Spatial Data Infrastructure for Digital Preservation and Access to Earth Observation Satellite Data

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ABSTRACT

Virtual research centre of digital preservation in Europe provides a natural basis for long-term consolidation of digital preservation research and expertise. Spatial Data Infrastructure will cover technical methods for preservation, access and most importantly re-use of data holdings over the whole lifecycle; legal and economic issues including costs and governance issues as well as digital rights; and outreach within and outside the consortium to help to create a discipline of data curators with appropriate qualifications. Main tasks of Spatial Data Infrastructure SDI development are building global infrastructure for IT and geodata; satellite information harmonization; usage of agreed upon set of standards; clear documentation describing the parts of the system; interoperability between independently created applications and databases; common standards within their interfaces, protocols and data formats; and finally support of a general data policy for data creation, access, and support of satellite information. Fundamental principle of Russian segment of SDI is providing interoperability – the ability of interaction for heterogeneous services and data catalogues within the bounds of a unified informational system. The Russian segment of distributed informational system has been built on the basis of EOLI-XML and SSE technologies.

Keywords: satellite data, Russian segment, e- infrastructure SDI, web service, online portal

INTRODUCTION

The problem of transparent and effective access to digital resources of satellite data becomes more and more significant nowadays. A Nobel prize winner and a former U.S. Vice President — Albert Gore — in his article “The Digital Earth: Understanding our planet in the 21st Century” spoke about it in the following manner: although there is a lot of information acquired, the access to it is difficult: “*The Landsat satellite is capable of taking a complete photograph of the entire planet every two weeks, and it’s been collecting data for more than 20 years. In spite of the great need for that information, the vast majority of those images have never fired a single neuron in a single human brain. Instead, they are stored in electronic silos of data. We used to have an agricultural policy where we stored grain in Midwestern silos and let it rot while millions of people starved to death. Now we have an insatiable hunger for knowledge. Yet a great deal of data remains unused*.”

Another example is the rapid growth of the amount of astronomical scientific data. The astronomers have accumulated terabytes of observational data in the last decades. This volume rapidly grows year after year, what makes the task of finding some rare object comparable to searching for a needle in a haystack. An effective way of accessing huge volumes of data has been developed. Its name is “Virtual Observatory” — this is a modern initiative in the international astronomical community, which aims to the development of informational infrastructure for providing transparent access to catalogues, data and means for their processing and analysis. The principal goal of the Virtual Observatory project is the increase in scientific yield in astronomical data, both observational and theoretical [1, 2]. The concept of Virtual Observatory provides researcher with the ability of using astronomic data from many different tools, with help of cutting-edge technologies and advancing international cooperation of scientific society.

An effective and long-term storing of scientific informational resources and analysis of large volumes of data becomes an issue comparable in importance to the results of astronomical observations and data modeling.

SPATIAL DATA INFRASTUCTURE: e-INFRASTRUCTURE SDI

A few years ago an idea for creating *e-Infrastructure* arose. *e-Infrastructure* is to become international spatial data infrastructure (SDI) as an aggregate of standards for interaction of open systems, technological solutions, human resources and legal agreements for collecting, processing, distributing and using spatial data.

SDI is a framework of spatial data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way. SDI is an infrastructure for spatial and digital cartographic data which joins information resources and metadata in a GIS portal. The portal provides access to the metadata, description-based search of metadata and delivery of geodata. The portal is an integrated node of access to spatial data, which is independent of data location, format and storing structure.

The scientists in the USA have been working on uniting informational resources since 1990's on the government level. The result of their work is the government state portal Geospatial One-Stop Operation Portal (GOS) as a part of National Spatial Data Infrastructure (NSDI) concept [3]. The national SDI programme has been started in the US by the executive order of President Bill Clinton: "Executive Order 12906: COORDINATING GEOGRAPHIC DATA ACQUISITION AND ACCESS: THE NATIONAL SPATIAL DATA INFRASTRUCTURE" which was signed on April 11, 1994. The annual budget of the SDI programme is 3.6 mln USD; 18 ministries participate in the programme, which is coordinated by FGDC (The Federal Geographic Data Committee).

The development of the European *e-Infrastructure SDI* began in the last years within the framework of INSPIRE program (*Infrastructure for Spatial Information in Europe)* of the European Union [4].

