—BANGKOK—

The City of Bangkok

Bangkok developed from an island in the Chao Phraya river in the 18th century. It achieved rapid economic growth from the 1970s, land which was originally the site of an agricultural village was converted into a residential area, and a cluster of commercial facilities has been located in the urban area. The population was 600,000 people in 1900 but it had expanded to 5,670,000 people by 2005. Roads and canals are used as the major modes of transportation while the development of the railroad network has lagged behind, and chronic traffic congestion is a problem in the city center.

Characteristics of the Urbanization of Bangkok

Yuichi Kagawa（The University of Shiga Prefecture）

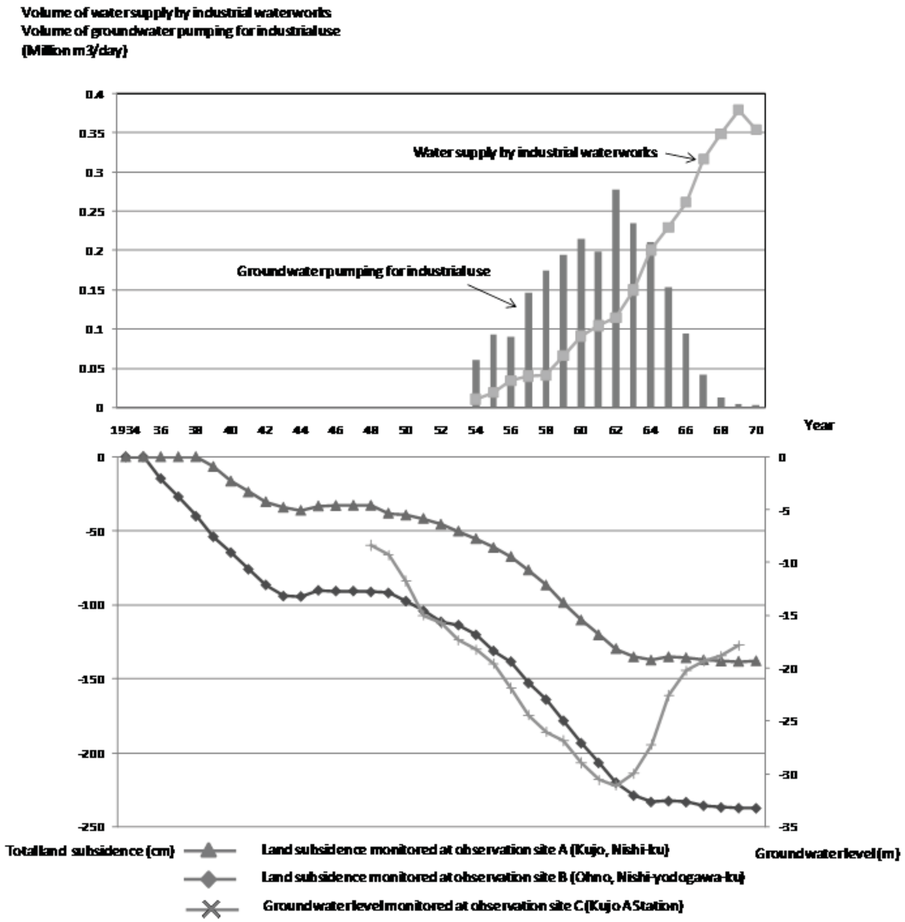
The location of temples alongside Bangkok’s canal network, highlights the relationship between life and water.

There also exists a high correlation between the number of Buddhist temples and the number of households in Bangkok.

Yuichi Kagawa（2009）‘Urbanization in Asian Metropolis and the Changes of hydrological environment in and around Bangkok’ M. Taniguchi, W. C. Burnett, Y. Fukushima, M. Haigh & Y. Umezawa (Eds.) “*From Headwaters to the Ocean: Hydrological Changes and Watershed Management*” Taylor and Francis. 577-582.

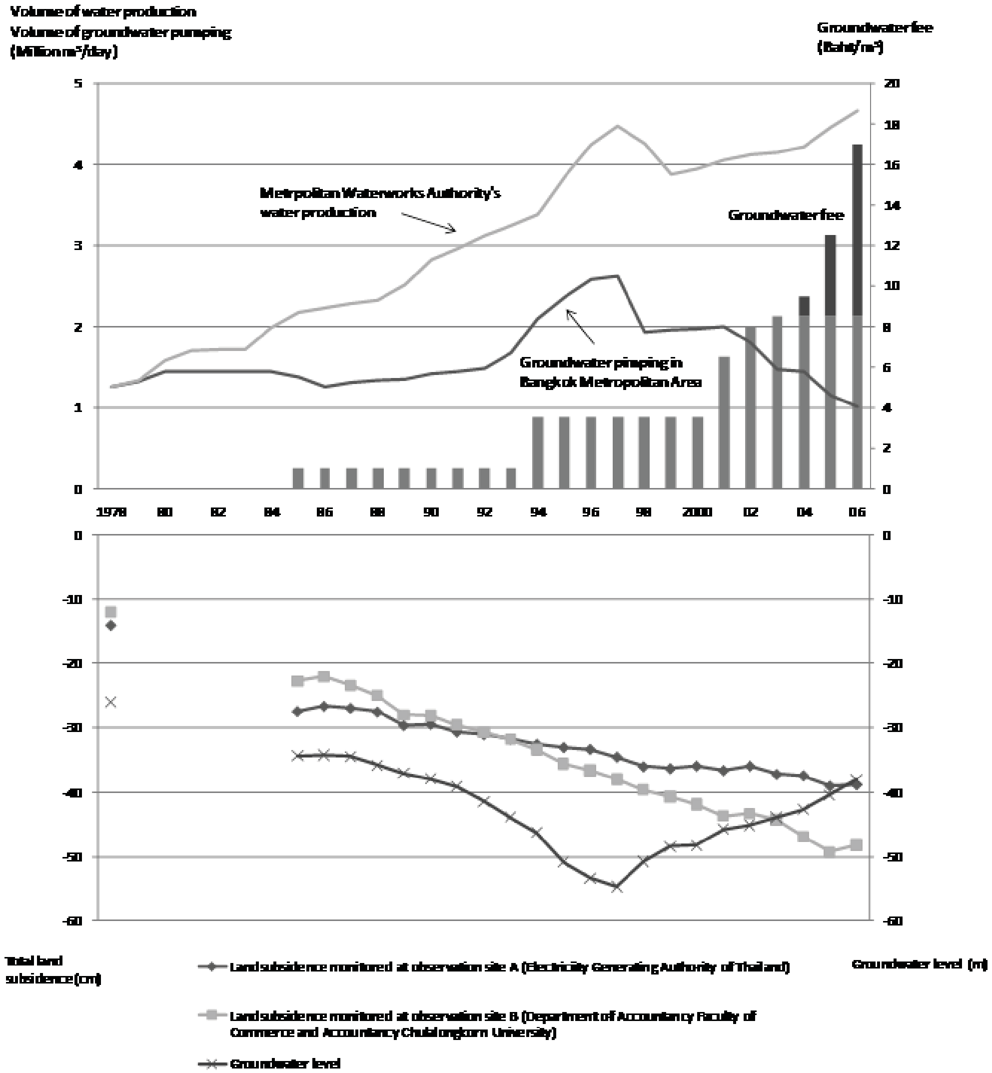
Solutions to Problems of Land Subsidence

