7th International Conference on DEVELOPMENT AND APPLICATION SYSTEMS
Suceava, Romania, May 27 – 29, 2004

MODEL-BASED APPROACHES IN GLOBAL ENVIRONMENTAL GIS APPLICATIONS

Bui Ta Long[1], V.F.KRAPIVIN[2], D.V.OLINICI [3], Ngyuen Minh Nam[1,]
[1] *Institute of Applied Mechanics, National Centre for Natural Sciences and Technologies of Vietnam, HoChiMinh City*
[2] *Institute of Radioengineering and Electronics, Russian Academy of Sciences, Moscow*
[3] *University "Poltehnica" of Bucharest*

Abstract. *The experience of recent years shows the possibility of creating a global model capable of its usage of adaptive mode for giving recommendations on monitoring structure and requirements formation to databases. The solution of this model creating problem is lagging, therefore it leads to injustified expenses on conducting of new expedition for environment investigations and building of new observation systems.*

Introduction

Accumulation of knowledge, giant scientific and engineering progress and unprecedented growth of human influences on environment were already setting the problem of global evaluation of the state and possibility of its long-term forecasting since seventieth. The scientific research in this field has led to the scientists through the world to the conclusion that the solution of the environmental quality objective control problem is possible only through creation of a unified international monitoring system equiped with a global Magnetosphere-Climate-Biosphere-Society (*MCBS*) system. Many international and national programs on environment are dedicated to realization of this system. In the framework of these programs a sufficiently capacious databases of environment parameters are created, for information dynamics about natural and anthropogenic processes of various scales are accomulated and model sets of biogeochemical, biogeocenotic, climatic and demographic processes are prepared. The technical base of global geoinformation monitoring is satiated with efficient data acquisition means, recording, accumulation and processing of measurement data obtained from the board space, craft, ground and floating laboratories. However despite significant progress in many fields of natural monitoring the main problem consisting in designing of optimum combination between all technical means, creation of efficient and economical monitoring structure and creation of reliable environment dynamics forecasting evaluation methods under anthropogenic effects remain unsolved.

Global environmental gis applications

For the last year many investigators (Aota et al., 1993; Sellers et al., 1995) put a problem of synthesis of complex system for collection of environmental information uniteing GIS, remote and contact measurements with models. Such systems are called Geo-Information Monitoring Systems (*GIMS*) and they are aimed in systematic observation and evaluation of environment, its changes under effects of economical activities of people. One of important aspects of these systems functioning is a possibility of forecasting sorrounding medium state and warning about undesirable changes of its characteristics . Realization of this monitoring function is possible while applying mathematical modeling, methods ensuring simulation of natural complexes functioning (Armand et al., 1987; Bui and Krapivin, 1997).

Development of models of biogeochemical, biocenotic, demographic, socio-and-economical and other biospherical and climatic processes on the whole causes the necessity of forming requirements to the GIMS structure and its database. According to the proposed in paper of Kelley et al.(1992) GIMS structure the simulation of the biosphere dynamics is one of important function of the GIMS. As result of it the necessity of a new approach to the estimation of the biosphere state is arising. After all, the basic aim of all investigations in direction of the GIMS-technology development comes to the following tasks: 1) the acceleration of optimization of expenditures on reconstruction of environment survey systems ; 2) creation of conditions for optimum planning of the organizational structure of human society ; 3) ensuring purposefull direction of global processes so that they are for the good of mankind and do not cause damage nature .As it was shown by investigations there are balanced criteria of information selection, covering hierarchy of causal-investigatory constraints in biosphere. They include coordination of tolerances, depth of spatial quantization in the course of description of atmosphere, land and oceans, degree of detailing biomes etc. At an empirical level, expressed in expert's evaluations by the results of computing experiments these criteria give a possibility to select informational structure of the geoinformational monitoring system indicating hierarchic subordination of models at various levels.

At the same time creation of an effective global system for environment state control runs across the requirement imposed by the regional social-economic structure of the society. This is expressed by non-uniform development of industrial ecologically impure productions, degree of their concentration by regions, in difference of regional service for control and collection of information, their technical equipping etc. Such differences inevitably have an influence on the choice of GIMS structure and its informational technical base.

Thus the hierarchic structure of combination of mathematical models, incoming both in GIMS and in GIMS structure itself is determined by natural-climatic and socio-economical factors, as well as by technical potentialities. Degree of detailing models depends on level of their entry into common structure and mainly on spatial-temporal characteristics simulated at the given level of natural processes.

