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Monitoring and prediction of natural disasters(*)

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Summary. — The problems of natural disaster predicting and accomplishing a synthesis of environmental monitoring systems to collect, store, and process relevant information for their solution are analyzed. A three-level methodology is proposed for making decisions concerning the natural disaster dynamics. The methodology is based on the assessment of environmental indicators and the use of numerical models of the environment.

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1. – Introduction

In the process of the civilization development, problems of forecasting future environment changes and relevant changes in the living conditions for people have become most important. The first problem of interest is the origin and propagation of dangerous natural phenomena which lead to losses of living beings and cause serious economic damage [1-44]. Such phenomena are called natural disasters [16]. In the course of evolution, natural anomalies of different spatial and temporal scales are known to have played an important role in the evolution of nature as mechanisms of natural systems regulation. Such anomalies can be exemplified by forest fires [22]. With development of industry and growth of population, these mechanisms have suffered substantial changes and reached a level of life threat [35, 39]. This is, first of all, connected with the growth and propagation of anthropogenic forcings in the environment. Numerous relevant studies have

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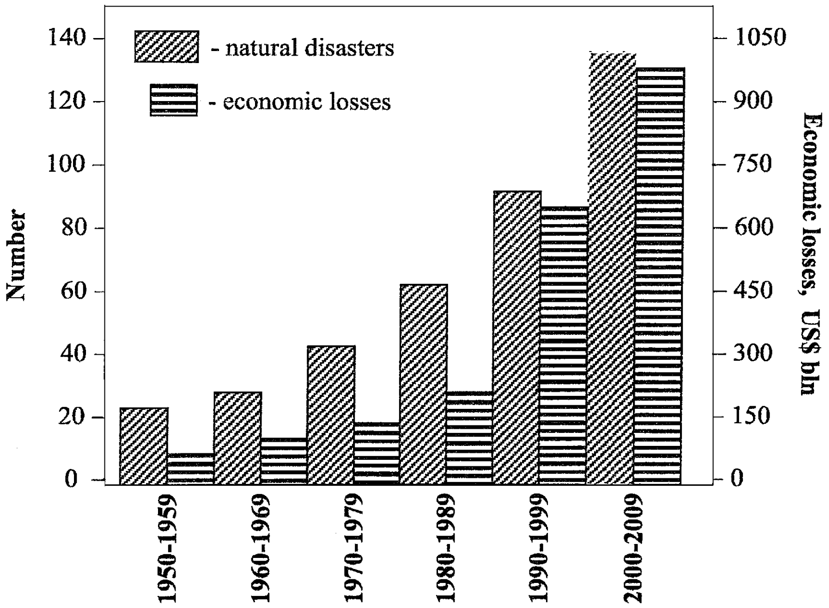

Fig. 1. – Dynamics of large-scale natural disasters and economic losses during six decades (1950-2009) [36].

been recently conducted [1-44]. They show that the frequency of disastrous phenomena in nature and their scale have grown (fig. 1) increasing the risk of losses in economy and human lives and violating social infrastructures. So, for instance, only in 2001 about 650 natural disasters occurred taking away the lives of more than 25 thousand people and causing damage reaching more than 35 billion dollars. The consequences of disasters depend mainly on readiness of the territory to reduce the risk of losses and change substantially in time. For instance, in 2002, with the same number of large-scale disasters ($\sim$ 700), 11 thousand people perished, with economic damage estimated at 55 billion dollars. The heaviest losses are caused by floods. The spatial distribution of disasters is strongly heterogenous. For example, the amount of human victims in 2002 is characterized by the following figures: Africa—51 catastrophes (661 people died), America—181 (825), Asia—261 (8570), Australia and Oceania—69 (61), Europe—136 (459) [16].

Natural disasters can be classified into different categories. Large-scale disasters include environmental phenomena that cause the death of thousands of people and ruin their dwellings with an accompanying economic damage to a given region. Hence, the scale of natural disasters depends on the level of economic development of the region that determines the degree of people's protection from natural disasters. Therefore studies of phenomena connected with natural disasters should be followed by analysis of the population poverty level for a given region. The results of studies accumulated during the last 25 years show that in developing countries the scale of losses from natural disasters is much larger than in the economically developed countries. Bearing in mind that during the last decade the number and scale of natural disasters substantially increased, it becomes clear what should be expected in the nearest future. Therefore the forecast of and warning about crisis phenomena on a global scale should be a subject to worry about for all countries, independent of their economic development.

At present the theory of environmental disasters and analysis of risks are well developed [6]. Their application to the description of events and processes in the actual environment requires a study of methods of the system analysis for synthesis of a global model of the nature-society system (NSS) with the use of technical means of the spaceborne monitoring. Solution of the relevant problems is the subject of ecoinformatics which ensures a combination of analytical simple, semi-empirical and complex non-linear models of ecosystems with the renewed global data bases [17]. Many international and national programmes on environmental-problem and space-oriented studies have recently raised the level of thematic coordination in order to reach a needed level of efficiency. For instance, it is true for the programmes Global Carbon Project (GCP) and Earth Observing System (EOS) within which most efficient information and technical means of assessment and prediction of the NSS dynamic characteristics have been concentrated.

The development of constructive methods to predict natural disasters requires a solution of some problems:

– Adaptation of ecoinformatics methods as applied to the problem of diagnostics and prediction of natural disasters in all their variety and on all scales.

– Determination of statistical characteristics of natural disasters in their historical aspect, selecting categories and determining spatial and temporal scales of catastrophic changes in the living beings' habitat. Analysis of the history of disasters is important for understanding the present dependences between crises both in nature and in society. The statistical characteristics of natural disasters in their dynamics enable one to formulate the basis of mathematical theory of catastrophes and to determine the first-priority directions of studies.

– Development of the concept and the synthesis of the model of survival to use it for assessing the effect of natural disasters on the humans' habitat.

