—TOKYO—

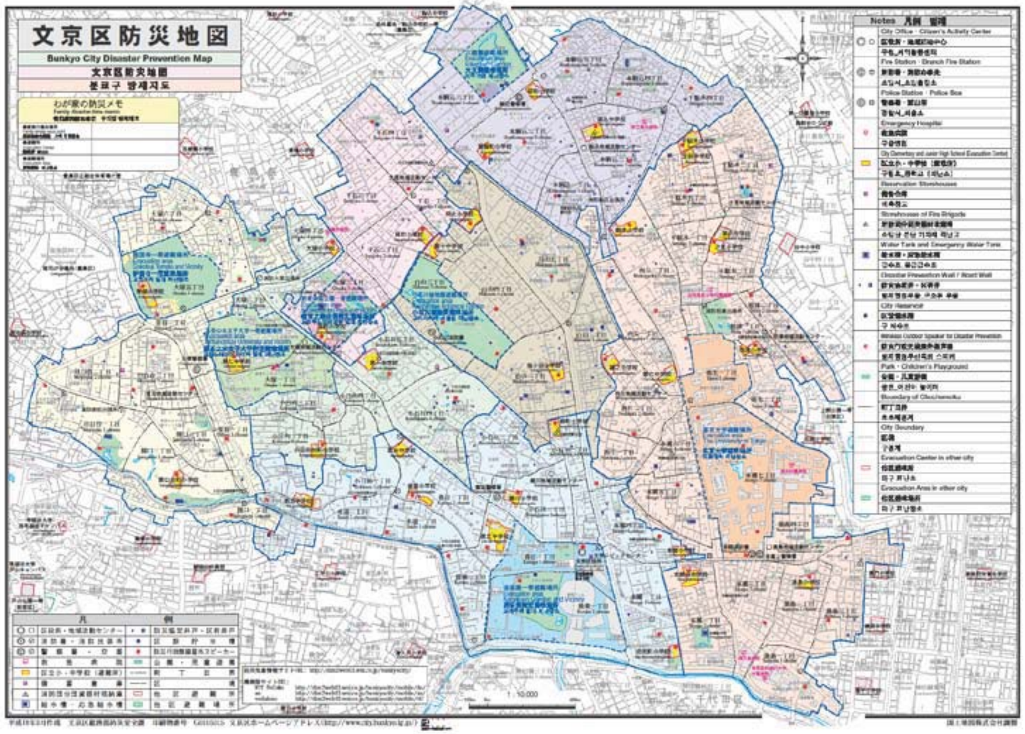
The City of Tokyo

Tokyo has continuously developed since it became the capital of Japan in 1868 and the city population grew from two million people at the beginning of the 20th century to a major city of approximately 13 million people by the beginning of the 21th century. One factor behind this rapid increase in population was that due to industrialization large numbers of workers flooded into the city in search of work. Currently Tokyo is one of the world's largest international cities. In order to use the limited land effectively, land space is used vertically, including the development of the subway system, the construction of skyscrapers, etc.

Historical Records of Wells and People

Tomomasa Taniguchi (Rissho University)

In this study, I looked at the historical and current distribution of wells in Tokyo. I reported on wells and their use in the historical reconstruction of water environments. The historical distribution of wells can be obtained using historical data and maps, while the current distribution can be understood using published data and field surveys.

