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CAPABILITIES OF THE “IKI-MONITORING” CENTER FOR COLLECTIVE USE IN ORGANIZING THE SATELLITE MONITORING OF THE CENTRAL ASIAN REGION

ABSTRACT

The computing power of modern technical equipment allow to solve different scientific and applied problems. The paper considers the practice of organizing special satellite monitoring service with the help of the “IKI-Monitoring” Center for Collective Use. A number of scientific and applied problems often require rapid access to satellite data, that sometimes is impossible because of the need to store all data locally. In this case the Center for Collective Use allows to analyze the long-term archives available online, process them and save the results right on the server or download it to the PC. The technology is now being practiced to organize a number of specialized services and adapt them to the needs of different regions. At the current stage the project is targeted to solve the problem of regular monitoring of water objects in Central Asia. The service is a part of “VEGA-Constellation” information systems set and was called

EcoSatMS (Ecosystem Satellite monitoring Service). The paper is focused on the capabilities of “IKI-Monitoring” and its application in framework of the new technology for remote monitoring the parts of river courses, i.e. the integration of virtual hydroposts. The methods used for the current research can be expanded and developed further to understand the influence of the water resources dynamics on agriculture and ecosystem in general.

KEYWORDS: Earth Remote Sensing, distributed data processing, water resources, Central Asia, virtual hydroposts

INTRODUCTION

Over the past few decades, there has been an almost exponential increase in the volume of data obtained by the satellite remote sensing systems [*Proshin et al.*, 2019]. As of the beginning of October of 2019, more than 320 remote sensing spacecrafts (https://www.ucsusa.org/resources/satellite-database) operated in earth orbit (except for nano-satellites), the data of several dozen of which are publicly available. Significant increase in demand for remote sensing data from modern satellites requires access to long-term archives of satellite data for certain regions. At the same time, it is very important for many scientific and applied projects to process multi-year satellite datasets, however it is not always possible because of the limits of local computational powers. Traditionally, data acquisition and processing do require to surf more than one source to find suitable satellite images. In case we need to process large data series this procedure can take extra time and memory storage.

There has been a great breakthrough in the field of cloud computing, cluster technologies, high load distributed systems etc. The new technologies and approaches were used in 2012 to launch the “IKI-Monitoring” Center for Collective Use (CCU) of systems for archiving, processing and analysis of satellite observations data in IKI RAS [*Proshin et al.,* 2019]. To date, more than 90 different scientific organizations from different countries have taken advantage of this opportunity. A variety of resources provided by the “IKI-Monitoring” CCU were used in the

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implementation of dozens of scientific projects including the ones supported by RSF, RFBR and the Ministry of science and education of the Russian Federation [in the same work].

The paper considers the application of the “IKI-Monitoring” CCU to the development of the new information system for remote monitoring and special online tools for satellite data processing. The results and research in the field of water resources of Central Asia have become a good starting point to clarify the needs of the region and develop a certain set of online functionalities to perform in-line-processing of the data. The article also provides examples of some information systems developed previously.

MATERIALS AND METHODS OF RESEARCHES

The depth of long-term archives of “IKI-Monitoring” CCU are currently estimated for more than 30 years. The CCU provides an overview of the accumulated archives of satellite data and thematic products derived from their processing. Currently, the archives of the "IKI-Monitoring" CCU contain data obtained by more than 35 different observation instruments installed on both Russian and foreign satellites for Earth remote sensing [*Proshin et al.*, 2019]. The total amount of data available to users online is currently about 3,2 petabytes. More than 3 terabytes of new data are being stored into the archives daily. The peculiarity of the CCU is that the data covers about 27 % of the land surface area of the Earth. Currently, the area of interest for permanent acquisition and processing of satellite data includes almost the entire territory of Northern Eurasia, including the Arctic territories, the border seas of Russia, as well as a number of regions in Africa, Asia, North and South America [in the same work]. Up-to-date information about available data can be found on the website of the CCU (http://ckp.geosmis.ru/default.aspx?page=6).

All available online data is actually divided by types and ways of acquisition, i.e. physically stored data in the archives is processed to generate “virtual” products. The main data sources of the Centre are performed on fig. 1.

