The Satellite Processing System in the Regional Centre for Remote Sensing FRC KSC SB RAS

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Abstract. Methods of creating multi-layer cartographic images for operational satellite monitoring systems based on web GIS technologies are discussed. The generated map can contain a set of raster and vector thematic layers of spatial data. Setting view parameters provides the ability to select the format of spatial data on the client, control the display parameters (interactive legend, list of displayed attribute fields), use custom templates to display tabular information.

Keywords: web mapping service, geoportal, spatial metadata, satellite monitoring system, web map-ping, spatial data catalog, web application, web GIS.

1 Introduction

The development of Earth remote sensing systems is currently due to a number of factors such as an increase in the number of spacecraft and improve their technical characteristics, increasing the availability of satellite information associated with the development of the Internet, including due to the increase in speed and lower cost of access, the development of web services and geospatial data transmission standards [1]. New technologies of automation of processes of reception and processing of remote sensing data, technologies of creation of ultra-large archives in specialized data centers allowed to organize essentially new schemes of work with satellite data, to create new generation of systems of operational monitoring of the natural environment. Their key elements were geospatial web technologies, interactive online mapping systems with direct access to satellite information, provided with the ability to configure various parameters of visualization of geospatial data and the construction of complex analytical queries.

Technologies of geospatial web systems and services are developing dynamically at the present time [2-4]. You can find more than a hundred Russian geoportals on the Internet, dozens of geoservices, web GIS, mapping services and spatial data visualizers. Various specialized solutions for working with satellite data have been created. Along with the traditional tasks of simple visualization of maps and mosaics of satellite images, modern software provide the user with the possibility of flexible configuration of various parameters of cartographic visualization, spatial data processing services [5].

It should be noted that significant changes are currently taking place in the area of applying remote sensing satellite data in solving various scientific and applied problems as follows:

- The capabilities of remote sensing satellite systems have abruptly increased. It became possible to organize monitoring of rapidly occurring processes due to the increase in the number of satellites. Over the past 4 years, the number of satellites has increased by an order of magnitude, the availability of high-resolution data has increased (up to 3 m/pixel).
- The number of remote sensing satellite systems with "measuring" properties has increased. Such systems provide not only qualitative but well-calibrated quantitative information about various objects, processes and phenomena.
- The level of information availability has increased. The data of many satellite systems began to be freely expanded both through the Internet and directly from satellites in an unencrypted form.
- A significant increase in the amount of satellite data and the development of the requirements and cost of the systems for their reception and primary processing led to the intensification of transition from the use of personal remote sensing processing systems to service-oriented solutions based on regional specialized remote sensing centers.

Catalyst studies on the subject under discussion was the commissioning of the new satellite reception station in Krasnoyarsk. It is a UniScan-36 station by ScanEx company which receive data in the X-band at a frequency of 8

GHz. It can acquire data from all the relevant low-orbiting meteorological satellites of medium spatial resolution (TERRA / AQUA, Suomi NPP / NOAA-20, FengYun-3). Such a station is capable of receiving up to 320 Mbit/s, the number of reception frequencies (receivers) and the type of phase modulation. Taking into account the orbital altitude of the polar-orbiting satellites of about 800 km and the capture band of 2-3 thousand km, the viewing area of such a station represents approximately an ellipse measuring about 5 by 8 thousand km long in longitude. For the station located near the geographical center of Russia, in Krasnoyarsk, about 80% of the territory of Russia is viewed twice a day from each receiving device.

The task was to create a modern data processing complex based on modern computer equipment (high-performance servers and storage hardware, local area network with a capacity of 10 Gbit/s). The logical division into stages of data transformation (data acquisition, primary and thematic processing) provides the construction of a modern scalable remote sensing data processing system.