Global ecoinformatics suggests to develop the banks of models for various processes in the biosphere taking into account of their spatial nonhomogeneity and combination of the existing global databases with the already functioning systems for environment observation. It is suggested to have the cooperation of specialists having the developed climatic, biospheric and social and economic models with aim at creation of a global model of Climate-Biosphere-Society (CBS) system. As subsequent improvement of the model we may study the interaction of the CBS system with processes in the near-earth space (first of all in the magnetosphere) and pass to creation of the MCBS model. As a result a system will be created that capable of forecasting the development of natural processes and evaluting long-term consequences of large-scale action on the environment. Application of this system will encompasses the problems of environment protection on global, continental, regional and local scales with function realization of project ecological expert examinations of topsoil, hydrological regimes and atmospheric air composition structure changing The realization of the MCBS model allows to integrate into a complex structure all international and national means of environment monitoring and gives a tool of objective evaluation of the environment quality to all states. The filling of the system with to-up-to-date efficient data monitoring processing techniques permits to solve a wide spectrum of problems of identification of pollution sources eliminating conflicts because of transborder contamination transferrings .New information technologies in global modeling in the framework of International Centre for Global Geoinformation Monitoring (ICGGM) (Fig.1) which will be used will create a principally new structure of monitoring which

will depends on a base of various quality data and many mathematical and physical models of

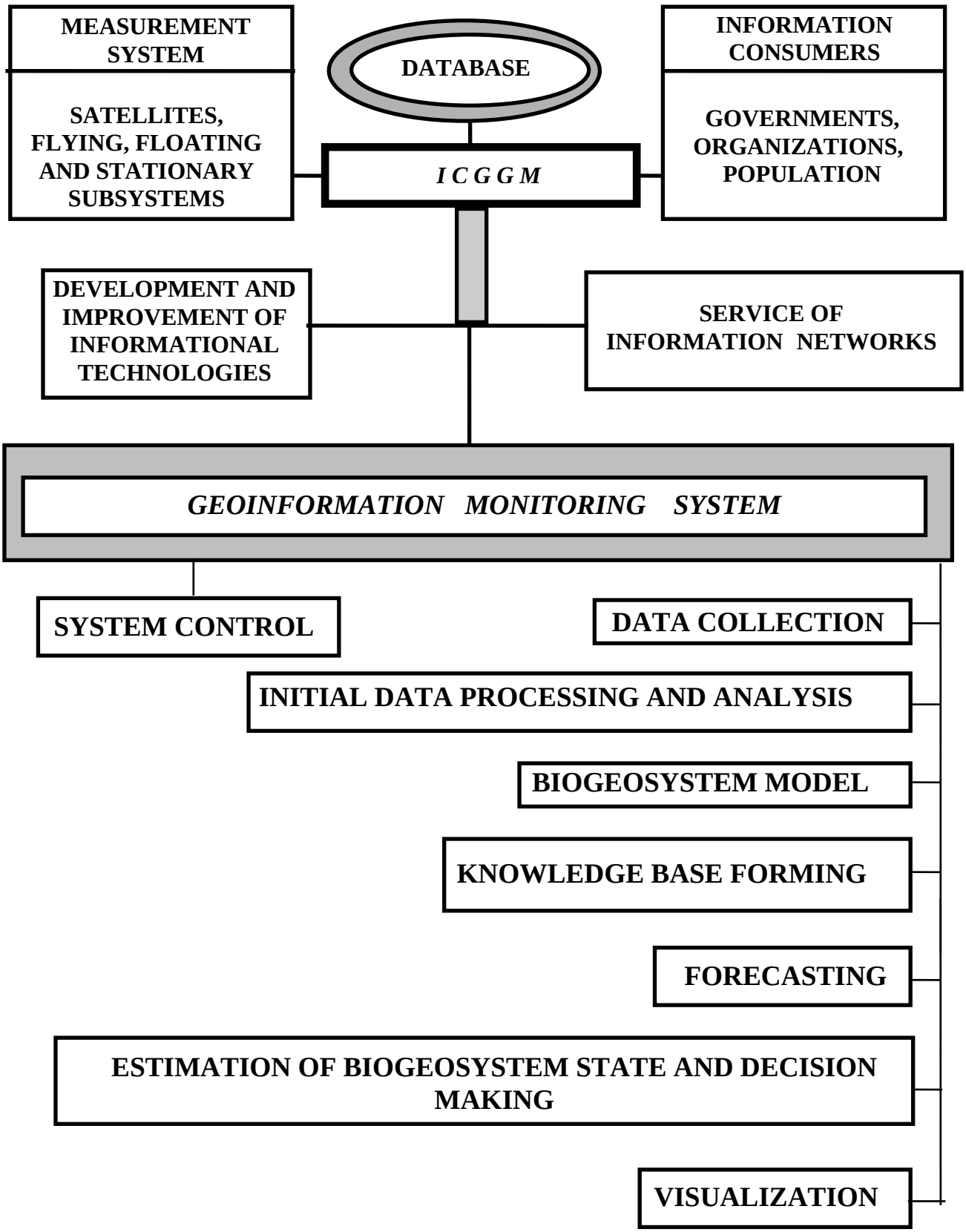

Fig.1. International Centre for Global Geoinformation Monitoring and its structure

