# Digital Monitoring of the Ecosystem of Lake BAIKAL

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**Abstract.** The urgency and directions of creation and development of integrated digital monitoring and assessment of changes in the ecosystem of Lake Baikal and its coastal area using large amounts of multi-format space-time thematic data and knowledge, service-oriented paradigm, OGC standards, Web-services, as well as the introduction of modern information and telecommunication technologies are considered.

**Keywords:** spatial and temporal data of digital monitoring; service-oriented paradigm services

## 1 Introduction

The questions of organization of the system of digital environmental monitoring of Lake Baikal and its coastal area with the use of modern digital technologies and services for processing large amounts of distributed space-time data are considered.

## 2 Monitoring Lake Baikal

Studies of unique ecosystems conducted in the world and Russia are based on comprehensive monitoring, storage and processing of large amounts of scientific data and knowledge about the system, which have a spatio-temporal character, as well as the use of distributed information and computing technologies and their applications and modern data networks [1, 2, 3].

Preservation of the Baikal Lake as a world source of clean fresh water and as a natural area with unique fauna and flora is the main environmental task of Russia and the most important condition for sustainable development of the region. Baikal natural area (BNT) is represented by unique landscapes that require its preservation in its natural form in accordance with the "Convention for the protection of the world cultural and natural heritage of UNESCO" and the legislation of the Russian Federation.

The main directions of research of the lake are noted in the Decree of the President of the Russian Federation №204 of may 7, 2018 "Preservation of unique water bodies, including the implementation of tasks for the conservation of Lake Baikal", as well as defined in the framework of the National project (program) "Ecology" (Federal project "Conservation of Lake Baikal").

The resolution of the Government of the Russian Federation of February 2, 2015 N 85 "About the statement of Regulations on the state ecological monitoring of unique ecological system of Lake Baikal" it is noted that it is a part of the state ecological monitoring (state environmental monitoring).

State environmental monitoring is understood as a complex system of regular observations in space and time over the state of the environment and its changes under the influence of natural and anthropogenic factors [4]. To ensure unification, the monitoring of strictly regulated observations is carried out according to the approved list of environmental parameters, as well as according to the specified requirements for the used means, measurement methods, sampling frequency and research methods. The environmental monitoring system includes the collection of data on the actual state of environmental pollution, careful processing, analysis of these data, followed by the identification of the dynamics of the state and the development of recommendations for the development of the economy of the region on the basis of scientifically based environmental forecasts.

One of the objectives of environmental monitoring is information support of management and investment decisions based on reliable, timely, complete data on the state of the environment.

The state monitoring of Lake Baikal ecosystem is carried out by the authorized Federal Executive authorities: the Ministry of natural resources and ecology of the Russian Federation, the Ministry of agriculture of the Russian Federation, the Federal service for Hydrometeorology and environmental monitoring, the Federal service for state registration, cadastre and cartography, the Federal forestry Agency, 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, TRANS-Baikal territory and the Irkutsk region according to their competence in the order established by the order of the Government of the Russian Federation of August 9, 2013 N 681 "About the state ecological monitoring and

the state Fund of data of the state ecological monitoring". Basic requirements for monitoring: territorial coverage within the BNT; detailing approaches – taking into account the environmental zoning of the BPT, established by article 2 of the Federal law "On the protection of Lake Baikal"; accounting of legal regimes – taking into account the special regime of economic and other activities carried out on the BNT. Unfortunately, the current regulations are contradictory and do not allow for the implementation of special powers to monitor the unique ecosystem of Lake Baikal.

Interdisciplinary research, expeditions and partial monitoring of Lake Baikal ecosystem and its coastal area are also carried out by RAS institutes and universities of the Ministry of education and science [6, 9].