The development of *e-Infrastructure* as a generalized architecture which provides creation of scalable templates for a certain data domain is a globally acknowledged actual scientific problem. Currently, distributed multi-user geoinformational systems, which provide transmission of the informational resources of Earth Remote Sensing and satellite data of ecological monitoring onto the Web, are being intensively developed on the grounds of SDI infrastructure and INSPIRE programme.

The INSPIRE programme (2004–2013) of the European Union [5] develops distributed infrastructure for geographical data for the protection of the environment in Europe, monitoring of natural resources and natural catastrophes. The European geoportal INSPIRE has been created in 2005 under the European Commission initiative. The components of INSPIRE are metadata, collections and data processing services; network services and technologies; agreements on distribution, access and usage of data; mechanisms for coordinating and monitoring. INSPIRE aims at making available relevant, harmonized and quality geospatial information, integrating other standards during the development process facilitates interoperability. INSPIRE infrastructure will address technical standards, OpenGIS specifications, and protocols, including data access and the creation and maintenance of spatial information

INTEGRATING SPATIAL DATA AND SERVICES

The integration of spatial information and services is formed with using uniform standards and protocols for data exchange. The preferred standards are ISO (International Organization for Standardization) ISO/TC 211 19115, CEN and world-leading IT companies — Open Geospatial Consortium (OGC) and W3C.

The fundamental standards for SDI are being developed by OGC [7-8]. The common goals of SDI and INSPIRE programmes are providing coordinated distributed access to satellite informational resources; supporting solution of fundamental and applied problems related to Earth Remote Sensing from space and ecological satellite monitoring. The intensive development of the programme of forming distributed informational infrastructure is due to extension of usage of satellite data in international programmes for ecological monitoring and prevention of anthropogenic catastrophes GMES (Global Monitoring for Environment and Security) and GEOSS (Global Earth Observation System of Systems).

The INSPIRE directive of the European Committee of March 14, 2007 thoroughly governs all the essential issues of data integration. Chapter 2 focuses on metadata — descriptions of collections; chapter 3 is about interoperability; chapter 4 is related to services, providing access and exchange of geographical information; chapter 5 is about administrative agreements, which regulate data access. Currently, systems which provide transmission on the Web of the Earth Remote Sensing informational resources and satellite information on ecological monitoring are being intensively developed on the foundation of SDI and INSPIRE programme. A long-term experience of getting, storing and processing the satellite data and the practice of providing processed satellite data to a large number of users shows the ever-increasing amount of potential users of satellite data and the growing variety of requests of each user to one or another type of satellite information processing. Such a trend is connected with gradual development of the problems which the satellite information users face due to the development of technical means for getting Earth Remote Sensing data and with the emergence of a new generation of satellites with an enhanced spatial resolution. According to the SDI concepts accepted on governmental and international levels, the initiatives on creating Global SDI (GSDI) are being extensively developed.

GSDI is an hierarchical system divided in national, regional and municipal levels. The National Spatial Data Infrastructure (NSDI) allows for forming a system for accessing basic spatial data covering the territory of a single country. NSDI is nested in the system of state administration and corresponds to its vertical and horizontal structure.

In the last years Russian Federation also began creating spatial data infrastructure for electronic exchange of spatial data and distributed access to cartographic products over the Web. The Russian Federation programme of creating *e-Infrastructure* of spatial data is being developed with a goal of developing electronic environment for interaction in the problems of studying environment, environmental protection and handling emergencies. The concept of infrastructure for spatial data of Russian Federation, developed by RosCartography [6], defines *e-Infrastructure SDI* as a system which provides interaction for end-users using various digital spatial data in their work.

The goal of creating SDI is forming a consolidated information environment which provides search, publication and exchange of various geographical information resources. SDI is a hierarchically arranged system build on informational and geoinformational technologies and based on common standards for spatial data and metadata.

SDI also consists of a network of geographical information nodes — geoportals and metadata catalogues. A geoportal is a core of the informational infrastructure; it is an essential element for internal and external data exchange. A portal is a key constituent of the geoinformational infrastructure; it is an informational node which contains interface for access to database (issue-related collections of satellite data, informational products of space monitoring) and a metadata catalogue.

THE e-INFRASTRUCTURE SDI CONCEPT

SDI concept analogous to a road or telecommunication network, providing more effective access to geo-bound information based on minimal set of standard practices, protocols and specifications. An infrastructure for spatial data is a generalized architecture, providing creation of extensible templates of a specified subject domain. A rational informational infrastructure (architecture) of a geoinformational organization allows for increasing the effectiveness of working with spatial information based on collaborative usage of spatial data and services.

