# Icing dynamic changes in Bayanzurkh district, Ulaanbaatar, Mongolia

Temuujin.Kh 1, Dashtseren.A 2, Ulambayar.G 3
*Permafrost division, Institute of Geography and Geoecology, Mongolian Academy of Science*
*ochir.temka@gmail.com*

## Abstract

The icing conditions in northern central Mongolia were assessed using satellite images, Electrical Resistivity Tomography and metrological data. The study result show that the area of icing is decreasing but it depends on its formation. The area of river icing more decreased than that spring icing, and however these decrease on icily likely due to increase in air temperature both in summer and winter rather than precipitation. As icing forms in the settlement, it has negative effects on the infrastructures.

**Keywords:** TTOP, modelling, permafrost, FDD, TDD

## Introduction

Icing is a sheet-like mass of layered ice which is formed on the ground surface or on top of river or lake ice in winter where water seep from the ground in springs, rivers and lakes (Van Everdingen et al. 1998).

In the northern hemisphere icing is regarded as a hydrological phenomenon which is linked to a seasonal periglacial process and can be observed in different regions with permafrost and without permafrost as reported by several sources (e.g., Van Everdingen et al. 1998, Pollard 2005, Yde et al 2005, Morse et al. 2014, Morse et al. 2015, Morse et al. 2017, Makarieva et al. 2018).

The study area is located 10 till 50 km east and northeast of Ulaanbaatar City in lower reaches of the Uliastai valley and in the Baruun Bayan Gol valley, both are small north-bounded tributaries of Tuul river. However icing can be observed at different other places in the upper Tuul valley and its tributaries. This region belongs to the extreme continental climate of Mongolia with seasonal annual air temperature amplitudes of around 60° C, a mean annual average temperature (MAAT) of 0.4° C (and lower) and an annual total precipitation of 271 mm at the Ulaanbaatar Meteorological station. The distribution of the precipitation pattern is very various and there is observed strong increasing tendencies of annual precipitation recently.

*Seasonal genesis of icing features in Mongolia.*

Icing is not strictly linked with permafrost and appear regularly in non-permafrost areas of the periglacial environment in Mongolia. In general it is bounded on river valley bottoms and the foot zone of the direct neighbouring slopes.

- Summer: Springs with gravitation outlet during summer in the valley bottoms or the edge of the valleys against higher niveaus (like river terraces, tectonic faults or alluvial fans)
- Autumn: increasing hydrostatic pressure by diminishing the outlet channels by freezing; thermal energy of the water temperature is slower decreasing than air temperature.
- Winter: hydrostatic water outlet (icing mound); at the begin of January cold water can reach the surface and freeze immediately at the surface of the outlet due to cold surface air temperatures. Due to the winter temperatures the spring water can block the outlet by freezing and the spring water find a different outlet.
- Spring: The icing dome thaw at the ice surface and at its outline in the contact with the warmer soil and vegetation. Increasing water temperatures accelerate the thawing process in March and April and artesic water is pressed on the surface, preferably at the sides of the icing plate.

## Distribution of icing in the study area

Study area is located at the north eastern border of Ulaanbaatar city in the lower part of the Uliastai river sub basin in the north Central Mongolia. The Uliastai River has a catchment area of 705.9 km$^2$ and includes several springs in the study area (Figure 1). The elevation of the river basin ranges from 1225 m a.s.l in the lower part of the catchment to 2773 m a.s.l in the uppermost part with the mountain summits.

In study area 1 three locations of icing (U1, U2 and U3) observations with different conditions were selected in the lower part of catchment of Uliastai valley. U1 and U2 represented icing under natural condition, while U3 represented an icing feature, which impact human infrastructure. Springs and river channels exist in U1 and U2 area, while U3 is located inside a settlement area, which is quite far away from the river channel. The ice hummock is wide distributed cryogenic landform in icing areas, and cracks usually form along the Uliastai river valley. The soil of the study area is unusually characterized by fine sediment in the valley, with abundant soil moisture, and predominantly stones and boulders on the slopes. According to geological study, there are several small faults in the study area, especially in the lower part of the basin (Figure 1).

