

Remote Sensing for Scientific Research in Earth Sciences in the Russian Far East

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Abstract: Long-term researches conducted by scientists from the institutes of the Russian Academy of Sciences have resulted in a large volume of data in Earth Sciences. The research data are systematized at the institutes. Archives, databases, Geo Information Systems, Data Retrieval Systems, and Digital Libraries have been establishing. Due to new methods for data collection, the amount of data increases constantly, the data acquisition becomes more efficient, and the change-over to whole new digital technologies of data collection, processing, distribution and using is almost complete. The Earth remote sensing space systems, systems of surface and aerial laser scanning, other digital and electrical geodetic equipment, digital areal cameras are used to get the initial data. The new digital and electronic environment for data in Earth Sciences makes it possible to use modern informational technologies.

Satellite data are widely used in geological and geophysical investigations. In order to encourage scientists in the Russian Far East to use satellite images, a system that provides data derived from satellite imagery for geological and geophysical investigations is being developed. This system is supposed to provide data from satellite imagery to users, IR-channels from AVHRR and MODIS radiometers, and measurements of visible channels from AQUA and TERRA, as well as LANDSAT.

1 INTRODUCTION

From time immemorial the Russian Far East has been attracting geologists and geophysicists due to its location in the global system of fold structures of the Pacific ore-tectonic belt and at the same time as the area of transition from the largest continent to the greatest ocean. It seemed that here exactly a scientist could find the solution for a lot of contentious issues in endogenic geology and reveal general regularities in order to increase the amount of tasks to be solved by developing of large theoretical problems. Indeed, travelling eastwards from the inner regions of the Asian continent to the Pacific Ocean, one can observe consistent change of Precambrian shield areas into Palaeozoic, Mesozoic and Cenozoic fold (orogenic) belts, then into depressions of modern margin-continental seas and into seismo-tectonic active volcanic island arcs and associated deep-sea trenches. And further is a wide deep-ocean floor, which is outwardly calm but

shows active submarine tholeiite -basaltic volcanism. This is the most complete set of structures characterizing the transition from the ancient parts of a thick and extremely complex continental crust through its intermediate types to a thin ocean crust with a rather simple structure (Khanchuk et al.,2009).

2 SATELLITES AND SATELLITE DATA RECEIVING AND PROCESSING CENTERS

In the Far East, existing Earth Observation Satellite Systems and data processing technologies provide hundreds of millions of measurements of various ocean, atmosphere and land geophysical and space parameters every day.

There are two centers for the Natural Environment Satellite Monitoring in this region: the

center of the Russian Academy of Sciences (RAS) in Vladivostok and the Branch of Scientific and Research Centre on Space Hydrometeorology "Planeta" (SRC "Planeta") in Khabarovsk.

SRC "Planeta" is the leading organization in Russia on exploitation and development of national space systems for the hydro-meteorological, oceanographic, helio-geophysical and natural environment monitoring and also on receiving and processing of data from foreign satellites. It cooperates with national hydro-meteorological services and space agencies in more than 30 countries: USA, EU, Japan, India, China, Korea and etc. The Branch of SRC "Planeta" receives and processes the real-time data from meteorological satellites Meteor M-1, MTSAT-1R, MTSAT-2, POES NOAA, Terra, Aqua, Suomi NPP and RadarSat-1 satellite. The satellite imagery processing is aimed to make a weather forecast from the information on the atmosphere state and the Earth's surface physical parameters reconstruction.

