Development of hydrometeorological services to support decision of enterprises leaders on examples of Russian Federation

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1. Introduction

Natural hazards and adverse weather conditions (hereinafter, for short NH) affect various sectors of the economy. Transport, agriculture, energy, construction, marine activities are the most meteorologically dependent activities. For example, forecasts of strong wave allow for increasing the safety of drilling platforms on the offshore shelf. Forecasts of strong wind make it possible to plan construction work. Storm warnings allow increasing the safety of the population, to reduce losses of enterprises (____, 2010). Rapid response of leaders of enterprises to changes of the hydrometeorological situation is a condition for increasing the efficiency of enterprises' operation.

The problem of increasing the efficiency of the hydrometeorological provision of the population and industrial enterprises is directly relating to the digital transformation of both the support facilities and the National Hydrometeorological Services (NHMS) itself. In NHMSs, almost 100% digitization of the main types of data made and there is a need to transfer the functioning of the NHMS as a digital enterprise (Viazilov, 2016b). Industrial enterprises have information systems and automate their business processes in which hydrometeorological information are using. Back in the nineties, the idea was putting forward to provide automatically information about the possible impacts of hazardous phenomena on the population and the activities of industrial enterprises (Vyazilov, at al, 1995). However, due to the lack of integrated hydrometeorological data available online, the absence of collected and formalized information on impacts and recommendations, to implement this idea for a long time was impossible.

Methods for recording observable, forecasting and climatic data in the design, construction and operation of industrial facilities based on the state standards, building codes and regulations, guidelines, manuals, various reference books, atlases. Moreover, sometimes the document directly presents the values of climatic parameters in the form of tables, for example, in Russia the standard “GOST 25870-83” is giving the regionalization and statistical characteristics of climatic parameters for technical purposes. Most often, climatic characteristics are presented in the form of atlases and aids, which show the geographical and temporal (by month, season) variability of parameters. Some documents provide a method for calculating indicators that determine the danger to the activity of objects.

If we are aware of possible changes in climatic characteristics, the forecast of NH, we can prepare for this in advance, think through our actions, and take competent steps that would reduce the impact. In recent

decades, many books, leaflets, instructions, reports in various countries issued[1], which give recommendations on behavior in various dangerous situations, including NH.

It is necessary to formalize business processes that determine the organization of work to increase the safety of the population and industrial enterprises, ranging from identifying threshold values of environmental parameters for various enterprises, types of activities, and ending with the adoption of preventive adaptation decisions, based on the observed, predictive and climatic parameter values. The main directions of using environment data are forecasting the development of the region, spatial planning, engineering design, infrastructure management, design, construction, and operation of enterprises.

Predicting the development of the region. It need for development of different industries, taking into account possible climate change. For example, the development of marine ports activities in the Caspian when the level falls in the coming years or a possible new rise in sea level in 10 or more years.

Spatial planning. Taking into account the forecast of the development of the region and the available resources, a target spatial model and a map of the existing infrastructure of the district are built. The needs of various industries are assessed over a certain period. At this stage, GIS allows you to quickly and efficiently perform a spatial analysis of facilities, estimate development costs, find opportunities to save and optimize development costs for the region.

Engineering design. Here it is necessary to use GIS in order to determine exactly how the existing infrastructure should be modernized: where to lay pipelines, transport communications, taking into account the real situation, where to place, etc.

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[1] https://www.cakex.org/ - EcoAdapt Climate Adaptation Knowledge Exchange.
http://www.ukcip.org.uk/wizard/ - UK Climate Impacts Programme Adaptation Wizard.
https://research.csiro.au/climate/wp-content/uploads/sites/54/2016/03/3_CAF_WorkingPaper03_pdf-Standard.pdf - CSIRO's Climate Adaptation Flagship best practices for engaging with stakeholders.
https://www.weadapt.org/knowledge-base/adaptation-decision-making/climate-change-adaptation-toolkit - Stockholm Environment Institute – Climate change adaptation toolkit and user guide: a comprehensive guide to planning for climate change adaptation in three steps.
http://econadapt-toolbox.eu/ https://econadapt-toolbox.eu/easy-access-guide - European Union's project ECONADAPT Toolbox provides easily accessible information on the economic assessment of adaptation.
http://www.swissre.com/eca/ - Swiss Re Economics of climate adaptation.
http://microstep-mis.com/src/references/povapsys_flood_warning_system/success_story_povapsys.pdf - POVAPSYS - Flood Warning System.

Infrastructure management. In the process of operating the existing and developing infrastructure, it is important to build an effective process for taking into account the current situation. GIS provides an inventory of industrial facilities with an indication of their exact location, maintenance of a database of objects and their status. This will help to determine the possible impacts of the environment on industrial facilities, the necessary actions to prevent or reduce negative impacts.

Designing enterprises under construction. This stage consists in the assessment of the environmental risk of enterprises under construction for the population and other objects and the climatic impacts of the environment on the construction and operation of enterprises.

Building. At this stage, it is important to keep track of the present and forecasting weather situation affecting various technological processes of construction.

Operation of objects. Here constant consideration of the present and forecasting weather situation affecting various technological processes of operating industrial facilities, it is important to organize automatic timely updating and communicating information about evolving situation to various facilities, taking into account their condition.