– Study of the laws of interaction between various elements and processes in the global NSS in interrelation with such a notion as biological complexity of ecosystems (biocomplexity) considering it as a function of biological, physical, chemical, social, and behavioural interactions of the environmental subsystems including living organisms and their communities. The notion of biocomplexity is connected with the laws of the biospheric functioning as a totality of its forming ecosystems and natural-economic systems of different scales, from local to global. In this connection, it is necessary to give a combined formalized description of biological, geochemical, geophysical and anthropogenic factors and processes taking place at a given level of the spatial-temporal hierarchy of units and scales. It is also important to assess possibilities to use various indicators of an approaching natural disaster, such as, for instance, biocomplexity.

– Study of relationships between vitality, biocomplexity and evolution of NSS with the use of the global modelling technology. Development of the units of the global model, describing the laws and trends in the environment, which lead to an appearance of stress situations and are initiated by human economic or political activity.

– Consideration of demographic premises for the origin of natural disasters and determination of mechanisms that govern the environment and hinder a realization of these premises.

– Assessment of the information content for the existing technical means of data collection on the state of NSS subsystems and available global data bases to allocate them in solving the problems of assessing conditions of the origin of stress situations in the environment.

2. – Natural disaster as a dynamic category of the environmental phenomena

Walker [43] has justly noticed that the notion of natural disaster is rather vague, and its definition depends on many factors. Kondratyev and Grigoryev [16] define a natural disaster as an "extreme and calamitous situation in the vital activity of population caused by substantial unfavourable changes in the environment" or as "abrupt changes in the system as its sudden response to smooth changes of external conditions". The number of such critical situations in the environment grows. At present, natural disasters are floods, droughts, hurricanes, storms, tornadoes, tsunami, volcanic eruptions, landslides, mudflows, snow avalanches, earthquakes, forest fires, dust storms, bitter frosts, heat waves, epidemics, locust invasions, and many other natural phenomena [7-16, 32, 43]. In the future, this list can be broadened at the expense of new types of natural disasters, such as collisions with cosmic bodies and those caused by man—bio-terrorism, nuclear catastrophes, abrupt changes in the Earth's magnetic field, plague, robots' invasions, and others. Therefore it is important to develop efficient quantitative technologies and criteria which would warn with a high reliability about a dangerous catastrophic natural phenomenon.

The notion of a natural disaster is associated by many authors with the notion of ecological safety which appeared in connection with the necessity to assess the danger for population of a given territory to injure health, buildings or property as a result of changes in the environmental parameters. These changes can be caused by fluctuations in natural processes connected with the changing ecological situation, epidemics or calamity. In the latter case the danger appears as a response of nature to human activity. For instance, having analyzed the environmental changes in the Himalayas, in the territory of India, Gardner [13] came to the conclusion that such factors as deforestation and changes in vegetation cover became causes and amplifiers of instability in this region characterized by degradation of soil resources and growth of consequences of the environmental destruction by water flows. Field and Raupach [11] explain changes in the laws of natural disasters occurrence by the growth of instability in the system "carbon-climate-man". According to [12], this instability can enhance substantially in the nearest two decades due to changes in many characteristics of the World Ocean's ecosystems. Analyzing the history of various large-scale disasters, Milne [31] gives a pessimistic prognosis with respect to the fate of humankind, using the notion of "doomsday".

In general, a threat of an ecological danger in a given territory results from deviation of the environmental parameters beyond limits where after a long stay a living organism starts changing in the direction not corresponding to the natural process of evolution. As a matter of fact, the notions of "ecological danger" or "ecological safety" are connected with the notions of stability, vitality and integrity of the biosphere and its elements [16-19]. Moreover, the NSS, being a self-organizing and self-structuring system and developing by the laws of evolution, creates within itself ecological niches whose degree of acceptability for population of a given territory is determined, as a rule, by natural criteria (ambient air standard, religious dogmas, national traditions, etc.).

When considering the prospects for life on Earth, one should proceed from human criteria of assessing the levels of the environmental degradation because in due course, local and regional changes in the environment are developing into global ones. The amplitudes of these changes are determined by mechanisms of NSS functioning which provide optimal changes in its elements. Humankind more and more deviates from this optimality in its strategy of interaction with surrounding inert, abiotic and biotic components of the environment. But at the same time, humankind as an NSS element tries to understand the character of large-scale relationships with nature, directing efforts of many sciences to this aim and studying the cause-and-effect relations in this system [18].

The human habitat is a complicated dynamic system. Its stability in time is connected with the structural regularity, material composition and energy balance as well as with stability of its response to the same external forcings. The system's stability can be broken as a result of both passive and active external forcings. In other words, under present conditions, nature N and human society H constituting a single planetary system and having a hierarchical structure ($|N|$, $|H|$), interact pursuing their aims (N, H). Formally, this interaction can be considered as a random process $\eta(x,t)$ with an unknown law of distribution, representing the level of tension in relationships between sub-systems N and H or assessing the state of one of them. Here $x = \{x_1, \ldots, x_n\}$ is a set of identifying characteristics of subsystems N and H which are components of a possible indicator of the origin of a natural disaster, that is, a deviation of $\eta(x,t)$ beyond the limits where the state of the subsystem N becomes a threat to H. Hence, the aims and behaviour of subsystems N and H are functions of the indicator η, depending on which, their behaviour can be antagonistic, indifferent or cooperative. The main objective of the subsystem H is to reach a high living standard with the long comfortable life guaranteed. The goal and behaviour of the subsystem N are determined by objective laws of co-evolution (in this context, one should concentrate on the concept of biotic regulation of the environment [20]). In this sense, a division between N and H is conditional, and it can be interpreted as a division of a multitude of natural processes into controlled and non-controlled. Clearly, with the growing population density, natural disasters will intensify the feeling of discomfort, affecting the social and cultural conditions in many regions.

