About Creating a Digital Twins in Field of Earth Sciences

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Abstract: - A brief analysis of the research results on the creation of digital twins in the field of earth sciences presented. For the first time approaches proposed to create a digital twin for this field. The approximate composition of the digital twin data for the development of hydrometeorological support for consumers has been determined. Requirements for the digital twin developed. Digital twins should become key components at the heart of smart buildings, cities, digital enterprises, self-driving cars, flying objects, ships, and others that require data on the state of the environment and the state of these objects. The digital twin can be used to impact models of the environment on enterprises, to solve tasks of calculating the possible damage and cost of preventive actions in the event of the passage of disasters.

Key-Words: **-** Digital twin, earth sciences, development, using for hydrometeorological support

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1 Introduction

The earth sciences data are big, complex and diverse in structure, heterogeneous and distributed, presented at different temporal and spatial resolutions. This data goes through multi-stage processing. At the same time, at any stage of processing, the data can be used in various models for: calculating new parameters, obtaining climate generalizations; for modeling of processes in various spheres of the earth, weather forecasts, pollution spread, etc. To study climate change, the impact of disasters on the population and enterprises, an interdisciplinary approach based on data integration is needed. Such opportunities open up due to the expansion of the accessibility of data on the environment, technical and economic indicators of the work of enterprises, the socio-economic state of the objects, etc.

In today's world, data must be accessible for analysis no matter where it is located. Heads need to get answers quickly to questions related, for example, to the organization of preventive actions before the disaster. For this, data integration is now actively used. Integration tools together all the necessary information to provide the consumers with metadata-based data visibility and access to all available data. Data integration eliminates the information disunity of institutions organizing hydrometeorological support (HMS). This allows the delivery of complex information to any consumer, accelerates the receipt of analytical results necessary for making decisions. Unfortunately, data integration, as a rule, is carried out based on databases (DB) and data arrays that present organizations, without taking into account all the tasks of their use. The prospect of HMS development is the widespread use of integrated data in various models and the creation of digital twins (DTs) for earth sciences with the inclusion of additional information from other sciences.

There are several definitions of the term DT. The most general definition is given in the ISO 23247 standard. *"*DT is a digital model of a specific physical object or process with connected datasets that provides convergence between physical and virtual states at an appropriate synchronization rate*"*. For each subject area, this definition is refined, for example, in industry, a digital model is understood as a virtual model that either describes a real-life object or serves as a prototype of a future object at the micro- and macro levels.

DT should be used throughout the life cycle of a physical object to model various activities [1]. Analysis of DT behavior is able to identify problem areas in a real object, which allows performing proactive actions that prevent accidents and damage [2]. DT will help to test different solutions and choose the best option before head start implementing them. DT allows support of business processes depending on changing environmental conditions, to work with the same information.

There are already many examples of DT development and use [3-5]. So yet 20 years ago there were projects called "Digital Earth Planet", the result of which is, for example, the application https://www.google.ru/intl/ru/earth/. Many countries have created Digital Terrain Model (DTM), which is widely used in geographical information systems. The DTM presents data for the entire globe at spatial scales from 1:5,000,000 to 1:500. The military-industrial company Lockheed Martin uses DT of real landscapes in the form of DTM to fight forest fires. NVidia Company is going to create a complete virtual copy of our planet with all its natural and man-made processes, and then begin to simulate potential climate change [6]. The system will allow predicting climate change on the planet for several decades to come, creating models of the movement of water in the oceans, sea ice, the earth's surface and groundwater.

The Arctic Labs digital platform was created in Russia. Its basis is the DT of the Northern Sea Route - a dynamic mathematical model, which allows to explore scenarios for the development of both the entire Arctic and individual territories, logistics routes (for example, to determine the logistics of delivery of oversized cargo from St.-Petersburg to Magadan). Here, a number of conditions should be taken into account, including accounting for the navigational and hydrometeorological situations throughout the route. The system will work in real time and take into account more than 10,000 parameters, including Arctic resources, infrastructure, transport, shipbuilding, and logistics, social, economic, and environmental data. This will allow for a comprehensive assessment of the feasibility of investment and infrastructure projects, their impact on the dynamics of the development of regions and individual territories, and the Arctic economy on Russia's gross domestic product.