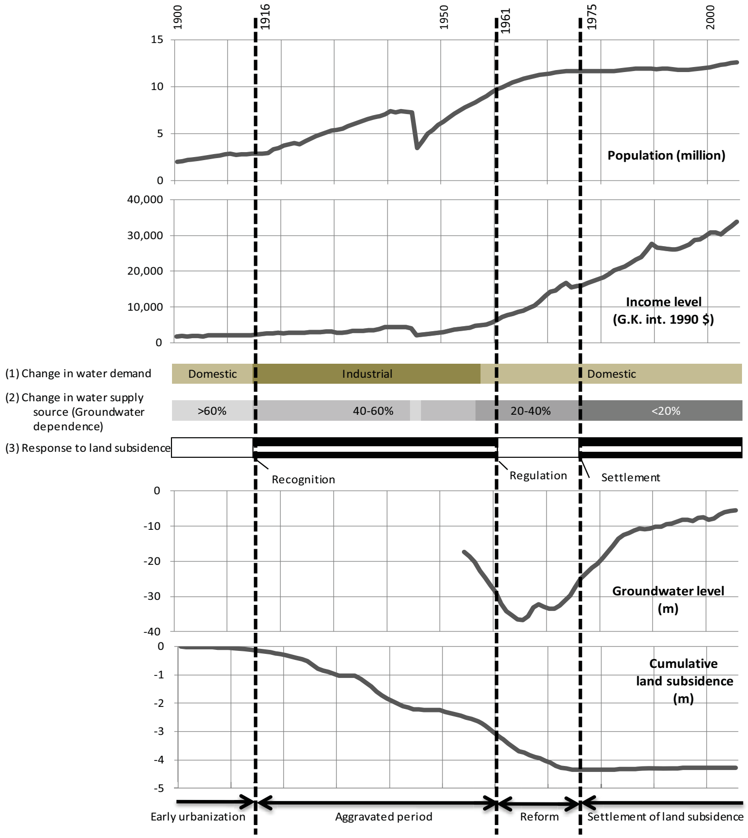


I used 1:5000 topographical maps published in 1887 to reconstruct historical groundwater environments in Tokyo. Many wells were seen to have existed in the late 19th century in residential areas of central Tokyo. The number of wells is decreasing due to the popularity of modern water services. However, many wells remain, such wells at temples and other religious sites, and emergency water wells. All historic wells are preserved and protected in Tokyo today.

Tomomasa TANIGUCHI, The restoration of historical hydro-environment from historical materials and topographical maps in Tokyo, Japan. *From Headwaters to the Ocean: Hydrological Change and Watershed Management*, Talor & Francis, 565-569.

Long-term urbanization and land subsidence in Tokyo: An indicators system approach

Tomoyo Toyota（JICA-RI）・Kaneko Shinji（Hiroshima University）



Subsurface environmental problems such as subsidence are occurring repeatedly in major Asian cities, though there is often a time lag between when the relevant urban development "stage" is reached and the point at which negative subsurface conditions are recognized.
We will summarize the characteristics of the relevant stage using Tokyo's experience as an example. This study covers 1900 to 2005, highlighting three relevant factors: the dominant sectors for water demand; the dominant sources of water supply; and response categories.

We have identified four periods in the relationship between urbanization and land subsidence. 1) The first stage is defined as the period from 1900 to 1916 when land subsidence was first recognized. 2) The second stage started with the recognition of land subsidence and ended in 1961, with the introduction of effective measures to remedy Tokyo's significant subsidence issues. 3) The third stage began in 1961 when the Industrial Water Law was enacted and ended in 1975, when high-levels of land subsidence control were reached. 4) The fourth and final stage continues to the present day, where the issue of land subsidence is close to being resolved.

Karen Ann B. Jago-on and Shinji Kaneko (2008) "Long-term urban growth and water demand in Asian mega-cities" From *Headwaters to the Ocean, Hydrological Changes and Watershed Management*, pp.483-489.
Karen Ann Bianet Jago-on, Shinji Kaneko, Ryo Fujikura, Akimasa Fujiwara, Tsuyoshi Imai, Toru Matsumoto, Junyi Zhang, Hiroki Tanikawa, Katsuya Tanaka, Backjin Lee, Makoto Taniguchi. "Urbanization and subsurface environmental issues: An attempt at DPSIR model application in Asian cities."*Science of the Total Environment* (in press).
Kaneko, S. and T, Toyota(Forthcoming) "Long-term urbanization and land subsidence in Asian megacities: An indicators system approach", Groundwater and Subsurface Environment, Springer.
金子慎治・豊田知世(2010)「都市の経済発展と地盤沈下」、谷口編『アジアの地下環境』、学報社, 37-65

