Landscape-interpretation mapping of the air temperature field of the Mondy depression

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Abstract. Air temperature is one of the most important climate characteristics, which is used for climate research, investigation and modeling of vegetation, hydrological parameters and other landscape components as well as geosystems entirely. The goal of this research is investigation and mapping of the seasonal and daily air temperature regime of different landscapes of Mondy valley. For the research we use landscape map of the area on the level of group of facies as well as thermochron devices. For the analysis of air temperature regime of different landscapes we used year-round time air temperature data for 2013 from 12 key areas. For each class of facies of the landscape map monthly air temperature characteristics were calculated, and maps of mean monthly air temperature were made. According to the annual mean air temperature values landscapes of the bottom of the valley are colder than landscapes of slopes. Temperature regimes of landscapes in summer and in winter are different. In winter landscapes of the central part of the valley are characterized by the lowest values of air temperature, and the landscapes of the ridges – by the highest temperature due to winter temperature inversions.

1. Introduction
Air temperature is one of the most important climatic characteristics used for studying climate, research and modeling of vegetation, hydrological parameters, various components of landscapes, and geosystems in general. The study of the change in air temperature has become particularly relevant in recent decades due to the observed global warming.

When mapping the air temperature field in mountainous regions, extrapolation of ground-based measurements (in most cases they are the data of meteorological stations) the consideration of a large number of factors requires [1], therefore, additional information such as space images and modeling results are used.

The aim of the research is to study and map the features of the seasonal variation of air temperature in different landscapes of the Mondy depression based on the data of micrometeorological measurements of the surface air temperature and the landscape map of the territory.

2. Objects, data and methods
The object of research is the territory of the Mondy intermountain bolson. The basin is located along the Irkut river near the border with Mongolia. It is the most highly located and compact of the basins of the Tunka branch and closes it in the west, and represents a lake-like expansion of the Irkut valley. Its length is about 15 km, width is 6-7 km. The absolute height is 1344 meters [2]. In the south the
bolson is bounded by the Khamar-Daban ridge, and in the north by the Tunka Goletz ridge (Eastern Sayans). The territory belongs to the zone of sporadic permafrost [3, 4] and is characterized by strongly continental climate [5]. The annual precipitation in the bottom of the basin is relatively small and increases toward its sides [6, 7]. The study area is characterized by a variety of landscape conditions, forms of relief and soil-forming rocks, and a long history of economic development [7, 8]. All this allows to explore a wide variety of landscapes (the goletz, mountain taiga and mountain steppe landscapes) and their temperature features, as well as the bolson effects on a compact territory.

In 2007 we started interdisciplinary physical-geographical studies in the Tunka valley [4, 9-11]. A GIS dataset of the research area was created, containing topographic, small-scale geological and landscape maps, a digital elevation model (SRTM), Landsat-5, -7 and SPOT-4 space images. In previous studies, the authors validated the data of Landsat satellite measurements in the far infrared band based on ground-based measurements of air temperature using autonomous thermographs DS-1922 [12]. Based on the remote sensing data an analysis of the space-time changes in the surface temperature field in the territory of the Tunka depression [4, 10, 11] was made. The mapping of the air temperature field of the Tunka bolson was made on a landscape basis [13].

The method of landscape-interpretation mapping [14] of the characteristics of the temperature field is applied in this paper. The method is based on the fact that a certain type of geosystem (for example, a class of facies) has homogeneous natural characteristics throughout its range. This allows extrapolating characteristics (including air temperature) measured at one or several points of the range of a certain class of facies to the entire range of this class of facies.

Mapping of the air temperature field is made based on a landscape-typological map of the territory at the level of facies classes M 1: 100000 [15]. The study area is represented by nine classes of facies, belonging to four groups of geomes (figure 1).