The experience of our own research and development in the subject area shows that the system-forming element in the development of software to solve the problems of monitoring the assessment of the state of the environment on the basis of remote sensing data is a GIS platform that conceptually determines the architecture and capabilities of implemented solutions. The main trend now is the transition to the use as a workplace of the end user GIS solutions based on a web browser, as well as embedding the necessary set of scripts to work with the system in geospatial web portals. In some cases, these solutions are auxiliary and perform mainly the functions of viewing spatial data.

2 Geospatial platform

Modern web GIS are built in the so-called service-oriented architecture, and they can be considered as a set of interrelated software tools for spatial data management, such as import/export, cataloging, visualization, creation, processing, distribution, etc. [6, 7].

The technological basis of such solutions are usually feature-rich specialized software libraries such as Google Maps API, Mapserver Mapscript, GeoMixer ScanEx, and so on. They provide access to the functions and context of map elements of web pages, including map visualization tools, spatial metadata such as, for example, a road network with traffic data, terrain, points of interest on the map, etc. [8]. Software and technological support of the satellite monitoring system is usually also created in accordance with this approach, as it is also a web GIS.

One of the first tasks at the design stage of any application system is the choice of technological scheme (geospatial platform) of GIS project, in particular: software, technologies for spatial data storage and processing. Currently, two alternatives in the choice of basic software are traditionally considered: on the basis of commercial software products or free & open source bundle. Leaving aside the financial, philosophical and hypothetical aspects of this choice, it is worth noting that today in practice there is often no opposition between these two approaches. And the reason is that now commercial and free GIS complement each other well due to the compatibility of data formats, standards of information exchange based on web services, etc. For example, you can analyze spatial data in ESRI ArcGIS, convert it to MapInfo for transmission to a customer, and use the free Mapserver software to present it on web pages, and create a catalog of spatial metadata using GeoNetwork Open Source. At the same time, you can use an open PostgreSQL database with the PostGIS extension module to store spatial data, which for the vast majority of tasks is almost as good as the performance and functionality of ESRI ArcGIS Server or Oracle database with the Oracle Spatial extension. The determining factor is the competence of specialists who provide technical support for the selected solutions. Commercial products are usually easier in the initial setup, working "out of the box" immediately. Free software also has its advantages associated with the openness of the architecture, the possibility of expansion.

Noting the specifics of satellite monitoring systems, it should be noted that most of the algorithms for processing satellite data created by NASA are available in the source code. Experts from around the world exhibit to such resources is of considerable interest because get the possibility of direct analysis of existing data processing methods and create your own modified algorithms. NASA is interested in constructive criticism and prompt correction of the observed errors.

3 Satellite data visualization system

As a software basis for the satellite data catalogue, a geospatial web server was used, whose modular architecture allows the system to be developed in the process of its operation, by adding new means of access to data, as well as improving existing means. All development is based on free and open source software, both in terms of GIS and in all other components. The considered web application provides the user with the means of filling and editing data and metadata of the system, search and classification of cartographic resources, web services of direct access to data based on standard WMS/WFS protocols, analytical processing capabilities [9].

The server part of the system is implemented using the design template MVC (model-view-controller), technologies "Web 2.0" [10]. Using this architecture involves separating application data, user interface, and control logic into three separate components: model, view, and controller. Thus, each component can be modified independently. In the conditions of constant modernization of the system, continuous specification of technical requirements and formulation of the problem, these opportunities become very relevant.

During the development of the system under consideration, several new software components and libraries were created that can be used (replicated) in other projects [11]. These are user interface elements, geospatial database services, applied web mapping services, etc.

Basic web GIS functionality is provided by the UMN Mapserver and MapGuide Open Source software. Also used geospatial database PostgreSQL/PostGIS, web content management system based on CMS Drupal and wiki system DokuWiki, a whole family of libraries for building the user interface and other system components for programming languages JavaScript, PHP, including JQuery, Fusion, TinyMCE, ExtJS, MapScript, and many others.