In the works [9-10] a set of main SDI components was studied: fundamental geospatial data; standards; technological infrastructure; institutional infrastructure. The fundamental geospatial data include

- fundamental maps of various scales where the main territorial objects are displayed;

- geodesic observation network;
- different-scale data of Earth Remote Sensing, bound with given precision;
- national catalogue of coordinates of overland control points (stable objects, which are clearly recognized on the snapshots);
- The institutional infrastructure includes
- a set of agreements and formats, governing exchange data and applied services;
- forming a coordinating structure;
- creating work groups for creating main components of National SDI;
- issuing fundamental regulatory documents, providing creation and functioning of NSDI;
- creation modern regulatory background, governing the issues of using Remote Earth Sensing data (the general principles are data access and accounting for interests of RES market participants).

The technological SDI includes the following components:

- a developed telecommunicational infrastructure for rapid ERS data transmission;
- RES and other geospatial information data catalogues;
- national network for managing metadata of data and services (portals, data archives, catalogue services, etc.);
- RES data banks and bases on the level of organization, field, state;
- technological chains of realization standard operations of processing RES data.

In the problems of sustained development of terrains, such components of technological infrastructure as supporting and developing a cartographical module and an interactive electronic map are of a large significance; they allow for conducting a complex study of objects of adjacent terrains based on geodata visualization and publishing cartographical data.

The development of geoinformational SDI along with using satellite data of space ecological monitoring of natural and anthropogenic occurrences provides realization of systematic research of environment parameters, aggregate of natural and anthropogenic factors, integration and displaying these factors on an electronic map using GIS Web services, developed by OGC — a Web Map Service (WMS) protocol [11].

The modern technologies of integrating and archiving Remote Sensing data and organizations of multi-user distributed access to the results of space monitoring of natural and anthropogenic events were studied in [12-13]. Authors have studied the problem of harmonizing standards and protocols, related to satellite data, to the corresponding international ISO standards in the geomatics field (ISO series 191xx), which belong to raster data and ERS technologies; also were realized calibration and testing of space shooting devices and a technology for processing ERS data and receiving informational products. Also was developed a technology for remote access to foreign satellite resources and embedding Russian satellite data into international information systems: European INFEO system, EOSDIS/USA system — based on standard means of integration, open protocols and standards ISO/TC 211 19115, OGC, Federal Geographical Data Committee/USA [14].

The problem of data exchange is one of the most important problems in the development of the informational ERS infrastructure. This is due to difficulties in getting and processing satellite data within single infrastructure. This is also related to various possibilities and requirements of providers and consumers and a lack of single standard and approach to the resources delivery. A comprehensive analysis of the problem of creating SDI is beyond the scope of this paper. Next we'll concentrate on forming SDI regarding creation of Russian e-Infrastructure as an electronic interaction environment for access to space research resources.

THE REASONS for CREATING RUSSIAN GEOINFORMATIONAL INFRASTRUCTURE

Despite the significant increase in amount of Russian space centres, which provide free access to the Earth Remote Sensing data, the essential problem for a user who wants to make use of Remote Sensing data is the absence of centralized access system — a catalogue, which would allow for searching necessary data in a number of centres simultaneously. According to the aforesaid, apart from possessing and storing information, a very important thing is to provide access to it — otherwise a large part of the information is useless, because it is too hard to find.

Thus, a natural step in further development of the satellite centres, catalogues and archives, is the creation of integrated global infrastructure, which goals are solving the above mentioned problems. For the global informational infrastructure to become reality in Russia, it was necessary to define those problems and singularities, which are faced by scientific societies of researchers while looking for optimal satellite data access. The initial stages of this research were carried out by authors in the *INTAS IRIS Project: Integration of Russian Satellite Data Information Resources with the Global Network of Earth Observation Information Systems*. The main goal of the project was the studying of singularities related to storing Remote Sensing data in the Russian satellite centres; building model of a one whole infrastructure which would allow for joining multi-level archives and catalogues; adapting open international standards for spatial metadata (ISO series 191xx) [15-16], and also protocols and instruments of *Service Support Environment* (SSE) [17-18], developed under the initiative of European Space Agency. The initial phase of constructing Russian SDI was to build an SDI prototype as a working Russian segment of SSE with implementation of additional features, which are to be considered further.