State ecological monitoring of Lake Baikal ecosystem includes:

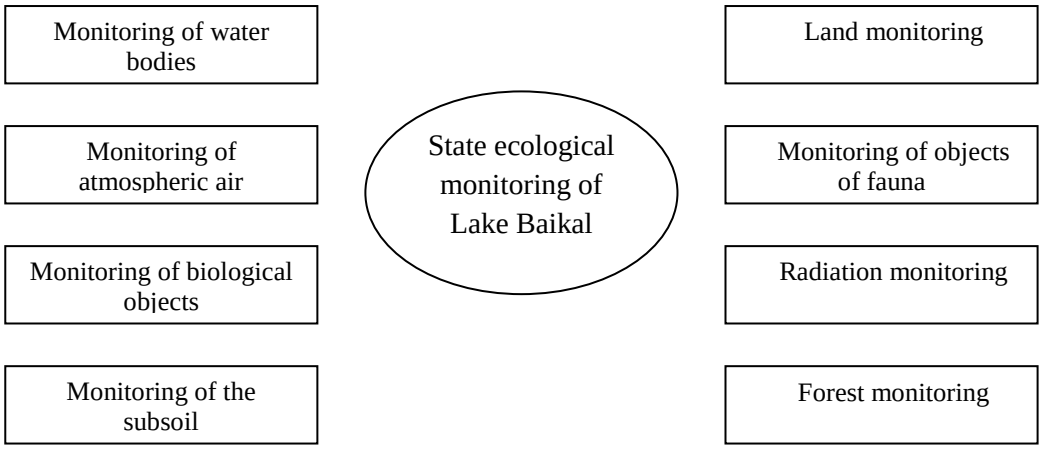


**Figure 1.** Structure of the State ecological monitoring of Lake Baikal ecosystem

Regular observations do not cover the shallow coastal zone of Lake Baikal, which is experiencing the greatest anthropogenic load. This is especially true of Olkhon Island and the area of the Small sea, where the summer at times increases the flow of tourists.

Over the past decade, Lake Baikal and its coastal area have undergone significant environmental and landscape changes. The most significant of these include: reduced water inflows, increased emissions of methane in the water column, abnormal development of filamentous algae; the extinction of Baikal sponges; change in structure and taxonomic composition of macrozoobenthos in the vicinity of towns and villages in the period of mass development of Spirogyra with the introduction of species, alien to the Baikal, the development of toxin-producing cyanobacteria in quantities close to the critical; reductions in the biomass of the Baikal omul, etc. Also, we should note the changing landscapes of the catchment area of Lake Baikal and the BNT due to massive fires and human activities, the growth of deposition of acidic atmospheric precipitation, epidemiological lesions of coniferous trees in the taiga area, pollution of underground hydrosphere. In addition, Lake Baikal and the BNT are subject to dangerous endogenous and exogenous geological processes, such as seismicity, landslides, mudflows, etc. the danger of significant fluctuations in the lake level as a result of the tsunami is not excluded.

Currently, the features of the ongoing monitoring of the ecosystem of Lake Baikal include:

• Use not coordinated networks of observations.

• Maintaining departmental monitoring schemes that generate and use large amounts of spatial and thematic data, which are generally localized and uncoordinated among themselves, in parametric, chronological and other aspects. In open access laid out only scattered data. This makes it difficult to carry out comprehensive assessments, forecasting and management decisions based on available data.

• The lack of assessment of the systemic sufficiency of the choice of "informative indicators" for monitoring the lake ecosystem and its coastal area, as well as a unified system for identifying spatial objects as universal elements of communication between departmental spatial and thematic databases.

• The absence, in real time, of full-fledged state monitoring of hydrochemical, hydrophysical and biological parameters throughout the lake, and only seasonal observations.

• Large part of the shallow zone of Lake Baikal, which is characterized by high anthropogenic load (the Small sea, the Barguzinsky and Chivyrkuisky Bays, Selenga shallow waters, the southern tip of Lake Baikal) remains outside the system of observations.

• Existing departmental systems for monitoring the ecosystem of Lake Baikal do not allow to respond quickly to changes of natural and anthropogenic nature, to identify components of local or global Genesis in them.

