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Comparison of Selyaninov's Hydrothermal Coefficient (Aridity Criterion) over Buryatia, Russia, in the Summer Period from 1979 to 2019 According to Meteorological Stations and ECMWF ERA5 †

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Abstract: We studied moisture content/aridity conditions in Buryatia (Russia) in summertime in 1979–2019. Selyaninov's hydrothermal coefficient (HTC) was used as the aridity criterion. HTC was calculated on the basis of precipitation and 2m temperature data from two datasets: meteorological stations and the ECMWF ERA5 project. Comparison of HTC calculations for these two datasets was performed. ERA5 data showed underestimated HTC values compared to observations. The inconsistencies found are mainly related to underestimation of precipitation in the ERA5 project compared to observational data. Air temperature from the two datasets agrees well for most stations both in value and in long-term dynamics. It has been shown that at the stations in central and southern Buryatia, the increase in aridity (HTC decreasing) in 1979–2019 is mainly due to the increase in air temperature.

Keywords: aridity; climatic changes; ECMWF ERA5; Selyaninov's hydrothermal coefficient

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1. Introduction

The Republic of Buryatia is located in the center of the Asian continent, in the southern part of Eastern Siberia, to the south and east of Lake Baikal. The relief of Buryatia is predominantly mountains covered with forests, and there is a small number of plains.

Most of Lake Baikal (60% of the coastline), the deepest freshwater lake in the world, is located in Buryatia. A great part of the Selenga River basin, the largest tributary of Baikal, providing about 50% of the inflow into the lake [1,2], [https://navostok.info/reg11.php, accessed on] is located in South Buryatia. Thus, fluctuations in water content of Lake Baikal are largely due to fluctuations in discharge of Selenga River, whose main supply is summer precipitation [1,2].

A third of the territory of Buryatia is occupied by agricultural land (wheat, rye, oats, buckwheat, corn, rapeseed, potatoes and other vegetables), cattle breeding is also well developed here [https://navostok.info/reg11.php, accessed on].

Almost 83% of Buryatia is occupied by forests. More than half of the forests (63%) suitable for exploitation are located near Lake Baikal. The forests of Buryatia are classified as forests of high fire hazard class [https://spravochnick.ru/ekonomika/lesnoe_hozyaystvo_kak_otrasl_ekonomiki/lesnoe_hozyaystvo_buryatii, accessed on]. Careless handlings of fire and dry thunderstorms in summer are the main causes of forest fires [3].

A specific resource of Buryatia is long duration of sunshine (1900–2200 h per year) [http://trasa.ru/region/buriatiya_clim.html, accessed on] and high frequency of clear sky

[4]. In the 1960s, this feature made this region attractive for placing large optical observatories aimed at solving scientific problems: the study of the Sun, near and far Space [http://en.iszf.irk.ru/Main_Page, accessed on].

Thus, the level of Lake Baikal, crop yield, livestock number, degree of fire hazard for forests, transparency of the atmosphere and conditions of optical observations depend on moisture content/aridity degree of Buryatia in summertime. Therefore, the study and explanation of the long-term dynamics of moisture content/aridity over this territory in summer is an important task. In this paper, we solve this problem using a simple parameter—the hydrothermal coefficient (HTC) by Selyaninov G.T. [5]. We are interested in the prospects for applying this specific agrometeorological index to solve a wide range of problems described above. We are also interested in the possibility of using grid data, in particular, ECMWF ERA5, in our research. We compared the results of HTC calculations according to ERA5 and to observations. The comparison results are presented below.

