

The System of Operational Processing of Satellite Remote Sensing Data in Krasnoyarsk Science Center of Russian Academy of Sciences

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Abstract

The results of research and development devoted to the creation of information and computing support for the system of operational satellite monitoring in the regional center for remote sensing of the Earth in Krasnoyarsk are considered. The initial information comes from its own satellite reception complex of Krasnoyarsk Science Center and via Internet channels from Roscosmos geoportal. The created software package provides a full cycle of operations with satellite data, including their reception and pre-processing, placement in the archive, conversion and visualization services with the help of a specialized geoinformation web system to work with the catalog of satellite data. Special information content of this system has also been created, including a collection of basic cartographic substrates, additional cartographic data layers. A set of tools for operational analysis of available information, including tools for working with different combinations of layers of multispectral images, has been implemented.

1 Introduction

For the solution of tasks to ensure effective use of results of space activity in the Krasnoyarsk territory in May 2017 was launched a new satellite receiving complex of Federal Research Center "Krasnoyarsk Science Center of the Siberian Branch of the Russian Academy of Sciences" (FRC KSC SB RAS) United Regional Center for Remote Sensing of the Krasnoyarsk Territory (URC RS). Receiving the complex is built on the basis of the Scanex UniScan Ground Receiving Station. Currently, it is used to receive data from the Terra, Aqua, Suomi NPP, NOAA-20 and Feng Yun satellites. The use of Suomi NPP and NOAA-20 data significantly expanded the capabilities of remote monitoring systems with the involvement of new data of increased spatial resolution and radiometric sensitivity. In addition, work on the formation of a local archive of actual images of Landsat and Sentinel satellites on the territory of the Krasnoyarsk territory began in the URC RS for information support of the tasks to be solved. Also, together with the Siberian regional remote sensing center of Rosmoskos in Zheleznogorsk, work was carried out to create an archive of satellite data from the Russian Meteor-M2 satellite.

2 Image processing technology

A large number of information systems based on Earth remote sensing data have been developed in the world [Wei18, Cas17, Ma15]. We can assume that the general arrangement of the remote sensing data processing has already been sufficiently established; basic units include receiving and archiving, as well as primary and thematic processing. At the first stages of monitoring systems development all the stages of processing remote sensing data had to be implemented in the construction of a specific system and a special infrastructure had to be completely created. However, today the use of specialized centers for data storage, processing and analysis is more efficient and appropriate from different points of view.

To access the data of the receiving complex and the created archives, a catalog of satellite data was developed, a set of tools for processing the initial data and preparing them for quick display through a web browser was formed. Before developing the software, the existing tools for cataloging satellite data in the world and Russia were analyzed [Gri10]. The considered solutions can be conditionally attributed to the following groups:

- a simple tool to search through a catalog of images with their viewing as small-scale color bitmaps;
- search and navigation tools with the ability to visualize different image channels and their combinations, as well as tools for analyzing satellite data.

The first group allows you to find pictures in the catalog, and then view them as one or more overview “quick look” images (a small image with simplified detail), or allows you to see a more detailed color image in natural colors on a limited scale. The second group of web services allows you to view detailed images, found pictures, and also allows you to manage the channels of pictures to create themed products with artificial colors.

As a result of the analysis of existing products, it was decided to create a service to access the satellite data catalog to the territory covered by our receiving station in the form of a combination of tools from the two groups considered. Currently, our receiving center is available file storage capacity of about 100 TB, which is not enough to store the entire range of finished products. To solve the problem with the limited size of the file storage, a pre-formed archive of images with a limited number of channels for visualization and analysis of satellite data. An additional task was to develop a technology for online publication of data from the catalog of images, as the internal structure of existing solutions is poorly represented in publications and the Internet.

