Digital transformation of hydrometeorological support - the basis for improving the safety of the population and enterprises

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Dependence from disasters

- The number of cases of disasters has doubled over the past decades.

- The most sensitive industries to disasters are agriculture, energy, transport, entertainment, construction, retail, travel, … ..“

- Weather is not just an environmental problem, it is an important economic factor. At least one trillion dollars of the economy is weather-sensitive. *1998 Speech by Former Secretary of Commerce William Daley*

- By predicting the weather, even oil and gas prices can be predicted.

Damage from disasters

- About 600 million people live on the coasts at an altitude of no more than 10 m above sea level.

- The state of Florida spends up to $ 100 million annually to deal with recurrent flooding caused by high tides.

- Floods from rising sea levels could push countries' spending on preventive actions up to $ 14 trillion. (BODC)

- Almost 20% of the US economy depends on the state of the weather (http://Investopedia.com).

- Direct damage from the consequences of global warming in the Arctic can reach 2-9 trillion rubles by 2050 (*First Deputy Head of the Ministry for the Development of the Russian Federation, Alexander Krutikov*)

Examples of impacts of weather conditions

Texas, February 2021, the air temperature dropped <-10 degrees C. As a result:

- Energy consumption has increased.
- The gas networks began to freeze.
- Gas wells stopped.
- There was a lack of fuel at the thermal power plant.
- Wind turbines froze and stood up.
- One power unit at the nuclear power plant has been installed.
- The water supply system is out of order.
- Power lines began to stop abnormally.
- It is not provided to take energy from other states.
- The peak of consumption coincided with the failure of energy generation.
- Water has not been drained from the heating systems of private houses.
- The temperature in the living quarters has dropped below 0 degrees C.
- Batteries burst.

The missiles for the S-400 complex that had been exposed to the storm during their transportation by sea to China had to be eliminated. Two claims for 11 billion rubles were filed in court against the Baltic Transport company, Rosoboronexport.

The ship "Sparta III" of the Murmansk Shipping Company, making a voyage from Dudinka to Arkhangelsk, was lost in ice in the Yenisei Gulf in December 2020. The tugboat "Kigoriak" could not ensure the movement of the vessel due to extensive hummocks formed during the formation of fast ice. I had to involve an icebreaker and a rescue vessel.
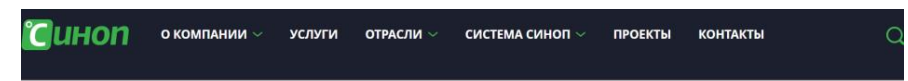
The existing system of Roshydromet for GMS

- UGMS - observations, local forecast, disasters detection and customers service

- Hydrometeorological Center of Russia, AARI - forecast, issuance of warnings about disasters and customers service

- RIHMI-WDC – data storage, preparation of climate data and customers service

- GGO, FERHRI, SibRIHMI, SOI, TsAO - development of regional forecast models, specialized customers service

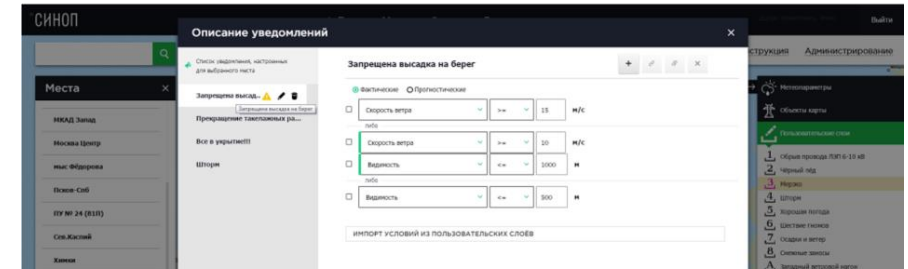- Research Center "Planet" - satellite information service

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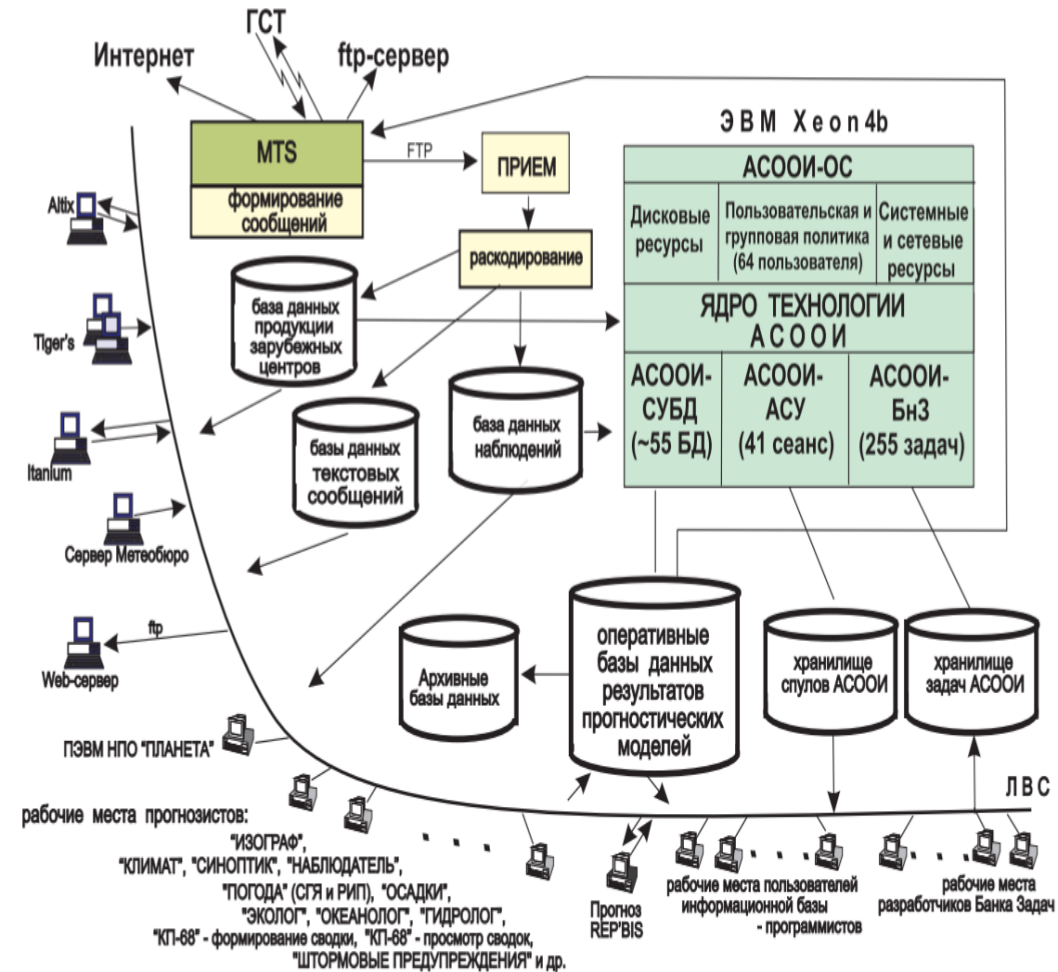
Existing tools

