Landscape and Climate Studies of Mountain Areas of the Baikal Natural Territory

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Abstract. The results of research of the Baikal Natural Territory in the western part of the Primorski Ridge and in the eastern part of the Barguzinskii Ridge are presented. The regional background and the main factors of the landscape differentiation of the research areas are analyzed. Some regularities in the structure of the topological level of the geosystems are revealed. We have found that the main factors affecting the landscape diversity are slope exposition and steepness, rock composition and structure, absolute height, precipitation, and anthropogenic impacts. We use data of weather stations on the Barguzinskii Ridge. The microclimatic observations along a macro-slope facing the Baikal Lake are used to examine the temperature-humidity regime of landscapes in detail, taking into account altitudinal zonality, exposure and steepness of slopes throughout the year. The thus obtained meteorological data can be used to give a climatic description of the study area.

1. Introduction
The intensity and orientation of many natural processes is caused by global climate change. However, there is a need to research these impacts, which have a pronounced regional character in the process of research within specific territories, i.e. the Baikal Natural Territory with mountain-taiga geosystems has been chosen as a case study, where warming and increasing climate humidification are recorded, along with a complex fire situation and tourism growth. The landscapes of mountain territories refer to the most dynamic, unstable natural systems with extreme instability to natural influences.

The landscapes of the Baikal Natural Territory are represented by a wide range of landscapes with different altitudinal-belt, expositional, and microclimatic situations. The research areas are located within the Baikal-Dzhugdzhurskii physiogeographical area. The specificity of the high-altitude landscape structure, which includes an almost complete set of geosystems of the Baikal mountain environment, is due to the manifestation of barrier-shadow, arid-hollow, and piedmont effects complicated by the influence of the Baikal water mass [1]. Furthermore, the formation of modern landscapes in the territory of the test site is associated with the specifics of the relief and neotectonics, as well as their influence on the vegetation and soils. Noteworthy among the main exogenous processes are frost weathering, rill and sheet wash, linear erosion, cryogenic processes on talus aprons, karst and suffosion in topographic lows [2-3].

2. Objects, data and methods
The landscape structure was investigated in key areas of the Primorskii and Barguzinskii Ridges. The first key site is located on the southeastern slope facing Lake Baikal, the macroslope of the Primorskii Ridge - from the Sarminsky Golets to the Lake Baikal shore. The relief of the territory is determined by an extended bench (Obruchevskii sbrosonadvig'dip-slip fault) along the Primorskii Ridge, where the Archean and Lower Proterozoic rocks are represented. The climate of the territory is characterized...
by an anticyclone regime with insufficient atmospheric humidity (100-400 mm per year), a short vegetation period (4-4.5 months), and dry winter. The mean air temperature in January is -17.3°C, in July - 14.4°C, and the mean annual temperature is 0.7°C [4].

To study the current state of mountain landscapes, the geosystemic regional typological approach of the Siberian geographic school was used, which was tested in various regions of Siberia [5–8].

The research on the Barguzinskii Ridge is moving according to the landscape macroprofile from the piedmont near the settlement Barguzin, along Bol. Chivyrkui to the Chivyrukskii Bay. The profile coincides with the path "Way to Clean Baikal" located in the northern part of the Trans-Baikal National Park as part of the "Zapovednoe Podlemorye".

3. Results and discussion

Thus, the golets belt of the ridges is represented by gravelly tundra with grassy wastelands, including low shrub, shrub, grass and lichen. The sub-golets belt is represented by mountain pine facies with the envelopment of yernik (shrubs). The transition zone from the sub-golets facies to the mountain taiga is represented by Siberian pine shrub-moss-lichen forests with groups of mountain pine.

In the mid-mountain taiga zone (from 1000 m) of the southeastern macroslope of the Barguzinskii Ridge, the thickets of mountain pine with dwarf birch (Betula divaricata) include rather oppressed pine (Pinus sylvestris) and Siberian fir (Abies sibirica). The distribution of vegetation on the western macroslope of the mountain range corresponds to the view of the wet Cisbaikalian type of beltedness [9]. On the western macroslope they include fir, Siberian pine, spruce, and finally on the Primorskii Ridge – Siberian cedar (Pinus sibirica). In the mountain taiga of middle mountains of the latter, the most widely distributed are various types of larch forests. On the slopes of the southern exposition of the Barguzinskii Ridge larch forests with pine and Siberian pine blueberry-ledum and cowberry-moss facies are predominant. On the western macroslope, pine forests are common here; they are common for moraine complexes and sandy alluvial and deluvial sediments. On the gentle slopes there are ripe and ripening pine-Siberian pine cowberry with aspen, spruce, and Siberian pine in the undergrowth, alder and mountain pine in the undergrowth. On the gentle shadow slopes of the ridge there are ripe Siberian pine ledum-lichen and blueberry-cowberry-mossberry with fir and birch in the second tier, with fir in the undergrowth on weakly podzolized sandy loamy soils. The eastern slope of the Barguzin range is characterized by the formation of pine grass cones of removal, merged into almost a single line [10].

