean are focused on environmental and human effects at high latitudes. These are the two regions now undergoing the most rapid climate change and have ecosystems that been heavily impacted by humans. The CLimate Impacts on Oceanic Top Predators (CLIOTOP) is focused on understanding processes involved in the impact of both climate variability (at various scales) and fishing on the structure and function of open ocean pelagic ecosystems and their top predator species. The Sustained Indian Ocean Biogeochemistry and Ecological Research (SIBER) is focused on understanding of the role of the Indian Ocean in global biogeochemical cycles and the interaction between these cycles and marine ecosystem dynamics that arise via climate change and harvesting. All IMBER regional programs have modeling components, which have projections of future states of the regional systems as a goal as well as integration of these regional systems into a global context.

To facilitate collection of high-quality data the IMBER Data Management Committee developed a guide for good data management practices. This IMBER Data Management Cookbook (http://www.imber.info/index.php/News/News/Data-Management-cookbook-english-and-spanish-versions) guides researchers through data collection and documentation so that the resulting data sets are consistent and well documented. These data traits are critical to the use of observations for development, implementation and evaluation of model projections.

Question 2: Can we anticipate the future with enough confidence to influence current actions?

All IMBER regional programs have modeling components that focus on long-term projections of climate variability effects and address the challenge of improving the usefulness of forecasts of environmental conditions and their consequences for society. The modeling studies within all IMBER regional programs are attempting to project future states and provide estimates of uncertainty for these. The identification of the processes and rates that provide the greatest uncertainty in future projections provides direct input into the design of observational and monitoring studies.

Through its Human Dimensions Working Group IMBER has developed a strong program on research at the interface between human and natural sciences. This

allows inclusion of human effects as part of the projections of future states and the associated uncertainties.

Question 3: How can we manage complex changes?

The IMBER Human Dimensions working group is working group is developing approaches for inclusion of effective governance (institutional and economic) structures that can be included in approaches for management of marine systems at a range of scales. This effort has resulted in the development of an IMBER-sponsored summer school, which will be held in July 2012, that is focused on development of model structures that couple human and natural systems. The coupling between policy, socio-economics, and natural science is also the theme for the next IMBER IMBIZO, which will take place in January 2012. The IMBIZO will have a specific focus on coastal environments.

IMBER has a strong focus on capacity building, especially at the interface between human and natural systems. The training of scientists who can make the connection between these two areas is critical to the development of any initiative that attempts to develop approaches to manage complex change.

Question 4: How can we promote and evaluate innovative responses that contribute to sustainable development?

SOLAS-IMBER Ocean Acidification working group is focused on coordination and synthesis of international ocean acidification research efforts and development of collaboration between the natural and social science communities that are engaged in this research area. This working group produced a best practices guide (first published in 2010, updated in July 2011) for ocean acidification research. They also run an international reference user group which provides a dialogue between scientists, stakeholders and policymakers on ocean acidification. An example of their activities is a web-based, interactive database of ocean acidification research, developed in association with Google Earth that provides a map-based overview of ongoing and past research projects on ocean acidification.

Question 5: What can be done to reduce current and future vulnerability and increase resilience?

IMBER places a strong emphasis on research at the interface between human and natural systems. In addition to the Human Dimensions working group, which is dedicated to understanding the interactions between human and natural (oceanic) systems, all the other IMBER working groups and regional programs include components involving natural science and socio-economic inputs. Results from these efforts will allow IMBER to make important contributions to sustainability investigations and activities. For example, the CLIOTOP regional program has components that investigate the flow of capital and knowledge in the world's large fisheries and responses to variability. The results from these investigations are being included in coupled ocean-ecosystem-fishery-socio-economic models. Results from the ICED regional program are input into deliberations of the Committee for Conservation of Antarctic Marine Living Resources, which is the international body that sets fishing and use policies for Antarctic living resources.

