Tôhoku Geophys. Journ. (Sci. Rep. Tôhoku Univ., Ser. 5), Vol. 36, No. 2, pp. 91-99, 2001

Dynamics of Permafrost in Mongolia

NATSAGDORJ SHARKHUU

Institute of Geography Mongolian Academy of Sciences Ulaanbaatar-210620, Mongolia E-mail : Geo-dgv@magicnet.mn

(Received October 30, 2000 ; accepted January 9, 2001)

Abstract : Recent dynamics of permafrost in Mongolia is studied by the author on the basis of analyzing trends or changes in mean annual ground temperature and active layer thickness which have been obtained during long term geotemperature measurements in more than 10 boreholes located in the Khentei, Khubsugul and Khangai mountain regions.

Permafrost under influence of recent climate warming in Mongolia is degrading by regional character. However, aggradation of permafrost has only been observed locally in the Khentei taiga area. Locally, degradation of permafrost is caused by human activities, especially near cities and mines, because of frequent forest fires.

1. Introduction

Estimating and foreseeing possible effects of climate changes and human activities on permafrost conditions, as well as developing appropriate strategies for monitoring critical parameters over long periods, are now vital part of long term environmental and ecological studies in permafrost zone of Mongolia. One of the topics of these studies is quantitative and qualitative assessments of permafrost development or dynamics, which are provided on the basis of conducting long term permafrost monitoring. Dynamics of permafrost can be changed in trends of degradation, aggradation and stability of permafrost development. To examine the trends or dynamics of permafrost development, since 1996 the author conducts permafrost thermal monitoring in more than 10 boreholes to depths of 25-100 m, where ground temperature measurements have been made 10-25 years ago. Now he is conducting permafrost monitoring in eight areas (or sites) of Mongolia. In particular, there are Baganuur, Nalaikh and Argalant (3) sites in the Khentei mountian region, Burenkhan and Ardag (2) sites in the Khubsugul mountain region, Terkh, Chuluut and Erdenet (3) sites in the Khangai mountain region.

Thus, based on analysis of the permafrost thermal monitoring data, the objectives of the paper are to determine dynamics of recent permafrost under influence of climate change and human activities in Mongolia.

2. Permafrost conditions

Mongolia is the country of predominated high and middle height mountains with continental climate, which promote occurrence and development of permafrost. Permafrost underlies almost two thirds of the country and comprises Khubsugul, Khangai, Khentei and Altai mountains and surrounding areas. Therefore, there is predominated