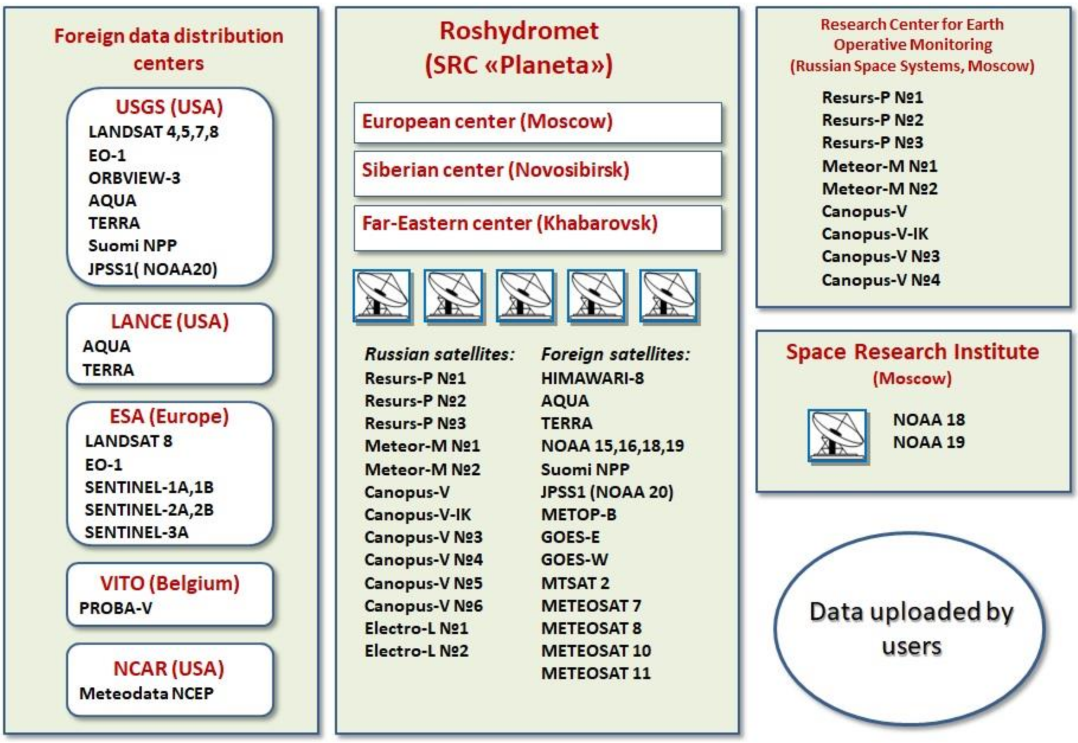

Fig. 1. The main data sources of the “IKI-Monitoring” CCU

In framework of the "IKI-Monitoring" CCU, the data access has been implemented in three ways:

- the “VEGA-Science” (http://sci-vega.ru) satellite information service providing the remote users with interactive access to the data archives of the “IKI-Monitoring” CCU, as well as with facilities for data processing and analysis;
- software interfaces for data access from auxiliary information systems;
- software gateway that provides access to data physically stored in external satellite data archives [*Proshin et al.*, 2019].

“VEGA -Science” is a unique scientific platform and is free to use for research and educational (non-commercial) purposes. The interface of the service allows to surf over data archives and filtering data by a number of parameters — satellite, scanning device, data source, cloud cover percentage, spatial resolution etc. Vega-Science is a base platform from the set of information systems “VEGA-Constellation” (http://sozvezdie-vega.ru/eng/). The fig. 2 shows the web-interface of the service and demonstrates the available data for MSI device (Sentinel-2A, -2B) for period from 2019-05-01 to 2019-05-05 on the map. The footprints on the Figure demonstrate the area of interest, that includes Northern Eurasia, South India, certain zones of Africa and South America.