The report of the Extraordinary session of the Commission for basic systems (____, 2014a) of the World Meteorological Organization (WMO) notes: "A large number of disasters on the planet have highlighted the need to find all appropriate means to enhance the ability of WMO Members to prepare for and respond to disasters by synthesizing practical experience acquired during disasters with a vital contribution from NHMS".

The prognostic organizations of the NHMS are engaged in detecting and notifying about NH. The issuance of timely forecasts and warnings about the emergence of NH, such as floods, strong winds, ice and other NH, gives an extremely effective return in the form of saved lives and reducing damage. Despite the fact that NHMS in many countries are constantly providing forecasts and warnings about NH, the amount of damage from them does not decrease (Korshunov, 2013). This is due to the globalization of economic enterprises and, accordingly, the complexity of their management, with the increase in the total value of enterprises and the individual cost of each decision.

So according to the data obtained at links[2] the greatest damage from the impacts of extreme weather and climate change, the death toll is observing in such developed countries of Europe as Germany, Italy, France, UK.

In addition, there are cases when information about NH is not sending in time to the leaders of enterprises and government organizations, or leaders do not effectively use her. The actions set by the standard instructions for adaptation and mitigation of impacts from NH are not apply. Information for leader of enterprises is scattered over a variety of sources. At the same time, information is visualizing without specifying the level of danger[3] for individual facilities and activities performed in enterprises. Leader of enterprises are not always aware of the possible impacts and do not have full information about the preventive actions, that must be taken in the case of a particular NH, since the accumulated experience of their impacts and decisions is not collected and formalized, lost after the change of leaders. There are also no practical implementations of economic and mathematical models capable of assessing the possible economic damage for a particular enterprise before the beginning of the NH, and calculating the cost of preventive actions.

There are examples of when NH was predicted, but its impact was not taken into account and / or was underestimated, or the reaction to this forecast was inadequate. For example, the flood on the river Amur (Russia), which occurred in August-September 2013 because of intensive protracted precipitation in the upper reaches of the river Amur and its tributaries[4], embraced five subjects of the Far Eastern Federal District of Russia[5]. In total, 37 municipal districts, 235 settlements and more than 13 thousand residential buildings were flooded. More than 182 thousand people suffered. The total area of flooded areas was more than 8 million square kilometers. Direct and indirect damage amounted to 527 billion rubles[6]. Repeatability of such floods is estimating as once in 200-250 years. Warnings about very heavy rainfall Roshydromet began to release a month before the flood. If the Ministry of the Russian Federation for civil defense, emergencies and elimination of consequences of NH (EMERCOM of Russia), administrations of constituent entities of the Russian Federation, cities, heads of

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[2] https://www.eea.europa.eu/data-and-maps/indicators/direct-losses-from-weather-disasters-3/assessment-1
[3] The danger level is the relative number that characterizes the possible damage and other consequences from the disaster, the process (1 - there are no consequences, 2 - moderately disturbed state, 3 - dangerous state, 4 - catastrophic state).
[4] http://www.meteorf.ru/press/releases/4688/
[5] http://ria.ru/spravka/20140720/1016605356.html
[6] http://www.interfax.ru/russia/373742

municipalities were given the forecast magnitude of possible consequences of floods and recommendations to support decisions, then the damage would have been much less.

The above example and the consequences of other NHs require not only warnings about NH, but also forecasts of possible impacts of NH on enterprises and population. Scientific advances in the prediction of hydrometeorological conditions have provided the opportunity to supply warnings about NH with such precision and advancement that enable NHMS to fulfill their task of bringing warnings to leaders of enterprise. In order for leaders of enterprises can take appropriate actions, they need to be aware of how NH will affect the economies of different countries. Getting the benefit from warnings depends on the ability of leaders of enterprises to use information and take effective action. In this regard, the improvement of observational and prognostic systems, the advancement of warnings is a necessary, but insufficient precondition for reducing the adverse impacts of NH. WMO has already drawn attention to the imperfection of current forecasts and warning formats. It noted the need to move from warnings based on fixed thresholds to warnings about NH impacts (____, 2014b). To do this you need:

- creation of means of constant automatic analysis of hydrometeorological conditions, taking into account threshold values of various environmental parameters and characteristics of enterprises;
- increasing the level of automation of methods for NH identifying;
- transfer of information about NH to mobile Internet devices;
- providing predictions of possible impacts and recommendations for decision making;
- wide application of the indicator "Danger level".

2 Existing approaches to hydrometeorological support

For many years, the following paradigm of hydrometeorological procuring has been widely used. The forecasts and warnings about NH give out a NHMS in form text, for example, "December 7, 2015 in St. Petersburg to 16-19 hours at the mouth of the Neva River is expected to raise the water level to 161-170 cm". Information about NH is periodically updating and communicated to leaders of enterprises and the public through telephone, fax, radio, TV, websites, and now in the form of text SMS messages, e-mail. Prognostic organizations of the NHMS transmit warnings about NH, based, as a rule, on fixed general thresholds for NH indicators for different danger levels (____, 2013). This information is characterizing by the transmission of messages in a semi-formalized form, indicating the location, time and intensity of NH, in recent years with indicating the level of danger by color-

coding (green, yellow, orange, and red). After the introduction of the code for NH data transfer from weather stations (WAREP), generated automatically (Zubritskaya, at al, 2014), they are transmitted in a formalized form.