Without getting deeper into philosophical aspects of this division, we assume the subsystems N and H to be symmetric and open. The system H disposes of technologies, science, economic potential, industrial and agricultural enterprises, sociology, size of population, and others [27]. The N-H interaction leads to a change in η, the level of which affects the structure of vectors $\mathbf{H}$ and $\mathbf{N}$. In fact, there is a threshold for $\eta_{\max}$, beyond which humankind ceases to exist, but nature survives. Asymmetry of subsystems H and N in this sense causes changes in the goal and strategy of the system H. Apparently, under present conditions of these systems' interaction, η approaches $\eta_{\max}$ rather rapidly, and therefore some components of the vector $\mathbf{H}$ can be attributed to the class of cooperative components. Since the present socio-economic structure of the world is presented with a totality of states, it is reasonable to consider a country as a functional element of the system H. The $\eta(x,t)$ function reflects the result of interaction between countries and with nature. A totality of results of these interactions can be described with a matrix $B = ||b_{ij}||$ each element of which has a symbolic semantic load:

$$b_{ij} = \begin{cases} + & \text{for the cooperative behavior,} \\ - & \text{under the antoganistic interaction,} \\ 0 & \text{for the indifferent behavior.} \end{cases}$$

Many theories are dedicated to studies of the laws of interaction of complex systems

TABLE I. – *A description of the NSSGM units.*

Unit identifier (see fig. 3)	Characteristic of the unit's functions
DEM	A set of demographic models that parameterize the population dynamics with the consideration of the age structure.
CLI	A set of climate models with various spatial resolutions.
MRE	Model of the mineral resources control.
AGR	Model of agriculture production.
MSTP	Model of the scientific-technical progress.
DAT	Control of the interface between the NSSGM units and database.
CON	Adjustment of the NSSGM units to the simulation experiment conditions and its control.
REP	Preparation of the simulation experiment results to visualized or other forms of reporting.
MBWB	Model of the biospheric water balance.
MGCDC	Model of global biogeochemical carbon dioxide cycle.
MGSC	Model of global biogeochemical sulphur cycle.
MGOC	Model of global biogeochemical oxygen and ozone cycles.
MGNC	Model of global biogeochemical nitrogen cycle.
MGPC	Model of global biogeochemical phosphorus cycle.
POL	A set of models of the kinetics of some types of pollutants in different media.
BIO	A set of models of the aquatic ecosystems in different climatic zones.
HYD	Model of hydrodynamic processes.
SPF	A set of models of the soil-plant formations.
MAG	Model of processes in the magnetosphere.

of various nature. In the asymmetric case considered here it is a matter of the system H survival and attempt to find means to assess the future dynamics of the system N. According to [37], the reflexive behaviour of H will eventually help to humankind to find a behavioural pattern able "to compare advantages and danger, to understand principal limitations of our capabilities and in good time to recognize new threats.

3. – The NSS global model as an instrument to predict natural disasters

In connection with various aspects of environmental changes during the last decades, many authors have brought forth numerous concepts of the NSS global dynamics and created models of different complexity to parameterize the dynamics of biospheric and

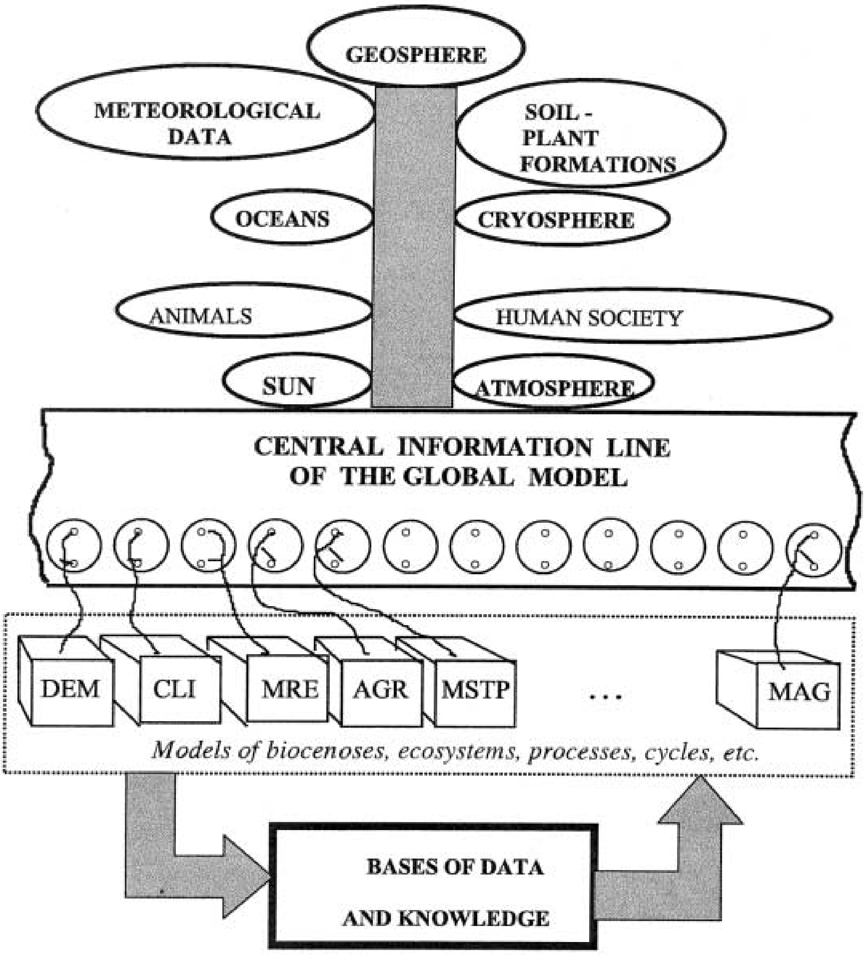

Fig. 2. – Organization of the global model of the Nature-Society system's functioning (see notations in table I).