Takahiro Endo（University of Tsukuba)･Shinji Kaneko(Hiroshima University) ･ Karen Ann Bianet Jago-on(RIHN)



Osaka's solutions to problems of land subsidence

In Osaka, groundwater was mainly used for industrial purposes. Problems of land subsidence were taken seriously after significant subsidence occurred with the Muroto typhoon of 1934. The Industrial Waterworks Law was enacted in 1956 (and later revised in 1962), and the Building Water Law was enacted in 1962. Under these laws, waterworks expanded in Osaka and groundwater users were required to change their water supply from groundwater to surface water. This change helped to mitigate land subsidence in Osaka.



Bangkok's solutions to problems of land subsidence

A comprehensive survey of groundwater, conducted from 1978 to 1981, identified an increased risk of flooding, after revealing rapid land subsidence in eastern and south-eastern Bangkok. The main cause of the subsidence was the excessive pumping of industrial groundwater. Various countermeasures were implemented, such as the enactment of groundwater laws, designation of pumping-restricted areas, expansion of waterworks, and a groundwater pricing system. Bangkok was successful in stopping land subsidence using theses countermeasures, with the groundwater pricing system proving to be a unique countermeasure, and one not seen in Osaka.

Takahiro Endo, "Sinking Cities and Governmental Action- Institutional Responses to Land Subsidence Problem in Osaka and Bangkok" in M. Taniguchi ed. *Groundwater and subsurface environment in Asia*, Springer, forthcoming.
Takahiro Endo, "The Case for Government in Groundwater Management: A Case Study on Land Subsidence Problem in Bangkok," *Journal of Japanese Association of Hydrological Sciences,* forthcoming.

Effects of Urbanization on Shallow Aquifer Recharge Using the SWAT Model

Katsuya Tanaka (Shiga University)

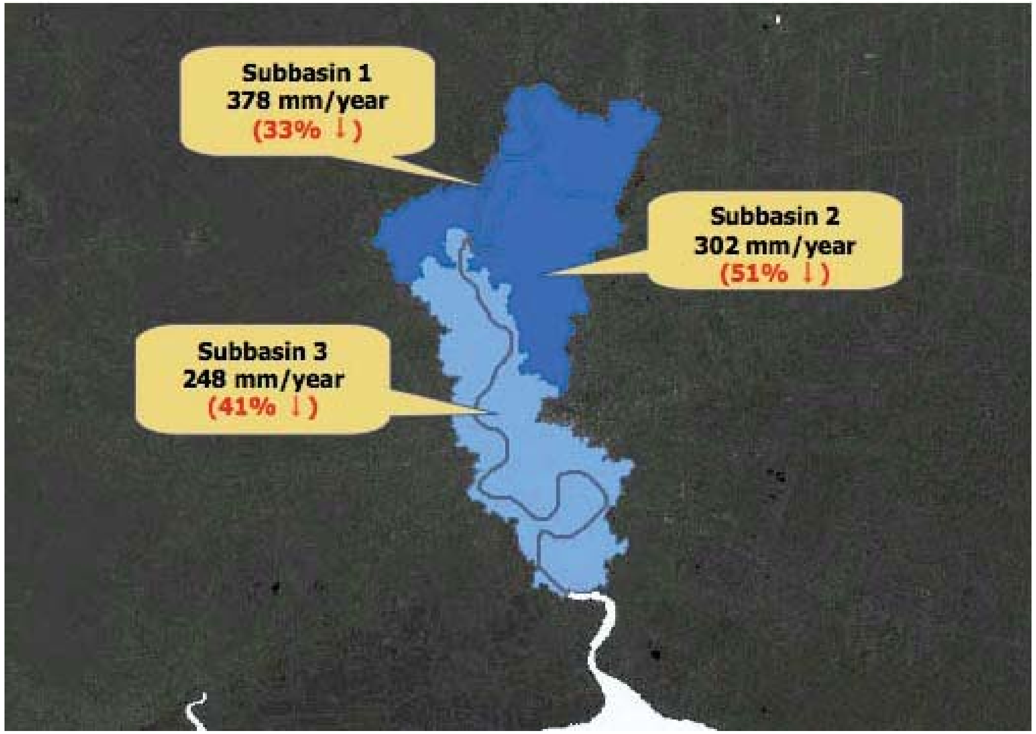


Figure 1. Effects of Urbanization on Shallow Aquifer Recharge in Bangkok (1960–2000)

Bangkok has been experiencing a significant loss of groundwater since the 1960s. Several studies have suggested that rapid urbanization is a major cause of groundwater loss because of a decrease in the recharge of shallow aquifers. Our study investigated groundwater loss using the Soil and Water Assessment Tool (SWAT) and land use GIS data from 1960 to 2000.