Groundwater in Tokyo

Industrialization rapidly progressed before and after the Second World War. When the water used in factories was pumped up from under the ground, the groundwater level fell and land subsidence occurred. Then when the withdrawal of groundwater was reduced by laws regulating the withdrawal of groundwater and by the development of industrial water facilities the groundwater level recovered and the land subsidence problem was ceased. On the other hand, Tokyo is now facing a new “groundwater problem” that the underground structures built during the low groundwater level period are suffered floating power caused by recovered groundwater level and the wise management including the effective use of groundwater are being required.

Effects of human activities and urbanization on groundwater environments

Takeshi Hayashi (Akita University) ・Tomochika Tokunaga（The University of Tokyo ）

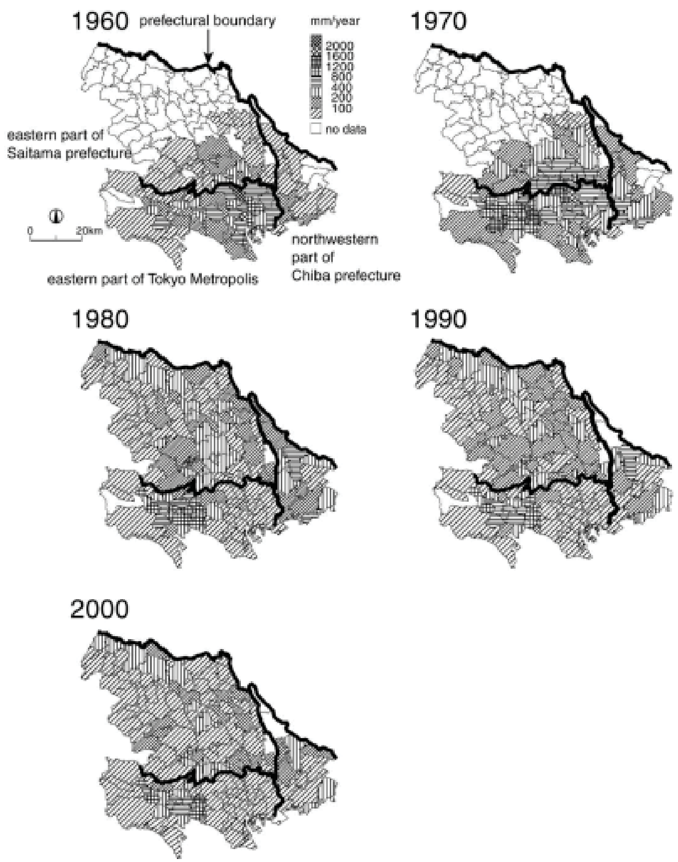


Fig. 1 Distribution of annual groundwater extraction rate in each municipality (Hayashi et al., 2007)

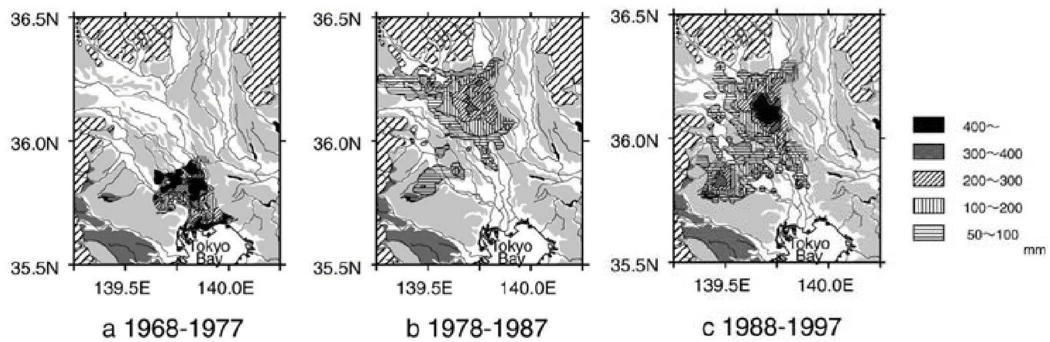


Fig. 2 Distribution of cumulative rate of land subsidence (Hayashi et al., 2007)