The applications of DT in the field of geosciences and data use are as follows:

- Modeling and forecasting the state of the environment;
- Global climate change modeling based on data for air temperature, sea level, precipitation and other parameters;
- Managing the economic efficiency of enterprises, taking into account the assessment of disaster impacts on enterprises and environmental situations on the population, of adaptation to climate change.

The first two directions of applying DT elements use existing data streams. Here, it is required to data from various spheres of research (air, water, soil, space). To do this can use the tools of integrating data from different domains based, for example, on the Unified System of Information on the Situation in the World Ocean (ESIMO, http://esimo.ru).

The third field of application of DT, according to the author, is the most important, promising and significant in the face of climate change and an increased number of disasters. To apply a DT in this field, it is necessary to solve the following tasks - to determine tools for its creation, to develop the composition of the data, to find data sources for it, and develop requirements for data models.

The creation of DT for the organization of consumers HMS requires the use of a wider range of data [7] - observed, prognostic, climatic generalizations, information on the state of serviced enterprises, reflecting the current economic, social, technical, economic and organizational situations at the enterprises. This will allow modeling possible impacts on various enterprises, assessing possible damage for different levels of danger, calculating the cost of preventive actions and optimizing business decision-making processes taking into account all available information.

In hydrometeorology, models for analyzing and predicting weather have been widely used for many years. However, each discipline (meteorology, oceanography, hydrology, ecology) uses its own models and data. These models use many of the same parameters. They must take from one source - DT. An interesting tool in the development of this area of DT use is the Logos software for supercomputer modeling and engineering analysis of the “Rosatom” State Corporation (https://www.cnews.ru/articles/2021-11-02_kak_razvivaetsya_inzhenernoe_po_v_rossii). She includes the modeling of aero-, hydro- and gas-dynamic processes, heat transfer, static and dynamic strength, deformation and destruction in industrial structures that occur under the impacts of disasters. The software is used both in the nuclear industry and in other industries: aviation, rocket and space, oil and gas, shipbuilding and mechanical engineering. An example of a topical problem solved with the help of this software is the study of the behavior of structural elements in permafrost. In this software new functions are needed to simulate icing (taking into account the operation of heaters), the behavior of rockets (taking into account wind loads, the behavior of systems when flying at up to and supersonic speeds).

An interesting discussion of the creation of DTs in the field of earth sciences has been presented in the article [8]. Many questions like “Why is it necessary to create a DT?” are in this paper. The DT blocks and problems to be solved (data integration, interoperability, scalability, reducing the complexity of existing systems and services) are considered.

The purpose of this article is to study approaches to creating DT in the field of using data of earth sciences in the business processes of enterprises, and developing requirements for it.

2 Methodology of digital twin's development in field of earth sciences

When creating a DT [9], it is necessary to consider three options for reflecting the properties of the environment that the consumer can use:

- Digital shadow - reflects various properties of a physical object obtained on the basis of observed data at irregular measurement points;
- Digital twin - allows, based on the values of the properties of a physical object and models, to restore the values of properties in regular spatial grid by interpolation or extrapolation and then predict condition in time;
- Digital product is obtained based on the values of the observed properties of the environment and a physical object and or calculated, predicted values based on models.

Properties reflecting the environment consider more detail. Now observations are being made of environment state and changes associated with human activities with increasingly detailed spatial-temporal scales of measurement. These observations are recorded digitally on technical media in the form of numerous files and DB. The Earth is covered measurementы very unevenly and they do not reflect with 100% completeness all the properties of the Earth. Therefore, observations are only a **digital shadow** of the Earth.

Integration of observational data on the properties of the environment and its natural and anthropogenic changes, as well as the use of models of interpolation, extrapolation, assimilation of various types of data in analysis and forecast models, allows to create the **digital twin** of the Earth or its individual objects (sea, federal subjects, cities, enterprises, business process) and forecast their behavior in time and space. Of course, interpolation models to grid points are not yet available for all parameters. Input and output formats of data from models are not standardized enough. Many models are based not on DB, but on file systems. In addition, when restoring and predicting the state of the environment, it is necessary to take into account DTM, the type of underlying surface, including artificial objects built by man.

Based on the obtained reanalyses, time series, operational analysis and forecasts, **digital products** are being prepared that can already be used to solve applied tasks using various models for optimizing decisions at objects that depend on the state of the environment; of assessment of impacts forecast of disasters; of economic development planning, etc. Unfortunately, still very few consumers are ready to accept digital products in their business processes.