Our results suggest that urbanization has significantly reduced the recharge of shallow aquifer in Bangkok. However, its impact varies across subwatersheds, depending on the degree of urbanization, soil properties, and land slope.

Groundwater in Bangkok

Demand for groundwater for use in industry and households is extremely high, while the city is located in a lowland swampy area and is called the “floating city” so serious land subsidence occurred due to the excessive pumping of groundwater. However, this problem is gradually being reduced because Bangkok has introduced a taxation system for groundwater use, an internationally unique initiative consisting of a “groundwater tax” and a “groundwater preservation tax.”

3D numerical simulation for long-term changes in recharge ratio

Tsutomu Yamanaka（University of Tsukuba ）･Makoto Mikita（ University of Tsukuba ）

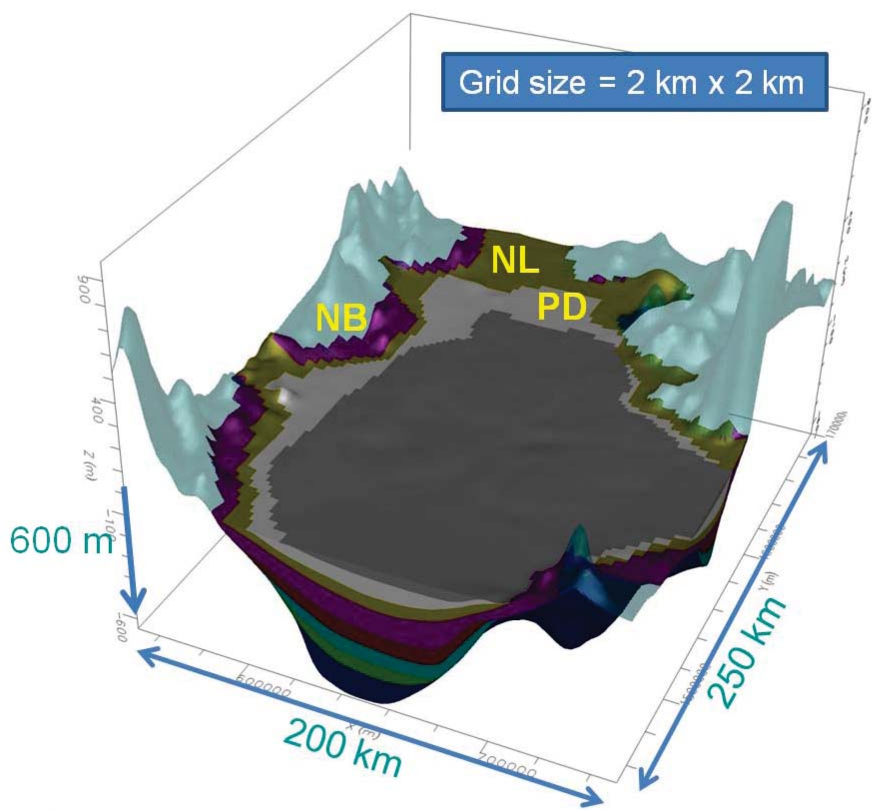


Fig. 1 Model construction of the Bangkok metropolitan area, Thailand

Since the 1950s, groundwater withdrawals have occurred in the Bangkok Basin, Thailand, and have resulted in a dramatic decline in the piezometric levels of confined aquifers. Consequently, land subsidence and seawater intrusion into groundwater have been detected. Using numerical experiments, we showed that groundwater pumping in urban areas enhanced the recharge of confined aquifers, with spatial heterogeneity reflecting hydrogeological settings.

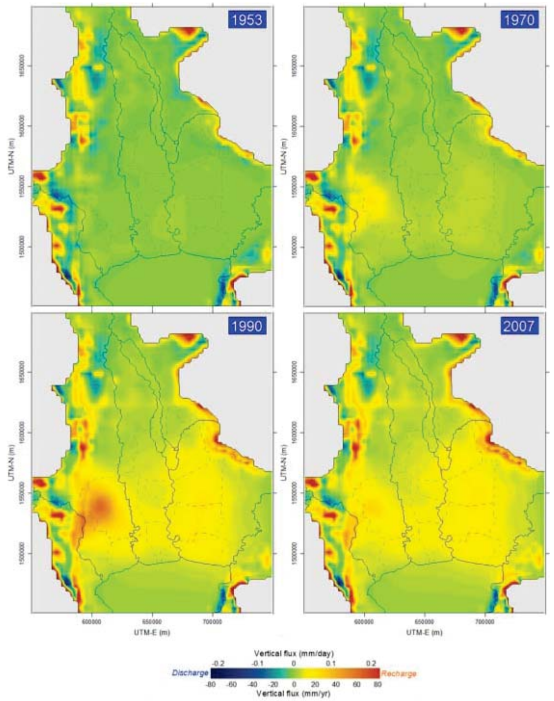


Fig. 2 Historical changes to the recharge ratio

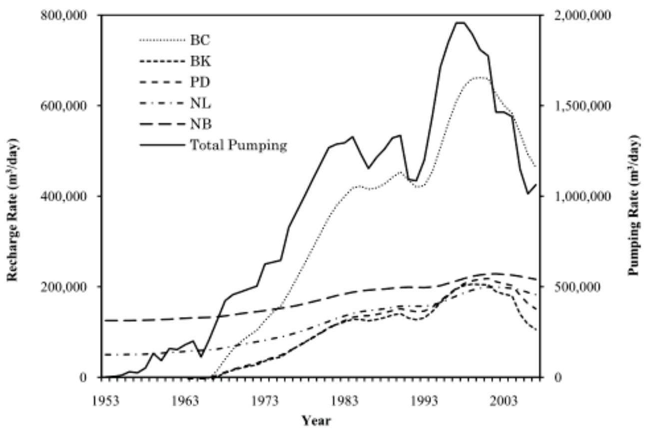


Fig. 3 Historical change of the groundwater abstraction amount and recharge ratio in each aquifer

(Mikita et al.)

