Microclimatic features of landscapes in the territory with a sparse network of meteorological observations

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Abstract. Automatic monitoring of air temperature and humidity in the mountain-depression landscapes of the Tunka depression has been organized. The results of the analysis of observation data for 10 years showed significant differences in the temperature regime in different landscapes. The sites can be divided into three groups – the slopes of the depression, pine-herbaceous landscapes, and the lacustrine-bog complex of the central part. The average annual air temperature at all sites is negative and vary in range $-0.7 \ldots -2.1^\circ\text{C}$. Vegetation has the greatest influence on microclimatic characteristics. The maximum contrasts in the temperature regime of the air throughout the year are observed in open areas with cloudless skies. In winter, this is explained by radiation cooling, and in summer – by the heating of the open surface in the daytime. In this case, not only the daily amplitude of air temperature in the open areas increases, but also the largest contrasts between the open and closed areas are observed.

1. Introduction

The description of microclimatic conditions, in this work, concerns mainly the Tunkinskie Goltsy and the adjacent depressions, the main attention is paid to the area of the Tunkinskaya depression, as the main object of research. The territory has good connections with large cities (Irkutsk, Ulan-Ude) and railway stations, thanks to a good highway, as well as rich natural, climatic, and balneological resources.

The position of the described territory within the southwestern part of the Baikal rift zone in the South Siberian physical-geographical region has imposed a number of peculiar features on the natural conditions of this region. The combination of high-mountainous relief and relatively low intermontane depressions, the latitudinal orientation of the main orographic elements, and local climatic conditions that complement the zonal features of the climate have created a wide variety of landscapes. The peculiarity of the climate of this territory lies in the fact that the territory is located in the central part of Asia, and almost no Atlantic and Pacific air masses come here. Thus, the meteorological regime is formed in the conditions of the Arctic air masses, which are transformed over the continent into temperate air masses. However, local forms of atmospheric circulation in mountainous terrain differ significantly from each other in terms of the regime of meteorological elements, therefore, it is rather difficult to subdivide the climate of individual territories of the region. Thus, the conditions of local circulation of the atmosphere and a wide variety of conditions of the underlying surface have a significant impact on the characteristics of the microclimate of the territory.
Weather stations, according to which it is possible to analyse the meteorological regime of territories with a wide variety of landscape conditions, are located mainly in river valleys, on flat, open areas, in relatively similar landscapes. On the territory of the Tunkinskaya depression, these are the stations Tunka, Kyren, and Arshan. The meteorological sites of these stations are located on an open, flat area in the Irkut River valley. Thus, the data of meteorological stations do not give an idea of the climatic regime of the prevailing high-mountainous forms of relief and the variety of landscape conditions. As a result, it becomes necessary to organize monitoring of microclimatic characteristics at the local level [1].

2. Models and Methods

Microclimate monitoring of various types of landscapes is carried out using automatic recorders of background temperature and humidity. The devices are a self-sufficient system with 8 kb volatile memory, which, after setting user-selected settings, measures and accumulates meteorological parameters in the internal memory [2]. The use of automatic recorders is a fairly good alternative to standard meteorological equipment and allows solving of many problems of modern science [3-12].

Observations in the study area are carried out within the framework of complex geographic work at the Tunkinsky Basin Station of the V B Sochava Institute of Geography SB RAS (http://irigs.irk.ru/station/tunka.html). Automatic recorders were located on sites with contrast landscape conditions, with varying degrees of closure, airflow, and at different altitudes above sea level. Thus, the data from automatic recorders reflect the temperature characteristics of a particular landscape of the Tunkinskaya depression. Automatic recorders are installed at model sites in the height range from 713 m to 2,119 m. A total of 58 sites have been organized on the territory of the Tunkinskaya depression, measurements of air temperature and relative humidity are carried out year-round with an interval of every 3 hours, synchronously with observations at the network of weather stations of Rosgydromet.

This paper considers such indicators as the onset of maximum and minimum values of amplitudes and average indicators in the daily and annual variations in air temperature and relative humidity. During the observations, significant differences were noted in the microclimatic characteristics of air temperature and relative humidity on sites with varying degrees of openness, properties of the underlying surface, and altitude.

3. Results and Discussion

According to the results of the cluster analysis of the air temperature characteristics, the observation sites were divided into two groups, located on the slopes of the basin and in the central part. Further, the sites of the central part of the basin, on the basis of average characteristics, are divided into two groups of pine-herbaceous landscapes and lacustrine-bog complex (Figure 1).