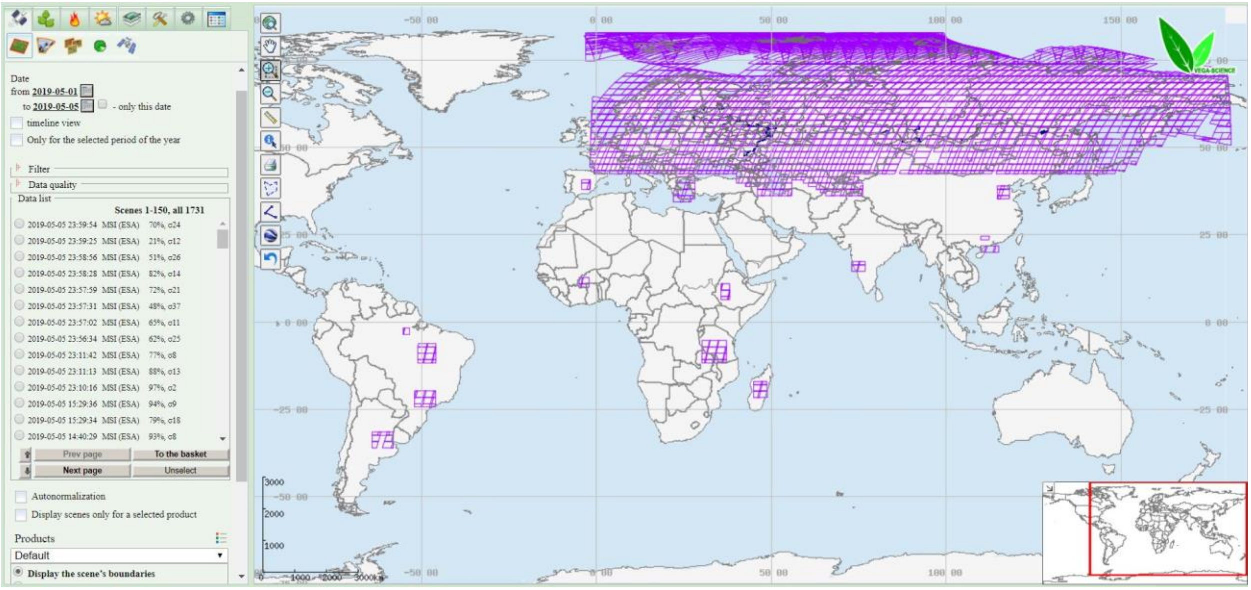

Fig. 2. Sentinel-2/MSI data coverage within 5 days.
The area of interest for projects of «IKI-Monitoring» includes
Northern Eurasia, South India, certain zones of Africa and South America (http://sci-vega.ru)

The two main technologies used to provide satellite data and the processing tools to the users through web-interfaces are GEOSMIS [*Tolpin et al.*, 2011] and UNISAT. The latter is a unique technology for building unified systems for maintaining extra-large distributed archives of heterogeneous satellite data. The key advantages of this technology are the support of the mechanism of “virtual information products”, i.e. products that are dynamically generated if requested by user and based on the satellite data available in the archives, as well as support tools for online analysis and data processing. GEOSMIS provides constructing interfaces for working with spatial information in remote monitoring systems. This technology is designed to create interfaces for working with distributed multidimensional archives of satellite data and the results of its processing. The technology is used also to create tools for analysis and data management.

Web-interface of a certain system contains a wide range of filters and interactive tools, adapted for the target problem and region. Below is just a short list of common tools for all services of “VEGA-Constellation”:

- tools for calculating spectral indices and image algebra, allowing to carry out arithmetic, logical operations and various mathematical transformations on the data, as well as to calculate spectral indices with arbitrary selected channels;
- supervised and non-supervised classification of satellite data, allowing split the area of the image into a number of classes according to certain parameters;
- color adjusting of images and color composition of several images, including multi temporal composition;
- use of palettes;
- data correction — this tool enables image filtering, topographic correction, limiting area of interest applied to selected channels of any selected satellite images from the archive;
- structural image analysis — this tool implements LESSA (Lineament Extraction and Stripe Statistical Analysis) technology. This technology is designed to automate the analysis in geological studies of the data of various types, including images, diagrams, digital elevation models (DEM) [*Proshin et al.*, 2019].