The enhanced recharge was more remarkable at locations where Bangkok clay is relatively thin. In addition, the response of the recharge flux to the temporal variation of groundwater pumping was faster within the Bangkok metropolitan area and slower in suburban areas. When the groundwater pumping rate was at its maximum in 2001, the total recharge flux onto the land surface within the model-domain, was approximately 13 times greater than that under natural conditions.

Mikita, M., T. Yamanaka and O. Lorphensri (2010) : Anthropogenic changes in a confined groundwater flow system in the Bangkok Basin, Thailand, part I: was groundwater-recharge enhanced? *Hydrological Processes*, in press.

Upgrade of Terrestrial Water Storage with a numerical model

T. Nakaegawa（MRI）･K. Yamamoto（RIHN）･Y. Fukuda（Kyoto University）

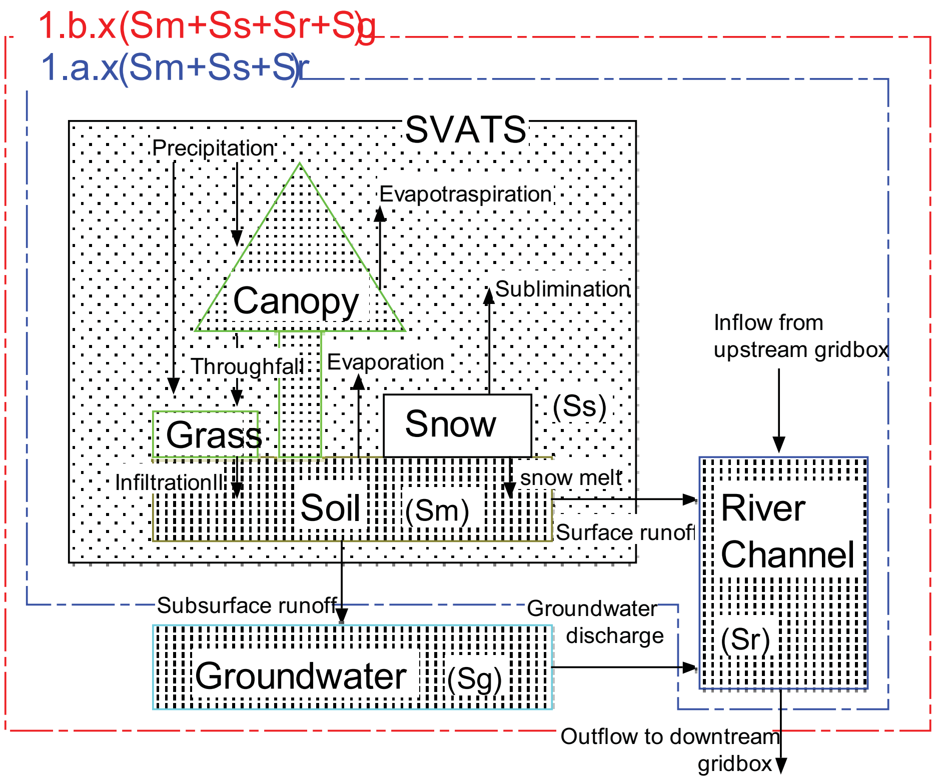


Fig. 1 Terrestrial water storage in a numerical model (Fukuda et al. 2009).

We determined terrestrial water storage (TWS) from the Land Data Analysis (LDA) using a soil-vegetation-atmosphere transfer scheme routinely performed by the Japan Meteorological Agency (JMA) for validating TWS derived from gravimetry satellite missions such as GRACE and CHAMP. In this project, we have upgraded the TWS by introducing reasonable hydrological processes.

