Assessment of the Impact of Meteorological Parameters of the Territory on the Distribution of the Siberian Silk Moth

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Abstract. Siberian silkworm is one of the main pests of coniferous forests. In 2014, there was an outbreak of its number in the Yeniseisk district of the Krasnoyarsk Territory. The forest of the left bank of the Yenisei River, unlike the right bank, suffers more from its impact. The purpose of the work is to analyze the heterogeneous forest damage by the silkworm on both banks of the Yenisei River according to meteorological data from 2009 to 2018. The results showed that the left bank is warmer than the right bank by an average of 1-1.5 ° C during the period under consideration. Also recorded a significant decrease in rainfall in 2012.

Keywords: surface temperature; Siberian silk moth; GFS; forest disturbance; Yenisei River; meteorological data; grib2; rainfall.

1 Introduction

Siberian silk moth is one of the most dangerous pests of coniferous forests of Siberia and the Far East, which are one of the most important natural resources of the country. This type of insect feeds on fir, Siberian cedar, spruce and larch. Low rainfall, droughts and relatively high air temperatures provoke mass reproduction of this insect in spring and early summer [1, 2]. On the Krasnoyarsk territory there are several areas of outbreaks of silk moth, such as Chulymo-Keski, Priamurskiy, Prieniseiskoi, Kansk-Biryusinskaya, Kuznetsk-Alatauskiy, West Sayan, Osinusi, Sibson-Tubinskiy, Mana-Agul regions. The greatest intensity of the different outbreaks of the moth in dark-coniferous forests of the Central part of the Krasnoyarsk territory are Chulymo-Ket, Priamurskiy and Prieniseiskoi areas. Many researchers note that the boundary of the focal spread of the silk moth is the temperature criterion – this is the average long-term temperature of August, which is +13.5°C [3].

Outbreaks of mass reproduction of this insect lead to serious environmental and economic consequences for the forestry of the regions [3]. In particular, in 1994-1996 there was one of the last mass outbreaks of the Siberian silkworm population in the forests of the Krasnoyarsk territory, which led to damage to dark coniferous plantations on the area of about 700 thousand hectares and death of forests on the area of about 200 thousand hectares [4, 5]. The year 2001 is considered extreme, when the total area of insect pests and diseases in Russia exceeded 10 million hectares. The Siberian silk moth accounts for almost 70% of this area [6].

It is revealed that after the death of dark coniferous forests their restoration is difficult. Succession include long-term-derivative change of rocks, and the intensity of reforestation depends on the size of the lesion and destructive factors such as frequent fires. In some cases, dark coniferous forests will not be able to recover [7].

In 2014, there was another outbreak of the Siberian silk moth population in the Siberian pine and fir plantations within the Yenisei valley in the South-West of the Krasnoyarsk territory. The Northern border of the outbreak was up to 60°26'N, and the total area of the focus was 800 thousand hectares. [8]. In this paper we consider the area with coordinates 89-92°E and 58-60°N, which lies between the settlements Podtesovo and Yartsevo. The territory is divided by the Yenisei river into two parts (left and right banks). Figure 1 shows the considered area according to the global Forest Change portal [9].

Figure 1 shows in red the areas of forest loss in recent years, as well as the four selected areas and the names of the nearest settlements. It can be seen that the left Bank of the Yenisei river suffered much more from the pest than the right.

As is known, the activation of an aggressive species of insect dendrofagous associated with climate change [10, 11]. The question arises: what is the distinctive feature of the left bank of the Yenisei river in comparison with the right bank in the territory under consideration from the right in terms of climate? The spatial analysis of the surface

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temperature for both banks of the Yenisei river is of interest. In our study, NOAA Global Forecast System meteorological data were used [12] to solve this problem.

The Global Forecast System (GFS) is a global numerical weather forecasting system containing a global computer model and variational analysis performed by the National meteorological service of the United States (NWS). GFS data is freely available. This is one of the world's most famous meteorological models. The data are published at intervals of 4 times a day, and the spatial resolution is currently 0.25 degrees (about 25 km for the latitude of Krasnoyarsk). In 2019, as a result of the recent tenfold increase in computing power, it is planned to update the GFS model, which will increase its horizontal resolution three times to 9 km.