We have chosen an approach that saves disk space and allows getting an acceptable result. On the basis of the initial source images, two "base products" are formed daily for data from the Terra and Aqua MODIS sensor, Suomi NPP and NOAA-20 VIIRS sensor and data from the downloaded archives for the Sentinel-2A MSI and data from the Landsat-8 OLI & TIRS instruments:

- Multichannel image with an incomplete set of channels unlike the original picture, but a sufficient list of channels to create the main products with the image in artificial colors. For all spacecraft data available in the catalog, combinations are formed such as a color-synthesized image in "natural colors", a combination of image channels most suitable for fire and fire detection, and a combination used to display snow and ice. In addition, the new image contains channels for calculating the indices NDVI (Normalized Difference Vegetation Index) [Shu16], NDWI (Normalized Difference Water Index) and the Land Surface Temperature (if there is a corresponding infrared channel) [Pch17].
- Single-channel image to determine the percentage of clouds. Since in most cases the images cover a very large area and almost always have areas covered with clouds on the territory of our country, the total cloud cover of the entire image is of no interest. Such images with a rough cloud mask allow you to search for images in the catalog by the percentage of clouds within a small selected area.

Developed a set of programs to create small overview color images in natural colors in png format to view multiple images at the same time. Such images allow you to get the overall picture for a day or several days in the reception area of the complex. For daytime scenes, a specific set of channels is used for each instrument in the range of 0 to 100% albedo with a gamma of 1.8. At night, a single-channel image based on a single channel in the range from 220K to 300K with a gamma of 0.5 in the negative is used.

The MODIS instrument uses a 7-2-1 channel combination to create overview images, and the following channel sets are used for multichannel images:

- 1-4-3 natural colors;
- 7-2-1 for fire detection;
- 3-6-7 to display snow and ice combination;
- 31 for surface temperature;
- 1 and 2 to calculate NDVI index.

For VIIRS, a combination of M11-I2-I1 channels is used to create overview images. For multichannel images, the following channel sets are used, which are closest to the MODIS device:

- I5-M4-M3 natural colors;
- M11 I2-I1 for the detection of fires combination;
- M3-I3-M11 to display snow and ice combination;

- I5 for surface temperature;
- I1 and I2 to calculate NDVI index.

For the Sentinel-2A MSI instrument, a 12-8-4 channel combination is used when creating overview images, for multi-channel images, the following channel sets are used, the closest to the MODIS device:

- 4-3-2 natural colors;
- 12-8-4 for fire detection.;
- 2-11-12 to display snow and ice combination;
- 4 and 8 to calculate the NDVI index.

No surface temperature was used for Sentinel-2A.

PNG files based on multi-channel images are used to quickly view overview images. In this part, the developed system works as a representative of the majority of existing satellite image cataloging systems. A multi-channel image is also used to analyze satellite images in the web browser, which allows you to combine different available channels online. Additionally, products are formed in the form of single-channel images that require calculation. For example, the NDVI index calculated from the data of the red (1 channel for MODIS, I1 channel for VIIRS, 4 channel for MSI) and infrared channels (2 channel for MODIS, I2 channel for VIIRS, 8 channel for MSI) by the formula $(2-1)/(2+1)$ for MODIS instrument, $(I2-I1)/(I2+I1)$ for VIIRS instrument, $(8-4)/(8+4)$ for MIS instrument. Another example is the land surface temperature in Celsius degrees, calculated from the brightness of the pixels of the corresponding infrared channel.

When forming color images, a LUT (Look Up Table) is used, this is a kind of "correction table" for making changes to each of the three channels [Gen17]. LUT allows you to change the brightness value of image pixels when converting images using linear interpolation and retains the overall contrast for all images. Additionally, the pixel brightness value is converted from 16 bit to 8 bit representation.

Before displaying the images in the browser web interface, the gamma setting for the MapServer software for 16-bit images is automatically performed using LUT tables for 10 reference points. Without these changes, rasters look much darker, had to use the automatic calculation of the raster histogram for each image, which in turn led to some artifacts when viewing images in the web interface and the overall contrast of all images was different, since the automatic calculation was performed for each raster independently.

PNG overview images are created using the GDAL library with image format and size conversion. Applies nonlinear scaling using the power function to change the brightness and contrast of the image. The operation is performed by the GDAL translate tool, which is designed to convert raster data between different formats:

```
gdal_translate -of png -a_nodata 0 -co worldfile=yes -outsize xsize ysize
-b b1 -b b2 -b b3 -exponent exp_val -scale 0 65535 0 255 file1 file2
```

In addition, a set of background base maps was created for the web interface using a projection more suitable for the Krasnoyarsk region territory. In particular, the Lambert Azimuthal Equal-Area (LAEA) projection (EPSG code: 3576) was used [Kad19a]. The same projection is used to generate most of the spatial data in the developed system to eliminate the resource-intensive reprojection operation when viewing such images.

