TOWARD STRUCTURE OF GEOSPATIAL DATABASE USED FOR GIS-BASED CLIMATE CHANGE MODELING

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ABSTRACT

Climate is a dynamic and extremely multifactorial phenomenon. Various climate models can be implemented to assess and forecast climate change, which incorporate various numbers of climate factors and consider these factors either as independent or as complex (through grouping more or less similar factors). In accordance to such flexibility of climate modeling, issues of models verification and model-based computations evaluation remain most important tasks. Solution for the verification and evaluation problems can be achieved, in particular, through implementation of a complex geographic information system (GIS) capable to provide accumulation and joint analysis of retrospective and real-time arrays of climate and supplementary geospatial data.

Our study series is devoted to the joint analysis of the dynamics of climate and vegetation cover parameters in the Northern regions. Currently we are presenting initial model of the geospatial database, which includes ground-based meteorological observations and satellite remote sensing data and allows assessment of various climate parameters (surface air temperature and humidity trends, framing dates and duration of growing seasons, etc.).

Keywords: Climate Change, Climate Parameters, Geospatial Database, Database Model

INTRODUCTION

More and more attention is paid last years to the phenomenon of climate change. It is well known that climate is a dynamic and changeable. However, while climate is influenced by many natural and anthropogenic factors, it is extremely hard to estimate its current state with needed detalization, and almost unfeasible to predict its future state reliably.

A study of the regional features of climate change and regional-scale dynamics of climate indicators can be a key to successful analysis and prediction of the climate variability and climate change on regional scale. To ensure such a study, a geospatial database have to be formed that is needed as a basis for regional climate computational model. This database must accumulate data series of meteorological observations and data series of observations of some climate indicator(s). Climate indicators are needed to fill gaps of meteorological observations, if presented, and to enhance accuracy when interpolating estimations of climate parameters onto the region area. One of possible climate indicators is the vegetation [3], [4], [10], that can be observed using remote sensing techniques, and can be monitored using vegetation indexes derived from satellite remote sensing data [1], [5], [9]. Previously we conducted a number of studies devoted to the exploration of interdependencies between dynamics of climate and vegetation parameters, and currently this study series is focused on software/data infrastructure design needed to verify detected interdependences and to ensure detailed analysis of dynamics of the climate-vegetation system on the study area.

STUDY AREA

In our study, we used Republic of Komi as a test area. The Republic is located in the northeast of the European part of Russia (Fig. 1). Covering about 416.8 sq. km, the territory stretches over more than 1,500 km from west to east and 2,900 km from south to north.

