# Features and Mapping of Permafrost Distribution in Ulaanbaatar area, Mongolia

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**Abstract:**

Mongolia situated in the southern boundary of Eurasian permafrost region in which permafrost distribution is mosaic-lake, being strongly affected not only by landscape conditions but also by global climate

The occurrence of mountain permafrost depends on many parameters, which have direct and indirect relationships between each other, such as solar radiation, elevation, sloppiness, aspect, mean annual temperature on permafrost table.

The modelling based on the relationship between the total incoming solar radiation and the mean annual temperature on permafrost table. The mean annual temperature on permafrost table depends on energy flux in an active layer and the ground parameters (ground moisture, heat capacity, and etc).

Also, the energy flux in an active layer depends on a solar radiation and landscape conditions. The rate of solar radiation varies in mountainous area. The minus mean annual temperature on permafrost table is one of the criteria of permafrost occurrence.

In valleys and depressions with same solar radiation rate, the permafrost occurrence depends on ground moisture. The permafrost distributes in an area with more moisture along the valley and in the bottom of depression.

Based on the modelling results, we compiled the map of permafrost distribution in Ulaanbaatar area using GIS applications and Remote Sensing.

As result of our research the permafrost in Ulaanbaatar area divides into 2 types (mountain permafrost /1/, permafrost distributed in wetland areas/2/)

*Key words: permafrost distribution, active layers,,GIS, Remote Sensing, mapping*

**Introduction:**

We have the map of seasonally frozen ground and permafrost distribution at a scale of 1:1500000. This map was compiled by the results of Soviet – Mongolian geocryological expedition in 1967 – 1971. After this period our senior researchers, doctor D.Tumurbaatar, N.Sharkhuu, compiled the series of permafrost distribution map at a different scale. The main methodology of these maps is the geographical elevation belts.

Two thirds of the population of Mongolia lives in the region with permafrost distribution. With the increasing activity of infrastructure networks, knowledge about the distribution patterns of mountain permafrost helps reducing installation costs, and improves life safety of people in such area.

Long-term researches of Joint Japan – Mongolian IORSGE project are concentrating and contacting in discontinuous permafrost zone of Nalaikh and Terelj areas near Ulaanbaatar last for 4 years. One of the main topics of the project is observation for dynamics of active layer and spring icing at Terelj, Nalaikh observation sites. The active layer is ground to annual thawing and freezing in areas underlain by permafrost. Icing is a sheetlike mass of layered ice formed on the ground surface by freezing of successive flows of water that may seep from the ground, flow from a spring through fractures. The above observations are very important to estimate and predict the features and the dynamics of permafrost, active layer and spring icing under influence of current climate change and human activities.

At this presentation, we concentrate on the features and mapping of mountain permafrost.

**Study area and observation sites**

Geographically, the study area is located in southern part of Khentii mountain region. Highest relief of study area is 2300m above see level. Lowest relief is 1300m ASL. Relief different is about 1000m. Ulaanbaatar, capital city of Mongolia, situates in center of this study area. According to permafrost distribution map of Mongolia with a scale of 1:1500000 the study area is located in island and sporadic permafrost region.

***Terelj valley***

The observation sites are located in small *Shijer* valley near *Terelj* village. The observation for dynamics of icing has conducted at *Shijer* spring site located in the upper part of the valley. Continuous and discontinuous permafrost is characteristic of the north-facing forested slopes of the valley. Isolated and sporadic permafrost develop on north facing low gentle slope without forest and at some swampy sites of the valley bottom.

***Nalaikh depression***

An observation site was established on sparse grassland at *Nalaikh* at 40km southeast of Ulaanbaatar. The site is located on a sediment plain in a vast depression. The topography at and around this site is very smooth.

The observation site was in a semi-arid region characterized by warm, dry summers and cold winters and therefore by a thick of active layer and higher ground temperatures of discontinuous permafrost.

**Used data:** The following data were used for the modeling and mapping of mountain permafrost patterns using GIS applications and Remote Sensing.