4 The particular implementation of the catalog of satellite data

The priority task of research and development at this stage was the creation of software for working with satellite data catalogs. The developed software tools provide a solution to the priority tasks of operational processing of remote sensing data coming from the new satellite receiving complex UniScan in the Federal Research Center "Krasnoyarsk Scientific Center of the Siberian Branch of the Russian Academy of Sciences" (FRC KSC SB RAS), which was put into operation in the spring of 2017. This station provides real-time data reception from the main meteorological spacecraft (Terra, Aqua, Suomi NPP, FengYun-3, JPSS-1/NOAA-20) via X-band frequency channels and includes an antenna system with a reflector diameter of 3.7 m, receivers allowing to receive data at a rate of up to 750 Mbit/s, the necessary software.

The basic software of the satellite receiving complex of the FRC KSC SB RAS forms a set of standard products of the 1st level – these are per-channel images (brightness of spectral channels). Further tasks related to the extraction of useful information and thematic processing of data are solved separately by means of special software.

The system of web visualization of satellite information is based on a set of specially formed collections of multi-scale images [12]. It is characterized by the possibility to choose in the web interface combinations of displayed channels at small scales and at the same time the availability of detailed data at the most accessible spatial resolution. The limitation in the choice of channel combinations at the detailed level is due to the saving of disk space. Thus, a compromise between the class system "work with rough quick-bows" and the level system "anything with maximum detail" is realized. The created web interface provides viewing of satellite images archive. It provides the ability to select the spacecraft sensor, select a predefined set of channels and products for each image for simple data analysis. The capabilities of the created software module allow you to combine any combination of channels available in the image without additional configuration of the server software.

When forming color images using Look Up Table (LUT), it is a kind of "table of corrections" to make changes to each of the three channels. Previously, to improve the image quality, spectral transformation was used, which is based on the work with a spectral diagram showing the relationship between the number of pixels in the image and the values of spectral brightness. When spectral transformation changes such a parameter as the contrast. To increase contrast, the histogram was stretched linearly, with all brightness values being assigned new values to cover the entire possible range from 0 to 255. The LUT allows you to change the brightness value of the pixels in the image when converting image to 8 bits from 16 bits by using linear interpolation between them. This allows you to take a brighter picture. An example of a web interface is shown in Fig. 1.

