Ground surface temperature history in the southeastern part of the Republic of Korea, inferred from borehole temperature data

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Past changes in temperature at the earth surface have penetrated into the subsurface and have been recorded as transient temperature perturbations to the background thermal field. In the absence of fluid moving, changes in ground surface temperature (GST) slowly propagate downward by heat conduction. Depth of the perturbation and time at which GST changes have occurred is linked nonlinearly by thermal diffusivity of rock. Subsurface temperature perturbations attenuate with increasing depth due to the diffusive process. The attenuation depends on frequency of GST variations: higher frequency components are diffused out at shallower depth. Thus, subsurface temperature perturbations indicate signals of long-term trend of GST variations.

GST is closely related to surface air temperature (SAT) that is in direct response to climate at that site at that time. To infer past climate changes, numerous borehole temperature profiles have been investigated and GST histories have been reconstructed. Northeast Asia is geographically important to study global and hemispheric climate trend. However, there are a few studies using geothermal approach to infer past climate change. The purpose of this study is to infer a change in GST over the last 300 years in Ulsan, one of the major industrial cities in the Republic of Korea, by inversion of borehole temperature logs.

Southeastern part of the Korea peninsula is occupied by thick Mesozoic sedimentary rocks with intrusions of Cretaceous volcanic rocks. In Ulsan, the most southeastern part of the peninsula, nineteen borehole temperature logs have been carried out for geothermal and hydrological surveys since 1986. To avoid non-climatic distortions (heterogeneity of the earth material and advection due to groundwater) to the GST history reconstruction, we selected three boreholes. Deviations of temperatures in these boreholes from the background temperatures show positive anomalies that decrease with depth, indicating recent warming at the ground surface.

We use the Bayesian inversion method, which can incorporate uncertainties of thermophysical properties model and measured temperatures into the form of a priori standard deviations. In the reconstructed GST history, a cold period is seen in the late 19th century. After the cold period, the GST shows an increase of 1.5 K by 1980. We compare the GST history with northern hemisphere (NH) temperature time series over the last 300 years (Jones et al., 1998). Before the 20th century, the GST change in Ulsan agrees with the long wavelength trend of the NH temperature time series. The beginning of warming on the GST history is almost the same as that of the NH temperature change. Although the NH temperature time series after 1930 is a stable condition, the GST in the same period shows continuous rising.

In Ulsan, SAT measurement has begun since 1946. The weather station (Ulsan Gauging station of Korea Meteorological administration) is located near the boreholes. Before 1970, the pattern of the SAT change is similar to that of the HN temperature time series. After 1970, the SAT increases although the NH temperature time series is stable condition. The GST history in Ulsan agrees with the long wavelength trend of the SAT records. Since 1962, Ulsan has developed as one of the major industrial cities in the Republic of Korea and major industrial plants and factories have been built. Thus, the increase in SAT in Ulsan suggests local warming due to the industrial activities in the area. If so, the GST history in Ulsan reflects a climatic history from pre-industrial period to industrial period in this area.