various types. Evolution technology will solve noncompleteness and undeterminated information base, fragmentary knowledge about nature laws, the absence and undevelopment of instrumental system in the field of simulation experiment .

The ICGGM functional structure is based on the idea of realization of the evolutionary neurocomputer technology, This realization will have the architecture of a modern computer system software including the network of the tutorial servers of evolution type. This will lead to such ICGGM structure which will simulate the MCBS system with look ahead giving out optimum evaluation of nature protection measures and other structural decisions in interaction of human society with nature . The practical embodiment of the idea about MCBS model creation requires realization of a purposeful complex studies among which most important questions are following: 1) Systematization of global changes and formation of complex ideas about biospheric processes and the structure of biospheric levels. Development of a conceptual model of the biosphere as a element of the global geoinformation monitoring system. 2) Inventory and analysis of the existing ecological databases and choice of the global database structure. 3) Classification of space-time characteristics and cause-effect connections in the biosphere with the aim at working out a scale of coordination of space-time scales of ecological processes.4) Creation of typical models banks of ecological systems, biogeochemical, biogeocenotical, hydrological and climatic processes. 5) Study of interaction processes of the biosphere and climate. Search of regularities in sun influence on biospheric systems. 6) Systematization of information about oceanic ecosystems. Description of geophysical and trophical structures with their region devision and coordination with space-time scales. 7) Constructing of models of biocenographic fields and development of algorithms of synthesis based on the oceanic block of the global model. 8) Formation of the scenarios bank for coevolution development of the biosphere and human society. Creation of demographic models. Parametrization of many contradictions which arise from scientific and technical processes in utilization of land resources. 9) Search of new information technologies of global modeling providing reduction of requirements on databases and knowledge bases. Development of architectural and algorithmical principles of functioning of computer systems of neuronlike elements for evolution processing of information with high speed and efficiency and integrating of these systems into the ICGGM structure. 10) Development of the ecological monitoring conception and creation of the theoretical ecoinformatics base. Development of methods and criteria of evaluation of stability of global natural processes. Analysis of biospheric and climatic structure stability. 11) Synthesis of the MCBS model and development of computer means for realization of computation experiments in the framework of evaluation of realization consequence of anthropogenic activity scenarios. The analysis of investigations in recent years in the fields broaching by indicated tasks shows that for successful in global modeling it is necessary development of new methods of system analysis of complicated natural processes and development of data processing methods directed to the synthesis of balanced criteria of information selection and consideration of hierarchy of a cause-effect connections in the MCBS system.

The accumulated knowledge and experience of global monitoring give possibility to separate the main blocks of the MCBS model: magnetosphere, climate, biogeochemical cycles, biogeocenotic processes, socio-economic structure, scientific and engineering progress. Development of methods of these blocks parametrization reached a level where the synthesis of MCBS model is possible based on the principle of system coordination of inputs and outputs of individual blocks. Realization of this process requires solution of principal tasks of coordination of space-time scales of natural processes and choice of algorithms of MCBS model connection with databases. Because of national and state borders two upper spatial levels in MCBS are differentiated: global and continental. The national and state level

encompasses three space scales: national, regional and local. There are intermediate levels. Creation of the MCBS model requires systematization of models and databases at national and state levels and connection them to global models and databases. One of results of this systematization must be creation of typical models of natural processes as MCBS model base elements encompassing the national, regional and local levels. Realization of the hierarchical structure of mathematical models complex included in MCBS model superimposes on requirements of modeling algorithms being used. Space-time fragmentary data, their noise and noncompleteness lead to necessaty of a research of new modeling methods facilitating parametrization processes of phenomena in models under the conditions of noneliminatable information interdeterminacy, possibly, nonstationary character of data measurements of environment parameters. Among these new approaches to modeling the simulation-evolution modeling technology was developed recently (Bukatova, 1979). This technology allows isolate in the MCBS model besides traditional natural phenomenon models the new types of models providing the description of weakly parametrization processes. Because of this in the MCBS model may appear blocks describing such processes as scientific and engineering progress, agricultural production, extraction and expenditure of mineral resources, demography etc. There are many parameters describing the environmental conditions on the Earth. For example, among them is a soil moisture and moisture related parameters like the depth to a shallow water table, contours of wetlands, marshy areas. The knowledge about these parameters and conditions is very important for agricultural needs, water management, land reclamation, for measuring and forecasting trends in regional to global hydrological regime changes, and for obtaining reliable information about the water conservation estimates.

