УДК 004.8, 004.032.26
МРНТИ 28.23.00, 28.23.37

DISASTER FORECASTING

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Abstract: *Disasters caused by natural phenomena are a source of tremendous social upheaval that can lead to mass suffering, loss of life, as well as significant material costs. The main factors in increasing the number of natural disasters and natural emergencies include global processes, examples of which are: population growth, degradation and environmental degradation, climate change and others. Obstruction of natural disasters is a key element of a global government strategy aimed at the sustainable development of the economy, as world experience clearly shows: the most effective way to reduce losses from natural, industrial and socio-economic accidents and disasters is to prevent them. The main basis for emergency prevention is monitoring and forecasting. Of course, forecasting emergencies and their socio-economic consequences is based on monitoring and forecasting the sources of emergencies. Accordingly, the fight against natural disasters should be based on the principle of the rational economic use of the territory, as well as forecasting and modeling of potential dangers with the implementation of preventive measures, which requires solving the urgent problem associated with the forecasting of natural disasters in the modern world.*
The main purpose of this article is to create a brief overview of research and the current method of modernity associated with the prediction of natural disasters in order to prevent damage caused by it. The article substantiates the high relevance associated with the object of study, discusses the basic concepts and terms, and explores some forecasting methods that can prevent the potential danger of a natural nature.

Key words: *catastrophes, natural disasters, forecasting, modeling, earthquakes, gravity, GRACE, ionosphere, gravitational anomalies, support vector machine, precursor.*

АПАТТАРДЫ БОЛЖАУ

Аңдатпа: *Табиғи құбылыстардан туындаған апаттар жаппай зардап шегуге, адамдардың қаза табуына, сондай-ақ елеулі материалдық шығындарға әкеліп соқтыратын, орасан зор әлеуметтік күйзелістердің көзі болып табылады. Табиғи катаклизмдер мен табиғи сипаттағы төтенше жағдайлар санының ұлғаюының негізгі факторларына халық санының өсуі, табиғи ортаның тозуы мен нашарлауы, климаттың өзгеруі және басқа да көптеген жаһандық процестер жатады. Табиғи апаттарға кедергі экономиканың тұрақты дамуына бағытталған әлемдік ауқымдағы мемлекеттік стратегияның негізгі элементі болып саналады, өйткені әлемдік тәжірибе бойынша табиғи, техногендік және жалпы әлеуметтік-экономикалық авариялар мен апаттардан болатын шығындарды азайтудың неғұрлым тиімді тәсілі оларды болдырмауды көздейді. Төтенше жағдайлардың алдын алудың маңызды негізі – мониторинг және болжау. Сондай-ақ төтенше жағдайлар мен олардың әлеуметтік-экономикалық салдарын болжау, төтенше жағдайлардың пайда болу себептерін мониторингілеу мен болжауға негізделеді. Осылайша табиғи катаклизмдермен күрес аумақты ақылға қонымды шаруашылық пайдалану қағидатына, сол үшін заманауи әлемдегі табиғи катаклизмдерді болжаумен байланысты өзекті міндетті шешуді талап ететін алдын алу іс-шараларын жүргізумен, әлеуетті қауіптерді болжау мен модельдеуге бағытталуы тиіс.*
Бұл мақаланың басты мақсаты, табиғи катаклизмдердің алдын алу бойынша жазылған зерттеулерге қысқаша шолу жүргізіп және қазіргі заманның өзекті әдісіне сипаттама шолу жасау болып

табылады. Мақалада зерттеу объектісінің өзектілігіне мән беріліп, негізгі ұғымдар мен терминдер қарастырылады, сонымен қатар табиғи сипаттағы қауіптің болу ықтималдығының алдын алу үшін болжаудың кейбір әдістері айқындалады.

Түйінді сөздер: *апат, табиғи катаклизмдер, болжау, модельдеу, жер сілкінісі, гравитация, GRACE, ионосфера, гравитациялық ауытқулар, тірек векторлар машинасы, прекурсор*