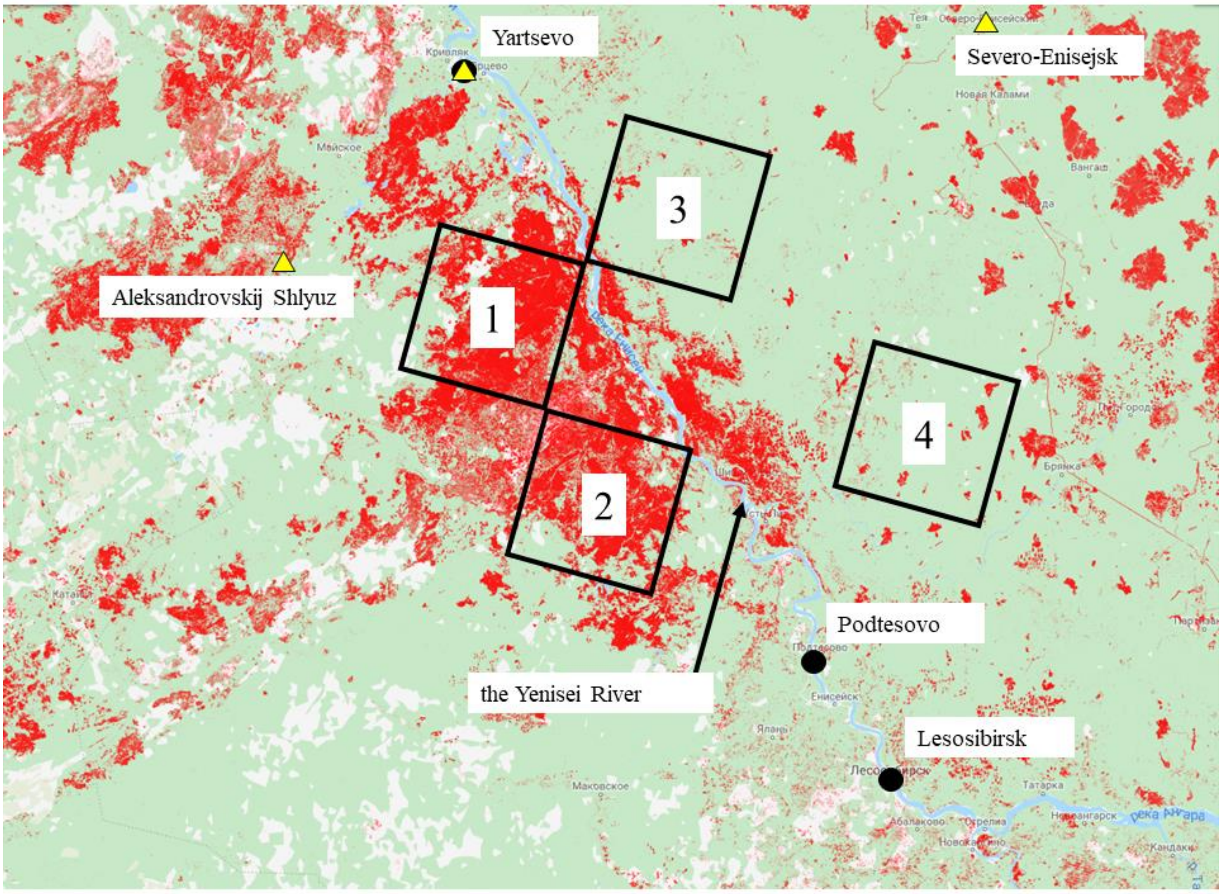

Figure 1. The considered territory near the Yenisei river.

To take effective management measures in solving the problems of forest protection and cost optimization is necessary to understand the causes of outbreaks of insect dendrofagous. Climate data can be a key tool in identifying the challenges of identifying these causes. In this regard, the task of this work is to analyze the situation with the heterogeneous defeat of the forest by the Siberian silkworm on both banks of the Yenisei river in the Krasnoyarsk territory according to meteorological data of GFS.

To perform the task in the territory under consideration, 4 test areas were selected: two on the left bank of the Yenisei river and two on the right (figure 1). Thus, two territories were analyzed: the left bank of the Yenisei river, which is characterized by a high degree of silk moth damage, and the right bank – with a relatively low forest disturbance.

2 Materials and methods

GFS (Global Forecast System) is a weather forecast model developed by US National Centers for Environmental Prediction (NCEP). Dozens of atmospheric and land-soil variables are available in this dataset, from temperature, wind and precipitation to soil moisture and atmospheric ozone. GFS covers the entire globe with a basic horizontal resolution of 28 km between grid points, which is used by forecasters to predict weather up to 16 days in advance.