In principle, required information may be obtained by using on-site measurements, remotely sensed data, by getting access to a prior knowledge-based data, formely accumulated and stored in the databases, in GIS. But the problem which is arising here consists in solving the following: 1) what kind of instruments are to be used for conducting the so-called ground-truth and remote measurements; 2) what is the cost to be paid for the contact and remote information; 3) what kind of balance between the information content of contact and remote observations and the cost of these types of observations is to be taken under consideration; 4) what kind of mathematical models may be used both for the interpolation of data and the extrapolation of them in terms of time and space with the goals to reduce the frequency and thus the cost of observations and to increase the reliability of forecasting the environmental behaviour of observed objects.

These and other problems are solved by using the monitoring system basing on joining of functions of environment data acquisition, formation of control archives of these data, their analysis and forecasting the characteristics of the most important processes in environment. In other words, this unification forms the new information technology called the GIMS-technology. The term "GeoInformational Monitoring System (GIMS)" is used for description of formula : *GIMS = GIS + Model*. Evidently that GIMS is a superset of systems showing in Fig. 1. Two various views of the GIMS exist. As far as the first view is concerned the term "GIMS" is synonim of "GIS". Other view is in that definition of GIMS expands the GIS. Keep up with the second view one will consider the main blocks of GIMS. This consideration does not depend from these views. A base component of GIMS is offered for consideration. It is considered as a natural subsystem interacting through biospheric, climatic and socio-economic connections with

