Analysis of accumulated precipitation based on information from weather stations

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Abstract. Knowledge about the spatial-temporal distribution of precipitation is important for a multitude of scientific and operational applications, and in agricultural monitoring particularly. Due to the irregularity of the network of meteorological stations and their small number in Central Siberia, a problem arises of filling in the missing data. Different ways are possible to solve this problem. This article addresses the problem of comparing data on the amount of accumulated precipitation received from ground-based weather stations and processed in various ways to reconstruct the spatial picture. Data analysis show that of all options considered, the use of a unified NOAA CPC dataset seems more appropriate in further agro-climatic studies. Only the satellite data can provide more complete and more accurate information.

1. Introduction

The main agroclimatic resources of a particular territory are specified by heat availability and water availability. Agroclimatic indicators of heat and moisture supply are developed on the basis of meteorological observations. Long-term average values allow us to establish the main features of the seasonal regime, annual or daily course of agroclimatic indicators. They are necessary for calculating indicators and indices of aridity of territories [1]. Precipitation is one of the system-forming factors in the study of the agrometeorological characteristics of agricultural territories, and it is necessary to ensure environmental research as discussed in previous publications by the authors [2, 3, 4]. Precipitation data are of two types: firstly, directly observational data from ground-based gauges, secondly, satellite data.

Since the network of hydrometeorological stations is not regular and it is not characterized by a sufficiently high spatial resolution, the next step was to use numerical models (both global and regional) to improve the spatial resolution of meteorological data. One of the most significant events was the creation of reanalysis databases, which include reasonably long data series for both the atmosphere and the ocean [5]. The creation of reanalysis has opened up a whole series of new opportunities and prospects for researchers. However, to study the meso- and microclimate, the reanalysis data still does not have sufficient accuracy for high spatial resolution. In this regard, interpolation methods (both dynamic and statistical), based on reanalysis and field observations and their use in mesoclimatic models are currently developed [6]. Grids with different temporal and spatial detail for interpolation are usually used.

A comparative analysis of the actual data of precipitation observations from weather stations in the central regions of the Krasnoyarsk Territory with the most known and accessible data, which are both
the result of a combination with satellite data and the results of various interpolations, has been carried out in this article.

2. Materials and methods
The following data as input sources for the study area of about 90 thousand square kilometers in the south of the Krasnoyarsk Territory are used:

- Digital model of catchment basins obtained using a digital elevation model MERIT Hydrologically Adjusted Elevations [7].
- Data from Agricultural Ecological Atlas of Russia and Neighboring Countries [8].
- Data archive from weather stations of the Krasnoyarsk Territory, obtained from the NOAA Global Summary of the Year (GSOY) dataset [9].
- Data from CPC Unified Gauge-Based Analysis of Global Daily Precipitation of National Center for Atmospheric Research, NOAA [10, 11].

The authors have recently paid considerable attention to research on this territory [12, 13]. Data processing using QGIS, has been carried out. Average annual precipitation value through the module "Zonal statistics" for each watershed has been calculated. Processing of weather station data using Microsoft Excel, has been carried out.

3. Results and discussion
Four catchments areas of the Kan, Mana, Tuba and Oja rivers for this study are selected, which are the watercourses of the Yenisei River watershed [14].

Figure 1 shows a map of the amount of precipitation during the year based on data from Agricultural Ecological Atlas of Russia and Neighboring Countries [8]. Data over elemental catchment areas using zonal statistics are aggregated.

Map is based on atlas data «Interactive Agricultural Ecological Atlas of Russia and Neighboring Countries» [8]. This atlas was created from 2003 to 2008 by leading scientists of three Russian institutes and the US National Plant Genetic Resources System and contain more than 1500 maps and their descriptions. A map of long-term average annual precipitation values for the territory of Russia is designed using data from climatic directories of average monthly precipitation values for stations of the former USSR for 1965-1974 (more than 7000 stations in total).

The data are presented on a 10×10 km grid. The authors use the kriging procedure for its formation. The monthly average precipitation values are restored using the GPCP_2.0_Combined satellite observation database [15], adjusted for ground-based observations in areas where the precipitation observation network is very rare or absent. In our case, the observation network is just rare and apparently, the mentioned data set GPCP_2.0_Combined is used for the territory considered in this article.