In the field of the environment, the creation of new and improvement of existing models for the analysis and forecast of atmosphere and hydrosphere is ongoing. These models have been widely used for over 60 years. To improve the quality of forecast results, the spatial resolution of analyzes and forecasts are increased. There are already regional models with resolutions down to 3 km or less. Models hide complex mathematical equations and different boundary conditions under their shell. The work results of these models are elements of the DT Earth. For example, the ERA5 reanalysis [10] includes more than 100 parameters. The site [11] at https://earth.nullschool.net/ru presents the "Virtual Earth" application for next parameters – wave heights, direction and speed of the current and the wind on the surface and heights, distribution of aerosols, of dust. Data obtained from the National Center for Environmental Predictions and the US National Weather Service. This is already good data for DT.

Any change in service, data flows and work processes must teste on DT and then implemented. With the help of this data, it is possible to solve not only the operational tasks of preparing for a disaster, but also the tasks of strategic planning on enterprises of different industries. DT is a tool that allows comprehensively reflecting the state of the environment, the processes occurring in the atmosphere (cyclones, anticyclones, fronts, etc.), hydrosphere (currents) and lithosphere (thawing permafrost). The models should allow describing the behavior of natural objects in all situations, including the impact of disasters and the behavior of real economic objects during the period of such disasters.

From the point of view of physical display, DT is a data model that digitally reflects the properties of real objects, based on which the following functions can perform:

- Providing a digital copy of the properties of specific objects and or processes;
- Display of objects and processes on the computer screen in the form of isolines of parameter values, areas of their extreme values, atmospheric front's lines, which helps to raise the awareness of heads;

- Description of the current location, economic state, operating conditions, behavior and other properties of enterprises;
- Management, aggregation, and analysis of data;
- Modeling of a system for monitoring the state, diagnostics of equipment and other elements of enterprise management on which impact by a disaster.

When using DT to predict disaster impacts on various activities, on equipment and materials), technical, economic and socio-economic information about objects should be used. In this case, the DT of the enterprise should be used, which describes the real cause-and-effect relationships between productions, economic, financial, organizational indicators of the enterprise and external impacts. Mathematical models of an enterprise should also reflect the economic side of its work; demonstrate how air temperature, wind speed, precipitation can affect it. For example, wind speed can increase or decrease the speed of a ship. The more accurate the calculation of impacts needed the more detailed data on the environment in space and time will be required. In this case, algorithms must take into account the vulnerability of the object (wind resistance, strength, reliability, survivability, corrosion resistance). Each of these indicators depends on climatic parameters, overall characteristics of the object, and the place of use. DT is becoming a source of up-to-date data for services and applications that will help solve every day and future tasks for a wide range of consumers.

To implement such calculations, it is necessary:

- Create unified rules for the formation of the data composition, structure, types of storage and designation of vulnerability indicators of enterprises;
- Develop algorithms and models for calculating enterprise vulnerability indicators;
- Prepare a digital formalized passport with indicators for all disasters and determine the main indicators of the object's vulnerability (mandatory, recommendatory, general, sectoral, and prospective).

The digital passport should reflect types of activities, materials used, components, manufactured products, and the production that is affected by disasters. The prototypes of passports for these objects already exist in the form of safety passports for industrial enterprises, territories (developed in accordance with Decree of the Government of the Russian Federation of December 18, 2014 No. 1413), which considers impacts of disaster on enterprises and their activities; manufactured products, materials used to create them. The development of such passports should involve Roshydromet organizations that provide HMS of enterprises, and experts from other industries.

With the help of DT, it is possible to assess the impacts of environmental changes on business processes by modeling disaster impacts scenarios of various danger levels on the activities of industrial enterprises. Consumers of materials and components should use digital passports with local threshold values for disaster indicators in impacts assessment models. The suppliers of materials and components must remember that each manufacturer lays down certain requirements for them for their use, both in the construction of the enterprise and in the production of products. It is also necessary to take into account the life cycle of an enterprise, manufacturing products from design to disposal. Manufacturers write in the instructions that accompany each product what should not be done with the product, what side effects can happen to it or to the enterprise, where the materials provided by the manufacturer can be used and under what external environmental conditions. Manufacturers of materials, components, products must determine in advance not only certain conditions (threshold values of parameters) in which they must be operated, but also what needs to be done to preserve the properties of a particular product during storage, transportation and use. This information will be the part of DT, claiming to be the object of modeling the impacts of the environment (Fig. 1).

