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INTERNATIONAL EARTH SCIENCE INFORMATION NETWORK FOR GLOBAL CHANGE DECISION MAKING

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Abstract

Effective environmental decision making depends upon the ability to predict physical changes in the environment, societal responses to these changes, and how both the physical changes and societal responses will be affected by changes in government regulations, public perceptions and the environment. Technological advances in remote sensing have provided a wealth of earth science data necessary to study global change problems; the Earth Observing System will provide an unprecedented data source in the late 1990's. The Consortium for an International Earth Science Information Network (CIESIN) will combine earth science data (both satellite and ground-based) with data on the social sciences (e.g., economics, demographics, public health) to support informed policy decisions and to transfer knowledge on global change and its causes to the public.

Background

It has been recognized for at least a decade by both scientists and policymakers that mankind may be altering the environment. Among the many processes acting over a period of time that will bring about global change are the buildup of greenhouse gases, depletion of the ozone layer, land use changes, and pollution, and it is well recognized that understanding these processes and their effects will require an interdisciplinary approach. In the past, "interdisciplinary" has usually implied physical scientists from different disciplines working together, and only recently have the biological sciences been included to any great extent.

Yet another aspect to the problem, the human dimensions of global change, has only recently begun to be addressed. Examples are ways in which the earth's surface is modified by human activities, e.g., farming and urbanization, and ways in which products of technology, such as chemical fertilizers, cause modification of the environment. In addition to the physical effects of global change on the environment, questions must be raised concerning value systems and the ways individuals, as well as institutions (governmental and private, including industrial enterprises), make decisions about broad societal goals that involve the use of resources. Answers to such questions would contribute to understanding how society can be expected to respond to environmental changes. It is clear that to advance toward that understanding, investigators in such disciplines as psychology, sociology, political science, and engineering must work together with biological and physical scientists on the problems of global change.

The Committee on Earth Sciences, an interagency committee, was established in the late 1980's to coordinate the federal research plan for global change. This Global Change Research Program includes a hierarchy of seven science priorities. Climate and hydrologic systems has the highest priority with "human interactions" listed as fifth. Yet if global change information is going to be used by the world community, it is clear that we must know not only how and why the human species causes changes to the environment, but also how we respond to those changes; thus characterization and quantification of attributes of human behavior are necessary components of the global change program.

There can be little doubt that our potential for causing environmental change is increasing rapidly. At present, the world's population is 5.3 billion. If we were equally distributed over the entire land area of the earth, our nearest neighbor would be only 500 feet away. By the year 2025, that distance is projected to decrease to only 400 feet.

Fortunately, technology is providing us with the tools to manage the environment. To monitor global change will require vast amounts of data that in many cases must be collected on a regular basis. Remote sensing, which began with the TIROS satellites in 1960, will provide this capability with the launching of the EOS satellites in the 1990's. Ultimately, one needs to make predictions as to how the climate will change, and this will require massive computing power that is projected to be available in about a decade. At present, even with the most sophisticated computers, a 100-year model scenario would require about 1000 hours on the fastest machines available today.

A rich source of remotely sensed land, atmosphere, and ocean data will be available in the 1990's from NASA's Earth Observing System (EOS). EOS had its genesis in 1985 when the NASA-appointed Earth Systems Science Committee developed NASA's program for global change. EOS has three components: the development of the instruments to provide the earth-related data, an information system to collect the data, and an interdisciplinary research program. The first of the satellites is scheduled to be launched in 1998. The information system is known as the EOSDIS, the EOS Data Information System. Each EOSDIS facility would be responsible for a subset of the EOS data, such as ocean data and land data.

In addition to the remotely sensed physical data, in-situ data must also be collected, e.g., methane release and changes in biodiversity, and relevant social science data, virtually all determined in-situ, must be pulled together. This includes demographic, economic, political science, behavioral, and health data.

Recognizing this, and with the concern of Congress about how data would be integrated and used, the Consortium for an International Earth Science Information Network (CIESIN) was established with the overall objective to enhance access to, and use of, earth science and related information by the international scientific and decision- making communities in pursuit of global change issues. The non-research community will include government decision makers, environmentalists, and farmers. CIESIN will be concerned with EOSDIS data as well as non-satellite (physical, biological, and social) data. Special products will be developed, archived, and distributed for use by non-researchers as well as researchers. The CIESIN facility, known as an Affiliated Data Center (ADC), will also have access to models for the prediction of global change for both natural and social systems as well as the capability for model development.

<u>The Role of CIESIN in the EOSDIS</u>

The Earth Observing System (EOS) is a satellite-based remote sensing system, spearheaded in the U.S. by NASA, which will receive considerable inputs from the international community. The European Space Agency, Canada, and Japan have all expressed their intentions to participate by providing satellites and sensors to EOS, and numerous countries have indicated their desire to participate in the analysis of data from these satellites. Eventually, EOS will consist of a series of 25 to 30 remote sensing instruments systems mounted on two to five large, polar-orbiting platforms, and a number of sensors mounted on smaller satellites or earth probes. While the remote sensing systems launched by NASA and others are considered to be experimental in nature, EOS will also include the National Oceanic and Atmospheric Association's (NOAA) Polar Orbiting Environmental Satellites, which are considered to be operational.