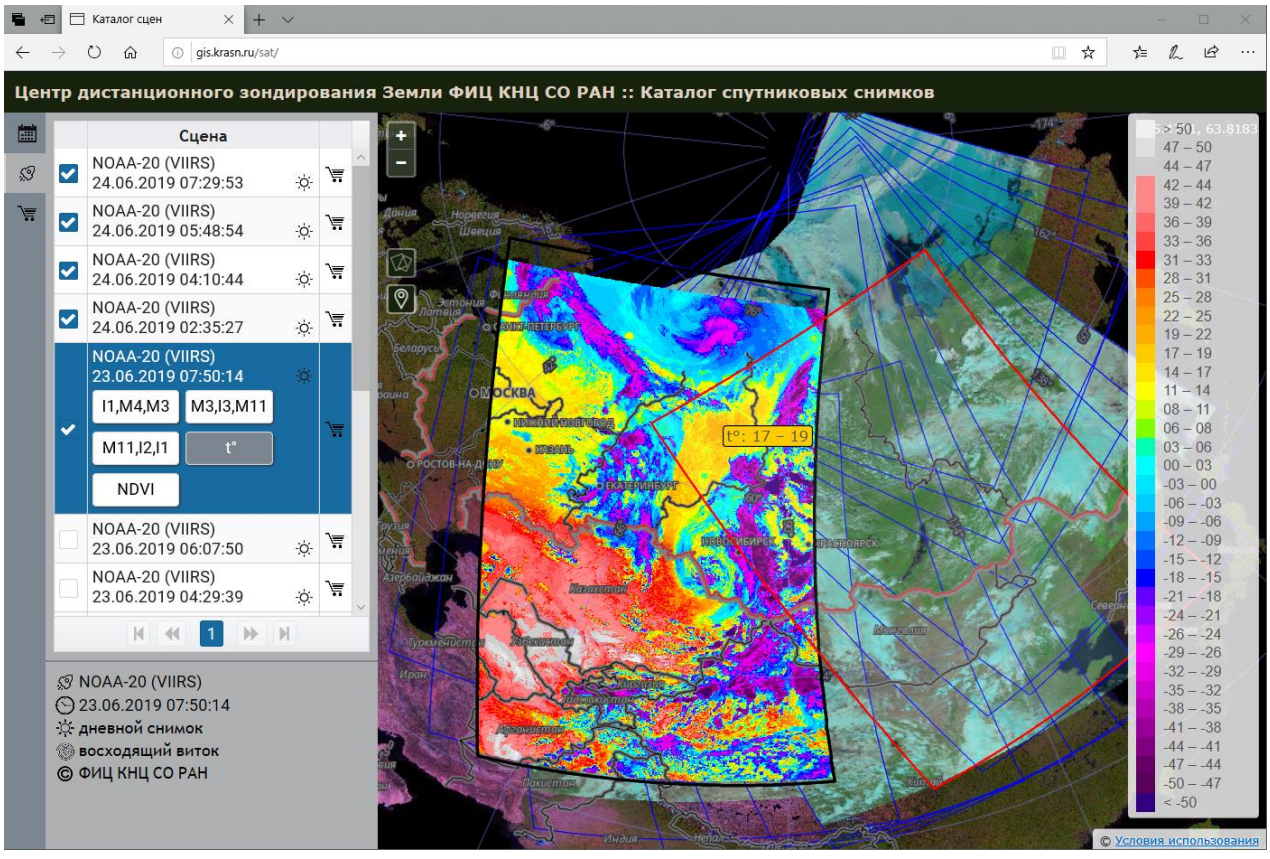

Fig. 1. The interface of the catalog of satellite images of the FRC KSC SB RAS.

The main tasks of the development at this stage are related to the implementation of methods and algorithms for satellite data processing. Technological features of working with raster data are determined by the need to quickly display large files. Experiments with different formats and their parameters have shown that the optimal choice in terms of minimizing the display time in a web browser is the format TIFF with geo-referencing (GeoTIFF), using the TILES structure (the image consists of a set of independently stored similar fragments), pre-calculated pyramidal (overview) layers OVERVIEW. All of these processing steps are performed by the GDAL library utilities.

The developed software tools provide a solution to the priority tasks of operational processing of incoming remote sensing data, their cataloging, interactive visualization using a web application. We considered the following data: MODIS TERRA/AQUA, Suomi NPP/NOAA-20.

For quick and easy search in the catalog of satellite data, to minimize the load on the server software and hardware, a set of server applications for pre-processing of satellite data, including the following stages of processing:

1. Conversion of the original raster data to the GeoTIFF format with conversion of the original projection to the Lambert Azimuthal Equal Area (code EPSG:3576), which is mandatory for the open Geospatial Consortium services.
2. Create a catalog of color images for all scenes in coarse resolution ("quick looks") in raster PNG format, with transparency. Such images are used for quick overview display of satellite data registered in the catalog, with simultaneous visualization of a set of such "quick-looks" in the web browser window, with scaling on the client side, without reloading/downloading data via the Internet.
3. The creation of a multiscale set of multiband images of format GeoTIFF. Each such image, created in a certain spatial resolution, contains several "significant" channels, from which a certain set of color composite images are generated on the fly in the web application. For example, for a TERRA/MODIS sensor, a multichannel image contains 1, 2, 3, 4, 7, 31 channels, on the basis of which a set of commonly used composite R-G-B images are dynamically formed: 1-4-3 ("Natural colors"), 7-2-1 ("Fires"), 3-6-7 ("Snow and ice"), as well as single-channel images with palettes – 31 ("Temperature"), 2-1/2+1 (NDVI). Examples of such images are presented on Figure 2.