The interface allows to save the result of data processing on the server or to download directly to PC. Among the products, that are available to be carried out with use of common processing tools (for all services):

- time series of data: values at specified points, indices on objects (fields), meteorological variables, etc.;
- spectral profiles at selected points or selected objects;
- meteorological data, including vertical profiles;
- spatial profiles along arbitrary routes.

As an example of special processing tools adapted for certain projects it is possible to pick out the following:

- modeling the behavior of ash plumes from volcanoes;
- modeling of fire dynamics;
- monitoring and analysis of the state of agricultural fields and monitoring the dynamics of agricultural crops;
- detection of forest logging based on the use of a time series of spectral channels of satellite images;
- sensitive to changes in vegetation cover [*Proshin et al.*, 2019].

Technologies for remote sensing of Central Asia

Research in the field of water resources of Central Asia often requires rapid and stable access to satellite data of the region. The methods and a schema of monitoring the water surface area of certain objects like water reservoirs have been implemented and organized as a separate system of Ecosystem Satellite Monitoring Service — EcoSatMS (http://suvo.geosmis.ru). EcoSatMS is a scientific project which is targeted to the development of the techniques of automation analysis and satellite monitoring of Central Asian water objects and the use of monitoring results for data analysis. The peculiarity of the service is that it realizes a brand-new processing tool for objects survey.

Today Central Asian countries face urgent problems of water resources, including water scarcity and inefficient use. For many decades, agriculture has been one the most significant field of economics. To support this filed at an appropriate level there should be a reasonable use of fresh water. As the most of Central Asian rivers are transboundary, it is necessary to get actual and independent information about its state on time.

The web-interface of EcoSatMS is similar to VEGA-Science (http://sci-vega.ru). However, the new service still differs from the base one, because it is adapted for the region and focused on the fast computation of the target information.

A new technology of "virtual hydroposts" was introduced to monitoring the sections of transboundary rivers and water bodies. Under the assumption "virtual hydropost" will make it possible to forecast river water content for a given period almost without using data from land-based hydrological stations. This technology is based on the functionality developed in the IKI RAS services — a unified subsystem for working with observations of natural and natural-anthropogenic objects called ObjectsSurveysSMIS. The subsystem consists of a database of objects, an access library to it, a processing system and tools to work with objects, control the processing of satellite data and analyze the dynamics of changes in objects in the web-interface (http://suvo.geosmis.ru/maps/?lang=eng).

In particular, a "virtual hydropost" is an arbitrary polygon (fig. 3) on the riverbed submitted by the user and saved to the database with the time range for selection of satellite images in distributed data archives. The main characteristic being determined for the "virtual hydropost" is the water surface area, which is determined by calculating the modified normalized difference water index or MNDWI [*Golyatina*, *Kurganovich*, 2019] for each image. Pixels in which the index value is greater than 0 form a water surface and are accepted as significant. This tool uses data from OLI, TIRS (Landsat-8), MSI (Sentinel-2A, -2B), TM (Landsat-4, -5) and ETM + (Landsat-7) systems. The resulting series of observations can be manually marked by the user as correct or incorrect and subsequently exported in tabular format (XLS). Indeed, "virtual hydroposts" can be added to database for small lakes, water reservoirs and parts of the river beds. The latter performs an idea, that MNDWI in this case shows actually the width of the river section.

