Distributed Remote Sensing System of Northeast Asia and Quality Assessment of Siberian Environment

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Abstract

The purpose of this paper consists in the description some approach for quality assessment of Siberian environment on the base on the international cooperation for exchange of data of Earth observing satellites and of the space monitoring technologies. The proposed distributed remote sensing system, named The Japan-Russian Project "Open Asia", will be based on the coordination of the existing national and regional programs of remote sensing of Northeast Asia parts of Japanese and Russian territories and of programs will be planned. The regions of the Earth, which will be involved in Program, are: Siberia, Far East of Russia, coasts of Northwest part of Pacific Ocean and Japan. Open Asia Project describes prototype of the distributed remote sensing system for space data receiving, storing and processing. The conception of the distributed remote sensing system is based on the using of the both space and information technologies simultaneously. Such system will provide the solving a wide spectrum of ecological problems and nature resources problems of Japan and Russia, including the quality assessment of Siberian environment too.

1. INTRODUCTION

The main idea of the proposed cooperation is concluded in the using of the newest achievements in the space and information technologies, especially in the computer network technologies for the creation of the distributed remote sensing system for the Northeast Asia. Usage of the modern telecommunication system, dedicated satellites channels, supercomputer and parallel data processing technologies, technologies of storing, processing and accessing the information and of the distributed databases, knowledgebase, networking geographic information systems and Infohighway technologies (World Wide Web, Internet, multimedia, electronic libraries, advanced systems of visualization, etc.) are supposed. This project is based on the existing network of space receiving stations in Siberia, Far East and Japan, on the national satellites programs of Russia and Japan and on the existing the space direct telecommunication channel between the Tohoku University (Sendai) and Siberian Branch of the Russian Academy of Sciences (Novosibirsk). A likeness in climatic natural

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environments of Russia and Japan will provide the using of the mutual space information for effective regional cooperation in the field of protection of an environment, prevention of acts of nature, hydrometeorology, rational use of marine biological and other important natural resources.

The using of all accessible Russian and Japanese data and the orientation of distributed remote sensing system to the needs and to the conditions of the concrete regions of Russia and Japan will enable to use an gathered a priori information about investigated area most effectively, to limit a stream of a redundant information and to study of observable processes in dynamics explicitly.

The financial and non-financial bilateral or multilateral forms of cooperation are assumed in the framework of this project.

The Open Asia Project is open for all governmental and non-governmental organizations from Japan and Russia, who is interested in the solving of applied problems on the base of new remote sensing and space- information technologies.

2. TYPICAL APPLIED PROBLEMS OF REMOTE SENSING FOR NORTHEAST ASIA REGIONS

Analysis of the user's requirements showed that the satellite information for the Northeast Asia regions (NEAR) is necessary (with the various resolutions and the various periodicity) for many industrial organizations and local governments in many application areas. The short description of remote sensing applications for some applications is described below.

2.1. Agriculture

Inventory of cultivated lands of NEAR.

The several spectral ranges may be used for observation of crops: panchromatic, 0,56; 0,6; 0,64; 0,68; 0,4-1,1; 1,55-1,7; 10-12 microns. Crop types, discriminated by satellite data, should be updated by field observations and data on the structure of the cultivated areas requested from the agricultural enterprises. The necessary periodicity of observation should be 7-15 days. Depending on periods of growth, it is necessary to pay attention to:

- assessment of germination capacity, development and harvest of plantings;
- analysis of vegetation cycles in various seasons.

Agricultural hydrology of NEAR.

The following problems are actual for NEAR:

- analysis of precipitation;
- study of soils moisture capacity;
- study of problems of melioration and water regime of arable lands.

Soil moisture content should be measured in the visible and near infrared ranges. One should note, that soil moisture content is determined by such factors, as intensity of evaporation of moisture by plants, surface evaporation, infiltration and absorption of moisture by surface layer.

Land use of NEAR.

Land use problems are especially actual for southern regions of Siberia and Altai; there is a need for the detection of the trends in landscape development and revealing of changes in terrestrial cover from natural and anthropogenic factors.

2.2. Environmental monitoring applications

For most of the NEAR it's extremely important to solve environmental monitoring problems, such as:

- Forest fires;
- Floods;
- Petroleum and gas contamination;
- Determination of ecologically harmful industrial wastes.

Analysis of satellite imagery for the monitoring of forest fires will allow formulating assessment of fire danger in Siberian and Far East forests. It will be possible to forecast appearing of new centers of fire, roughly estimate localization of burning fires and dynamics of their potential development with account of meteorological processes.

Only information from NOAA's satellites (with one kilometer resolution) is used for the monitoring of forest fires today (see Fig.1.). Acquisition and analysis of high-resolution (2-4 meters) and middle-resolution (10-40 meters) images will, at the same time, provide information on (i) forest types in the region of fire, (ii) what is the possibility of fire