The multiple-access regional center for the natural environment satellite monitoring of FEB RAS receives, holds and distributes satellite and relevant data for scientific investigations in the Russian Far East, makes the data processing automatic and integrates the data into global information systems, as well as conducts primary processing-correction, calibration and geographic reference of the imagery (Remote Sensing of Environment, 2013). Several receiving stations work simultaneously in the center. Using the ordering system, the customer is given temperature fields, reflection coefficients and other physical parameters in the form of instantaneous and composite measurements. Historically, the laboratory for satellite monitoring of the Institute of Automation and Control Processes of FEB RAS, on the base on which the center was established, was aimed to provide the data on the ocean surface temperatures fields to the Pacific Scientific-Research Fisheries Center and the Pacific Oceanological Institute of FEB RAS. This aim predetermined the choice of the polar-orbiting satellites: POES NOAA, AQUA, TERRA, FY-1C, FY-1D, MetOp, Meteor M-1, MTSAT-1R, MTSAT-2, FY-2B, FY-2C. Using these and other satellite Centers data, the researches solve geological and volcanological problems in the Russian Far East.

2.1 Volcanogenic Processes Analysis

Daily satellite monitoring of Kamchatka volcanoes, using MTSAT, NOAA (AVHRR), TERRA и AQUA (MODIS) imagery, is carried out to reveal the

increase of volcanic activity, predict volcanic eruptions, and track on-going eruptions (Girina, 2013; Gordeev and Girina, 2014).

Volcanogenic process is analyzed in detail. The data from TERRA ASTER, LANDSAT and other satellites allow studying thermal anomalies, ash plumes, extrusive cones, distribution and morphology of eruptive products (lava and pyroclastic flows, tephra etc).

Detail analysis of volcanic processes (the development of thermal anomalies and the state of volcanoes) allows revealing, for example, a gradual decrease of activity at Kizimen Volcano in 2013, and vice versa a resumption of explosive activity at Karymsky Volcano. Different satellite imagery showed aerosol clouds and plumes, ash clouds and plumes, lava flows and their height and length.

2.2 The Development of a Satellite Monitoring System the Kurile Island

The territory of the Russian Far East hosts 66 active volcanoes, 36 of them on the Kurile Islands, 30 active volcanoes on the Kamchatka Peninsula. Though the Kuriles are almost uninhabited at the present time, the probable ash emissions from volcanic eruptions into the upper atmosphere are extremely dangerous to aviation. In 2003 SVERT (Sakhalin Volcanic Eruption Response Team) was established on the base of the Institute of Marine Geology and Geophysics of FEB RAS in cooperation with the Sakhalin Geophysical Survey of RAS and the Russian Federal Geological Fund "RosGeolFund" of the Federal Subsoil Agency RosNedra with the support from the Alaska Volcano Observatory (AVO, the University of Alaska Fairbanks). The SVERT members process the data from the MODIS/AQUA into one satellite imagery per day to have the information on the current state of the Kurile Islands volcanoes (Diakov and Rybin, 2013). Satellites do not provide nighttime images and prevent from observations of "hot spots", which are the eruption precursors.

The members of the Center for Regional Satellite Monitoring of Environment FEB RAS organized full automatic delivery of satellite data for the SVERT specialists.

The pseudocolor images for detection of gas and steam emissions, ash emissions and hot spots (in case of the nighttime satellite images), the monochrome images of 11micron and 12micron, 8 micron and 12 microns channels differential for ash clouds detection and the monochrome images of

3,75 micron and 11micron channels differential for hot spots detection are delivered.

In addition to the products developed on the basis of the TERRA MODIS and AQUA MODIS data, the analogous products developed on the basis of the AVHRR/POES NOAA data are delivered.

2.3 The Development of Technologies for Satellite Data Analysis in Order to Find the Solution of Problems of Structural Geology and Tectonics

The detection of linear structures, faults, tectonic blocks of various recycling rate, the definition of boundaries of different types geological structures and zones.

Usually to solve the problems of structural geology and tectonics based on the data from remote sensing we apply hyper-spectral method, using the data on the visible and near-IR spectrum and the ground temperature inversion. This technology does not fit the conditions of the Far East, therefore the main method to solve this problem is to detect the linear structure on the basis of the data from the channels of the visible band of electromagnetic spectrum and the data from the radar sounding.

