Analysis of WEB-resources of satellite data

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The paper presents the results of analysis of functional capabilities of Russian and foreign WEB-resources for distribution of remote sensing satellite data used in solving a wide spectrum of scientific and applied problems.

Introduction

The development of methods and means of remote sensing, as well as the development of information technologies (IT) allowed environmental studies with a new type of information, which has no analogs by spatial and time characteristics. This information includes space measurements of the Earth surface and atmospheric parameters. For example, satellite data are successfully applied to solution of different problems of atmospheric optics, climatology, meteorology, as well as to ecological monitoring of the atmosphere, ground and water surfaces.

The global INTERNET became the main informational space for distribution of scientific knowledge: publications, software, and measurement data. A huge amount of measurements from different satellite systems have been accumulated for the last decades in centers of receiving and processing satellite images. The remote sensing data (RSD) are distributed among users of this information both traditionally, using the standard mail service, and via INTERNET. To do this, the distributors create WEB-resources of various functionality and complexity.

In this work we have analyzed the functionality and content of Russian and foreign WEB-resources of data of the Earth remote sensing from space, estimated their current state of the art and the directions of further development.

1. Classification of WEB-resources of the satellite information

The development of Web infrastructure and the related technologies makes rapid strides. As for the trends in development of Web-resources, it is possible to separate the following "evolutionary" forms of their existence in the INTERNET:

— archives of data and programs, i.e., resources for information storage and distribution;

— databases (DB), i.e., resources for information storage and distribution with an additional function of data handling (manipulation);

— resources, which are capable of realizing the computational algorithms and processing the information stored in the databases and archives.

The archives are the most early and primitive form of information storage. The capabilities of DB better satisfy the present-day requirements of users, therefore, they are widely used.

Until recently, the software distribution via Internet was realized via electronic archives, i.e., the program source codes with or without documentation were available for computers of potential users. In this case, users often faced numerous problems, such as porting programs on different carriers, study the documentation, which often leaves much to be desired or is absent at all, incompatibility of the data formats, and so on. All this often made the implementation of such software rather expensive or completely impossible. The attempts of software developers to solve these problems have led to the invention of Web-resources with both informational and computational capabilities. This approach allows users to gain access to data, processing algorithms and results via the WEB.

At present, global scientific Web-sites are mainly informational resources, although the amount of data-processing resources increases in different fields of science as well.

2. Foreign WEB-resources

Among numerous foreign governmental and commercial structures involved in the space research of our planet three undoubted leaders can be distinguished:

— National Aeronautics and Space Administration, NASA, USA;

— National Oceanic and Atmospheric Administration, NOAA, USA;

— The European Space Agency, ESA, EU.

The French space system of studying the Earth nature resources SPOT (Systeme Probatoire d'Observation de la Terre) also ranks among such structures.

The scope of our survey does not give us the possibility to enumerate and describe all sites created for distribution of RSD in the World Wide Web.

Therefore, we will analyze WEB-resources developed by major governmental foreign structures, which are leaders in space investigations (first of all USA): NASA, NOAA, ESA.

2.1. NOAA informational WEB-resources

One of the main spheres of NOAA activity is the maintenance of a satellite group consisting of satellites with different characteristics and of different purposes. Polar-orbiting environmental satellites POES and geostationary operational environmental satellites GOES of NOAA series are the main information sources for weather stations all over the world.

For many years, measurement data of POES instruments have been providing for a valuable information for problems of climatology and oceanography, studies of ozone layer and aerosol content in the atmosphere, as well as the snow and ice cover, and for monitoring natural phenomena from space. The policy of free access to POES data and noncommercial distribution promoted their wide use in scientific investigations. According to these rules, the POES information is free or conditionally free of charge for users, i.e., their price includes only expenses for maintenance of archives and mailing data.