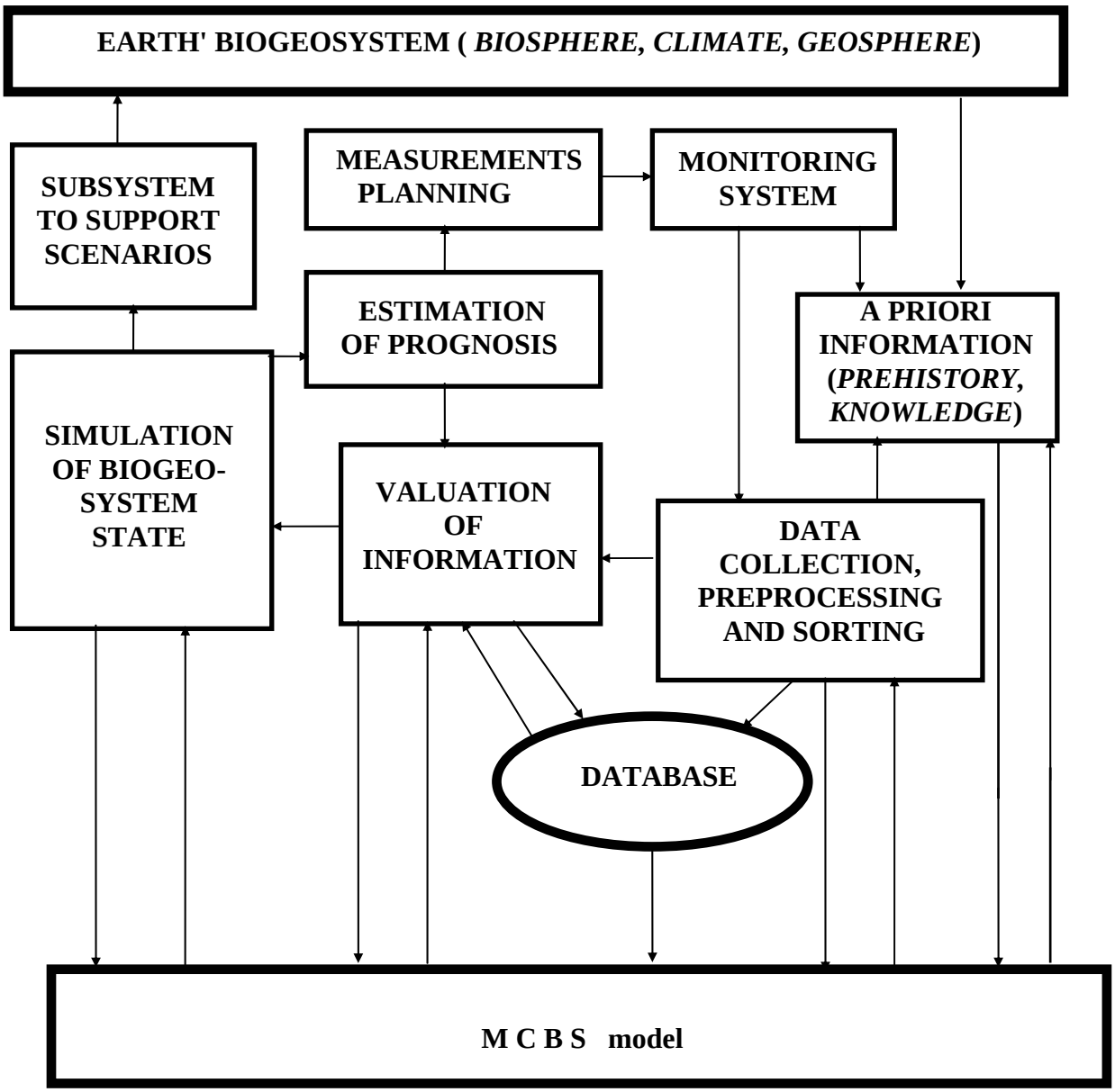

Fig. 2. Conceptual block-diagram of geoecoinformation monitoring and using the MCBS model

the global MCBS system. A model is created describing this interaction and functioning of various levels of space-time hierarchy of the whole combination of processes in the subsystem. The model encompasses existing information base.

characteristic features for typical element of natural and anthropogenic processes and the begining of model development is based on the The model structure is oriented to adaptive regime of its usage (Fig. 2).

Conclusions

Combination of environment information acquisition system, the model of functioning of the typical geoecosystem, the computer cartography system and artificial intelligent

means will result in creation of geoinformation monitoring system of a typical nature element capable of solution of the following tasks: 1) evaluation of global change effects on the environment of the typical element of MCBS; 2) evaluation of a role of environment change occuring in the typical element in climatic and biospheric changes on the Earth and in territories; 3) evaluation of ecological state of the atmosphere, hydrosphere amd soil-plant formations; 4) formation and renewal of information structures on ecological, climatic, demographic and economical parameters; 5) operatively cartographing of landscape situation; 6) forecasting ecological consequences of anthropogenic scenarios realization; 7) performing of typifying of land covers, natural phenomena, populated points, surface contaminations of landscapes, hydrological systems, forests; 8) evaluation of population security. Constructing of GIMS is connected with separation of components of the biosphere, climate and social medium characterized for the given level of spatial hierarchy.

References

[1] Aota, M., K. Shirasawa, V.F. Krapivin, and F.A. Mkrtchyan (1993) *A project of the Okhotsk Sea GIMS*. Proc. of the Eigth Int. Symp. on Okhotsk Sea & Sea Ice and ISY/Polar Ice Extent Workshop, 1-5 Feb. 1993, Mombetsu (Japan), pp. 498-500.

[2] Armand, N.A., V.F. Krapivin and F.A. Mkrthyan (1987) *Methods for data processing in the radiophysical investigation of the environment*. Moscow, Nauka, 270 pp.

[3] Bui, T.L. and V.F. Krapivin (1997) *System of survey and simulation for air pollution over large industrial regions*. Proc. of Int. Conf. 'Pollution Control'97', Bangkok (Thailand), 12-16 Nov. 1997, p. 122.

[4] Bukatova, I.L. (1979) *Evolutional modelling and its applications*. Moscow, Nauka, 280 pp.

[5] Kelly, J.J., G.L. Rochon,O.A. Novoselova, V.F.Krapivin and F.A.Mkrtchyan (1992) *Toward global geo-eco-information monitoring*. Proc. of Int. Symp. 'Problems of Ecoinformatics', 12- 18 Dec. 1992, Zvenigorod, pp. 3-7.

[6] Sellers, P.., B.W.Meeson, F.G.Hall et al. (1995) *Remote sensing of the land surface for studies of global change: models-algorithms-experiments*. Remote Sensing of Env., 51, 1: 3-26.

[7] C.Nitu, V.F.Krapivin ,F.Mkrtchan *Remote measurement methods application in ecology*, Int. Conference DAS,pp.271-274, Mai 2002, Suceava

[8] C.Nitu, *Inteligent technics applications in ecology for soil monitoring systems* by Internet, Int.Conference DAS, pp.268-271, Mai 2002, Suceava