Information and analytical provision of the satellite monitoring system

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Abstract. This scientific work discusses the problems of formation of information and analytical support of satellite monitoring tasks. The information and computational technologies for regional level monitoring systems, peculiarities of their organization and software architecture are considered. A brief description of the completed work, aimed at development of software for the satellite image catalogue, formation of a regional satellite data center is given.

1. Introduction

Intensive current development of natural resources in Russia inevitably forms the problem of developing new modern means of appropriate environmental control, monitoring of changes in the state of the environment. The existing nowadays ideas about what kind of information support system should be used to solve these problems, need to be clarified and reinterpreted due to the significant progress in the field of Internet technologies during the recent years. We should also note the dramatic changes in the situation with high-resolution satellite imagery: the information becomes available almost daily, which opens up unprecedented earlier opportunities [1–4].

The traditional monitoring system today includes an information and measurement network, a data transmission network, a monitoring center and a network of user terminals, including mobile terminals. As a rule, extensive databases of spatial data, remote sensing data (RS), and analytical support tools are used, all this means allow real-time mapping of current and predicted changes in state, resources and objects of the controlled territory, based on mathematical modeling methods and by solving direct and inverse transfer problems. A modern automated information system should also provide its users with effective means of information interaction [5, 6].

Web technologies can provide a new quality of monitoring systems, bring them into a new level, and improve dramatically the task solving effectiveness. On the other hand, modern geoinformation systems (MIS) provide a huge range of tools, including measurement tools, advanced tools for topological and spatial analysis, as well as tools for working with external databases. In addition, GIS provide work with any reporting materials, remote sensing data (aerial photographs, space images, seismic sounding data, etc.) [7, 8].

On the basis of the analysis of the current information and computational technologies and the corresponding functional requirements of the modern monitoring systems, it can be concluded that the most appropriate technical model of such systems is a multicomponent software and technology complex, i.e. a distributed geoinformation system based on the modern web interfaces and services, it provides high-level interactive user and program interfaces to geospatial data (web GIS). The client software, forming the basis of automated workstations for users (AWs), is created on the basis of a standard web browser that can work on personal computers, tablets, and smartphones. It is also necessary to create specialized software that provides, among other things, automatic loading of monitoring data from remote sensors and observation posts [9]. The system server components are usually built on the basis of relational DBMS, business logic servers, tools for providing spatial data stores. Given the current realities, we should consider the distributed storage systems, specialized data centers of the regional level in the "cloud" architecture. The specific configuration of the systems depends on the tasks that should be solved [10, 11].

This scientific work studies the experience of research and development carried out on the topic under consideration at the Federal Research Center "Krasnoyarsk Scientific Center of the Siberian Branch of the Russian Academy of Sciences" (FRC KSC SB RAS) is considered.

2. The system software architecture

As a program basis of this GIS, a geoinformation web server was used, the modular architecture of which allows to develop the system already in the process of its exploitation, by adding new means of access to data, and also improving the existing ones. The entire development is performed on the basis of free and open source software – both in the GIS part and in all other development components.

The basic functional components of the considered system are:

- database of characteristics of monitoring objects;
- catalog of information resources and spatial metadata;
- a set of auxiliary web services.

In particular, the catalog of information resources contains objects of various types:

- structural elements (organization, server, folder);
- the security system elements (user, role);
- information resources (cartographic layer, map, attribute data, analytical service with web access, publication, etc.);
- elements of classification of information resources;
- information and navigation elements (HTML documents).

This GIS provides the user with means for filling and editing the system data and metadata, searching and classifying of cartographic resources, web services for direct access to the data based on standard WMS / WFS protocols, and analytical processing possibilities [12, 13].

The server part of the system is implemented using the MVC design pattern (model-view-controller) [14]. Using this architecture involves splitting of application data, the user interface, and control logic into three separate components, i.e. a model, a view, and a controller, so that each component can be modified independently. In conditions of the system constant modernization, continuous specification of technical requirements and task statement, these possibilities become very actual [15, 16].

In the process of the considered system development, several new software components and libraries, that can be used (replicated) in other projects, were created. These are the elements of the user interface, services for working with geospatial DBMS, the applied cartographic web services, etc. [17].