As a result, a set of server applications for satellite data preprocessing has been prepared, which provides a quick and convenient search in the satellite data catalog, while minimizing the load on the server software and hardware. It contains the following processing steps [Yak19, Kad19b]:

1. Convert the original raster data to GeoTiff format and convert the original projection to LAEA projection.
2. Create a basic color image for different display scales, consisting of several spectral channels. Such images will be used for detailed viewing of the satellite image while maintaining the original resolution.
3. Create a PNG bitmap to show "quick looks" in a web application for different display scales, but at a lower resolution (up to 1 km per pixel). Unlike a basic color image, quick looks in a web application can be displayed in groups, depending on the user's choice, whereas a basic color image will only be active for one selected image.
4. Creation of products in the form of multichannel raster image in GeoTIFF format with NDVI and NDWI indices for Meteor-M2 satellite and single-channel images with NDVI index for MODIS, VIIRS and MSI instruments.
5. Conversion from 16-bit to 8-bit format, more suitable for displaying satellite images in a web application and requiring significantly less storage resources.

A set of programs has been developed for the preparation and publication of limited-use satellite data from the Russian Resurs-P and Canopus-V satellites received from the Research Center for Earth Operative Monitoring (NTs OMZ) of JSC "Russian Space Systems". The data are centrally downloaded for the needs of FRC KSC SB RAS and its subdivisions.

For the convenience of end users of the web directory, the data obtained are processed and presented in a single format. These data are automatically downloaded from the Roscosmos geoportal (<https://www.gptl.ru>) and pre-processed in semi-automatic mode. This additional processing is due to the fact that the resulting source raster image files have a different folder hierarchy, file names differ in format, and do not have data about the time the snapshot was created (the snapshot name contains only the time it was processed by the operator). Different snapshots have a different set of bitmap files, binding files, and metadata in XML format. The XML metadata format differs for different levels of processing of the resulting images. File names can contain Russian characters, which introduces a number of problems when working with them on Unix systems. Files of the same image in different views can be uploaded by operators to the Roscosmos geoportal FTP server at different times (with a time difference from a week to a month). In the developed system, interactive tools are created to solve problems associated with errors in the preparation of images by operators. For example, there were situations when files fell into erroneous folders on the ftp server, file names were set incorrectly, and these errors were corrected by operators only in the following uploads. The developed system tries to process the data automatically, but in situations where this cannot be done, the system sends a message to the administrator to make a decision and manually make corrections. The process of processing data from the Roscosmos geoportal is shown in Figure 1.