environmental characteristics [18,21,24]. Availability of a large data base on these characteristics enables one to consider and evaluate the consequences of a possible realization of various scenarios of the development of the subsystem H. Traditional approaches to the synthesis of global models are based on consideration of a set of balance equations which contain parameters $\{x_i\}$ as functions, arguments, coefficients and conditions for transition between parametric descriptions of the processes in the environment. Other approaches are also applied, which use the evolutionary and neuronet algorithms [17]. The global model of the $N \cup H$ system's functioning can be presented in the form of a conceptual scheme in fig. 2. This scheme is realized though an introduction of the geographic grid $\{\varphi_i, \lambda_j\}$ with the step of discretization of the land and World Ocean surface $\Delta\varphi_i$ and $\Delta\lambda_j$ in latitude and longitude, respectively, so that within a pixel $\Omega_{ij} = \{(\varphi, \lambda) : \varphi_i \leqslant \varphi \leqslant \varphi_i + \Delta\varphi_i, \lambda_j \leqslant \lambda \leqslant \lambda_j + \Delta\lambda_j\}$, all processes and elements of NSS are assumed to be homogeneous and are parameterized by point models. The choice of pixels' sizes is determined

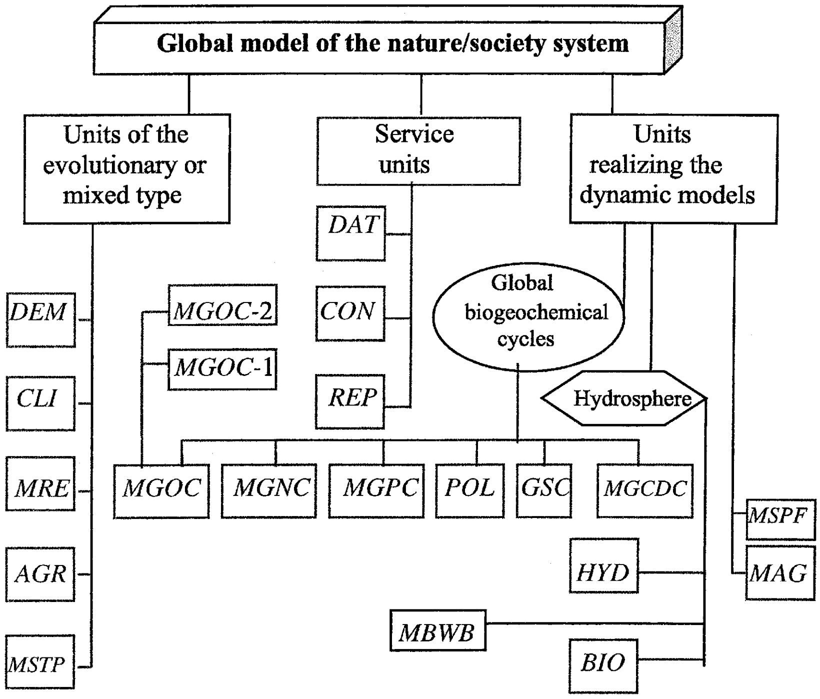

Fig. 3. – The block-scheme of the NSS global model (NSSGM) (see notations in table I) [19].

by conditions governed by spatial resolution of space-derived observational data and the availability of the needed global data base [9, 19]. In the case of water surface, in the Ω_j pixel there takes place a division of water mass into layers by depth z, that is, 3D volumes are selected $\Omega_{ijk} = \{(\varphi, \lambda, z) : (\varphi, \lambda) \in \Omega_{ij}, z_k \leqslant z \leqslant z_k + \Delta z_k\}$ within which all elements are uniformly distributed. Finally, the atmosphere over the Ω_{ij} by the height h is digitized either by levels of atmospheric pressure or by characteristic layers Δh_s.

It is clear that the global model can only be created with the use of knowledge and data on an interdisciplinary level. Among many global models, one of the most sophisticated is the model described in [19]. The block-scheme of this model is shown in fig. 3.

An adaptive procedure has been proposed [17] to build the global model within the geoinformation monitoring system. This procedure is schematically demonstrated in fig. 4.

4. – Search and detection of natural disasters

An approaching of the moment of the origin of a natural disaster is characterized by the vector $\{x_i\}$ getting into some cluster of the multidimensional phase space X_{ij}. In other words, proceeding from verbal reasoning to a quantitative estimation of this process, we introduce a generalized characteristic $I(t)$ of a natural disaster and identify it with the calibrated scale Ξ, for which we postulate the presence of relationships of the type $\Xi_1 < \Xi_2$, $\Xi_1 > \Xi_2$ or $\Xi_1 = \Xi_2$. It means that there always exists a value of $I(t) = \rho$ which determines when a natural disaster of a given type can be expected: $\Xi \to \rho = f(\Xi)$, where f is some conversion of the notion of "natural disaster" into a