The world is actively working on early warning and notification about NH. For example, the European NHMS community has created an information service[7] that provides the current information necessary to prepare for the extreme weather conditions expected in Europe. With the help of this service, you can assess the probability of severe weather conditions. Currently in Japan, the United States and other countries, studies are underway to develop means for prompt notification of the population about earthquakes, tsunamis.

In Russia, according to the order of Roshydromet[8], a tsunami warning system has been developed, whose functions are continuous monitoring of the seismic and hydrophysical conditions; timely warning of the executive authorities about the tsunami threat; issuing recommendations on safe operations in the coastal zone of the Russian Far East. The Roshydromet established the procedure (____, 2008) for the preparation and the form of the transfer of information on the origin and development of the NH, which contains list and indicators NH, as well as rules for alerting state authorities, leaders of enterprises by telegraph, telephone, e-mail. However, at the same time, there are no means of automatically notifying users about NH.

The company Namos[9] has developed a system of specialized weather monitoring, which is designing to monitor and forecast NH and their combinations. The system allows providing information about NH and their impact on infrastructure facilities and production processes of different enterprises. The company "SYNOP"[10] and the Hydrometeorological Center of Russia have developed a meteorological monitoring system for business, which provides automatic generation of detailed weather forecast at an arbitrary geographical point. The system generates forecast maps of weather risks: the list of expected emergencies, the place and time of their occurrence, and automatically sends users warning about NH.

The first developments of decision support systems (DSS) in the field of researches the environment was started in the nineties (Gelovani, at al, 2001). Large studies have been carried out in the field of risk assessments (____, 2014a), formalization of adaptation methods to weather and climate changes (Gardner, at al, 2009), as well

[7] http://www.interfax.ru/russia/373742
[8] Order of Roshydromet (N 171, 2006) "On approval of the Regulation on the functional subsystem of tsunami warning for a unified state system for the prevention and liquidation of emergency situations"
[9] http://www.namos.ru/about
[10] http://www.synop.ru/

as economic assessment of adaptation[11]. Analysis of the above and other systems[12] (Zagorecki, at al, 2013) shows that the shortcomings of existing methods and means of information services to the population, leaders of enterprises and government organizations are following:

- existing systems transmit an information for NH with modern means (SMS, e-mail) only before certain levels of management, and the population and some top-level leaders of enterprises may not always receive this information on time;
- information necessary for decision-making is scattered across multiple websites, portals, and is issued in the form of not formalized text for example, (Kattsov, at al, 2011; _____ , 2012), big tables, a large number of maps that no specified detail for separate enterprises;
- leaders of enterprises are rarely aware of all possible impacts of NH on enterprises, their activities and personnel, since the accumulated experience is not formalized or used;
- geographical information systems are the main tool used to decision support;
- threshold values of NH indicators are oriented to a wide range of users, without specifying the values for various enterprises, their activities;
- missing automatic communication of information about NH to leaders of enterprises and the public immediately after detection of NH;
- the values of hydrometeorological data, or simply information about NH are transmitting without possible impacts and recommendations for making decisions;
- methods and means have not developed for assessing the possible damage from NH to its manifestation, calculating the expected cost of preventive actions.

[11] http://econadapt-toolbox.eu
[12] http://microstep-mis.com/src/references/povapsys_flood_warning_system/success_story_povapsys.pdf

3 Development of new approaches for hydrometeorological support of leaders of enterprises

A new paradigm for hydrometeorological support is being born (Chunaev, at al, 2016) - the storm warning - consultation, when NH forecasts and warnings are accompanied information for possible impacts depending on the level of danger. The information in storm warnings sometimes describes the expected impacts. For example, "In connection with the intensification of the south-west wind up to 20 m / s on January 26-28 at the Azov coast of the Krasnodar Territory in the area Temryuk-Yeysk, ice movement, compression, ice pressure on shore will be" (____, 2009, p. 109). Another example is when in the Murmansk commercial port, when loading coal and the wind velocity >10 m / s from the western direction, it is necessary to stop the operation of the port cranes because of the possible emergence of dusting in the city. These examples show the need to clarify the NH criteria for individual enterprises and their activities. Leaders of enterprises must get the impacts forecasts and recommendations for decision support.

The main approach to the development of such services is the implementation of the following idea. Knowing the environmental conditions (NH indicators, based on observed, forecast and climatic data); it is possible to predict in advance the possible impacts of NH on the population and enterprises. If we know impacts, it is possible to make a list of recommendations on the behavior of the population in these situations, to support the decisions of leaders of enterprises and various levels of state government.

Warnings about NH are characterizing by the transmission of messages with specific headings, indicating the level of danger by color-coding (yellow, orange, and red) or a digital indication of the level of danger on the graphics. Warnings are mainly based on common threshold values of parameters, for example wind speed > 15 m / s, thickness of snow > 30 cm and others defined in regulatory documents, for example in Russia (____, 2013). Some territorial offices of Roshydromet use local threshold values of parameters to detect a NH.

