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COMPARATIVE ANALYSIS OF GLOBAL AND NATIONAL SYSTEMS FOR OBSERVING, MONITORING AND FORECASTING NATURAL DISASTERS AND HAZARDS WITH A VIEW TO REDUCING RISK

The object of research is modern systems for observing, monitoring and forecasting natural disasters and hazards. Although early warning systems are often used to predict the magnitude, location and time of potentially hazardous events, these systems rarely provide impact estimates, such as the expected amount and distribution of material damage, human consequences, service disruption or financial losses. Supplementing early warning systems with predictions of impact has the dual advantage of providing better information to governing bodies for informed emergency decisions and focusing the attention of various branches of science on the goal of mitigating or preventing negative effects.

The publication analyses current trends in the growth of natural risks, taking into account the risks associated with global climate change. The issues related to the growing risks of natural disasters and catastrophes at the present stage of societal development and directions of activities at the international and national levels for their reduction are considered. Disaster risk prevention and mitigation measures are described and areas of work in this area are highlighted. The decision-making sequence model is given, global and regional systems of observation, analysis, detection, forecasting, preliminary warning and exchange of information on natural hazards related to weather, climate and water are described. The factors that «unbalance» the global economy in terms of intensity, magnitude, magnitude of losses due to catastrophic events are analyzed.

Addressing disaster prevention requires a structure at the national level in each country that includes policy, institutional, legal, strategic and operational frameworks, as well as at the regional and societal levels. This structure will organize and implement disaster risk reduction activities and establish an organizational system that will understand disaster risk and ensure that it is reduced through public participation.

Keywords: *disaster monitoring, observing systems, natural hazards, risk minimization.*

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1. Introduction

Natural disasters are natural phenomena of a catastrophic nature that contribute to the destruction of the social, economic and environmental spheres of human civilization and impede their sustainable development.

Natural disasters occur worldwide and frequently. They threaten human society, natural ecosystems and major infrastructures. According to the United Nations (UN), global average annual losses caused by disasters such as earthquakes, floods, droughts and tornadoes ranged from 250 to 300 billion USD in 2015 [1, 2]. Over the past decade (2010–2019), related natural disasters worldwide have caused an average of more than 187 billion USD in economic losses. United States dollars per year [1] and before the displacement of an average of 24 million people per year [2]. Among global risks, extreme weather events and geophysical events, such as destructive earthquakes and tsunamis, are considered as the main ones and, according to the risk assessment scale, belong to the first and third hazard levels, and from the point of view of impact, occupy the third and fifth place in the risk assessment scale [3]. Urbanization, population growth, increased interconnections and interdependence of critical infrastructures are expected to further increase the risks associated with natural hazards [1, 4]. Climate change adds to these risks, which is also one of the main drivers and enhancers of losses associated with Hydrometeorological phenomena [2]. Both heat waves and droughts will become more frequent and are expected to persist for longer periods of time in the face of climate change. Thus, the increase in flooding in rivers, cities and coastal areas due to climate change is a global problem affecting mainly developing countries as well as industrialized regions [1, 4]. Forecasting, early warning and provision of operational information on natural disaster risk are an important issue in reducing the risk of such events [2]. The Sendai Framework for Disaster Risk Reduction, agreed at the Third United Nations World Conference on Disaster Risk Reduction in 2015, calls for a significant increase in the availability of hazard early warning systems and operational information on disaster risk by 2030 [5]. Prediction and warning typically cover the physical characteristics of events, such as the magnitude, spatial propagation, and duration of an impending event. In recent years, attention has been paid to providing information on the potential consequences of events such as the number and location of victims, damage to buildings and infrastructure or disruption of services. This requires consideration of additional information on the impact, that is, people, property or other elements present in hazardous areas [1, 6] and damage, defined as the characteristics of exposed communities, systems or assets that define them as harmful effects of danger [6]. Impact forecasting and prevention is a new direction in science, for companies developing forecasting technologies, and at the level of institutions responsible for managing natural hazards [1]. Therefore, creating and maintaining a scientific and technical knowledge base is one of the priorities of risk management. It is critical at all stages of disaster risk mitigation, from hazard assessment, impact analysis, risk assessment to risk prevention, preparedness, response and recovery. For example, the World Meteorological Organization (WMO) has recently launched a programme to provide risk-based forecasting and impact prevention services [7, 8]. The programme aims to assist WMO members in further developing forecasting and prevention services tailored to the needs of users. To ensure that they fully understand and understand the consequences of severe weather events and, as a result, take appropriate mitigation measures.