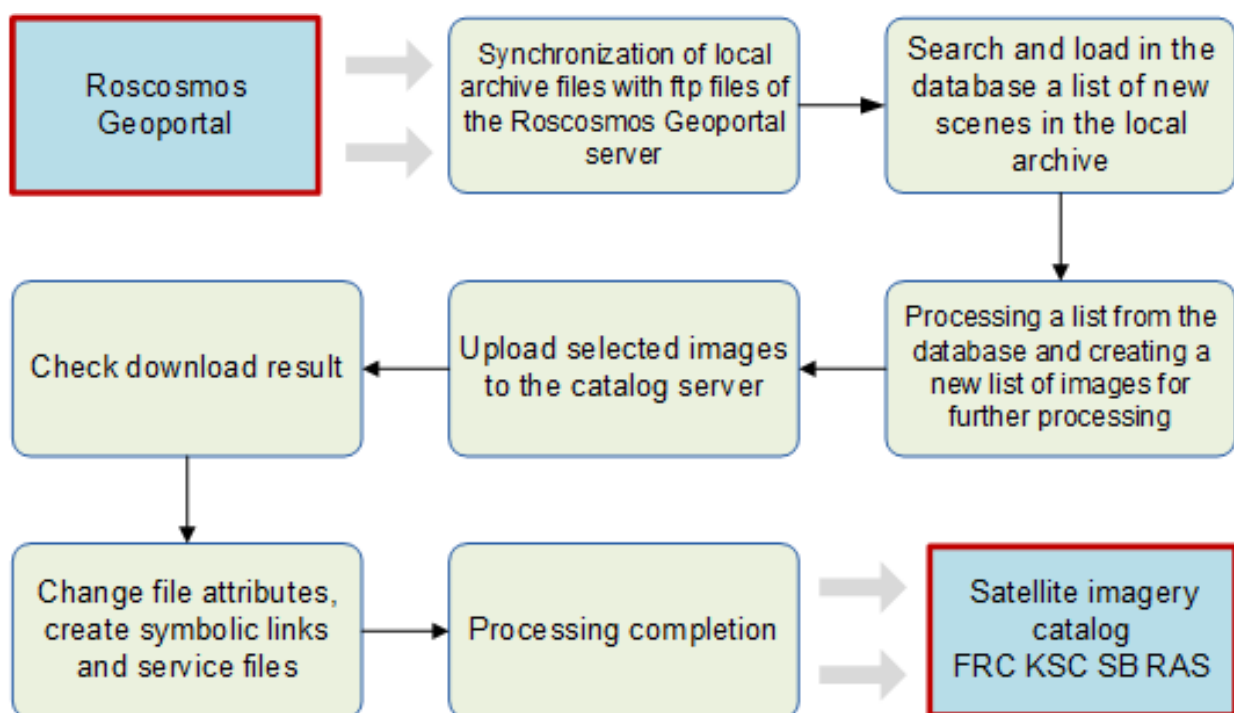


Figure 1: The processing of satellite images.

3 Catalog database

To store information about the collected satellite images, a database for the PostgreSQL DBMS with the PostGIS extension module has been developed. The basic elements of the physical database model are shown in Figure 2. Tables for storing reference data are shown in gray, including:

- t_satellites – registered satellites.
- t_sensor_types – types of devices.
- t_sensors – survey equipment are available on each spacecraft.
- t_providers – data providers from which images come, including: local receiving complex, external data providers.
- t_storages – data stores registered on the server. The set of disk stores can be expanded during the operation of the system. It supports the transfer of resources between repositories, and the synchronization of links to files is performed automatically.
- t_product_types – types of products.
- The tables for storing master data are as follows:

- t_images – individual scenes received from satellites. The attributes store the date and time of the shooting; the device with which the shooting was performed; describing the polygon; the storage where the files and other parameters are placed.
- t_images_cl – table for storing service rasters with coarse resolution for each scene. Separate channels store data on cloud cover and Zenith angle of the sun. This data is used when searching for scenes with no clouds in the specified areas.
- t_image_files – metadata for the original scene files.
- t_products – additional products built on the data of the original scene.
- t_product_bands – description of the channels of each product.