The accuracy of the model is constantly improving. In particular, data with a spatial resolution of 1° have been available since March 2004, with a resolution of 0.5° since January 2007 and with a resolution of 0.25° since January 2015 [12, 13]. GFS data is a special file format *.grib2, which was developed by the world Meteorological Organization (WMO). This data format is standard for storing historical and forecast weather data. For example, each individual GFS file of type "analysis", with a spatial resolution of 0.25° contains 354 layers of different meteorological information and has an average size of about 200 Mb.

We used actual weather analysis data from the NCEP archive, not predictive information. Their spatial resolution was 0.5° for 2009-2014 and 0.25° for 2015-2018.

To achieve this goal, all the necessary meteorological data of GFS were downloaded from the official website of NOAA (National Oceanic and Atmospheric Administration) [12, 14].

After downloading the 10-year GFS datasets, they were pre-converted. Namely, all the data obtained were cut into four selected areas of the territory under consideration and the layer "TMP:surface", that is, the surface temperature. The wgrib2 program was used to accomplish this task. This program is specially designed by NCEP programmers to read and write meteorological data of the format *.grib2.

To automate the processing of source data, a special script was written, which is a batch command file for Windows. This script initiates a cyclic reading of the source files and runs the program wgrib2 [15] with certain parameters for each of them. These parameters satisfy the task, namely, they contain the coordinates of the four selected areas and the name of the desired data layer. Output files are files that take up more than a hundred times the size of the original data.

After preliminary conversion of the resulting GFS data, they should be tabulated for further analysis. To do this, a batch script was also written that runs the wgrib2 program with a certain parameter and converts each received file into a file format *.csv.

A special program was written in the C programming language that reads all individual files of the *.csv format across four areas over a 10-year period and will store their contents in a common file of the same format.

The final processing and analysis of the converted GFS data was performed in Microsoft Excel.

It is known that one of the most important factors of forest insect population outbreaks, including the Siberian silkworm, is the previous drought [16]. Therefore, also studied the dynamics of rainfall in the study area.

Precipitation data were also obtained from the GFS archive. This data has a spatial resolution of 0.5° degrees. The layer containing the precipitation information is called "APCP", which stands for "Total Precipitation" and contains the accumulated data for 6 hours. These data were processed using a special script and wgrib2 program as well as surface temperature data. Thus, an archive of data on rainfall in the study area was obtained.

However, it is necessary to check how accurately the GFS model estimates the level of precipitation in comparison with ground weather stations. To check the data on the level of precipitation, 3 ground stations were selected, which are located on the left and right banks of the Yenisei river, near the study area. In figure 1 they are marked with yellow triangles. Ground-based weather stations: "Aleksandrovskij Shlyuz" (No. 29059) coordinates: 59.43° n, 89.28° E.; "Yartsevo" (No. 23987) coordinates: 60.25° n, 90.23° e; "Severo-Enisejsk" (No. 23986) coordinates: 60.36° n, 93.03° E. the weather data from ground monitoring stations were obtained from National Centers for Environmental Information (NCEI) [17].

Three polygons corresponding to the three regular grid cells of the GFS model were selected. On the territory of each landfill is the corresponding ground weather station. The summer months of 2016 and 2017 were selected for verification.

As a result, the correlation between precipitation data from ground stations and meteorological information from the GFS model averaged about 0.5 (Table 1).

Table 1. The correlation coefficients between the three land-based meteorological stations and data of the GFS model over the summer months in 2016 and 2017.

Years	Ground weather stations		
	Aleksandrovskij Shlyuz	Yartsevo	Severo-Enisejsk
2016	0,54	0,42	0,5
2017	0,65	0,45	0,5

This level of correlation coefficients does not allow accurate observations for short periods of time. However, this assessment should be sufficient to identify potential anomalies in rainfall levels in long-term time series.

At the same time, the correlation between the air temperature data from the ground stations and the meteorological information of the GFS model is high and averages about 0.96.

3 Results and discussion

As a result of processing the initial data, an archive of surface temperature data for the summer months for 2009-2018 was formed for the four selected areas of the territory under consideration.