There is a network of centers, receiving satellite data, in the NOAA structure, which accumulate measurements for many years. The Comprehensive Large Array-data Stewardship System (CLASS) WEB-portal [http://www.class.noaa.gov/] was built on the base of archives of such data. Through this portal, the access to the archives of telemetry data of different satellite measurement systems and thematic products, containing the environmental parameters retrieved on the base of this telemetry data is conducted. The following types of information are included in the archives:

1. Data of the Defense Meteorological Satellite Program of the USA Ministry of Defense (the part open for common use).

2. GOES measurement data on the Western hemisphere.

3. Measurement data of the NOAA POES satellite devices.

4. Measurement data of the Canadian nature-resources satellite RADARSAT.

5. Numerous thematic products.

The peculiarities of access to the CLASS system

The access to the CLASS system is allowed only for the registered users. The registration procedure affords to a user his unique identifier for operation in the system.

The following services of electronic archives are realized in the CLASS system:
— the automatic mode for filing data and service information;
— the electronic catalog accessible via Internet;
— the system of data preparation and storage;
— metadata collecting.

The following possibilities for the users to operate with electronic archives of CLASS system are afforded:
— the access to data stored at ftp-servers;
— the search in the E-catalog;
— visualization means, including survey and composite images;
— quick access to archived thematic products;
— data ordering and delivery via Internet;
— servicing by subscription;
— the access to data sets.

The CLASS system has a user-friendly interface for the search and acquisition of archived data. After selection of the product type via the system interface, the user defines the search criteria like data type, spatial and time interval or the name of data set, thus gaining access to the references to the product information, metadata, and corresponding documents.

Functional characteristics of CLASS system can serve as an example of successful realization of typical approach to the building of WEB-resource for storage and distribution of satellite information and thematic products on its base.

2.2. NASA informational WEB-resources

In 1991, in the framework of U.S. Global Change Research Program NASA has developed and invented The Earth Science Enterprise (ESE) program, intended for the integrated study of the Earth. The main components of the ESE are:

1) a series of satellites of the Earth Observing System (EOS), designed for an integrated study of global changes;

2) the distributed computer network The Earth Observing System Data and Information System (EOSDIS) designed for the processing, storage, and distribution of data obtained in the framework of the ESE program;

3) research teams all over the world for analysis of these data.

A huge scientific, methodological, and organizing work has been done to realize the ESE program. Satellites of the EOS system were launched, which were designed for long-term observation of the land surface, biosphere, ocean, and atmosphere. The main satellites of this system are EOS-AM1 — Terra (1999), EOS-PM1 — Aqua (2002), and EOS-Chem1 — Aura (2004) [http://eospso.gsfc.nasa.gov/ index.php].

A great amount of data, which are obtaining with the help of the EOS satellite measurers is used for solution of a wide spectrum of problems (Table 1).

Based on the EOS measurements, standard thematic products are produced, which contain retrieved values of environmental parameters [http:// modis.gsfc.nasa.gov/data/dataprod/index.php]. Thematic products are divided into five groups: CALIBRATION, ATMOSPHERE, LAND, CRYOSPHERE, and OCEAN.

The main products of the ATMOSPHERE group distributed via LAADS WEB-resource (Level1 and Atmosphere Archive and Distribution System) [http://ladsweb.nascom.nasa.gov/data/] are of particular interest for specialists in the field of optics and atmospheric physics:

MOD04 — aerosol characteristics,

MOD05 — total humidity content,

MOD06 — cloudiness characteristics,

MOD07— profiles of atmospheric parameters (temperature, humidity, ozone).

The receiving, storage, and processing of EOS data are realized in special centers: Distributed Active Archive Centers — DAAC). The EOSDIS system unites electronic archives of the DAAC network. Names and addresses of the centers are listed in Table 2.

The united informational media has created for a great amount of data types of the EOS system, which is based on the use of common format for data storage and distribution and common software for processing. The Hierarchical Data Format for storing data from the Earth Observing System (HDF-EOS) [http://hdf.ncsa.uiuc.edu/index.html], was chosen for realization of this purpose. HDF format was designed in National Center for Supercomputing Application's (NCSA), University of Illinois, Urbana-Champaign [http://hdf.ncsa.uiuc.edu/index.html] for recording scientific data.

In the framework of EOS program, a network of WEB-resources was created, gaining the access to satellite data archives, software for primary and thematic processing, scientific and methodical literature. WEB-portals, uniting the distributed

electronic archives were built [http://redhook.gsfc.nasa.gov/~imswww/pub/imswelcome/].

