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# Geo-integration bases of services generation for the Multipurpose aerospace system for forecasting monitoring of disasters

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**Abstract.** The article describes the principles for development of information services for disaster monitoring and forecasting within the Multipurpose Aerospace System for Forecasting Monitoring (MAKSM) of Natural and Man-Caused Disasters in Russia and the Commonwealth of Independent States in the context of the MAKSM main target tasks at the initial stage of its development and with reference to the status and functions of information services in the system. It defines the target tasks addressed by the services to implement the main information conversion of estimates of disaster precursor parameters into parameters of disaster forecasts. The article explains the geo-integration functional for communication of the services with monitoring data sources and the functional for thematic processing, data storage and presentation of forecast results to consumers. The authors describe implementation patterns of the geo-information functional of the services at the current stage of remote monitoring system development.

## 1. Introduction

The Multipurpose Aerospace System for Forecasting Monitoring (MAKSM) of Natural and Man-Caused Disasters in Russia and the Commonwealth of Independent States (CIS) is being developed to ensure high quality forecasts of emergencies based on data obtained from aerospace and ground systems for monitoring disaster precursors so that timely emergency alerts can be issued to government agencies and citizens of the Russian regions and CIS member states. The MAKSM project is listed as an Interstate Innovation Project (in force as of October 30, 2015) under the Interstate Program for Innovation Cooperation between the CIS Member States valid through 2020 [1]. Activities under the MAKSM project are being currently considered to be prolonged for the following period of the Interstate Program.

The MAKSM uses information services for monitoring and forecasting of natural and man-caused disasters [2] (hereinafter referred to as the services) as main components for processing data on precursors to forecast emergencies. Quality of forecasts generated by the above-mentioned services (timeliness, high levels of accuracy and correctness, a low level of false alerts) depends on the efficiency with which the services receive monitoring information, on the amount, completeness and contents of such information, and on the efficiency and quality level of such information processing by the services. Monitoring data on disaster precursors is of a geo-informational character as it refers to the processes occurring both underneath and on the ground, and in the near-Earth space, as well as to the objects lying on the Earth's surface. The geo-informational character of the monitoring data on disaster precursors

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makes it possible for informational resources to be integrated into the services on a single platform (monitoring data on disaster precursors, algorithms and programs of their processing) thus providing for a higher quality of forecasts generated by the services and for unification of their design. This article mainly focuses on the analysis of the principles of such integration and possible ways of their implementation in the course of development of the MAKSM services.

## 2. Tasks and main information conversion in the MAKSM services

The MAKSM services for monitoring and forecasting of natural and man-caused disasters should be developed keeping in mind tasks addressed by the services and with respect to conversions of monitoring data on disaster precursors into disaster forecasts, which the services perform. The tasks addressed by the services are defined in the context of the MAKSM tasks, the composition of its elements and the nature of their communication.

Functionally the MAKSM includes subsystems and tools that address target, control and support tasks.

At the early stage of MAKSM development, it is reasonable to address the target tasks by means of special tools included in the following subsystems, which communicate with monitoring objects and consumers of monitoring and forecasting information:

- Subsystems of monitoring and short-term forecasting of violent earthquakes (magnitude $M \geq 6$);
- Subsystems of flood monitoring and forecasting;
- Subsystems of wildfire monitoring and forecasting;
- Subsystems of monitoring and forecasting of man-caused disasters (in particular, subsystems of monitoring and forecasting of destructive displacements and deformations of complex engineering structures.)

The scope of the MAKSM subsystems is limited because the above-listed subsystems are designed to forecast primarily those natural and man-caused disasters that are deemed the most dangerous and common in Russia and the CIS member states. New subsystems can be added to the MAKSM to forecast other natural and man-caused disasters in the course of its further development.

The MAKSM control subsystem has a hierarchy structure reflecting a decision-making hierarchy to ensure controls of the MAKSM as a whole, its subsystems and their elements. It communicates with control subsystems of a higher level using forward and backward channels, for example with control subsystems of the National Emergency Management Centre of the Russian Ministry for Civil Defence, Emergencies and Elimination of Consequences of Natural Disasters, and control subsystems of the relevant centres of the CIS member states.