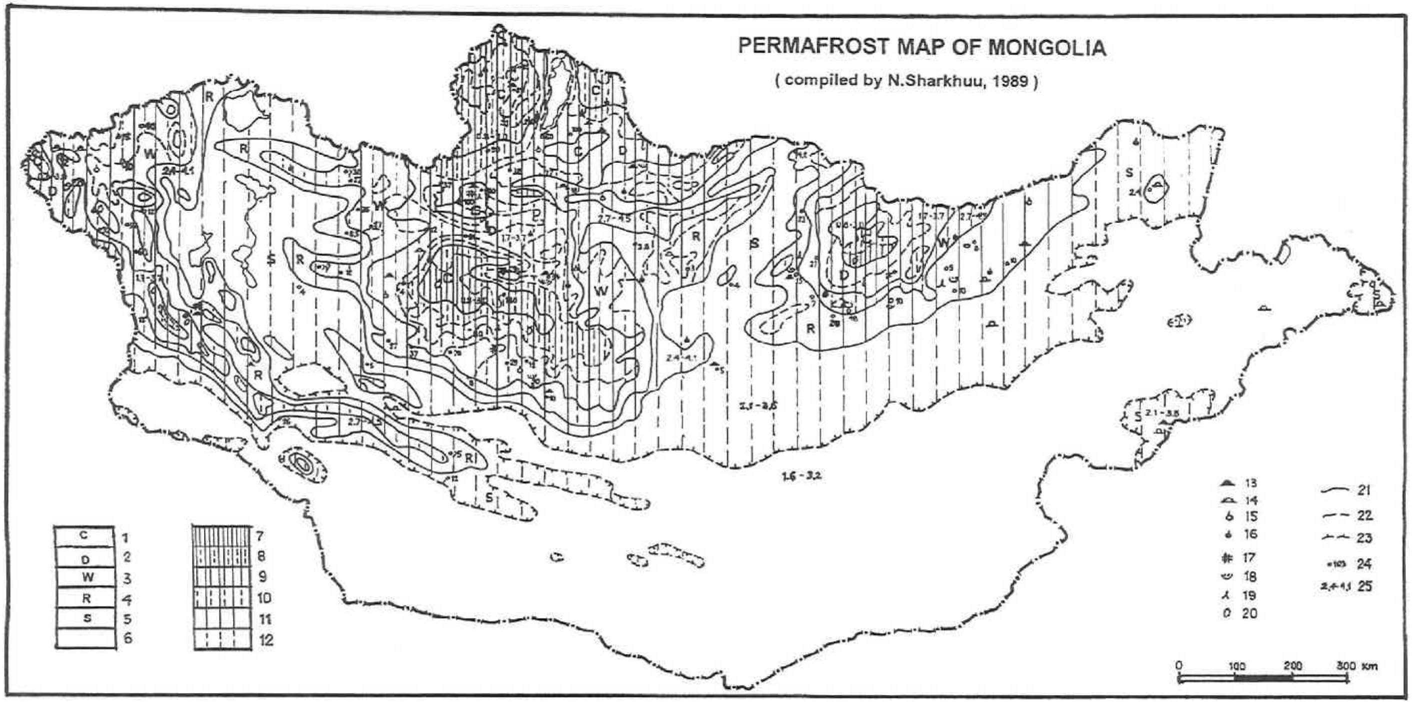


Fig. 1. Permafrost map of Mongolia (N. Sharkhuu, 2000)

Permafrost areas: 1) continuous, 2) discontinuous, 3) widespread island, 4) rear island, 5) sporadic, and 6) without permafrost. Thickness and temperature of permafrost: 7) 250-500 m, −4-6°C, 8) 120-250 m, −2-4°C, 9) 50-120 m, −1-2°C, 10) 15-50 m, −2-−1.0°C, 11) 5-15 m, −0.1-−0.2°C, 12) 0-5 m, 0.3-0.1°C. Cryogenic processes and phenomena: 13) Perennial frost mounds, 14) Seasonal frost mounds, 15) River icings, 16) Ground icings, 17) Frost cracks, 18) Thermokarst; 19) Solifluction, 20) Stone polygon. Other signs: 21) Boundary of permafrost distribution, 22) Bounday of permafrost thickness and temperature, 23) Southern limit of permafrost occurrence, 24) Thickness of permafrost determined in boreholes, m, 25) Average depths of seasonal freezing and thawing of groupd in the given nermafrost areas, m.

