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Analysis of climatic characteristics of the territory of distribution of the Siberian silk moth

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Abstract. Siberian silk moth is one of the most dangerous pests of coniferous forests of Krasnoyarsk region, which are the most important natural resource of the region. Climate change is considered to be one of the essential criteria for the growth of the silk moth population. In 2014, there was another outbreak of the number of silk moth in the Yenisei district of Krasnoyarsk region. It is known that the forest area of the Yenisei river left bank is subject to severe damage by the silk moth, and the right bank is characterized by a weak forest damage. The task of this work is to analyze the situation with the heterogeneous lesion of the forest by the Siberian silkworm on both banks of the Yenisei river of the territory under consideration according to most detailed available meteorological data for the period from 2009 to 2018. The results of the study showed that the left bank of the river has an increased surface temperature compared to the right bank by an average of 1-1.5°C during the period under review. This effect may be the reason for the spatial distribution of the Siberian silk moth population.

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 temperatures provoke mass reproduction of this insect in spring and early summer [1, 2]. Several regions of moth outbreaks are highlighted in Krasnoyarsk Territory: Chulymo-Keski, Priamurskiy, Prieniseiskoi, West Sayan, Kansk-Biryusinskaya, Kuznetsk-Alatauskiy, Osinusi, Sibson-Tubinskiy, Mana-Agul. The greatest intensity of the different outbreaks of the moth in dark-coniferous forests of the Central part of the Krasnoyarsk territory: Chulymo-Ket, Priamurskiy and Prieniseiskoi areas. The boundary of the focal distribution of the silkworm is the temperature criterion – 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. Thus, there was one of the last mass outbreaks of the Siberian silk moth population in the forests of the Krasnoyarsk territory in 1994-1996, 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 silkworm 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 forest species, 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 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' north latitude, and the total area of the hearth is 800 thousand hectares. [8]. In this paper we consider the territory with coordinates 89-92° East longitude and 58-60° North latitude, which lies between the settlements: Podtesovo and Yartsevo. The selected area is divided into two banks of the Yenisei river. Figure 1 shows the area under consideration 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 square-form sample 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 one.

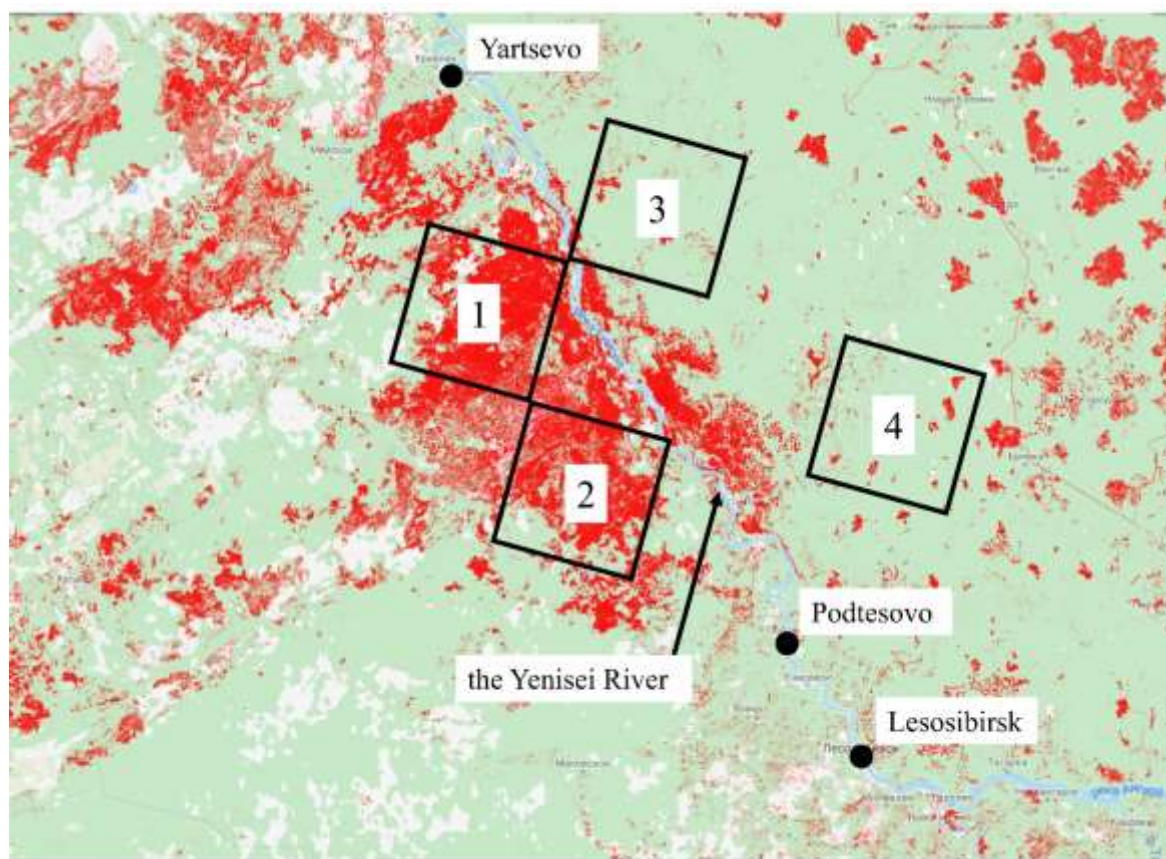


Figure 1. The study area, which shows the forest loss in recent years. The map also marks the square-form sample areas for which meteorological data were analyzed.