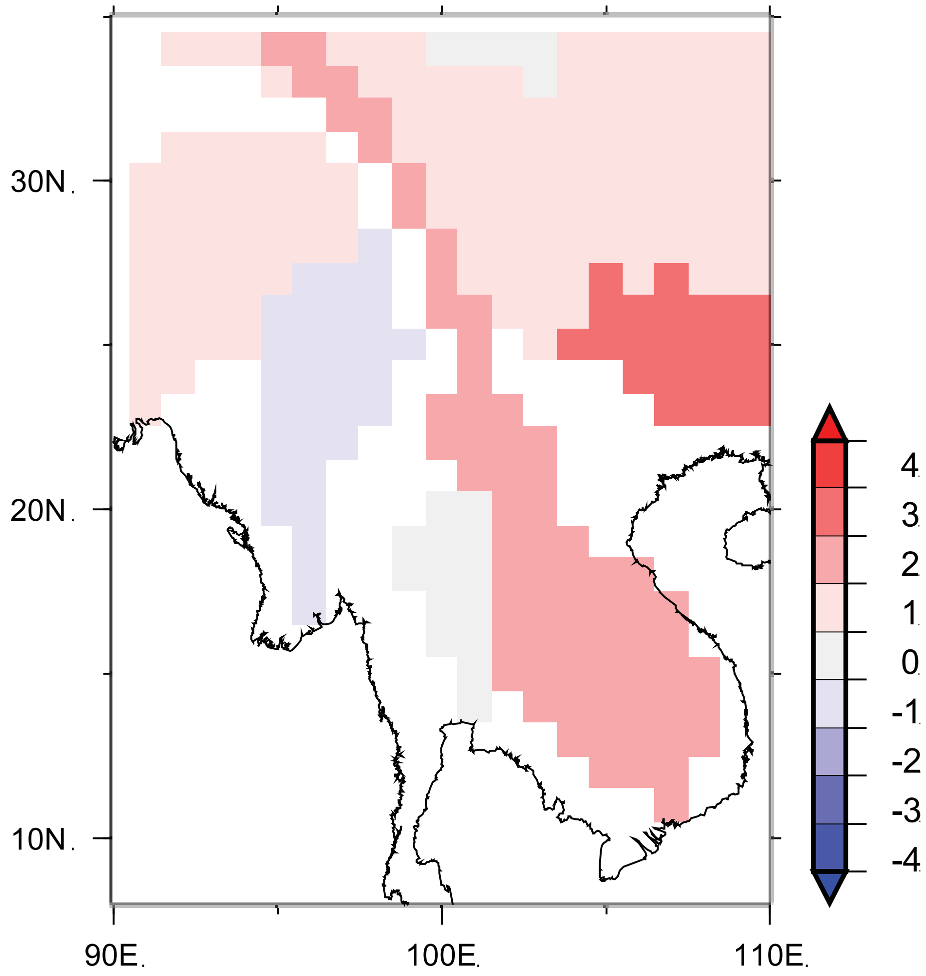


Fig. 2 Comparison of the TWS phases obtained from the model, and employing the combined water balance method.

The figure compares the TWS phases obtained from the model simulation and employing the atmosphere-terrestrial combined water balance method over the Indochina peninsula. The phases are generally well reproduced for these river basins; in particular, there is no difference for the basin of the Chao Phraya River.

A series of numerical experiments shows that the tuning can compensate for the drawbacks of the TWS reproducibility, due to there being no implementation of the groundwater scheme.

Nakaegawa, T. 2008: Reproducibility of the seasonal cycles of hydrological variables in Japanese 25-year Re-Analysis, Hydrological Research Letters 2, 18-21.

Interpretation of the interannual change in TWS observed by GRACE

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T. Hasegawa（Kyoto University）

Interannual variations in terrestrial water storage (TWS) over the Indochina peninsula were recovered using GRACE (Gravity Recovery and Climate Experiment) satellite gravity data. One of the advantages of using GRACE data is that GRACE can detect variations in the total TWS over a large area including groundwater, which is generally difficult to detect employing other methods. The recovered interannual TWS mass variation shows the change in trend around the beginning of 2004—a decreasing trend until the end of 2003 and then an increasing trend to 2009 (Figure 1).

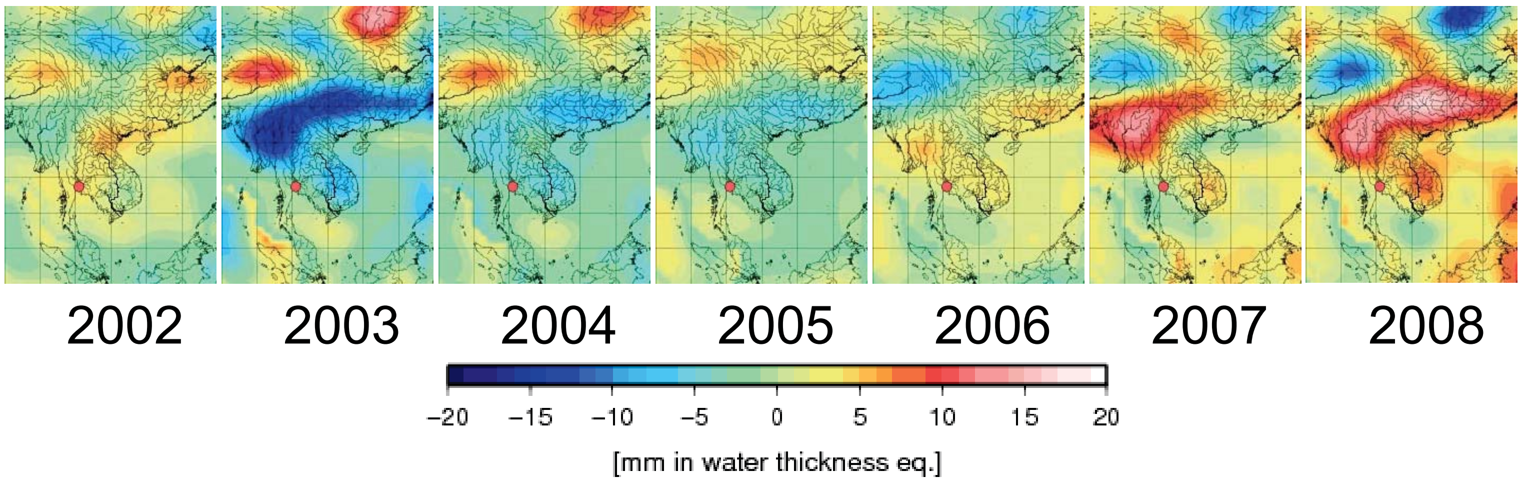


Figure 1. Yearly average of the GRACE-derived TWS mass variations over the Indochina peninsula derived after removing annual and semiannual components.