The first water supply well was installed in the Kanto Plain in 1913. Further wells were sunk and a considerable amount of groundwater was extracted from the Tokyo Bay area. The rate of extraction increased significantly with the economic growth of the 1950s and 1960s. Increases in land subsidence corresponded with changes in high-level extraction areas.

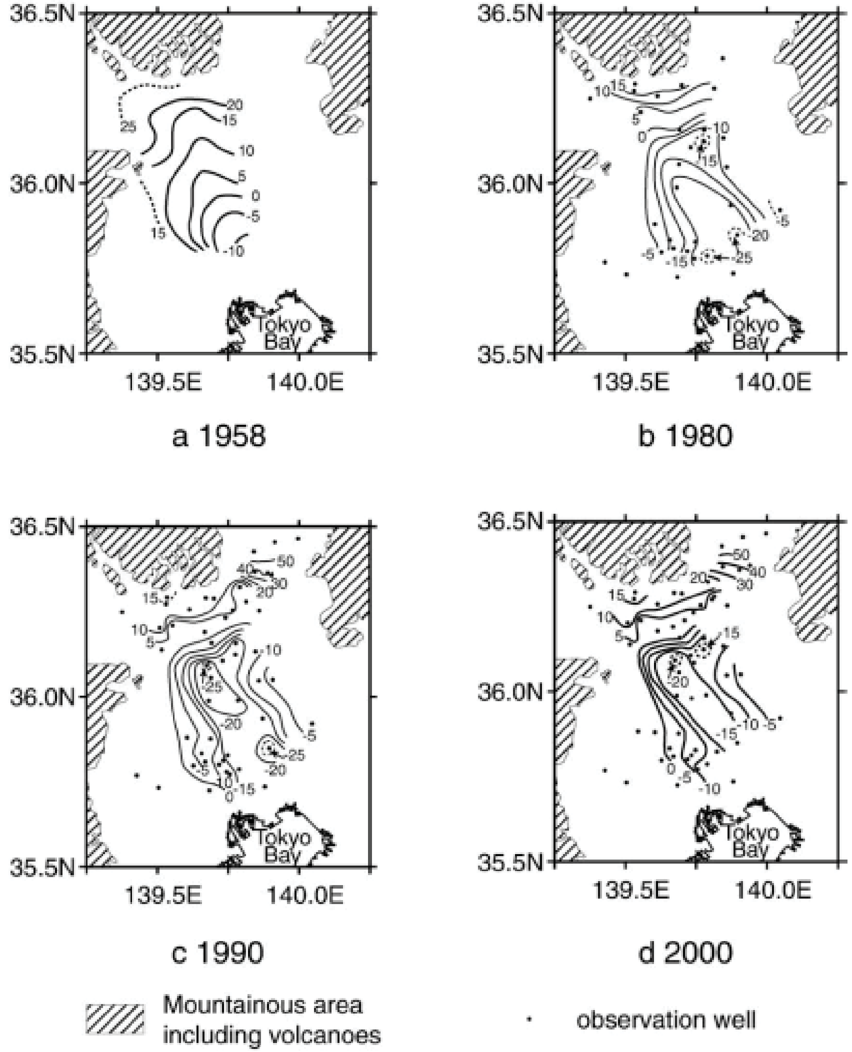


Fig. 3 Horizontal distribution of the hydraulic head in the 2nd aquifer (Hayashi et al., 2007)

Excessive groundwater extraction resulted in a marked decline in the quality of the hydraulic heads in the extracted aquifers, which caused land subsidence in certain areas. In addition, when several confined aquifers in eastern Tokyo became unconfined, accidents resulting from oxygen-deficient air masses began to occur. However, the recovery of groundwater creates new issues that affect subsurface structures and increase the demand for groundwater.