Challenges to IMBER

The transition to a new sustainability initiative has presented several challenges for IMBER. All four of the IMBER regional programs, ESSAS, ICED, SIBER and CLIOTOP, have life-spans that extend beyond the projected 2014 end date for IMBER. The uncertainty about the future of the IGBP core projects makes planning by these regional programs difficult at best. The IMBER SSC has requested guidance from IGBP and SCOR (the co-sponsors) about the project end date. However, because of the uncertainty about the structure of the new initiative and its timeline for implementation the IGBP has been unable to provide a definite answer about the future of IMBER. This uncertainty has resulted in planning and funding challenges for IMBER and its regional programs. For example, funding agencies such as the US NSF and NASA are reluctant to commit funds to a program that may or may not exist in 2-3 years. The ICSU visioning process is lagging the decisions already made by national funding agencies and the European Commission about what science is needed in the future. Continued delay will only hurt the core projects.

Funding for global change research has made a transition to sustainability and coupling between human and natural systems. This change has already been incorporated into IMBER regional programs and working groups, and is an integral part of all planned IMBER activities. The delay in the IGBP transition process via the ICSU visioning activity is making it difficult for the core projects to convince funding agencies that these research areas are endorsed by the international research community as important and needed areas of research. As a result, core projects such as IMBER are viewed as undertaking important but unrelated research. The continued delay in making decisions about the future structure of will adversely impact the ability of the core projects to secure funding for activities.

Future interdisciplinary research on changing social ecological systems in global coastal zones - a contribution to the Earth System Sustainability Initiative

(Comments from LOICZ – an IGBP/IHDP core project)

LOICZ, the Land-Ocean Interactions in the Coastal Zone core project of the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP) is a central element in the Earth system science landscape facing continuously growing expectations for information services and research synthesis by scientific and user communities in future.

LOICZ studies Earth's heterogeneous, highly productive, dynamic and sensitive coastal zone. Its science concentrates on the estimation of nutrients fluxes and coastal metabolism incl. indicators and proxis. The scale covered reaches from river catchments and land-based drivers to the continental margins.

Following its first synthesis 2003 – 2005 LOICZ has successfully managed its transition from an IGBP core project to an IGBP/IHDP joint project (in effect since 2004), incorporating the social sciences on equal footing with natural sciences. As such LOICZ also explores the application and adaptation of the Driver-Pressure-State-Impact-Response (DPSIR) concept to include the human dimensions of coastal change.

An ever growing portfolio of currently 50 affiliated projects which are LOICZ endorsed independent research activities world wide provides an in kind contribution of excellent topical science into LOICZ worth several 100 Mio. €

LOICZ is currently funded by the Helmholtz-Zentrum Gesthacht, GmbH, Centre for Materials and Coastal Research (HZG). This arrangement is likely to continue until 2013 though on a considerably reduced budget taking effect in 2012.

LOICZ SSC and IPO have been following both, the visioning process by ICSU/ISSC and the Belmont Forum discussions closely and carefully. The resulting challenges and recommendations originating in an excellent interim evaluation commissioned by the host institute in 2010 have guided LOICZ into its current research directions which are:

Research concepts, hotspots and collaboration

to evolve from its conceptual focus on

- social ecological systems research,
- biogeochemical assessment and
- the assessment of governance structures and capacities

into a global change experiment and infrastructure that addresses hotspots the vulnerability and resilience of coastal systems and communities and to explore options risks and investment needs for adaptation. Currently LOICZ is moving on to address the following "Hotspots" of changing coastal systems (partnerships that have been or will be established are listed):

- Arctic Coasts (collab. IASC, IPA, AMAP, Arctic Net, IASSA etc.)
- Urbanization in coastal zones and Megacities (collab. with IGBP, UGEC, UNU-EHS, UN Habitat, govt. of Taiwan etc.)

- River Mouth System, incl. Deltas and Estuaries (collab. with GWSP, CSDMS Boulder, ESA, UNEP, UNU-INWEH, IWMI, UNESCO-IOC, IHP etc.)
- Islands at Risk (APN, UNESCO, World Bank, IGU etc.)