2.3. ESA informational WEB-resources

ESA develops and maintains its satellite group, the main elements of which are space stations (SS) European Remote Sensing satellite (ERS-2) and ENVIronmental SATellite (ENVISAT). Measurement data of ERS-2 and of its predecessor ERS-1 are used for more precise weather forecasts basing on measurements of wind direction and sea surface temperature; ice covers mapping; detecting zones of the sea surface pollution; monitoring of the state of coastal zones, and solving the oceanographic problems. Measurement data of ENVISAT SS are used for solution of a spectrum of oceanographic problems, as well as for ice and snow cover monitoring, determination of atmosphere chemical composition, water cycles, and energy balance.

The policy of satellite information distribution, in ESA program differs from that of NASA and NOAA. Conditions of affording the information depend on the purpose of its application. In order to be used in scientific investigations, the data are distributed either free of charge or for the price including only expenses for the data production. To obtain the necessary information, a user has to make an application with a description of the scientific task, for solution of which satellite data will be used. After completion of the work the user has to present a report with the results obtained on the basis of the afforded satellite information.

Table 1

Satellite	The problems, for the solution of which the EOS satellite information is needed
Terra	The analysis of atmospheric dynamics and chemical composition, physical and energy characteristics of clouds; measurement of carbon dioxide and water vapor content in the atmosphere; analysis of processes of the atmosphere and land surface energy interaction; measurement of CO and methane vertical profiles; solution of some problems, connected with volcanoes
Aqua	The analysis of atmospheric dynamics, including water cycle and the processes of global heat exchange, cloud formation and precipitations; observations of snow and ice cover; measurements of the sea temperature
Aura	The analysis of atmospheric dynamics and chemical composition; monitoring of water and energy balances of the planet

Table 2

Center	Address
Alaska Satellite Facility (ASF) DAAC	http://www.asf.alaska.edu/
GSFC Earth Sciences Data and Information Services Center (GES DISC) DAAC	http://daac.gsfc.nasa.gov/
Global Hydrology Resource Center (GHRC)	http://ghrc.msfc.nasa.gov/
Land Processes (LP) DAAC	http://lpdaac.usgs.gov/
NASA Langley Atmospheric Science Data Center (LaRC) DAAC	http://eosweb.larc.nasa.gov/
National Snow and Ice Data Center (NSIDC) DAAC	http://nsidc.org/daac/
Oak Ridge National Laboratory (ORNL) DAAC	http://www.daac.ornl.gov/
Physical Oceanography (PO) DAAC	http://podaac.jpl.nasa.gov/
Socioeconomic Data and Applications Data Center (SEDAC)	http://sedac.ciesin.columbia.edu/

ESA develops its network of electronic resources, the main of which is ESA EO PIP (Earth Observation Principal Investigator Portal) [http://eopi.esa.int/esa/esa]. Thematic products distributed by ESA contain data on the underlying surface temperature, atmospheric gas composition, vertical profiles of the temperature and humidity, and so on.

The following software-informational products provide for the access of users to e-catalogs and satellite information archives:

EOLI-Web [http://eoli.esa.int/servlets/template/welcome/entryPage2.vm],

EOLI-SA [http://eoli.esa.int/geteolisa/index.html],

DESCW [http://earth.esa.int/descw/],

IONIA [http://dup.esrin.esa.it/ionia/], and

ATSR Global Fire Atlas [http://dup.esrin.esa.int/ionia/wfa/index.asp].

A feature of the ESA resources is a possibility for users to operate both in on-line and off-line modes. EOLI-Web, EOLI-SA, DESCW programs function as user's applications at local computers and make possible the search of data, browsing survey images, and generation of off-line orders. The copies of catalogs, necessary for work, are regularly updated and uploaded on the ftp-server. The programs are realized, using Java language, which makes them compatible with major operating systems (Windows 95/98/ME/2000 /NT/XP, Linux, Solaris, MacosX and so on).

2.4. SPOT program

The SPOT program is financially supported by the government and commercial organizations of France, Belgium, Swiss, and other European countries. The SPOT data have a high and medium spatial resolution. They are used in such areas as mapping, land use, agriculture, forestry, and so on. The information is distributed on the commercial basis. In order to make the search, browse, and order of the SPOT data, the SICORP-SIRIUS (Spot Image on-line catalog) electronic catalog is built [http://sirius.spotimage.fr/anglais/welcome.htm].