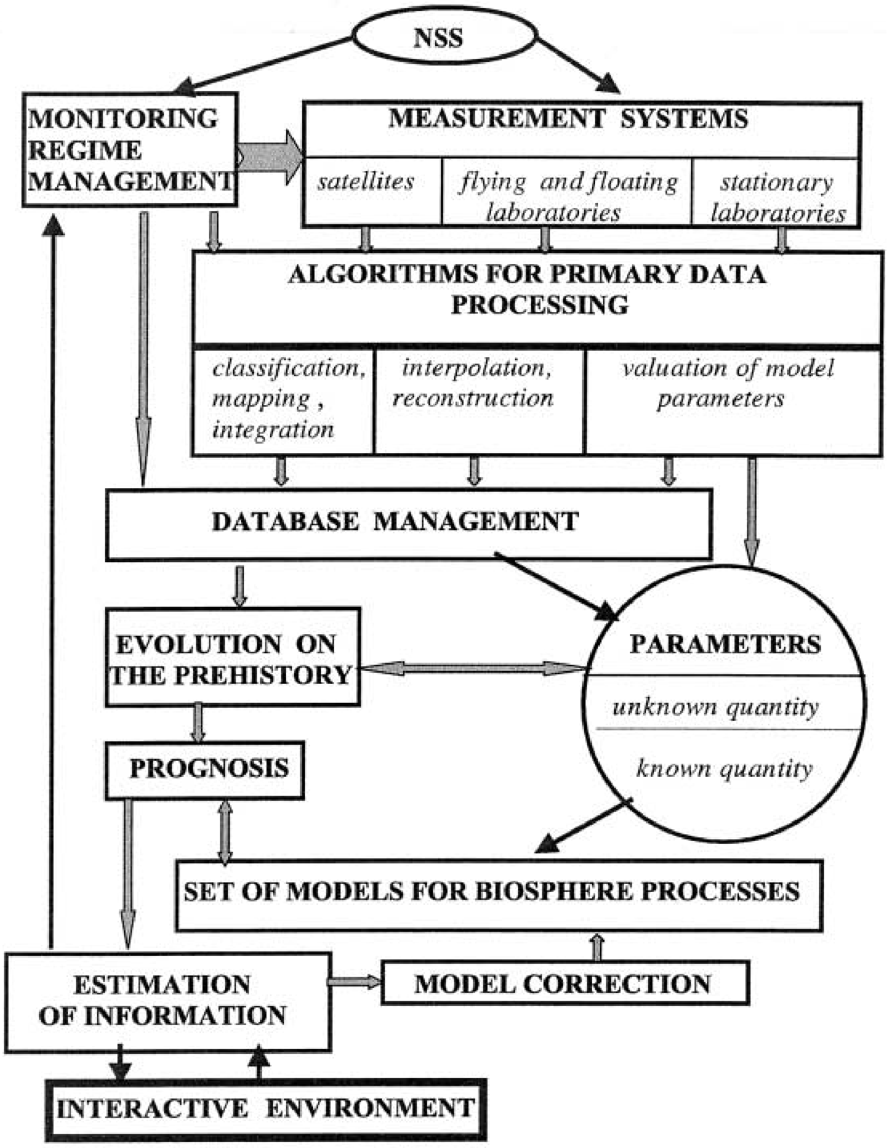

Fig. 4. – The concept of an adaptive adjustment of the NSSGM under conditions of the geoinformation monitoring.

number. As a result, the magnitude $\theta = |I(t) - \rho|$ determines the expected time interval before the catastrophe occurs.

Let us search for a satisfactory model to transform the verbal portrait of a natural disaster into notions and indicators subject to a formalized description and transformation. With this aim in view, we select m of elements-subsystems of the lowest level in the $N \cup H$ system, an interaction between which we determine with the matrix function $A = ||a_{ij}||$, where a_{ij} is an indicator of the level of dependence of relationships between

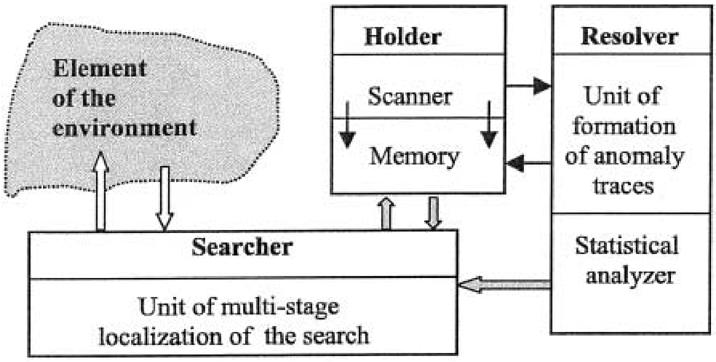

Fig. 5. – Block-scheme of the monitoring system to detect natural anomalies in the environment [25].

subsystems i and j. Then the $I(t)$ parameter can be estimated as the sum

$$I(t) = \sum_{i=1}^{m} \sum_{j>i}^{m} a_{ij} \, .$$

In general, we have $I = I(\varphi, \lambda, t)$. For a limited territory Ω with an area σ the indicator I is defined as an average value:

$$I_\Omega(t) = (1/\sigma) \int_{(\varphi,\lambda)\in\Omega} I(\varphi, \lambda, t) \mathrm{d}\varphi \mathrm{d}\lambda \, .$$

An introduction of the characteristic I_Ω enables one to propose the following scheme of monitoring and predicting natural disasters. Figure 5 demonstrates a possible structure of the monitoring system with functions of searching, predicting, and monitoring a natural catastrophe. There are three levels in the system: recorder, decision maker, and searcher, whose units have the following functions:

1) regular control of the environmental elements to accumulate data about their state in the regime permitted by the applied technical means;

2) recording suspicious elements of the environment for which the value of the indicator $I_\Omega(t)$ corresponds to the interval of a natural anomaly danger of a given type;

3) formation of the dynamic series $\{I_\Omega(t)\}$ for a suspicious element to make a statistical decision about its noise or signal character and in the latter case the test of the suspicious element by criteria of the next level of accuracy (getting of the $\{x_i\}$ vector into the cluster, etc.);

4) making the final decision about the approaching moment of a natural catastrophe occurrence with the transmission of information to the respective environmental control services.

5) iterative procedure to locate an anomaly.

An efficiency of such a monitoring system depends on parameters of the technical measuring means and algorithms for observational data processing. Here of importance is the model of the environment used in parallel to the formation and statistical analysis of the series $\{I_\Omega(t)\}$ and adapted to the regime of monitoring according to the scheme in fig. 4.

As seen from the introduced criterion of an approaching natural catastrophe, the form and behavious of $I_\Omega(t)$ are special for each type of the processes in the environment. One of the complicated problems consists in determination of these forms and their respective classification. For instance, such frequent dangerous natural events as landslips and mudflows have characteristic features, such as preliminarily changing relief and landscape, which are successfully recorded from satellites in the optical range, and together with data of aerial photography and surface measurements of relief slopes, exposition of slopes and the state of the hydro-system make it possible to predict them several days beforehand. However, restricted capabilities of the optical range under conditions of clouds or vegetation cover should be broadened by introducing the systems of remote sounding in the microwave region of the electromagnetic spectrum. Then, in addition to the indicators of landslips and mudflows, one can add such information parameters as soil moisture and biomass, since a soil moisture increase leads to landslips, and an enhancement of biomass testifies to the growth of the restraining role of vegetation cover with respect to the dislocation of mountain rocks. It is especially important when controlling the snow-stone or snow avalanches. Compiling the catalogue of these indicators for all possible natural disasters and introducing it into the information base of the monitoring system is a necessary stage of raising its efficiency.