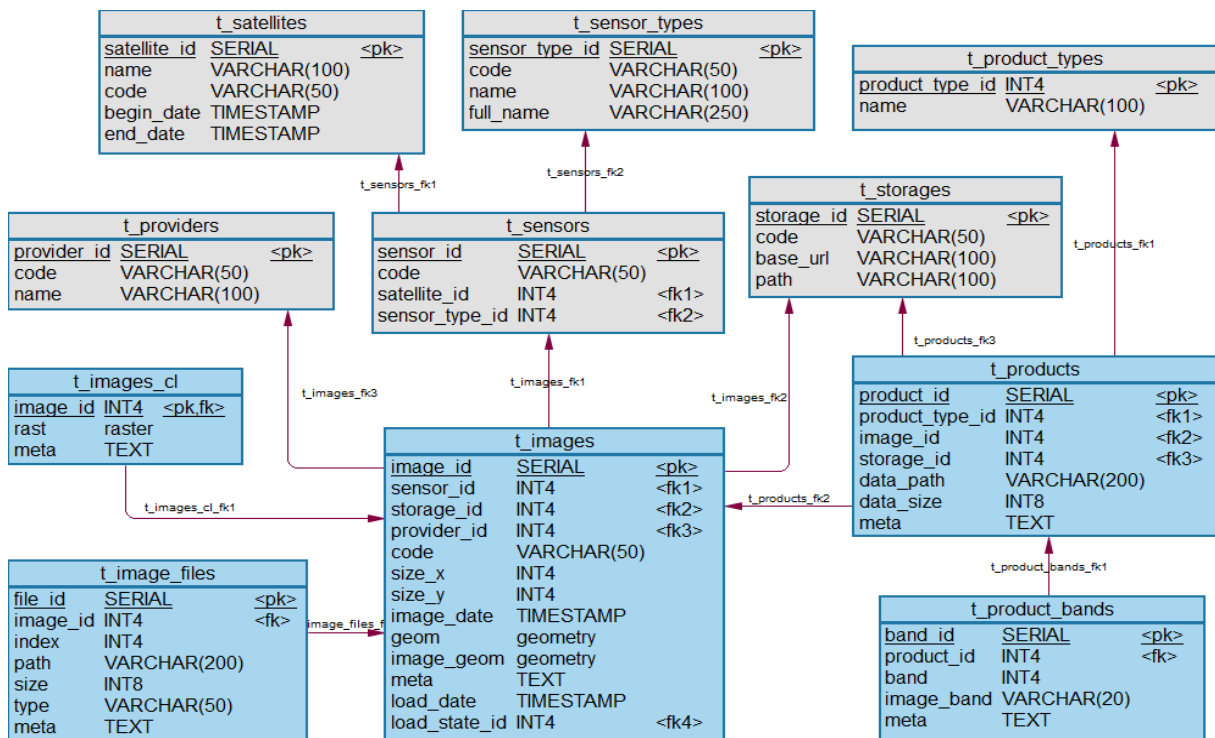


Figure 2: Fragment of the physical database design

The directory database is populated by the synchronization service. It scans the file directories of all registered data sources on a scheduled basis. In the process of work, both the appearance of new images and the movement of files between repositories are monitored.

Integration of the catalog with the client application for data search is performed at the database level. To do this, it has prepared a set of views and stored procedures.