It is important that experiments with DT can carry out long before the disaster. The development of DTs will help create new tools for predicting the possible impacts of a disaster and assessing their consequences. Such DT tools should be models of impacts, damage assessment, calculation of the cost of preventive measures, as well as modeling the consequences of decision-making.

DT should describe not only all the properties of the objects, but also their changes under certain conditions. In other words, it intends, first, for mathematical modeling of an object in order to predict, for example, how the state of an object will change during a disaster. DT is especially important for the development of digital transformation and the transition to Industry 4.0, allowing radically changing business processes that take into account the impacts of disasters.

To create a DT in the field of the environment, it is necessary to develop end-to-end automatic processing of data in the form of a pipeline “from observation to decision making” [12]. At present, this is possible so far only in special cases, when all indicators of the state of the environment are monitored directly at the object. Given the needs of consumers and the pace of automation, the solution of this problem will be possible in the coming years.

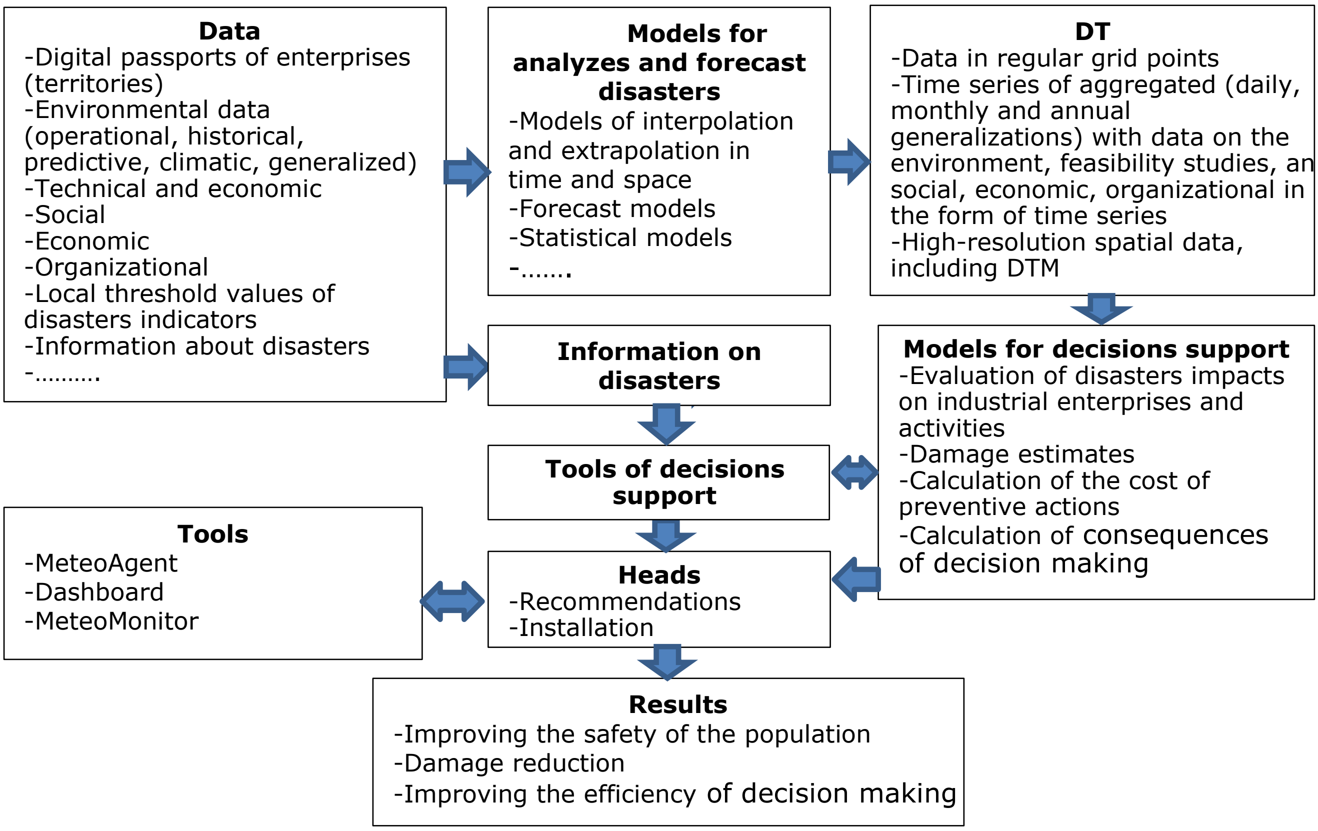

Fig. 1. Scheme of DT creation and using.