Despite the insignificant height difference, the average annual air temperatures in the central part of the basin differ significantly. At the observation sites within the lacustrine-bog complex of landscapes, the minimum values of the average annual air temperature were noted. Thus, on observation sites located in the valley landscapes of boggy meadows (A-34, A-36, A-38), in the altitude range from 721 m to 726 m above sea level, the average annual temperature reaches \(-2.1^\circ\text{C}\). The maximum values of the average annual air temperature were recorded at the observation sites located in the complex of pine-herbaceous landscapes. On sites located in the landscapes of pine forests and cedar-larch pine forests (A-26, A-28, A-30), in the altitude range from 766 m to 890 m above sea level, the average annual temperature is \(-0.4^\circ\text{C} – -0.7^\circ\text{C}\).

Also, on the sites located in the central part of the Tunkinskaya depression, in the complex of pine-herbaceous landscapes, high values of the absolute maximum air temperature, 40.5°C, were noted. In the conditions of meadow-steppe landscapes, the lacustrine-bog complex, the absolute maximum does not exceed 35°C.
Figure 1. Average annual air temperature in the central part of the Tunkinskaya depression:

a – observation sites located in a pine-herbaceous complex of landscapes,
b – observation sites located in the lacustrine-bog complex of landscapes.

The absolute minimum was recorded on the sites located in mires areas, the height of which does not exceed 729 m. The values of the absolute minimum here reach $-41.0^\circ C$. In the conditions of pine-herbaceous landscapes, the absolute minimum temperature does not exceed $-36.0^\circ C$. The maximum amplitude of changes in the average monthly values during the year was noted on sites located in meadow-steppe landscapes at 79.0°C. In the conditions of pine-herbaceous landscapes, the temperature amplitude during the year is a minimum 68°C.

For a more vivid demonstration of the influence of landscape conditions on the microclimatic regime, sites with different conditions of the underlying surface and the projective crown cover were selected. Further, the diurnal variation of air temperature in clear and cloudy weather, in warm and cold periods of the year is analysed.

In winter, the average daily air temperature in conditions of minimal cloudiness at sites in a pine forest with a high degree of the projective crown cover was $-30.1^\circ C$, at sites in open areas of crowns $-33.6^\circ C$. The onset of the maximum and minimum on sites under the canopy of a pine forest and in open areas were recorded at the same time – 15:00 and 6:00, respectively. At the same time, the difference in the values of the daily maximum and minimum was noted. In the open area, the maximum and minimum values of the urgent air temperature reach $-20.0^\circ C$ and $-41.0^\circ C$, respectively, on the site under the canopy of a pine forest $-21.7^\circ C$ and $-35.9^\circ C$. In conditions of maximum cloudiness, the differences in the diurnal temperature variation are less noticeable. The average daily temperature in a pine forest is $-10.2^\circ C$, in an open area $-10.8^\circ C$; maximum $-8.6^\circ C$ and $-8.0^\circ C$; minimum $-12.4^\circ C$ and $-13.5^\circ C$, respectively. Thus, in winter, under conditions of minimal cloudiness, the differences in the extreme of the daily variation of air temperature are more pronounced.

In the warm period, with maximum cloudiness on areas with contrasting conditions of the underlying surface and the projective crown cover, the differences in the daily variation of air temperature are less pronounced, and in some places are insignificant. Under conditions of minimum cloud cover, the degree of openness of the observation site affects the diurnal temperature variation to a greater extent. So, the average daily temperature in the forest is $13.9^\circ C$, in the open area it is $15.6^\circ C$. The minimum temperature in the forest was $2.9^\circ C$, and in the open area it was $2.0^\circ C$, the maximum was $26.5^\circ C$ and $33.5^\circ C$, respectively. In the warm period of the year, in the daytime, in open areas, due to the large influx of solar radiation on the underlying surface, the air temperature is higher than in a pine forest. At night, the difference in air temperature at the sites is minimal. Due to the crown of trees, radiation cooling in the forest is less than in open areas.
One of the characteristic features of the microclimate of mountain-hollow landscapes is the inversion of air temperature. On the territory of the Tunkinskaya depression, air temperature inversions are most pronounced on the southern slope of the Tunkinskie Goltsy. On the example of average annual values of air temperature, stable temperature inversions can be observed. Observations of the temperature regime of the air were carried out at sites in the range of heights from 870 m to 1,970 m a.s.l. The average annual air temperature on the slope was 0.8°C (Table 1). From the foot of the southern slope of the Tunkinskie Goltsy (870 m a.s.l.) to an altitude of 950 m above sea level, a standard decrease in temperature with altitude is observed. So, the average annual air temperature at the foot of the slope is −0.7°C. The average annual temperature drops to −2.1°C at 1,970 m a.s.l. The altitude gradient is negative its value up to −1.75°C/100 m. Further, the air temperature rises with altitude, the gradient remains positive up to an altitude of 1,210 m a.s.l.