One of the examples of such works, being carried out in the Far East, is the work of the researches of the Institute of Tectonics and Geophysics FEB RAS (Melnichenko et al., 2013). They estimated the absolute value of the relief gradient, analyzed the linear structure, investigated the morphometric characteristics of the bottom and the character of its deformations in Philippine Sea. They revealed that structurally the Philippine Sea is a very special, isolated part of the Pacific Ocean. Its west part comprises of fault structures of the ocean, which were renovated in the new Cenozoic Period of the Philippine Sea development. Its east part developed in sharply changed geodynamic conditions and is the newest overlaid structure.

2.4 The Remote Sensing Survey in the Russian Far East Ore-Bearing Areas for Minerogenic Reconstruction

The characteristic feature of the south-east of Russia is the abundance of the alluvial and the hard-rock gold occurrences and the platinum-group elements. More than 15 Late Mesozoic minerogenic belts and their fragments were revealed in the east of the continental part. The existence of not evident signs

of Late Mesozoic intraplate magmatics zonal distribution allows assuming that location of the platinum-metal and the gold-bearing massifs within the raise areas is caused by the influence of homogeneous processes and their probable belonging to the single structure of the stagnate 410-670 km-deep mantle slab associated with the subduction zone. If we consider tectonic zones and belts to be dissipative structures, then we can apply the same methods of investigation. This approach opens the possibility of integration of the results from the remote space, geophysical and geochemical observations with the possibility of a formal test of hypotheses of a logic deposits location (Shevyrev, 2013).

2.5 The Development of the System Providing Satellite Measurements Data to the Far East Scientific Investigations in Geology

The usual source of satellite data to solve such problems are the U.S. Geological Survey's EarthExplorer and GloVis. The EarthExplorer and GloVis services provide an open access to a large amount of satellite data available upon the request. The request execution time for the full-resolution images can take up to three days, the formats for the results presentation could be of interest for the experts in satellite data processing and interpretation. At present time the data from satellite sounding are hardly used in the Far Eastern geological investigations. One of the ways to activate the use of satellite data is the decision to establish the System providing satellite measurements data to the Far Eastern investigations in the field of geology. We assume that this system will provide the access to the main satellite data useful for geological investigations such as: the satellite topography data, the infrared channels of the Advanced Very High Resolution Radiometer (AVHRR) and The Moderate Resolution Imaging Spectroradiometer (MODIS) data, the data from the visible channels of the TERRA MODIS and AQUA MODIS measurements, the data from the Landsat series satellites.

The specific features of this system should be the limited amount of satellite images because the geological objects are rather constant and the observation conditions for selected images are rather similar and this should make the search and comparison of satellite images easier. On the other hand, in order to make the immediate use of the data easier, we offer to use the GeoTIFF data formats for

the Geographic Information System (GIS) projects and the ESRI Grid format for the measurements results and digital products. This system is being developed in the Far East Geological Institute FEB RAS. In 2013 the functional prototype of the System, providing the access to the satellite topography data STRM and the data from Landsat 8, Landsat 7 satellites was realized. The functional prototype helps to investigate the data domain and work out the interaction of the Far East Geological Institute GIS portal with the other systems providing the access to satellite data (Diakov and Naumova, 2013).

We can distinguish the main application fields for the data and the data processing technologies of this System:

types of underlying surfaces classification (basalts, granites and so on) on data from the visible channels of MODIS, OLI (LANDSAT-8), ETM+ (LANDSAT-7);

heat capacity mapping of the earth's surface (the data from IR radiometers);

use of the satellite topography (STRM, Aster) data for geo-morphological analysis of the earth's surface, topographic bases generation and etc.;

search and analysis of geometric structures at the Earth's surface: faults, ring structures on the basis of satellite topography data and measurements in the visible spectrum;

"hot spots" and "hot" faults investigation on data from MODIS and AVHRR IR spectrum radiometers;

monitoring of gas composition penetrating into atmosphere through the earth's crust;

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