This paper considers the current state of forecasting the impact of hazardous phenomena for a wide range of geophysical and weather/climate-related natural hazards. Forecasting is defined as providing timely information to improve management during an emergency, that is, shortly before, during, and after a hazardous incident. Advantages and disadvantages of advance forecasting systems are indicated.

Disaster statistics over the past 20 years are alarming, but it is important to remember that the level of loss of life and material damage could be much higher. If there were no hazard prevention services. Here, the early warning provided through the WMO global network and the NMHS (National Meteorological and Hydrological Services) is important. Every year, natural disasters caused by weather, climate and water hazards affect societies around the world, killing people, destroying socio-economic infrastructure and deteriorating fragile ecosystems. Natural disasters seriously undermine the results of investment in development in a fairly short time and therefore remain one of the greatest obstacles to achieving sustainable development and eradicating poverty [9, 10]. About 90 % of all natural disasters over the past 10 years have been the result of such phenomena as floods, droughts, tropical cyclones, heat waves, severe storms, landslides, debris flow. Natural disasters and their consequences contribute to the development of the crisis in the world economic system. Among the characteristics of catastrophic events as a factor in the «imbalance» of the global economy, the key ones are:

1) increasing frequency of occurrence;
2) increase in the number of victims;
3) increase of losses and losses;
4) relationship with the problem of climate change;
5) relationship between natural and man-made disasters.

For example, climate change leads to changes in the frequency, intensity, spatial scale, duration and timing of extreme meteorological and climatic events.

Today, there are scientific and technical programs and networks with a developed global infrastructure that allow to create and provide products and services. They play a more important role in developing international, regional and national strategies for disaster risk management and response strategies. Decision-making process concerning management in the conditions of risk, connected with natural disasters, can be described by model: prevention and mitigation – ensuring readiness – reaction – restoration, paying special attention to preventive measures.

Thus, modern systems for observing, monitoring and forecasting natural disasters and dangerous events have been chosen as *the object of research. The aim of research* is to analyze space, air and ground-based early warning systems for natural disasters and events with a view to preventing and minimizing the consequences and managing risks in emergency situations.

2. Methods of research

Therefore, in order to better understand the problems of community damage to natural disasters related to weather, climate and water, interdisciplinary scientific research is needed using archival materials and relevant information by industry. At the present stage, the main objective is to ensure the provision of fully integrated products and services at the national, regional and international levels for decision-making on disaster prevention, preparedness, response and response. The main objectives of the relevant disaster prevention and mitigation structures should be:

a) increasing attention to preventive strategies for risk prevention and preparedness;

b) ensure the optimal use of basic scientific and technical capacity, especially early warning systems, at all relevant stages of the management process in the face of natural disaster risks at the international, regional and national levels;

c) maintaining and strengthening the role of the NMHS as critical components of national disaster risk reduction programmes, particularly in developing countries;

d) increase awareness of the feasibility of investing in disaster prevention, especially early warning systems;

e) working with international, regional and national partners and the private sector to create a safer world.

In recent years, there has been increasing emphasis on rapid response decisions and responses to disasters. Otherwise, no country or even all of humanity can achieve sustainable development. In this context, the following were adopted:

– Declaration [9];
– Reports [9, 10];
– Programmes [7];
– Road Maps [11] et al. [12].

