IMAGE 2.0

IMAGE 2.0: INTEGRATED MODELING OF GLOBAL CLIMATE CHANGE

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FOREWORD

During the UN Conference on Environment and Development (UNCED) in 1992 much attention was given to global environmental problems. The Framework Convention on Climate Change and other international agreements, such as the Montreal Protocol for the protection of the ozone layer, are ample demonstration that governments take the issues of global change seriously.

Many of the international political agreements could not have been developed had it not been for the underpinning provided by scientific reserch and assessment. There are three major programmes established to reduce the scientific uncertainties related to global environmental change: the World Climate Research Programme (WCRP since 1980), the International Geosphere-Biosphere Progrqamme : A Study of Global Change (IGBP, since 1986) and the Human Dimensions of Global Environmental Change (HDP, since 1990).

Results from these and other scientific programmes can be made more useful for the policy process if they are evaluated and synthesized. At the international level, this is carried out by the Intergovernmental Panel on Climate Change (IPCC) for issues about climate change. It is hoped that the HDP/IGBP/WCRP initiative System for Analysis, Research and Training (START) can perform a similar function at the regional level for global change issues..

Simulation models are crucial as a means to formalize the synthesis of data from different disciplines. Models can also have predictive capabilities and be used to develop and analyze scenarios of global environmental change. Only few laboratories in the world have taken the bold step to attempt the integration of sub-models of the climate system, the global biogeochemical cycles and the human/societal components. This volume reports on such a major undertaking and is an important step towards an integrated approach to global change science.

Models attempting to link the physical, biogeochemical and societal subsystems at the global scale are, by necessity, simplifications. Their major role is to show the interdependence of the three subsystems, provide a formal structure for synthesis, and identify major weaknesses in our understanding. Any attempt to do so is brave, as scientists have a tendency to analyze and criticize the model subcomponent they are most familiar with while losing the overall objective of the integrated model development. The IMAGE 2 model is important in demonstrating our current ability to model the complex global system. It will stimulate further refinement and development within RIVM and will also lead to the development of similar models in other laboratories and institutions. The authors should be congratulated for making available a model description that will stimulate an essential debate and further model development. This will lead to improved scientific assessments on which policy decisions must be based.

Professor Thomas Rosswall
Executive Director, International Geosphere-Biosphere Programme (IGBP)

PREFACE

The main purpose of this publication is to document the development and testing of the IMAGE 2.0 model, together with a selection of its applications. One of the main objectives of IMAGE 2.0 is to link science with policy, but in this publication we emphasize the scientific rather than policy aspects of the model, because a strong scientific foundation is necessary before a model can be useful for policy analysis.

IMAGE 2.0 is a type of earth systems model, a new category of simulation tool made possible by two recent developments. The first is rapid progress in understanding the workings of the global system based on new data that is rapidly becoming available. These data have come from comprehensive measurement programs such as *TOMS* (Total Ozone Mapping Spectrometer), *ALE/GAGE* (Atmospheric Lifetime Experiment/Global Atmospheric Gases Experiment), and *ERBE* (Earth Radiation Budget Experiment), as well as impressive efforts to compile global data bases through *IGAC* (International Global Atmospheric Chemistry Programme), *IGBP-DIS* (International Geosphere Biosphere Programme - Data and Information System), and other programs. The second development making earth systems models possible is the increase in power and utility of computer hardware and software which has allowed more and more institutes and researchers to handle the simulations of large geographic and dynamic systems.

Apart from being made possible by the above advances, the IMAGE 2.0 modeling approach evolved from two directions. First, it stems from the earlier, global-average version of IMAGE (now referred to as "IMAGE 1" which was developed at the National Institute of Public Health and Environmental Protection of the Netherlands (RIVM) under the leadership of Jan Rotmans. Rotmans' determination and skill led to one of the first integrated models of climate change (Rotmans, 1991; Rotmans *et al.*, 1991), which coupled calculations of energy, emissions, climatic consequences and sea level rise within a single framework. Second, IMAGE 2.0 evolved from developments in global change modeling that took place during the 1980s at the International Institute for Applied Analysis, Laxenburg, Austria. In particular, the BIOME model (Prentice *et al.*, 1993) and the RAINS model (Alcamo, et al. 1990) contributed ideas about rule-based simulations, process-based models applied on a geographic scale, and spatial mapping, which led to the geographically-explicit calculations of IMAGE 2.0. The crucial advantage of geographically-explicit modeling is that it increases the opportunity to test global models against data from comprehensive inventories and/or field campaigns. Hence, model development can keep pace with the state of understanding of global systems as new data become available.

As with other new developments in science, the field of earth systems modeling has already taken many different directions depending on the type ofquestions researchers wish to address. It is likely that these varied efforts will lead to rapid and exciting advances in the coming years in understanding and simulating the global system.

Joseph Alcamo
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