Figure 2 presents the plots of the averaged for the summer month values of surface temperature T for the four selected regions for 10 years. Here, solid lines indicate areas 1 and 2, which correspond to the left bank of the Yenisei river, and broken lines – areas 3 and 4, which are located on the right bank.

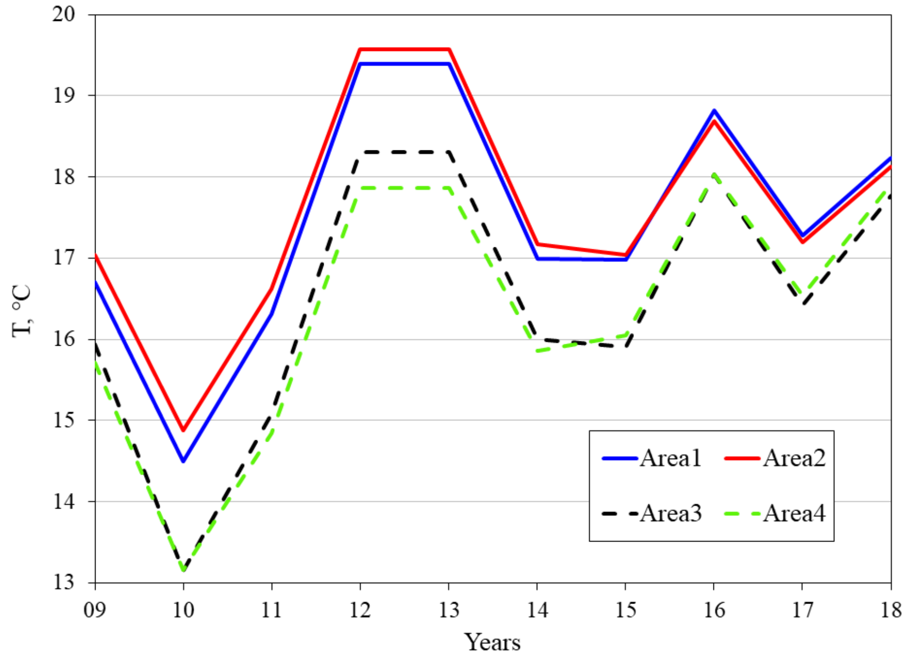

Figure 2. Average summer surface temperature over 10 years for four sample areas.

It should be noted that the surface temperature T values for areas 1 and 2 are higher than the T values for areas 3 and 4 by an average of 1-1.5° during the selected time interval from 2009 to 2018. This means that the surface of the zone affected by the silkworm warms up more than the area with relatively little damage to forest growth.

For a more detailed analysis of the data from the formed archive, the averaging of the surface temperature T values for the summer months of the two selected areas on the left Bank of the Yenisei river and two areas on the right Bank was carried out and their difference ΔT was calculated (Fig. 3).