3. Research results and discussion

Hazard forecasting: timely provision of information on physical characteristics of events. United Nations (UN) terminology on disaster risk reduction [6] defines an early warning system as a set of capabilities necessary to obtain and disseminate timely and meaningful warning information. In order for individuals, communities and organizations at risk to be able to prepare and act properly and to take action during that time and prevent harm or loss. Hazard monitoring, analysis and forecasting are a critical task of early warning systems. Hazard predictions provide information about the physical characteristics of an incident, such as the location, time, and magnitude of the incident, which predetermines potential threats.

Events are considered natural phenomena with a certain magnitude, which unfold in space and time with a certain frequency and with the potential to manifest adverse effects. The manifestation of the event can differ significantly from the danger caused. For example, they can be classified into short-term with local manifestation and long-term with large manifestation scale, and cyclic, which tend to be repeated at the time and space scale (Fig. 1). However, among the hazards there are those that cannot be predicted in advance, since warning systems do not record them. In the case of earthquakes, for example, predicting the location, time and magnitude of an accident is not possible before it occurs. However, a quick assessment of the characteristics of the event can be performed once the event has been detected. The same situation with landslides, debris flows, since they may have different origins and depend on different factors (in particular, landslides).

The dangers of disasters of various natures are a great obstacle to sustainable development in Ukraine. There is a constant increase in dangerous Hydrometeorological phenomena in the country, which contribute to the development of floods, landslides, mudslides, flooding, drought, fires, etc.

Science and technology programmes, as well as their involvement and participation in them, contribute to the strengthening of global capacities for observation, analysis, identification, forecasting, early warning and exchange of information on natural hazards related to weather, climate and water. They range from severe phenomena occurring on limited geographical scales with short lifetimes, such as tornadoes and violent floods, to large-scale phenomena such as drought, which can cover whole regions and peoples for months or years regardless of their geographical location (Fig. 1).

The need for a better understanding of the climate system and the development of opportunities for forecasting natural climate variability and human-induced climate change is therefore important at the present stage.

Modern observing systems. The Global Observing System (GOS) allows observation and collection of information on weather, climate and water bodies worldwide. The system collects data from 14 satellites, hundreds of ocean buoys, aircraft and ships and some 10 000 ground-based observation stations. NMHS monitor and collect data on their countries. More than 50 000 weather reports and several thousand maps and products are distributed daily through the Global Telecommunications System (GTS), which links meteorological centres around the world. The Global Data Processing and Forecasting System (GDPFS) brings together global, regional and national data centres and provides countries with regular analyses and forecasts, including early warnings of weather hazards. Based on the analysis and projections made by the World Meteorological Centres (WMC – Washington, Melbourne, Moscow) and the Regional Specialized Meteorological Centres (RSMCs), NMHS prepare and provide, where countries are threatened by hazards, early warnings adapted to local conditions and requirements (Fig. 2).

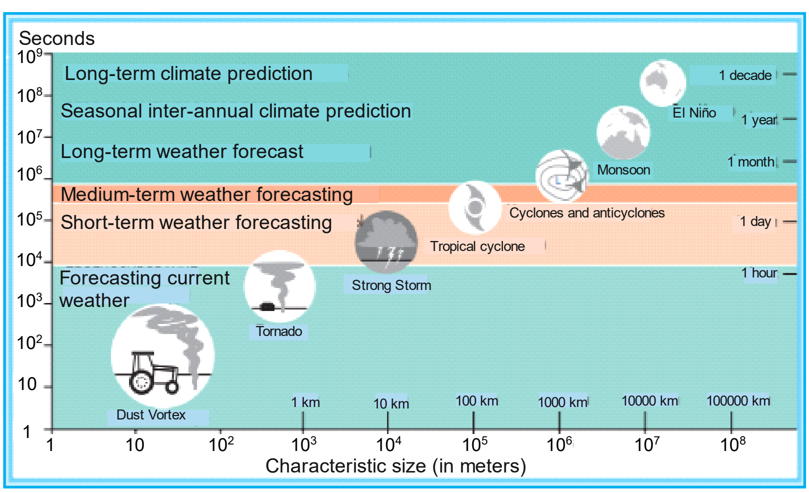

Fig. 1. Examples of varieties and extent of natural hazards observed, tracked and predicted by [6]