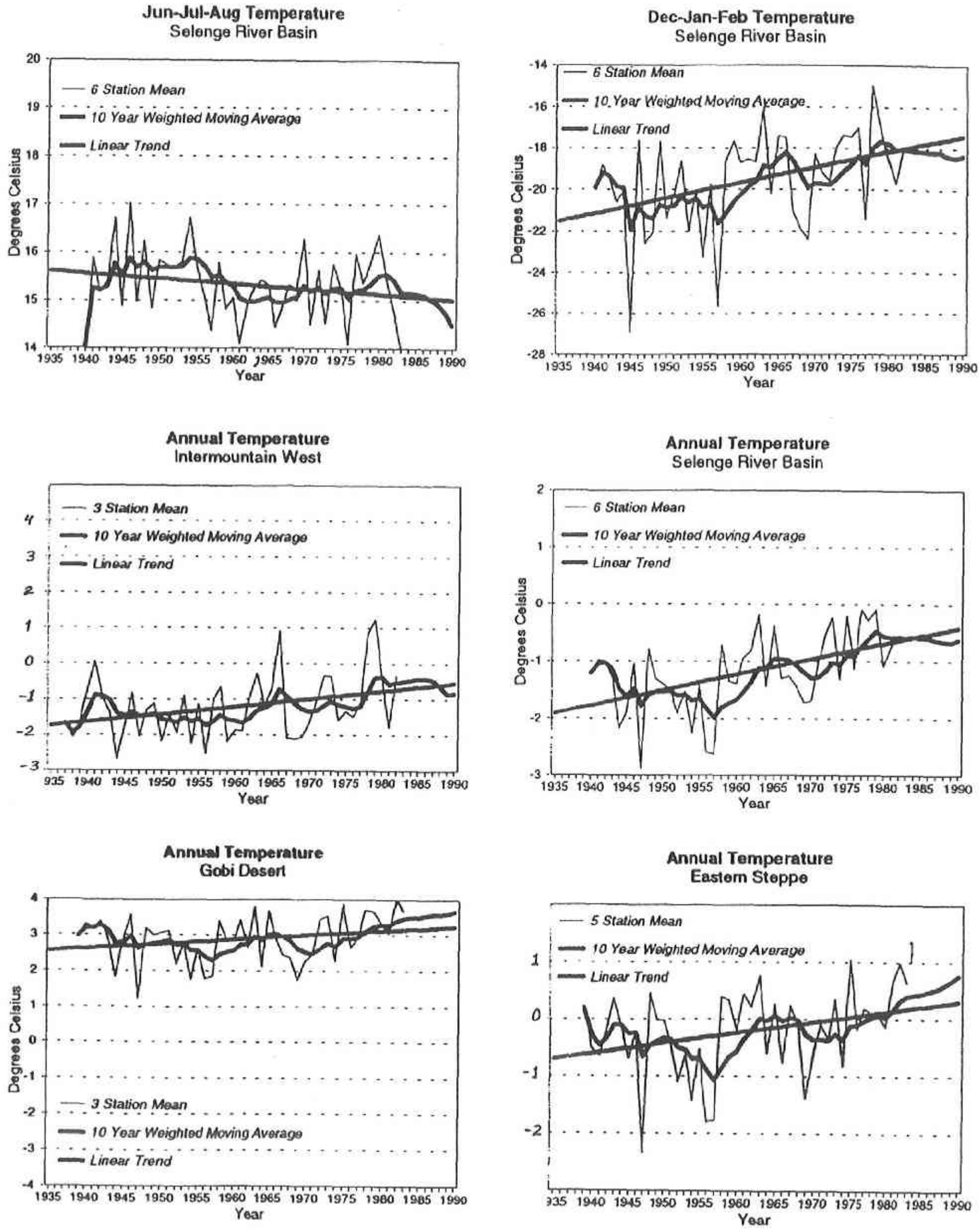


Fig. 2. Change of air temperature in various parts of Mongolia.

mountain and arid land permafrost from sporadic to continuous distribution which is spread along the southern fringe of the Siberian permafrost occurrence.

Figure 1 shows the distribution of permafrost thickness and temperature. It is divided into five categories: continuous permafrost (>85%), discontinuous (50-85%), widespread isolated (10-50%), sparsely-spread isolated (1-10%), and sporadic (<1%).

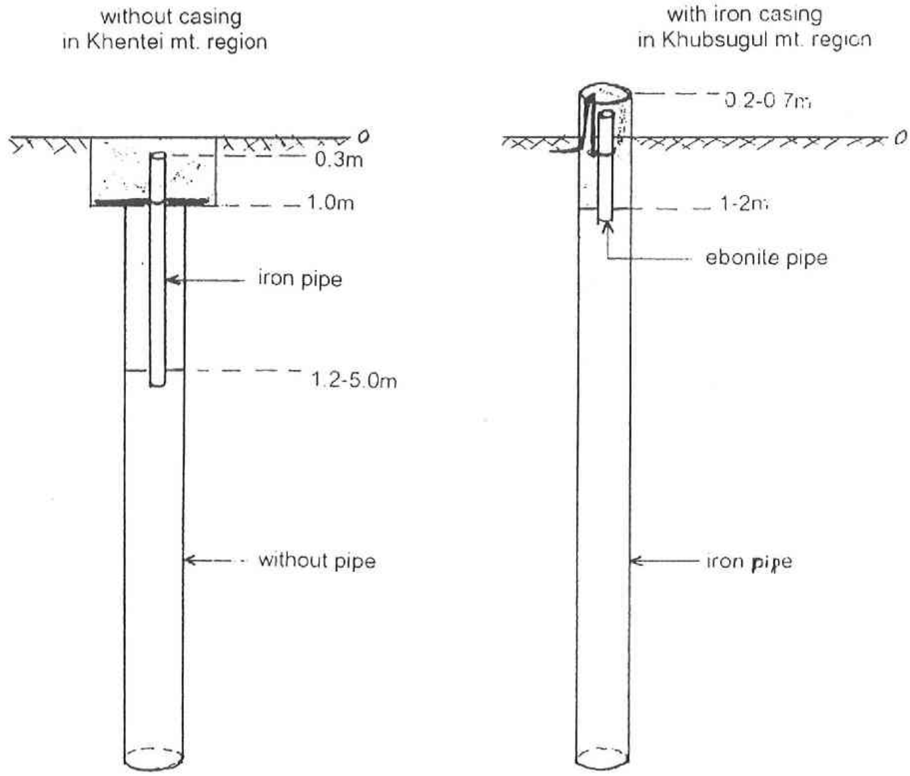


Fig. 3. Instrumentation and technique of measuring permafrost temperatures in boreholes.