Figure 1. Landscapes of the Mondy depression: 1-6 – classes of facies; Tunka Goletz ridge: 1- Class of goletz facies; 2 - Class of mountain taiga (larch fwith Siberian pine) facies on steep slopes; 3 - Class of meadow-steppe facies of the Irkut valley; 4 - Class of steppe facies on slopes; Khamar-Daban ridge: 5- Class of mountain taiga (larch with Siberian pine) facies on smooth slopes; 6 - Class of mountain taiga (larch with Siberian pine and dwarf birch) facies on flat interfluve, 7 – thermographs locations; 8 – rivers. 9 – absolute isohyps (in 100m), 10 – roads.
For micrometeorological measurements of the surface air temperature, autonomous thermographs DS-1922 are used, which allow solving the problems of climate research at a local level. The thermograph is an electronic recorder (logger), protected from external influences, accumulating in its own memory the values of the temperature of its surrounding environment, with reference to real time.

At present, 12 observation sites are located on the territory of the Mondy bolson in the altitude range from 1100 to 2100 m above sea level (table 1), which form a transect from the right to the left side of the basin and situated into the range of each class of facies. The devices are installed at a height of 2 m from the underlying surface and programmed for measurements at a frequency of 3 hours, synchronously with measurements at weather stations. The measurement data are read from the thermal registers once a year. For the analysis of microclimatic features of the temperature regime of air in different landscapes, year-round data for 2013 were used.

3. Results and discussion

For each class of facies, the average monthly air temperature values for each month of 2013 are calculated (table 1) and are presented in the form of maps (figure 2).

| Table 1. Average monthly air temperature within different classes of facies of the Mondy depression |
| Classes of facies | Range of altitudes | N \( ^a \) | Average monthly air temperature °C, 1 – 12 - months of the year |
|-------------------|-------------------|------|-----------------------------|
|                   |                   |      | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 |
| 1                 | 1915-3081         | 1    | -15.8 | -18.6 | -9.7 | -4.3 | 2.1 | 7.1 | 9.9 | 9.2 | 1.6 | -3.9 | -8.8 | -12.2 |
| 2                 | 1199-2550         | 4    | -15.5 | -17.4 | -8.3 | -2.3 | 4.2 | 8.8 | 11.0 | 10.6 | 3.3 | -2.0 | -6.5 | -11.2 |
| 3                 | 1182-1429         | 1    | -22.1 | -19.3 | -8.0 | 0.1 | 7.5 | 11.8 | 14.4 | 13.6 | 4.9 | -1.9 | -6.7 | -14.1 |
| 4                 | 1235-1534         | 2    | -18.0 | -17.0 | -7.1 | 0.8 | 8.0 | 12.1 | 14.4 | 13.6 | 5.3 | -1.0 | -5.7 | -12.4 |
| 5                 | 1182-2072         | 2    | -18.5 | -18.4 | -8.2 | -0.5 | 6.6 | 10.8 | 13.0 | 12.3 | 4.6 | -1.5 | -6.0 | -12.3 |
| 6                 | 1576-2017         | 2    | -18.5 | -19.0 | -9.5 | -2.8 | 3.5 | 8.8 | 11.1 | 10.3 | 2.3 | -3.5 | -8.3 | -13.3 |

\( ^a \)Note: number of sensors

The average annual air temperature (according to the data of the installed sensors) in the territory of the Mondy depression varies from -3.6 °C on slopes to -0.6 °C in the central part. These values are average according to the data from the sensors from all over the basin and do not reflect the microclimate peculiarities in certain types of landscapes. The coldest and warmest months are January (on slopes - February) and July, the average monthly temperature of the basin air in these months is -18.1 (-18.3) and 12.3 °C, respectively.

Microclimatic features of the distribution of air temperature in various landscapes of the Mondy depression are most visible in January, the difference between the warmest and the coldest class of facies is 6.6 °C. The lowest mean monthly air temperature in January is fixed in the landscapes of the central part of the basin: this is the class of meadow-steppe facies of the Irkut valley (-22.1 °C). Slopes of the Tunka goletz ridge are 3 °C warmer than the slopes of the Khamar-Daban ridge. This is due to the presence of winter temperature inversions, when the temperature rises with altitude. Therefore, the landscapes of the central part of the basin are the most cold, and the most elevated slopes of the Tunka goletz ridge are the warmest. Vegetation conditions on the slopes do not have a significant effect on the average monthly temperature values in the winter, the differentiation of the temperature along the slope is due to the presence of powerful temperature inversions.