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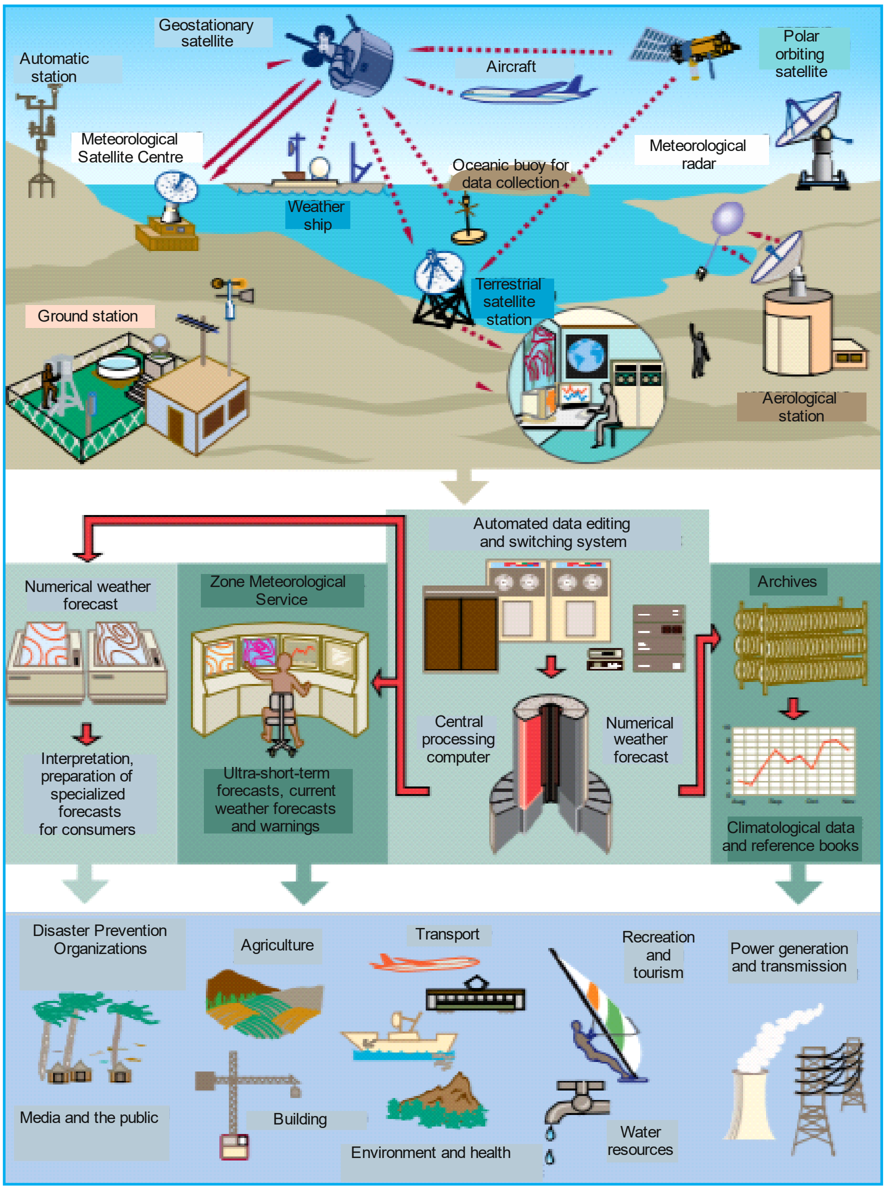

Fig. 2. Principal disaster management systems and organizations [7, 11]

ing system (Fig. 3). Effective international and national satellite data dissemination systems operated by the NMHS provide timely and reliable access to information on weather, water and climate. EVMIN is a wireless computer relay system with a priority orientation for meteorological data transmission, which provides fast satellite transmission of notifications/warnings, forecasts, graphic information and images. This system is free and allows to use inexpensive and affordable technologies.