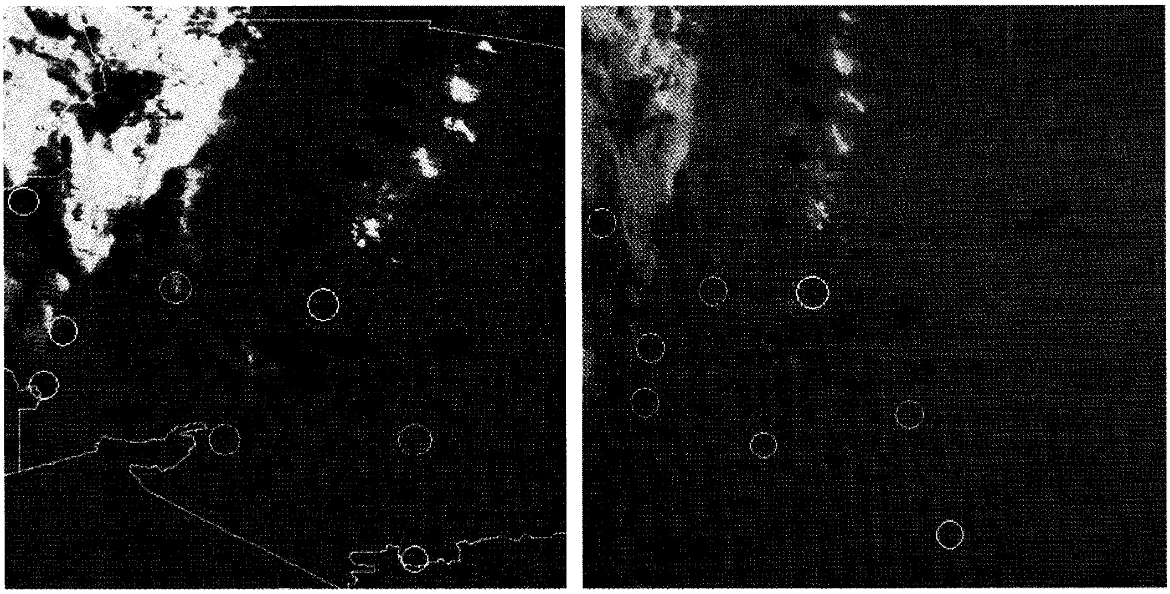

Fig.1. NOAA satellite image after processing. Forest fires in Novosibirk region, Siberia, August 12, 2000, morning -left, noon- right, hot weather. Resolution 1 km. Size of region is 200x200 km. Red points show fires detected by image processing. Yellow circles show the fires detected by the fire service.

spreading on neighboring forest-covered regions, and (iii) how to organize measures for fire localization, using resources available and natural features of the territory. The example of forest fires 40 meters resolution images see at Fig.2. (copyright RSA)

Consequent analysis of satellite images of the fire-affected territory will provide

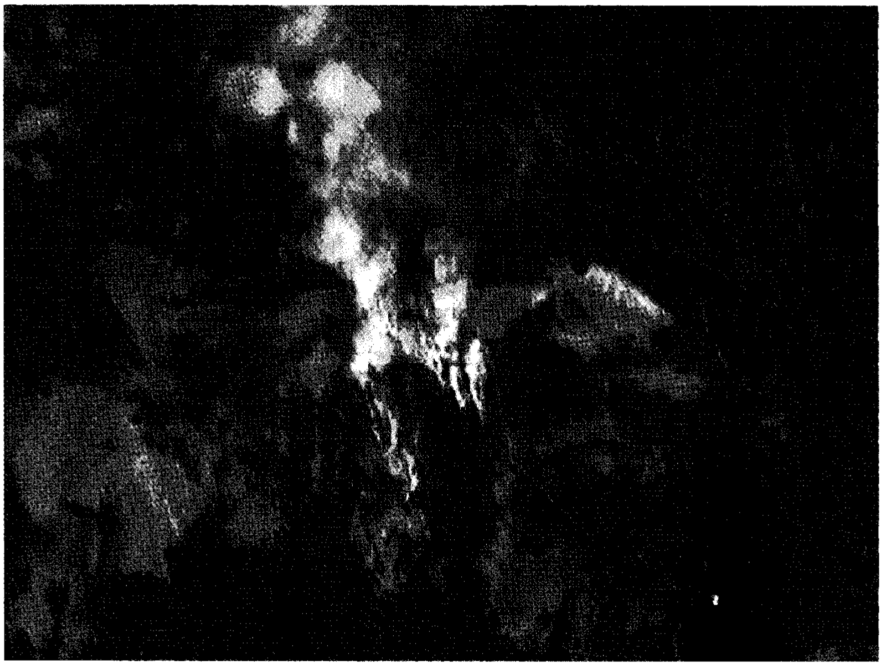

Fig. 2. Resurs O1 N3 satellite image of forest fire. Resolution 40 meters. Size of region -10x10 km.

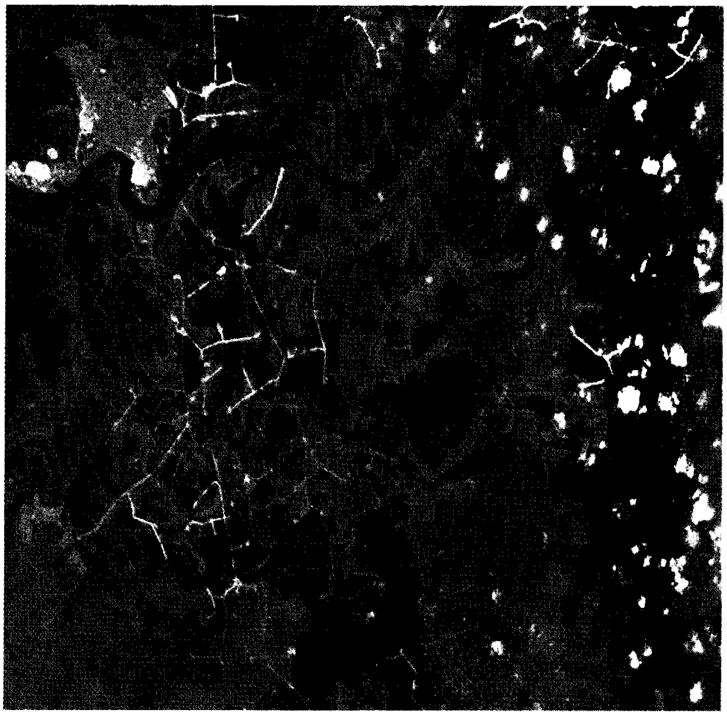

Fig. 3. Example of saturation by pipelines and technogenic objects for an oil deposit in West Siberia. Resurs O1 N3 satellite image. Resolution 40 meters. Size of region is 40x40 km.

assessment of rate and characteristics of forest cover restoration.