ПРОГНОЗИРОВАНИЕ КАТАСТРОФ

Аннотация: *Катастрофы, вызванные природными явлениями, являются источником колоссальных социальных потрясений, способным привести к массовым страданиям, гибели людей, а также существенным материальным затратам. К основным факторам увеличения числа природных катаклизмов и чрезвычайных ситуаций природного характера относятся глобальные процессы, примерами которых являются: рост численности населения, деградация и ухудшение природной среды, изменение климата и другие. Препятствие природным катастрофам является ключевым элементом государственной стратегии в мировом масштабе, направленной на устойчивое развитие экономики, так как мировой опыт наглядно показывает: наиболее эффективным способом снижения потерь от природных, техногенных и вообще социально-экономических аварий и катастроф является их предотвращение. Основной основой предупреждения чрезвычайных ситуаций является мониторинг и прогнозирование. Безусловно, прогнозирование чрезвычайных ситуаций и их социально-экономических последствий базируется на мониторинге и прогнозировании источников возникновения чрезвычайных ситуаций. Соответственно борьба с природными катаклизмами должна основываться на принципе разумного хозяйственного использования территории, а также прогнозировании и моделировании потенциальных опасностей с проведением превентивных мероприятий, которая требует решения актуальной задачи, связанной с прогнозированием природных катаклизмов в современном мире.*

Основной целью данной статьи является создание краткого обзора исследований и актуальных методов современности, связанных с прогнозированием природных катаклизмов с целью предотвращения урона, наносимого им. В статье обосновывается высокая актуальность, связанная с объектом изучения, рассматриваются основные понятия и термины, а также исследуются некоторые методы прогнозирования, способные предотвратить потенциальную опасность природного характера.

Ключевые слова: *катастрофы, природные катаклизмы, прогнозирование, моделирование, землетрясения, гравитация, GRACE, ионосфера, гравитационные аномалии, машина опорных векторов, прекурсор*

Introduction

A huge number of natural processes taking place in the modern world are accompanied by energy conversion, and also serve as a driving force for the constant change in the face of the planet - its geodynamics. The considered natural phenomena are capable of creating and causing destructive disasters on the surface and in the atmosphere of the Earth. Particular examples of such phenomena are: volcanic eruptions, floods, tsunamis, earthquakes, tornadoes, hurricanes and others.

Over the past decades, the number of natural disasters around the world has increased at least 5 times, and the material damage caused by the same phenomena has grown tenfold. The main reasons for this phenomenon are the rapid process of population and economy growth, as well as the characteristic degradation of the natural ecosystem. This fact is due to the fact that the technogenic impact of mankind on the lithosphere is not only able to activate the development of various natural disasters, but also

leads to the emergence of new, already techno-natural disasters.

The management of natural disasters is a key element of the global government strategy for sustainable development. During the development of the "disaster management" program, it is necessary to understand that a person is not able to suspend or reduce the course of evolutionary events and Earth's transformations. A person is capable of predicting or forecasting their development with only a small degree of probability, but sometimes also influencing their dynamics. That is why one of the priorities of the world is the timely forecasting of natural disasters, as well as mitigation of their negative consequences.

Today, there are many data analysis methods developed to predict, detect and develop an appropriate disaster management strategy based on collected disaster data with a detailed description of the availability of data from geological observatories (seismological, hydrological), Earth remote sensing satellites dedicated to solving individual problems, the main purpose of which is the prediction of natural disasters.

1. Earthquake prediction has long been of interest to scientists with the goal of creating timely warning algorithms designed to save lives and reduce economic losses. Each year, more than 20 earthquakes with a power of more than 7 Mw on the Richter scale are observed on our planet. Earthquakes are among the most devastating natural disasters. During the preparation of an earthquake, the dynamic process involves the transfer of energy due to the displacement of the earth's crust, and at the time of impact there is a gap between the source and the environment. The change that precedes or accompanies an earthquake can have different physicochemical effects on the lithosphere, atmosphere, and ionosphere and, accordingly, make it possible to detect it. These variations in the parameters of the lithosphere, atmosphere, and ionosphere before major earthquakes are regarded as a hint of impending earthquakes (earthquake precursors) [Akhoondzadeh et al. 2010]

Over the past few decades, scientists have been able to record and classify the effective parameters of earthquakes through rigorous research. The result of one such research is an article by scientists Mohsen Shahrisvand, Mehdi Akhoondzadeh, Mohammad Ali Sharifi "Detection of gravity changes before powerful earthquakes in GRACE satellite observations"

The relevance of this work is to create an analysis of the gravitational field variations by the authors in order to find disturbances in the vicinity of the epicenters of the recent major earthquakes of more than 8 MW, including Maule Mw 8.8 in Chile (February 27, 2010), Tohoku-Oki Mw 9.0 in Japan (March 11, 2011) and the Indian Ocean with two earthquakes, where the first with Mw 8.6 and the second with a delay of ~ 2 hours, ~ 120 km from the main event with Mw 8.1 (April 11, 2012), in order to ensure reliability of detection of changes in the gravitational field using GRACE data before the earthquake.