- IGEMS - web GIS resource designed for continuous monitoring of disasters (USA).

- SYNOP company (https://synop.ru)

- The international insurance company, uses geospatial analytic tools to assess damage.

- Ready website (https://www.ready.gov/) – it can search information about preparing for the disasters.

- "Smart notification" of the population by SMS about emergency situations ("Beeline Business" Company).

- Mobile rescuer (EMERCOM of Russia).

HMS problems

The Ministry of Emergency Situations carries out the delivery of information about the disasters to the population using SMS, but with the participation of a stuff.

Mainly self-service of users is carried out.

Enterprise managers are not always able to correctly assess the situation in the digital indicators of disasters .

Government bodies are busy with their own affairs and do not always respond to disasters forecasts in time.

There is no systematized and formalized information on the possible impact of disasters on industrial enterprises and the population, as well as recommendations for decision-making.

Disasters are detected mainly on the basis of general threshold values and information about them is delivered to the heads of industrial enterprises and the population.

What can happen and what needs to be done in each situation is now the task of enterprise heads.

There is no end-to-end technology from observation to decision making.

Required – Digital transformation

Digital transformation

Digital transformation in Roshydromet is a radical change in HMS of enterprises, government bodies and the population due to a significant increase in the level of automation of all processes of data collection and processing; application of new business models for the use of HMI in the business processes of enterprises.

The differences the new business model are:

- Delivery the necessary HMI to consumers on a smartphone in accordance with its requirements for the composition of the necessary parameters.

- Detailed awareness with the current situation in the point or region.

- Use of analytics (frequency of disasters, trends, deviations in climatic values, etc.).

- Forecasting impacts and issuing recommendations for decision-making.

- Optimization of the use of HMI in decision-making.

- Reducing the time between observation and use of the HMI.

Principles development of digital transformation

- **Data integration -** creating a single window for integrated data and create digital twin for HMS

- **Personalization** of HMS is only what is needed at the moment, for a given area, for local threshold values of hydrometeorological parameters

- **Mobility -** delivery of information to any mobile Internet device

- **Automation** of disasters detection based on observed and prognostic data

- **Automatic** accounting of the state of the environment at each object

- **Formalization** of the impact of disasters on enterprises and the population, recommendations for decision-making

- **Forecast** of impacts and issuance of recommendations before, during, after disasters

- **End-to-end technology** of a closed automatic cycle "from observation to decision making" in the form of a continuous data processing pipeline.
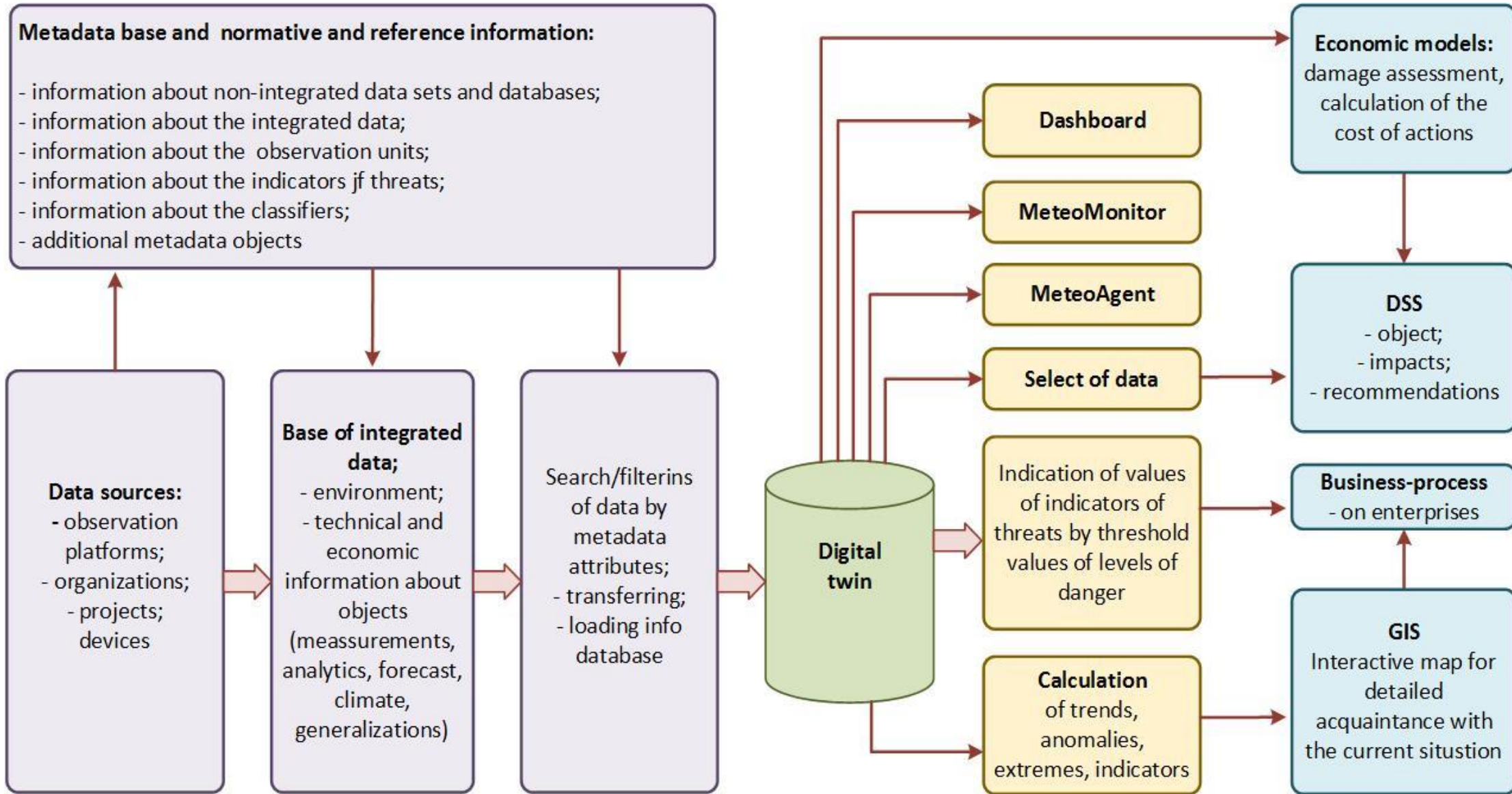
What needs to be done?