The UMN Mapserver and MapGuide Open Source software tools provide the basic web-GIS functionality. Geospatial DBMS PostgreSQL/PostGIS, Drupal CMS-based web content management system and DokuWiki wiki system, a whole family of libraries of building the user interface and other system components for JavaScript programming languages, PHP – JQuery, Fusion, TinyMCE, ExtJS, MapScript, and many others – are also used [18].

3. Peculiarities of satellite data catalogue implementation

Priorities for research and development carried out at the FIC of the KSC of the SB RAS at this stage were related to creation of software tools for working with satellite data catalogs. The developed software tools provide the solution of the priority tasks for the operational processing of remote sensing data from the new UniScan satellite reception facility at FIC KSC of the SB RAS, which was put into operation in spring, 2017, as well as via a dedicated data transmission channel from the Siberian Regional Center for Remote Sensing of Roscosmos based on JSC "Information Satellite Systems" named after academician M.F. Reshetnev in Zheleznogorsk (JSC ISS).

The basic software of the receiving complex UniScan forms a set of standard products of Level 1, i.e. channel images (brightness of spectral channels). Further tasks related to the extraction of the useful information, thematic data processing, are solved separately, by means of special software.

The priority task of the first stage was creation of a system of web-visualization of satellite information available in the formed regional archive of satellite data. It is based on sets of specially created collections of multiscale snapshots, with possibility to select in the web interface the combinations of displayed channels on a small scale, and, at the same time, with the availability of detailed data at the maximum possible spatial resolution. The limitation in the choice of channel combinations at a detailed level is associated with the disk space economy. Thus, a compromise is realized between the class system "we work with rough Quik Looks" and the level system "anything with maximum detail". The created web interface provides viewing of the archive of satellite images. It provides the ability to select a spacecraft sensor, to select a predefined set of channels and products from each snapshot for simple data analysis. The advantages of the created software module allow to combine any combination of channels available in the image without additional configuration of the server software.

To create the color images, LUT (Look Up Table) is used, this is a kind of "table of corrections" for making changes to each of three channels. Previously, to improve the image quality, a spectral transformation was used, it is based on work with a spectral diagram showing the relationship between the number of the image pixels and the spectral brightness values.

With spectral transformations, such parameter as the contrast changes. To increase the contrast, a linear histogram stretching has been used, meaning that all brightness values are assigned with new values in order to cover the entire possible range from 0 to 255. LUT allows to change the brightness value of the image points when converting a picture to 8 bits of 16 bits by linear interpolation between them. This allows to make the picture more vivid. An example of a web interface is shown in Figure 1.

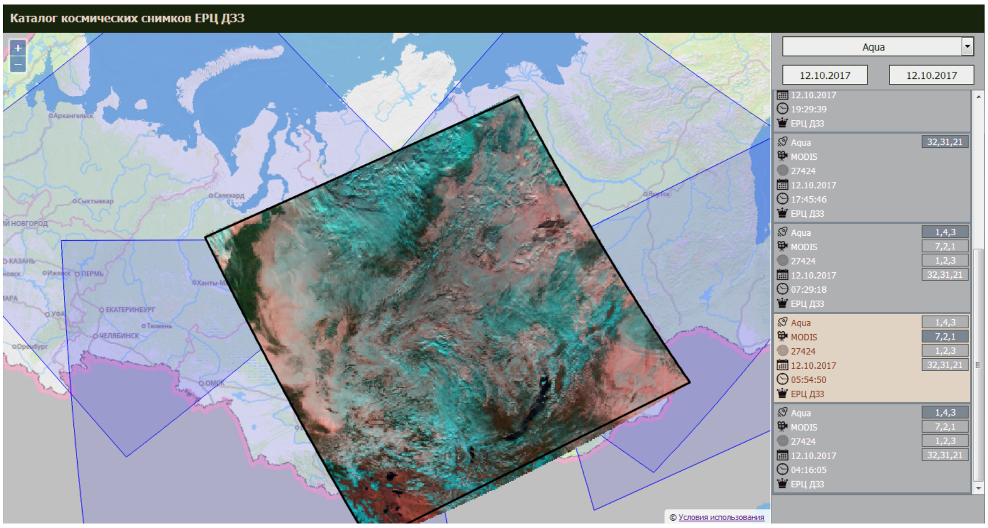

Figure 1. Web-based directory of satellite imagery.