The results of measurements of Vegetation (VGT) radiometers, installed on SPOT-4, SPOT-5 satellites, are of particular interest for scientific investigations. This device is designed for vegetable cover observation, crop capacity monitoring and prediction, as well as for the study of processes of biosphere and geosphere interaction.

The products obtained based on Vegetation radiometer measurements are distributed via specially designed WEB-resources. The products synthesized on the basis of ten-day measurements, in three months are recorded in electronic archive [http://free.vgt.vito.be/] and are distributed free of charge. The rules of distributing other SPOT/Vegetation products [http://www.spot-vegetation.com/] depend on the purpose of their application. The price of SPOT/Vegetation data,

used for scientific purposes, includes only expenses for data media and mailing.

3. Russian WEB-resources

Russian distributors of satellite data can be conventionally divided into 2 groups:

— government centers of data accumulating and processing, built on the basis of large state scientific-production structures formed, as a rule, in the soviet period;

— private commercial companies, working in the sphere of accumulating, processing and distributing remote sensing data. They were formed in the post-soviet period.

Although data distribution via Internet is not always possible in Russia (because of insufficient development of telecommunication infrastructure) RSD distributors continue to develop r WEB-services for information representation and distribution via Internet.

3.1. Scientific-production enterprises

Among scientific organizations, which design and maintain informational systems for operation with RSD, the Institute of Space Research RAS (ISR RAS), Fryazino department of the Institute of Radio Engineering and Electronics RAS (FIREE), Earth On-line Monitoring Scientific Center of Rosaviakosmos (SC EOM), "Planeta" Research Center ("Planeta" RC), "Priroda" State Research, and Productional Center (Goscentr "Priroda") are the first.

Laboratory of Space Monitoring Technologies (LSMT) of ISR RAS is the leader in the design of software complexes for satellite data distribution. In Russia, the task of creation of the system of automated receiving of satellite data, processing and distributing was first solved at IRS RAS (Space Monitoring Information Support — SMIS) [http://smis.iki.rssi.ru]. This system realizes the following functions[1]:

— input control and accumulation of data;
— data storage, allowing immediate access;
— long-term data storage;
— quick access to the data of remote users;
— affording data to processing systems;
— remote control for the system.

The SMIS system affords the following services to users:

— browsing of catalogs;
— browsing of survey images and text annotations;
— search and selection of data according to certain criteria;
— a possibility of ordering data via Internet.

The creation of such system is an indisputable success of its authors.

"Sputnik" Server [http://sputnik.infospace.ru] is a mutual project of "Planet" RC, Rosgidromet, and IRS RAS. The server stores the information about

Russian meteorological satellites and archives of their measurements accumulated at "Planet" RC and IRS RAS. There are also concise descriptions of geostationary meteorological satellites "Electro," "Meteor-3," and "Meteor-3M," oceanographic satellites "Okean-01" and "Okean-O," as well as satellite "Resurs-01" studying natural resources, on the server.

The archives contain measurement data of devices MSU-E (SS "Resurs 1–3," "Meteor-3M," 1991–1993, 1995–2000, 2003–2006) and MSU-SK (SS "Resurs 1–3," "Okean-O," 1991–2002). "Sputnik" server affords information from Russian meteorological satellites and gains access to NOAA POES telemetry data, as well as to the thematic products received on the basis of this data (maps of the sea surface temperature, composite images of cloudiness). This server is developed and maintained by LSMT ISR RAS.

Space information storage and processing center IRE RAS (RSSI IRE) [http://www.ire.rssi.ru/cpssi/cpssi.htm] includes electronic archives containing high resolution data received from Russian satellites in the last century.

Earth On-line Monitoring Scientific Center (EOS RC) [http://ntsomz.ru/]. EOS RC electronic archives contain remote sensing data of different spatial resolution from Russian satellites: "Resurs-DK," "Monitor-E," "Meteor-3M" No. 1, "Meteor-M," "Electro-L," "Resurs-01," "Okean-O," as well as from foreign satellites – QUICKBIRD, IKONOS, EROS, SPOT, IRS, LANDSAT, RADARSAT, TERRA (MODIS, ASTER radiometer), NOAA (AVHRR radiometer), ERS. The data sets of the archive contain metadata, survey images, quality estimates. WEB-resource of EOS RC has a searching system with a friendly interface, allowing the search of information by different criteria, selecting and ordering data. WEB-resource of EOS RC has a necessary documentation and continuous maintenance.