T.Hayashi, T. Tokunaga, M. Aichi, J. Shimada and M. Taniguchi (2007) : Effects of human activities and urbanization on groundwater environments: An example from the aquifer system of Tokyo and the surrounding area. *Science of the total environment*. 407, 3165-3172.

Long-term changes to groundwater recharge ratio using numerical simulation

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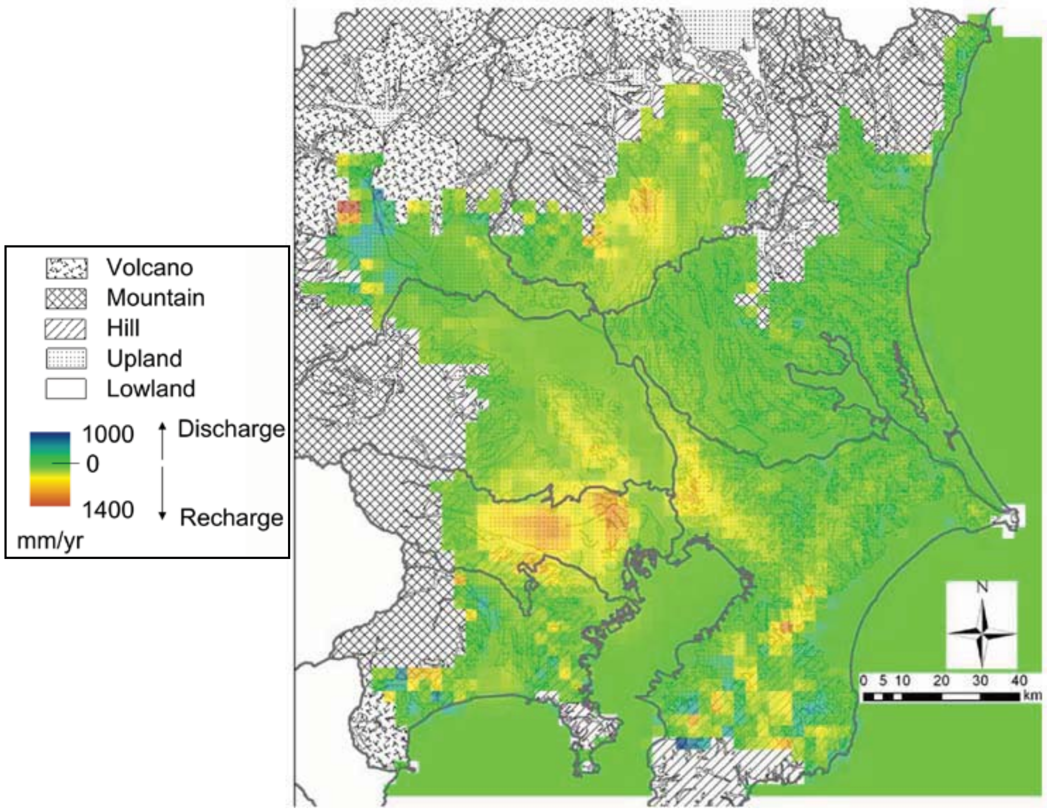

Fig. 1 Spatial distribution of simulated recharge rates (2000)
(Aichi et al., 2008)

The historical changes experienced in the Kanto Plain recharge area can be illustrated using a numerical simulation method.
The high-level recharge area moved to include inland areas, which correspond with the changes in the low hydraulic head area. The estimated high-level recharge rate is caused by excessive pumping in urban areas. This induced recharge rate is greater than the rate of natural recharge.

M. Aichi, T. Tokunaga (2008) : Estimation of the spatio-temporal change of the groundwater recharge in the Kanto Plain, Japan, from numerical simulation. *Proceedings of IAH Toyama conference*. Oct. 2008, S23.