For this purpose, the authors of the study used a 10-year time series of the components of the gravitational gradient, obtained from weekly solutions of the gravitational recovery and climate experiment (GRACE). In each case, the authors, using the reported geographical latitude and longitude relative to the epicenter of the earthquake, analyzed the time series of the component of the gravitational gradient (∞Vxx and ∞Vxz) obtained from GRACE measurements several years before the earthquake. They also checked the outer boundary of each epicenter to detect anomalies, since other pre-seismic anomalies (for example, precursors of the ionosphere) are not found in the vertical projection of the epicenter of the earthquake.

The Gravity Restoration and Climate Change Experiment (GRACE) was the first space flight that can measure the temporal variations of the Earth's gravitational field. According to the authors, some of the components of the gravitational gradient are independent in order to compensate for the striped error and enhance the high-frequency components of the gravitational field, so this pre-seismic activity can be better illustrated by GRACE.

The main method for detecting anomalies that the authors used was the Interquartile range of data to construct higher and lower boundaries in time series to detect an external solution beyond the boundaries associated with impending earthquakes. The study showed that weekly time-varying gravity solutions obtained from GRACE satellite data are capable of detecting striking anomalies in the gravitational field near the epicenters of recent major earthquakes that preceded it several weeks before they occur. For this purpose, the authors used weekly global gravitational solutions of level 2 (L2) GeoForschungsZentrum (GFZ, 30 Potsdam RL05), consisting of fully normalized spherical harmonic coefficients, complete to a degree and of the order of 30. In total, they used 448 gravitational field solutions covering the period from the first week of January 2004 to the third week of February 2013. The main reason for the authors to use weekly data instead of monthly decisions was that weekly data show short-term (less than one month) changes in the gravitational field in the seismic field. Also, the flatness of the Earth (C20) has been replaced by satellite laser range (SLR) values due to its accuracy [Cheng and Tapley 2004]. Then, to calculate the gravitational field variations, they subtracted the spherical harmonic coefficients of each individual weekly solution from the average value of the solutions for the period from January 2004 to December 2012.

In this study, the authors showed the effectiveness of integrating the methods of the neural network interquartile and NARX to detect anomalies in the time series of the gravitational gradient. Both of these methods detect significant abnormalities within 2-5 weeks prior to earthquakes. It may be worth mentioning here that ANN was first used in this study to successfully detect anomalies in the time series of gravitational field variations.

The statistics of the results accumulated and described by the authors in the study show that the anomalous deviations before the earthquakes have different signs and amplitudes in different cases, they also found that due to GRACE errors, the analysis of gravitational changes does not show any anomalies before the earthquakes.

The results obtained indicate that the largest deviations from the normal state, which were considered as anomalies, occurred in the time interval of 2-5 weeks before the earthquake. It should be noted that pre-seismic gravitational anomalies before earthquakes can be both positive and negative.

In this study, the authors showed that the anomalies found using applied methods can be associated with three recent large earthquakes, since variations in the gravitational field represented by changes in the gravitational gradient show anomalies several weeks before these earthquakes over several years of data on the region of impending earthquakes .

2. Recent advances in modern technology have allowed the authors Pouria Hajikhodaverdikhan, Mousa Nazari, Mehrdad Mohsenizadeh, Shahaboddin Shamshirband, and Kwok-wing Chau of the article “Earthquake prediction with meteorological data by particle filter-based support vector regression” to learn about the causes and symptoms of earthquake by monitoring the surface of the earth and collecting the necessary data from orbiting satellites [Ikram & Qamar, 2014; Torabi, M., Hashemi, S., Saybani, MR, Shamshirband, S., & Mosavi, A. 2018] in the study and development of the earthquake prediction methodology presented by scientists.

The relevance of this work lies in the creation, by the authors of the article, of demonstrations of earthquake precursors through changes in the ionosphere layer (i.e., the total electron content). For this purpose, the authors of the study conducted a thorough check at the equator. The results of which showed that satellite means can help diagnose precursors in the ionosphere layer from several hours to eleven days before the main impact.

Precursor, as one of the most important parameters, represents a change in the concentration of radon gas in the earth's crust released by faults. The measurement and comparison of this predecessor requires the installation of appropriate equipment in the

immediate vicinity of faults. The extraction of this gas and its lead ions will create additional precursors in the atmosphere. Thanks to the intelligent analysis of such historical meteorological data sets that are measured and recorded in most parts of the world, earthquakes can be predicted. Precursors can be divided into several categories from the point of view of the scientific field necessary for review and analysis, such as changes in the amount of radon gas in groundwater, changes in temperature in groundwater, changes in groundwater, foreshock before the main earthquake, magnitude of foreshock, number of foreshocks, absence earthquakes in areas, including foreshocks due to a fault, on clouds due to the reaction of atmospheric gases with leaded ions released from radon gas, changes in air temperature and pressure, wind speed, changes in relative humidity, bird flutter and rain worms outflow.