All this adversely affects the ecological and socio-economic situation in the Baikal region, as well as the image of its tourism potential.

In order to improve the efficiency of environmental monitoring of the lake, it is necessary to strengthen three components:

– *Technological.* To Supplement the existing departmental networks of stations for monitoring natural and anthropogenic factors with automatic stations, loggers and equipment for low-altitude remote sensing, UAVs, etc., allowing to register the parameters of the water environment and atmosphere in a quasi-continuous mode, with online transmission of information to the data center.

– *Scientific*. To introduce modern molecular genetic and information methods, technologies, etc. into the existing methodology and schemes of monitoring of natural and anthropogenic factors of Lake Baikal and BPT. Currently, the departments have created large amounts of data on the processes taking place in the ecosystem of Lake Baikal, the forms of these processes and mechanisms of formation have been studied. Unique models, as well as information systems for processing, analysis, forecasting, optimization and assessment of the impact of natural and climatic factors and life processes on Lake Baikal have been developed for certain types of monitoring.

– *Integration.* To integrate the existing experience it is necessary to modernize computer and software of the Shared Equipment Centers ( Integrated information and computing network of Irkutsk Research and Educational Complex, Irkutsk supercomputer center SB RAS) and algorithms, models, information databases and methods of their processing for complex monitoring, to create a unique network infrastructure, supplementing the existing facilities with new equipment, new hardware capacities for data collection, storage and transmission, using new methods of processing, interpretation and forecasting.

## 3 Digital monitoring of Lake Baikal ecosystem

Research on the formation of a comprehensive digital monitoring of ecosystems is fully consistent with the priorities of the strategy of scientific and technological development of the Russian Federation - the transition to advanced digital, intelligent manufacturing technologies, robotic systems, new materials and methods of construction, the creation of systems for processing large amounts of data, machine learning and artificial intelligence.

You need to create information and telecommunication platform of Digital environmental monitoring (DEM) to ensure coordination of interagency (Roshydromet, Ministry of natural resources, Federal forestry Agency Federal Agency for water resources, Federal Agency for fishery of the Russian Academy of Sciences, Ministry of education) and regional (Republic of Buryatia, Zabaykalsky Krai and Irkutsk Oblast) interaction. On the basis of the CEM, the collection, storage and processing of space-time thematic data of digital environmental monitoring should be carried out, with the possibility of direct information access. Integration of distributed interdisciplinary data (Big Data) into the CEM will significantly improve the quality of analytical and predictive models for the conservation and development of the Baikal ecosystem. Such a data center is implemented within the framework of the National oceanic and atmospheric administration (NOAA).

The key components of the information and telecommunication platform of digital monitoring of the ecosystem of the Lake Baikal and BPT are: infrastructure of the Shared Equipment Centers of IDSTU SB RAS " Integrated information and computing network of Irkutsk Research and Educational Complex (IICN)" and "Irkutsk supercomputer center SB RAS (ISC)", as well as "Information and analytical environment" (IAE), which will ensure the collection, transmission, search, storage, and parallel processing of large amounts of data, the ability to access online data, catalogs, services and information and analytical systems, possibility of carrying out on the basis of the received data of an assessment, modeling and the forecast of ecological and climatic changes of Baikal and adjacent territories with application of means of supercomputer modeling and cloud computing.

Effective methods and technologies, as well as distributed service-oriented information and analytical environment (IAE) of geoportal type, including subsystems of collection, transmission, storage, search and processing of large volumes of multi-format space-time data and knowledge are developed for digital monitoring of Lake Baikal [5].

The research methodology is based on the complex application of service-oriented paradigm and modern technologies of distributed data processing, 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 by transformational and other procedures. In turn, the use of a service-oriented approach allows for a full accounting of distributed information resources in combination with ease of testing scalability and the ability to reuse the created services [5].