These hotspots will be complemented by a set of Cross Cutting areas:

- Ecological economics (ecosystem goods and services)
- Modeling, indicators and global assessments (international, e.g., UN, GEF etc.)
- Capacity building (e.g. ERASMUS MUNDUS master and PhD level, methodological training and certification of coastal practitioners)
- Governance in coastal zones (multiple institutional partnerships, namely IHDP partners)
- Social-ecological system assessment, indicators, scenarios, a focus on human welfare (e.g. the GEF International Waters, EU, intergovernmental networks on regional scale)

In parallel LOICZ is putting increasing effort into the further development of its biogeochemical flux assessment and in context of drivers, impacts (welfare) and responses. The current focus is on links of eutrophication with harmful algal blooms, and nitrogen and nutrient relations in general with fisheries/aquaculture.

Together with the global change project IMBER, LOICZ is establishing and supporting a new Continental Margins Task Team, CMTT focusing on changing shelf processes and food-webs.

The future role of LOICZ – reflections for the Transition Team

a) Bridging world views and building interdisciplinary community

In a future ESSI landscape the project considers it critical to further evolve into a focal international platform for innovative science that links the natural and social sciences, humanities and economics communities with local and indigenous knowledge. The goal is to support sustainability and adaptation to global change in the coastal zone.

b) Participatory science and knowledge transfer

an important feature will be to develop functionality as an engaging research and network infrastructure inviting and serving a wide spectrum of scientific and coastal stakeholder communities including and with special focus also on early stage researchers.

c) Balancing fundamental and applied research and knowledge needs

In view of the Grand Challenges and the Belmont Challenge the research communities are asked to find a balance between basic and applied science in a participatory way. The task is to bridge between societal issue driven information demand and sound process understanding on multiple scales. In this light coastal research will aim to move

- from “concepts” and “theoretical approaches” to a more (regional and/or global) applied and integrated Earth system science having in mind the paradigm of sustainability and with an adequate disciplinary integration

- towards a continuing focus on larger scales. Scientific directions should be based on globalised processes and large regional scales (priority setting for scientific agenda within which the “hotspots” concept could be embedded)
- to explicit evaluation of the needs of policy making, addressing concrete political problems as well as the need for adaptive management based on precise science input. Decision support research which can aid the prioritization of management interventions will be important.

d) Providing best excellence, global coverage and buy in

Coastal change science in the ESS context has a proven record of leadership and working in strategic partnerships to address urgent knowledge demands (e.g., Arctic coasts). The LOICZ SSC and IPO are prepared to work in the emerging context and with the guidance of the new ESSI to explore the opportunities of targeted issue driven research partnerships that contribute to global sustainability.

e) Maintaining and building global support

to take a lead in global Earth system sciences regional coverage and ownership is critical. Based on experience a strong case can be made for a well organized independent and professional international Regional Nodes concept following approved and harmonized terms of reference and ESSI standards.

f) outreach and services

Coastal Earth System research conducted in LOICZ finds itself to a growing extent in the role of a provider and disseminator of scientific information to target audiences beyond the traditional scientific arena. This has and will have implications for the role of and tasks required from the support infrastructures i.e. an IPO and a network of Regional Nodes and it calls for considerable effort to be channeled into the area of science dissemination, education and training.

Concluding remarks

Structural weaknesses and sometimes financial constraints of voluntary based globally coordinated research networks need innovative approaches.

Attracting the research communities may rely on mutually beneficial and flexible arrangements with key scientists/institutions and may benefit from improved involvement of early career scientist.

The LOICZ community is prepared to contribute to a globally coordinated Earth System Sustainability Initiative and to bring in global oversight of coastal change and human dimensions issues. From a core project perspective it is expected that a concerted effort including structural and organization aspects of a new ESSI will bring a clear strategy and assist in reaffirming and even strengthening commitments of agencies and institutions supporting these science platforms.