To predict the magnitude and number of earthquakes in this study, the authors used regression based on a particle filter and support vector machine. To assess the validity of the proposed method, they compared the obtained results with a multilayer perceptron neural network and a reference regression vector. The proposed method showed a relationship between climate data and the occurrence of earthquakes, which led to an accuracy of 96% for predicting the average magnitude of earthquakes and high accuracy of 78% for the expected number of earthquakes per month. The accuracy of the method was measured by the correlation coefficient.

Any parameter that changes before the earthquake is called a “precursor”, since this phenomenon can be predicted by studying, measuring and finding the relationship between them and the earthquake. The authors of the article have identified and evaluated more than 30 earthquakes and harbingers of this phenomenon. The data used in this study by the authors were extracted from two Iranian climate database data from the meteorological center of the Islamic Republic of Iran (www.irimo.ir) and seismic data from the Iranian Seismological Center (www.irsc.ut.ac.ir) during 2006-2014 the region under consideration was in Tabriz in the range of 37-39 ° latitude 45-48 ° longitude, Tabriz is located on the active fault northwest of Iran. In this study, seismic data included the number and magnitude of earthquakes, and meteorological data included average temperature, maximum temperature, minimum temperature, average wind speed and rainfall.

The support vector machine (SVM) as one of the methods of supervisory training used for classification and regression, according to the authors, is more efficient than other ANNs, such as perceptron neural networks. The goal of SVM is to find a hyperplane that completely shares the dataset. The performance of the regression of the reference vector depends on its parameters and data set. The correlation between the regression parameters of the reference vector and the data can affect the model, therefore, parameter estimation is an important and necessary process to achieve strong correlation.

The particle filter method was used by the authors in the study to optimize the performance of the regression of the support vector machine. The model used can increase the accuracy of forecasting the magnitude and number of expected earthquakes during the month with an accuracy of 96% for the average earthquake and more than 78% for the number of earthquakes, which led to a decrease in the accuracy in the number of earthquakes due to seismic disturbance in November 2013. More than 477 earthquakes occurred in the study area, which may be due to a human error in data recording. This study could demonstrate the relationship between meteorological data and the occurrence of an earthquake and predict it in terms of the quantity and magnitude of the earthquake using the proposed method based on artificial intelligence with high accuracy.

Also, the database of this study was limited to monthly data; when accessing daily data, the proposed method was probably capable, according to the authors, of identifying the results within the diurnal range.

3. Over the past decades, the problem of predicting natural disasters has occupied and continues to occupy a leading place in the

field of priorities for solving contemporary problems. Today, there are many dissertations, books, textbooks, monographs, articles and not only dedicated to solving individual problems, the main purpose of which is the prediction of natural disasters.

Achieving an effective result requires the development and implementation of a set of specific measures aimed at forecasting and monitoring negative natural phenomena, as well as reducing the danger to the population at all levels of government. In the dissertation of Kolesenkova A.N.: "The system of information support for management decision-making procedures for the prevention of emergency situations: the dissertation of the candidate of technical sciences. HAC RF 05.13.10. 2012" a more detailed study is made of the issue related to the analysis and solution of the problems of the monitoring and forecasting system of natural and man-made emergencies.

The relevance of the author's work is emphasized by the fact that on the territory of the globe there are many production facilities of high risk, which can pose a threat to the life and health of people in case of emergency situations. That is why it is necessary to create an effective system capable of timely and uninterrupted forecasting of technological disasters.

The aim of the work is to reduce the risk of exposure to potentially dangerous objects of technogenic and natural factors using a monitoring system that allows for information support of the development and implementation of measures for the timely forecasting, identification and prevention of threats and crisis situations in relation to potentially dangerous objects.

The author emphasizes that monitoring refers to a system of continuous monitoring of phenomena and processes occurring in nature and the technosphere, designed to anticipate potential threats to people and their environment. The key task of monitoring risks and processes in nature is to increase the accuracy and reliability of forecasting emergencies by combining the intellectual, information and technological capabilities of various departments and organizations involved in monitoring certain types of risks. The obtained data on natural processes and phenomena during monitoring serve as a basis for forecasting in the developed system.