3 Composition of data for the digital twin associated with the processes of the impact of disasters on enterprises

From the point of view of users, DT is a DB, which operates through a single user interface. To create it, it is necessary to collect and analyze not only environmental data, but also information about its impact on various objects and their activities. Together, all these data will make it possible to predict the behavior of a real object under the impacts of the environment.

DT based on research data and ancillary data related to existing real systems from different domains. Research results include data:

- Experimental, collected with the active participation of researchers;
- Observed, collected by measuring the properties of disasters and natural processes using contact and remote devices with various sensors;
- Simulated, created with the help of computer models based on imitation of processes or systems of the real world;
- Compiled / derivatives created by transforming and/or combining data already collected, including various data sources;
- Analyzes - the results of interpolation of observational data in points of a regular grid with different scales of space-time resolution;
- Generalized, including climate data, obtained by aggregating with different spatial-temporal resolution observed data
- Prognostic with different lead times - calculated values of the properties of objects, possible in the near or distant future;
- Archival / documentary, created from existing archival sources and / or documents in which experimental or observed data published;
- Historical data - includes, for example, information about disaster indicating what happened at the enterprise, when, what damage was, what was done;
- Formalized descriptions of indicators - local threshold values of disaster parameters for levels of danger and depending on the type of industrial enterprise, type of activity.

For DT, in addition to the properties of the environment, socio-economic, technological, organizational and other information on objects that may affect a disaster are added.

Organizational information includes information for managing the HMS. These are information about objects - detailed technical characteristics of objects with indication of dimensions and other properties.

Economic information includes planned performance indicators of enterprises, information about damages; results of the functioning of objects.

Technological information includes, for example, information about merchant ships approaching the port and located under unloading, the movement of export and import cargo in the port, etc.

Technical and economic information includes danger indicators for objects (remoteness from the water's edge, distance to the nearest shelter; critical exposure time; year of construction; characteristics of the terrain, soil; building density). Some of this information is already included in the safety passports of objects.

Social information includes place of residence, place of work, crowded places (theaters, cinemas, railway stations, and stores), etc. Need information about the types of activities on which are affected by the disasters, information on local roads, the composition of the population, and technical resources for cases of spills of oil, oil products and toxic substances.

A key feature of DT is the availability of enriched data with high-resolution in space and time. When creating technical, economic and socio-economic information, up to 90% of the data for each object of the economy will be created and remain unchanged. The transition to integrated data will provide enriched data and additional slices of data on the activities of the enterprise (indicators of output, the number of employees, others); information about the products manufactured by the enterprise (average values).

For a full-fledged decision-making, in addition to the entities listed above, a significant development of information resources about the environment is necessary, which are not currently being prepared, for example, there are very few long-term hydrometeorological forecasts. They are either absent in existing information systems or presented in a form not suitable (in the form of text) for automatic analysis.

The most obvious way to populate DT is to get the necessary data automatically from the outside from physical systems (Internet of things, RFID, mobile Internet devices); other departmental and corporate IT systems using API and REST services. Due to the need to take into account environmental conditions, enterprises purchase their own automatic stations and other devices, with the help of which they control the minimum list of parameters necessary to solve exclusively their tasks. The data obtained are not always included in the state observation network. Enterprises create their own composition, structure, storage types, and data attributes.

"DT serves as a framework for development and training" in many applications [13].

4 Data storage requirements for digital twin

Currently, data on the environmental and related domains for DT are located in various sources, DB and file systems. A large number of data sources, each of which has its own formatting rules, a system of local names, and classifiers with various standardization levels, are one of the main difficulties for data integration. When integrating data from multiple sources, many details need to be analyzed to present the data in a way that all consumers can understand. Harmonization of different formats and classifiers from different sources, standardization of parameter names and other information are necessary processes when performing data integration. For the functioning of DT, it is necessary to use the data collected and calculated by models from the different agencies. Additional data for DT in the field of earth sciences arise at the stage of design, construction and operation of enterprises, and, changing over time, accompany throughout its entire life cycle.