Knowledge of a set of information indicators $\{x_i^j\}$ of a natural catastrophe of the j-th type and *a priori* determination of its cluster X^j in the space of these indicators makes it possible in the process of the space-borne monitoring to calculate the rate v_i of the approaching of the point $\{x_i^j\}$ to the center of X^j and thus to calculate the time of the catastrophe occurrence. Other algorithms for predicting natural disasters are also possible. For instance, a forest fire can be predicted using the dependence of microwave emission of forest at different wavelengths on the moisture content of the inflammable materials in the forest, being stratified as a rule. Knowledge of this dependence gives a real possibility to assess the fire risk in the forest with the moisture content of vegetation cover and upper soil layer taken into account [24].

Many studies have shown that there is a real possibility to assess the fire risks of waterlogged and boggy forests considering the water content of vegetation cover and the upper soil layer, using the microwave sounding in the range 0.8–30 cm. The multichannel sounding makes it possible with the use of algorithms of cluster analysis to solve the problem of classification of forests by categories of fire risks. The efficiency of these methods depends on a detailed simulation of the forest structure reflecting the state of canopy and threes' density. The low fires are most dangerous and difficult to detect. In this case a 3-layer model of the system "soil-trunks-canopy" [22] agreed-upon with the fire-risk indicator $I(\lambda_1,\ \lambda_2) = [T_b(\lambda_1) - T_b(\lambda_2)]/[T_b(\lambda_1) + T_b(\lambda_2)]$ is efficient. For instance, at $\lambda_1 = 0.8$ cm and $\lambda_2 = 3.2$ cm the indicator I changes approximately from -0.25 in the zone of the absence of the danger of forest fire to 0.54 in the zone of fire. In the zone of appearance of first indicators of the litter catching fire, $I \sim 0.23$. The I value depends weakly on the distribution of the layers of the forest inflammable materials such as lichen, moss, grass rags, dead pine-needles or leaves.

A realization of this 3-layer regime of decision making about an approaching natural disaster depends on the agreement between spatial and temporal scales of the monitoring

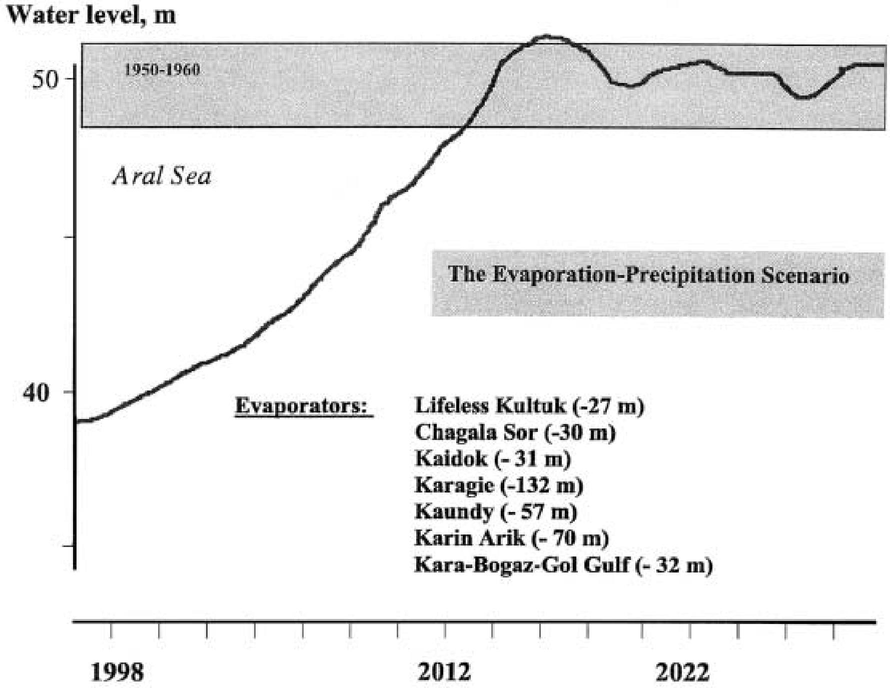

Fig. 6. – Possible dynamics of the Aral Sea levels (in metres with respect to the World Ocean level) as a result of the impact of the forced evaporators on the hydrological regime of the territory of the Aral-Caspian aquageosystem beginning from 1998 [17].

system and the respective characteristics of the natural phenomenon. Most difficult for decision making are natural catastrophes of "delayed action" which can take place in decades. Such expected disasters include ozone holes, global warming, desertification, reduced biodiversity, overpopulation of lands, and others. A solution for the base problem of a reliable prediction of the occurrence of such disasters or undesirable regional-scale natural phenomena initiated by them with the use of the NSS global model (NSSGM) has been proposed [13, 24], the input data for which being information put in the renewable bases of global data as well as current satellite and surface measurements.

The use of NSSGM in a number of studies has shown that this technology enables one not only to forecast the delayed-action disasters but also to propose scenarios for their prevention. An example is the scenario for reconstruction of the water regime of the Aral-Caspian system considered in [23]. Figure 6 shows the final result of the use of the NSSGM in solving this problem. It is seen that the realized procedure of irrigation of some lowlands on the eastern coast of the Caspian Sea without the subsequent anthropogenic interference can sharply change the hydrology of the territory between the Aral and Caspian Seas. Of course, this result is only a demonstration of the NSSGM capability to evaluate the consequences of realization of scenarios of the impacts on the environment. In this connection, many problems appear in the organization of studies, which can be solved within the complex scientific-technical programme of monitoring the zone of the impact of the Aral and Caspian Seas.

