The influence of the urban environment on the thermal pollution of river runoff, using the example of the Ingoda River (Russia)

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Abstract. The paper presents the results of a study of the own thermal radiation in the infrared range of the Ingoda River, flowing within the city limits of Chita (Russia) A track was built along the river runoff to determine the surface temperature of the object, with a length of 155 km. Space images obtained from Landsat-8 and Landsat-9 Earth remote sensing satellites in channel 10 were used for analysis. In this channel, its own thermal radiation is accepted at wavelengths lying in the range of 10.60…11.19 microns. As a result of the study, it was shown that the optimal time for observing thermal pollution of a river flow is winter time. It is shown that the increase in brightness temperature of the river surface due to the influence of the city in January is on average 6…8 K. This value is not registered in summer. The thermal trace along the Ingoda River from the city is observed over a distance of 7…10 km. Also, one of the results is that not only cities but also settlements with a population of no more than 5000 people affect thermal pollution of water bodies.

1 Introduction

Currently, as a result of anthropogenic impact, climate changes are taking place, which are reflected both globally and regionally [1-3]. Thermal pollution plays a certain role in this process, which is manifested in the increased temperature of water, air and earth covers compared to normal temperature indicators of the above media.

Remote sensing methods occupy a special place in the study and monitoring of the natural environment. At present, there are few thousands active satellites orbiting the Earth. They all perform their specific tasks, for example, in cartography, monitoring environmental situations, measuring humidity, temperature, salinity, greenhouse gas emissions and others [4, 5]. Satellites that receive Earth's own thermal radiation in the infrared range are used to monitor the surface temperature of the underlying layer. An example is the Landsat-8 spacecraft, which has a channel that registers this radiation at wavelengths lying in the range of 10.60…11.19 microns [6]. Thus, in the work [7], thermal anomalies in the urban environment were identified using this satellite. Another example of the influence of the urban environment on the thermal field of the surface is the work [8], in which so-called "thermal islands" were recorded. They are formed primarily in industrial areas and in central

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parts of cities. Monitoring the temperature regime of water resources is also important. For example, in the work [9], the most polluted area of Lake Kenon (Zabaykalsky Krai) was recognized as the Chita TPP-1 area, which is consistent with remote measurement data on thermal pollution of the lake in [10].

The purpose of this study was to conduct an assessment of the impact of the urban environment on thermal pollution of a river? using Chita as an example. This study includes monitoring of its own thermal radiation of Ingoda River for January 2020, 2021 and 2022. Another goal is to establish optimal conditions for observing thermal features of river water surfaces throughout the year.

2 Measurement methodology

The object of study was Ingoda River which flows through a number of settlements including Chita (Russia). The section of river for assessing impact of urban environment on water body was chosen as follows: upstream relative to Chita city ~70 km and downstream ~80 km. Figure 1 shows an image in visible range with points marked: points 1 and 3 represent beginning and end of measurements while point 2 marks center of city.

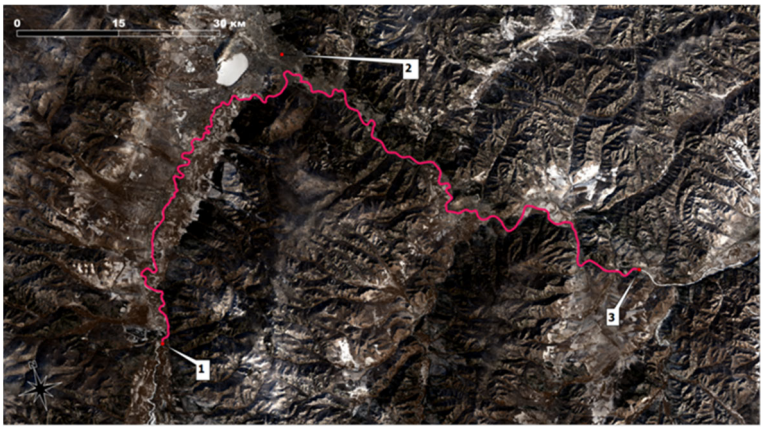

Fig. 1. Image obtained from Landsat-8 Earth satellite. The studied section of Ingoda River is highlighted with red line.

Measurement of its own thermal radiation was carried out using high spatial resolution Earth remote sensing satellites ~30 m/pixel such as Landsat-8 and Landsat-9. Images obtained in channel 10 were used for analysis where thermal radiation is accepted at wavelengths lying in range from 10.60 to 11.19 microns. “QGis 3.24” software with Semi-Automatic Classification Plugin [11] was used for image processing. Image processing methodology is given in [7]. Images were selected so that there was no cloudiness on track 1-3 (Figure 1) due to its contribution to radiation power values. As a result for analysis of thermal pollution of water body namely Ingoda River three images taken in January for years 2020, 2021 and 2022 as well as one image for July 2021 were selected.

3 Obtained results and their discussion

When studying the influence of the urban environment on the subject of increasing the values of its own thermal radiation of the Ingoda River, some features were revealed. In particular, Figure 2 shows a graph of brightness temperature of river surface in Kelvins for January 2020-2022, depending on distance along track 1-3 (Figure 1) with length l = 155 km. Number

1 marks Novaya Kuka village, 2 marks Chita city. The graphs show that as it approaches urban environment, an increase in level of its own thermal radiation is observed, confirming fact that urban environment affects temperature regime of natural environment.