The scientific novelty of the work lies in the creation of a technology that combines multi-time images for operational monitoring of potentially dangerous objects, the use of three-dimensional means for displaying potentially dangerous objects, and the development on this basis of a geoinformation system for monitoring and preventing natural and man-made emergencies.

The scientific and practical value of the results of the dissertation research lies in the fact that on the basis of the created automated system for monitoring and forecasting emergencies of a natural and technogenic nature, it is possible to increase the effectiveness of the assessment and forecast of crisis and emergency situations, as well as reduce human and material losses.

In work "E.I. Ponomarev, E.G. Shchvetsov, N.D. Yakimov, K.Yu. Litvintsev, O.I. Ponomarev: Monitoring and forecasting the characteristics of natural fires // Monitoring, modeling and forecasting of dangerous natural phenomena and emergency situations. 2017" the issue of forecasting one of the most significant, as well as causing tremendous economic losses of natural disasters, like fires, is being studied.

The relevance of this problem is confirmed by the fact that in modern conditions there is a tendency in increase the level of forest burnup around the world. The first decade of the 21st century was characterized by an increase in the frequency of fires and areas that are subjected to pyrogenic exposure annually. The authors emphasize that the study, understanding and forecasting of fire regimes requires the use of objective means of control, long-term monitoring of materials, a wide range of attribute information, including spatial and temporal reference of fires and information about their energy characteristics. In the modern range of fire processes, these data can only be obtained on the basis of long-term satellite observations.

The main goal of this work was the creation of a geospatial analysis of combustibility in Siberia and the generalization of fire parameters

recorded for various conditions based on data from a 20-year satellite monitoring.

In conclusion, the following results were obtained: in particular, the characteristic time intervals necessary for the implementation of a certain stage of the fire were evaluated. So the initial stage lasts 70-120 hours, the phase of exponential growth of the fire area has a characteristic time in the range of 150-275 hours, then within 45-65 hours, as a rule, the logarithmic attenuation of the field growth rate occurs. The obtained indicators have rather large differences in values, and the variance reaches up to 40% of the absolute values. However, the dynamics of the fire area can be calculated at any time, since the range of acceptable values is determined and limited by model curves that are similar in appearance to the normal distribution function. It should be noted that the obtained time intervals and the model curve describing the maximum value of the dynamics of the increment of the area are applicable for cases of fires that develop in rural areas under natural conditions.

It was also noted in the work that another urgent direction is solving the problems of analyzing the dynamics of fires and developing methods for predicting the characteristics of fires.

The article “Plotnikov D.S., Safonova N.L. Prediction and prevention of natural disasters and man-made disasters using space monitoring systems // Problems of ensuring safety in emergency response. 2015 ” is devoted to the main issues of forecasting natural disasters based on the use of space monitoring systems.

The relevance of the use of aerospace technology is due to high efficiency and mobility in the production of images, as well as their current analysis and prediction of potential hazards in the future. The authors declare that the main tasks of the work of aerospace systems are daily global monitoring of the country's territory with high frequency and low resolution, as well as emergency optical and all-weather radar surveys of a given area from medium, high and ultra-high resolution spacecraft to predict and mitigate emergencies. The main advantage of aerospace systems, as the authors of the work, is the ability to work in real time with satellite images as a source of objective and relevant data.

In conclusion, the fact that in the current decade operational space-based monitoring of emergency situations was able to form as an independent area of space geoinformatics and continues to develop rapidly, which is facilitated by progress in space and information technologies, is cited.

Conclusion

Finishing this work, it should be noted that in recent decades dangerous trends have been outlined associated with the development of natural phenomena, caused to a greater extent by the growth of the population and economy of terrestrial civilization. The tremendous increase in the number of irreversible catastrophic events, including those of techno-natural origin, singles out the assessment and development of methods of dealing with natural phenomena and cataclysms as a task of national priority on a global scale.

Effective risk management and forecasting natural disasters is based on the current level of knowledge regarding natural phenomena, the systematic organization of monitoring hazardous processes, an adequate culture of economic activity, as well as the adoption of appropriate management measures at different levels of government. The risk management strategy must be implemented in all projects and investment programs related to such areas as: construction, education, social security, healthcare and others.

The main goal of this work was to create a review of current methods and research of the present, related to the prediction of natural disasters. During the writing of the work, the relevance of the tasks associated with earthquake prediction was studied in more detail, and the proposed methods and solutions aimed at creating effective and rational means of monitoring and predicting natural disasters were investigated.

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