Subsurface Thermal Environment in Tokyo

Over the past 100 years the temperature in the city center has risen approximately 3°C and due to the impact of this rise the underground temperature has also risen. Normally, the underground temperature increases with depth, but in the subsurface of Tokyo the reverse phenomenon is obsreved: the temperature falls until a depth of about 100 meters. In response to the heat island above ground a “subsurface heat island” is forming.

Subsurface thermal environment changes, because of artificial effects, in the metropolitan areas of Tokyo, Japan

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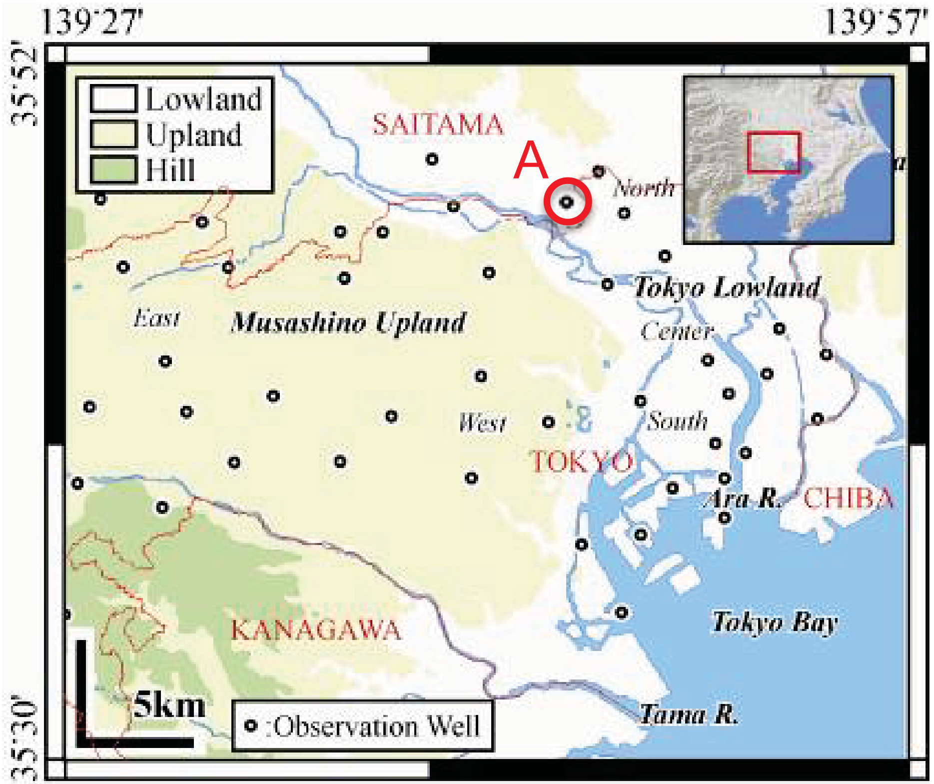

Fig.1 Location of observation wells

Purpose: To evaluate the effects of human activity on subsurface thermal environments.

Observation: Three-dimensional subsurface temperature distribution and its temporal changes were examined using temperature–depth profiles measured in observation wells since 2000. Long-term temperature monitoring at four stations in the Saitama Prefecture has also been conducted since 2007 (Miyakoshi et al., 2008, 2009).