Besides forest fires, paramount importance for NEAR has the assessment of the scale of other natural hazards - floods, as well as acquisition of information for control and forecasting of spring-flood, snow avalanche and mud flow risks.

Among hazardous processes that can be detected by high- and medium (20-50 meters) resolution satellite observations are riverbed and ravine erosion, floods caused by snow melting or cyclonic activity, seasonal or constant excessive moisture content in the soils, large landslides or mud flows and complexes of small landslides, snow avalanches, forest and peat fires.

The most important problem for ecological monitoring of the NEAR is monitoring of territories of intensive oil and gas production, as well as oil and gas pipelines because more than two thousands case of oil pipeline leakage occur annually in Siberia. Fig. 3 shows the example of the Resurs O1N3 image of the typical region of intensive oil exploration in Tumen region of the Siberia with the network of pipelines.

2.3. Forestry applications

Assessment of surfaces and location of areas with natural ecosystems in the regions damaged from previous total forest logging

Forest logging on the Siberian territory was done previously by total logging on the areas with surface of several hundreds of hectares. Therefore the boundary between sites with preserved natural and significantly deteriorated secondary vegetation is clearly visible on images even of 150-meter resolution. Large swath width of such images allows to use them for the planning of nature protection for the whole regions.

In order to correct boundaries of planned protected territories, their protected zones and water-protection zones, satellite imagery of 35-meter or higher resolution can be used. Their application for environmental purposes is sometimes more informative, than use of common types of land- and forest management information The quantitative estimation of the amount of forest can be obtained on the base of the using the space image technology NDVI (Normalized Vegetation Difference Index), which is usually proportional to the volume of chlorophyll. Fig. 4 shows the 3D NDVI image of the some part of Novosibirsk city (2 km per 2 km) after processing the 10 meters resolution Spot satellite data image.

Evaluation of the actual boundaries and state of areas of near-tundra forests.

Actually, at the expense of displacement of the northern forest boundary as a result of the climatic factors, fragmentation of the boundary due to damage from oil and gas production, fires etc., actual width of the near-tundra forests is much less than minimum allowed width of 30 km. The use of satellite images with 35 and 150 m resolution will allow state authorities to effect control over correctness of discrimination of the band of near-tundra forests and its conformity to the operating specifications.

2.4. Geology applications

Satellite images with resolution better than 100 meters may provide the information, which will be necessary for:

- Detection of regional lineaments, ruptures, jointing, zones of the newest activation, faults etc.;

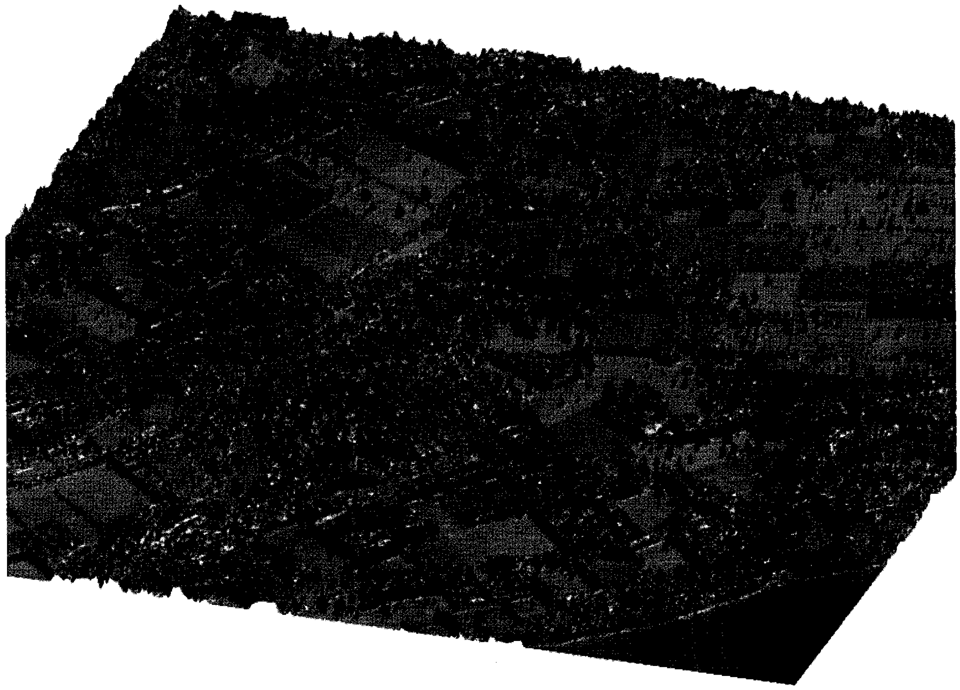

Fig. 4. 3D NDVI image of the Novosibirsk city (2x2 km) after processing the 20 meters resolution Spot satellite data.

- Revealing of structural-tectonic elements (fractures, elements of folding, areas with different degree of the newest activation, oval- and ring-shaped structures, elements of jointing etc.);
- Discrimination of age and genetic types of newest sediments, elements of geomorphology, local class tectonics (ruptures, elements of local structures, faults, grabens, limbs);

Direct searching of underground oil deposits.

This information can be also used for the study of tectonic beds, detection of regions of geological activity (for example, along linear breaks in regions of large Siberian waterpower plants). In this case additional remote sensing information on surface temperature and Earth surface albedo is necessary. Fig. 5 shows the example of highly precise satellite image processing for the direct finding of the oil deposit. The red color is associated with some anomaly of reflection from lakes, which are located over the oil underground deposit.