- To organize the DT in the form of an end-to-end conveyor of continuous collection, processing, forecasting, data integration and delivery of HMI, it is necessary:
  - Extend data integration up to the creation of a **digital twin**
  - To identify disasters based on local threshold values of indicators for dangerous levels based on the received operational data on the GTS;
  - Predict and warn heads of enterprises about disasters, depending on the level of its danger;
  - To develop a forecast of the possible impacts of disasters on enterprises and the population;
  - Provide heads with a list of recommendations for decision-making;
  - Draw up a plan for carrying out preventive actions based on DSS recommendations;
  - Assess the possible damage from the impacts of disasters;
  - Calculate the cost of preventive actions;
  - Simulate the consequences of decision making$
  - Choose a solution from alternative ones based on an assessment of the difference between the damage and the cost of preventive actions;
  - Monitor the implementation of preventive actions.

End-to-end scheme "from observation to decision making"

Metadata base and normative and reference information:

- information about non-integrated data sets and databases;
- information about the integrated data;
- information about the observation units;
- information about the indicators jf threats;
- information about the classifiers;
- additional metadata objects

Data sources:
- observation platforms;
- organizations;
- projects; devices

Base of integrated data;
- environment;
- technical and economic information about objects (meassurements, analytics, forecast, climate, generalizations)

Search/filterins of data by metadata attributes;
- transferring;
- loading info database

Digital twin

Dashboard

MeteoMonitor

MeteoAgent

Select of data

Indication of values of indicators of threats by threshold values of levels of danger

Calculation of trends, anomalies, extremes, indicators

Economic models: damage assessment, calculation of the cost of actions

DSS
- object;
- impacts;
- recommendations

Business-process
- on enterprises

**GIS** Interactive map for detailed acquaintance with the current situtsion

Integration of distributed and heterogeneous data

- The basis for the development of HMS consumers is preliminary the creation of metadata and data integration .

- On the basis of integrated data, it is possible to deliver to each consumer the data he needs only.

- Personalized customer service is provided.

- It is proposed to use ESIMO, http://esimo.ru. There is organized by HMS of consumers in the "self-service" mode.

- A personalized delivery of the HMI is carried out at the initiative of the system in case of exceeding the values of the disasters indicators of the local threshold values of the hazard levels.

Digital twin for development HMS

- **Digital twin for HMS** must includes:
  - Indicators of the environment on which the activity of the enterprise depends;
  - Economic indicators of an industrial enterprise;
  - Technical - economic, social, technological indicators of the enterprise;
  - Information about business processes that depend on hydrometeorological conditions;
  - Organizational information on the state of HMS.
- The following functions can be performed with the help of the **Digital twin**:
  - Provide a digital copy of the properties of industrial enterprises and processes of HMS;
  - To simulate the influence of external impacts of the environment of the enterprise;
  - Monitor and diagnose the state of the object.
- **Digital twin** is a tool that allows to:
  - To comprehensively reflect the state of the environment, processes occurring in the atmosphere (cyclones, anticyclones, fronts, etc.), hydrosphere and lithosphere;
  - Understand the impact of environmental changes on business processes by modeling scenarios of disasters impacts;
  - Manage business-process, in which use HMI.
- **ESIMO can be as the basis for creating a digital twin**

Distributed data
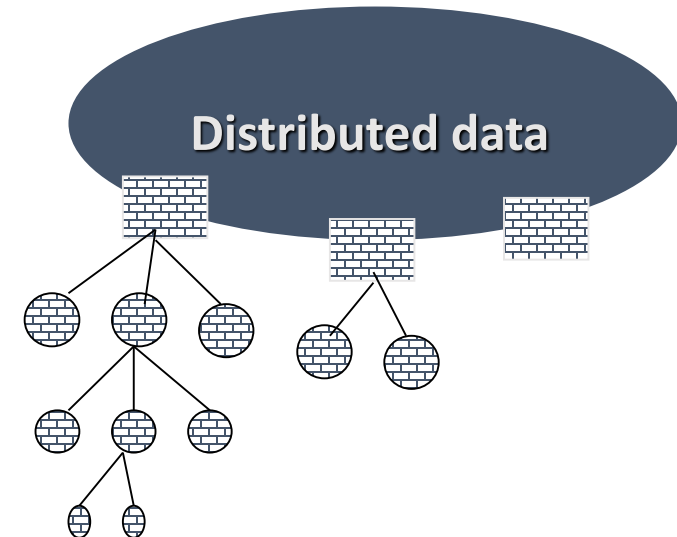
Assessment of the dangerous level of a disasters

- On the basis of operational data transmitted over the GTS channels in the form of SYNOP, SEA, HYDRO telegrams, etc., using local threshold values, it is possible to identify disasters according to the dangerous levels for specific enterprises.