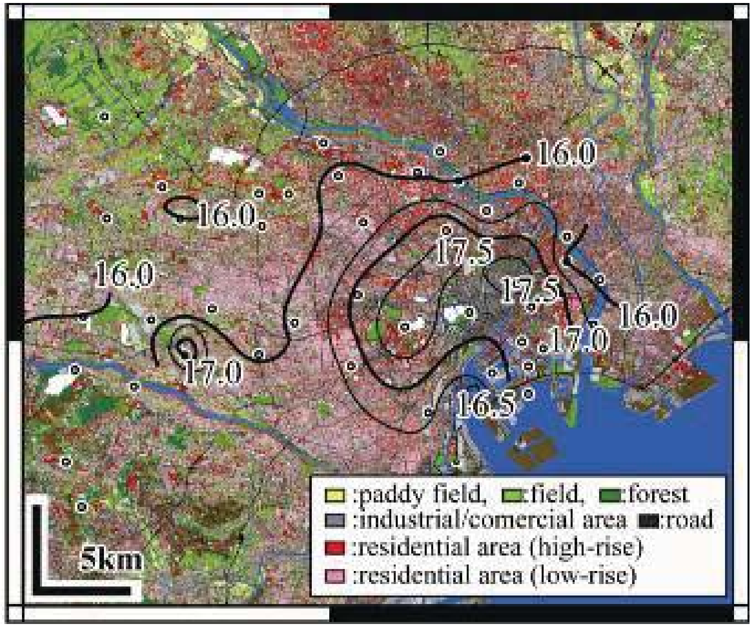

Fig. 2 Distribution of subsurface temperature (50 m) and land map (after GSI, 1994)

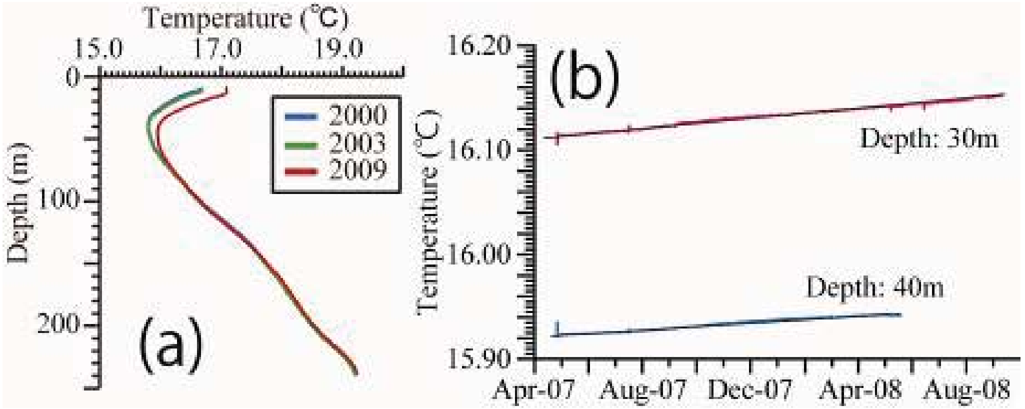

Fig. 3 (a) Temperature-depth profile measurements, and (b) long-term temperature records from Site A (Fig. 1)

<u>Results:</u> Comparisons between the distribution of subsurface temperatures and the land use map (Fig. 2), show that the high temperature area at 50 m corresponds with the urban area. This result suggests the existence of the urban subsurface heat island phenomena in the subsurface environment of the Tokyo metropolitan area. Moreover, comparisons between the temperature-depth profiles measured at Site A (Fig.3 a) show warming of 0.2 K at 30 m from 2000 to 2008. Long-term monitoring results (Fig. 3b) also show warming at a rate of 0.025 K/year at the same depth, from 2007 to 2008. These observations suggest that subsurface temperatures in relatively shallow areas have been rising and the urban subsurface heat island phenomena have occurred in the Tokyo metropolitan area, due to the effects of human activity.

Miyakoshi et al. (2008) Evaluation of change in subsurface thermal environment due to groundwater flow in the Tokyo Lowland, Japan, International Journal of Earth Science, 97:401-411.

Miyakoshi et al. (2009) Subsurface thermal environment change due to artificial effects in the Tokyo metropolitan area, Japan. From Headwaters to the Ocean (Taniguchi et al, eds.), Taylor & Francis, London, 547-552.

Groundwater Pollution in Tokyo

The trends are largely the same as in Osaka.