SERVICE SUPPORT ENVIRONMENT (SSE)

The SSE system is an infrastructure; a single environment for users and providers of data and services, using SOAP message exchanging protocol and WSDL — Web Service Definition Language [19].

The main aims of creating SSE infrastructure are:

- give service providers an environment that would at most simplify interaction such as “service-provider — user” and “service-provider — service-provider”;
- simplify integration of existing services, providing universal XML-based interface, allowing for keeping their structure;
- provide users with a single entry point — Internet portal.

The core of the system consists of two main components — SSE Portal Server and AOI Server, which together form an Internet-portal, with which a user interacts.

SSE Portal Server provides a web interface for users to access the portal. The server is constructed on the J2EE industrial technology, which satisfies the SSE requirements: good scalability, integration with existing information systems, flexible security policy, support of standard protocols and languages, components transferability without necessary recompilation. Following these requirements is mandatory for successful construction of informational infrastructure. The open-source *JBoss* server was chosen as an application server.

AOI Server works together with *SSE Portal Server* and it is used for providing service providers with functions of visualizing search results and of visual selection of an area on the map (*Area of Interest, AOI*) when specifying search criteria.

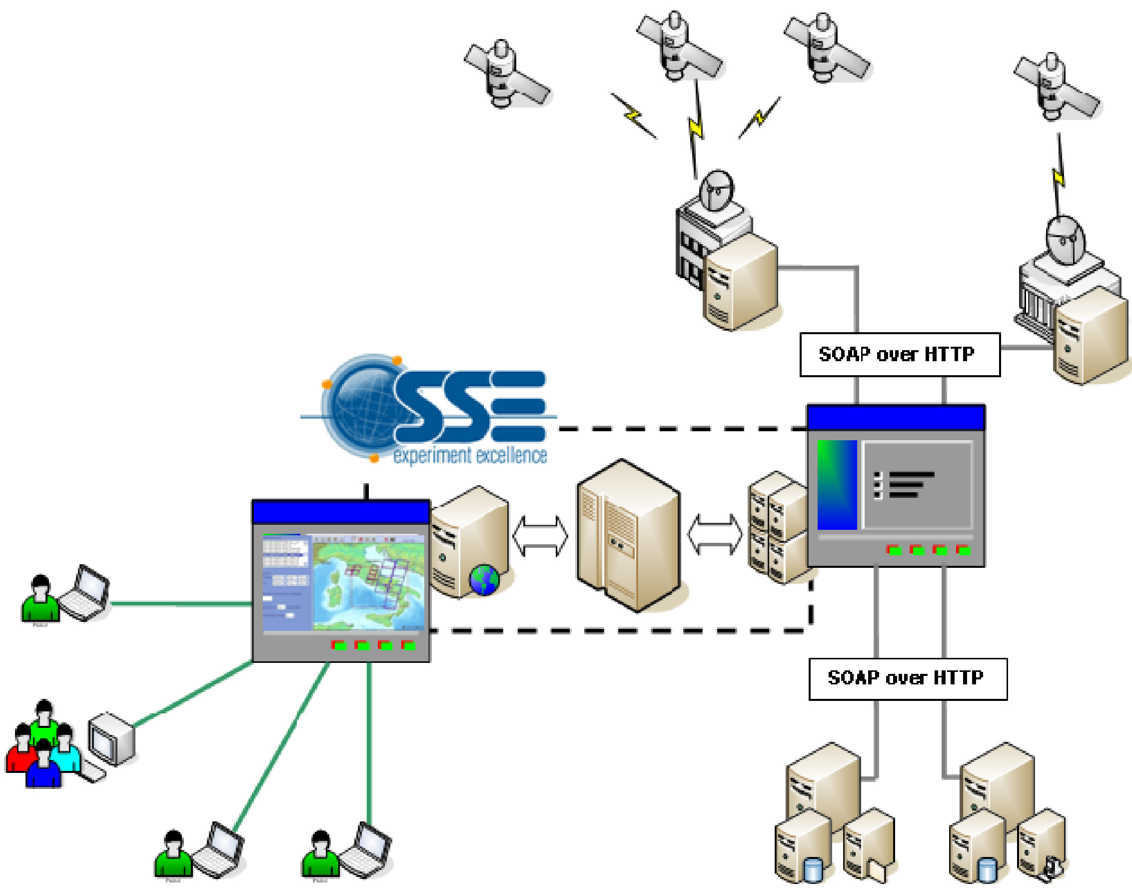

Figure 1: Overview of SSE.