- The dangerous level is the value of the indicator of the phenomenon, which is characterized by possible losses and other consequences from disasters(1 – dangerous and impacts are not expected, 2 - weather conditions are potentially dangerous, 3 - weather conditions are really dangerous, 4 - a catastrophic situation).

- The dangerous level is now assessed based on common thresholds (vary from country to country).

- The proposed assessment methodology evaluates the dangerous level of the values of meteorological parameters based on local threshold values for various enterprises and types of activity.

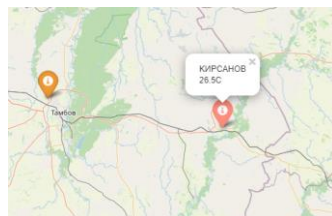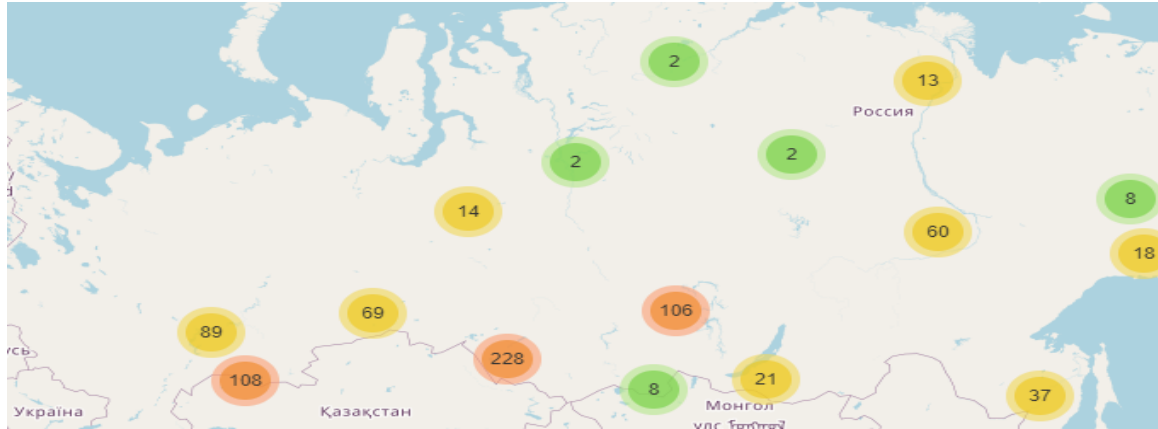# Example of local thresholds for dangerous levels

a) General criteria

Disasters	Пороговые значения уровней опасности ОЯ
Strong wind - ff	If ff=10-14 м/с, than Danger=E. If ff=15-20 м/с, than Danger=O. If ff=>20 м/с, than Danger= R. End of danger: If ff <10 м/с.
Precipitation (very strong)	If Precipitation =20-30 мм for period < 1 hour., than Danger =O. If Precipitation =>30 мм, than Danger=R. End of danger: If Precipitation <15 мм.

b) Local criteria for objects and types of their activities

Country	Lat min	Lat max	Long min	Long max	Object	Activity	Indicator of disasters	Values		
Russia	40	90	7	180	Ship small	Crossing the ocean	Wave: height, м	1.0	2.0	Ж
Russia	40	90	7	180	Ship small	Crossing the ocean	Wave: height, м	2.1	5.0	О
Russia	40	90	7	180	Ship small	Crossing the ocean	Wave: height, м	>5.0		К
Russia	40	90	7	180	Ship big	Crossing the ocean	Wave: height, м	2.0	5.0	Ж
Russia	40	90	7	180	Ship big	Crossing the ocean	Wave: height, м	5.1	8.0	О
Russia	40	90	7	180	Ship big	Crossing the ocean	Wave: height, м	>8.0		К

Automatic detection of disasters in the operational data stream

Number of detected disasters by constituent entities of RF

Examples of identified disasters were detected

Stations at which disasters

Delivery information about identified disasters to enterprises heads for decision support

❑ Application for automatic delivery of information about the various disasters by SMS (name of the object, the type of activity, and the name of the indicator, value, and dangerous level).

❑ MeteoAgent application configure for a specific object, hydrometeorological station and threshold values of disasters indicators.