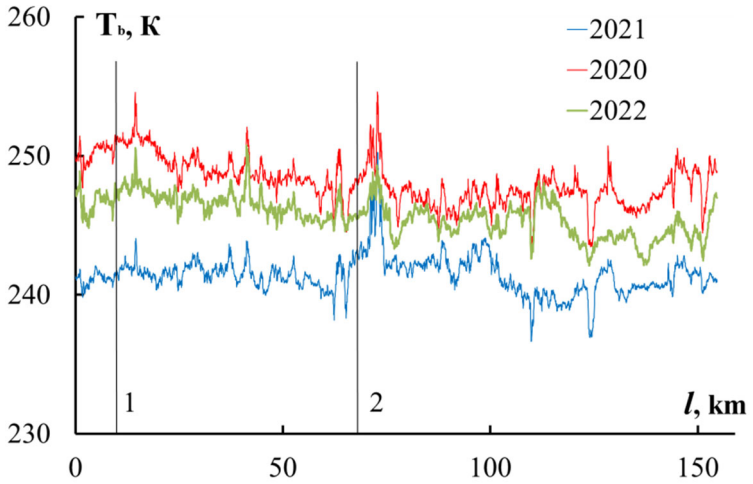

Fig. 2. Graphs of dependence of brightness temperature of its own thermal radiation for January depending on distance along track 1-3 (Figure 1). Number 1 marks Novaya Kuka village, 2 marks Chita city. Dates: January 11, 2020, January 29, 2021, January 16, 2022.

Temperature spikes of about 6 K…8 K are registered in industrial zone of Chita city. Thermal trail with length of 7 km…10 km is also confirmed which ends in Atamanovka village area. The graphs also show that not only urban environment but also small settlements affect increase in value of intensity of its own thermal radiation. This is confirmed by sharp rise in brightness temperature value in different years in Novaya Kuka village area.

The presented graphs also show areas where there is negative increase in its own thermal radiation. For example, in area of 125 km the brightness temperature value from average intensity value drops by about 3 K…4 K. This is due to fact that this area of river is in shadow of mountain ridge which leads to such phenomenon. This fact is confirmed when analyzing images in visible radiation spectrum.

Figure 2 shows graphs of brightness temperature of its own thermal radiation T1 for July (red) 2021 and T2 for January (blue) 2021 depending on distance along track 1-3 (Figure 1). Analyzing data for summer month some features can be noted related to noticeable increase in power of its own thermal radiation by about 2 K…6 K. This is due to fact that active mixing of water masses occurs in river at certain sections which corresponds to average value of brightness temperature while increased can be associated with smooth laminar flow. It promotes heating of water layer where main part of its own thermal radiation is formed. Water layer forming radiation has value around 10 microns [12]. Also this fact may be related to fact that sandy shores under influence of solar radiation heat up more intensively than water surface. Since satellite resolution is about 30 m/pixel it is possible that such peculiarity contributes to measurement of its own thermal radiation from water surface.

Comparing data from summer measurements and winter ones it can be concluded that detection and monitoring of thermal pollution should be carried out during winter time. In summer underlying surface heats up due to solar radiation and thus thermal anomalies are not observed.

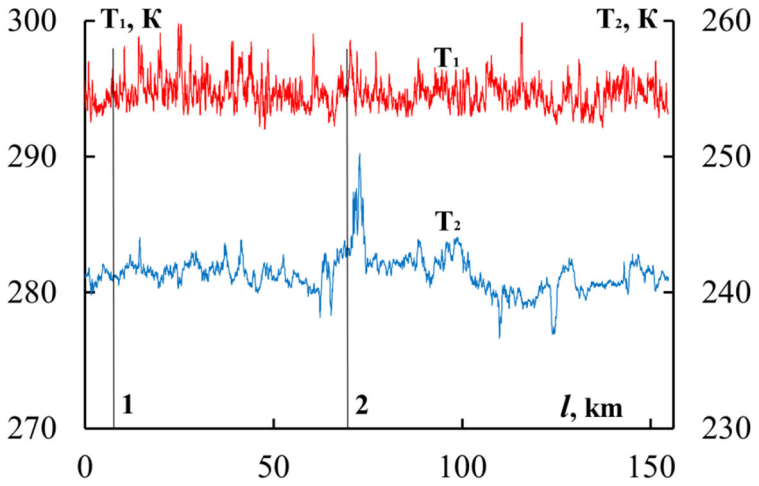

Fig. 3. Graphs of brightness temperature of its own thermal radiation T_1 for July (red) 2021 and T_2 for January (blue) 2021 depending on distance along track 1-3 (Figure 1). Number 1 marks Novaya Kuka village, number 2 marks Chita city

Thus from analysis of presented results it can be seen that city and settlements significantly affect thermal regime of natural environment. Similar studies also confirm this fact [13, 14]. Urban environment affects river runoff not only in temperature features but also in hydrochemical state. This was studied in work [15].

4 Conclusions

The results of measurements of its own thermal radiation of water surface and snow-ice cover of Ingoda River flowing through urban environment and territories of other settlements are presented. An increased value of brightness temperature of about 6…8 K in thermal infrared range was found in such areas. It turned out that optimal time for observing thermal pollution of rivers is winter time. Also, one of results of this work is measurement of distance of thermal trail from Chita city with length of 7 km … 10 km.

It should be noted that for studying internal structure of ice cover and its monitoring, microwave research methods should be used due to greater thickness of radiation formation in this area of electromagnetic spectrum compared to infrared range. Thus, in work [3], water bodies, in particular fresh lakes, were studied using radiometric receivers studing with different frequencies. This methodology is necessary for analyzing impact of urban environment on microwave properties of river ice cover. Microwave measurements will allow to establish possible contribution to radiation from thin layer of pollution on surface of snow-ice cover.

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