In the continuous and discontinuous permafrost areas, taliks are found only on steep, south-facing slopes, under large rivers and deep lakes, and along tectonic fractures with hydrothermal activity. Outside the continuous and discontinuous areas, permafrost is found only on north-facing slopes and in fine-grained and moist deposits. Average thickness and temperature of continuous permafrost is 50-100 m and minus 1-2°C in valleys and depressions, 100-250 m and minus 1-3°C in mountains respectively. Permafrost in Mongolia is characterized mainly by low and middle ice content loose sediments. Ice rich permafrost is characteristic of lacustrine and alluvial sediments in valleys and depressions. Seasonal thaw to depths of 2-3 m in silty soils and 4-5 m in coarse materials, occurs between May and September. In non-permafrost areas, ground freezing occurs between mid-October and the end of April. There are wide spread various cryogenic processes and phenomena in permafrost zone (Sharkhuu and Luvsandagva, 1975 ; Sharkhuu, 2000).

3. Climate change

Since permafrost is a thermal condition, it is potentially sensitive to climate change

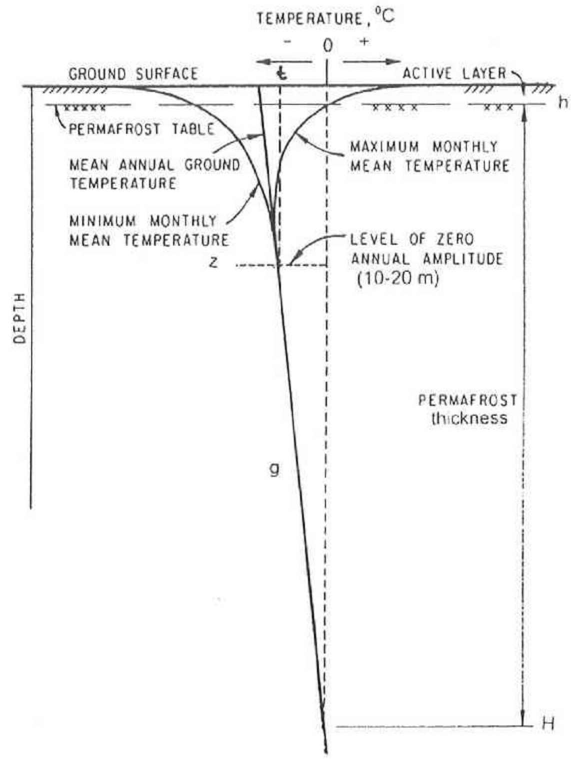


Fig. 4. Main criteria of permafrost monitoring.

and human activities. Impact of climate on dynamics of permafrost is characterized, mainly, by changes in air temperature and precipitation for many years. Recent climate in Mongolia is under influence of global climate warming. However, values of recent climate warming in various territory of Mongolia are very different. Figure 2 shows changes and trends of air temperatures in period of 1940 to 1990 in various parts of Mongolian territory. According to the meteorological data, mean summer temperatures in the Selenge river Basin, embracing Central Mongolia have increased by only 0.5°C whereas winter temperatures have increased by 4.0°C in the past 50 years. During the past 50 years, mean annual air temperatures have increased by 1.8°C in the western Mongolia, 1.4°C in Central Mongolia and 0.3°C in southern and eastern Mongolia. During the past 50 years, trends of mean summer, winter and annual precipitation have not been changed practically (Mizhiddorj, 1990).

4. Method

The method of studying dynamics of permafrost is based on long term permafrost thermal monitoring or repeated measurements of ground temperatures in boreholes. Permafrost profiles of every borehole must be determined in a detail. Besides, every boreholes for monitoring must be installed by certain instrumentation in order to defend boreholes from human activities or damages and to decrease air convection in the boreholes. According to the figure 3, the author has used two techniques of borehole instrumentation. The first technique is used in conditions, when the borehole has no casing pipe. In this case, the borehole is not noted from Earth surface, where it is located. The second technique is used in conditions, when the borehole has casing pipe. Ground temperatures in boreholes have been measured by using thermistors and digital multimeter. Temperature measurements in certain boreholes are made by the same or permanent thermistors at the corresponding depths, and by the same dates of an year.