●●●●● MTS RUS   12:17   ⏰ 62 % ▮

‹   +7 (███) ███-██-██   Контакт

████████:
Объект:МУРМАНСК.
Дата:2015-09-09
03:00:00 GMT.
Втр.ск.порыв.=15.
Состояние:Умеренно-
возмущенное.
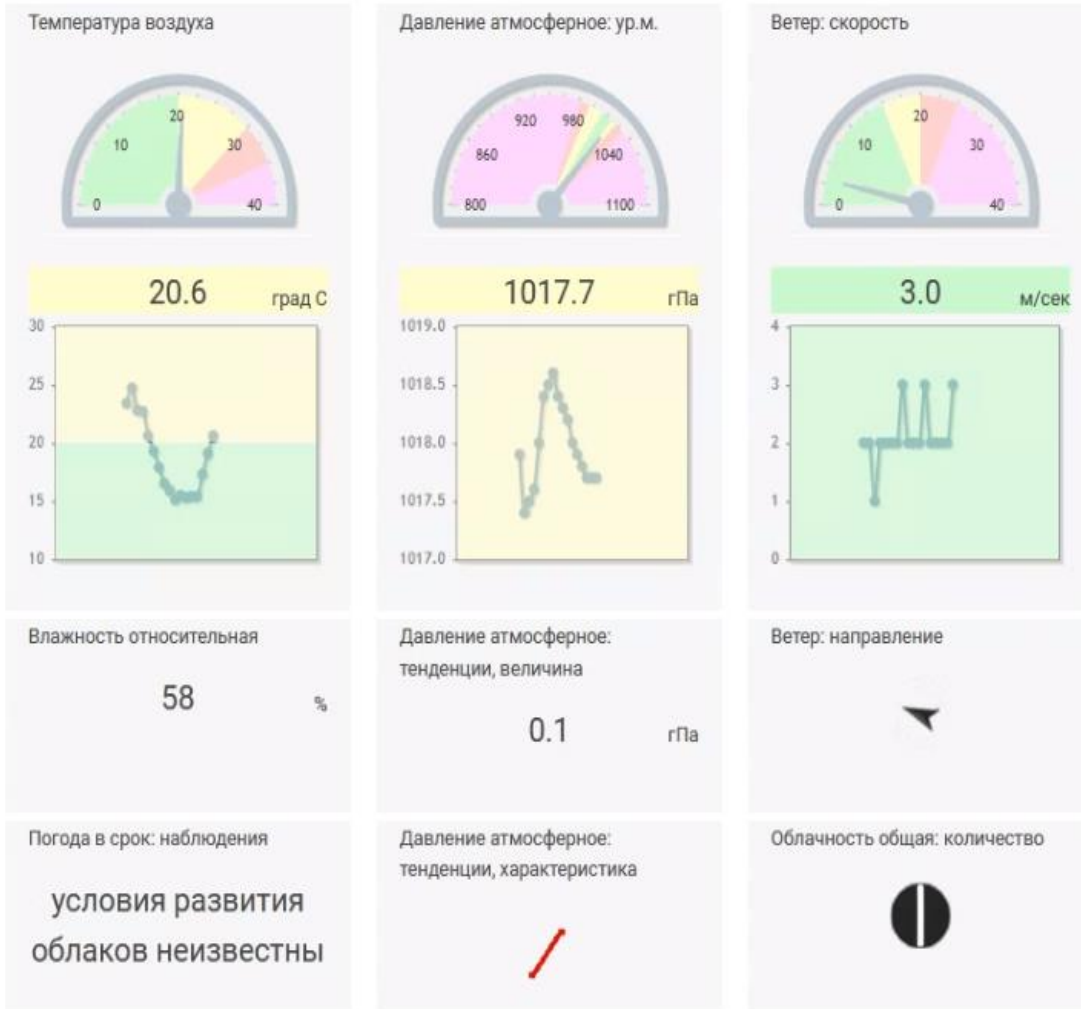Подробнее: http://
esimo.ru

17
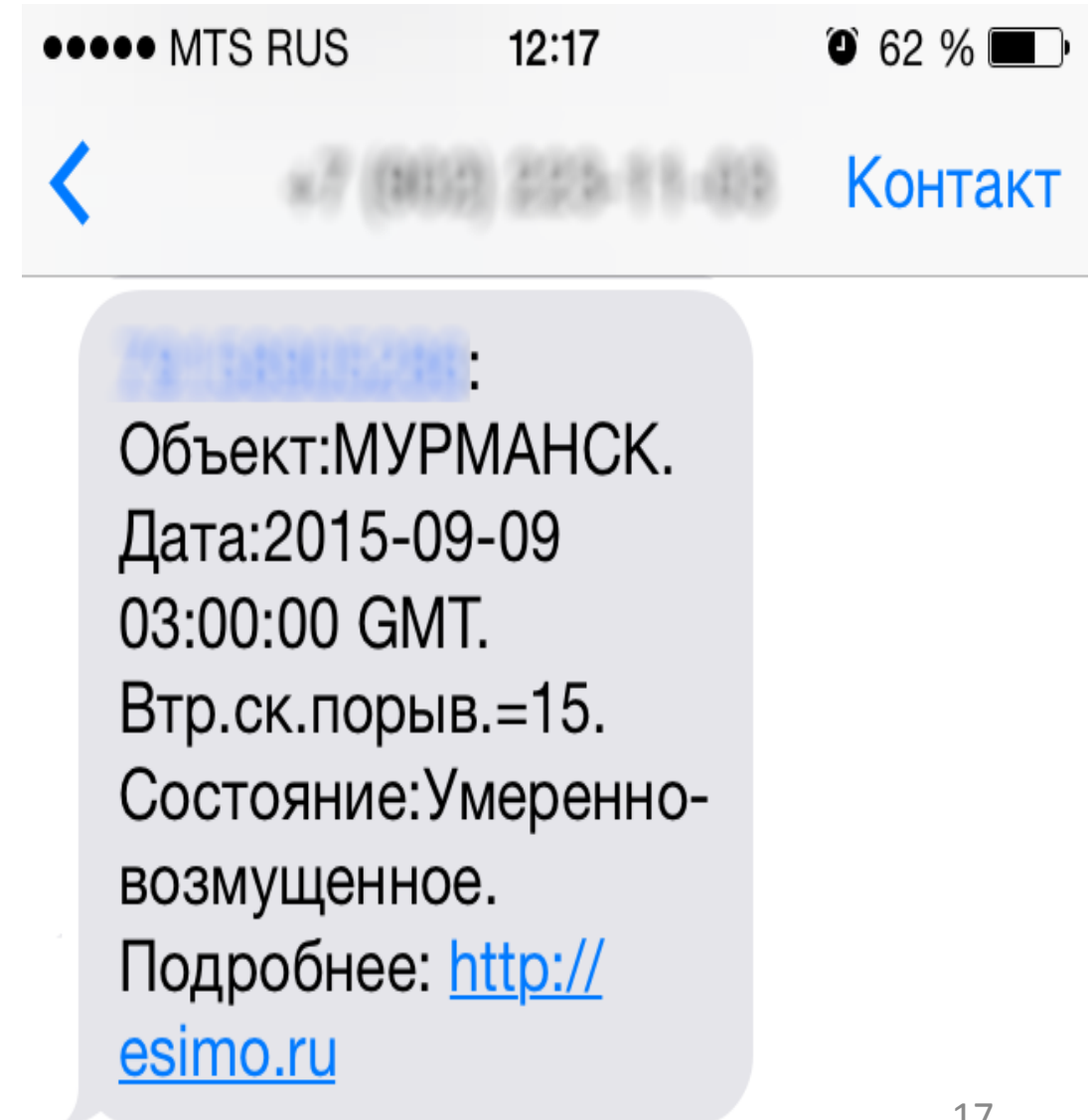
Dashboard for visualization of observing and forecasting hydrometeorological information