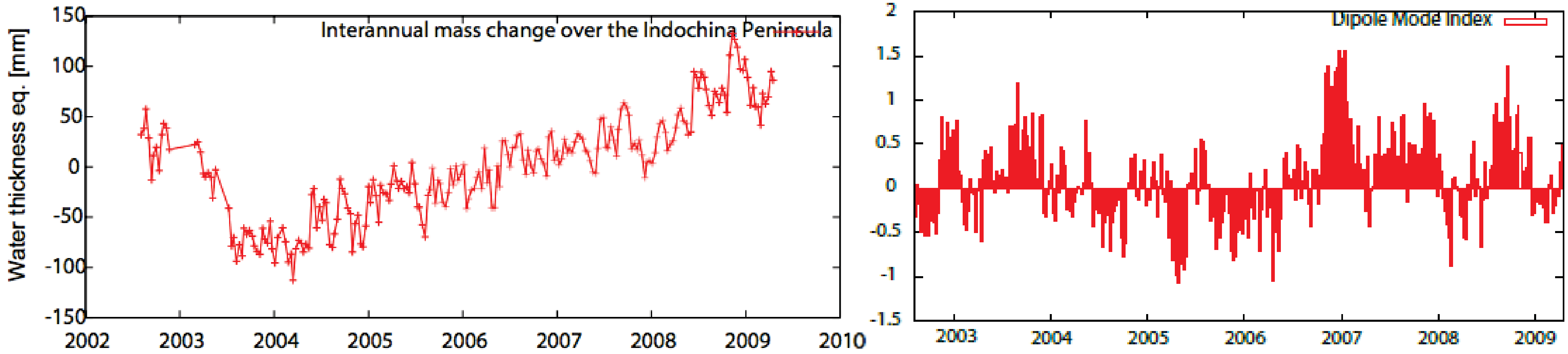


Figure 2. Comparison of the GRACE-derived interannual TWS change (left) and the Dipole Mode Index provided by UNESCO (right).

The comparison with the results obtained using the local groundwater model shows that the change in trend observed by GRACE is much larger than the change in the trend of the expected local groundwater, which is mainly caused by excessive groundwater pumping and subsequent recovery. On the other hand, the change in trend has good correlation with the Dipole Mode Index, which is a climate index of the Indian Ocean Dipole phenomenon (Figure 2). Thus, we conclude that the observed interannual mass change over the Indochina peninsula is due not to human activity but to a global-scale meteorological event.

K. Yamamoto, Y. Fukuda, T. Nakaegawa, Interpretation of interannual mass change over the Bangkok area observed by GRACE, Abstract for 2nd Hydrology Delivers Earth System Science to Society, 2010.

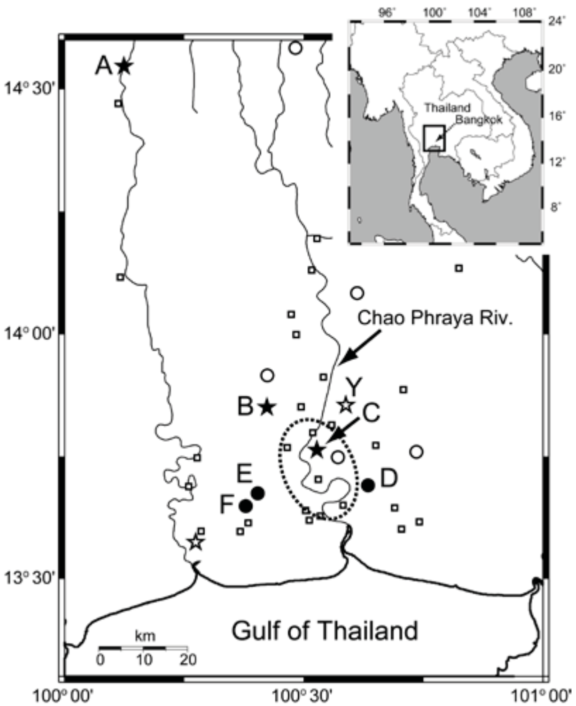
Subsurface Thermal Environment in Bangkok

In the center of Bangkok the ground surface temperature has been rising due to urbanization, and due to the impact of that rise large amounts of heat have been accumulating underground. On the other hand, in rural areas far from the city center the underground temperature has hardly risen, and no significant accumulation of heat has occurred.

Estimation of historical ground surface temperature history using subsurface temperature distribution

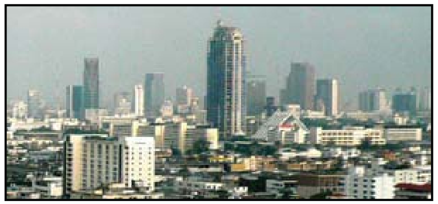
Hideki Hamamoto（Center for Environmental Science in Saitama）･Makoto Yamano（The University of Tokyo）･Vuthy Monyrath （ Chiba University ）･Shin Kamioka（Kyushu University ）･ Shoichi Hachinohe（Center for Environmental Science in Saitama ）

Fig. 1



Rural area (A)

Suburb area (Y)



Metropolitan (C)

Ground surface temperature changes slowly propagate into subsurface formations via thermal diffusion. Thus, ground surface temperature (GST) history for the past several hundred years can be estimated using temperature profiles measured in boreholes. We applied this method in Bangkok and its surrounding areas, where numerous groundwater monitoring wells are available for temperature profile logging. Temperature measurements were conducted at 44 stations in 2004, 2006, 2008, and 2010 (Fig. 1).

Fig. 2

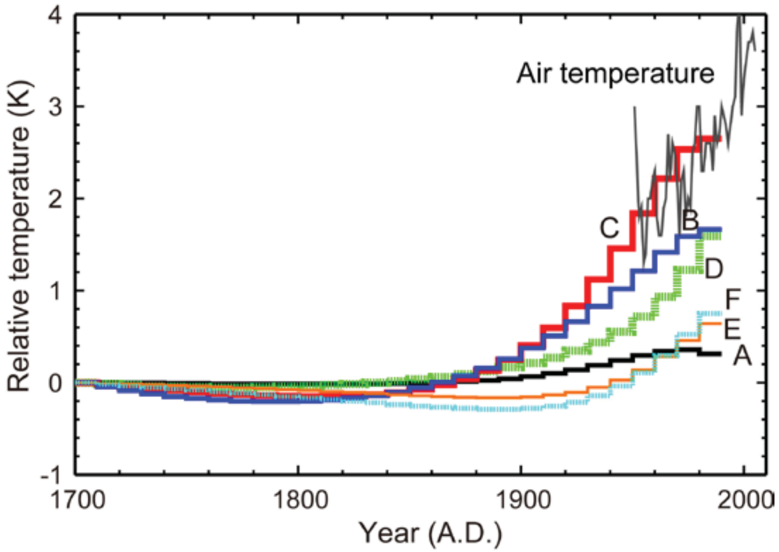
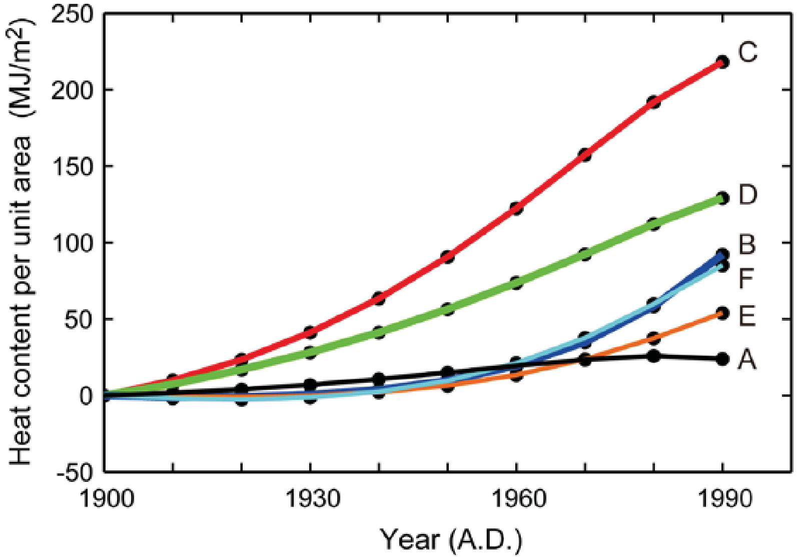


