Observation of temporal variations in temperatures in boreholes

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Temperature changes at the ground surface, including climate changes, penetrate into subsurface rocks by thermal diffusion. This diffusion process may be detected in real time by long-term monitoring of temperatures in boreholes. Temperature records in boreholes can also include information on movement of the water inside the holes. We conducted temperature monitoring with a high resolution of 1 mK in four boreholes in Japan and Kamchatka and found three different types of temperature variations.

In a borehole located on the southeastern coast of Lake Biwa, we have been monitoring the temperature at 30 m below the surface since October 2002. Precise temperature logging in this hole conducted in September 1993 and April 2002 revealed that the temperature above 70 m significantly increased between the two logs by up to 1 K. It indicates that the temperature structure above 70 m was disturbed by some recent event(s) near the ground surface. We tried to investigate the nature of this temperature change through temperature monitoring at 30 m. The obtained temperature data show an increase of 22 mK in 13 months at a nearly constant rate. This slow and steady temperature increase is thought to be a continuation of the temperature change between 1993 and 2002. The most probable causes of these temperature variations are: 1) construction of the main building of the Lake Biwa Museum in 1996, which covered the top of the borehole, 2) 6.7 m thick sediment cover on the original ground surface overlaid sometime between 1982 and 1991. Both of these two factors can result in an almost linear temperature increase at 30 m as observed.

In Kamchatka, temperature profiles were measured repeatedly in twelve boreholes in 2000 to 2002 for a past climate reconstruction study. We found that temperatures in most holes were quite stable, except for two holes (E-1 and UZ), where the profiles changed by up to 200 mK. To investigate the nature of the temporal variations, we monitored temperatures at 325 m in E-1 and at 108 m in UZ for about 6 months in 2001 to 2002. The temperature records obtained in both holes showed short period fluctuations with amplitudes of 20 to 30 mK. In 2003, we made monitoring at the same points with a high sampling rate (5 sec) for two weeks. These records are characterized by sawlike oscillations with amplitude of 10 to 60 mK and dominant periods of 5 to 20 minutes. Such temperature variations strongly indicate the existence of water convection in these two holes.

In one of the boreholes with stable temperature profiles (Malki-19), we monitored temperatures at four depths, 25, 30, 35 and 40 m for 10 to 11 months. The temperatures at 25 and 30 m showed rapid variations probably due to groundwater flows, while the temperatures at 35 and 40 m had been almost constant. An interesting feature common in all the four records is short-period oscillations with amplitudes of 1 to 4 mK. Spectral analyses revealed that they have strong diurnal and semidiurnal components corresponding to earth tides. These oscillations can be explained by vertical movement of water in the hole associated with earth tides. We are now monitoring the water level and the temperatures at 25 and 30 m to examine the correlation among them.