The MAKSM support subsystem processes information, energy and material resources to ensure functioning of its elements.

Each of the target subsystems includes two main groups of tools:

- Tools for aerospace and ground monitoring of disaster precursors and actual disasters; for monitoring data gathering and preprocessing; and for monitoring data storage and presentation;
- Tools for gathering and thematic processing of data on disaster precursors; for generation of disaster forecasts and for storage and presentation of disaster forecasts.

The first group includes airborne equipment of space vehicles for remote sensing of the Earth; aircrafts; space vehicles of the global navigation systems (GLONASS and GPS); communication and data exchange space vehicles; various ground systems for monitoring disaster precursors integrated into the observation stations; hardware and software complexes for prior processing of monitoring information integrated into the observation stations; stations for receiving data from space vehicles and aircrafts; hardware and software complexes of centres for monitoring data acquisition and reduction.

The second group includes network tools and hardware and software complexes to address the target tasks of the services.

Broadly speaking, “the information service for monitoring and forecasting emergencies” integrated in the MAKSM should be understood as an activity [3] to satisfy the demands of government bodies and citizens of the Russian regions and CIS member states for timely alerts about natural disasters and man-caused catastrophes through rendering information services, namely through providing consumers with disaster forecasts. Strictly speaking, we will describe this service as a number of tools included in the second group of each MAKSM target subsystem.

The main service tools are designed to address the following tasks:

- Gathering and storage of monitoring data on disaster precursors, gathering and storage of data on actual disasters, their precursors and generated forecasts;
- Thematic processing of information on disaster precursors and generation of the corresponding forecasts;
- Providing consumers with disaster forecasts.

The service also includes tools to address the control and support tasks.

While MAKSM development is at the formation stage, the formula below presents the main information conversion performed by an individual j-service no matter what the objective of this service is.

$$\tilde{Q}_j(G_j, t_j + \tau_{Qj}, r_{Qj}) \to \Pi_j(t_j + \tau_{\Phi j}), \tag{1}$$

where $\tilde{Q}_j(G_j, t_j + \tau_{Qj}, r_{Qj})$ is an evaluation vector for parameters of the j-disaster precursors observed (for example, a vertical total electron content of the ionosphere);

$G_j(t_{Gj}, r_{Gj})$ is a vector of unknown parameters (for example, a magnitude of a violent earthquake) of the forthcoming j-disaster as a function of an unknown time point $t_{Gj}$ and unknown space point defined by the vector $r_{G\,j}$;

$\tau_{Qj}$ is a time period from the beginning of observation of the j-disaster precursors to the receipt of the evaluated parameters;

$r_{Qj}$ is a space point lying in the observation field of j-disaster precursors;

$\Pi_j(t_j + \tau_{\Phi j})$ is a forecast vector of the j-disaster which contains estimates of its parameters (for example, an estimated magnitude of a forthcoming earthquake), estimated time of the j-disaster and its estimated space domain as well as assessment parameters of the forecast quality (for example, estimated probability of the forecast accuracy);

$\tau_{\Phi j}$ is a time span from the beginning of observations to the moment of disaster forecast generation, $\tau_{Qj} < \tau_{\Phi j}$.

Patterns of the conversion (1) depend on the properties of the predicted j-disaster and its precursors under observation. In addition, vectors $\Pi_j(t_j + \tau_{\Phi j})$ and $\tilde{Q}_j(G_j, t_j + \tau_{Qj}, r_{Qj})$ have a common feature that is their geo-informational presentation, which enables to create services for disaster forecasting on a single geo-informational platform.

## 3. Geo-Integration principles of MAKSM information services development

Development of the MAKSM services on a single geo-informational platform involves integration of the available and newly developed information sources as represented by monitoring data on disaster precursors, and algorithms and programs for their processing in order to generate forecasts of disasters.

Public sources that give access to updated space monitoring information include Russian (Roscosmos Geoportal, Basic Products Bank of the Research Center for Earth Operative Monitoring of JSC Russian Space Systems, Sovzond's Geo-Catalogue, SCANEX Space Imaging Services) and international (services of NASA, NASA Firms, MADAS, Weather Channel) sources.