Table 1. Characteristic of the air temperature on the slope of the Tunkinskiye Goltsy, °C.

| Observation area number / Height above sea level, m | T-2/870 | T-7/950 | T-11/1,070 | T-8/1,210 | T-4/1,420 | T-10/1,740 | T-9/1,970 | Tunka weather station/721 |
|---------------------------------------------------|---------|---------|-------------|-----------|-----------|-----------|-----------|--------------------------|
| Annual average                                    | −0.7    | −2.1    | 1.1         | 1.0       | −0.7      | −1.4      | −3.3      | −1.7                     |
| Min                                               | −29.0   | −27.0   | −26.5       | −26.5     | −27.5     | −27.5     | −30.0     | −41                      |
| Max                                               | 30.5    | 31.0    | 28.0        | 31.0      | 27.0      | 26.5      | 23.0      | 32                       |
| Annual amplitude                                  | 59.5    | 58.0    | 54.5        | 58.0      | 54.5      | 54.0      | 53.0      | 73                       |

Due to the powerful inversion of air temperature in the winter period at an altitude of 1,210 m a.s.l., the average annual air temperature remains positive and amounts to 1.0°C. Compared to the Tunka weather station, located in the central part of the basin at a distance of 25 km from the foot of the southern slope of the Tunkinskie Goltsy, the average annual temperature in the middle of the slope is 2.8°C higher. The minimum annual air temperature along the slope is −28.2°C, which is 11.1°C higher than in the centre of the basin. The maximum air temperature at the study sites is on average 28.4°C, which is 5.1°C less than in the basin.

The maximum frequency of inversion processes is observed in winter. The greatest gradient of air temperature change with height was noted in January. From the foot of the southern slope to an altitude of 950 m a.s.l., the value of the gradient is 2.1°C/100 m. An increase in the average monthly temperature in January is observed up to an altitude of 1,210 m a.s.l. The change in temperature with height closest to the standard distribution in the atmosphere, in the absence of inversions, is observed in June, July, and September.

4. Conclusion

Based on the data of observations of air temperature from model sites located in contrasting landscape conditions on the territory of the Tunkinskaya depression (Republic of Buryatia), the features of the temperature regime of mountain-depression landscapes were analysed.

As a result of the analysis of the average annual, average monthly data on air temperature, the following groups of sites were identified: located on the slopes and the central part of the hollow. In the central part of the basin, observation sites are divided into two main types – pine-herbaceous landscapes and lacustrine-bog complex of landscapes.

Despite the fact that the sites are located at relatively the same altitude (the difference in altitude is less than 176 m), the average annual air temperature has significant differences. Less warmed-up areas are located in open areas in the bog-lacustrine complex of landscapes. The warmest sites are located in pine-herbaceous landscapes.
In the cold period of the year, at night in open areas, due to radiation cooling, the air temperature is lower than under the forest canopy. In the warm period of the year, in the daytime, the heating of open areas is more significant. The result is a higher amplitude of the average annual and daily air temperature values. A feature of the temperature regime of the slopes of the basin is the inversion of the air temperature. The highest frequency of inversion processes is observed in winter. The maximum gradient of air temperature change with height in January from the foot of the southern slope of the Tunkinskie Goltsy to an altitude of 950 m above sea level, the temperature gradient is 2.1°C/100 m.

The above features of the temperature regime of the air are formed due to landscape conditions – height above sea level, the orientation of the slope, type of underlying surface, presence or absence of woody vegetation, etc. The weather stations in the study area are located in the central part of the basin, in a levelled open area. Thus, according to the station data, it is impossible to study the temperature regime of the air and its features.

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