Fig. 3



Selected profiles from six stations were analyzed to reconstruct GST histories of the last 300 years (Fig. 2). All the estimated GST histories show surface warming in the last century. The rate of temperature increase varies by site, with greater increases in city areas than in suburban and rural areas. These results may reflect the effects of the urbanization process occurring in the Bangkok metropolitan area, such as heat island effect and land use change.

Based on the reconstructed GST histories we were also able to estimate the amount of heat stored in the subsurface since 1900 (Fig. 3). The subsurface heat content in central Bangkok is much higher than the average levels found in the Northern hemisphere.

Hamamoto, H., M. Yamano, S. Kamioka, J.Nishijima, M. Vuthy, S. Goto, M. Taniguchi (2009), Estimation of the past ground surface temperature change from borehole temperature data in the Bangkok area for studies of human impacts on climatic change in East Asia, In: Taniguchi, M., Burnett, W. C., Fukushima, Y., Haigh, M. and Umezawa, U. (ed) From Headwaters to the Ocean, Taylor & Francis Group, London, pp. 535-539.

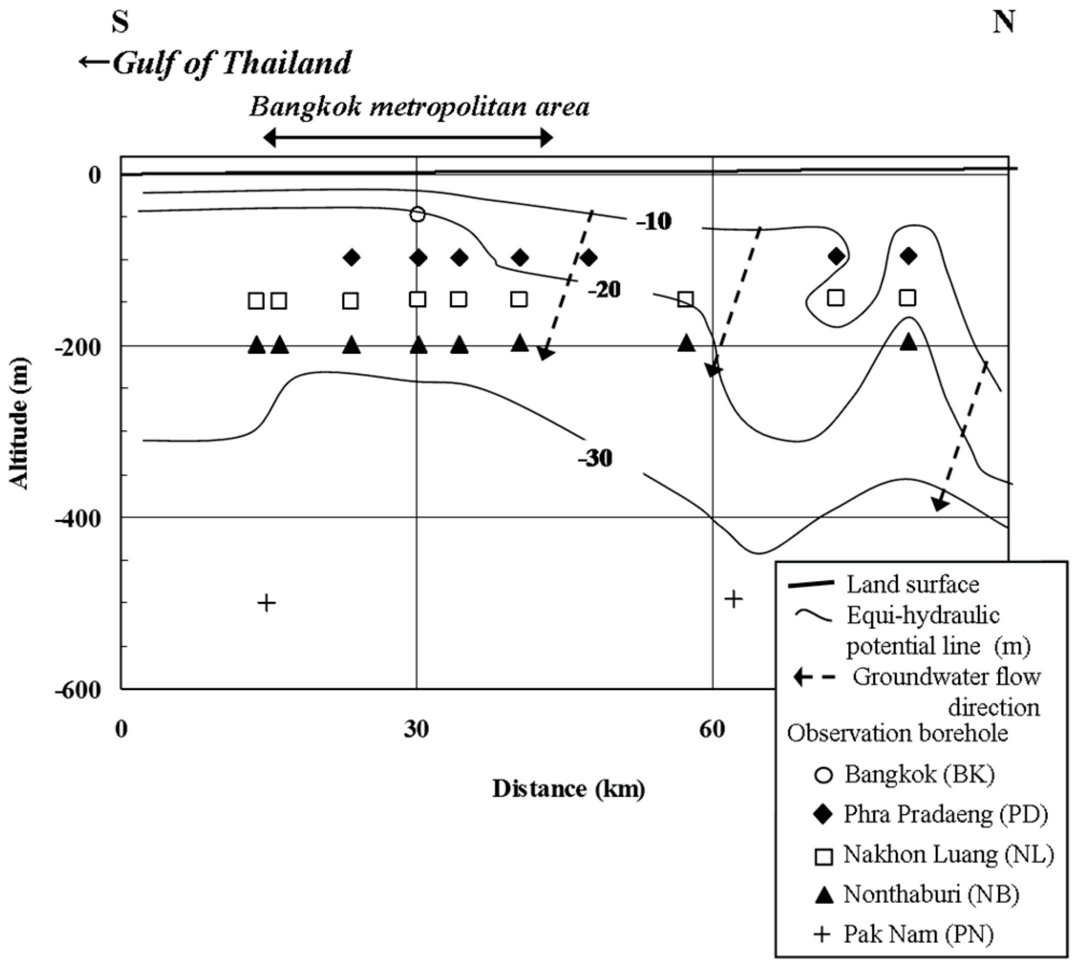
Hamamoto, H., M. Yamano, S. Goto, M. Taniguchi (2009), Estimation of the past ground surface temperature history form subsurface temperature distribution -Application to the Bangkok area-, Butsuri- Tansa, 62, 575-584 (in Japanese with English abstract).