1. Data from AWS in Terelj & Nalaikh (Sort-wave and long-wave radiations and temperature on the bottom of seasonally thawing and freezing were measured directly on these AWSs)
2. Topomap 1:100 000 compiled in 1986.
3. Satellite data:
   a. DEM data from SRTM(3arc) & ASTER DEM data
   b. Landsat7ETM+ on August 31, 2001, path/row=131/027
4. GIS applications (ArcView3.2a, ArcView Extension for Solar Radiation (Authors: Pinde Fu and Paul M.Rich), ArcGIS8.3, Erdas8.4, ENVI4.0)

## Method applied and results

### *Features and Dynamics of Active layers*

Dynamics of active layer has studied by soil temperature recordings at sites D and F.Deep located on north-facing forested slope of the Terelj valley. Temperature sensors are set at the depths of 0, 0.2, 0.4, 0.8, 1.2, 2.4, 2.8, 3.25, 3.5, 4, 5, 6 and 7m.

The active layers at the sites D, F.Deep are composed of debris with silt and sandy fill. Mean annual ground temperature at a depth of 3.2m was -0.94$^0$C, thickness of permafrost was estimated to be about 15 m and depth of active layer was 2.31, 2.48 and 2.41 m in 2003, 2004 and 2005 respectively. Seasonal thawing of ground begins from 13th April, reaches of active layer 73% of active layer by 1st July and finishes in late September. Refreezing of the active layer 22th October and finishes in beginning of December.

Dynamics of active layer has studied by soil temperature recording at site AWS located on Nalaikh depression. Temperature sensors are set at the depths of 0, 1, 2, 3, 4, 5, 6 and 7m.

The active layer at the site AWS is composed of sand, sandy loam and gravel. Mean annual ground temperature at the depth of 5m was -0.170C, depth of active layer was 4.7m in 2005. Seasonal thawing of ground begins from late March and finishes in 6th October.

### *Mapping of Permafrost Distribution*

As shown on modeling of permafrost occurrence the temperature on bottom of thawing or freezing is as a function of multi parameters.

$$t_\xi(R_{net}, A_m, C, Q_{ph}) < 0$$

$$t_\xi(R_{net}, A_m, C, Q_{ph}) \geq 0$$

For this mapping of permafrost occurrence we have used the following functions:

$$t_\xi(R_{t(inco\min g)}) < 0,$$

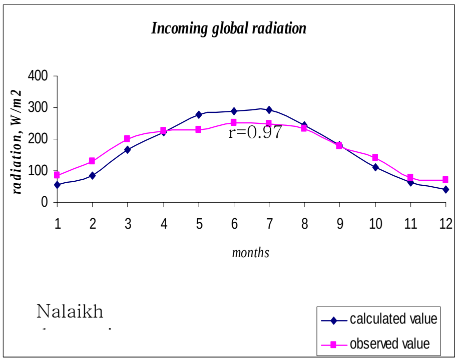
$$t_\xi(Wetland) < 0$$

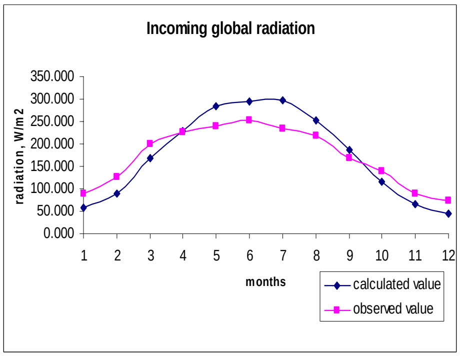
$R_{t(inco\min g)}$ – total incoming solar radiation

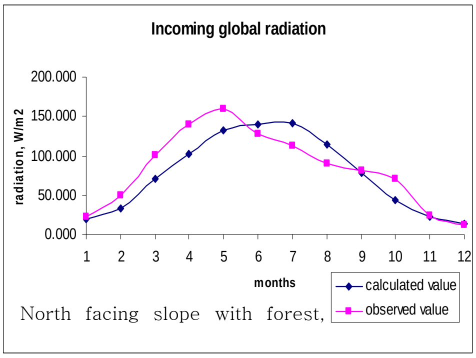
$Wetland$ – Wetland area

Using the ArcView Extension for Solar Radiation we have generated the global solar radiation map.