Refinement of the threshold values of indicators of NH is made in accordance with the area of location and characteristics of an industrial enterprise. For example, in the Northern and Primorsky reginal offices of Roshydromet local threshold values specified for wind speed, air temperature. For such phenomena as, for example, the water level in rivers, there are only local threshold values for each observation point. At the same time, there is a need to clarify threshold values depending on the type of an industrial facility, for example, for a vessel - a large tanker, a fishing vessel and a boat, a yacht uses different threshold values of hydrometeorological

parameters, which are determined during the construction of ships. On different types of activity are affecting differently by NH, for example, for a port there is a difference in unloading at the roadstead, at the pier, at the ice. Concretization of the maintenance of various objects allows determining threshold values not only for typical objects (for example, vessel), but also for specific objects (tanker, fishing boat). The type of the object is specifying by the codifier, which takes into account the branch of the object (industry), the class of the object (port), the type of object (seaport).

By creating a database of local thresholds for specific enterprises and types of activities, taking into account the three hazard levels, personalization and mobility of services can be ensured.

The same NH affects different enterprises and activities performed on them differently. Therefore, it is required to determine not just local threshold values of parameters, but also to specify them for each enterprises and even the type of activity. Given the large number of enterprises and activities carried out at the site, the preparation of such messages should be automating. That is, based on the forecasts in the points of regular grid, messages with the NH forecast should automatically be generating. Similarly, based on the operational data received from the Global Telecommunication System, messages about the occurring NH for each enterprise may be compiling.

The threshold values should be specifying by the enterprises leaders in the relevant company passports. In this case, the type of enterprise, the type of activity, the region of NH, the stage of using information about NH (before, at the time of the disaster and after), the level of danger, the climatic zone, the season of the year should be taken into account. For example, NH thresholds for port operation will differ for different activities: parking of ships, operation of cranes, etc. (TABLE 1).

TABLE 1. Example of hazard levels description for a seaport, depending on type of NH and activities

Note: The numbers indicate the level of danger: 1 - normal (green); 2 - adverse phenomenon (yellow); 3- dangerous (orange); 4 - catastrophic (red)

Activities	Wind velocity, m/c				Precipitation, mm				Visibility, km				Icing of vessels, mm			
	10—14	15—19	20—30	>30	0-19	20—29	30—49	>50	>1	0,9—0,5	0,4—0,1	<0,1	0—0,1	0,2—0,6	0,7—1,3	>1,3
Parking of vessels	1	2	3	4	1	1	2	3	1	1	1	2	1	2	3	4

Activities	Wind velocity, m/c				Precipitation, mm				Visibility, km				Icing of vessels, mm			
	10—14	15—19	20—30	>30	0-19	20—29	30—49	>50	>1	0,9—0,5	0,4—0,1	<0,1	0—0,1	0,2—0,6	0,7—1,3	>1,3
Unloading of ships	2	3	4	4	1	2	3	4	1	2	3	4	1	2	3	4
Work of cranes	3	4	4	4	1	2	3	4	1	2	3	4	1	1	1	1

Depending on the life cycle of the enterprise (planning of the development of the district, construction of enterprises, its operation and decommissioning), the list of NHs and the composition of the transmitted messages may differ. The stage of using information about NH dictates the need to use certain information type, so before NH it is necessary to apply climatic and prognostic information, in moment of the NH - real time information and after the NH - current and prognostic information). Thus, it is necessary to create a database of threshold values of NH indicators for various activities, depending on the level of danger, as well as the degree of influence on enterprises.

The development of hydrometeorological support is necessary because the volume of decisions actually came into conflict with the possibility of rapid and effective support of solutions to ensure the safety of enterprises and the population (Viazilov, 2016a). Therefore, to strengthen the intellectual power of enterprises leaders, decision support tools are creating. Systems of this kind are able to analyze the current situation and provide information on possible impacts and recommendations for supporting solutions separately for different activities, climatic zones and seasons.

For leaders of enterprises, it is required to organize access to information about NH through a single interface that must unites many different sources and services, which will allow to react more quickly to the emergence of NH and effectively manage the enterprises in these conditions.

To increase the effectiveness of the use of information about NHs needs: unified sources of observed analytical, forecasting and climatic data; specification of NHs threshold values for different enterprises, types of activities, depending on the geographic location of the enterprise; assessment of the level of danger - allows to assess the degree of influence on the enterprises and type of activity, both for each hydrometeorological parameter separately, and for their combined impacts.

Leaders of enterprises cannot continuously monitor the changing hydrometeorological situation; therefore, it is necessary to provide this kind of information regardless of the location of leader of enterprises at a particular moment in time. Information should be presenting in an understandable and easily perceivable form, so that the leader of enterprises, receiving such an alert, could instantly imagine the level of danger.

The most important product of the DSS is the recommendations that help the leader make a decision that minimizes or eliminates economic and other losses. Such recommendations should be determined based on the type of NH, its level of danger for the facility, the technical and economic performance of the facility, and its experience. Leaders need to understand what actions (or inaction) can reduce or prevent losses.

Thus, the development of hydrometeorological support will automatically transmit information to users not only in the form of figures, but also in the form of information on impacts, recommendations, estimates of damage and the costs of preventive actions.