Станция: ЛАВАЛЬ ЭНТРАМЕС (07134)

Дата/время наблюдения: 2018-07-18 08:00:00
Широта: 48.03
Долгота: -0.75

Температура воздуха

20.6 град C

Давление атмосферное: ур.м.

1017.7 гПа

Ветер: скорость

3.0 м/сек

The values of the observed and predictive parameters are displayed with an indication of their level of danger.

Graphs of changes in values, anomalies and trends for the previous period are presented.

The data is updated automatically.

One glance at this form is enough to understand the current hydrometeorological situation.

Влажность относительная

58 %

Давление атмосферное: тенденции, величина

0.1 гПа

Ветер: направление

Погода в срок: наблюдения

условия развития облаков неизвестны

Давление атмосферное: тенденции, характеристика

Облачность общая: количество

Delivery of information to enterprises IS

❑ Delivery to ftp-server or by e-mail

❑ Loading into DB

❑ Using of hydrometeorological data in the automated
business processes of enterprises

MeteoMonitor

Software for more detailed acquaintance with the hydrometeorological situation:

- maps of the spread of disasters in spatial;

- graphs of changes in disasters indicators in form time series;

- tables of values of environmental parameters in observation point or closest point on regular grid;

- indication of values, showing the status of indicators of disasters for objects and types of activities

- messages about disasters;

- warning about disasters via sound, color.

- updating data automatically ensuring.
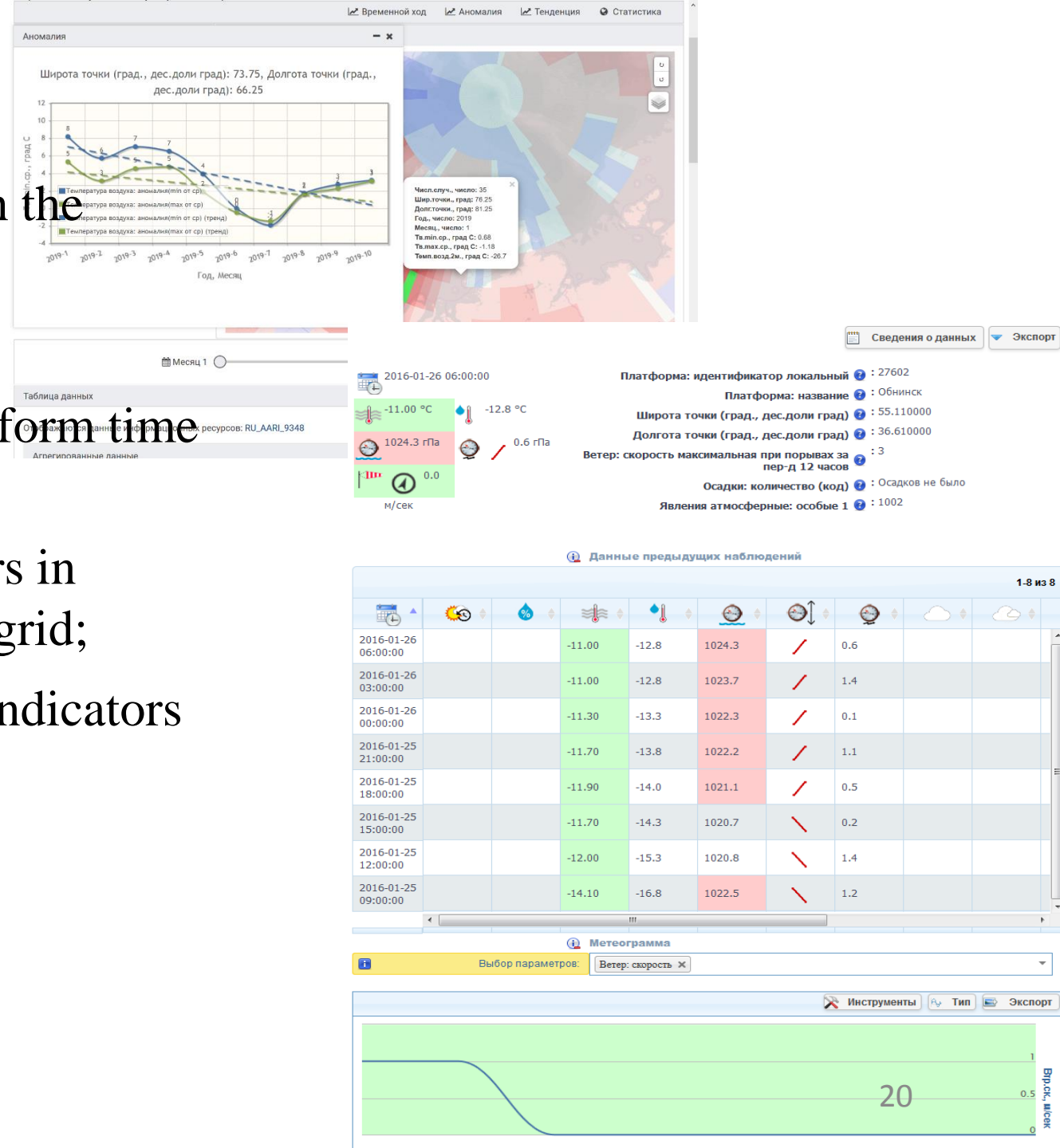
New paradigm of HMS

WMO Recommendation: Provide not only a prognosis of disasters, but also a prediction of possible impacts

The decision-maker, not on his own initiative (self-service), must enter the Internet resource, and the system itself must automatically inform him about the disasters for each object separately.