Maps indicating local hazards play an important role in raising public awareness.

Space and ground-based observations are important for risk assessment, identification, monitoring and early warning of natural hazards (Fig. 4).

So, today's disaster risk management system is:

1. *Real-time hazard monitoring.* An extensive network of observations uses modern technologies and advances in the field of telecommunications. On a round-the-clock basis, its observing tools detect hazards and transmit relevant information.

2. *Advance warnings.* Scientific and technological advances have enabled the development of new hazard warning systems that have not received adequate coverage in the past. And they also contribute to new opportunities to increase advance warnings from forecasts for the coming hours to longer forecasts at the time scale of climate change.

Archival and operational databases support disaster risk assessment, risk prevention, response and response. Historical meteorological and hydrological data are essential for assessing the sensitivity and vulnerability of communities to weather, climate and water hazards. Archival databases play a crucial role in quantifying the intensity and frequency of events, assessing potential damage from extreme events and predicting expected damage by providing future scenarios. Systematic studies of meteorological and hydrological observations of hazards – such as tropical cyclones, severe hurricanes and floods – and their impacts form a valuable knowledge base (KB). This KB can be used by risk management specialists at all levels to enable them to develop effective risk management, prevention strategies to reduce the impact of natural disasters. Effective and timely communication is an essential element of the early warn-

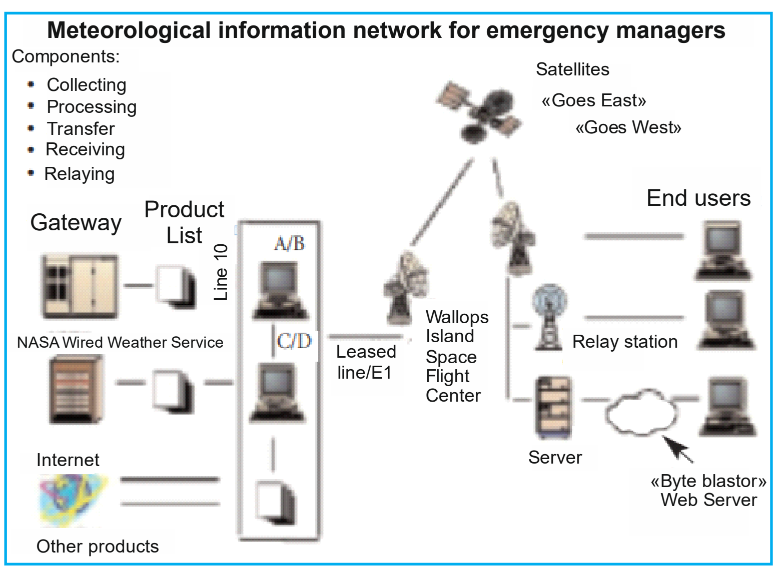

Fig. 3. Effective and timely communication system [7, 11]

3. *Risk assessment tools*. Create easy-to-use risk detection tools, such as digital maps for various hazards, based on technologies that make it easy to update and transmit information. This will allow for the practical use of these tools in decision support systems for disaster risk management at the national, regional and international levels.

4. *Historical climatological data*. Past observations are an essential component of risk assessment, disaster preparedness and early warning.

5. *Expert advice on application of the management system at risk*. Provides expert advice and other necessary technical support on sector-specific disaster risk management issues. This work may include the implementation of observation systems and sector-specific analysis, the identification of early warning methods and their application. May also be implemented through the creation of innovative risk management tools, such as financial instruments used to mitigate or neutralize risks.

