Organization of digital monitoring of the Baikal natural territory

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Abstract. The Baikal Natural Territory includes Lake Baikal, its water protection zone, the basin within the territory of the Russian Federation, adjacent specially protected natural areas, and also the territory adjacent to the lake up to 200 kilometers wide to the west and northwest of it. The development of decisions to solve environmental problems of Baikal Natural Territory should be based on a comprehensive analysis of the monitoring data. The monitoring data and analysis methods are distributed among participants (organizations and departments). But data and analysis methods exchange is very low. An approach is proposed for the introduction of digitalization in the environmental monitoring of the Baikal natural territory, based on the integrated implementation of cyber-physical systems, the digital method of data transmission, as well as the use of digital ecosystems and platforms using the service-oriented paradigm, OGC standards, end-to-end and WEB technologies, cloud and distributed computing, large amounts of spatio-temporal data. Based on service-oriented paradigm digital resources and processing services implementing REST or WPS standard should be created by the monitoring participants. Requirements for digital resources have been defined. Infrastructure components have been developed to simplify development of digital resources, processing services and to organize interaction among participants.

1. Introduction
The Baikal Natural Territory (BNT) includes Lake Baikal, its water protection zone, the basin within the territory of the Russian Federation, adjacent specially protected natural areas, and also the territory adjacent to the lake up to 200 kilometers wide to the west and northwest of it. BNT is represented by unique landscapes that require their natural preservation in accordance with the "Convention on the Protection of the World Cultural and Natural Heritage of UNESCO" and the legislation of the Russian Federation (Decree of the President of the Russian Federation No. 204 of May 7, 2018 "Preservation of unique water bodies, including the implementation of tasks for the preservation of Lake Baikal"). Preservation of Lake Baikal, as a world source of clean fresh water and as a natural site with unique fauna and flora, is the main conservation task of Russia and the most important condition for its sustainable development.

The main directions of scientific research of Lake Baikal are noted in the Decree of the President of the Russian Federation No. 204 of May 7, 2018 "Preservation of unique water bodies, including the implementation of tasks for the preservation of Lake Baikal", and are also determined within the National project (program) "Ecology" (Federal the project "Conservation of Lake Baikal"). Decree of the Government of the Russian Federation of February 2, 2015 N 85 "On the approval of the Regulation on state environmental monitoring of the unique ecological system of Lake Baikal" noted
that it is part of state environmental monitoring (state environmental monitoring). Unfortunately, the current regulations are contradictory and do not allow the implementation of special credentials to monitor the unique ecosystem of Lake Baikal.

Among the environmental problems of the Baikal natural territory, the following should be highlighted:

- significant changes in landscapes due to massive fires and economic activities;
- decrease in the basin of Lake Baikal, water content of the tributaries of Lake Baikal; pollution of the underground hydrosphere;
- growth of anthropogenic pollution and acid precipitation;
- decline in forest resources due to forest pathologists, illegal logging and fires;
- abnormal development of filamentous algae, the extinction of endemic Baikal sponges, an increase in methane emissions, the introduction of unusual species for Lake Baikal;
- hazardous endogenous and exogenous geological processes, such as seismicity, landslides, mudflows, etc.

The development of decisions to solve the listed environmental problems should be based on a comprehensive analysis of the BNT monitoring data. State environmental monitoring at the BNT is carried out by: the Federal Service for Hydrometeorology and Environmental Monitoring, the Ministry of Natural Resources and Ecology of the Russian Federation, the Ministry of Agriculture of the Russian Federation, the Federal Agency for Forestry, the Federal Service for State Registration, Cadastre and Cartography, the Federal Agency for Subsoil Use, the Federal Agency for Water Resources and the Federal Agency for Fisheries, as well as the executive authorities of the Republic of Buryatia, the Trans-Baikal Territory and the Irkutsk Region in the manner prescribed by the decree of the Government of the Russian Federation [1-3]. Moreover, scientific environmental monitoring is supported by institutions of the Ministry of Education and Science.

It should be noted that it is difficult to carry out a comprehensive analysis of environmental monitoring data from BNT due to:

- missing integrated monitoring systems in the mode (24/12/365), also ongoing analysis of the state of the BNT ecology;
- localization of departmental observation schemes, territorial distribution of hardware and software of monitoring systems.
- formation of spatio-temporal monitoring data, which are not coordinated with each other, in parametric, chronological and other aspects, including due to their different formats;
- limited access to monitoring data, which complicates management decisions, as well as interdisciplinary research.