The foundations for the creation and development of DT are:

- Data management at the object level, i.e. all data about one object is stored in a single database;
- Data integration - combining information resources in one place for their further use;
- Availability of metadata about sources and the integrated data themselves;
- Ensuring the compatibility of integrated data on the unity of attribute names for the same entities, the use of standardized classifiers;
- Standardization of presentation of properties of objects used in different DB (for example, location coordinates - latitude, longitude, time - date and other key object attributes must have the same names);
- Use of a unified system of classifiers and codes (local, departmental classifiers should be brought to a higher level of standardization - national or international);
- Linking data for different DT objects – the presence of links for joint consideration of different data.

All the necessary information to create DT objects must be integrated and always up to date. The scheme of data integration, creation of DT and its application in various services has been shown in Fig.2.

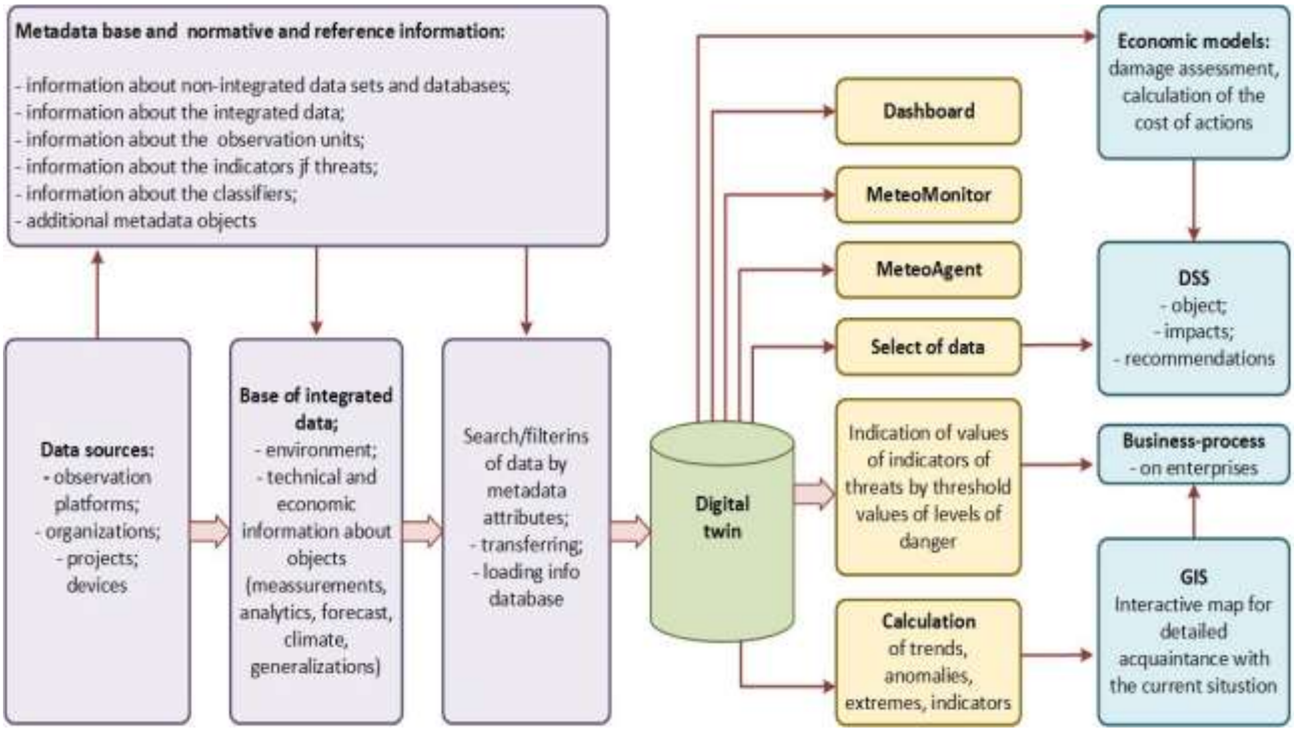

Fig. 2. Scheme of data integration, creation of DT and its application [14].