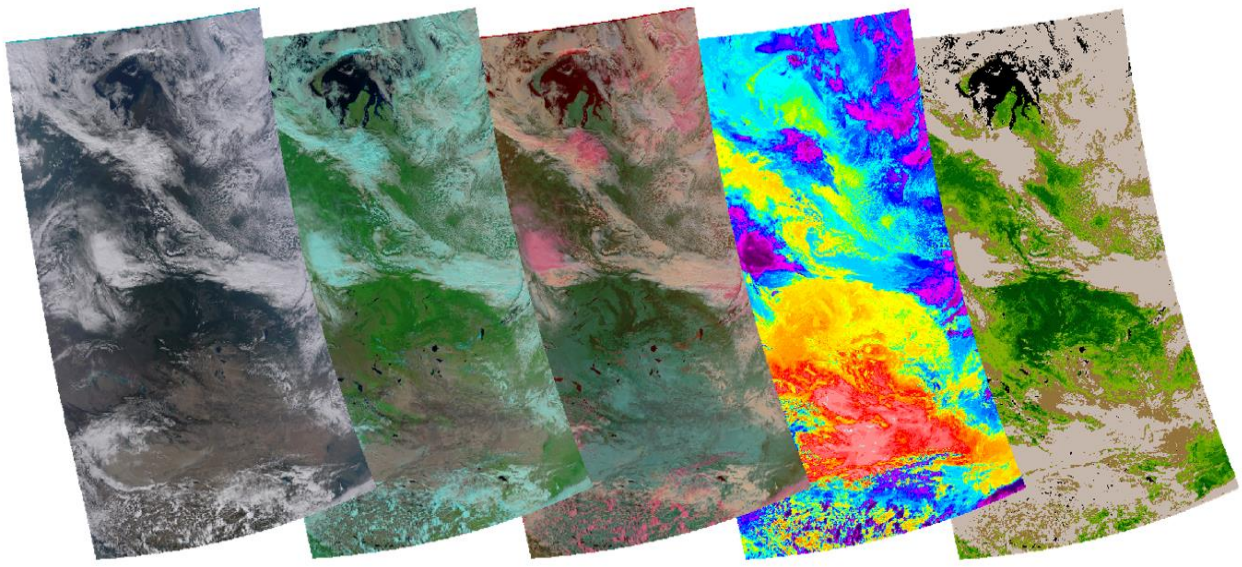

Fig. 2. Options for displaying combinations of spectral channels in the satellite data visualization system.

The presented development of the satellite data catalog should be considered as a basic software tool set of components focused on the creation of applied monitoring systems, the solution of individual tasks on the basis of operational satellite data. In particular, the prospects for the implementation of such projects in the field of fire and agricultural monitoring are currently being analyzed.

It should be noted that the already created implementation of means of access to satellite data can be used in a number of applications. In particular, by analyzing the available data using the web interface of the developed catalog of satellite images, it is possible, for example, to determine the dynamics of the opening of the rivers of Siberia from the ice in the spring (Fig. 3). To do this, select the date range, specify the desired fragment of the territory, choose the optimal mode of visualization of images. Thus, the data cataloging system acquires the functions of an analytical system, becomes a tool for preliminary data analysis, for which it is not necessary to download images to your computer from catalog, because the web application solves all the problems.

Another similar example of the preliminary analysis is the solution of the problems of assessing the dynamics of vegetation development on the basis of the NDVI vegetation index (far right image on Fig. 2). The user can simply

click on the image to determine the value of the vegetation index at the desired point. Looking through the time series of images, you can make preliminary conclusions about the change in NDVI.