Annexes

LOICZ Products

Publications:

- Peer-reviewed publications
- Books (text and teaching and reference works e.g., treatise)
- Targeted topical special issues
- Synthesis books
- Regional studies
- Research and Study series (R&S Reports)
- Newsletter (INPRINT)

Digital Media and web presence:

- New and social media; featuring of affiliates, calendar, online application interface for research activities and support (launch in 2012)

Education and Training:

- Digital training material and heritage lectures
- Digital Tools e.g. model application software

Promoting young researchers:

- "Young LOICZ" i.e. scientific and training For a, summer schools and supervision of master/PhD students through SSC and IPO,
- Intern training and capacity building,
- Platform for affiliation of early stage research supervised by recognized senior peers

Scientific tool developments:

- New model, assessment and indicator development approaches – covering both the natural and social sciences
- Databases
- Vulnerability assessments and typology (e.g. Asia)
- Platforms for science / user interaction and collective working

Networking and services:

- Active and strategic partnerships providing critical mass for new innovative studies on multiple scales
- Scientific input in global and regional assessments (scientific quality, tools, indicators – e.g. International Waters)
- Advisory in assessments and agenda setting on national and international level e.g. UN, the GEF etc.
- Global platform of exchange and peer review for individual and project based research (e.g. affiliates)
- Services for international congresses of partners, own congresses and commissioned organization of workshops and congresses

In general:

- Provision of a globally recognized and credible research and innovation platform and network
- embedding individual, project or institution based research into the credible and globally recognized context of the Earth system sciences under ICSU and ISSC
- Agenda setting and science prioritization in targeted consultation with global and interdisciplinary peers
- A platform for discussion and exchange across disciplines and sectors to address key social ecological system questions of priority concern

LOICZ features in a nutshell:

- Over 2500 individual researchers
- Currently over 50 affiliated individual research projects world-wide
- International Scientific Steering Committee (15 scientists): agenda settings in key coastal change research questions of societal concern – embedded in the programmatic Earth system sciences under ICSU and ISSC
- currently 5 Regional Nodes
- International Project Office (IPO) representing natural and social science expertise, communications, administration and management

PAGES position on the Earth System Sustainability Initiative and associated transitioning process

Thorsten Kiefer*, Hubertus Fischer, Bette Otto-Bliesner, on behalf of the PAGES Scientific Steering Committee

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PAGES is a core project of the International Geosphere-Bioshpere Programme (IGBP) and as such affected by the planned restructuring of the network of Global Change organizations.

PAGES coordinates science on past climatic and environmental changes. Activities are organized in currently 25 active working groups, co-led by a total of more than 100 scientists. The more than 5,500 scientists currently subscribed to PAGES provide an indication of the size of the community.

PAGES is funded through project grants of the US and Swiss National Science Foundations. The next grant proposals for PAGES are due for submission in fall 2013 for funding beginning in mid-2014.

Since its July 2011 annual meeting, the Scientific Steering Committee of the Past Global Changes (PAGES) project has closely followed the developments in the transitioning process towards the Earth System Sustainability Initiative and discussed its opportunities, challenges and implications. The following points reflect the main PAGES perspectives for consideration by the Transition Team:

1. Maintain communities and expertise
It appears essential to maintain the scientific communities and expertise pools that have grown over many years through the core projects. The initiative should build on those foundations and avoid top-down reorganization at the core project level. Core projects should not be redesigned but should be provided with conditions that support evolution within the new framework.

2. Commit to basic science
Basic science of increasing detail and quality on the biophysical Earth system will be needed to provide the solid foundation on which sustainability science can build. Therefore, basic science and its coordination must not be cut down, but must instead be strengthened to allow advancement of "sustainability science" in the mid-term.