Since the majority of services require specifying geographical area as one of the search parameters, *SSE Portal* provides special support of this feature. When forming a query, user should specify a geographical area. S/he can do it in a several ways:

1. choose from a list,
2. specify an area on the map,
3. upload a file, describing AOI,
4. specify AOI by providing coordinates explicitly.

The SSE Portal processes user's request using applet, loaded from AOI server, for displaying selected area on the map. SSE can visualize both locally stored information and additional map layers, downloadable from remote OGC WMS servers. The description of the selected area is stored in GML (Geography Markup Language) format and is sent to the service provider as a SOAP-message.

FORMING THE RUSSIAN SEGMENT OF SSE

The structure of SSE was initially designed based on principle "one service provider — one data array". While forming the Russian segment of SSE structure for participation in SSE system, another approach was used, which is based on what has become traditional three-level informational system: data level, computations level, knowledge level. Using three-level scheme while developing global infrastructure and while organizing data exchange between its components is a promising way of building information-computer environments for supporting regional and global researches in the field of Earth sciences and ecological monitoring [20]. A new feature was implemented in the scheme of accumulating and exchanging data in the Russian segment of the SSE: appearance of conceptually different components — so-called “network nodes” — which aggregate data from several service providers without the necessity of installing and setting-up additional software. In such a connection scheme all the required data conversion to a single standard is realized in one node, while in a standard scheme this work needs to be done individually by each service provider. Besides, a user will be able to search in all the data arrays of all the service providers which are connected to the system. This system uses modern technologies and standards and open-source software which is necessary to solve all the problems on all the development levels. These are the standard for geographical metadata of ISO series 19115-2 [16], widely acknowledged technologies WSDL, SOAP and WMS [11], which are the basis for the search engine, and *Eclipse* development environment.

An experimental prototype of the Russian segment on the infrastructure is constructed (based on the SSE technologies) in the Space Research Institute of Russian Academy of Sciences (see Fig. 2), which currently joins two independent satellite data providers: the information on terrains of the Far East and the Pacific Ocean is supplied by Institute for Automation and Control Processes, Far Eastern Branch of Russian Academy of Sciences, based in Vladivostok and the data for terrains of Western and Eastern Siberia is supplied by the Institute of Computational Technologies, Siberian Branch of Russian Academy of Sciences, based in Novosibirsk. The realized solutions are well-scalable and they allow for joining together a large numbers of service providers of heterogeneous data.

To provide users' access to satellite data, Institute of Computational Technologies of Siberian Branch of Russian Academy of Sciences (ICT SB RAS) creates Siberian node for collecting, storing and processing Remote Sensing data. The main functions of the node are providing telecommunications for data collecting, archiving raw data, preliminary data processing, cataloging processed data, providing long-term storing of processed data, providing access to data and topical data processing.