The distribution of the average monthly temperature in July according to the classes of facies is more homogenous than in January. The difference between the warmest and the coldest class of facies is 4.5 °C. The most warm in the summer are the facies classes located in the central part of the basin, the average monthly temperature here is 14.4 °C.
Figure 2. The spatial distribution of the mean monthly air temperature (°C) within the various classes of facies of the Mondy depression: II - IX - months of the year; 1 - -23 - -22; 2 - -22 - -21; 3 - -21 - -20; 4 - -20 - -19; 5 - -19 - -18; 6 - -18 - -17; 7 - -17 - -16; 8 - -16 - -15; 9 - -15 - -14; 10 - -14 - -13; 11 - -13 - -12; 12 - -12 - -11; 13 - -11 - -10; 14 - -10 - -9; 15 - -9 - -8; 16 - -8 - -7; 17 - -7 - -6; 18 - -6 - -5; 19 - -5 - -4; 20 - -4 - -3; 21 - -3 - -2; 22 - -2 - -1; 23 - -1 - 0; 24 - 0 - 1; 25 - 1 - 2; 26 - 2 - 3; 27 - 3 - 4; 28 - 4 - 5; 29 - 5 - 6; 30 - 6 - 7; 31 - 7 - 8; 32 - 8 - 9; 33 - 9 - 10; 34 - 10 - 11; 35 - 11 - 12; 36 - 12 - 13; 37 - 13 - 14; 38 - 14 - 15

On the Khamar-Daban ridge, the average monthly July temperature in the lower part of the slope is 13.0 °C (the class of mountain taiga (larch with Siberian pine) facies of smooth slopes) and decreases to 11.1 °C in the upper part of the slope (the class of mountain taiga (larch with Siberian pine and dwarf birch) facies of flat interfluve). On the Tunka Goletz ridge, the average monthly temperature in July falls from 14.4 °C in the foothills (the class of mountain taiga facies) to 9.9 °C in the goletz belt.

Thus, relative to January, the picture of the change in mean temperature values from the center of the basin to its sides is transformed: the central part of the basin is heated in summer, the values of the temperature decrease upon transition to the mountain taiga landscapes, the higher is altitude the lower is temperature.

In February, March, and also in October-December, the difference in mean monthly temperature between different classes of facies is insignificant. It peaks in January and May. From December to
February, there are insignificant temperature inversions, the maximum in January, in the remaining months the temperature decreases with altitude.

To extrapolate the data of point observations of air temperature, various models are used, taking into account predominantly the relief characteristics, as well as the circulation of the atmosphere, the distribution of solar radiation and other parameters [16, 17]. Such models are often based on the data of meteorological stations and they contain general patterns of temperature changes with other parameters, for example, a decrease in temperature with altitude. On the territory of the Mondy bolson due to temperature inversion processes, the general laws of temperature decrease with altitude are violated, which leads to erroneous calculations of such models. Also in recent decades remote data have been widely used to analyze the spatial distribution of the temperature field [18]. However, these data contain uncertainties [11, 19], and also reflect only a certain time sample (time of survey). Using these data, it is difficult to assess the diurnal and seasonal temperature changes, especially the average monthly values.

The advantage of this work is the use of a dense network of ground-based observations with the use of thermographs DS-1922, as well as the method of landscape-interpretation mapping. The landscape approach in the mapping of meteorological parameters allows to take into account the influencing factors that have already been considered in the compilation of the landscape map, which greatly simplifies the mapping process.