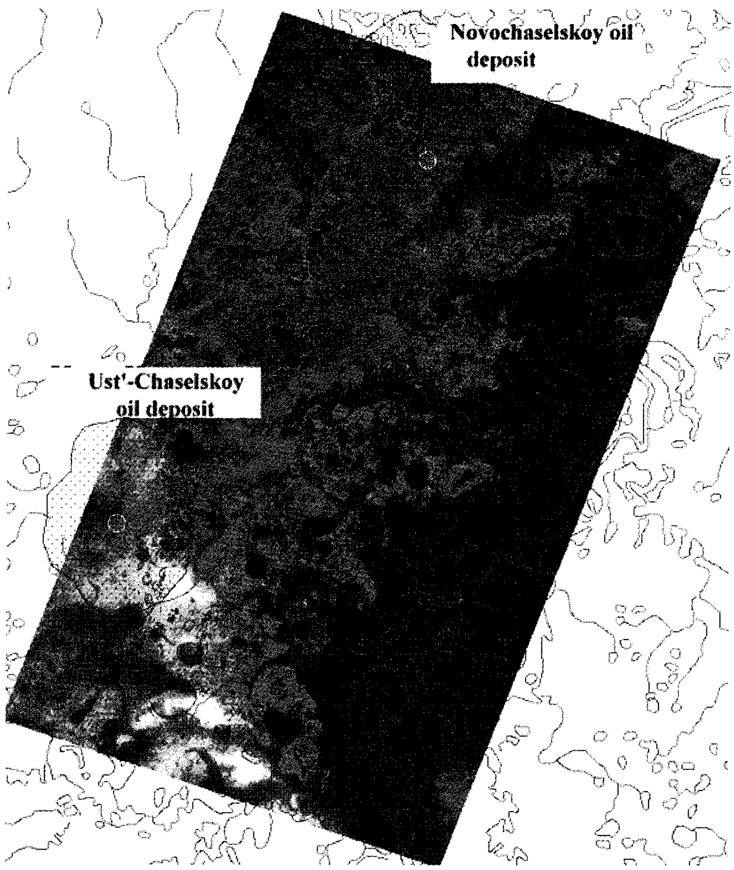

Fig. 5. The example of highly precise satellite image processing for the direct finding of the oil deposits.

2.5.Mapping applications

Topographic mapping provides scientific research and applied programs that study environmental changes, with topographic data and data on Earth surface characteristics, such as:

- Vegetation;
- Open ground;
- Snow or ice covers;
- Constructions;
- Infrastructure;
- Agricultural areas;
- Water objects.

The most convenient spectral ranges for these purposes are: panchromatic; 0,56; 0,6; 0,64; 0,68 microns; spatial resolution 30-100 m, observation period 7-30 days. It is also expedient to use high-resolution radar imagery, that can be very useful for the study of geomorphological phenomena such as:

- Landslides;
- Deluvial and proluvial cones;
- Changes in coastal line;
- Mud flows;

- Deltas,
- Volcanic forms;
- River valleys

The detection of areas with changes of surface relief as a result of earthquakes can be used in seismic zoning and earthquakes prediction. In order to acquire multy-year data for land use, such factors as albedo and reflective properties of Earth surface should also be studied.

At the last time the high resolution images are often used for the mapping application, in particular for urban planning. Fig. 6 shows the using the two meters resolution image from Russian satellite together with high resolution DEM (Digital Evaluation Model) for reconstruction the 1 km per 1 km region near the Bandai-san, Aizu-Wakamatsu City, Fukushima, Japan.

Fig. 6. Urban planning application. The using DEM with vector data and high resolution space image (2 meters resol.) for the 3D region's reconstruction. Aizu -Wakamatsu City, Fukushima, Japan. Size of region is 1x1 km.

3. THE NATIONAL EARTH OBSERVING SATELLITE PROGRAMS IN 2000-2005

The Open Asia Project will be the real project if the national satellites programs will be successful, of course. It means that in the nearest 3-5 years the remote sensing satellites of Russia and of Japan must be successfully launched and could provide the receiving stations by the information.

3.1. The Japanese Earth observing satellite program

The Japanese Earth observing satellite program in 2000 -2005 years consists of two series: satellites mainly for atmospheric and marine observation, and the ones mainly for land observation.

In the second series of satellites the Advanced Land Observing Satellite (ALOS) is a satellite following the Japanese Earth Resources Satellite-1 (JERS-1) and Advanced Earth Observing Satellite (ADEOS), which will utilize advanced land-observing technology. The ALOS will be used for cartography, regional observation, disaster monitoring, and resource surveying. The ALOS has three remote-sensing instruments: the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) for digital elevation mapping (2.5-meter spatial resolution), the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) for precise land coverage observation (four bands and 10- meters spatial resolution), and the Phased Array type L-band Synthetic Aperture Radar (PALSAR) for day-and-night and all-weather land observation (10-100 meters spatial resolution). The ALOS will be launched by an H-IIA launch vehicle from the Tanegashima Space Center in 2002.

The Advanced Earth Observing Satellite II (ADEOS-II) is the satellite which will take over ADEOS's observation mission of monitoring frequent climate changes occurring in the world, expansion of the ozone holes, and global environmental changes, as well as investigating the causes of these phenomena.

3.2. The Russian Earth observing satellite program

Russia plans to launch the Earth observing satellites of two types. The first type is traditional like Resource O1 using the big satellite platform (1-6 tons). This type of satellites will be launce by Russian Airspace Agency. Another new type of satellites will be using the small platforms and will be launching on the commercial bases (see Table).