2. Method and Data

We have selected 10 meteorological stations in Buryatia, whose data are freely available [meteo.ru]: Taksimo, Bagdarin (north and northeast); Barguzin, Romanovka, Sosnovo-Ozerskoye (center); Ulan-Ude, Ivolginsk, Babushkin (south); Tunka, Orlik (southwest, west) (Figure 1). We calculated the Selyaninov's hydrothermal coefficient (HTC) at each station for each of three summer months, according to formula:

$$HTC = SumP_{05}/(SumT_{05}/10) \quad (1)$$

where $SumP_{05}$ is precipitation for the period with air temperature above +5°C; $SumT_{05}$ is the sum of daily temperatures for the same period [http://www.agroatlas.ru/ru/content/Climatic_maps/GTK/GTK/index.html, accessed on].

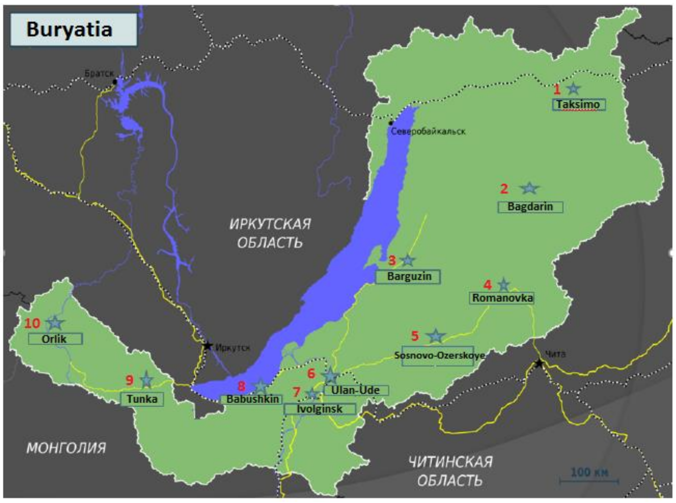

Figure 1. Figure 1. Meteorological stations of Buryatia, whose data were used: 1—Taksimo, 2—Bagdarin, 3—Barguzin, 4—Romanovka, 5—Sosnovo-Ozerskoye, 6—Ulan-Ude, 7—Ivolginsk, 8—Babushkin, 9—Tunka, 10—Orlik.

According to this formula, the lower HTC, the drier the conditions.

In agrometeorological practice, to identify droughts and their intensity, periods with daily air temperatures above +10°C are taken for HTC calculation. We used the less stringent +5°C condition. Since as mentioned, firstly, we consider the possibility of broader HTC application, not only in agriculture. Secondly, in general (not applicable to agricultural crops), the growing season begins when daily air temperature passes across +5°C [6].

We used the following data:

1. daily 2m air temperature and precipitation from 1979 to 2019 for three summer months (June, July, August) for 10 meteorological stations: Taksimo, Bagdarin (north

and northeast part of Buryatia); Barguzin, Romanovka, Sosnovo-Ozerskoye (central part); Ulan-Ude, Ivolginsk, Babushkin (south); Tunka, Orlik (south-west and west) [meteo.ru] (Figure 1).

2. 3-h 2m air temperature and precipitation grid data from 1979 to 2019 for three summer months (June, July, August) from the ECMWF ERA5 project [7] on the single level. Based on these data, we calculated daily temperature and precipitation.

Then we calculated the sums of precipitation and daily temperature for each summer month for every station and ERA5.

In order to compare HTC from observations and that from ERA5, we selected four ERA5 grid points nearest to the meteorological station and averaged data over these four points. This procedure was performed for each station selected. Of course, this is not entirely correct. It would be necessary to interpolate ERA5 data into points with station coordinates. However, we compared HTC in each of the four grid points with each other and considered the similarity to be good. Figure 2 shows HTC calculated from ERA5 data in four grid points nearest to Ulan-Ude (left), Ivolginsk (center) and Tunka (right) stations. So, we decided to use simple averaging now.