3. Complement disciplinary science with well-funded interdisciplinary platform
An effective new platform for more integrative Earth System Science than is currently happening will be welcome to complement (not replace) the more disciplinary oriented Earth system sciences usually carried out in core projects. This platform will necessarily need a very solid funding base in order to serve its purpose.

4. Provide professional science communication
Also welcome would be an integrative structure above the project level with a well-funded mandate to bring scientific results to best use in the form of outreach to the

public, science-policy dialogue, and climate services (or better: environmental services) for users.

5. Adopt long-term and historical/geological observations in observation strategy

Paleoscience has contributed fundamental knowledge to Earth System science and will continue doing so to the rephrased science initiative. Next to satellite observation and instrumental measurements, paleoscience provides longer-term observations by means of proxy records and associated modeling. Accordingly, paleoscience is considered to be centrally rooted in the "Observation" Grand Challenge of the ESSI strategy and will demonstrably contribute to all other Grand Challenges as well (see “Past Lessons” documents on the following pages).

6. Timing and framework for planning

A re-organization and re-orientation of coordinated Global Change science constitutes a chance to increase innovation and efficiency. The PAGES SSC acknowledges the opportunities enthusiastically and is ready to adopt new ESSI directions into its scientific and structural considerations. This will become vital when the next grant proposals for core project base funding are due. Certainty about the design of the ESSI framework will be essential to develop convincing strategies at the core project level and hence to successfully acquire grants. It therefore essential that the ESSI concept will be developed without delay.

The PAGES leadership is excited about the opportunities that the ESSI can open up for Earth system science and its global coordination. We are keen to contribute constructively to the development and the transition process and appreciate opportunities for getting involved and for our feedback to be considered.

2 Dec 2011

PAGES
PAST GLOBAL CHANGES

A SOLAS perspective on the *Future Earth: Research for Global Sustainability Initiative*

Prepared by Eric Saltzman and Véronique Garçon
on behalf of the SOLAS Scientific Steering Committee

This document briefly describes how the Surface Ocean Lower Atmosphere Study (SOLAS) views the new ICSU initiative in Earth System Sustainability. SOLAS is a core project of the IGBP, with joint sponsorship by SCOR, WCRP, and iCACGP.

The goal of SOLAS is "*to achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere, and of how this coupled system affects and is affected by climate and environmental change*."

SOLAS was established in recognition of the enormous challenges involved in understanding the myriad of physical and biogeochemical interactions between the Earth's ocean and atmosphere. These challenges are both scientific and institutional, requiring inter/multi-disciplinary training of scientists and a high level of international collaboration to coordinate field observations, satellite missions, process studies, modeling efforts, data archival and exchange, and scientific integration and synthesis.

The importance of the SOLAS realm to the future trajectory of Earth's climate and habitability is very clear. One of the major lessons learned over the past few decades of research is that the evolution of climate and global environmental quality over the next century is intimately linked to biogeochemical interactions and to human activities as a driver of biogeochemical fluxes. Our ability to manage and improve the quality of both natural and human systems will depend ultimately on our understanding of these interactions. SOLAS science provides the scientific basis of forecasts of future climate, future climate variability, and quantitative estimates of uncertainty in future projections.

The coastal zone is heavily populated and most people are well aware of the impact that coastal water quality can have on their lives and local economy. Although the open oceans cover most of Earth's surface, they are largely uninhabited, and there is a tendency for the average person to see them as remote, unchanging, and disconnected from their daily lives. The truth is far from that, and it is critical that societal decisions take into account the myriad of interactions that link us with the surface ocean/lower atmosphere. It is an enormous challenge, to identify and understand these linkages, to inform the public about them, and to integrate our knowledge into societal decision-making.