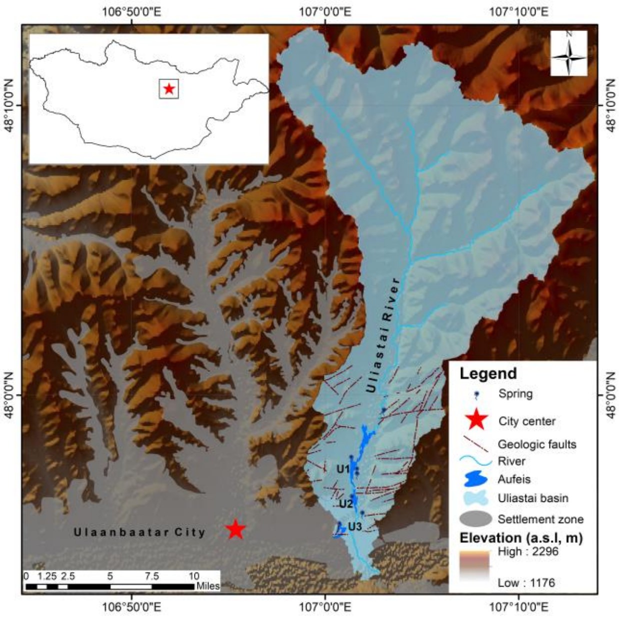



Figure 1. Location of study area Uliastai valley. The area of icing based on Landsat image with the scene id of LT05_L1TP_131027_19940329_20170114_01_T1 and, springs, river and faults are based on topographic and geological maps with scales 1:100,000.

## Method

We used Landsat and Sentinel-2 satellite images in order to evaluate the area of icing and its special dynamics. The satellite images obtained from https://eos.com/, with resolutions of 30 m for Landsat and 15 m for Sentinel-2. Several researches successfully have used the satellite images and normalized difference snow index (NDSI) for mapping the icing area [e.g., 2; 4; 5; 6; 7], permitting to use this index for our study.

$$NDSI = (Green-SWIR1) / (Green+SWIR1) \quad (1)$$

However, NDSI maps both snow and ice, making difficult to separate ice from snow. In order to avoid from this problem, we selected the satellite images for U1 and U2, which have the date with after snow melt in springs. Snow quickly melts in the settlement area compared with countryside, even in the middle winter. This is probably due to the heat from settlement and city dust.

We also used air temperature and precipitation data from the Ulaanbaatar metrological station in Ulaanbaatar city. Form the air temperature data, we calculated freezing degree days (FDD)—the daily degrees below freezing summed over the total number of days the temperature was below freezing; and thawing degree days (TDD)—the daily degrees above freezing summed over the total number of days the temperature was above freezing.

*The dynamics of icing*

Additionally, the vegetation index was calculated to investigate the vegetation differences between icing areas and non-icing areas.

$$NDVI = (NIR — Red) / (NIR + Red) \quad (2)$$

## Result

*Climate condition*

The long term air temperature data from 1969 to 2018 at the Ulaanbaatar station indicates that the daily air temperature ranges from -35.9º C to 30.6º C, with an average of -0.4º C. During the observation period, mean annual air temperature (MAAT) increased by 2.6º C, and increase rate was 0.51º C/10year (Figure 2a). The air temperature turns to positive values at the 10th of April and negative values at the 20th of October, respectively. The precipitation ranged from 166 mm to 395 mm between 1980 and 2018, with an average of 271 mm. From 1995 to 2006, precipitation sharply decreased, but after it increased continuously (Figure 2a). During the observation period, ratios of FDD and TDD significantly changed, and the former ranged from -3039.5 to -1866.4 and the later ranged from 1952.5 to 2699.3 (Figure 2b). The increase ratio of FDD was lower with an average of 52.6/10year than that the increase ratio of TDD with an average of 122.6/10year. No significant changes are observed on precipitation, and approximately 90 percent of precipitation occurs between April and September (DASHTSEREN et al. 2014).