4. Conclusions

Thus, the conducted study and mapping of the seasonal air temperature of various landscapes of the Mondy basin in the facies class section showed that, by average annual temperature, the landscapes located in the central part of the bolson are cooler than the landscapes of the sides of the basin. However, the temperature regimes of the landscapes in summer and winter are very different. In winter, the landscapes of the central part of the basin are characterized by the lower temperature values than the landscapes of the slopes of ridges, which is due to the presence of winter temperature inversions; in the summer the reverse picture is observed.

References

[1] Isaev A A 1988 Statistics in Meteorology and Climatology (Moscow: Moscow State University Press) p 248
[2] Vyrkin V B, Kuzmin VA and Snytko VA 1991 The generality and differences of some features of the nature of the Tunka branch of the hollows Geography and Natural Resources 4 61-8
[3] Lamakin V V 1935 Past relief formation in the Tunkinsky Baikal region Earth science vol 38 (Moscow — Leningrad: ONTI) pp 1-26
[4] Vasilenko O V and Voropay N N 2015 Features of formation of the climate of the depressions of the southwestern Baikal region Izvestiya RAS, Geographic Series 2 104-11
[5] Belousov V M, Budhe I Yu and Radziminovich Y B 2000 Physico-Geographical Characteristics and Problems of Ecology of the Southwestern Branch of the Baikal Rift Zone (Irkutsk: Irkutsk State University Press) p 160
[6] Kartushin V A 1969 Agroclimatic Resources of the South of Eastern Siberia (Irkutsk: East-Sib) p 100
[7] Larin S I 1991 The main stages of development of landscapes of the Tunka hollows Historical and Geographical Studies of Southern Siberia (Irkutsk: Publishing House of the IG SB RAS) pp 70-85
[8] Holboyeva S A and Namzalov B B 2000 Steppes of the Tunka Depression South-Western Priibaikalye (Ulan-Ude: Publishing house of the Belarusian State University) p 116
[9] Istomina E A 2012 Geoinformation mapping of landscapes of the Tunka depression basing on the method of factorial-dynamic classification Geodesy and Cartography 4 32-9
[10] Voropay N N, Istomina E A and Vasilenko O V 2011 Investigation of the temperature field of the terrestrial surface of the Tunka depression with the use of Landsat satellite images *The Atmosphere and Ocean Optics* **1** 67-73

[11] Istomina E A and Vasilenko O V 2015 Geoinformation analysis of the temperature field of the landscapes of the Tunka depression with the use of Landsat satellite imagery and ground data *Geography and Natural Resources* **4** 162-70

[12] Scientific and Technical Laboratory «Electronic Instruments» 2007 (in Russian) Income accessed online on 11th May 2017 via http://www.thermochron.ru

[13] Vasilenko O V, Istomina E A and Voropay N N 2017 Mapping of the air temperature field of the Tunka depression on a landscape basis *Geography and Natural Resources* **2** 182-9

[14] Cherkashin A K 2005 *Landscape–Interpretation Mapping* (Novosibirsk: Nauka) p 424

[15] Istomina E A and Ovchinnikova E V 2018 Geoinformation mapping of landscapes of the Mondy basin *Geodesy and Cartography* **4** 23-30

[16] Stahl K, Moore R D, Floyer J A, Asplin M G and McKendry I G 2006 Comparison of approaches for spatial interpolation of daily air temperature in a large region with complex topography and highly variable station density *Agricultural and Forest Meteorology* **139** 224-36

[17] Global Climate Data 2016 (in Russian) Income accessed online on 13th June 2018 via http://worldclim.org/

[18] Li Z, Tang B, Wu H, Ren H, Yan G, Wan Z, Trigo I F and Sobrino J A 2013 Satellite-derived land surface temperature: Current status and perspectives *Remote Sensing of Environment* **131** 14-37

[19] Kochendorfer K P J, Dumas E J, Guillevic P C, Baker C B, Meyers T P and Martos B 2015 Comparison of in-situ, aircraft, and satellite land surface temperature measurements over a NOAA Climate Reference Network site *Remote Sensing of Environment* **165** 249-64