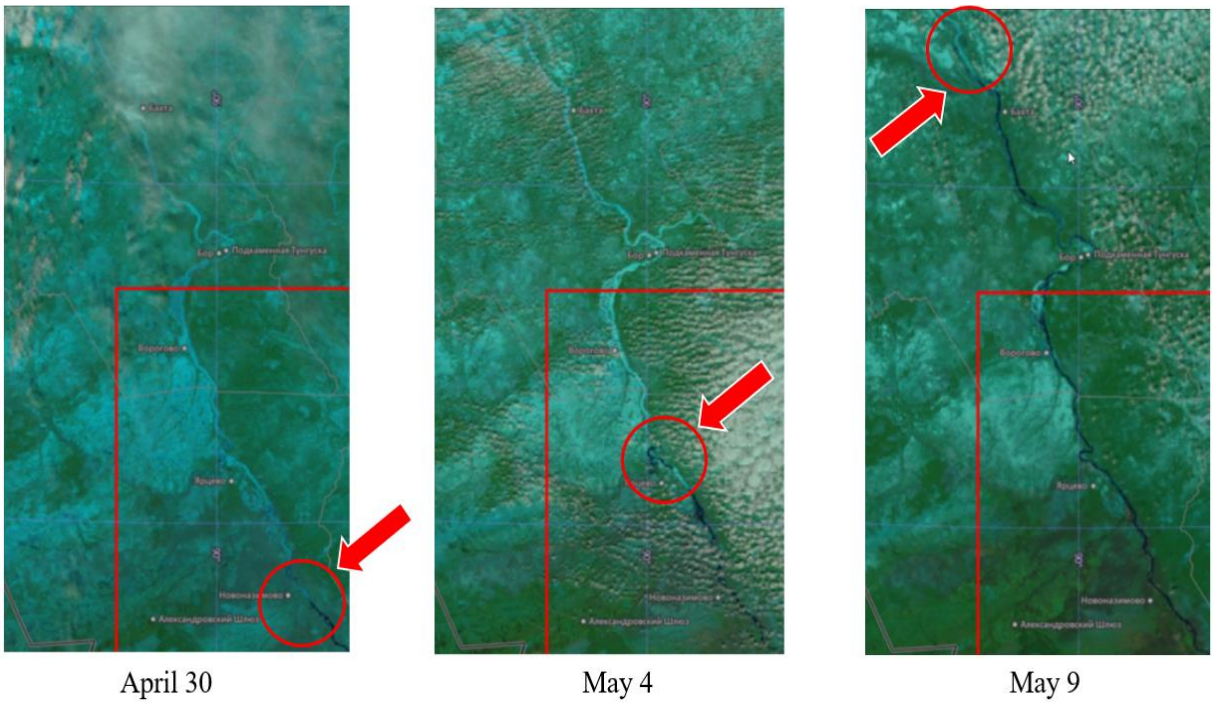

Fig. 3. Displacement of the ice edge on the Yenisei river in the spring of 2018 at a distance of about 400 km in 10 days (VIIRS NOAA-20 data).

Catalog of satellite data currently contains the daily satellite imagery of medium spatial resolution TERRA/AQUA, SUOMI NPP/NOAA-20, as well as a set of selected cloud-free high spatial resolution images (LANDSAT 7/8, SENTINEL 2). A number of satellite catalog data is in limited access, due to licensing restrictions (images from Russian satellites CANOPUS-B, RESOURCE-P). The presence of such high-resolution data in the catalog saves time when solving problems.

5 Conclusions

The creation of effective software and technological tools for the tasks of regional satellite monitoring based on the technologies of geospatial web systems has significant prospects. Modern technologies and software provide the implementation of reusable tools that can be replicated on different current applications. Simple developed satellite image cataloging systems are becoming analytical information systems with special tools for data analysis and presentation.

The developed approach can become the basis for solving actual applied problems, which are based on the use of remote sensing data, modern spatial data infrastructure for effective socio-economic and innovative development, competitiveness and ensuring safe life.

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