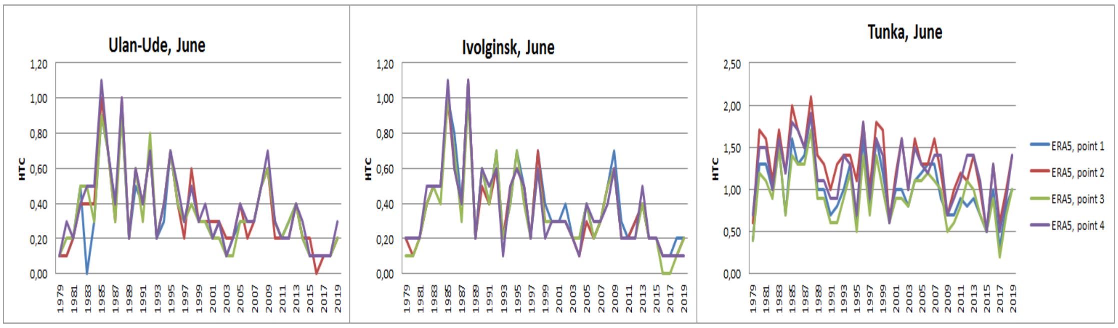

Figure 2. HTC from ERA5 in four grid points nearest to Ulan-Ude (**left**), Ivolginsk (**center**) and Tunka (**right**) stations.

3. Results

Figures 3–5 show HTCs for both datasets in June, July and August, respectively. In June at most stations and in August at Orlik station (Eastern Sayan Mountains), air temperature was below +5°C for several days of the month in some years. Thus, it is not possible to correctly calculate HTC in these years for these months. In this paper, we show the results only for those stations where during the entire period 1979–2019, it was possible to calculate HTC. These are three stations in June (south and west of Buryatia): Ulan-Ude, Ivolginsk and Tunka (Figure 3), all 10 stations in July (Figure 4), and 9 stations in August, except Orlik (Figure 5).

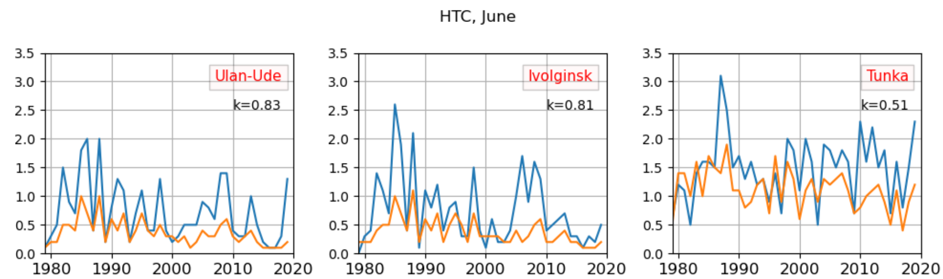

Figure 3. HTC in June. Blue color—meteorological stations data; orange color—ERA5 data. k is the correlation coefficient. X-axis—years; Y-axis—HTC.