It needs to create a metadata catalog containing contextual information about the data the consumer is going to access, such as where the data came from, who created it, and when it was last updated. Metadata change as additional data sources are connected, algorithms are configured and modified. The metadata catalog provides a semantic layer that represents each object (person, organization, impact process, material, and product) and their relationships to metadata objects. This will help consumers get more relevant and faster responses to queries.

For the manufacture of DT, data from automatic stations operating in real time should be used. The data must be up-to-date and updated in accordance with the regulations. Each data set should include fixed properties - metadata, dynamic - life cycle of object, links with other data sets.

Data presented in the form of analyzes and forecasts must meet the following requirements - to be issued with a time resolution of up to 3 hours, and in some cases up to 10 minutes. The following requirements apply to data that is additionally involved in DT:

- Information on the possible impacts of disasters on various enterprises, activities, raw materials, products and people should be formalized;
- Information should be of high quality and detailed - from urgent observations to climate generalizations;
- Information must be in digital form.

Passports of enterprises and other information should be formalized, digitized, normalized and integrated. In fact, integrated data should be created, both for points and in regions.

All data must be managed from the moment it enters to the DT to the moment it is used. Heterogeneous data are integrated, processed and used to create new systems (modeling, forecasting, and decision support). DT should be created in such a way that any application can get the necessary slice of data without human intervention. It is important that DT reflects the emerging situations at an industrial facility, that is, the data must be constantly updated, checked for correctness and be available in real time.

DT must also comply with the FAIR principles (findability, accessibility, compatibility, reuse) [15], the repository for DT must satisfy the TRUST criteria (transparency, responsibility, user orientation, sustainability, manufacturability) [16] and CARE (collective benefit, authority on control, responsibility, ethics) [17].

An equally important requirement for DT is the development of the new data model for it. At this stage of research, it is too early to talk about a specific data model, but even now, it can be argued that the main requirement for such a model is the following.

The storage unit of the DT is the properties of one instance of the object. Each type of DT has own database. The DT model must include all the required objects. All object properties must be stored in one table [18].

DT must have a consistent set of services, search capabilities, and data accessibility that will enable consumers to obtain the required digital production to solve an application task.

To create either a global, or national, regional, or local DT, it is necessary to develop a Data

Management Plan, which reflects the data sources for the formation of DT, the rules for their replenishment, as well as the rules for its use in solving various tasks. The latter is necessary to increase the level of automation of its creation and use it as a continuous data processing pipeline from observation to decision-making [12].

5 Discussion

Data integration will make it possible to convert all data into a common format and visualize it in a uniform way or deliver it to consumers by subscription by REST and other services. The resulting operational data allows consumers to identify disasters based on local thresholds. Namely at these disasters is a necessity of support of decisions. This requires the use of not only data of earth sciences, but also additional information about the socio-economic objects, various enterprises, that depend on disasters. To do this, data from different domains must be in the DT. Thus, a single data source will be created for its subsequent use in various tasks of forecasting and modeling. Based on DT, it will be possible to develop applications to take into account impacts of disasters on the activities of enterprises and the population. Consumers will be able to receive up-to-date data at any time, for any region and in the required composition of attributes, on any Internet device, wherever the consumer is.

Digital products obtained with the help of the DT are as follows:

- Operational continuously updated observational and forecast data;
- High resolution data with higher update frequency;
- Forecasts of disasters;
- Climate generalizations;
- Data from various sectors of the economy (social, economic, technical, etc.);
- Impacts of disasters on businesses and the public.
- The performance indicators of DT are following:
- Reliability of DT infrastructure operation - not less than 99.9%;
- Failure time should not exceed 5 minutes;
- Response time to the actions of the head of the enterprise using DT tools - 5 s;
- Relevance of data – data should receive from hydrometeorological stations with a delay of no more than 30 minutes;
- Time of collection and processing should not exceed 40 minutes for operational data and two hours for the forecast of the main meteorological parameters after their measurement;
- Measurement of disaster indicators should be carried out as often as possible, but not less than once every three hours during normal conditions and more frequent observations (every 10 minutes) when the disasters occurs;
- Time for delivering to consumer's information about a disaster should not exceed 15 minutes after it received or identified;
- Time for obtaining additional information about the current situation should not exceed three minutes after uploading to the DB.

