Long-term temperature monitoring in boreholes for studies of the ground surface thermal environment and groundwater flow

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Temporal changes of the ground surface temperature (GST), which result from climate changes or many other phenomena, penetrate into subsurface layers by thermal diffusion. The subsurface temperature distribution is also disturbed by groundwater flows with temporal and/or spatial variations on various scales. Since 2000, we have been conducting long-term monitoring of subsurface temperatures in East Asian countries to detect effects of GST changes and groundwater movements. We deployed water temperature recorders with a resolution of 1 mK in boreholes at relatively shallow depths (25 to 70 m below the surface) and obtained continuous records for up to four years.

At one site in the Kamchatka peninsula, we found short-period temperature oscillations with amplitudes of 1 to 4 mK. Spectrum analyses revealed that they have strong diurnal and semidiurnal components corresponding to earth tides. To reveal the nature of the oscillations, the water level in the borehole was monitored together with the temperature. The variations of the water level and temperature were in phase, indicating that vertical movement of borehole water due to earth tides resulted in temperature variations. In a borehole located on the coast of Lake Biwa, Japan, we made continuous measurements of temperature at depths of 30 m and 40 m for four years and two years respectively and observed slow but steady increases at both depths. Probable causes of the temperature increase are: 1) sudden rise in the average GST due to construction of a building, which covered the top of the borehole, 2) increase in the depth from the surface due to fill-up of artificial sediment before drilling of the borehole. For obtaining more information on the subsurface heat transfer process, a temperature monitoring experiment using a thermistor cable with 10 sensors is under way.

We recently started monitoring of borehole temperatures in groundwater observation wells in Taiwan, Bangkok and Jakarta as part of a research project 'Human Impacts on Urban Subsurface Environments' by the Research Institute for Humanity and Nature, Japan. The main purpose is to detect downward propagation of the GST variation. Three water temperature recorders were installed in the upper part of each well at intervals of 5 or 10 m. In Taiwan and Jakarta, temperature records for 11 months to 1.5 years were successfully recovered at most of the stations. At one station in the Taipei area, peculiar short-period variations were detected at a depth of 25 m. The spectrum of the temperature record shows prominent peaks at periods of one day and one week, suggesting that the short-period variations arise from human activities.