SOLAS contribution to the scientific underpinnings of sustainability: SOLAS is actively engaged in sustainability science. SOLAS has made scientific contributions across a wide range of climate-related issues, from assessing the uptake of CO_2 by the oceans, to

understanding the link between atmospheric deposition of desert dust and oceanic biological productivity. Many important questions remain, such as the relationship between ocean biota and cloud radiative properties, man's impact on oceanic nutrients, the fate of the ocean's oxygen minimum zones, the rate and impact of ocean acidification, and the ocean's influence on aerosols and atmospheric reactivity. Biological productivity partly controls availability of marine living resources. Ocean acidification and deoxygenation may have a significant future impact. For instance, oxygen minimum zone expansion and shoaling will induce habitat compression of some pelagic fishes increasing the risk of overfishing of some species by surface fishing gear.

One highly visible example of the intersection between SOLAS science and sustainability is in the context of the debate about geoengineering solutions to climate change. Climate modification by addition of iron to the surface ocean was proposed by various entities as a means of reducing atmospheric carbon dioxide. SOLAS scientists have played a key role in bringing the best available science to bear to assess the viability and risks inherent in geoengineering strategies, and communicate them effectively to the public and to policy-makers. SOLAS scientists will continue to play an important role in assessing the physical and biogeochemical impacts of the new technologies aimed at marine resource utilization, from fisheries to wind power to ocean thermal energy conversion. Of course, the largest scale environmental "experiments" are the unintended changes associated with population growth and migration, energy utilization, technological change, and trends in land use. Developing the understanding and tools needed to predict how the ocean/atmosphere system will evolve in response to such changes remains a major goal for SOLAS science.

Moving forward: SOLAS and the Future Earth: Research for Global Sustainability Initiative:

Moving forward, we see SOLAS evolving in response to the increasing need for science-based decision-making information and tools to support global sustainability in the following areas:

1. Reducing uncertainties –SOLAS science will continue to focus on reducing the key scientific uncertainties which limit our ability to deliver accurate predictions of future changes in climate, natural resources, and environmental quality. This effort includes large scale observational and modeling efforts and smaller scale process-oriented research. The SOLAS community will continue to contribute to major scientific assessments, such as the WMO Stratospheric Ozone Assessment and the IPCC.
2. Capacity-building – The linkages of science and society are not part of traditional scientific training and many scientists (both junior and senior) are not well versed in the ways that science is made usable to policy makers and other stakeholders. SOLAS conferences and summer schools can become a venue where scientists can become exposed to the issues, approaches, and vocabulary of sustainability and

environmental decision-making. It is critical to bridge this gap between science and society. SOLAS will work to entrain social scientists studying the human dimensions of global change into its community of researchers.

3. Understanding societal impacts – Most SOLAS scientists frame the impact of their research in terms of physical/biogeochemical parameters, i.e. global mean temperature, primary productivity, atmospheric pCO_2, etc. SOLAS can provide leadership in providing support for scientists to connect their research to impacts of direct societal relevance, such as food security, water availability or human health. SOLAS science can also be used to develop tools for the attribution of environmental impacts on the open ocean and overlying atmosphere. This must be done by providing new opportunities for our scientists to engage with scientists in these areas, and will likely lead to an increased focus on modeling activities.
4. Informed assessment of mitigation strategies – SOLAS scientists will continue to be an invaluable resource for the assessment of strategies to mitigate the consequences of environmental change through geoengineering. These assessments include the application of our science to evaluating both the effectiveness and the risks inherent in such action.

In summary, SOLAS science is intimately linked to some of the major environmental issues facing society. We welcome the *Future Earth: Research for Global Sustainability Initiative* as an exciting opportunity to help our scientists provide the foundation for science-based societal decision-making and to help develop the tools for sustainability science. To be effective, this will require forging new connections across the Earth Sciences and social sciences and between the research community and other environmental stakeholders. At the same time, we wish to sound a note of caution that we must not underestimate the effort needed to keep our core science moving forward. Getting the science right is the fundamental responsibility of our community and the foundation for sustainability science - *if we don't do it no one will.* Therefore, we recommend it be recognized that the new initiative represents an expansion of our mission, and that it will require additional resources to be carried out effectively.