Decision Support System

The basic idea of DSS creating to serve consumes is as follows:

❑ If we know hydrometeorological conditions, then it is possible to determine in advance the list of disasters impacts on enterprises and population

❑ If we know impacts, then it is possible to determine recommendations for making decision

❑ Knowledge is presenting in the form of two databases:

    -information about local threshold values of disasters indicators

    -Information on impacts and recommendations for making decision
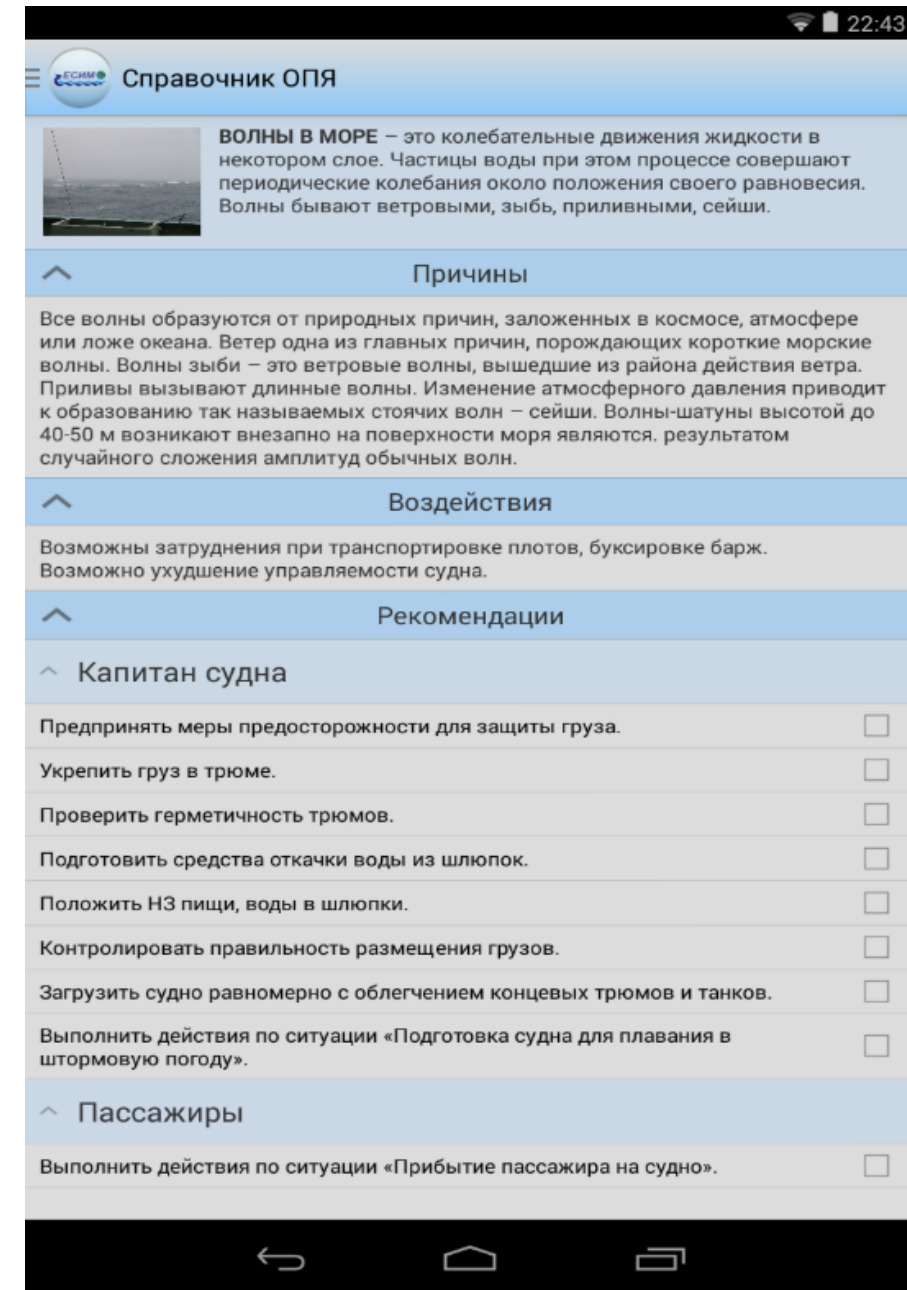
Scheme of adaptation for disasters

Adaptation
*Before disaster***:-**
- Build-
- Prohibit accommodation

*During disaster***:-**
- Announce alarm
- Save yourself....

Object
- Number of personals
- Volume of production
- Location
- Disasters
- Threshold values
- …..

*After disaster***:**
- Restore
- Assess damage
-
….

Properties of disasters:-
-Intensity
-Location
-Repeatability
-Period
- ....