3.2. Commercial enterprises

Commercial companies involved in distribution and processing of different RSD products mainly work with information of high spatial resolution. A review of their WEB-resources is beyond the scope of this paper. However, in order to present a complete analysis of Russian RSD WEB-resources, the Engineering and Technological Center "ScanEx" (ETC "ScanEx") [http://www.scanex.ru/] should be mentioned.

The ETC "ScanEx" is the leading commercial organization involved in archiving, distributing, and processing of RSD and products of their thematic processing. Having started with the production of satellite information receiving complexes, the company now offers a wide range of services for satellite data receiving and processing. The company has the license on direct receiving of satellite data

from the companies, which are leading operators of the Earth remote sensing.

The company designed and maintained the following WEB-resources for RSD distribution:
– on-line catalog of Earth satellite images, stored in ScanEx ETC archives [http://catalog.scanex.ru];
– site of non-commercial partnership "Prozrachnyi Mir" [http://www.transparentworld.ru/] with a collection of data libraries (Landsat-4,5,7) free for copying;
– on-line access to MODIS data via Internet [http://eostation.scanex.ru];
– Internet-shop: Earth images from space, GPS-maps, posters, geo-assigns, tourist maps [http://www.kosmosnimki.ru].

3.3. Regional centers for RSD receiving

There is a network of regional centers for data receiving and processing (RCDRP) in Russia. These centers belong to different governmental structures, such as Ministry of Emergency Management (MEM), Rosgidromet, Ministry of Natural Resources (MNR).

Rosgidromet structure consists of three large centers of receiving and processing satellite data (RCDRP). They are: PI "Planeta" RC with receiving centers in Moscow, Obninsk, and Dolgoprudnyi); RCDRP (Novosibirsk), West Siberia; and RCDRP FE, Khabarovsk, Far East. These centers provide for satellite information, received all over the territory of Russia. Rosgidromet receiving centers receive, process and distribute satellite data from all Russian and a number of foreign SS (NOAA, Meteoсаt, GMS, and others).

"Planeta" RC affords quick access to satellite information. The delivery of this information to users is actualized via different communication channels. "Planeta" RC is also the head organization of Rosgidromet, responsible for organization of the access of users to the satellite data archives built on the base of Russian natural-resource and oceanographic satellites.

The archive of "Planeta" RC is a department of Russian Federation Consolidated Fund of natural-resource and oceanographic information (the data of "Resurs" and "Okean" SS series). Besides, "Planeta" RC prepares informational products for the Department of Consolidated Fund, responsible for meteorological information. The total amount of initial data and prepared informational products is also stored at the "Planeta" RC.

E-catalogs of NOAA POES and MODIS telemetry archives, storing in "Planeta" RC, WestSibRCDRP, and FERCDRP, are accessible via SMIS system

Baikal regional center of the Earth remote sensing data receiving MNR Russia (Baikal IRK) is also involved in RSD distribution on a commercial basis. Observation data of the following SS are located on the IRK WEB-site [http://www.geol.irk.ru/bricc.htm]: EOS AM-1 (MODIS), IRS –

1C/1D (LISS-III, WIFS, PAN), Meteor-3M (MSU-E), NOAA POES (ATOVS, AVHRR).

The WEB-interface for operation with image catalogs, formed on the base of IRS-1C/1D data (PAN and LISS-III units) for the period from March, 2002 to December, 2003, is actualized on this site. This interface allows selection of images according to the type of the device and temporal and geographic parameters, as well as filling the electronic form of the order in advance. Archival and survey monitoring images of Lake Baikal and nearby territories (estimates of snow cover, ice state, and land temperature), as well as forest fires can be presented in disposal of users.

Besides, Baikal IRK has a site defined as "Web-interface" to the data of MODIS camera. These data are transmitted in on-line mode from satellites Terra and Aqua [http://eostation.irk.ru:8000/index.html]. The software of this resource was designed by the ETC ScanEx. General technical information, satellite flight schedule, useful references can be found there. The data of thematic processing, including all thematic products on the Baikal natural territory and forest fire maps for Irkutsk Region and Buryatiya Republic are in free access. The specialized information requires payment.