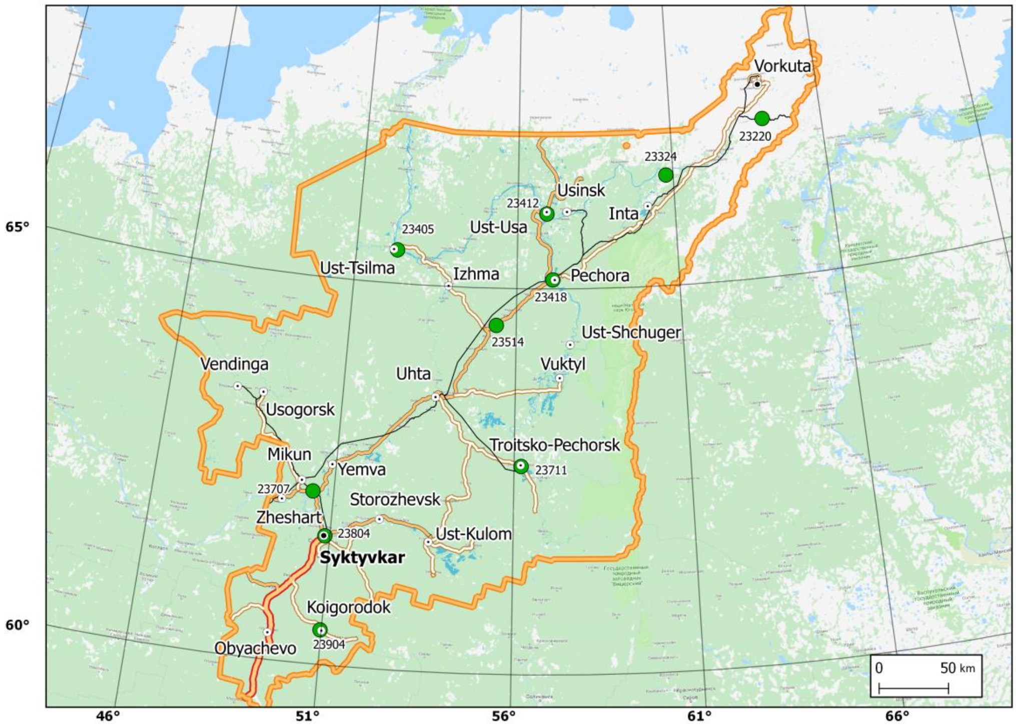

Figure 1. Study area location

The territory is covered by Taiga in southern part and by Tundra in northern, has dense river network, and covers slopes of Ural Mountains in eastern part, so the climate here is heterogeneous and arrives as a good example when studying regional differentiation of climate.

DATA AND METHODS

Taking into account 8-day time resolution of data series available for analysis on previous study stages (MODIS data were used [6], [7], [8]), we established the aim of time resolution enhancement to one day. Accordingly to this, we used AISORI database (*http://aisori-m.meteo.ru/waisori/*) as a source of the meteorological data (daily averaged ground air temperature and air precipitation data series were used); and Level-1 MODIS satellite imagery (*https://ladsweb.modaps.eosdis.nasa.gov/search/*).

AISORI database covers 58-129 years periods of temperature and precipitation observation for 10 meteorological stations located in Republic of Komi. The daily MODIS Level-1database is collected over 18 years (beginning from 2000), and incorporates imagery having 250-1000 m/pix spatial resolution (depending on imagery 5 channel).

Data processing was organized using Python scripting (*https://www.python.org*) in QGIS software (*https://qgis.org*) following the ideas of optimization and acceleration of operating with huge satellite imagery dataset.

RESULTS AND DISCUSSION

Meteorological and remote sensing data were incorporated into file-based data storage operated as common geospatial database through GIS shell (QGIS) with the help of Python scripts set. Currently, the database stores gridded maps of vegetation indexes (Normalized Difference Vegetation Index – NDVI, used as climate indicator [5], and Normalized Difference Water Index – NDWI, used as growing season indicator [2]); partially preprocessed gridded maps of growing season framing dates (estimated on the basis of NDWI analysis [6] and used to estimate dynamics of climate parameters [7]); and data series of ground air temperature and precipitation observations (used to interpolate and produce maps of temperature and precipitation and their normals). Data flows, used to fill the database with data and to provide data processing and analysis presented in Figure 2.