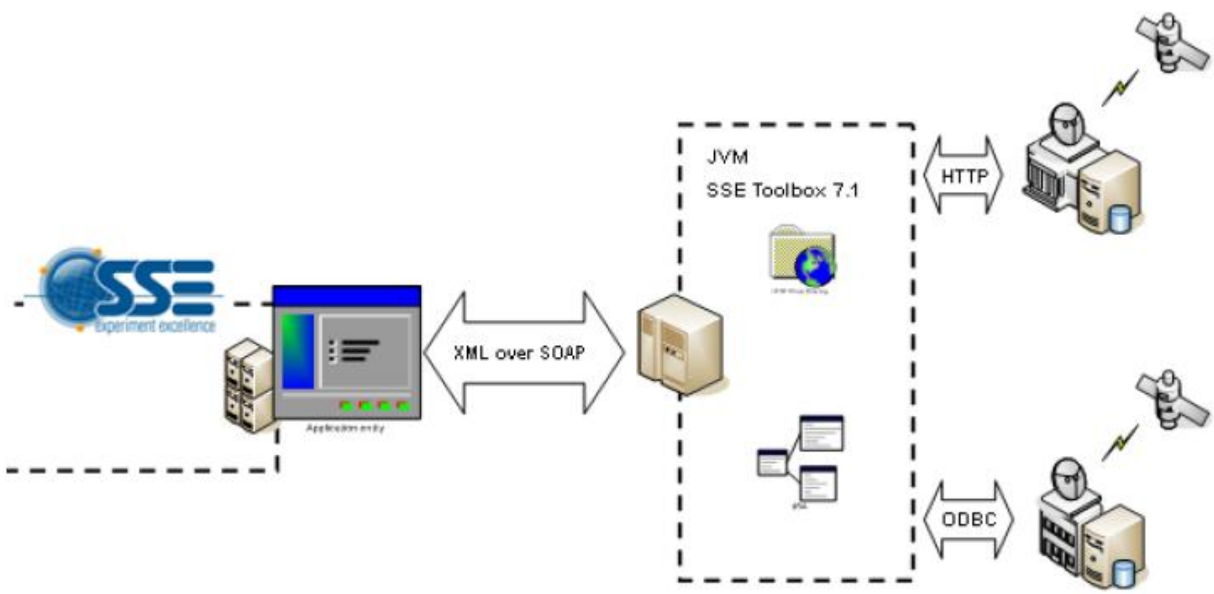

Figure 2: Interaction of satellite centres with a segment node

In 2008, a catalogue was created based on data storing system of ICT SB RAS; the catalogue is regularly updated with SPOT 4 data. The catalogue also includes archive data of Russian territory of years 1982–2002 from Landsat series satellites. A service-oriented system is created based on this catalogue; the system is realized as a basic set of applications, working in the environment of the Tomcat application server. The user interfaces are developed using PHP and JavaScript technologies. The CAS (Central Authentication Server) module is used to provide access to the system. This module allows for creating multi-level system of user rights and access levels. The centralized user base is created on top of LDAP catalogue of Siberian Branch of RAS.

The location of the receiving complex ensures receiving data which cover Siberia, parts of Far East and Yakutia and lands of Ural and Central Russia. It is possible to receive data from other currently active platforms. The designed software of a network node can connect data providers by using various protocols and data exchange interfaces: SOAP, ODBC, HTTP, FTP.

THE FUNCTIONALITY OF RUSSIAN SEGMENT AND INTERACTION WITH DATA CENTRES

Let us consider the interaction scheme of two satellite centres with a segment node in IKI RAS, which use different methods of data transmission (see Fig. 3).

The dashed line represents the program-hardware complex of a segment node, which performs the following tasks:

- direct interaction with the SSE server, processing its search queries and returning the results (message exchange with the server by XML over SOAP);
- receiving, converting and storing metadata in the local database from the satellite centres which are part of the segment:
    - data exchange with ICT SB RAS — through HTTP gateway;
    - data exchange with IACP FEB RAS — via ODBC interface;
- providing Web interface (via portal) to a node for local search within the segment without using SSE portal.

The node uses its own DMBS which is needed for storing metadata storing local collections of each satellite centre which is connected to the node. The Earth Remote Sensing data themselves are not stored on the node server; instead, only links to them are kept in the local bases, and direct access can be provided via these links, when necessary.

The metadata in the node database are updated automatically with specified periodicity; they are synchronized with local databases of each satellite centre. All the necessary conversion is done in the process, since every provider stores its data in a proprietary format.

Apart from the local mirror of the metadata database, each of the data providers which is connected to the server corresponds to its own programme module which is used for receiving and processing of the requests and for forming the response with the search results.