6. *Capacity-building and training*. In order to continue to strengthen its capacity-building and training activities, the NMHS, especially in developing countries, is able to better meet their national needs. Cooperation in sector-specific training partner organizations at the international, regional and national levels.

7. *Public awareness* – provide a wide range of products and services for education to raise public awareness of the causes and consequences of natural disasters and how to prevent and mitigate hazards. Public awareness-raising work with the NMHS is particularly effective when carried out before the season of heightened risk of specific weather, climate and water-related disasters.

8. *Global and regional Internet networks*. For example, the WMO-PND website (World Meteorological Organization for the Prediction of Natural Disasters). This site contains links to operational forecasts, notifications and warnings, WMO programmes and networks, their activities and outputs, and other relevant information [13].

Thus, to eliminate technological gaps inaccurate and intelligent monitoring, key characteristics such as an accurate interpretation of comprehensive information about the danger and danger of disasters, which covers all spheres of the Earth – the atmosphere, hydrosphere, lithosphere, biosphere («space – air – earth – sea»), joint processing, rapid analysis and intellectual monitoring are required. A three-dimensional disaster monitoring system with full spectrum, full coverage and multidimensional cooperation is needed to collect disaster information. The risks of disasters associated with climate change and terrestrial processes are becoming more serious. Changes in the intensity and frequency of climate-related disasters also interact with other types of disasters. As before, large-scale, cascading and complex disasters will occur. Their intensity becomes increasingly difficult to predict, increasing the possibility of catastrophic risks. The high degree of dependence of modern society on the most important benefits and networks allows the spread of the impact of disasters through socio-economic systems. Consequently, disaster risk reduction has become a major challenge for many countries. A number of key scientific issues related to disaster preparedness, formation, evolution, prevention, relief and management need to be addressed in order to prevent and reduce disaster risk. There are also technological shortcomings: risk identification, modelling, forecasting and early warning, risk assessment, prevention and control, as well as recovery and reconstruction after natural disasters. Overall, disaster risk should focus on disaster risk reduction in order to improve disaster prevention, mitigation and relief capabilities, as well as risk prevention and management.