Groundwater Pollution in Bangkok

Not much “nitrate-nitrogen” pollution that comes from chemical fertilizers and domestic wastewater can be seen currently due to the progress of development. On the other hand, “groundwater salinization” which is seawater intrusion into the groundwater is occurring widely in the coastal area. Furthermore, water and soil pollution caused by the conversion of mangrove forests into shrimp aquaculture ponds is occurring in recent years.

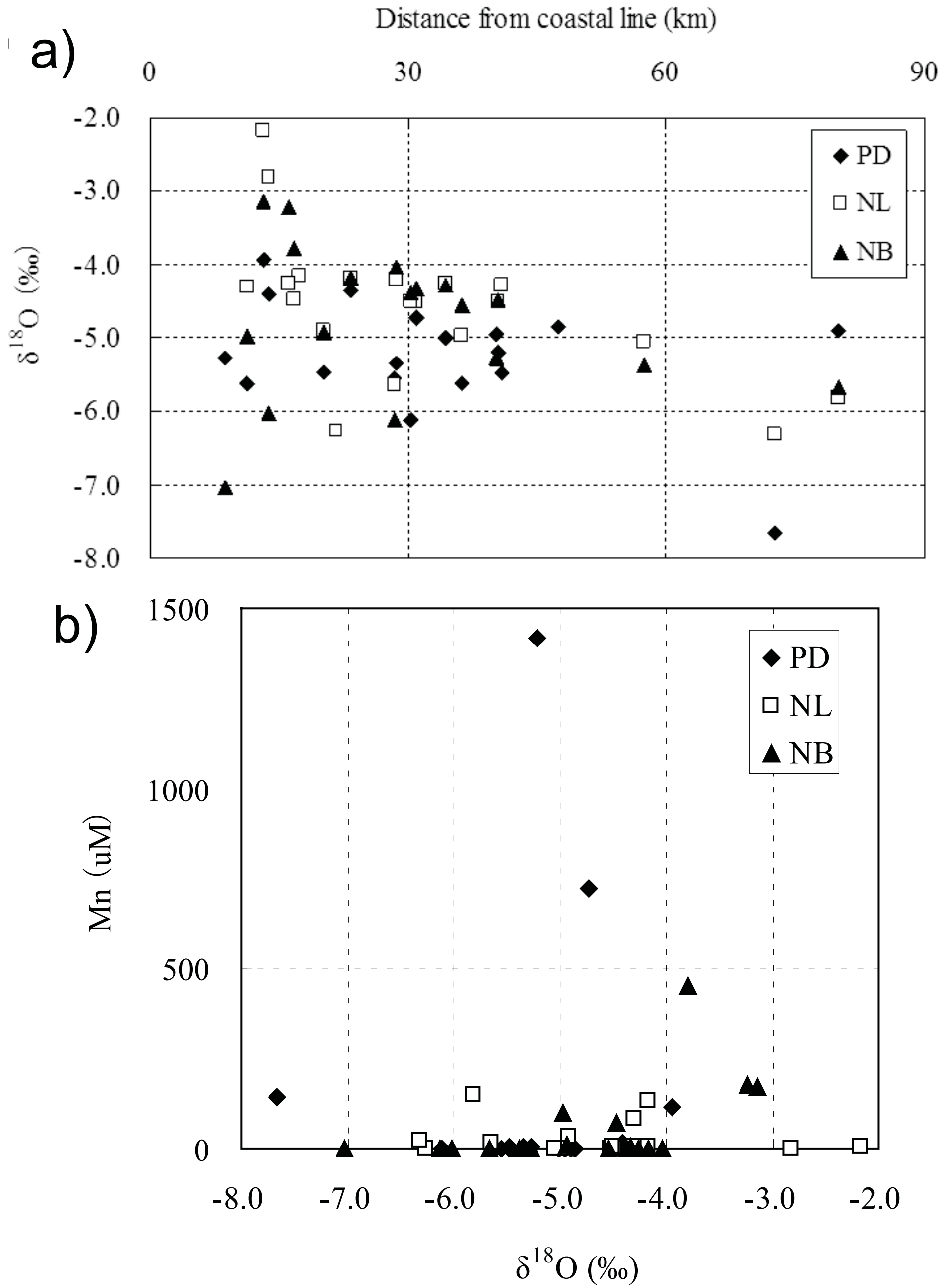
Salinization and heavy-metal contamination in groundwater

Onodera S. (Hiroshima University) ･Saito M. (Ehime University)



The metropolitan area of Bangkok is a coastal area. Generally, there is upward groundwater discharge in a coastal area. However, the distribution of the hydraulic potential indicates that groundwater flows downward in the metropolitan area of Bangkok . This suggests that the groundwater level has fallen because of excessive pumping, which has changed groundwater flow.

Figure 1. Distribution of the hydraulic potential in metropolitan and suburban areas of Bangkok



The oxygen stable isotope ratio (d^{18}O) of groundwater is relatively high in the coastal area (Fig. 2a). This suggests groundwater salinization in the metropolitan area. Furthermore, d^{18}O is higher in the deeper aquifer (NL and NB) than in the shallower aquifer (PD), suggesting that seawater intrudes selectively into the deeper groundwater with low hydraulic potential. On the other hand, a high manganese (Mn) concentration in the PD aquifer (Fig. 2b) suggests the infiltration of contaminated surface water.

Figure 2. a) Relation between the distance from the coastline and d^{18}O in the groundwater. b) Relation between d^{18}O and Mn concentration in the groundwater.

Onodera et al. (2009) “Effects of intensive urbanization on the intrusion of shallow groundwater into deep groundwater: Examples from Bangkok and Jakarta." Science of the Total Environment, 407: 3209-3217.