Disasters

*Before disaster***:-**
Climate Forecasts:
-ultra-long-lasting
- long-term
- short-term

*During disaster***:**
- Real-time data
- Forecast

*After disaster***:**
-Real-time data
- Forecast

Time scale of impacts:

-Possible in near year

-Possible within the next month

-Possible within the next day, week, decade

-Currently moment

-Search and rescue

Disasters Situations Description Model

1) Name of disaster
2) The determination of the disaster from the meteorological dictionary
3) The reasons of the disaster
4) Photos with examples of the manifestation of disaster
5) Impact objects (port, housing and communal economy, population)
    5.1) Name of the object, on which may be impact by disasters
    5.2) Information type (climate, forecast, in the moment disaster and after
        the disaster)
    5.3) Impact indicators and their meanings
    5.4) Level of danger (green, yellow, orang, red)
6) Impacts (type of activity affected by disaster, name, priority, author,
    possible potential damage)
7) Typical impacts (using for several disasters)
8) Recommendations (level of management to which the recommendation,
    name, priority, author, cost of preventive activities, references)
9) Typical recommendations (used for several disasters)
10) Links on situations related to others disasters
11) Sources of information (bibliography)

For examle situation description "Permafrost"

Type of information: climate.
Indicators: intensive thawing of frozen rocks >4 cm/year.
Danger level: red. ***Object***: *enterprise, local administrations*
Impacts:
Operation of enterprise:
Accidents of oil and gas pipelines occur.
There is a loss of stability of the foundations.
Environmental impact:
The runoff of the northern rivers is increase.
The spring flood power is increase.
Dangerous processes thermokarst, thermoerosion develops.
Coastal erosion and destroys coasts increases.
Planar, linear erosion arises, ravines erosion is increasing.
Entire houses go underground.
Recommendations:
National, regional and local administrations:
To allocate a financial resources to prevent the harmful impacts of disaster.
Do not cut down a forest in permafrost areas.
Change the environmental behavior of the population.
Industry enterprises:
To organize freezing in the industry areas in the form of the "Chinese wall".
To reconstruct a homes to people living in the permafrost zone.
To remove designed structures from the risk zone.

Damage assessments and calculation of the cost of preventive actions

To calculate various types of **damage** (**Z**) associated with equipment downtime, personals of the enterprise, lost products, it can apply formula:

$$Z = \sum S \cdot N$$

S – a cost of productions units, **N** – the number of unproduced product.

The costs of preventive actions for the removal of property from a dangerous area (**Zp**), which depend on the cost of removal of 1 ton of materials (**Sv**) and the weight (or volume) of the exported (moved) equipment (**V**)

Zp = Sv * V

28° (!) (100)   E ᵃⁱⁱ 16:14

METEO *damage*

Уровень опасности явления

Выберите виды ущерба

простой оборудования   ✓

простой персонала   ✓

уничтожение   ✓

ремонт оборудования   ✓

Снимок экрана сохранен в
фотоснимках камеры

Добавить

26

Development of DSS

- Collect and formalize information on potential impacts and recommendations
- Develop a database of threshold values of disaster parameters for individual objects of the economy and activities type
- To develop a tools of disasters identification by threshold values for various objects of the economy
- Create an economic models for assessing of possible damage, calculation the costs of preventive measures
- Develop a knowledge base in the form of rules "disasters - possible impacts"

To create a knowledge base, it is necessary:
- Determine the unit of description of the situation
- Create the DB of threshold values.
- For the unit of description in the knowledge base it is necessary to choose a situation that determines the solutions for one of the observation, or prognostic, or climatic values of the disaster indicator

Directions of HMI use at various stages of enterprises life cycle

1) *Prediction of the development of the industrial region taking into account the risk of disasters*. (climatic conditions, geographical location, transport and etc.).
2) *Planning*. Based on the forecast for the development of the industrial region, taking into account the risk of disasters, an appropriate development option is selecting. DSS allows to assess the possible impacts of disasters on industrial enterprises.
3) *Engineering design*. Designers, using DSS, to determine possible impacts on specific projected enterprises.
4) *Design of construction*. At this stage, it is important to take into account the relationship between the enterprises under construction and possible disasters by DSS.
5) *Construction*. This step consists in providing data of observations and prognostic information of construction and installation work on the constructed enterprises by DSS.
6) *Operation of an industrial enterprise*. DSS here will help decision maker in time to take actions to prevent or mitigate the consequences of disasters, as well as increase the efficiency of business processes.
7) *Disposal of the enterprise*. In addition to monitoring the state of the enterprise itself, it is necessary to take into account possible disasters.

Fundamentally new tasks

- Automatic delivery of information about disasters to mobile devices of heads of enterprises, executive authorities, taking into account local threshold values of the dangerous levels of disasters

- Automatic delivery of the observed and predictive information about the disasters drivers, self-driving cars

- Automatic provision of HMI for drones and other flying objects

- Safe city - automatic notification of the population about an impending threat and the issuance of information on possible impacts and recommendations for preventive actions.
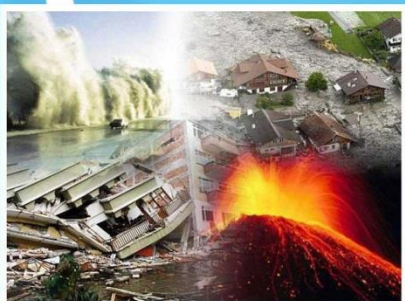
Obninsk: RIHMI-WDC. 2021. 356p.
Reviewer: Dr. Sc., Marine forecasting department of «Hydrometeocentre Russia» E.S. Nesterov
 Figures - 22, tables - 35, refences – 123.

Volume 1: Approaches to Implementation. 2021.
1 Status of means of warning and use of information on hazardous natural phenomena
2. Methodological foundations of digital transformation of hydrometeorological support of consumers
3 Creation of decision support systems in the field of hydrometeorology

Volume 2: Directions for use. 2022.

Conclusion

❑ DT for HMS consumers is aimed at implementing end-to-end information processing technology "**from observation to decision making**".

❑ The personalization of service is being developed on the basis of local threshold values of the dangerous levels of disasters, with a forecast of possible impacts and the issuance of recommendations for decision-makers.

❑ An assessment of the damage and the cost of preventive actions before the start of the disaster is proposed to be taken into account in business processes.

Thank you for your attention !