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Information Technologies for Remote Monitoring of the Environment

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Preface

The growing amount of published work dedicated to global ecological studies indicates just how urgent nature conservation has become. The question of finding the principles that underlie the co-evolution of humankind and nature is being posed with ever-increasing persistence. Scientists across the globe are attempting to find ways of formulating the laws that govern the processes that are going on in the environment. Many national and international programs have been set up to study the biosphere and climate in the quest to find a means of resolving the conflict between human society and nature. However, attempts to find efficient ways of regulating human activity globally have come up against major difficulties. Arguably one of the most difficult is the absence of an adequate knowledge base pertaining to climatic and biospheric processes as well as the incompleteness of databases concerning global processes going on in the atmosphere, in the ocean, and on land. Another difficulty is the inability of modern science to formulate the requirements that global databases need to meet for reliable evaluation of the state of the environment and forecasting its development over the long term.

A dramatic aspect of anthropogenic activity is its influence on the biospheric water cycle. This influence is global and is composed of a hierarchy of regional changes, especially in arid areas. This is the reason being able to reconstruct biospheric water systems is such a major element of climate system monitoring.

Many scientists are trying to find answers to these questions. Most suggest that an efficient way of resolving the conflicts between nature and human society would be creation of a unified planetary-scale adaptive geoinformation monitoring system (GIMS). Such a system should be based on knowledge bases and global datasets that are constantly updated. The adaptive nature of such a system should be provided by continuously correcting the data acquisition mode and by varying the parameters and structure of the global model.

The attempts of many scientists to create a global model—the major component of the GIMS—have not been implemented so far as a result of a limited knowledge

base. The creation of a model that adequately represents the real processes going on in the environment is clearly not possible: on the one hand, complex models including every last environmental parameter are sure to lead to boundless multidimensionality and, on the other hand, simplified models including restricted numbers of parameters are clearly not fit for purpose. Moreover, creation of an adequate global model cannot be done simply because of the practical impossibility of providing the exhaustive information required. The uncertainty attached to simulation of socioeconomic processes is inevitable. In attempting to surmount these difficulties many researchers have resorted to the methods of game theory, evolution modeling, and describing the behavior of systems as sets of scenarios. Such an approach takes expert opinions into account. However, without a concept of global changes all such attempts are doomed to failure. There needs to be a mechanism for singling out information-carrying elements and determining their interrelation so that global model redundancy is kept to a minimum.

The first steps toward understanding the key problems that need to be resolved in global ecology and climate were made by Kondratyev (1990, 1998a, b, 1999, 2000a, b). The discussions in Krapivin (1993, 1995, 1996, 2000a, b) and Shutko (1986) have made synthesizing a global model of natural processes by considering sets of spatial scales possible.

The present book proposes ideas that could help solve these problems and describes a simulation system based on sets of computer algorithms that process data from global and regional monitoring. A global simulation model that describes spatial interactions in the nature–society system is synthesized. The model comprises blocks describing the biogeochemical cycles of carbon, nitrogen, sulfur, phosphorus, oxygen, and ozone; the global hydrologic balance in liquid, gaseous, and solid phases; the productivity of soil–plant formations and their definition; photosynthesis in ocean ecosystems with depth and surface inhomogeneity taken into account; demographic processes and anthropogenic changes. The model is designed to be connected to a global climate model.

Creating an information interface between the global model, algorithms, and experiments makes it possible to use global sets of vegetation-related parameters, datasets about meteorological fields and hydrologic processes, and other global environmental and anthropogenic data to forecast global change. The information interface supports the relationships between different components of a global model.

The theoretical part of the book has chapters that describe various algorithms and models. The applied part of the book considers specific problems of environmental dynamics. Development of a universal information technology to estimate the state of environmental subsystems under various climatic and anthropogenic conditions is the purpose of having theoretical and applied parts. Combination of geographical information system techniques with modeling technology to estimate the functioning of the nature–society system is the basic idea behind the approach proposed in this book. This idea can be implemented by using new methods to spatiotemporally reconstruct incomplete data.

Algorithms, models, methods, criteria, and software are created with the objective of synthesizing a GIS with modeling functions capable of complex estimation of the state of nature–society subsystems. The newly developed Geoinformation Monitoring System (GIMS = GIS + Model) is focused on systematic observations and evaluation of the environment related to changes attributable to the human impact on environmental subsystems. An important functional aspect of the integrated system is the possibility of early warning of undesirable changes in the environment.

Various applications of GIMS technology are described. There are chapters describing how GIMS technology can be applied to the study of the dynamics of radionuclear pollutants, heavy metals, and oil hydrocarbons in the Angara/Yenisey river system and in the Arctic Basin; to estimation of the Peruvian Current and Okhotsk Sea ecosystems; to estimation of excess CO_2 distribution in the biosphere; and to the study of the Aral/Caspian aquageosystem water regime.

The book also deals with microwave radiometric methods. These are the traditional methods of remote sensing of the Earth's surface from aircraft and satellites. Combined use of microwave remote sensing, mathematical modeling of the environment, data processing, and decision-making procedures is proposed. This book aims to focus the attention of the reader on microwave radiometric technology as one of the most powerful technologies in radiophysics for the remote sensing of lakes, seas, oceans, rivers, agricultural land, irrigated land, desert areas, forested areas, wetlands, snow-covered ground, and ice in the wavelength range from 0.5–2 cm to 21–30 cm.

This book brings together the wide spectrum of theoretical and applied techniques used to estimate global change. It presents the theoretical and practical notions of modeling calculations associated with environmental and human systems in a systematic way. Applied mathematicians, hydrologists, geophysicists, ecologists, socioeconomists, and other researchers of global change will find this book useful.