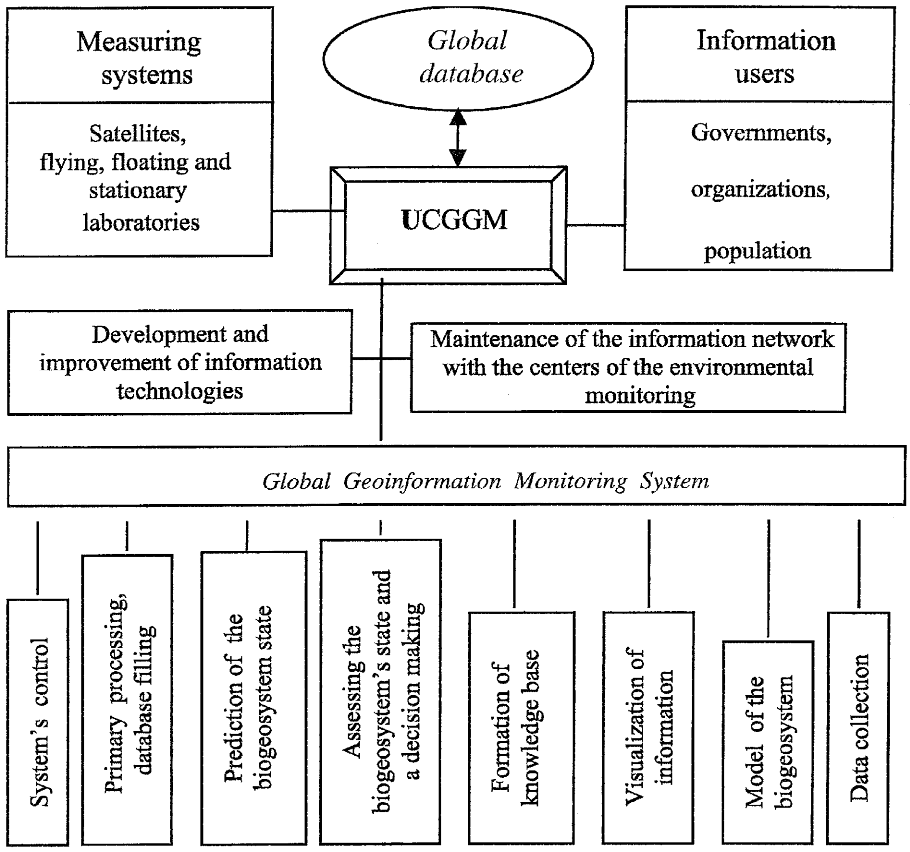

Fig. 7. – Concept of the United Centre for the global ecoinformation monitoring.

5. – Conclusion

The solution of the problem of reliable prediction of natural disasters requires the development of an efficient information technology for its use in the environmental monitoring system. This technology should include sections responsible for planning of measurements, development of algorithms for complex processing of data from different sources, development of methods of decision making on the basis of dynamic information analysis, and relevant risk assessment. An assessment of the risk of human losses from a natural catastrophe dependent on the regional parameters is one of the first-priority future studies. Such a risk is known to be non-uniformly distributed in space. For example, the annual average risk for certain territories is characterized by the following indicators (ppm): Globe—1, Bangladesh (floods)—50, China (floods and earthquakes)—25, Turkey/Iran/Turkmenistan (earthquakes)—20, Japan (earthquakes)—15, Caribbean region/Central America (storms, earthquakes, volcanic eruptions)—10, Europe - < 1, and USA/Canada—< 0.1. Hence, a consideration of this non-uniformity in the models of natural disasters will enable one to optimize requirements to future monitoring systems.

The proposed approach is aimed at creation of the technology mentioned above. However, to achieve this goal, it is necessary to undertake some fundamental studies and to solve many organizational and engineering problems. The first-priority task is to point out the necessity of a ranked systematization of natural disasters with emphasis on their characteristic features, which is a principal condition for realization of the stages of the above-mentioned 3-level procedure of making decisions with respect to an approaching natural catastrophe. The solution for such a problem can be exemplified by maps of dangerous natural zones of the USA territory with indicated types and levels of danger [32]. Another important problem is a modernization of the NSSGM with an adaptation to problems of predicting natural disasters and its parametric introduction into the existing and planned systems of the environmental monitoring. Finally, an actual realization of the ideas discussed here requires the concentration of intellectual, economic and technical resources at a united Centre of the global geo-information monitoring (UCGGM) such as the Centre of Aerospace Monitoring Problems (AEROKOSMOS) of the Ministry of Education and Science of the Russian Federation and Russian Academy of Sciences. Figure 7 demonstrates a possible functional scheme of this Centre. Its functioning will provide information on:

– the impact of global changes on the regional environment;
– the role of on-going or potential environmental changes in the region in changes of the environment and biosphere on Earth and in various regions;
– the state of the atmosphere, hydrosphere and soil-plant formations for the territory of the region;
– the availability of needed data on ecological, climatic, economic and demographic parameters of a region;
– the level of ecological safety for a given territory;
– phenomena harmful for people and the environment;
– the trends in changes of the state of forests, marshes, pastures, agricultural crops, river and lake systems, and other natural complexes;
– risks from measures to change the environment.

The UCGGM can solve the following problems:

– the long-term and timely planning and management of economic activity with due regard to its ecological expedience and development of strategy of rational nature use as well as creation of comfortable conditions for human life;
– operational identification and warning about processes beyond and within a given territory, which can aggravate the ecological situation and cause long-term changes in the environment with the growing risk for human health;
– identification of the reasons of undesirable changes in the environment in individual territories with indicated scales of their deviation from natural background;
– assessment of consequences for various territories from realization of anthropogenic projects;
– working out of first-priority measures to mitigate the causes of ecological catastrophes and calamities.