4. The development of informational-computational WEB-resources

Analysis of satellite data Internet-resources shows that users of satellite data can be afforded by the following information:
— survey images and annotations,
— primary images (telemetry),
— thematic products (retrieved values of environmental parameters).

However, the use of satellite data for scientific investigations is accompanied by a lot of difficulties.

First, "raw" satellite images are usually of large sizes. For example the size of the POES telemetry data occupies 17 Mb, while the size of MODIS telemetry data occupies 380 Mb. Downloading such files via Russian network channels is a serious problem.

Second, the use of "raw" data requires their primary processing (geo-assigning, calibration).

Third, the difference in satellite data formats is a serious problem. For example, all EOS data are recorded in the HDF-EOS format, the received NOAA telemetry data have a 10-bit representation. Therefore, the use of raw satellite data in scientific investigations requires additional skills, hardware, and software.

The affording of ready thematic products, which are based on satellite data, has its advantages and disadvantages. First, the range of thematic products is quite wide, and they can be used in different investigations. Second, in comparison with telemetry data, thematic products occupy much lesser volume (for example, the size of MOD04 file occupies about

1 Mb) that makes them easier to download. However, the problem of different formats still persists. The precision of such data depends on the retrieval algorithm quality and the software used. Therefore, sometimes modifications of algorithms make it necessary to change the whole data set. It is evident that despite the variety of thematic products, a limited data set can not be used for the whole range of scientific investigations. However, the use of these products is efficient. Regional studies of atmospheric characteristics were performed at IAO SB RAS on the basis of MOD04 and MOD05 products (Institute of Atmospheric Optics).[2] Thematic products of MODIS Atmosphere Products form the basis of the regional database of atmospheric parameters.[3]

Recently, a new approach to the design of scientific WEB-resources has been used, when the software for data processing is installed in the WEB-resources and can be used via Internet. Thus, a user gains remote access to the data, processing algorithms, and processing results. Web-calculators are the most simple way for adding more calculating functions into sites (for example, Web-calculator Landsat [http:// atmcorr.gsfc.nasa.gov/] for correction of atmospheric images). Complicated WEB-resources, combining informational and computational capabilities, are sometimes called virtual laboratories (VL). An example of such VL is a virtual laboratory for modeling the scattering of electromagnetic waves and radiation transfer, built in DLR 's Remote Sensing Technology Institute, or the portal built at IAO SB RAS, uniting various atmospheric research sites [http://atmos.iao.ru/].

To a wider use of RSD in scientific investigations, WEB-recourse has been designed at IAO SB RAS, being now under development.[4] This resource includes digital satellite information and algorithms for its thematic processing. The WEB-resource is designed to provide for user access to the existing satellite information and to the software, designed for its primary and thematic processing. The information and software are used for regional integrated studies in the field of remote sensing of atmospheric characteristics and land surface, as well as for learning methods of thematic processing of the multi-channel satellite images.

Conclusion

The analysis of satellite data Internet-resources allows us to make the following conclusions.

1. Present day WEB-resources contain comprehensive satellite data on environmental parameters accessible for all users. Scientific researches in various fields of knowledge are conducted on the basis of these data. Russian WEB-resources are mainly orientated on distribution of data on remote sensing of the Earth surface.

2. Taking into account informational and functional capabilities, the following WEB-resources of foreign leading scientific structures are most

efficient for solution of a wide range of problems of atmospheric physics and optics, climatology and meteorology:

— WEB-portal CLASS [http://www.class.noaa. gov/] (NOAA);

— WEB-resource for distribution and storage of primary and thematic products of ATMOSPHERE LAADS WEB group [http://ladsweb.nascom.nasa. gov/data/] (NASA);

— WEB-portal ESA EO PIP [http://eopi.esa. int/esa/esa].

3. Present day WEB-resources are informational systems designed mainly for satellite data storage and distribution. A promising direction of their development is in the expansion of system functions by means of installation of data processing algorithms into the system, such increasing its computational power. This will allow the use of Internet-resources both as a data source and as a powerful tool of scientific investigations.

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