3.3. Third Countries Programs of Remote Sensing

In the framework of Open Asia Project it is supposed to use the information from satellites, which belong to other country. The first at all, it concern to the NOAA's polar

Table. The technical parameters of the Russian satellites in 2000-2005.

	Lanch year	Resol. m.	Swath Width, km	High Km.	Obs. Width Km	Bands	Weight Tons
Meteor3M	2000	30	100	1000	2000	6	1,3
Resource O1-N5	2003	5-25	50 -200	690	200-500	5	1,4
Resource -DK	2001	1-4	27-40	500	640	4	6,3
Obzor2	2000	7-14	115	500-1000	620-1200	4	0,2
Obzor3	2001	1,5-2	30	650	680	1	0,11
Poputchik	2001	10-20	35	700	700	4	0,12
System	2003-2005	1-2 5-50	20 - 200	800-1200	500-1000	5	0,2-0,8

orbiting environmental satellites. The information from NOAA;s satellites is received already for a long time in the Center for Northeast Asian Studies (Tohoku University, Sendai, Japan) and in the Institute if Inorganic Chemistry of the Russian Academy of Sciences (Novosibirsk). Both of them are the

participants of Open Asia Project. The information from IRS, Landsat-7, Spot and Envisat is very interesting for the using in Project too.

4. THE NETWORK OF THE GROUND STATIONS FOR THE RECEIVING INFORMATION FROM SATELLITES

The Open Asia Project will be based on the both existing ground receiving stations of Russia and Japan and on newest, which will be established in framework of this project.

The NEAR's part of the Russian network of receiving stations includes the two types of stations. The NOAA's receiving stations (1.7 GHz) belong to the first type. The receiving stations which allow to receive information from satellites like "Resource -O1" , "Ocean", "Meteor 3M" (.8.2 GHz) compose the second type of stations. The total amount of NOAA's receiving stations in Siberia and Far East is more than ten. The amount of stations of second type is eight but only three of them are working now (Ushno-Sakhalinsk, Irkutsk and Novosibirsk). Fig. 7 shows the Siberia, observed from NOAA satellite. Information was received in Novosibirsk.

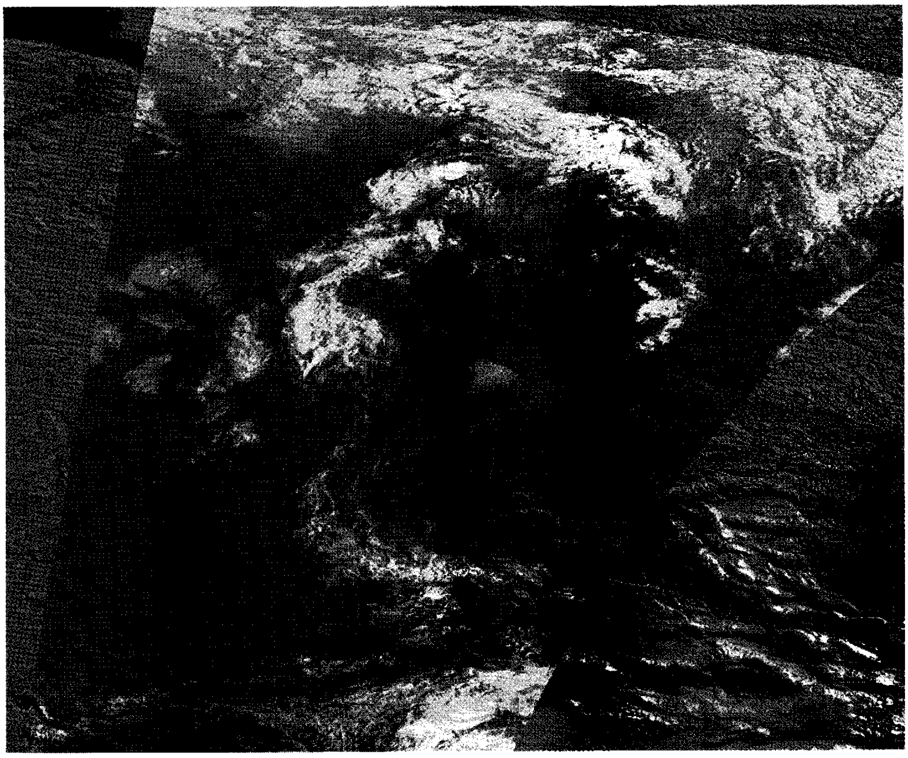

Fig. 7. Siberia from NOAA satellite. Novosibirk receiving station.

Among the Russian's receiving stations only the Novosibirsk's station is outstanding. It concern with big diameter of the mirror (12 meters). So, the Novosibirsk's station covers the big part of NEAR (see Fig. 8) .

In the framework of the Open Asia Project it's supposed to install the new receiving station in Vladivostok. The technical parameters of the Vladivostok's station will be the same as in Novosibirsk. The region of observing from that point of surface see at Fig.9.