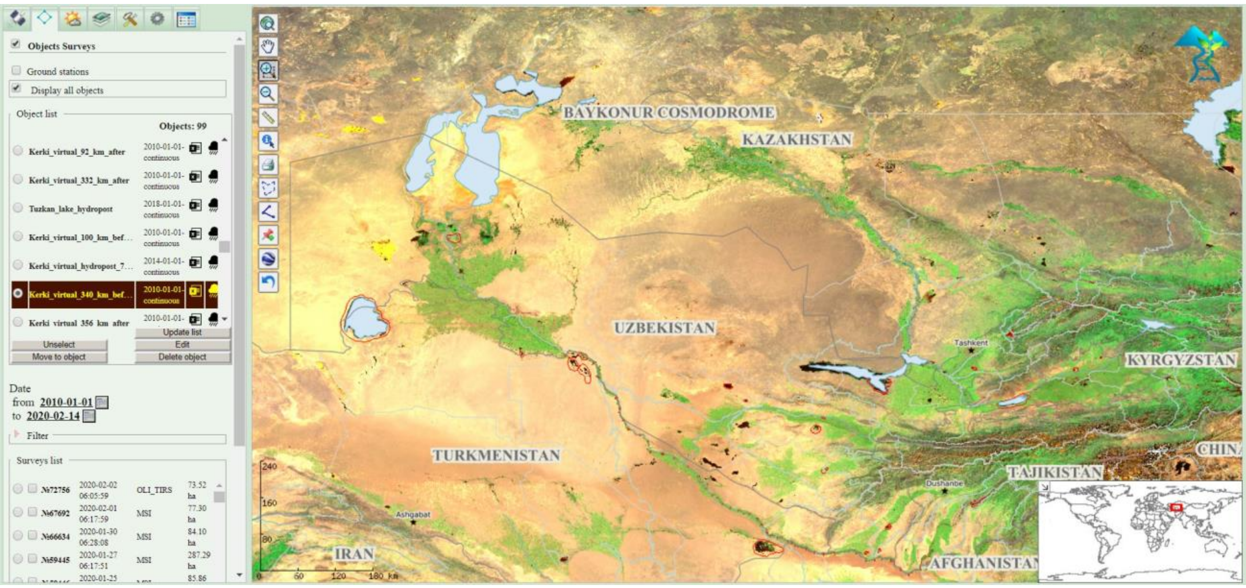

Fig. 3. The objects survey tool in EcoSatMS (http://suvo.geosmis.ru). "Virtual hydroposts" are shown as red polygons

The user can also use resulting series in the analytics module with automatic charting, which provides the ability to analyze the seasonal, annual and long-term dynamics of the water surface area.

Due to the availability of continuously updated long-term archives of satellite data of various resolutions based on the resources of the “IKI-Monitoring” Center for Collective Use, it is possible to provide access to up-to-date information and statistics derived from the processing of the obtained satellite images. Depending on the time range and the size of the “virtual hydropost”, the calculation of the water surface area for one object takes from several minutes to several hours.

RESULTS OF RESEARCHES AND THEIR DISCUSSION

In framework of EcoSatMS, MNDWI was implemented as a virtual product. The fig. 4 demonstrates the result of processing the satellite image within a polygon set on the river bed. According to the figure, the water pixels are registered by the threshold when MNDWI is 0.

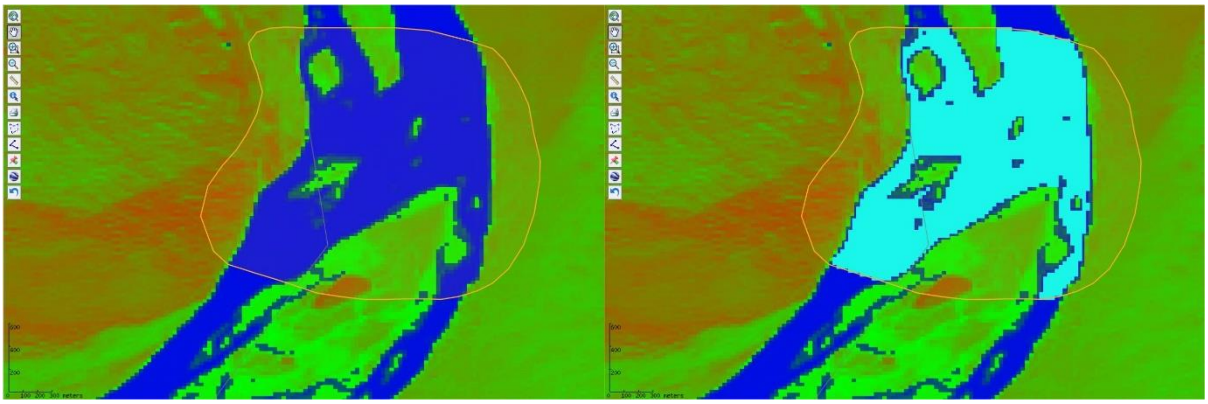

Fig. 4. Water pixels extraction result in EcoSatMS. MNDWI virtual product is on the background