As is known, the activation of an aggressive species of insect dendrofagous associated with climate change [10, 11, 12]. The question arises: what is the difference between the left bank of the Yenisei river in the territory under consideration from the right one in terms of climate? The spatial analysis of the surface temperature for both banks of the Yenisei river is of interest. In our study, meteorological data from NOAA Global Forecast System [13] were used to solve this problem.

The Global Forecast System (GFS) is a global numerical weather prediction system containing a global computer model and variational analysis run by the United States' National Weather Service (NWS). GFS data is not copyrighted and is available for free in the public domain. It is one of the most famous global 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, an upgrade to the GFS model is planned that will increase its horizontal resolution three times to 9 km.

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 shaping the challenges of identifying these causes. In this context, the task of this work is to analyze the situation with the heterogeneous defeat of the forest by the Siberian silk moth on both banks of the Yenisei river in the Krasnoyarsk territory according to the GFS meteorological data.

To accomplish this task, four sample areas were selected on the territory under consideration: two on the left bank of the Yenisei river and two on the right one (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 damage.

2. Materials and methods

2.1. Global Forecast System model

GFS is a weather forecast model produced by the US National Centers for Environmental Prediction (NCEP). Dozens of atmospheric and land-soil variables are available through this dataset, from temperatures, winds, and precipitation to soil moisture and atmospheric ozone concentration. The entire globe is covered by the GFS at a base horizontal resolution of 28 km between grid points, which is used by the operational forecasters who predict weather out to 16 days in the future.

The accuracy of the model is constantly improving. In particular, data with a spatial resolution of 1° has been available since March 2004, with a resolution of 0.5° since January 2007, and with a resolution of 0.25° since January 2015.

GFS data is distributed in a special GRIB file format, which was developed by World Meteorological Organisation (WMO). This data format is standard for storing historical and forecasted 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.

2.2 Converting of meteorological information

We used the actual data of the analysis of meteorological conditions from the NCEP archive, while not prognostic information. Their spatial resolution was 0.5° for 2009-2014 and 0.25° for 2015-2018.

To achieve this goal, all the necessary GFS meteorological data were downloaded from the official website of NOAA (National Oceanic and Atmospheric Administration) [14, 15].

After downloading the GFS data sets for a 10-year period, they were pre-converted. Namely, all received files were cropped in four selected areas of the territory under consideration and the layer "TMP:surface", that is, the surface temperature. The wgrib2 program was used for this task. This program is specially designed by NCEP programmers to read and write meteorological data of the *.grib2 file format.

To automate the processing of source data, a special script was written, which is a batch file for Windows. This script initiates a cyclic reading of the source files and runs the program wgrib2 [16] 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. The output is files that occupy a size of more than a hundred times smaller than the original data.

After preliminary conversion of the resulting GFS data, they should be adjusted to the tabular view to their subsequent analysis. To do this, a simple batch script was also written, which runs the program wgrib2 with a certain parameter and converts each received file to the *.csv file format.

A special program was written in the C programming language that reads all individual *.csv files in four areas over a 10-year period and brings their contents into a common file of the same format. The final processing and analysis of the converted GFS data was carried out in Microsoft Excel.

3. Results and discussion

As a result of processing the initial data, an archive of surface temperature data for the summer months 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 sample areas for 10 years. Here, solid lines indicate areas 1 and 2, which correspond to the left bank of the Yenisei river, and discontinuous lines – areas 3 and 4, which are located on the right bank. It is noteworthy that the T surface temperature values of the areas 1 and 2 is higher than T values of 3 and 4 areas on the average on 1-1.5°C throughout the selected time interval from 2009 to 2018. This implies that the middle of the climatic temperature of the surface zone that is affected by silk moth, heated stronger than the area with the relatively low forest damage.

