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Trends in heat capacity changes of some layers in Southern Baikal during the modern period (from 2000 to 2020)

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ABSTRACT. Here, we present the results of a study of heat capacity in Southern Baikal based on the data on water temperature from 2000 to 2020, which were obtained at the buoy station near Ivanovskiy Cape. The revealed differences in trends in heat capacity changes in the upper 100 m layer and throughout the water column are associated with changes in some meteorological and hydrological factors during the study period.

Keywords: Lake Baikal, heat capacity, temperature regime, meteorological factors.

1. Introduction

The issue of the influence of climate change on the temperature regime of the entire Lake Baikal has been studied for a long time. However, taking into account the high diversity of biotopes confined to some area of the lake, the issue of climate influence at the meso- and microscale is relevant. The data obtained near Ivanovskiy Cape provide an opportunity to trace changes in some characteristics of the temperature regime at the mesoscale in Southern Baikal over the two past decades.

2. Materials and methods

For the analysis, we used the data on the water temperature from 1999 to 2020 from the Ice Camp buoy station (IC BS) located near the Baikal-GVD deep-water neutrino telescope (Ivanovskiy Cape, Southern Baikal). IC BS was installed in 1999 at the foot of an underwater slope (depth 1367 m) 3.5 km from the coast. For recording, from 5 to 19 thermistors of the TR series (accuracy ± 0.002°C) were used, which were located at depths from 15 to 20 m to the bottom. The discreteness of measurements in different years and different layers varied from 15 s to 15 min.

To calculate the heat capacity, *Q*, the formula adopted in (Verbolov et al., 1965) was used. Analysis of long-term changes in heat capacity was carried out taking into account thermal and dynamic features (Shimaraev, 1977): under-ice warming (March-April), spring warming (May), summer warming (June-September), autumn cooling (October), pre-winter cooling (November), and winter cooling (December-February). The materials of the 1999-2018 observations of the air temperature and wind speed at the Kultuk, Angara source and Bolshoye Goloustnoye weather stations were also used in the study.

3. Results

During the study period, the *Q* trends in the upper layer (15–100 m) and the entire water column were different. In the upper layer, significant positive changes in *Q* occurred during the autumn and pre-winter cooling. In the entire water column, we observed significant negative changes almost throughout the year, except for the autumn cooling. This indicates i) redistribution of heat in the water column (an increase in heat in the upper layer during autumn months) and ii) its general decrease over the year.

The change in heat capacity at the stage of the autumn cooling during the study period was 26.3 mJ/m^2·year, and at the stage of the pre-winter cooling – 12.8 mJ/m^2·year. An increase in the heat capacity values can be associated with an increase in wind speeds during months without ice. This led to an increase in the epilimnion thickness and change in the occurrence depth of the thermocline. The consequence of this was the accumulation of more heat in epilimnion in spring and summer, which weak insignificant trends in heat capacity at the stages of the spring and summer warming, as well as significant positive temperature trends in the upper water layer, indirectly confirm. At the stage of the autumn cooling, with the seasonal increase in wind speed, the thermocline was washed out and heat was redistributed in the layer of up to 200–250 m, which led to heat retention. At the stage of

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the pre-winter cooling, the change in wind speed was insignificant. During that time, at low temperatures, evaporation from the surface of the lake and heat transfer to the atmosphere increased. However, the positive significant trend in heat capacity remained in the layer from 15(19) to 100 m.

In the entire water column, there were negative trends in heat capacity. We recorded significant changes at all stages of the lake heating. At the same time, the correlation coefficient increased as the water column warmed: under-ice warming was 0.42 (0.1), spring warming – 0.45 (0.07) and summer warming – 0.57 (0.01). At the cooling stages, we observed significant correlation coefficients ($r = 0.47$, $p = 0.05$) during pre-winter and winter cooling. Although heat capacity of the autumn cooling stage had a high trend (–67.6 mJ/m^2·year), it was insignificant. A decrease in the values of heat capacity in the layer from 0 m to the bottom at the stages of pre-winter and winter cooling can result from the later periods of the lake freezing (Magnuson et al., 2000; Shimaraev et al., 2002; Shimaraev and Troitskaya, 2018). This leads to higher heat losses from the lake surface and retention of less heat in the water column, which we also observed during the under-ice and spring warming. The earlier dates of ice-break up and a positive trend in wind speed, an increase of which leads to redistribution of heat in the water column and reduces heating of the surface water layer, serve as an additional heat loss at this time (Magnuson et al., 2000; Shimaraev et al., 2002; Shimaraev and Troitskaya, 2018). Due to the earlier ice-break up of the lake, the upper layer (5–10 m) begins to warm up earlier owing to greater input of solar radiation to the water. During the summer warming, due to the stronger heating of the upper water layers, the stratification intensifies, i.e. an increase in the vertical gradients of temperature and density in the layer of epi- and metalimnion. This leads to an increase in the heat supply to hypolimnion through the thermocline and, consequently, a decrease in the amount of heat throughout the water column.

4. Conclusion

Therefore, we identified different trends in the heat capacity change of the layer from 15(19) to 100 m and throughout the water column near Ivanovskiy Cape (Southern Baikal) from 1999 to 2020. These differences in trends were due to the change in the air temperature and wind speed in the Baikal region, the dates of freezing and ice-break up in Southern Baikal, an increase in the duration of wind exposure to the water surface in spring and autumn, an increase in the duration of penetration of solar radiation into the water column as well as the intensification of temperature stratification in the summer season.

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