The first stages of the research with use of the new satellite service are focused on looking for the correlation between the dynamics of the water surface area on Amu Darya, Syr Darya, Kara Darya river beds and daily runoff at the nearest to polygon physical gauging stations. This research could be a good base to find significant figures for a target model of water use and water balance for the certain basins. An automated analysis tool has been developed to accelerate the time-series analysis procedure, as well as a module for 3D performance of the “virtual hydropost” using ASTER GDEM V2 are being tested now. As these tools are implemented in test mode, they are being improved to increase the accuracy and performance. Some “virtual hydroposts” have already been processed for different periods and the time-series for satellite and ground-based data. The approach shows to be quite useful to detect the correlation between two different types of data and even find a linear relationship for certain cases. EcoSatMS allows to plot the results and scale them in interactive mode, when the analysis takes a few seconds and can be started right from the map interface.

CONCLUSIONS

Every system developed with the use of GEOSMIS and UNISAT has a unique application area and is to be used by the specialists in specific fields. Today a number of hydrologists in Central Asia are making various investigations in the field of water resources. Actual and on-time information about the state of water objects is a base to make forecasts, enrich datasets and develop models. That is why it is very important to make the satellite service easy to use, fast, stable and capable of providing reliable functionality for making surveys.

The further development of EcoSatMS includes implementation of online calibration procedures of MNDWI curves using ground ones. This can help to understand the dynamics at “virtual hydroposts” and build a forecast model using the relationship of distance-days. It means that the further “virtual hydropost” is located, the highest time lag it has (fig. 5). In addition, the algorithms of computing the water surface area are improved to reduce time required to separate reliable surveys from the outliers.

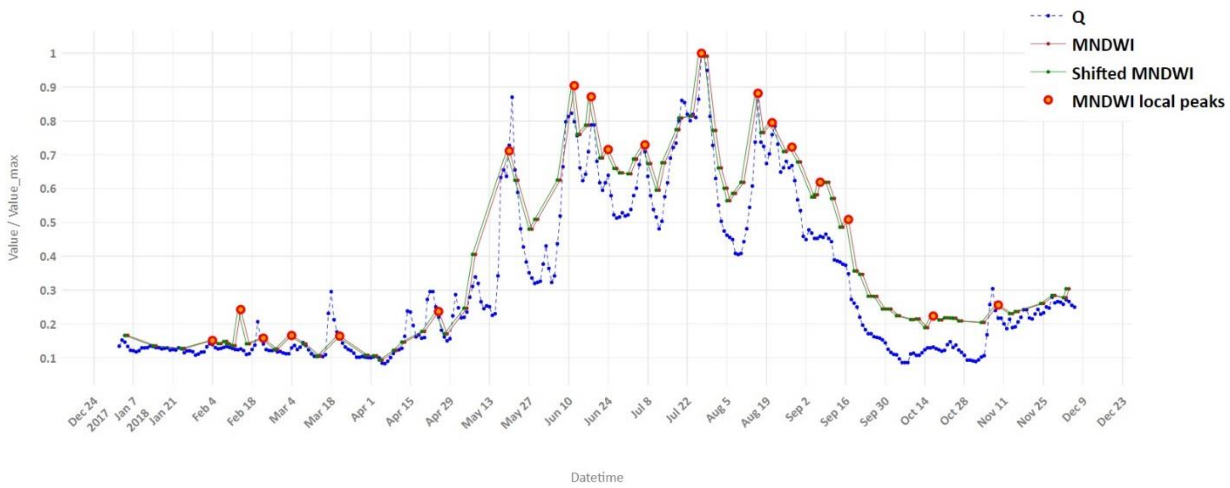

Fig. 5. The sample of common diagram for normalized figures as time-series. Shifted MNDWI demonstrates the lag for MNDWI curve to get the best correlation value with the ground figures.

In the future EcoSatMS will also integrate the algorithms for assessment of the state of agricultural fields adapted for Central Asian region.

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