One of the open access functional information sources is represented by an algorithm [4] of reestablishing values of the vertical total electron content of the ionosphere using available observation and navigation files of receivers of GPS/GLONASS signals [5, 6, 7] to ensure short-term forecasting of violent earthquakes.

Integration of the information resources is feasible due to the geo-informational nature of monitoring and forecasting data that circulate in the services. For the informational resources to be integrated into the MAKSM services it is necessary to ensure availability of a geo-integration functional intended to address the following tasks:

- Interaction with external geo-informational mapping resources and geo-services, as well as with the relevant regional and institutional information systems and services through the open standards.
- Obtaining and representing data coming from mobile units, video cameras, and various sensors.

This task can be implemented providing that the most popular bitmap and vector formats of GIS data are supported; videos, photos and audios are obtained from sites of various events and presented in the geo-information environment as fast as possible; and users are provided with spatial information using GIS and web-technologies, network client-server solutions and geo-portal solutions.

All the above-mentioned contributes to generating the geo-informational user space consisting of the required and sufficient data set to address thematic tasks of disaster forecasting.

The data storage functional ensures thematic data generation, processing and centralized storage, and provides users with the authorized access to these data.

The thematic processing functional should be based on advanced geo-informational technologies for dedicated processing of spatial data and should ensure:

- Generation and on-line dynamic linking of services for thematic processing of various data (Earth Remote Sensing, navigation, etc.)
- Generation and dynamic linking of functional modules for statistic, analytic and mathematic processing of attribute data;
- Execution of the operating procedures for implementation of thematic tasks.

It seems reasonable that the standard operating procedure for implementation of a thematic task of disaster monitoring and short-term forecasting should include the following stages:

- Gathering of data on disaster precursors from various available sources and analyzing their quality;
- Pre-processing of data on disaster precursors to enhance the informational quality of materials and to integrate them into the single geo-information space;
- Thematic processing of data on disaster precursors to identify anomalies in the observed processes associated with a forthcoming disaster;
- Comprehensive analysis of the obtained results and generation of disaster forecast parameters;
- Generation of reporting documents based on the forecast results and presentation of archive records to be indexed in the thematic database of disaster forecasts.

The thematic processing of data should be supported by means of statistical, attribute and spatial analyses of objects and processes, by spatial information presented in 3D including digital models of landscapes and objects, and by implementation of a wide range of generally available user-defined functions to ensure a prompt overview of the situation including:

- Measurements of a distance between objects;
- Measurements of a length, area and perimeter;
- Settings of an image scale;
- Settings of layer visibility;
- Settings of layer transparency;
- Settings of a custom-developed style for vector object representation;
- Review of attribute data of an object;
- Animation of layers;
- Implementation of overlay operations with cartographic objects and other operations.

Communication with consumers of forecasts should be supported by facilities enabling to publish data using an original built-in publishing server and other popular publishing servers for spatial data; by facilities enabling to deliver forecast information to various consumer groups; and by facilities enabling consumers to generate and run their own thematic geo-informational projects.

Technical implementation of the described geo-integration principles of the MAKSM information services development should be to the greatest possible extent based on the results achieved in the field of development of tools to gather and process monitoring data [8].

Functionality, design technologies and approaches to implementation of remote monitoring systems including processing of space monitoring data have gone through four stages of development and are currently at its fifth stage [9]. For the MAKSM services, this stage can be defined by an application of external information resources (data presentation services, distributed computing resources). This communication is based on the advanced information technologies enabling to support sophisticated distributed information systems in an efficient way through the technical infrastructure provided by various data centres. Information resources can be also provided using cloud technologies. Patterns of functioning of the MAKSM services depend on their communication with the monitoring systems that process large amounts of continuously incoming satellite data and vary large Earth remote sensing databases and their products.

## 4. Conclusions

The defined principles of information resources integration into the MAKSM services will ensure a comprehensive communication of the services with sources of monitoring information on disaster precursors, enhance processing quality of this information and improve communication with potential consumers of disaster forecasts.

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