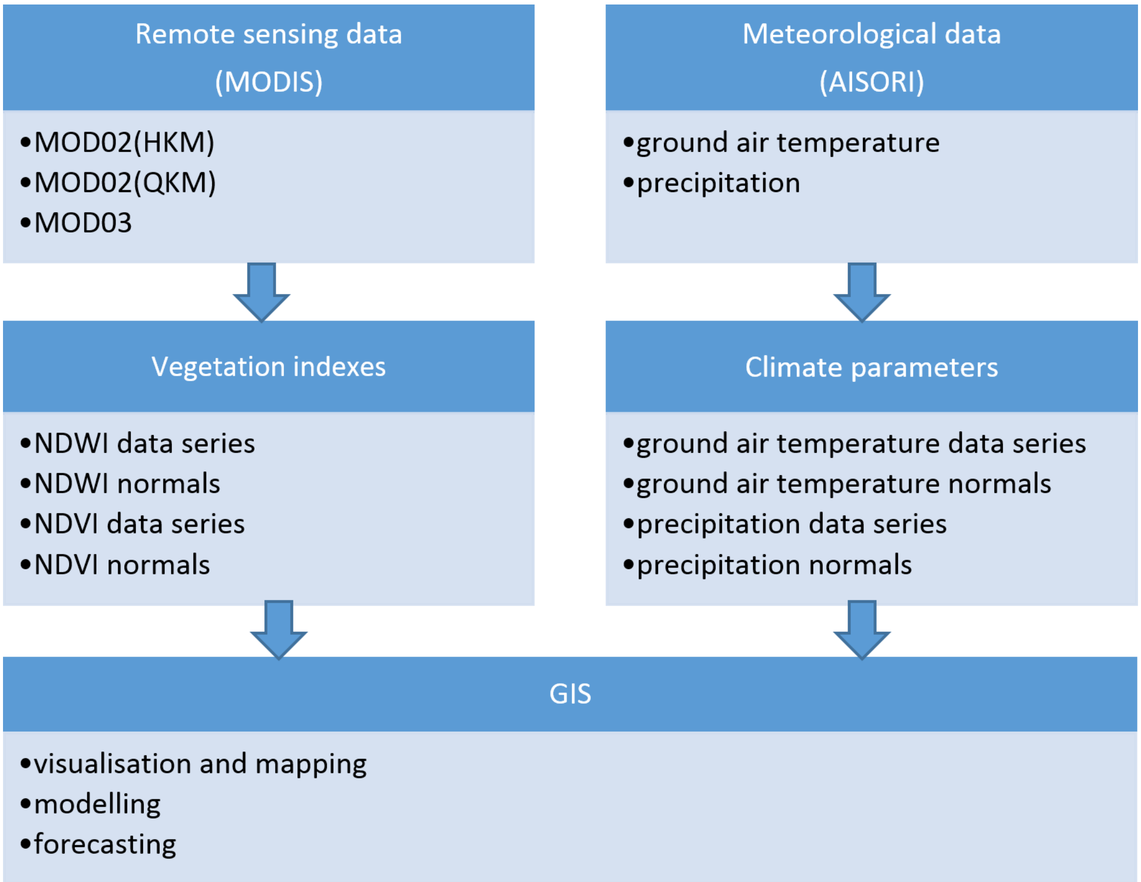

Figure 2. Data flows used to form and operate developed geospatial database

Accordingly to the Figure 2, visualization and mapping facilities of developed GIS are implemented on the basis of QGIS, and GIS-based modelling and forecasting facilities are the issues for future work. It is needed to be underlined also, that the database can be modified and adapted to new initial data types and data processing flows, as well as assimilation of developed software infrastructure is possible for any study area can be made. Examples of automated mapping of interpolated normals for average daily ground air temperature are presented in Figure 3.

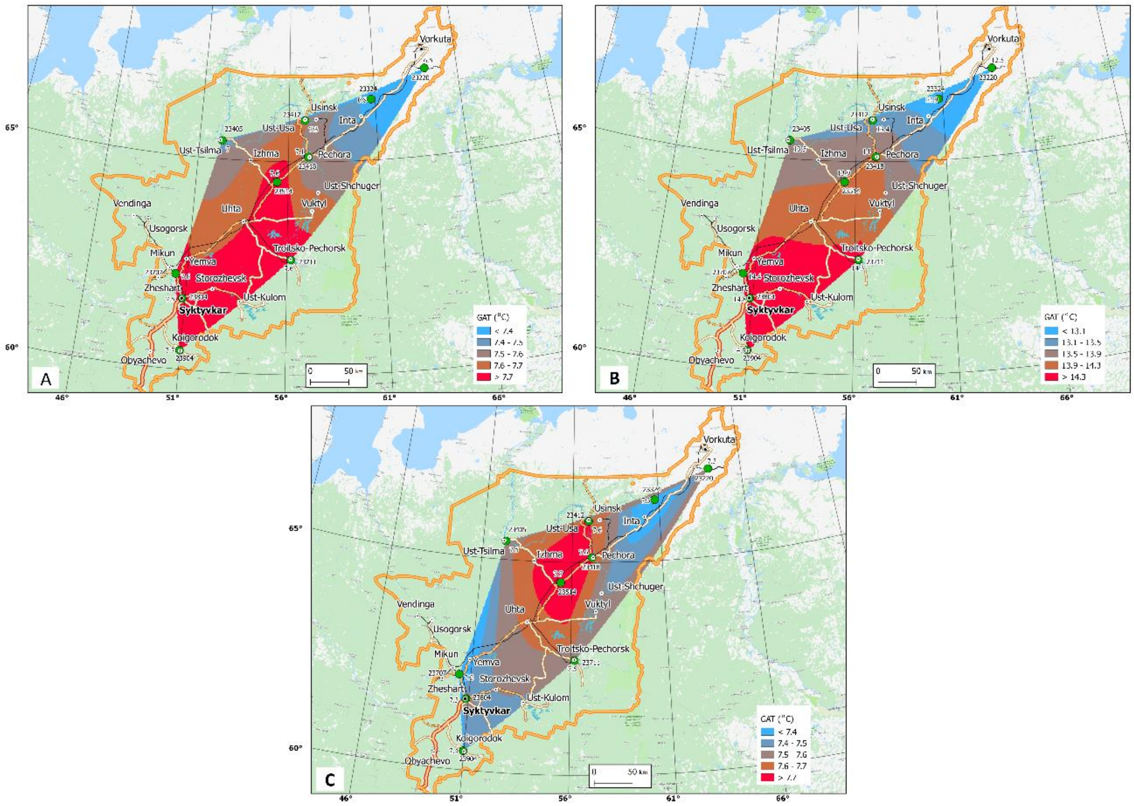

Figure 3. Spatial distribution of average daily ground air temperature (GAT) normals for the spring (A), summer (B), and autumn (C) growing seasons