4 Identifying of NHs

To identify NH, a continuous analysis of the observed and forecast data streams is necessary based on the threshold values of hydrometeorological parameters for each enterprises and activity. The level of danger NH for different activities of enterprises depends on the type of enterprises, type of activity, values of indicators NH. For example, for a large-tonnage tanker, the wave height of <2 meters is not dangerous, but for a small sailing yacht, such a wave height can become catastrophic.

The following parameters should be taken into account for the detection of NHs:

• parameter values (the observed values of the parameters is one of the main criteria, since it is a direct quantitative expression of the degree of influence of the parameter on the enterprise, each dangerous level is characterized by the minimum and maximum values of the indicators of NH);

• the current season (the degree of influence of hydrometeorological parameters varies depending on the season of the year, for example, the air temperature around zero in winter or in spring are two completely different situations);

• geographic region (depending on the geographic location of the facility, the degree of impact of various parameters on the enterprise varies, for example, on the seashore or at the mouth of the river);

• industry, type of enterprise (the degree of influence of a particular NH depends directly on what enterprise is being considered);

• type of activity performed at the enterprise (accounting of the activity type makes it possible to provide more accurate recommendations for the adaptation of the facility).

Each factor is taking into account when the threshold values for different enterprises and activities are specifying. The specification can define for threshold values for a geographical area or a specific point. Exceeding the threshold values for the prognostic values is determining by the closest to the enterprise of the grid point. Gradation of values by hazard levels allows estimating the degree of influence on the enterprise and activities, both for each meteorological parameter separately, and for their combined impacts. Threshold values should be stored in the database. The scheme for identifying of NH is showing in FIGURE 1.

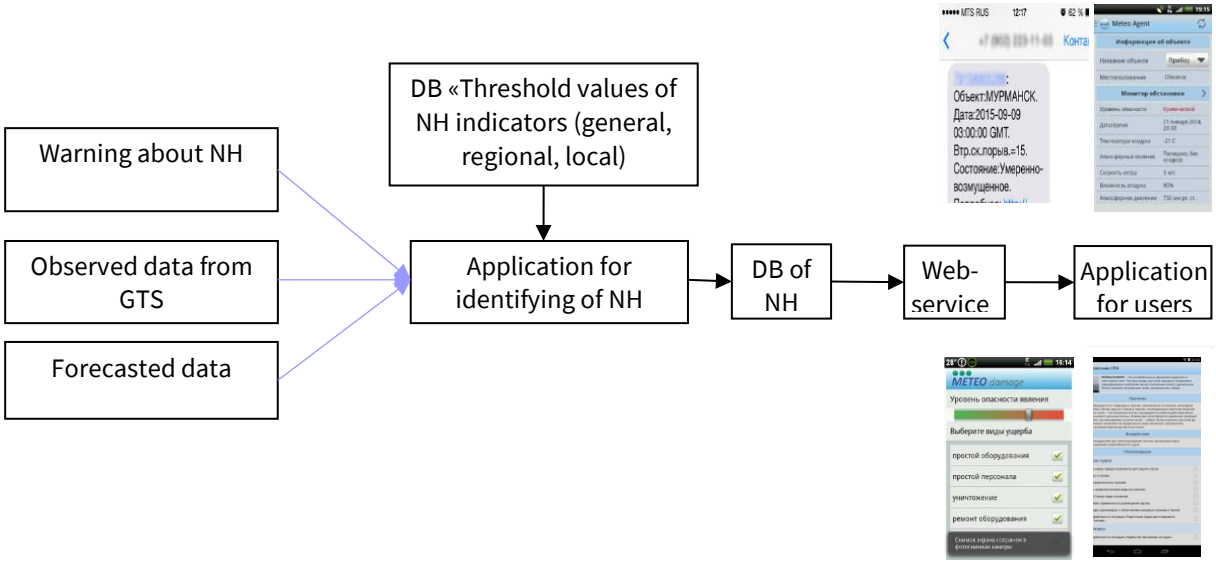

FIGURE 1 - The scheme for identifying of NH

The characteristics of enterprise, information about NH must be register in the system. When registering an enterprise, the necessary information resources are automatically identified, which contain indicators of NH that affect the enterprise. In the information resource, the nearest for enterprise observation points are automatically determined. The user is made the choice of a specific observation point, which is representative for the enterprise. The user specifies the industry, the type of the enterprise, and the type of activity that characterize the enterprise.

To be to identify the NH, the user needs to determine the threshold values of the environment parameters. He can select threshold values for typical enterprises, or specify parameters and threshold values precisely for the enterprise of interest. After the user has determined all the necessary parameters affecting the enterprise, an automatic, continuous analysis of the incoming information resources will be performing. At each data update, are analyzing for the presence of a possible NH. When the threshold is exceeded for the several

hydrometeorological parameters, the hazard level is automatically assigned based on the following rule. The "Danger level" parameter is assigned the maximum value of the level of danger, identified for individual parameters.

Each portion of the observed data is analyzed for the diapasons of threshold indicators values, the tendencies of the parameter changes are calculated, the hazard level of NH for specific enterprises is determined. The result of this analysis is "Information on NH" database containing the identifier of the enterprise; the code of the parameter that exceeded the threshold value; date of observation / forecast period; value type (observation or forecast); the identifier of the information resource; the value of the parameter; level of danger.