For the organization of integrated monitoring of ecological systems of Lake Baikal, thematic environmental monitoring services are integrated with the help of logical structures to solve data processing problems, control the flow of execution, etc. A variety of collections of services of thematic environmental monitoring will allow to transfer data between them, coordinate data formats, run asynchronous computing processes

The IAE should store all types of environmental monitoring data with a given degree of reliability: time series with measurements of various sensors, expedition materials, space images, vector maps, etc. (Fig. 2). All of these data, which are spatially and temporally bound, can have a number of additional attributes specific to a particular type of information.

Geoportal service-oriented information and analytical environment of integrated digital monitoring of Lake Baikal will provide:

- online access to distributed sensors;
- access to archived sensor data;
- high-speed data processing;
- access to high-performance computing and storage resources in shared centers;
- scaling of computing resources and data storage and processing resources of shared use centers, taking into account the growth of the number of tasks and the volume of monitoring data;
- the possibility of using different methods and technologies of distributed data processing.

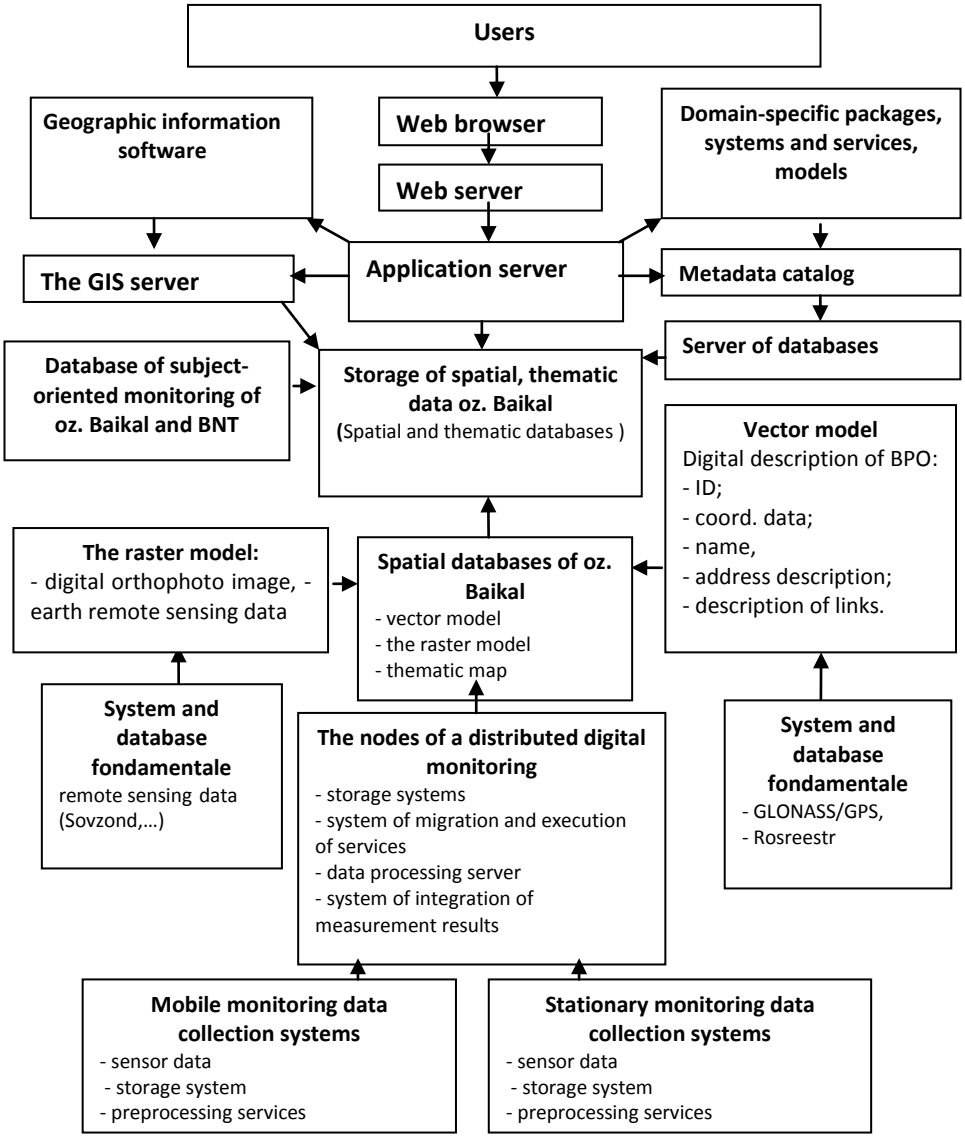


**Figure 2.** Structure of IAS.

As a hardware-software platform that provides continuous operation of the IAS, the scheme is used (Fig. 3) construction of data centers , which are based on the following fundamental principles:

• at least 2N-redundancy of components of engineering infrastructure and hardware;
• more efficient use of equipment by organizing pools of computing resources;
• virtualization of resources and applications;
• backup and restore systems.

Creating a data center at the initial stage includes:

• reconstruction of engineering infrastructure – uninterruptible power supply and cooling systems;
• modernization of network infrastructure;
• deployment of servers, storage and processing systems based on HPE hardware with hybrid MS Hyper-V / VMWare vSphere virtualization platforms.
• scale compute infrastructure - retrofitting a compute cluster ISC nodes on the basis of:
– Intel Xeon processors and NVIDIA Tesla graphics accelerators of the latest generations (+ 300 TFlops);
– high-performance data storage with parallel file system with Panasas ActiveStor 18 (+ 120 TB).

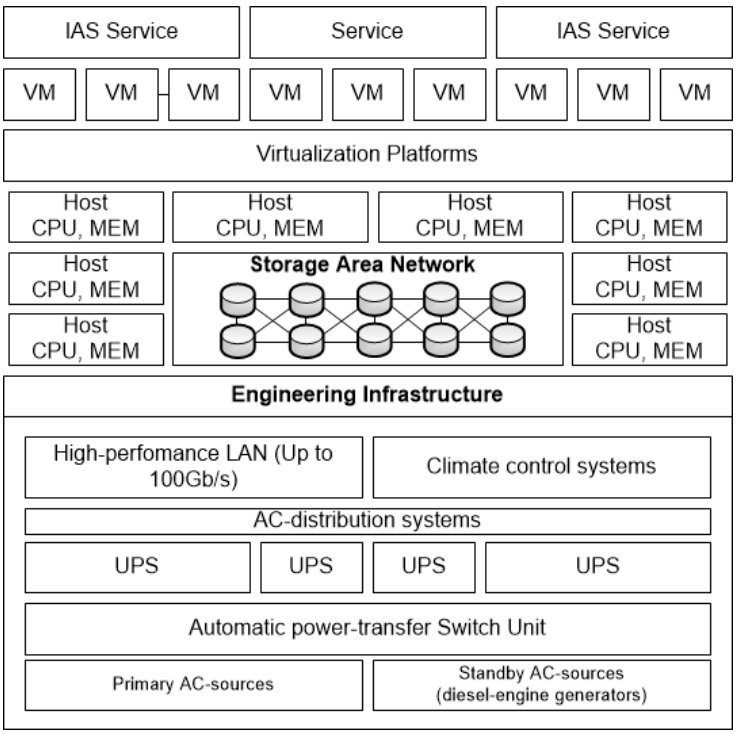


**Figure 3.** The data center infrastructure

The existing and successfully functioning Shared Equipment Centers (IICN, ISC) will be used as a launch site for the deployment of data centers, which will increase the availability of high-performance computing resources for processing digital monitoring data, including the use of supercomputer modeling.

## Conclusion

The proposed information and telecommunication platform for digital monitoring of Lake Baikal ecosystem and BPT will allow to move to a qualitatively new level of interdisciplinary research, as well as provide operational analysis and decision-making on the problems of the lake and its natural territory.

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