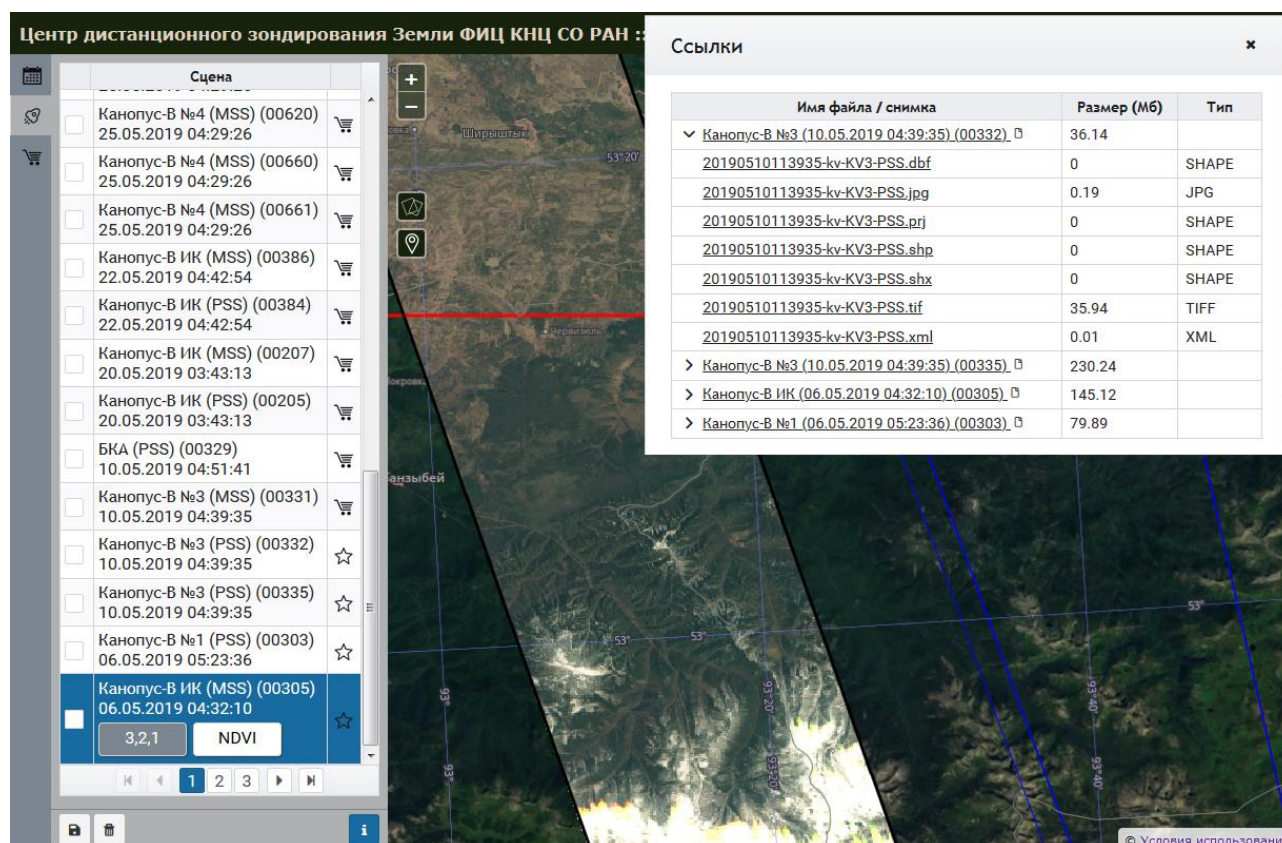
4 Client web application

To search and navigate through the catalog of satellite data, a web application has been developed using the server programming language PHP, PostgreSQL, SQLite3 and the client web interface in the TypeScript programming language using the Angular 5 framework.

The analysis of existing technologies and software designed to work with spatial data in the web environment, the long-term experience of the team of authors and the software developed by them led to the use of open technologies and software. The developed software tools for spatial data analysis in the geoportal environment of the Institute of Computational Modeling SB RAS using technologies offered by the international organization OGC (Open Geospatial Consortium) and MapServer and MapProxy software as a basis [Rau13]. MapProxy is used to create a map from fragments. Satellite images for the web application are generated using MapServer and GDAL software. The snapshot preprocessing Toolkit is developed using Python 3 and the Bash processor in a Unix environment. The main modules for Python applications were the GDAL and NumPy libraries. An example of the web interface of the satellite imagery catalog is shown in Figure 3. The developed approach allows sharing and reusing code fragments, providing a basis for legacy systems [Mat13].

5 Conclusions and Future Work

The developed platform for the catalog of satellite images provides the user with modern tools for working with satellite data and navigation among them within the reception complex of the regional center in the Krasnoyarsk territory and neighboring regions. The capabilities of the created software product allow you to combine any combination of channels available in the image without additional configuration of the server software, which distinguishes the created system among similar satellite data cataloging systems. The developed technology and algorithms allow to implement the elements of the system for other archives of satellite data. In the near future, the developed platform will allow to create new specialized products based on satellite data in cooperation with other institutes of the Siberian Branch of the Russian Academy of Sciences, which can be used for analysis and monitoring of various processes.



Центр дистанционного зондирования Земли ФИЦ КНЦ СО РАН

Ссылки

Имя файла / снимка	Размер (МБ)	Тип
Канопус-В №3 (10.05.2019 04:39:35) (00332)	36.14	
20190510113935-kv-KV3-PSS.dbf	0	SHAPE
20190510113935-kv-KV3-PSS.jpg	0.19	JPG
20190510113935-kv-KV3-PSS.prj	0	SHAPE
20190510113935-kv-KV3-PSS.shp	0	SHAPE
20190510113935-kv-KV3-PSS.shx	0	SHAPE
20190510113935-kv-KV3-PSS.tif	35.94	TIFF
20190510113935-kv-KV3-PSS.xml	0.01	XML
Канопус-В №3 (10.05.2019 04:39:35) (00335)	230.24	
Канопус-В ИК (06.05.2019 04:32:10) (00305)	145.12	
Канопус-В №1 (06.05.2019 05:23:36) (00303)	79.89	

Figure 3: The web interface of the satellite imagery catalog

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