Spatial variations of frozen ground and their contributions for Hydrology in Khentei Mountain region

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Introduction

Permafrost, a thermal condition of a ground, is a climatic phenomenon and occupies more than 20 per cent of the world's land area (Washburn, 1979). The widest permafrost area in the world occurs in the north-east Eurasian continent. Mongolia is located in the southern boundaries of the north-east Eurasian permafrost and corresponds to transition zone from continuous permafrost of the north to the seasonally frozen ground of the south.

It is well known that the hydrological processes in permafrost regions are different from those in non-permafrost regions. Since permafrost occurrence and its geometries vary with even in small areas in Mongolia, intensive observations here should well delineate the role of permafrost for regional hydrological processes.

Frontier Observational Research System for Global Change (FORGS) established Special Observation Area (SOBA) for intensive hydrological, meteorological and geocryological monitoring in Kentei Mountains especially along Tuul river basin, north-east from Ulaanbaatar. We have set up deep borehole for ground thermal monitoring and soil temperature and moisture monitoring network in this year. This paper will summarize the aims, preliminary results and some perspectives of these observations.

Regional Setting

SOBA basin, a part of Khentei Mountains, is composed of two main tributaries, Tuul and Terelj River. Topography of these river basins is characterized by significant relief with the range of 1300 to 2500 m ASL. Mean annual air temperature (MAAT) in the Ulaanbaatar, which is located on the southern most latitude of SOBA, is -1.0 ℃, corresponding to that of the southern limit of the discontinuous permafrost zone in Canada (Brown, 1967).

Thermal conditions of frozen ground have been monitored through several boreholes in the Nalaikha depression and its surroundings. The permafrost temperatures, which are the ground temperatures at the depth of zero annual amplitude (ZAA), are close to 0 ℃ (Sharkhuu, personal communication).

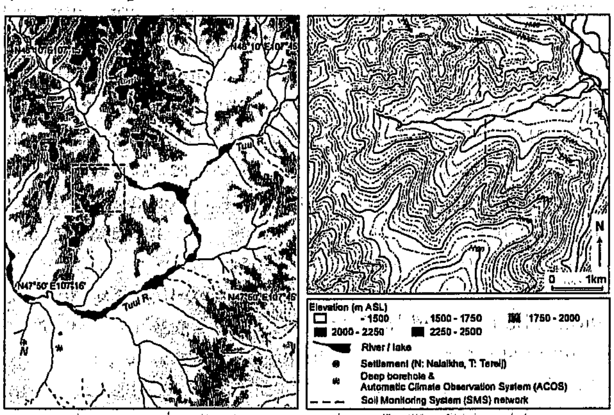

Figure 1. Map of observation area.

Observations and their preliminary results

Geothermal monitoring

Owing to the changes in global climate and local ground surface energy flux, the warming and degradation of permafrost are reported, especially in discontinuous and sporadic permafrost region (e.g. Osterkamp and Romanovsky, 1999). These facts have been reported in mainly Canada and Alaska, although few evidences have been shown in the north-east Eurasia continent.

In order to understand thermal stabilities of permafrost, we started inter-annual monitoring of ground temperature profile through 30 m depth borehole at east of Nalaikha (Figure 1). The combined monitoring of deep ground temperature and energy balance by Automatic Climate Observation System (ACOS) may promote the understanding not only of permafrost degradation but also of past changes in ground surface heat balance and ground surface temperature over annual time scales. This is because permafrost filters the higher frequency signals of the atmosphere and stores systematic running mean (Lachenbruch and Marshall, 1986).

Through drilling operation in the early October 2002, the depth of thawing front was observed to be 5.3 m depth, indicating thick active layer. Considerable amount of unfrozen water was found around the thawing front. These observations suggest that thermal condition permafrost in this site is typical of that on southern limit of discontinuous permafrost.

Network monitoring of soil temperature and moisture

In SOBA, upper streams of Tuul River, complicated topography affect spatial variations of frozen ground and thus regional hydrological processes. The most visually observed feature is unevenly distributed forest, which seems to agree with slope aspect and inclination. Dense forests, composed of *Larix* and *Pinus*, occupy the steep northern slopes, while grasslands on southern slopes and flat grounds. This is probably due to the number of factors and their interrelations. The most possible predominant factor is the difference in amount of incoming solar radiation, which determines regional differences in evaporation, soil moisture contents and frozen ground conditions and forest distribution. Another important factor is near subsurface materials. Grain size, porosity and organic matters determine the apparent thermal and hydraulic properties of subsurface materials and thus may control soil moisture contents and permafrost occurrences. In addition, presence of forest may positively act as feed back for increasing soil moistures and decreasing soil temperatures.

These complicated subsurface hydro-thermal regimes should be clarified both spatially and temporally in order to understand regional hydrological processes in SOBA. We observed soil profiles, temperatures and moistures up to 1.5 m depth in mid-September 2002 along transect from northern forested to southern grassland slopes near Terelj settlement, about 80 km far northeast from Ulaanbaatar (Figure 1). This experimental site seems to be representative of SOBA. Preliminary observation in summer 2002 showed that soils were composed of various materials such as hummus, moss, silt and sand gravels beneath northern slopes. On the other hand, subsurface materials on the southern grassland slope were simpler, composed by sand-gravels beneath thin (10-20 cm in thickness) humus. Lower soil temperature, sometimes reaching 0 ℃at 1.5 m depths, were observed on the northern slope, while higher temperature on the southern slope. Higher soil moisture contents are observed near the river bed, where vegetated hummocks are distributed. Soil temperature monitoring indicated that spatial difference on ground temperature has continued until mid-October.

Based on the preliminary knowledge above, Soil Monitoring Systems (SMSs) network were installed in mid-October 2002 along transect from northern and southern slopes (Figure 1). This network includes two control points (3.2 m in depth), three deep points (2.0 m in depth) and four shallow points (1.5 m in depth). Soil temperatures and moistures are monitored at several depths at each point.

Groundwater hydrology

The groundwater hydrology of permafrost regions is unlike that of non-permafrost regions since permafrost act as an impermeable layer. In permafrost regions, the movements of groundwater are restricted to supra-permafrost, open talik and sub-permafrost zones. These groundwater movements are more complicated and significant in the regions of discontinuous than those of continuous permafrost. Therefore, spring from underground water may play an important role for runoff system of SOBA basin.

We observed in experimental site of SMS network (Figure 1) that stream flow continuously from forested slopes throughout summer period, while no water flow from grassland slopes. This difference is due to the difference in frozen ground condition. Presences of supra-permafrost zone (i.e. active layer) may affect the interflow and runoff on the northern slopes.

In contrast to above findings in SMS site, some natural springs and wells, supplying high amount water to the basin, exist on the grassland of southern fringes of Nalaikha depression. Even in abnormally dried summer in 2002, water was observed to be spouting. Most of these springs are located on the topographic knick point where groundwater easily upward to the ground surface.

The subsurface pathways of the water, e.g. from supra-permafrost or from open talik zones, are still remained unclear. This issue should be studied on the basis of geochemical observations, including isotope analysis. We sampled water from these springs and soils every 20 cm up to the depths of 30 m through deep drilling operation in order to analyze stable isotopes in the water.

Summaries and Perspectives

Followings are summary of hydrological and geocryological observations by FORSGGC;

1. Geothermal monitoring for investigation of thermal stabilities in southern boundary permafrost.
2. Monitoring of soil moisture and temperature under the various topographic, geological and micro-meteorological conditions for investigation of subsurface hydro-thermal regimes.
3. Geochemical analysis for investigation of groundwater contributions for land-surface water budget.

References

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