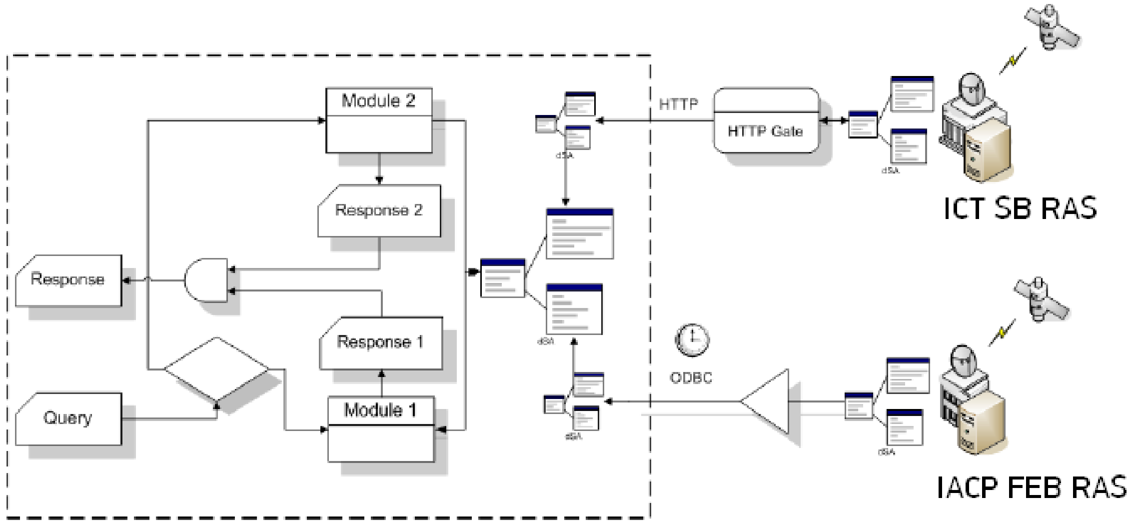

Figure 3: The structure of Russian segment node

After receiving query from the SSE server, the query is redirected to the entry of each of the programme modules, after what a request to each of the metadata databases is formed, taking into account their structure and content. The results of queries processing are being consolidated, converted to a given format and sent back to SSE server. The user who sent the query gets the response as a list where he can select necessary data using preview and then get direct links to the data.

To manage the segment node, a programme has been written for an administrator workplace. Its main purpose is on-the-fly managing of the services which search and process information. It has such functions as

- viewing and editing service configuration files,
- viewing logs (diagnostic and error messages),
- running and stopping services,
- testing running services by emulating input queries,
- creating new services based on existing templates,
- exporting and importing services configuration.

Besides, the administrator workplace has a set of instruments to work with the node database. It allows performing such tasks, as

- viewing logs of adding metadata to the database,
- viewing and editing configuration files of auxiliary services, which perform tasks of automatic data receiving from satellite centres,
- running, stopping and checking the auxiliary services for data receiving,
- manual correction of metadata, if required.

THE SEARCH WEB-INTERFACE OF THE RUSSIAN SEGMENT

On the server of the Russian segment there is a portal running, which provides searching among the data of the providers, which are elements of the segment, bypassing the main SSE portal, which allows for using our own more flexible interface for specifying search criteria. The Geoportal works in experimental mode (see Fig. 5).