5. CONCEPTION OF THE DISTRIBUTED REMOTE SENSING SYSTEM OF NORTHEAST ASIA

At the first stage of the creation of the distributed remote sensing system, it is supposed, that the system will be consist of the next centers:

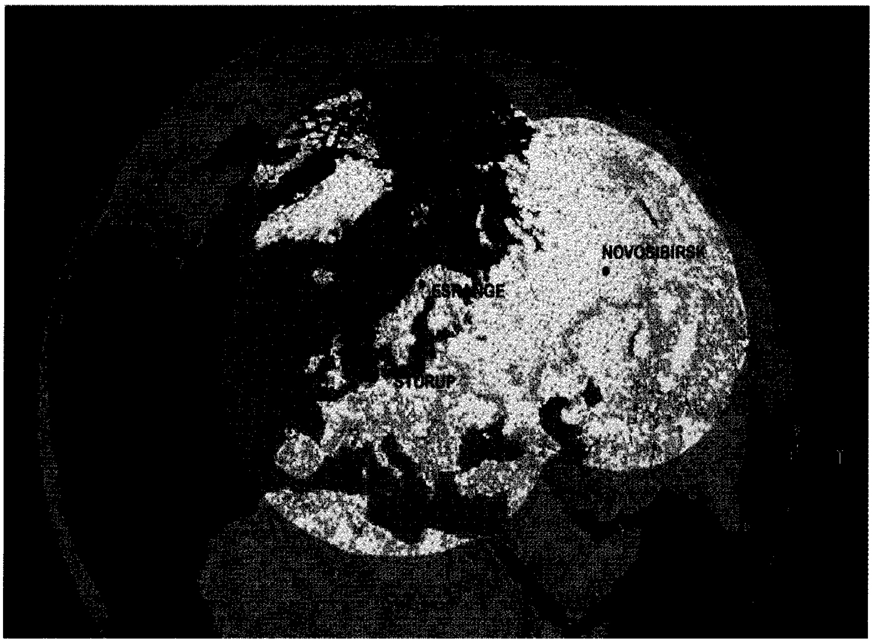

Fig.8. The scheme of the observing the Northeast Asia regions from Novosibirsk's receiving station.

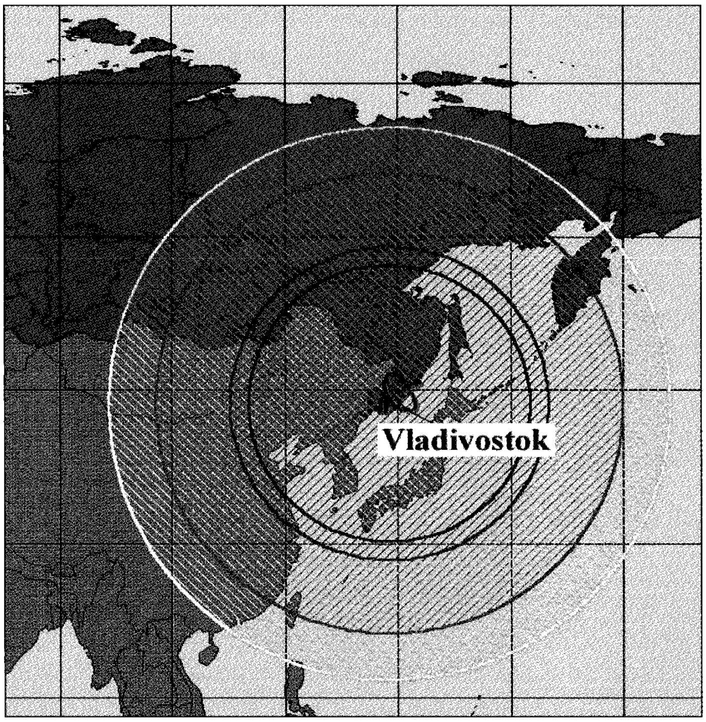

Fig.9. The scheme of the observing Northeast Asia regions from Vladivostok's receiving station.

- Novosibirsk's Inter-Regional Center of Space Monitoring (Russia)
- Vladivostok's Center of Space Monitoring (Russia)
- Sakhalin Center of Remote Sensing (Russia)
- Tohoku University Remote Sensing Center (Japan)
- Aizu Space Monitoring Center (Japan)

The one of the main goals of this project is to create the uniform distributed geoinformational database including basic remote sensing data archive, thematically treated information and a priori information (vector lines of rivers, altitudes etc.).

The main features of created system are:

- Orientation to needs of specific regions allows directing all works on solution of certain problems for certain region (administrative or geographical area). It will enable to use collected a priori information about researched area most effectively, to limit a stream of a redundant information and to study dynamics of observable processes explicitly.
- Integration of diverse satellite data with data of ground observations enables to analyze all accessible information with maximum effectiveness.
- Network access to data and results of processing gives consumers simple and convenient method for data access.

Modal structure of the system will allow tuning it easily for solving of diverse problems.

5.1. General system structure.

The developed system consists of a set of technological lines adjusted on realization of concrete thematic processing for observable region and a database, in which all information on investigated regions and processing results are stored.

Fig. 10 shows the scheme of a system as a whole: system unites in itself a set of separate technological lines appropriate to concrete regions. Input information enters from ground and remote observation sources (photomaterials, scanner and radar data, ground measurements, statistics). Thematic processing is realized with for solving specific problems, it can be ecological monitoring, vegetation observation, forest fires monitoring etc. Consumers can receive all necessary data through network access to the system.

The block scheme of system's main modules is represented on Fig.11. Each technological space information processing line of system consists of the following modules:

- Preprocessing module (prepares data to thematic processing),
- Thematic processing module (depends on a type monitoring),
- Network access system module (represents the user outcomes through Internet).

The integration of information streams fulfils in the distributed geoinformational medium, which is built on RDBMS like Oracle and network GIS interoperability.