Figure 4 shows main criteria of determining dynamics of permafrost based on permafrost monitoring. They include: 1) mean annual ground temperature (t) at a level of zero annual amplitude (z), 2) depth of active layer or seasonal thawing (h), 3) thickness or depth of permafrost (H) and 4) gradient of permafrost temperatures (g). Among them, mean annual ground temperature is the main criterion of assessing dynamics of permafrost. Qualitative and quantitative assessments of permafrost development or dynamics can be made on the basis of comparative analysis of each of the mentioned criteria. In addition, based on the data obtained, one should make approximate calculations for predicting permafrost evaluation near future (Kudrayavtsev *et al.*, 1974).

5. Results and discussions

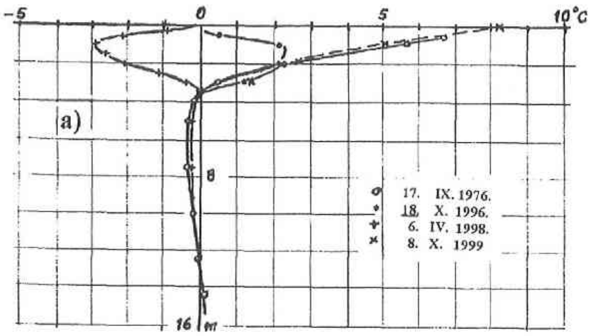
The main results of studying permafrost degradation under influence of recent climate warming in Mongolia are as follows:

1) during last 10 to 30 years, mean annual ground temperatures have been risen at a rate of 0.05 to 0.20°C per 10 years. This value in the western part of Mongolia is more than in its eastern part.
2) the rate of temperature change is relatively high on south-facing slopes, than on north-facing slopes of mountain.
3) the temperature increase in ice-rich permafrost is less, than in ice-poor permafrost.
4) thickness of active layers has increased at a rate of 0.5 to 3.0 cm per year.
5) the average geothermal gradient is about 2°C per 100 m deep. However, it decreases in the near surface due to the recent warming.

For examples, the author takes only three borehole monitoring results, which are shown in Figure 5.

First borehole for Khentei mountain is located in Baganuur depression, at altitude of 1,340 m. Profile consists of ice-rich clay. The temperature profile shows that mean annual ground temperature here increases by 0.06°C per 10 years, depth of active layer and thickness of permafrost decrease by 0.5 cm and 0.9 cm per year respectively.

Second borehole for Khubsugul mountain is located on Burenkhan north facing slope, at altitude of 1,700 m. Profile consists of bedrock or mainly of limestone. This



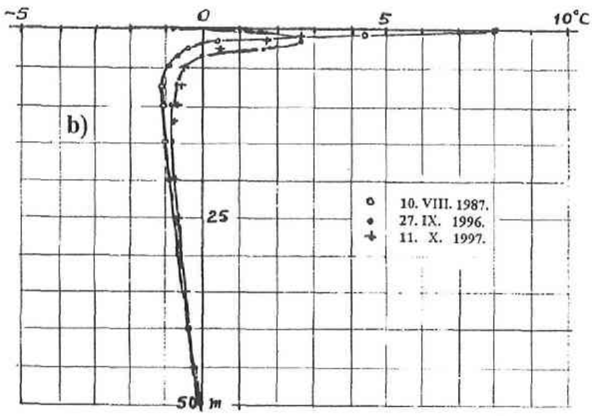


Fig. 5. Dynamics of permafrost in Baganuur (a) and Burenkhan (b) boerholes.

temperature profile shows that mean annual ground temperature here increases by 0.15°C per 10 years, depth of active layer decreases by 3 cm per year.

Third borehole for Khangai mountain is located in Terkh valley bottom, at altitude of 2,050 m. Profile consists of middle ice content alluvial gravely sand and lacustrine clay down to a depth of 90 m. This profile shows that mean annual ground temperature here increases by 0.12°C per 10 years.

In the Khangai and Khubsugul mountain regions, thermokarst and thermal erosion processes are active. They are direct indicator of recent permafrost degradation. However, it is necessary to note, that aggradation of permafrost has only been observed locally in the Khentei taiga area. It is believed that the aggradation results from increased precipitation there.