All this justifies the necessity of introducing digital transformation into the environmental monitoring system of the BNT, which implies the introduction of cyber-physical systems, the digital method of data transmission, and also the use of digital platforms based on service-oriented, end-to-end technologies, cloud and distributed computing, large volumes of spatio-temporal data, etc.

2. Digital transformation of monitoring of the Baikal natural territory

The digital transformation of BPT monitoring involves the creation of a digital monitoring ecosystem (DME) of BPT, as a partnership of departments, organizations (participants) that maintain it and support open digital information and telecommunications exchange for the development and receipt of new services. The authorized bodies of the federal and regional executive authorities, RAS institutes, universities, business and the public should act as participants in the DME. The creation of a digital monitoring ecosystem for BNT requires formalizing the requirements for participants to provide tools and organize the workflow to create new services.

Within the DME, participants form digital resources and processing services. A digital resource is a logically connected set of data that is created and replenished by one or more participants. For a digital
resource, it is necessary to implement a life cycle that includes acquisition (continuous updating), storage, processing and publication. A digital resource in DME must meet the following requirements:

- digital resource data is stored in the data center, on shared servers in the form of databases with standard network programming interfaces (SQL) or as files on network resources provided by the data center data;
- methods and components of data adjunction should be implemented, allowing to expand the number of data sources;
- the data of the digital resource is published on one of the thematic geoportals in a form that is visual to the user (tables, diagrams, maps). Data changes are automatically displayed upon publication;
- digital resource data is provided using a REST-based service or with the WPS specification. The service is registered in the service catalog;
- digital resources are completely open.

Data processing services that implement methods, algorithms, processing techniques, analysis of digital environmental monitoring data and must meet the following requirements:

- implementing the OGC WPS standard;
- ensuring the continuity of the service and the ability to scale it;
- registering services in the catalog of services with the provision of all the necessary meta information, data used, examples of publication of results;
- providing examples for testing services.

The creation of digital resources and services for processing spatio-temporal data in the DME that satisfy the developed requirements is a rather complex process that must be simplified as much as possible and supported by various software, hardware and organizational solutions. Participants of the BPT monitoring have different resources, know-how, qualifications in information technologies: from maintaining data in Microsoft Excel to their own centers for collective use, cluster systems and unique software. This justifies the need for unification of digital exchange of thematic spatio-temporal data and services for their processing.

Currently, qualitatively new conditions have been formed for creating a digital ecosystem for monitoring based on the principles of digital platforms that accumulate the latest information and telecommunication technologies, providing participants with open access to data, processing services, digital tools and services.

By definition, a digital platform (DP, digital platforms) is an open system of algorithmic network interaction of independent monitoring participants united by a single information environment, leading to a decrease in transaction costs and to an increase in the efficiency of services through the use of a package of digital technologies for working with data (storage, processing, analysis, etc.) and changes in the system of division of labor [4-8].

For each direction of digital environmental monitoring of BNT, its own digital platform is being created, which should include a set of digital spatio-temporal data, algorithms, services, models and tools, information-technologically united by a single information environment and telecommunications infrastructure.

By the level of information processing and provision of services, the basic types of digital platforms are distinguished: instrumental (IDP), infrastructural (INDP), applied (ADP), and also industry-specific, that form a hierarchy. The IDP is a part of the INDP, which, in turn, support the operation of the applied DPs in different directions of the BPT monitoring.

Thus, the creation of digital resources and data processing services assumes the use of basic types of DPs for sharing services, services and data by all monitoring participants.

2.1. **Instrumental digital platform**

Instrumental digital platform (IDP) for monitoring BPT and Lake Baikal contains instrumental software to support participants’ access to the development and debugging of applied software and
hardware monitoring tools by providing standard functions, instrumental (universal) services and their interfaces for processing spatio-temporal data.

Repeated use of ready-made IDP tools allows you to reduce the time required for the creation of infrastructure and application DPs, and also the provision of services for organizing digital environmental monitoring of BNT.

The software development methodology is based on the complex application of modern service-oriented (SOA) [9] and end-to-end technologies, distributed storage and processing of spatio-temporal data, the use of declarative specifications and intellectualization using methods and technologies of deep learning. At the same time, declarative specifications provide compactness, expressiveness and subject orientation, including the possibility of interpretation, transformation, and other procedures. The use of SOA allows full accounting of distributed information resources, combined with ease of testing, scalability and the ability to reuse the created services.

The IDP includes tools for creating three main types of components that are embedded in the general environment:

- development of WPS services and their compositions intended for software data processing, implementing standards for software interoperability;
- creation of data exchange services that support the provision and collection of thematic data;
- deployment of geoportals providing access to thematic data and services.