Upon detection of an NH pertaining to an enterprise, an alert is automatically generating, which is immediately sending to the user by the selected delivery method. The leader of enterprises is giving information about NH, the NH danger level, and the possibility of obtaining a more detailed description of the hydrometeorological situation.

Storm warnings (STORM, SIGMET, WAREP telegrams) are processing immediately after their arrival and have the highest priority when issuing alerts to leaders of enterprises. Information about NH sends for all enterprises falling into the zone of influence of the NH.

The method of automatic detection of NH takes into account the current and prognostic state of the environmental parameters. Processing of prognostic data is performing using the same algorithms as the observed data, but the prognostic data have a lower priority when issuing warnings. If the NH detected, but there is no official storm notification, than the leader of enterprise is informed of the possible NH as forecast.

The tasks of transfer hydrometeorological information to automated systems of federal executive authorities, government bodies and industrial enterprises are:

- preparation of a regulated composition, hazard criteria, update dates;
- identification of individual objects exposed to NH with complex social or technical conditions;
- indication of the values of environmental parameters in the form of a “traffic light” (green, yellow, orange, red);
- determination of the hazard level of NHs for industrial facilities and the impacts of NH on industrial enterprises and the public;
- identification of secondary impacts from accidents and disasters;
- issuing recommendations for decision making;

- assessment of damage and cost of preventive measures and decision making.

For each object should be drawn up regulations, which should include:

- list of indicators of NH;
- a list of operations for the automatic detection of NH and the delivery of information about it to managers;
- the sequence of actions to obtain information about the impacts and recommendations necessary to prevent the impacts of NH, taking into account the state of the object and the NH forecast;
- a list of operations for estimating damages from NH, calculating the cost of preventive measures;
- determination of decision criteria;
- decision making sequence before, during and after the NHs.

5 Tools of data visualization and automatic information delivery

For data visualization and automatic delivery of information about NH the ESIMO[13] resources and services are using as the main data source (Mikhailov, at al, 2014). This system integrates data of various types (observed, analytical, prognostic and climatic). The use of integrated data in DSS is proposing, for example, in article (Yan Xu, et al, 2017). The data visualization should allow displaying the current hydrometeorological situation in real time in the form of a table with icons of meteorological instruments, which reflect the values of the parameters and the level of danger. To alert business executives using automatic massage delivery to a mobile Internet device, he needs a special application for device.

A pilot project of such a service scheme implement by RIHMI-WDC (Vyazilov, at al, 2015) using smartphones to send SMS messages and for more detailed acquaintance with the hydrometeorological situation, providing information on NH impacts and recommendations for decision support. As a means of promptly receiving alerts, any mobile Internet devices (smartphones, tablets, netbooks) can be using. Operative notification carry out by activating a pop-up notification, sound and vibrates on the mobile device. Such a tool is one of the most promising and convenient ways of delivering information and alerting leaders of enterprises. The advantage of this approach is that the leaders of enterprises will pay attention to the situation only when the facility is in

[13] http://esimo.ru

danger. The functions of such a program are to assimilate existing storm warnings, notify users about NH, promptly provide leaders of enterprises with additional information on hydrometeorological conditions, and provide information on NH impacts and recommendations for decision making. The application running on the Internet device necessary to display:

- values of hydrometeorological parameters exceeding threshold values;
- brief information about the enterprises;
- forecast data for a particular facility;
- current values of the observed hydrometeorological parameters;
- trends of parameters.

The formalized example of the message looks like this: "At the enterprise "Name", the threshold values were exceeded: "Parameter name" = "value" and "Unit of measure". Danger level of NH: "Value". A concrete example of the message is written as follows: "The threshold value is registered at "the Murmansk Sea Port" facility: "Wind speed = 11 m / s". Danger level of NH: "Moderately indignant".

Leaders of enterprises should also see the status of the parameters in the form of current and prognostic values, their deviations from the threshold values marked by the color of the hazard level. In addition to current data, information about past NHs with archival data provides. After the leaders of enterprises is notified, it can get additional information in the form of hyperlinks to information support services that will allow to timely and correctly assess the situation in the enterprise.

6 Decision support

DSS allows to inform users not only in the form of numbers, but in the form of predictions of impacts, recommendations, estimates of damage and the costs of preventive actions (Khandozhko, 2005). Before applying knowledge accumulated in various sources, a person must find them and interpret them to solve a specific problem. In practice, the use of knowledge and decision-making should occur immediately after the source information is receiving in real time. Systems of this kind are able to analyze the current situation and provide information on possible impacts and recommendations for decision-making. The accumulation of a knowledge base containing information about all arising NH in an enterprise will allow in the future to be basing on the experience of historical NHs.

Recommendation should be classified by management level, because at different levels (federal, regional, and local) they will be different. In the case of a local NH, which affects only a particular enterprise,

actions are necessary to reduce losses. However, most often NH develops on a wide geographical area, which requires a reaction not only at specific, sites, but also at the regional and sometimes - federal levels. Therefore, depending on the scale of NH, it is necessary to ensure the reaction on impacts at all levels of management, by providing recommendations depending on the area of responsibility of leaders**.**

To maintain information about impacts and recommendations, it is necessary to ensure storage and constant replenishment of the knowledge base. The DSS knowledge base is a set of rules "If, That" that take into account NHs indicators, management level, activity type and using data type (forecast, observations, climate).