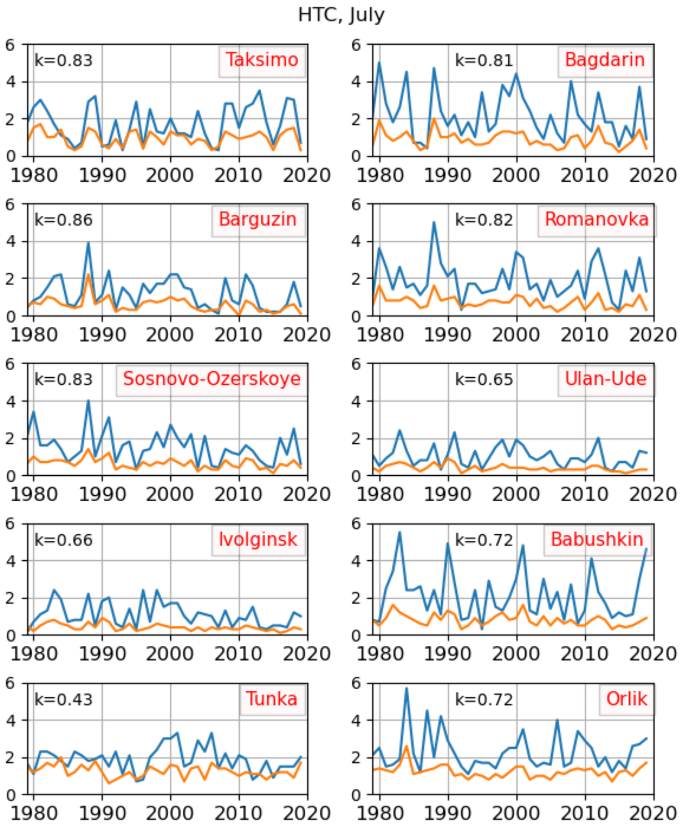

Figure 4. HTC in July. Blue color—meteorological stations data; orange color—ERA5 data. k is the correlation coefficient. X-axis—years; Y-axis—HTC.

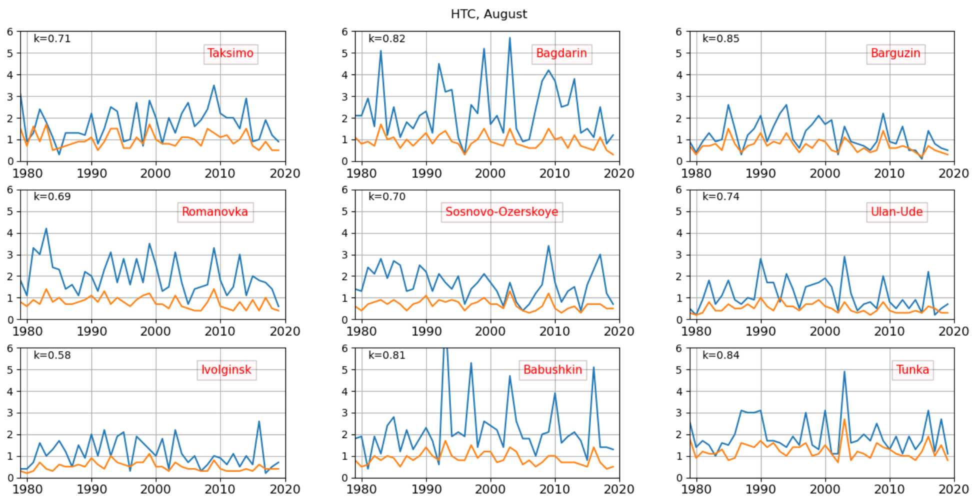

Figure 5. HTC in August. Blue color—meteorological stations data; orange color—ERA5 data. k is the correlation coefficient. X-axis—years; Y-axis—HTC.

Comparison of observational and ERA5 data. The main feature that draws attention in Figures 3–5 is underestimated HTC calculated according to ERA5 in comparison with HTC calculated from data by meteorological stations. At low HTC (<1.5) that corresponds to arid conditions and droughts, in some cases there is also an opposite situation—HTC from ERA5 is higher than HTC from station data. This feature is clearly visible in June for Tunka station in 1980–1983, 1996, 1997 and 2003. (Figure 3).

To find out what are the reasons for the differences found in HTC, we constructed plots of the monthly mean air temperature and total monthly precipitation for each station, based on which HTC was calculated. Figure 6 shows these plots for June. The results for July and August are similar to those shown in Figure 6. Observational and ERA5 air temperatures have a very good agreement, both in values and in long-term dynamics, except for Tunka (Tunka Valley) and Orlik (mountains, East Sayan) stations. So, as we see in Figure 6, the main reason for underestimation of HTC calculated using ERA5 is the strongly underestimated precipitation in the ERA5 project. At low precipitation (under 20 mm per month), precipitation from the ERA5 project, on the contrary, shows higher values than observations (see, for example, Ivolginsk in 2000 and Tunka in 2003). We noted a good agreement between interannual variability of precipitation from observations and from ERA5 (with the exception of the mountain and valley stations Orlik and Tunka).