Tactical development tasks are associated with implementation of methods and algorithms for processing satellite data. Technological features of working with raster data are predetermined by the need to quickly display large files. Experiments with various formats and their parameters have shown that the optimal choice in terms of minimizing the display time in a web browser is the TIFF format with georeferencing (Geo-TIFF), with application of the TILES structure (the image consists of a set of independently stored one-type fragments), with previously computed pyramidal (survey) layers OVERVIEW. All the above processing steps are performed by the GDAL library utilities [19].

To generate a number of information products based on satellite imagery, it is assumed that indexed rasters are widely used, where each image pixel contains an index, and the file header, i.e. a table with color values for all palette indices (Figure 2).

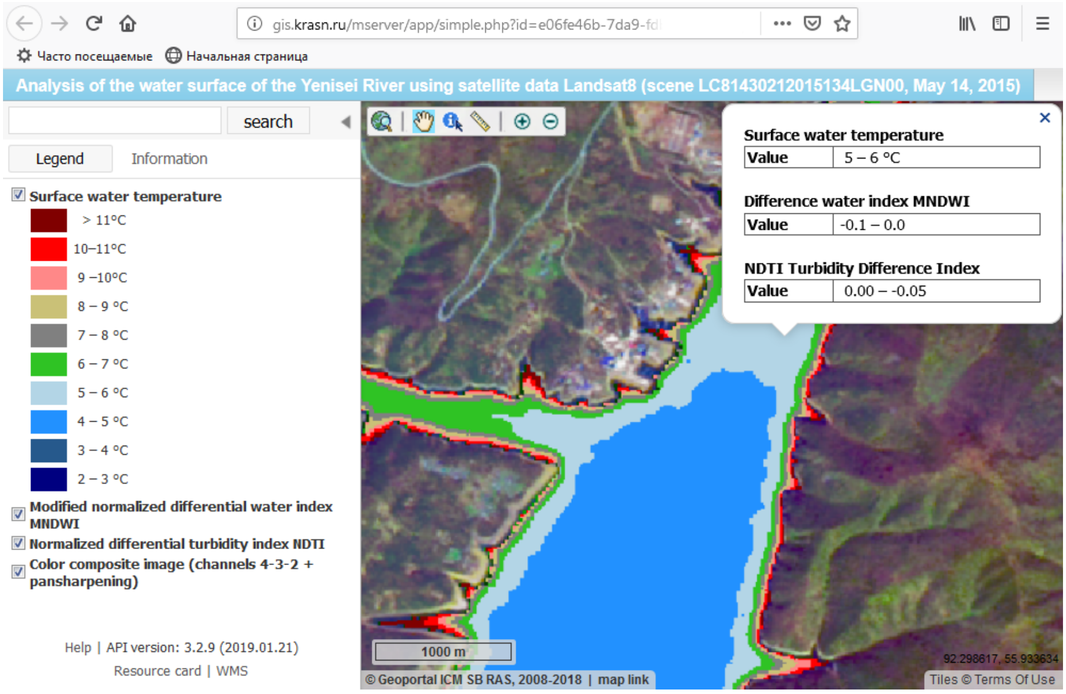

Figure 2. Thematic maps of water temperature and a number of other characteristics of the Krasnoyarsk reservoir, based on Landsat-8 satellite data.

The developed software tools provide the solution of the priority tasks for operational processing of the incoming remote sensing data, their cataloging, and interactive visualization with use of a web application. The following data were considered: MODIS TERRA / AQUA, Suomi NPP, Meteor-M No. 2 CMCC.

To make a quick and easily search in the satellite data catalog, to minimize the load on the server software and hardware, a set of server applications for preliminary processing of the satellite data, including the following processing steps is prepared:

1. Converting the original raster data to GeoTiff format with transformation of the original projection into the Lambert Azimuthal Equal Area (EPSG code: 3576), which is mandatory for functioning of the OGC services (Open Geospatial Consortium). EPSG Geodetic Parameter Dataset is a structured set of data, coordinate systems and coordinate transformations accessible through the Internet registry (www.epsg-registry.org).
2. Creation of a color image for different display scales, consisting of three spectral channels. Such images will be used to view the satellite image in detail, maintaining the original resolution. For MODIS, day and night shots are combined as a basis for a color RGB image: in the daytime shooting time, channels 7-2-1 are used in the range from 0 to 100% albedo with a gamma of 1.8; at night channels 21-31-32 in the negative display are used from 235K to 305K with gamma 1. For the spacecraft Meteor-M No. 2, the base color image contains a red, green and blue channel, calculated on them and the near infrared channel of the CMMS device.
3. Creation of a multi-channel image to show Quicklooks in a web application for different display scales, but with a lower resolution (up to 1 km per point). Unlike the basic color image, the "Quicklinks" in a web application can be displayed in groups, depending on the user's choice,

whereas the basic color image will be active only for one selected picture. For MODIS spectroradiometer, the multichannel image contains 1-4, 7, 21, 31, 32 channels. Combinations of these channels allow the construction of images with natural colors for the human eye, pseudocolor images for classification of snow and ice, images for determining fires and smoke, etc.