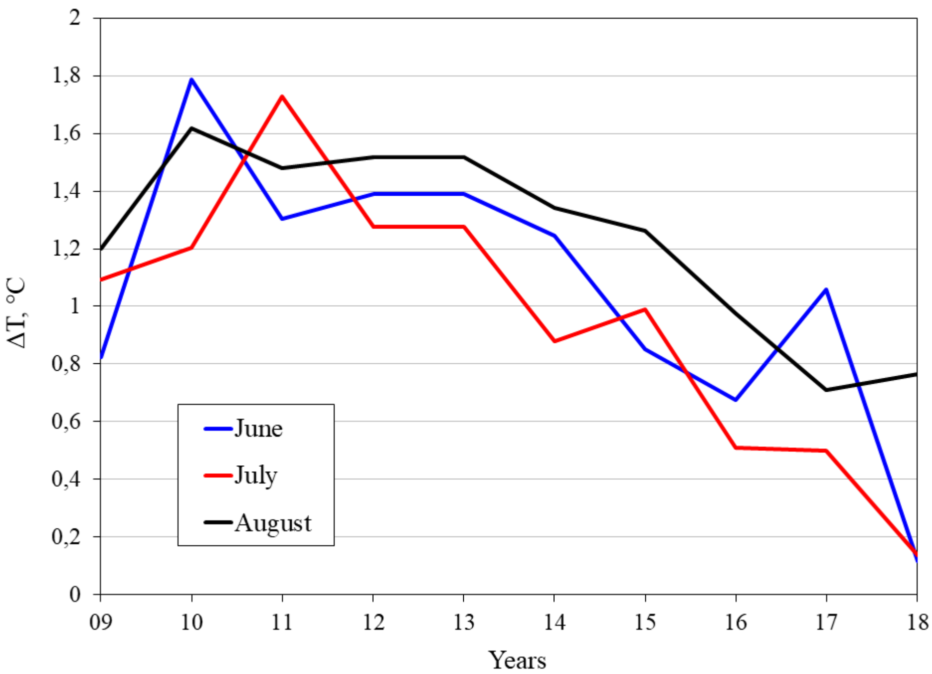

Figure 3. Calculated temperature difference of the underlying surface ΔT of the left and right banks of the Yenisei river for June, July and August from 2009 to 2018.

Figure 3 shows that in the year of the outbreak (2014) of the Siberian silk moth population in the territory under consideration, the average surface temperature of the significantly affected left bank of the Yenisei river was higher in

June by 1.24°C, July – 0.9°C, August – 1.34°C, compared with the less affected right bank. The graphs also show that the difference between the average surface temperatures ΔT between the left and right banks of the Yenisei river decreases over time.

The dynamics of the level of rainfall P accumulated during the summer seasons for 2009 – 2018 is shown on Figure 4.

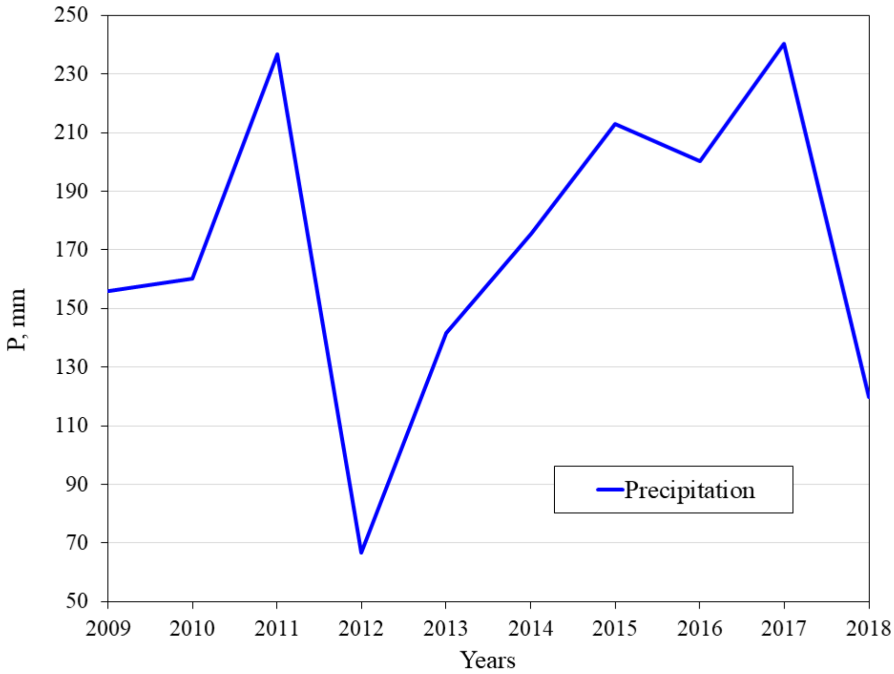

Figure 4. Dynamics of rainfall for the summer seasons for 2009-2018.

The graph in Figure 4 shows that precipitation fell sharply in 2012 (to 66.8 mm) compared to the previous year (236.6 mm). Then began a gradual increase in the level of precipitation. The drought caused by low rainfall in 2012 and 2013 (66.8 mm and 141.5 mm, respectively) was probably also one of the factors that led to the outbreak of the Siberian silkworm in 2014.

3 Conclusions

Recently, new meteorological data with high spatial resolution have opened up fundamentally new possibilities for the analysis of various natural phenomena and processes. In particular, they help to identify possible causes of observed anomalies of reproduction and spread of forest pests. The analysis of the obtained data shows that a slight deviation of the average surface temperature can significantly affect the population growth and activity of the Siberian silk moth on the left bank of the Yenisei river of the considered territory, in contrast to the right bank. Probably, the surface temperature can be one of the key climatic factors affecting the outbreaks of mass reproduction of the Siberian silk moth.

Along with the heterogeneity of surface temperature, a decrease in rainfall can also be a factor in the outbreak of wood pests.

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