In order to make the knowledge base more understandable, the threshold values of parameters are stored in a separate database and used to identify NHs. Each NH can give a different level of danger for a particular enterprise and type of activity. When describing a NH situation, impacts and recommendations are added depending on the type of data used (observations, forecast and climate) and the level of management.

The structure of the knowledge base allows accumulating information about impacts and actions taken during historical NHs for further possible use in new situations. Taking into account the accumulation of experience of previous NHs, the knowledge base makes it possible to specify the available impacts and recommendations for typical enterprise.

Currently, semi-formalized materials in the form of impacts and recommendations collected for more 100 NHs, that affect 30 typical enterprises, nearly 100 various types of activities, three danger level, four types situations (before disaster, at moment disaster and after disaster). General volume is several thousand pages (nearly 10 000 impacts and more 10 000 recommendations). For storage of this, materials created the test database[14]. All recommendations are pre-classified for the three danger levels, the three decision-making stages - before the NH (separately based on climate and forecast data), during the NH (based on the observed data), after the NH (based on the observed and forecast data).

The model for describing situations related to NHs includes the following attributes:

- name of NH;
- short description of NH;

[14] http://test.shpirat.net/

- reasons of the NH;
- photos with NH examples;
- objects of impacts (executive authorities, port, ship, agriculture, life support of the population, etc.): the name of the object, on which can impact the NH; type of information (climate, forecast, the moment, after the NH); names of impact indicators and their values; danger level;
- impacts (name, type of activity affected by NH, priority, author of impact, possible potential damage);
- recommendations (name, level of management for which the recommendation is intended, priority of recommendation, author, cost of preventive actions, references to model recommendations, which may use for many NHs);
- references to the related NHs;
- information sources for situation description.

An example of the description of the impacts and recommendations for NH ice-covered ground presented below:

Natural hazard: Ice-covered ground.

Indicator: Ice thickness 6-10 sm.

Type of information: in the moment of passing the NH.

Danger level: red.

Impacts on vital activity of populations:

1) The meltwater accumulates and freezes at the eaves of the roof, icicles are forming.
2) Icicles are falling from the roofs of houses.
3) Electricity in settlements disconnects.
4) There are interruptions in the work of transport.

Recommendations for the population:

1) Be extremely careful when walking.
2) Keep hands free as possible and not in your pockets.
3) Watch under the feet while walking.
4) Be careful when walking on the sidewalks, footpaths, landing areas public transport, stairways of bridge structures and underground passages.
5) Go along the roadside, walls, and other potential supports.

6) Be as attentive as possible at pedestrian crossings.
7) Do not cross the road in front of the car, their braking distance in the conditions of ice can be unpredictable.
8) Be as far as possible from the edge of the road, the railway platform, so as not to slip and fall under the wheels.

Associated NHs: snow, rain, air temperature about 0 ^{0}C.

References: Rules of survival in Ice-crusted ground, how to save feet, paws and wheels. http://ria.ru/moscow/20091209/198132134.html.

7 Assessment of potential losses from NHs impacts and calculation of the cost of preventive actions

In the NHMS, nowadays, the calculation of the economic efficiency of hydrometeorological support and the calculation of damages after the passage of NH is widely used. In addition, need damage assessments and calculating the cost of preventive actions prior to NH.

As a next step in the evolutionary process of development of hydrometeorological support, in addition to predicting impacts and providing man leaders of enterprises agers with recommendations to support decisions in advance (before the onset of NH), it is proposed to estimate the possible economic damage and calculate the cost of preventive actions. According to the annex to the Agreement between Roshydromet and the Ministry of transport of the Russian Federation, not only forecasts, storm warnings, but also recommendations for the selection of the optimal strategy included in the indicative list of special purpose services (___, 2009, p. 98).

That is, instead of the digital indicators of the hydrometeorological situation, the leader of enterprise should evaluate the possible damage and cost of preventive actions. At the same time, the obtained hydrometeorological information should be taking into account directly in business-processes implemented in information systems of enterprises.

Damage is as either a direct reduction in profits, or a total loss of live and materialized labor, part of the potential profit that an enterprise could receive if it operated under normal conditions. The model of damage calculation includes accounting for both direct and indirect indicators of economic damage.

To calculate the amount of different types of damage (Z), formula (1) is applied:

$$Z = \sum S * N \quad (1),$$

where, S is the unit cost of production, N is the number of units.

Indicators of direct economic damage - mainly these are the elements of material damage caused by NH, which are determined in the value dimension, reflecting the destruction, damage or other forms from the economic turnover of property and various material values. Such indicators may include wage losses; losses associated with reduced output, damage, destruction of products, costs of rescue activities. Indicators of indirect damage are the costs incurred by individuals, enterprise s, the natural environment (Khandozhko, 2005).

The cost of preventive actions consists of the costs of evacuation of people and goods; salary of employees when carrying out emergency recovery actions; construction of engineering protective structures; consumables for preventive actions.