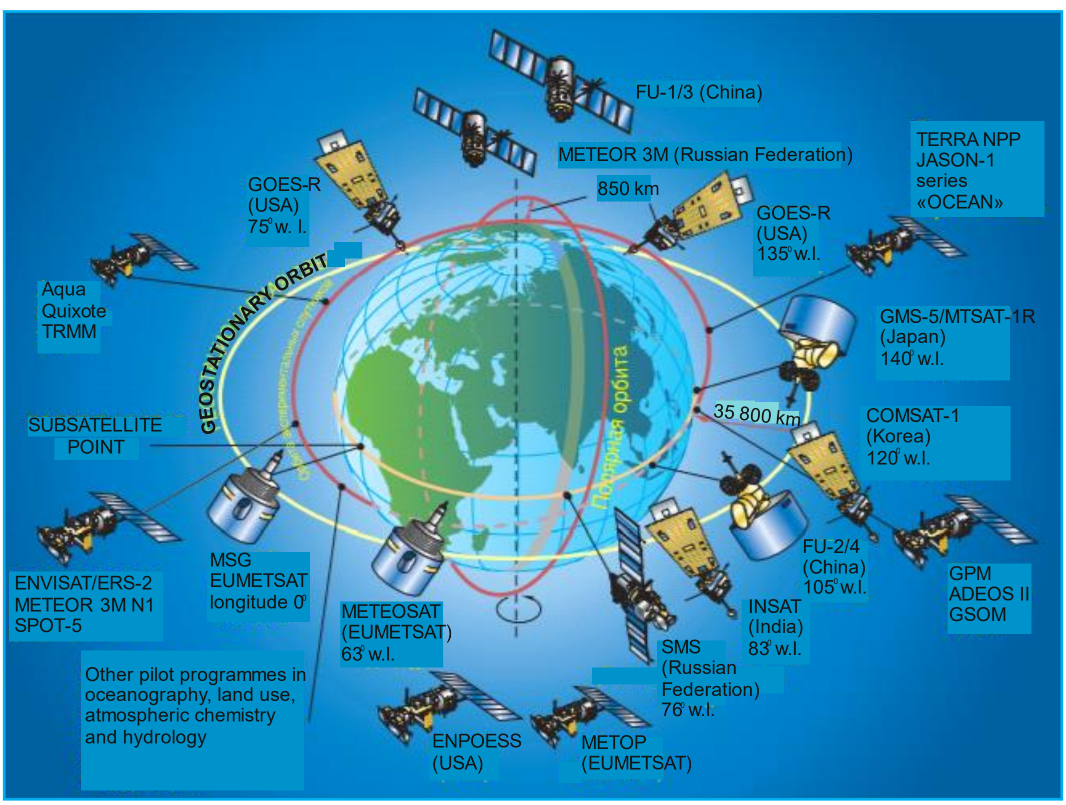

Fig. 4. Space and ground observation system [7]

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In the light of human-Earth harmony and the «Habitable Earth» initiative, disaster risk assessment research has gradually shifted from a semi-quantitative approach based on statistical analysis to a quantitative approach based on hazard formation and movement and from individual hazards to multiple hazards. Forecasting manifestation and influence is an important topic for all hazards, as evidenced by the increasing number of publications and specific programmes of international organizations, such as the WMO project, the Declaration, the Convention, the Road Maps, etc. For most hazardous types, impact prediction is in its infancy, while operational impact prediction systems exist for only a few hazard types, such as heat waves and earthquakes. There is a wide range of impact modeling approaches from a process and complexity perspective, but very simple approaches are often used. Modelling should cover all stages of scenario development from natural disasters to impacts, minimization and mitigation risks.

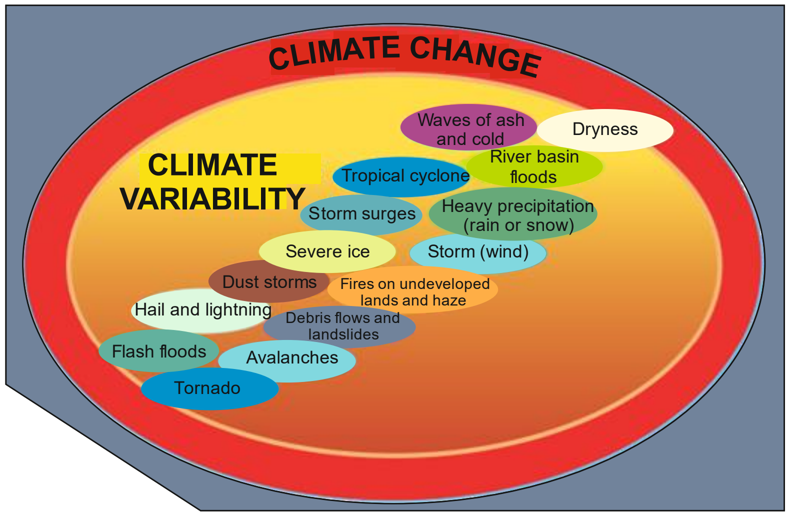

Fig. 5. Integrated system of the forecasts of all hazards ranging from forecasts for the coming hours to projections for the time frame of climate change for [7]

4. Conclusions

The study shows that in the context of global and national observation systems, there are advantages and disadvantages in:

1. Hazard predictions provide information on the physical characteristics of an incident/natural disaster, namely location, time and magnitude of the incident, which predetermines potential threats. However, these systems do not justify a full assessment of the impact, in particular the expected amount and distribution of material damage, human consequences, service disruptions or financial losses.

2. Global and national forecasting and monitoring systems do not provide long-term forecasts, as well as forecasts of certain types of natural disasters – earthquakes, landslides, mudslides, etc. However, a rapid assessment of such phenomena can be performed after they are detected.