The results of solar radiation's modeling and measured results from three weather stations on different landscape show that the correlation between the modeling and measured data is very high as shown bellow.



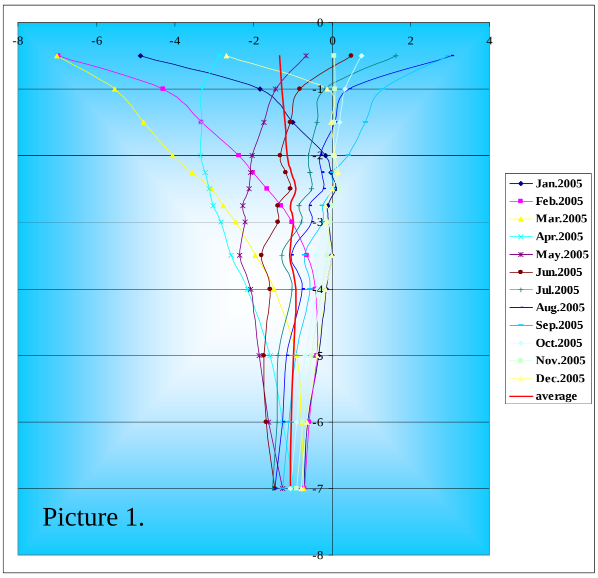

Using data for total incoming radiation from three weather stations and data for temperature on bottom of thawing or freezing from these three stations we have calculated regression equation. As shown of regression analysis the temperature on bottom of thawing or freezing is minus when the total incoming radiation is low than 1650.083 W/m2 a year.

Also we calculated the affect of forest on total incoming solar radiation.
From this solar radiation map with a forest affects we have generated the permafrost distribution map.
Where total incoming solar radiation is less than 1650.083W/m2 there are permafrost islands.
In depression area and in river valleys, where the total incoming radiation is more 1650.083W/m2, there are some permafrost islands. Because, these island permafrost areas are located in wetland area.
From the topo map and Landsat image we have calculated the wetland areas which are permafrost island areas.

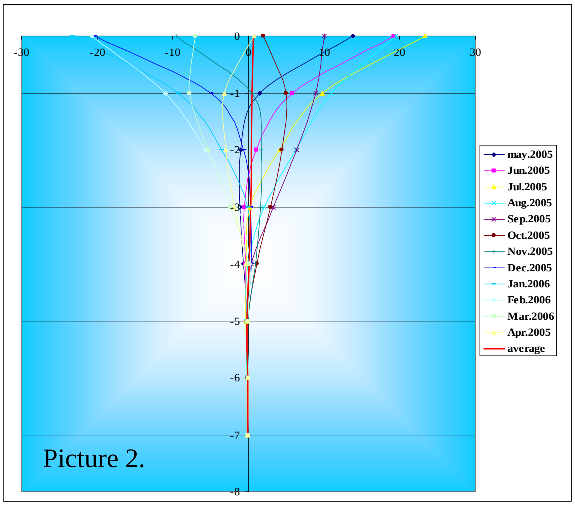
**5. CONCLUSIONS**

Thickness of active layer in Nalaikh area is relatively higher than in Terelj area. High rate of seasonal thawing of active layers occurs in May and June, and high gradient of its refreezing in November.
Dynamics of active layer is very changeable and different depending on climate and hydrological condition, soil freezing and temperature regime and on human activities.
Permafrost distributes in Ulaanbaatar area is characterized by follows: there are 2 types of permafrost.

1 Permafrost distributes in mountain areas with ground temperature of about (-2) degree. (see pic.1)
2 Permafrost distribution in wetland areas along the river valleys and on the bottom of depression. This type of permafrost is very sensitive to climate change. The temperature of ground of this permafrost is about 0 degree.(see pic.2)



Picture 1.



Picture 2.

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