Local degradation of permafrost is caused by human activities. For example: During the past 50 years, in the territory of Ulaanbaatar city, mean annual ground temperatures have been increased by 1 to 3°C and islands of permafrost with thickness of 5 to 30 m have been completely melted. There were considerable impacts of frequent forest fires to dynamics of permafrost in certain areas of the Khentei and Khubsugul

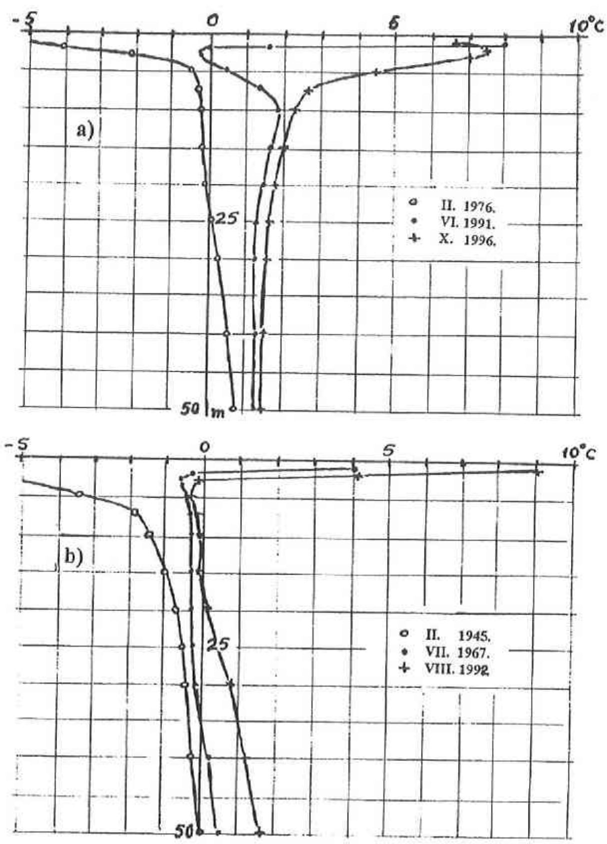


Fig. 6. Permafrost degradation under influence of Baganuur open-pit (a) and Nalaikh close-pit (b) coal mining exploitation.

taiga zone, Mongolia. Fire impacts to permafrost degradation in the Khentei taiga zone are studying by Japanese scientists since 1999. Figure 6 shows considerable degradation of permafrost under influence of Baganuur and Nalaikh coal mining exploitation.

Baganuur open-pit coal mining operation, especially pumping underground waters here, caused 25 m thick permafrost to be completely thawed in 8 to 10 years and correspondingly the spring to dry up and the swamp to drain. Besides, under influence of Nalaikh close-pit coal mining operation during the last 50 years, permafrost with a thickness of 50 m has been thawing from below at a rate of 70 cm per year. Its temperature has increased by 0.04°C per year at a depth of 50 m and 0.02°C per year at a depth of 15 m (Sharkhuu, 1998).

6. Conclusions

Permafrost, especially sporadic and discontinuous permafrost in Mongolia are very sensitive or dynamically to climate change and human activities. Factors aggravating permafrost degradation are deforestation in the taiga and desertification in the steppe zone of Mongolia. Therefore, study of the trends or dynamics of permafrost is of both practical and scientific importance.

Acknowledgments : The author gratefully thanks Professors Masami Fukuda and Fujio Tsuchiya for providing good opportunity to visit Japan and present his paper at the Sendai workshop, as well as to Dr. Isao Murata for editing and publishing the paper.

References

Kudrayavtsev, V.A., L.S. Garagulya, K.A. Kondrateva and V.G. Melamed, 1974 : Fundamentals of permafrost prediction under engineering geological investigations, *Moscow State University*, 203-211, (in Russian).

Mizhiddorj, R. 1990 : Variations of air temperature and atmospheric precipitation in Mongolian territory during the last 50 years, *Transactions of the Scientific and Research Institute of Hydrology and Meteorology, Ulaanbaatar*, 15, 9-19, (in Russian).

Sharkhuu, N. and Luvsandagva, D. 1975 : Basic features of permafrost in Mongolia, *Ulaanbaatar*, 45-58, 96-103, (in Mongolian).

Sharkhuu, N. 1998 : Trends of permafrost development in the Selenge River Basin, Mongolia, *In Procedings of the Seventh International Conference on Permafrost. June 23-27, 1998, Yellowknife, Canada*. 979-985.

Sharkhuu, N. 2000 : Regularities of permafrost distribution in Mongolia, *In Transactions of the Institute of Geoecology, MAS, Ulaanbaatar*, 217-232, (in Mongolian).