Early warning is a critical factor in disaster prevention. One of the most effective disaster preparedness measures is a good-functioning early warning system that can provide accurate and reliable information in a timely manner. In addition to these activities, the main objective of research on weather, climate and water issues is to develop common end-to-end operational systems for early warning of hazards, ranging from forecasts for the coming hours to timescale projections of climate change (Fig. 5).

At the present stage, early warning systems should base their work on:

a) advance, accurate, detailed and understandable forecasts of hazardous conditions;

b) fast and reliable system for the dissemination of forecasts, advisory information, observations and warnings to all interested parties;

c) rapid and effective response to warnings, from the national to the local level.

The conducted study is recommended for the attention of government leaders, risk management professionals in both the public and private sector, organizations at national, regional and international levels and scientific environments. As they are required to take more proactive and concerted action to build capacity to support preventive strategies for disaster risk reduction and mitigation, given the increase in technical and scientific capacities that can be seen year after year, it is evident.

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Leonid Ivanov

ANALYSIS OF THE STATE OF CREATION OF ROBOTIC COMPLEXES FOR HUMANITARIAN DEMINING

The object of research is robotic military complexes used in the system of humanitarian demining. This work aims to study the requirements for robotic military complexes (including manipulators that are sucked into them) and to develop proposals for their use in humanitarian demining. The research is based on the application of a functional approach to the construction of models for the formation of requirements for robotic military complexes (RMC), which are sucked into the system of humanitarian demining. It is established that the creation of RMC requires a significant study of the core of the most important technologies that are needed to create the entire range of promising RMC. Thus the standard sample RMC can be presented in the form of set of functionally connected elements: the basic carrier, the mobile platform, the specialized hinged/built-in equipment in the form of a set of removable modules of useful (target) purpose, means of maintenance and service used at preparation for application and technical operation robot. The composition of specialized equipment is set based on the functional purpose of the RMC. The classification of RMC is given, which provides for their division into three categories: the first generation – controlled devices, the second generation – semi-autonomous devices and the third generation – autonomous devices. The analysis of modern RMC which are developed in Ukraine and the advanced countries of the world and the analysis of structure of components of system of humanitarian demining is carried out. It is established that the organization of the humanitarian demining system with the use of RMC should include of explosive objects (EO) reconnaissance, search, marking, their identification and direct demining. Unmasking signs of EO, as well as modern methods and detectors of EO detection are considered. One of the new promising methods of mine detection is parametric. However, in real application, the most promising is the use of a combination of electromagnetic, optical and mechanical methods. The application of the proposed approaches will increase the efficiency of humanitarian demining and reduce human losses in its implementation.

Keywords: *explosive object, robotic military complexes, humanitarian demining, mobile platform.*

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1. Introduction

All military conflicts are accompanied by the widespread use of anti-personnel mines and explosives object (EO) by the warring parties. One of the problems that countries in all regions where hostilities have taken place or there are military conflicts caused by international and international liberation movements (for example: Iraq, Syria, Afghanistan, the former Yugoslavia, Ukraine, etc.), face the problems of humanitarian demining.

According to a report by the International Campaign to Ban Landmines (ICBL) for 2020, 2019 was one of the most tragic years in terms of mortality from mine explosions in the world. Afghanistan, Colombia, Iraq, Mali, Nigeria, Ukraine and Yemen had the highest deaths from mine explosions. One third (33 %) of deaths from anti-personnel mine explosions in 2019 were recorded in 55 countries that joined the Ottawa Treaty. Anti-personnel mine explosions in 2019 claimed at least 2,170 lives worldwide, another 3,357 people were injured. More than 80 % of mine deaths are civilians, 43 % of whom are children [1].

For example, during the years of the military conflict in Donbass (Ukraine), which began in 2014, it has become one of the most mine and EO-rich areas in the world.