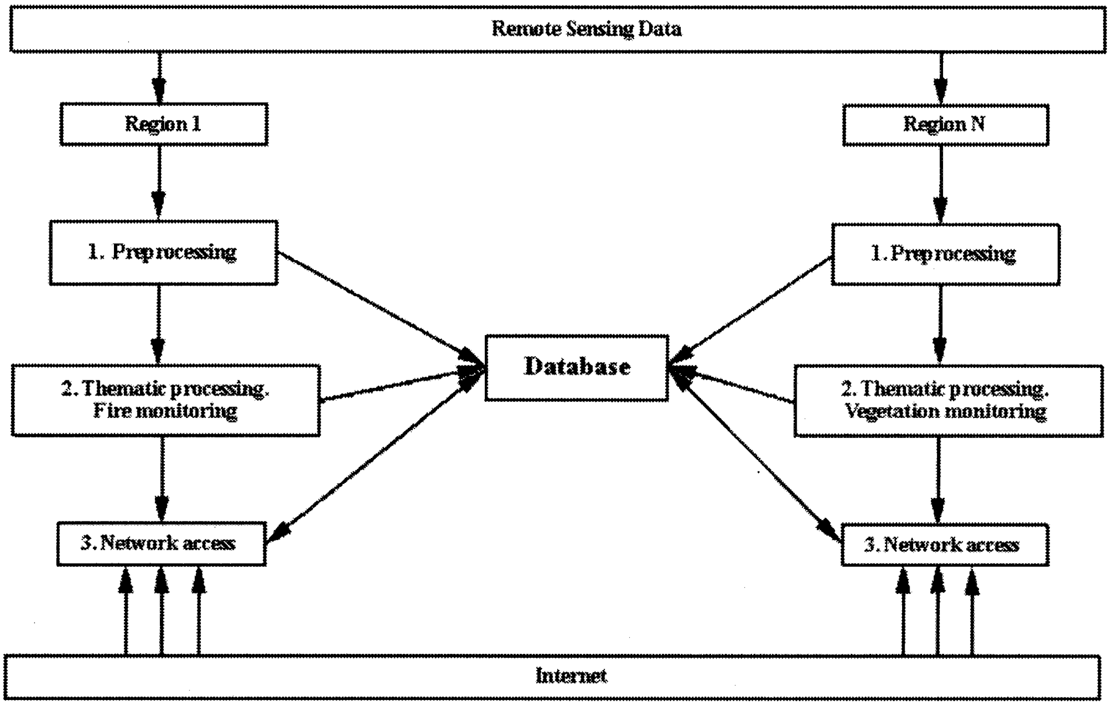

Fig. 10 General scheme of distributed satellite data storing and processing system

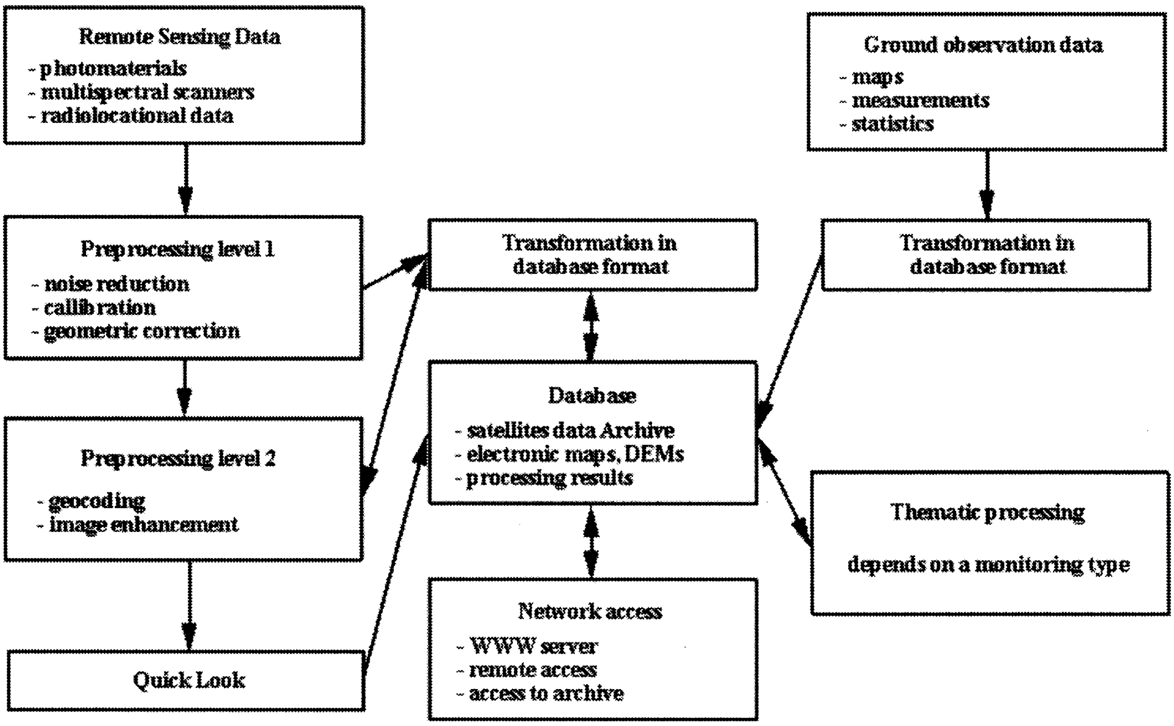

Fig. 11. The scheme of distributed satellite data storing and processing system

5.2. Distributed geoinformation medium.

The prototype of the satellite information storing and processing system is developed with use of GIS GRASS technological possibilities. GRASS (Geographic Resources Analysis Support System - freely distributed multi-user system supporting own database for raster, vector, and site data and containing modules for realization of various data processing algorithms for space monitoring.

Distributed database will be organized with RDBMS Oracle8i. GRASS and Oracle integration realizes with help of gateways between these systems (Oracle Internet Application Server). Thus, the GIS can directly use information stored in database.

Preprocessing module.

The first problem of data conversion and preprocessing subsystems is data preparation and transformation to uniform formats of geoinformational medium, where will be carried out further data processing and analysis.