The Baikal terrace of the Barguzinskii Ridge is occupied by pine and Siberian pine forests with fir and larch. The Priol’khonskoe plateau stretches from the foot of the Primorskii Ridge to the Lake Baikal shores, where dry larch and pine-larch forests are predominant, as well as arid mountain steppes with rare and endemic plant species. On the Barguzinskii Ridge steppe landscapes occur only on gentle slopes of southern exposures within the sub-golets belt in the form of cryophyte-xerophyte sedge-fescue wastelands (Figure 1).

The mountain-taiga belt of all three macro-slopes of the ridges is covered by burned-out ground of different ages.

For analysis of climate changes in the study area, the data of weather stations of the Roshydromet network were used for an instrumental observation period of 1900-2016. The trends in the air temperature and precipitation were studied, which are the main climatic factors affecting the characteristics of the landscape.

The research results show that warming occurred throughout the territory, on average, over the year. The thermal regime at the weather stations is characterized by considerable variability, which is mostly noticeable in the winter months. Long-term changes in the air temperature at some weather stations are shown in Figure 2. The equations of the linear trend are shown during the period of the most intensive global warming (1975-2016).

The annual trend values at all stations are positive and range from 0.28 to 0.42°C / 10 years. The air temperature fluctuations in the region are in synchronism with the global ones. Statistically significant trends (p<0.05) for all months are positive. On average, they vary from 0.33°C / 10 years.
(September) to $0.99^\circ C/10$ years (February) for the territory. The mean-square deviation for the entire sample ranges from 0.072 (April, May) to 0.368 (January), and for significant trends from 0.070 (April) to 0.409 (December).

Figure 1. Landscape-typological map of the test site Sarma [11]:
1-4 Golots mountain-tundra (1650-1500 m); 5-6 Sub-golots (1450-1350 m); 7-12 Mountain-taiga geosystems of reduced development (1400-900 m). The upper part of the belt (1500-1300 m); 13-22 Mountain-taiga (1300-900 m) of transverse mountain spurs of the ridge, watersheds and gentle slopes; 23-28 Low mountain-taiga and mountain steppe (900-600 m) slopes of the Primorskii Ridge; 29-32 Foothill taiga (subtaiga) and mountain steppe of the Priol’khonskoe plateau (hillocky area) (600-500 m); 33-39 River valleys and debris cone introzonal; 40-44 Coastal inclined plains and subaquatic; 45 Anthropogenic.

In the context of warming, we can note a decrease in the climate continentality due to a decrease in the annual temperature amplitudes, which is associated with a positive trend of minimum temperatures. Unlike the mean values, the extreme ones have greater variability and less repeatability. The greatest changes in the upward direction are observed in the minimum air temperatures: on average, $2^\circ C/10$ years, which is an order of magnitude higher than the analogous characteristics for the absolute maxima. This once again testifies that the largest contribution to the change in the mean annual temperatures is made by the air temperatures of the cold period.
Figure 2. Long-term changes in mean annual air temperature values at weather stations.

The trends in the annual precipitation for most stations are statistically insignificant. However, significant interannual fluctuations are observed. Figure 3 shows long-term changes in the sum of atmospheric precipitation for the cold (October-April) and warm (May-September) periods for the selected weather stations.

Figure 3. Long-term changes in sums of atmospheric precipitation for cold (CP) and warm (WP) periods.

In addition to the winter precipitation, the height of the snow cover is of interest. The changes in these trends on the Lake Baikal shore in the 20th century are positive. Negative trends are observed in the first decade of the 21st century. The maximum decadal height of the snow cover (60-86 cm) was recorded at the weather stations of the eastern shore, with an average long-term value of 25-35 cm. At the weather stations of the western coast, the maximum decadal height of the snow cover does not exceed 30-40 cm, with a long-term average height of 2-6 cm. On the Lake Baikal shore the average date of stable snow cover formation is November 24, and the date of its destruction is March 27 (April
23 on the eastern shore and March 19 on the western shore). After the 1980s there was a tendency to shift the dates of the onset and destruction of the snow cover to earlier periods. The average long-term duration of the snow cover in the region is 138 days, on the eastern shore it is 178 days, and on the western shore 126 days. There is a linear dependence of the stable snow cover duration on the mean air temperature over the cold period and on the precipitation.

To estimate the temperature and humidity regime of the mountain landscapes, the data of weather stations are not sufficient; they are usually located in river valleys on the bottom of basins. Microclimatic observations were organized for a detailed analysis of the influence of climatic factors on the landscape characteristics. The test site is located near the Sarma River. The sites are located in the altitude range of 450-1650 m above the sea level. Measurements of the temperature and humidity, the soil surface temperature, and the soil temperature at a depth of 40 cm are carried out using electronic thermographs (DS1922) and hygrographs (DS1923) with a periodicity of 3 hours synchronously with observations at weather stations of Roshydromet. During an expedition of 2017 a series of weather data was added (the beginning of observations in 2013) (see Figure 4).