REFERENCES

[1] Avakyan A. B. and Istomina M. N., *Herald Russ. Acad. Sci.*, **72**, No. 12 (2002) 1059 (in Russian).
[2] Bigham N., Blowers A. and Belshaw C., *Contested Environment* (Wiley, New York) 2003.
[3] Boyd J., *Resources*, **154** (2004) 18.
[4] Braun R. A., Todd R. M. and Wallace N., *J. Risk Insur.*, **66**, No. 4 (1999) 583.
[5] Brebbia C. A. and Sakellaris I. (Editors), *Energy and the Environment* (WIT Press, Southampton) 2003.
[6] Brebbia C. A., *Risk Analysis* IV (WIT Press, Southampton) 2004.
[7] Changnon S. A. (Editor), *The Great Flood of 1993: Causes, Impacts, and Responses* (Westview Press, Boulder, CO) 1996.
[8] Changnon S. A., *Flood prediction: Immersed in the quagmire of national flood mitigation strategy, Chapter in Prediction*, in *Science, Decision Making, and the Future of Nature* (Island Press, Washington, DC) 2000, pp. 85-106.
[9] Changnon S. A., *Thunderstorms Across the Nation: An Atlas of Storms, Hail and Their Damages in the 20th Century* (Changnon Climatologist and Office of Global Programs, NOAA, Washington) 2001.
[10] Dauvergne P. (Editor), *Handbook of Global Environmental Politics* (Edward Elgar, U.K.) 2005.
[11] Field C. B. and Raupach M. R. (Editors), *Global Carbon Cycle: Integrating Humans, Climate, and the Natural World* (Island Press, Washington) 2004.
[12] Field J. G., Hempel G. and Summerhayer C. P. (Editors), *Oceans 2020: Science Trends and the Challenge of Sustainability* (Island Press, Washington) 2002.
[13] Gardner J. S., *Geograph. Rev.*, **92** (2002) 172.
[14] Harris F., *Global Environmental Issues* (Wiley, New York) 2003.
[15] Klyuev V. V. (Editor), *Safety of Russia: Ecological Diagnostics* (Knowledge Publ., Moscow) 2000.
[16] Kondratyev K. Ya. and Grigoriev Al. A., *Environmental Disasters: Anthropogenic and Natural* (Springer/PRAXIS, Chichester U.K.) 2002.
[17] Kondratyev K. Ya., Krapivin V. F. and Phillips G. W., *Global Environmental Change: Modelling and Monitoring* (Springer, Berlin) 2002.
[18] Kondratyev K. Ya., Krapivin V. F. and Savinykh V. P., *Perspectives of Civilization Development: Multidimensional Analysis* (Logos, Moscow) 2003 (in Russian).
[19] Kondratyev K. Ya., Krapivin V. F., Savinykh V. P. and Varotsos C. A., *Global Ecodynamics: A Multidimensional Analysis* (Springer/PRAXIS, Chichester U.K.) 2004.
[20] Kondratyev K. Ya., Losev K. S., Ananicheva M. D. and Chesnokova I. V., *Stability of Life on Earth* (Springer/PRAXIS, Chichester U.K.) 2004.
[21] Kondratyev K. Ya. and Krapivin V. F., *Modeling of the Global Carbon Cycle* (Physical-Mathematical Publ., Moscow) 2004 (in Russian).
[22] Kondratyev K. Ya. and Grigoryev Al. A., *Optics Atmos. Ocean*, **136**, No. 4 (2004) 279.
[23] Krapivin V. F. and Phillips G. W., *Remote Sens. Environ.*, **75** (2001) 201.
[24] Krapivin V. F., Kondratyev K. Ya., *Global Environmental Change: Ecoinformatics* (St-Petersburg State Univ. Publ., St.-Petersburg) 2002 (in Russian).
[25] Krapivin V. F. and Mkrtchyan F. A., *Ecolog. Systems Dev.*, **6** (2002) 3 (in Russian).
[26] Kuznetsov O. L. and Bolshakov B. E., *Sustainable Development: Scientific Basis of Planning Nature-Society-Man System* ("Gumanistika" Publ., St. Petersburg-Moscow-Dubna) 2002 (in Russian).
[27] Malinetskiy G. G., *Information Technol. Comput. Syst.*, **4** (2002) 83 (in Russian).
[28] McGuire B., Mason I. and Kilfurn C., *Natural Hazards and Environmental Change* (Arnold/Oxford University Press, Southampton) 2004.
[29] McKibben W., *Enough. Staying Human in the Engineered Age* (Times Books, New York) 2003.

[30] Melillo J. M., Field C. B. and Moldan B., *Interactions of the Major Biogeochemical Cycles: Global Change and Human Impacts* (Island Press, Washington, D.C.) 2003.
[31] Milne A. Doomsday, *The Science of Catastrophic Events* (Praeger Publisher, Westport, CT) 2004.
[32] Monmonier M., *Cartographies of Danger: Mapping Hazards in America* (The University of Chicago Press, Chicago and London) 1997.
[33] Morgen K., Spector M. J. and Brebbia C. A. (Editors), *New Learning. Paradigms and Tools* (WIT Press, Southampton) 2004.
[34] Munich Re. *Annual review of natural catastrophes 1997, 1998*, `http:www.munichre.com`.
[35] Nazaretyan A. P., *Herald Russ. Acad. Sci.*, **74**, No. 4 (2004) 319 (in Russian).
[36] Pelling M., *Natural Disasters and Development in a Globalizing World* (Routledge, London) 2003.
[37] Podlazov A. V., *Self-organizing criticality and risk analysis*, in *Proceedings of High School: Applied Nonlinear Dynamics*, Vol. **9**, No. 1 (2001) pp. 49-88 (in Russian).
[38] Ruck M., *Natural Catastrophes 2002: Annual Review* (Munich Re Topics, Dresden) 2002.
[39] Shahramantyan M. A., *New Information Technologies to Provide National Safety of Russia (natural-anthropogenic aspects)* (Russian Ministry for Emergency Situations Publ., Moscow) 2003 (in Russian).
[40] Steffen W., Jaeger J., Carson D. and Bradshaw C. (Editors), *Challenge of a Changing Earth* (Springer for Science, The Netherlands) 2003.
[41] Tiezzi E., *Beauty and Science* (WIT Press, Washington, D.C.) 2004.
[42] Wainwright J. and Mulligan M., *Environmental Modelling. Finding Simplicity in Complexity* (Wiley, New York) 2003.
[43] Walker G., *Snowball Earth: The Story of the Great Global Catastrophe that Spawned Life as We Know It* (Crown Publishers, New York) 2003.
[44] Watson R. T., Noble I. R., Bolin B., Ravindranath N. H., Verardo D. J and Dokken D. J. (Editors), *Land use, land-use change, and forestry* (Cambridge, Cambridge University Press) 2000.