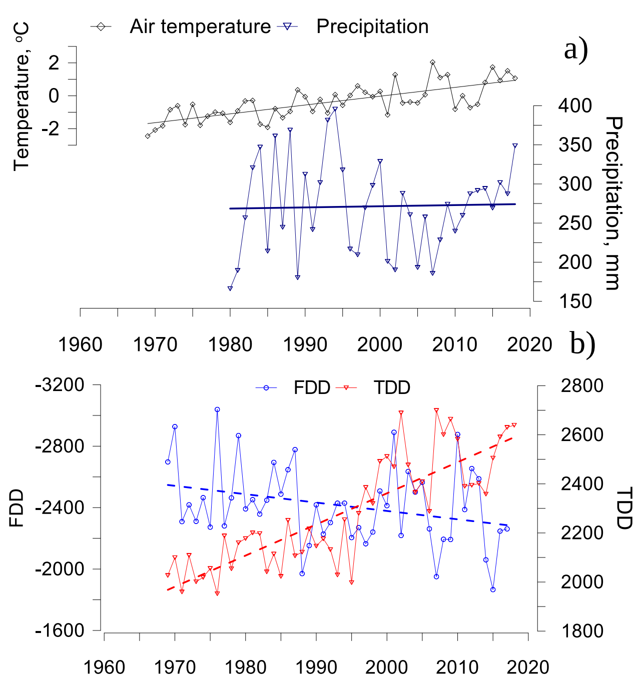
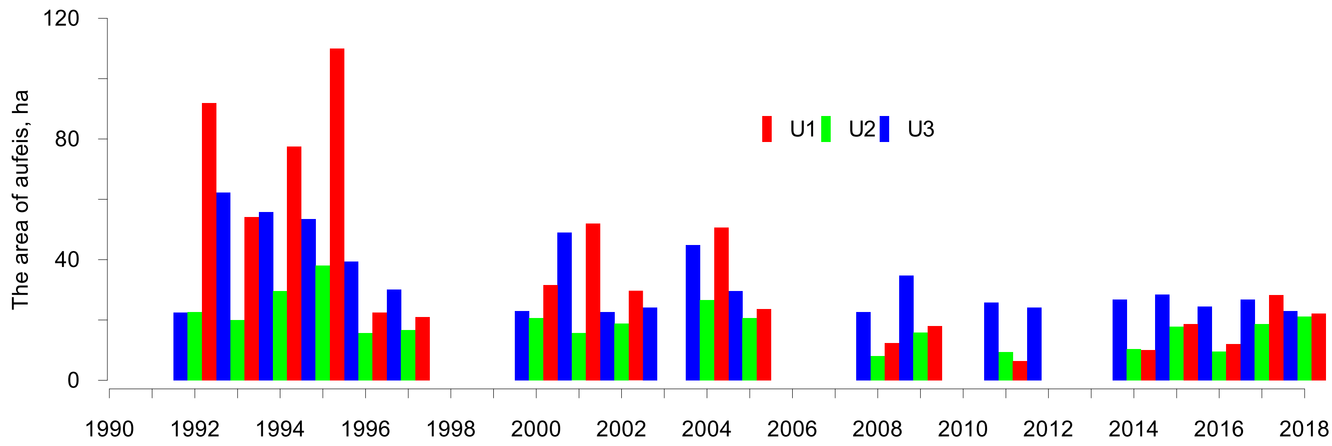



Figure 2. a) Changes of air temperature and precipitation and b) FDD, TDD at the Ulaanbaatar meteorological station.

Figure 3 shows the long term icing area changes at U1, U2 and U3. According to this result, the area of icing at the sites gradually decreased, and most significant was accounted at U1. During the mapping period between 1992 and 2018, the icing area contracted from 110.0 ha to 6.4 ha at U1, from 38.0 ha to 6.0 ha at U2 and from 55.8 ha to 22.7 ha at U3, respectively. After 1995s, icing was not developed at the head of U1, but only formed down at the foot of U18 by leaving spring water. In 2018, the icing was formed 1.2 km long and 0.36 km wide at U1, 1.30 km long and 0.34 km wide at U2 and 0.68 km long and 0.82 km wide at U3, respectively. Based on satellite images of 1997-1998, 2001-2002, 2008-2009 and 2013-2014, icing at U3 begins to developed in the beginning of October and continues until the mid of February when icing has the largest extension, then it gradually degrades and completely disappears by the beginning of May.




## Conclusions

The result of this study show that the formations of icingess belong to spring and river. The meteorological data from 1969 to 2018 within the study area indicate that MAAT increased by 2.6ºC, while no significant changes are observed on precipitation. The areas of icing significantly decreased at all sites and it is likely related to the air temperature regime. Icing features are influencing human infrastructure negatively and can contribute to environmental pollution. To avoid these negative effects a careful urban planning can be useful and an adapted technology for disadvantaged environmental location must be implemented.

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