The cost of evacuation (E_1) is calculating by the formula (2):

$$E_1 = \sum C_{ev} S_{pas}, \quad (2)$$

where, S_{pas} - the cost of one passenger on different types of transport; C_{ev} - the number of evacuees from the danger zone.

The costs for the salaries of employees (E_2) in the course of emergency recovery actions are calculating by the formula (3):

$$E_2 = C_m N_4 T_d, \quad (3)$$

where, C_m - the average cost of participation of one person in emergency recovery actions for one day; N_4 - number of rescuers participating; T_d - number of days worked.

The costs for the construction of engineering protective structures (E_3) are determining by the formula (4):

$$E_3 = \sum C_{spec} S_P, \quad (4)$$

where, C_{spec} is the unit cost of building one hectare; S_P - area in need of protection, hectare.

Expenditures for consumables (E_4) in carrying out preventive actions are calculating by the formula (5):

$$E_4 = \sum C_{mat} N_{mat}, \quad (5)$$

where, C_{mat} is the value of the material used; N_{mat} is the number of materials.

The cost of leased equipment (E_5) for the export of goods from the danger zone is calculating by the formula (6):

$$E_5 = C_{un\_eq} N_{hour} K_{eq}, \quad (6)$$

where, C_{un_eq} is the average hourly cost per unit of equipment; N_{hour} - the number of hours worked; K_{eq} is the number of units involved.

The cost of the training program for employees (E_6) to counteract the impact of NH is calculating by the formula (7):

$$E_6 = C_{edu} N_{pers}, \quad (7)$$

where, C_{edu} - the cost of the training program, N_{pers} - the number of employees.

Certainly, to evaluate some other damage, calculate some costs for preventive actions, the similar simple formulas can apply. The library of such calculation modules will accumulate as the system develops.

DSS recommendations of may be alternative. Based on the main economic indicators of the enterprises, it is possible to calculate the ratio of possible economic losses to the cost of preventive actions. For each case, the ratio of possible economic losses to the cost of preventive actions is calculating by formula (8).

$$K = \frac{P}{S}, \quad (8)$$

where, P - economic losses; S - the cost of preventive actions; K - coefficient of economic benefit.

If the economic benefit ratio is more than 50%, then it makes sense to carry out preventive actions. Thus, the leader of enterprises, with real quantitative indicators, can act in accordance with the current hydrometeorological situation.

Of course, there are other methods for assessing and calculating damage and the cost of preventive measures, as well as decision-making methods based on the appropriateness of protective measures with optimal solutions (strategies). In this case, optimality criteria are used, which can be average losses, the minimum probability of losses, that exceed a certain specified level of maximum profit, average profit, average loss, minimax, the most likely result. The actions strategy options are evaluating on the basis of decision trees, the usefulness of functional matrices, the matrix of regret, matrix of loss at different values of water levels during floods, decision making under risk (___, 1990; ___, 2002; ___, 2012; Cornford S.G., 1997; Kobysheva N.V., 2015; Maslov S.F, 2000; Yares, O. B., at all, 2011.).

8 Conclusion

The analysis of existing systems of hydrometeorological support show the evolutionary shift of the paradigm of a hydrometeorological support for leaders of enterprises, government and the population has been revealing. The new paradigm is basing on local thresholds values for NHs detection, automatic transmission of information about them, prediction of impacts and issuing recommendations. To implement these tools, it is necessary to develop local threshold values of NHs indicators, in the direction of specification of indicators not only for the regional office of Roshydromet, but also for specific enterprises.

There is a basis for predicting the impacts of NHs before, the moment of NH or after the NH in order to facilitate planning, response to and mitigation. There is a coordinated process for preparing preventive actions for NH and responding to NH impacts. In result the awareness of the current situation increase among leaders of enterprises. At the same time, leaders of enterprises will rely on economically sound recommendations for support solutions.

Automatically detect NHs allows deliver information about them to leaders enterprises very faster. At the initiative of the system, it is possible to bring information about NHs at any time, for any point, to any Internet device, taking into account the type of enterprise, type of activity, level of danger. Rapid delivery of information will increase the time for carrying out preventive actions.

In order to successfully predict the impacts and make recommendations, it need the closer collaboration of NHMS with leaders of enterprises with expertise is required to collect and formalize NHs impacts on various enterprises and recommendations for conducting preventive activities to reduce or prevent these impacts. Of course, the organization of such hydrometeorological support is possible only with the use of integrated, heterogeneous and distributed information resources in the form of observed, diagnostic, prognostic and climate data prepared by NGMS.

Political advice for different countries is that it is necessary:

- NMHSs switch to a new paradigm of hydrometeorological services related to predicting the possible impacts of NHs on the population and industrial enterprises and issuing recommendations to managers for decision-making;
- create a database of threshold values of the indicators of NHs for various levels of danger, typical objects and types of activity;

- develop tools for the automatic detection of NHs for typical objects and types of activities and transferring them to business leaders;
- accumulate information on impacts and recommendations for decision making in the form of a database;
- create a DSS for the automated issuance of information on impacts and recommendations, taking into account economic estimates of costs and damages.

The work financially supported by the Ministry of Science and Higher Education of the Russian Federation, a unique project identifier RFMEFI61618X0103.

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