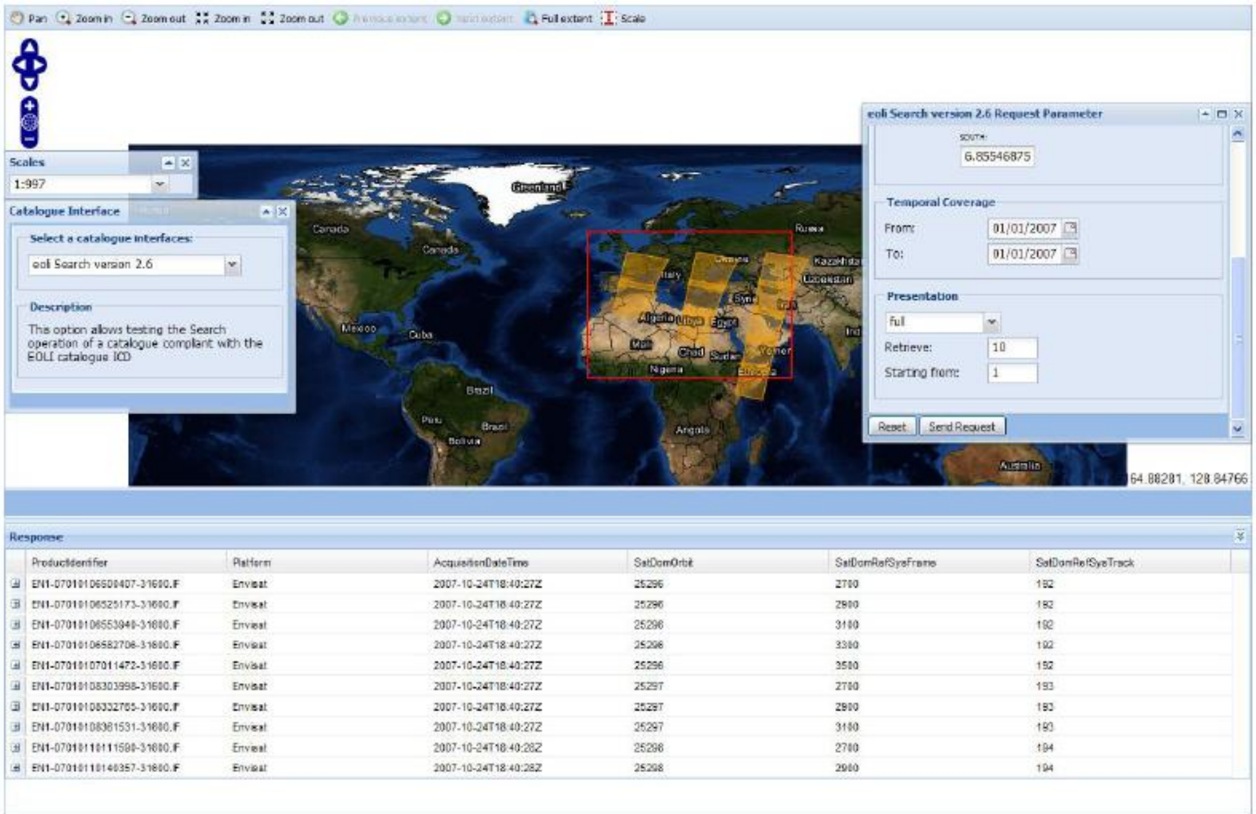

Figure 4: The search web-interface of the portal

The geographical portal is a combination of separate applications and services. It is used for publishing, administrating and searching standardized geoinformational resources. The portal consists of the following elements:

- web application — Geoportal Site Starter;
- content management system (CMS);
- task service interface;
- search widget;
- previewer map interface;
- data extraction service.

The portal is located on the web server and it is a client application of the GIS server. The users, who interact with it, query the services which act as intermediates between the web server and the GIS server and which call the geoservices on the GIS server via its SOM component. These geoservices are made as a specialized objects (for instance, for ESRI company products it is ArcObjects) on SOC machines.

The following could act as the initial data for the geoportal: local and global metadata, local and global web services, wiki-based projects, YouTube data, SharePoint documents, KML, etc.

Using local portal, which is independent from SSE, allows for implementing additional search options, forming search queries more flexibly, while the search interface on the SSE portal is specified rigidly and does not always allow for specifying necessary search criteria. The search interface of local portal is build based on WMS (Web Map Server) technology, which allows for using multi-layer maps from various sources for specifying AOI visually by selecting vertexes of a rectangle for forming a query. The search interface map is interactive and user can choose necessary layers from the sets which are stored in the database, daily updated with new snapshots. Thus, user can form the query more flexibly, based on the existing data, which leads to more precise search results.

After the user has specified search parameters, a query in the same format as in the SSE is being formed, and then it is sent to the entry point of the module, which takes incoming requests from SSE server, and the query is processed normally (as described above); the only difference is that the response is sent to the same interface of the local portal, where the query has been formed.

CONCLUSIONS

Global change and Environmental research require effective access to geospatial data worldwide. Improving the accessibility of Russian satellite data could make a very substantial contribution to environmental monitoring and natural disaster mitigation in Europe. Digital preservation offers the economic and social benefits associated with the long-term preservation of environmental information, knowledge and know-how for re-use by later generations. Virtual research centre of digital preservation in Europe provides a natural basis for long-term consolidation of digital preservation research and expertise. Spatial Data Infrastructure will cover technical methods for preservation, access and most importantly re-use of data holdings over the whole lifecycle; legal and economic issues including costs and governance issues as well as digital rights; and outreach within and outside the consortium to help to create a discipline of data curators with appropriate qualifications.

The main aim of this project is to improve the accessibility of Russian Satellite Remote Sensing data, generating Russian satellite information resources, linking the information resources with Russia and with the European eo/Porrtal (metadata/catalogue) system in order to provide interoperable catalogue access and ensuring that end users are involved, provide a single point of access to data.

Thus, International Scientific community of Remote Sensing has gained the opportunity to access data of one of Russian EO satellite data providers via a global distributed system. Technologies and principles of building distributed systems considered in this article have great potential for further development, and even today they provide extensive means for arranging distributed heterogeneous data and services in a single global system. The future plan for the next generation of the distributed informational system consists of three main parts: a) correcting shortcomings of the existing system, b) enhancing technical and informational characteristics, and c) providing solutions to new problems which were unknown during the development of the original system.

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