Preprocessing module allows carrying out color correction and orthorectification for scanned photomaterials. Software can remove color shift from center of an image to edges due to lens refraction. Image distortions due to camera geometry, angles of observation and contour of district eliminate during image orthorectification. All these functions are supposed to be realized with the help of appropriate packages in GIS GRASS, ERMapper and Erdas.

First stage scanner and radar data preprocessing removes noise due to fluctuations in sensors, calibration, geometric correction (for scanners), carry out antenna pattern correction, diminution of interference (for radars). This processing phase is accomplished immediately on receiving station with help of specialized software. Output formats of these program modules are standardized, and are supported by majority of GIS. It allows realizing of further preprocessing (geocoding and image quality improving). These functions are implemented with ER Mapper.

Vector and attribute data preprocessing is made in vector-oriented GIS (for instance, in Arc/Info). It can be such processing as separation or confluence of vector layers, annotation corrections, digital elevation models (DEM) calculation etc.
The existence of interfaces between different GIS used in system actually reduces problems of transformation in a database format to data import - export (if necessary some intermediate formats can be used).

Thematic processing module.

The module is adjusted for specific monitoring tasks. System can use necessary algorithms of processing- detection of forest fires and oil spoils, vegetation observation etc. Module uses not only pretreated satellite information but also a priori data stored in a database on researched region (for example, information about forested areas allows excluding of false fire alarms). Results of processing and necessary initial data are immersed in database; results can be used hereafter as a priori information.

Network access system module.

Last module - system of network access through a global information network Internet is responsible for granting necessary data and main results of processing to end-users. Any user can receive all represented information with browser like MS Internet Explorer. It is possible to give an opportunity to end-users to look through outcomes of completed space monitoring measures and to receive necessary information.

Space monitoring data storing and processing systems usually operate with large volumes of data, frequently large computational capabilities are required for their operation. End-users of geoinformation not always have such possibilities and it is not necessary - they can work with results of processing represented for them or process raw data remotely with some network system.

Experienced consumers of satellite data can receive access to a database, where they can get all initial geoinformation, necessary for them, for example, raw snapshots and electronic maps, and to treat it themselves. We complete development of prototype of network access system to satellite data catalog based on Quick-Look technologies. The access system to archive of data of Russian satellite Resurs-O1, stored in the RDBMS Oracle8i is based on Oracle iAS (Internet Application Server) and Java technologies and permits to search satellite data on necessary region. Java-system has some possibilities for remote data preliminary and thematic processing. The first version of such system is desired. The Fig. 12 shows the snap screen of remote access.

5.3. Telecommunication Infrastructure of Distributed Remote Sensing System

Because the all of the Japanese and Russian centers of the distributed system should be exchanged by the satellite data and by the other special information, the centers will be connected through the some telecommunication channels. It is may TCP/IP lay on network with sufficient bandwidth of a channels (Open Asia Project network - OASNet for example).

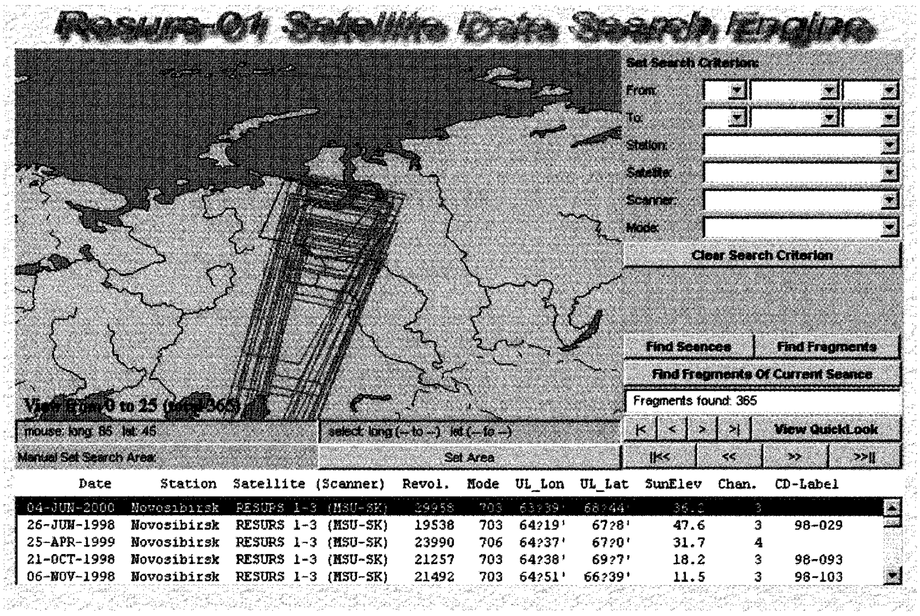

Fig. 12. Resurs-O1 Satellite Data Search Engine on the base iAS technology and Oracle8i RDDMS (http://gisos.sscc.ru:7777/resurs/).

The OASNet will be provide the real-time (or quasi real-time) access to the integrated data base of the space images, results of thematic processing and to the some vector lines data and other a priory information of the regions belong the NEAR. There are exist already some parts of the such network. It is the dedicated space channel between the Tohoku University and Institute of Inorganic Chemistry in Novosibirsk and channels between the some Siberian towns. The Sendai or Vladivostok could be a Control Center of the OASNet.

6. SUMMARY AND CONCLUSIONS

The conception of the creation the co-operative remote sensing system for Northeast part of Asia was proposed. The realization of this project will allow to solve the actual ecological and other important natural resources problems of Japan and Russia, including the quality assessment of Siberian environment, on the base of the mutual using the information from Russian and Japanese satellites. Project is based on the existing network of space receiving stations in Russia Japan, on the national satellites programs and on the existing telecommunication channel between the Tohoku University (Sendai) and Siberian Branch of the Russian Academy of Sciences (Novosibirsk).