4. Products for the spacecraft Meteor-M # 2 are in the form of a raster multichannel image in GeoTIFF format with NDVI indices (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index). The NDVI index is designed to detect and assess the intensity of vegetation of plants. To calculate the index, the spectral brightness values in the red and near infrared spectral ranges are used. The NDWI index shows the moisture content in the soil and leaves of plants. To calculate the index, the spectral brightness values in the green and near infrared spectral ranges are used. The NDWI index shows the moisture content in the soil and leaves of plants. To calculate the index, the spectral brightness values in the green and near infrared spectral ranges are used.
5. Conversion from 16-bit format to 8-bit, more suitable for displaying satellite imagery in a web application and requiring significantly less resources in the storage system.

4. Prospects for Implementation

Creation of an effective software and technology tool for objectives of the regional satellite monitoring has significant prospects. The strategic task of research and development in this context at FIC KSC SB RAS is solving the actual applied problems, related to the current and future needs of the Krasnoyarsk Territory, based on the use of the remote sensing data, the modern spatial data infrastructure, for effective socio-economic and innovation development, improving the level of competitiveness and safe living. The regional center for satellite monitoring, in conjunction with other regional and federal information systems, should contribute to solving the following tasks of the state authorities and local self-government of the Krasnoyarsk Territory:

- creation of information and analytical tools for making well-founded management decisions based on an analysis of operational and objective information from space monitoring and other sources;
- increase of the efficiency of the exchange of geospatial data between the registered monitoring center and the government of the Krasnoyarsk Territory;
- provision of operational work with the order, collection, storage, and display of space monitoring materials on the territory and individual objects of the Krasnoyarsk Territory;
- implementation of possibility to monitor the land resources, carry out transport management, comple with the terms of licensing agreements for extraction of mineral resources, and also environmental management systems, detection of unauthorized disposal of domestic waste, selection of investment sites;
- realization of possibility to collect and display data on incidents and events in the region on a specialized geoportal;
- providing a quick search and ordering the archival materials of satellite imagery, stored in the archive of space and attributive information;
- display by means of the geoportal of the ready geospatial data sets about various territories of the regional infrastructure of the Krasnoyarsk Territory;

The expanded activities cover a wide range of areas, i.e. water and forestry, prevention and liquidation of emergencies, agriculture, ecology and nature management, land and real estate, territorial planning [20].

During the 2017, specialists from the FIC KSC SB RAS and JSC ISS conducted consultations with the sectoral ministries of the Krasnoyarsk Territory and subordinate institutions. As a result, a preliminary list of priority tasks have been identified, these objectives are supposed to be made "pilot projects" in the Krasnoyarsk Territory. Among them are:

- Monitoring of flood and ice conditions in the areas of transport highways, water transport routes of the Yenisei Basin;

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- Monitoring system of flood and ice conditions in the area of the 2nd stage of the Novo-Angarsk concentrator;
- Monitoring systems of specially protected natural territories of the Krasnoyarsk Territory; areas affected by the oil and gas industry and landfills of solid domestic waste;
- Operational twenty-four-hour monitoring of forest fires in selected (agreed) areas in the Krasnoyarsk Territory.
- Mapping the agricultural lands for the purpose of precision farming.

One of the possible mechanisms for infrastructural support of these tasks is formation of a "regional priority project", secured by targeted financing in accordance with the Krasnoyarsk Territory law on priority projects (programs).

5. Conclusion

The system of satellite monitoring opens new opportunities in solving important tasks of the regional level, which it is impossible to settle by other means today. The effectiveness of the proposed approaches is based on modern computer technologies, software, new satellite data, and methods for large data processing. The use of the remote sensing data and technologies can radically improve the efficiency and quality of decision making.

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