The information environment of the IDP includes geoportals, services for receiving and processing spatio-temporal data based on the open standards of OGC. Services can be implemented on various operating systems, development environments, etc., and the problem of their compatibility is solved by using virtualization mechanisms.

To take into account the diversity of spatio-temporal monitoring data and their processing services, thematic geoportals can be created to simplify the work of participants, integrating data and services in the areas of BPT monitoring.

IDP contains tools for creating typical geoportals and services in the cloud based on pre-configured templates of virtual machines. Templates are available with Zoo project, 52° North Web Processing Service (WPS) systems to simplify the implementation of the standard. A typical geoportal has built-in tools for generating services for entering and editing relational spatial data and providing them based on REST. To do this, the user defines the data structure, display methods and access rights. A transfer of relational data to WPS services is implemented. Geoportal allows users to create new WPS services by composing existing ones using JavaScript or JSON, DAG specifications [10].

For collective use, taking into account the growth in the number of tasks and the amount of information on monitoring the BPT, the IDP supports the scaling of information and computing resources, their storage and data processing.

2.2. Infrastructure digital platform

The Infrastructure Digital Platform (INDP) is created on the basis of the IDP and supports the development of applied software and hardware, T-services for processing and distributed data storage based on the information environment (geoportal type), service-oriented and end-to-end technologies, using declarative specifications and intellectualization.

Thematic service (T-service) is a service created on the basis of an instrumental digital platform and functioning within the framework of the INDP, which solves the tasks of a given direction of digital monitoring of BNT (water bodies, forests, aquatic biological objects, atmospheric air, etc.) based on spatial-temporal data received from platform participants or external sources. The specialization of T-services is determined by the tasks of the direction of monitoring. Functionality of T-services is determined by the type of information being processed (geospatial, navigation, biological, etc.). T-service uses functions and interfaces for processing spatio-temporal data, their services and combinations, implemented in an instrumental digital platform.

The structure of INDP of the digital monitoring BNT includes:

- catalogs of T-services for the provision and processing of monitoring data;
- basic spatial data and services, which provide unified reference books and classifiers and the operation;
- scalable computing resources, service execution;
- a system for planning and executing services on distributed computing resources;
- services for publishing data in the form of maps and diagrams.

As an information and technological component of the INDP, the infrastructure of the centers for collective use of the IDSTU SB RAS “Integrated information and computing network of the Irkutsk scientific and educational complex” and the “Irkutsk supercomputer center SB RAS” can be used.

One of the tasks of the INDP is to support the construction of applied digital platforms, the main activity of which is to provide monitoring participants with access to T-services developed within the framework of the infrastructure platform.

2.3. Applied digital platform
The applied digital platform (ADP) of BNT environmental monitoring operates with processed data at the level of a separate direction or monitoring as a whole.

The ADP supports the algorithmic exchange of services (services) between the participants using a single information environment and information technology infrastructure. The ADP has its effect by combining many streams within one information environment.

The applied digital platform includes the following services:
- geoportal of digital environmental monitoring of BNT;
- services for providing monitoring data of the BNT (by areas);
- thematic WPS services for identifying and assessing changes in the environmental state of the BNT based on time series of remote sensing data under the influence of destructive factors.

2.4. Scheme for creating digital resources and data processing
The scheme for creating digital resources and data processing services varies from the capabilities of the participants. The creation of digital resources and data processing services is carried out within one of the applied digital platforms. The most important thing for the participants when creating digital resources and processing services is the availability of their own computing resources, ready-made digital resources, processing services and information technology specialists. If ready-made digital resources are available, they need to be built into the digital monitoring ecosystem, i.e. lead to the specified requirements for the organization of unified software access, i.e. ultimately register with the service catalog.

Computing nodes are required to create digital resources and processing services. Keeping servers running smoothly and reliably is expensive. The instrumental platform provides for the provision of computing resources in the cloud infrastructure. Therefore, for teams with specialists in information technology, it is possible to develop their own digital resources and services on dedicated virtual nodes.

In most digital resources, data differ in structure, number of attributes, data types, reference books, etc. In the instrumental digital platform, you can use a tool for creating data exchange services that support the provision and collection of thematic data. Service creation is done without the need for programming. This work can be done by experienced users.

3. Conclusion
Formalization of requirements for digital spatio-temporal resources and services for their processing, development, provision of computing resources is a prerequisite for digital environmental monitoring of BNT. The platform approach allows integrating information and analytical resources of participants in digital environmental monitoring to support interdisciplinary scientific research and decision-making on environmental problems of the Baikal natural territory.
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