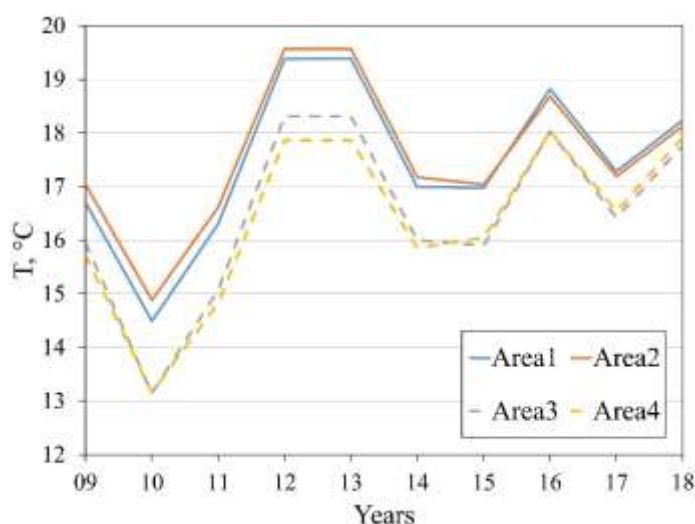


Figure 2. Average summer surface temperature over 10 years in four sample areas.

For a more detailed analysis of the data from the formed archive, the averaging of the surface temperature T values for the three 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 (figure 3).

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.

4. Conclusions

Recently, new high spatial resolution meteorological data have opened up fundamentally new possibilities in the analysis of various natural phenomena and processes. In particular, they help to identify possible causes of observed anomalies in the reproduction and spread of forest pests.

The analysis of the obtained data shows that a slight deviation of the average surface temperature could 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 Siberian silk moth.

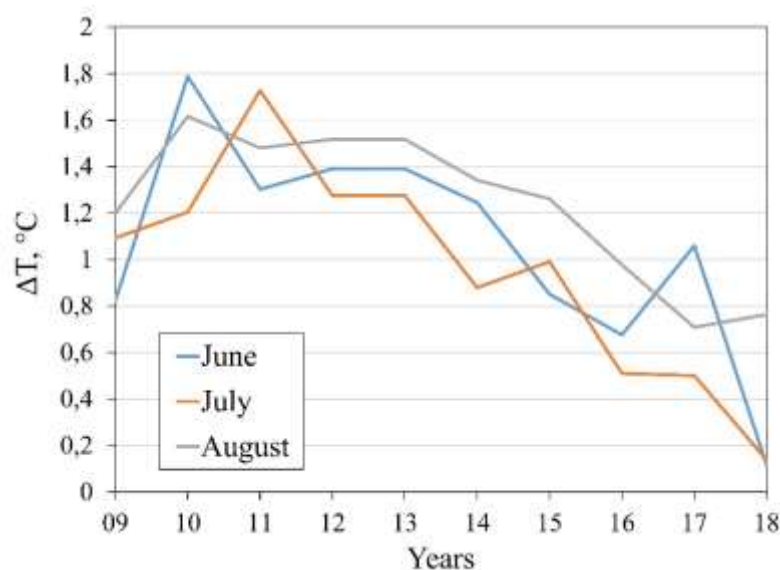


Figure 3. Temperature difference of the underlying surface of the left and right banks of the Yenisei river for June, July and August from 2009 to 2018.

References

- [1] Kolomiets N G and Maier E I 1963 (Tomsk: Tomsk. Knizhn. Izd.)
- [2] Kondakov Yu P 2002 *Entomologicheskie issledovaniya v Sibiri* **2** 25–74
- [3] Stegancov R I 2018 *Molodezh' i Nauka XXI Veka* 2018 65-7
- [4] Bartalev S A, Ershov D V and Isaev A S 1999 *Issledovanie Zemli iz Kosmosa* **4** 78-86
- [5] Isaev A S, Korovin G N, Lukina N V, Sukhikh V I and Ershov D V 2008 (Moscow: Institute of Physicochemical and Biological Problems of Soil Science RAS, Institute of Physics of the Earth, RAS) 66-79
- [6] Bruhanov A 2009 *Sustainable Forestry* **2** 21-31
- [7] Grodnitsky D L *Priroda* 2004 **11** 31-40
- [8] Kharuk V I, Im S T and Yagunov M N 2018 *Contemporary Problems of Ecology* **11** 26-34
- [9] Hansen, M. C., P. V. Potapov, R. Moore, et al. *Science* **342** 850–3
- [10] Kharuk V I, Im S T, Ranson, K J and Yagunov M N 2017 *Forests* **8** 301
- [11] Bentz B J, Régnière J, Fettig C J, Hansen E M, Hayes J L, Hicke J A, Kelsey R G, Negrón J F and Seybold S J 2010 *Bioscience* **60** 602-13
- [12] Weed A S, Ayres M P and Hicke J A 2013 *Ecol. Monogr.* **83** 441-70
- [13] Global Forecast System (GFS) Available from: <https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forcast-system-gfs>
- [14] NCEP Global Forecast System (GFS) Documentation Available from: <https://www.emc.ncep.noaa.gov/GFS/doc.php>
- [15] NCEP GFS 0.25 Degree Global Forecast Grids Historical Archive Available from: <https://rda.ucar.edu/datasets/ds084.1/index.html#!access>
- [16] Utility to read and write grib2 files Available from: <https://www.cpc.ncep.noaa.gov/products/wesley/wgrib2/index.html>