The influence of landscape characteristics, primarily the high-altitude zonality, on the temperature and humidity regime is manifested by the mean monthly and mean annual values of meteorological variables (Table 1). Analysis of the results of observations shows that the contrasts become more pronounced. The differences between the mean temperatures at the sites located on the slope in several months do not exceed 6-7°C. In this case the temperature conditions in the lower part of the slope are more contrasting.

Two groups of sites can be revealed according to the relative humidity regime: dry ones located in the foothills (the mean monthly values do not exceed 70%) and wet ones (the mean monthly values throughout the year, except for April and May, are in the range of 70-95%). At the same time, the most humid ones throughout the profile are December-January, and the driest one is April. The temperature regime of the soil is formed under the influence of a number of factors; the main one in our territory is vegetation (its availability and type). In the summer months, in more exposed (burnt, golets) areas, more intensive heating of the soil occurs than at the forest ones. In winter, the lack of vegetation contributes to the blowing out of the snow and, correspondingly, to a more intensive cooling of the surface and deeper freezing of the soil.
Table 1. Annual and extreme climate characteristics at study sites.

| Site number | S1  | S2  | S3  | S4  | S5  | S6  | S7  | S8  | S9  |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Height above sea level, m | 1656 | 1418 | 1101 | 1117 | 908 | 807 | 670 | 603 | 460 |
| Air temperature, °C | Mean | -3.3 | -2.0 | -1.7 | -0.9 | -1.8 | 0.5 | 2.4 | 2.8 | 0.1 |
| Max | 25.5 | 26 | 29 | 31.5 | 28.5 | 28.5 | 28.5 | 30 | 33 | 35 |
| Min | -35.5 | -33.5 | -33.5 | -32.5 | -35 | -29 | -27 | -26 | -25 | |
| Amplitude | 61 | 59.5 | 62.5 | 64 | 63.5 | 57.5 | 57 | 59 | 60 | |
| Air humidity, % | Mean | 80.3 | 76.9 | 75.9 | 73.5 | 81.8 | 71.4 | 63.9 | 63.7 | 66.1 |
| Max | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Min | 4.6 | 15.7 | 15.2 | 17.9 | 18.4 | 15 | 12.9 | 11.8 | 14.2 | |
| Amplitude | 95.4 | 84.3 | 84.8 | 82.1 | 81.6 | 85 | 87.1 | 88.2 | 85.8 | 99.9 |
| Soil surface temperature, °C | Mean | -4.2 | 2.2 | 2.0 | 2.0 | 2.1 | 2.9 | -0.4 | 6.0 | 1.9 |
| Max | 37.4 | 25.6 | 21.6 | 22.3 | 26.5 | 52 | 35.8 | 72 | 38.8 | 38.8 |
| Min | -24.2 | -6.2 | -5 | -9.7 | -6.7 | -13.3 | -18.4 | -16 | -21.6 | |
| Amplitude | 61.6 | 31.8 | 26.6 | 32.0 | 33.2 | 65.3 | 54.2 | 88 | 60.4 | 60.4 |
| Soil temperature at a depth of 40 cm, °C | Mean | -2.0 | 1.0 | 0.4 | 1.0 | 0.7 | 2.8 | 2.3 | 4.7 | 2.8 |
| Max | 10.9 | 7.2 | 3.8 | 11.8 | 9.3 | 15.3 | 13.6 | 17.8 | 19.1 | 19.1 |
| Min | -17.7 | -1.7 | -1.6 | -4.6 | -3.6 | -9.7 | -9.9 | -7.8 | -11.5 | |
| Amplitude | 28.6 | 8.9 | 5.4 | 16.4 | 12.9 | 25 | 23.5 | 25.6 | 30.6 | 30.6 |

Thus, at sites S1 (Golets) and S2 (the upper boundary of the forest), the mean monthly and minimum air temperatures differ by not more than 1-2°C. In this case, in the exposed area (S1) the surface temperature of the soil drops to -24.2°C, and the soil temperature at a depth of 40 cm is up to -17.7°C. At the forested site (S2) these values are -6.2 and -1.7 °C, respectively. In the warm seasons the contrasts between these areas can reach 11.8°C on the surface and 3.7°C at a depth of 40 cm.

4. Conclusions
The spatiotemporal organization of the geosystems of the Baikal Lake shores consists of thick dark-coniferous taiga with neighboring steppizated subtaiga, shrub and dwarf Siberian pine trees, mountain tundras, and scree with waterlogged lowlands. This indicates diverse regional and local responses to changes in the environmental conditions. The data of microclimatic observations can be used to study the temperature and humidity regimes of the landscapes in detail, taking into account the altitudinal zonality, exposure and steepness of the slopes throughout the year. The above-obtained unique observational data can be used to correct the climatic description of the research area, which is currently based mainly on data from weather stations, whose network does not cover mountain areas.

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