DTs in the field of earth sciences are not something completely new. This is a transition to a new level of abstraction (work with databases at the objects level); an increase in the level of automation of data processing; an expansion of the data sets required to solve the business processes of an enterprise. Each data source can no longer fully satisfy the information needs of enterprises, preliminary coordination of data from various sources is required in terms of both standardizing data structures, applied attribute names, units of measurement, used classifiers, and organizing fast delivery of update data. These tasks will be performed by DTs.

DTs should become components of smart cities, digital enterprises, self-driving cars, drones, ships and other objects that require data on the state of the environment. This is especially important in terms of predicting possible disasters impacts on the population, enterprises, and protecting the environment from the harmful effects of enterprises. DTs will allow quickly identifying the causes of equipment failures related to disaster impacts. DT can be used to model disaster impacts on industrial plants as well as for green promotion [19].

The development of a DT in the field of earth sciences will require a lot of time for understanding the problem, implementation and widespread use in industrial enterprises by all participants in the HMS processes.

6 Conclusions

For the first time, approaches were presented to create a DT in the field of earth sciences, which can be used at the global, regional or local levels. An exemplary composition of DT data for HMS of consumers proposed; requirements for DT developed.

DT is a tool for creating a DB for many objects and his further application in various computer models. DT is a shared data space ecosystem in the domain of earth sciences, social and economic objects interacting with the environment. DT implies the presence of metadata (information about it, including the creators, what, when it was changed), compliance with the FAIR principles, TRUST and CARE requirements. Each DT should have a unique identifier and name, associated metadata to make them easier to use. Metadata should reflect both the content of the DT and information about data sources (organizations, observation platforms, instruments, methods for obtaining and processing parameters).

Thus, the creation of a DT will allow any external system to obtain the necessary data slice without human intervention. It is important that DT will reflect the emerging situations at enterprises, that is, the data will be constantly updated, checked for correctness and available in real time. This allows monitoring deviations and instantly determining the level of danger.

DTs can use to solve such tasks as, for example:

- Assessment of possible damage in the event of a disaster, calculation of preventive actions cost an optimization decision support;
- Optimization of fuel consumption (coal, gas, electricity) depending on the season, short-term or long-term forecast of weather conditions;
- Taking into account the actual values of wind indicators (speed and direction) and other parameters on the runway;
- Operational adjustment of the route of delivery of electronic equipment, taking into account the weather forecast or the mode of operation of the refrigeration unit when transporting perishable products.

DTs of enterprises will allow modeling the impact of disasters on certain objects at various stages of their life cycle. Creating a DTs based on integrated data allows saving on data entry into information systems of enterprises; improve data quality by removing the human factor; and increases the safety of objects exposed to disaster impacts. At the same time, it will be possible to use modern modeling methods using machine learning, neural networks, which will allow us to study physical objects in more detail. For example, it is possible to detect anomalous situations, both in the environment and at enterprises, in equipment, which can lead to serious problems during a disaster. DTs will also allow refinement of danger levels based on local thresholds for each enterprise and activity. DT will provide various interfaces in the form of dashboards, Weather Monitor for the operator and decision support. For business heads, these are recommendations for managing the enterprise.

Further research in the field of creating DTs in the earth sciences, in the opinion of the author, should be aimed at developing models for assessing impacts of environment on enterprises, calculating possible damage before the onset of an disasters, the cost of preventive actions, and the optimization of decision-making based on simulation results.

DT will develop in the framework of the "The Caspian Sea Digital Twin" Programme performed as part of the IOC activities related to the UN Decade of Ocean Science for Sustainable Development. The Caspian Sea DT would include an updated archive of satellite, oceanographic, hydrometeorological, hydrodynamic model; atmospheric reanalysis data, results of regional climate change forecasts, electronic atlases, and electronic library of publications on the Caspian Sea. The DT database will allow assessment of anthropogenic loads on the Caspian Sea environment, ongoing climate change, extreme weather and climate events, the impact of climate change on natural and socio-economic systems, development of a strategy and mechanisms for adaptation to climate change and the state of the Caspian Sea.

Getting data from the DT will lead enterprise heads to partners from hydrometeorological organizations for the development of new products, services, and the accumulation of experience in data processing that cannot be implemented independently. Thanks to digital transformation and DTs, consumers will think about business development, and not solve the technical issues of IT development

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