Thus, air temperature for 2m of the ECMWF ERA5 project can be used to calculate HTC over Buryatia. Unfortunately, precipitation in the ERA5 project is greatly underestimated, so it cannot work correctly in calculations, we need to look for other precipitation data.

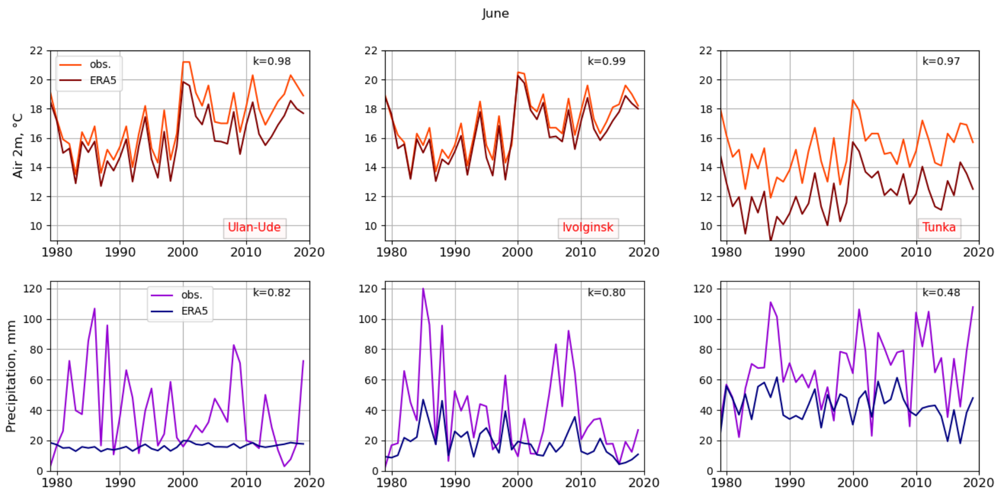

Figure 6. Air temperature (**top**) and precipitation (**bottom**) in June at Ulan-Ude, Ivolginsk and Tunka stations.

Climatic variability of HTC, temperature and precipitation. Figures 3–5 show the long-term decrease in HTC (increased aridity) after 2000: in June at all three stations shown in Figure 3 (south and west of Buryatia), in July at stations Barguzin, Sosnovo-Ozerskoye, Ivolginsk (center and south) (Figure 4), and in August at stations Barguzin, Ulan-Ude, Ivolginsk (center and south) (Figure 5). Figure 6 shows that the main reason for this is the increase in air temperature. This fact requires a more thorough study: quantitative estimation of trends and their interpretation. Note that the increase in aridity at the stations in the south of Buryatia shown in Figures 3–5 is consistent with the information about long-term low-water period (since 1996) in the Selenga River basin in summertime [1,2]. The increase in temperature and decrease in precipitation in summertime in the territory that includes the south of Buryatia are discussed in papers [1,8–10]. Papers [10–12] say that the increase in temperature and the decrease in convective precipitation in summer result from the fact that high pressure areas began to form over Mongolia more often.

We also note that in 2020–2022, there were signs of exiting the long arid period in the Selenga River basin, but we think it is premature to assert this.

4. Conclusions

The work studies the long-term variability of the hydrothermal coefficient (HTC) by Selyaninov G.T. (dryness/humidity criterion) according to observations and ECMWF ERA5 data on temperature at 2m and precipitation inside the Republic of Buryatia, Russia, in summertime. HTCs calculated from these two datasets were compared in order to study the potential of using ERA5 grid data in research inside Buryatia. It was found that in the ERA5 project, precipitation is underestimated, and therefore, its use in HTC calculations is not possible. Air temperature from the two datasets agrees well for most stations both in value and in long-term dynamics. It is shown that at the stations in central and southern Buryatia, the increase in aridity from 2000 to 2019 is mainly due to the increase in air temperature.

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