Computing of climatological normal (temperature and precipitation normals) and vegetation index normal are needed to ensure resolution of weather instability problem ([8], [11], [12]) in future, when analytical functionality will be implemented to study climate dynamics. Time series of climate parameters, vegetation indexes and their normal can be mapped (Fig. 3) or visualized as graphs (Fig. 4). Maps and graphs can be formed for spring, summer and autumn growing seasons separately (as presented in the figures), or for full growing season. Figure 4 shows multiyear graphs for ground air temperature observed at Syktyvkar meteorological station (station ID 23804), the temperature increased by 2.3 °C, 0.9 °C and 1.8 °C during the spring, summer and autumn growing seasons respectively.

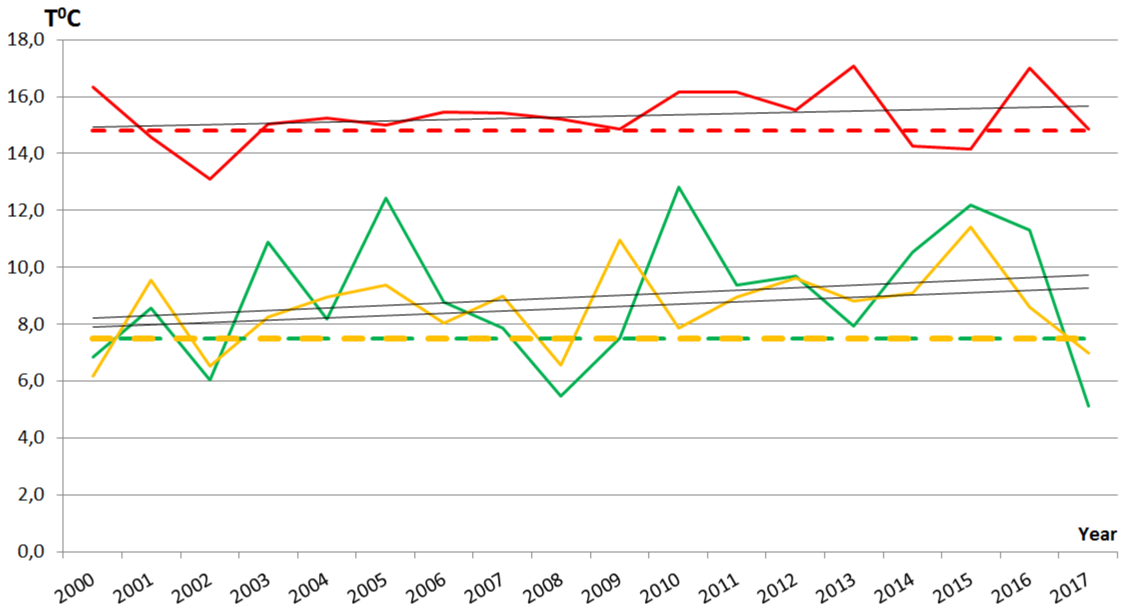

Figure 4. Graphs of average daily ground air temperature mean values for spring (solid green line), summer (solid red line) and autumn (solid yellow line) growing seasons for the period of 2000-2017; average daily ground air temperature normals (dashed colored lines) and trends (solid black lines)

CONCLUSIONS

Working on joint analysis of the dynamics of climate and vegetation cover parameters in the Northern regions, we have passed initial stage of the geospatial database formation and software infrastructure development. Having 1-day time resolution, the database designed to ensure detailed regional-scale estimation and study of climate dynamics. Currently implemented software functionality ensure loading of initial data into database and data visualization facilities. Next stage of work have to be devoted to formation of full-length data series for studied region (Republic of Komi).

ACKNOWLEDGEMENTS

MODIS Level-1 data were retrieved from the NASA Level-1 and Atmosphere Archive & Distribution System of Distributed Active Archive Center (*https://ladsweb.modaps.eosdis.nasa.gov/search/*).

Meteorological data were retrieved from AISORI online database operated by World Data Center of All-Russian Research Institute of Hydrometeorological Information (*http://aisori-m.meteo.ru/waisori/*).

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