A study of long-term observations of precipitation accumulated over the year according to weather stations of the Krasnoyarsk Territory, the Republic of Tyva and Khakassia has been carried out. The data from the Global Summary of the Year (GSOY) free access archive [9] are taken, which aggregates and processes weather data from weather stations around the world. In particular, many weather stations of the Hydrometeorological Center of Russia also provide it with their data. Moreover, for most of them, data for the history of long-term observations are presented (some of them from 1909-1915). Analysis of the accumulated annual precipitation shows a tendency to increase the amount of precipitation at all weather stations from decade to decade over the past 100 years. Generally speaking, according to physical laws, global warming should be accompanied by changes in the hydrological cycle, manifested in an increase in precipitation intensity, the number of extremes, etc., although there are compensation mechanisms that can reduce these effects [16]. It is possible to detect an increase in precipitation intensity according to observations in a number of regions [17, 18].
Figure 2 shows the average values for one of the weather stations for 100 years lag behind the time trend. Therefore, for the long-term forecasts of WMO [1] proposes to take a 30 years period.

A pronounced increase in annual precipitation is noted in [19] since the second half of the 1980s. The most significant trends are observed in the regions of Central Siberia by 3.1% over 10 years [19]. Figure 2 shows that, according to the MINUSINSK weather station, the increase is of 2.6% over 10 years on average.

![Figure 1](image1.png)

**Figure 1.** Amount of average annual accumulated precipitation based on data from Agricultural Ecological Atlas of Russia and Neighboring Countries [8]. Data has been aggregated over elemental catchment areas using zonal statistics.

![Figure 2](image2.png)

**Figure 2.** Annual accumulated precipitation according to the weather station MINUSINSK since 1916. Average value (green line) = 342 mm / year. The trend of changes (dashed red) shows that over 100 years the amount of precipitation per year increased by an average of about 90 mm (26.3%).
The average annual accumulated precipitation based on the specified initial information for each weather station has been calculated. A point-type layer with the values of these long-term average precipitation has been created in the GIS. A map of the distribution of precipitation over the entire study area for this layer, using B-spline interpolation has been designed. This data over elementary catchment areas using zonal statistics has been aggregated (shown in figure 3).

The data have been interpolated based on annual mean values over the past 40 years. Data over the past 30 years was not enough, as there are large data gaps. For many weather stations, there is a data gap in 1997-2012. For some weather stations there is no actual data for the last 4-5 years. Nevertheless, the weather stations for which a series of data had at least 15 values over the past 40 years have been taken for processing. The results were obtained from the initial observational data at all available weather stations over the past 40 years - a total of 39 were in the area of interest. Weather stations for which data were available for at least 15 years have been selected; the number of years for which data were available ranged from 15 to 35, with an average of about 25 years.

Figure 3. Average long-term value of the accumulated precipitation according to long-term observations at weather stations.

Figure 4 shows a map of average annual accumulated precipitation based on CPC Unified Gauge-based Analysis of Global Daily Precipitation (CPC Unified V1.0/RT) data for a 30-year period from 1990 to 2019. This data set is created at the Climate Prediction Center (CPC), which is one of the structural units of the NOAA National Weather Service. When creating this product, authors paid special attention to optimal interpolation with orographic consideration using the algorithm of Shepard [20].

The initial data are daily, have a spatial resolution of 0.5° (for this territory, the grid cell has a size of approximately 33×56 km), their total volume is more than 20 GB. It should be noted that, in general, for the indicated period in the considered area, the data were relatively weakly changing from year to year. The standard deviation for all grid cells is in the range from 50 mm (in the flat areas) to 100 mm (in the highlands), and the coefficient of variability (variation) is within 11–16%.
As in the previous case, the data into polygons of elementary catchment areas have been recalculated using zonal statistics.

Figure 4. Average annual accumulated precipitation based on CPC Unified V1.0/RT data.

4. Conclusions
Accumulated precipitation amount and the dynamics of their change over time are one of the system-forming variables of agrarian climatology. The more accurate and detailed the information on precipitation, the better we can solve the problem of assessing the current state of agricultural land and forecasting yield. The study conducted in this work is devoted to comparing several sets of precipitation data based on ground-based observations. In view of the planned further studies, we have considered only the data that have at least daily temporal resolution. Therefore, many popular precipitation datasets with information aggregated to the level of average monthly data have not been considered.

The results show that the data designed using available information on GSOY weather stations are generally very close to the NOAA specialized CPC Unified dataset. At the same time, there is a noticeable difference with the data of the Ecological Atlas created using the former USSR weather stations data for 1965-1974.

Summing up, we can conclude that of all the options considered, the use of NOAA CPC Unified dataset in further agroclimatic studies seems more appropriate. Since there are currently no data from meteorological radars in the area under consideration, more detailed and accurate information we can only obtain from satellite data.

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