The goal of the EOS program is to develop and evaluate the remote sensing techniques required to address research priority areas identified by the U.S. Global Change Research Program. These interdisciplinary science priority areas are: (1) climate and hydrologic systems; (2) biogeochemical dynamics; (3) ecological systems and dynamics; (4) Earth system history; (5) human interactions with the Earth system; (6) solid Earth processes; and (7) solar influences. The studies being pursued by the EOS program principally address priorities (1), (2), (3) and (6), although studies in the other areas will also have to be pursued.

In order to manage and distribute the large amounts of data being generated by the EOS satellites, a significant amount of effort is being directed towards the development of an EOS Data and Information System (DIS). This data management activity is truly formidable, and as illustrated in Figure 1, involves receiving and archiving the unprocessed instrument data at full resolution (Level 0 in Figure 1), annotating, georeferencing and transforming the data into sensor units (e.g., microwave backscatter, brightness temperature) at Level 1, deriving environmental or scientific parameters (e.g., soil moisture and sea surface temperature) at Level 2, remapping the parameters at uniform space and time scales at Level 3, and generation of model or analytical outputs using Level 1 to 3 data.

DATA LEVELS WITHIN EOS AND THE GLOBAL CHANGE RESEARCH PROGRAM

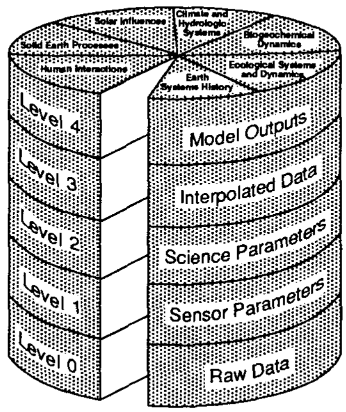

Fig. 1.

The different sections of the "data layer cake" presented in Figure 1 are representative of the various process studies required to address the global change science priorities. One conceptualization of the purpose of the EOSDIS, presented in Figure 2, is to facilitate the flow of information and data between the various levels, or even within the same level, as required by scientists pursuing global change research. Note that the principal user of EOSDIS data and information is the earth science research community.

RELATIONSHIP OF EOS DIS TO GLOBAL CHANGE RESEARCH PROGRAMS

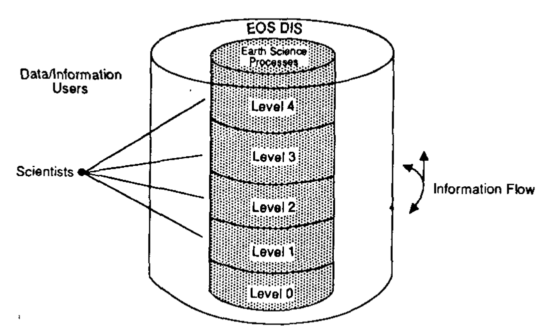

Fig. 2.

A primary focus of the studies being performed by CIESIN has been to determine how data archived in the EOSDIS can best be used to address global change issues, which is a subtle, but significant difference from the focus of the EOS and GCRP programs, which is to understand the earth science processes associated with global change. To meet the challenge of using EOS data in addressing global change issues, CIESIN investigators have identified several key areas which must be addressed, as diagrammed

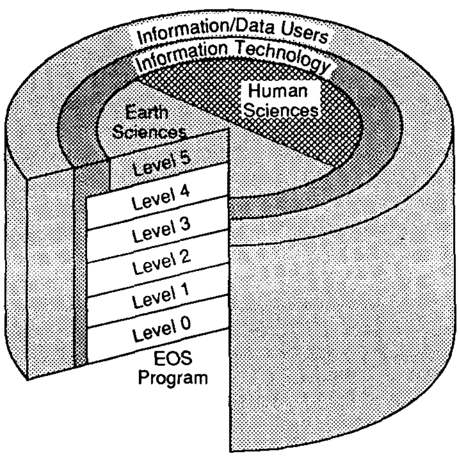

Fig. 3.

in Figure 3. First, fundamental scientific research on the human dimensions of global environmental change must be pursued to provide the types of data required in decision making. This needed expanded research is represented schematically by the human/earth sciences interface in Figure 3. Second, the users of data are expanded beyond just the scientific users. These additional users include both social and application scientists, policy makers, legislators, resource managers, students, educators, industrial and agricultural users and interest groups, and the media. It is important to recognize that these users will require data in different formats than envisioned within the four levels provided by EOS. These different formats will require the generation of an additional level of data, as represented by Level 5 in Figure 3. Finally, the information technology infrastructure required to both facilitate the flow of data and information to the various user communities, as well as to assist in the interdisciplinary research on the human dimensions of global change, will have to be expanded considerably beyond that planned for the EOSDIS.

In the following sections, we will further discuss the activities in these three areas which are presently being pursued by CIESIN.

Information Technology

Many of the information technology issues CIESIN faces are the same as those faced by the Distributed Active Archive Centers (DAAC's), and the other Affiliated Data Centers (ADC's). These include archiving, analyzing, and distributing extremely large volumes of data, and cataloging data and information into the EOS master directory and catalog. EOSDIS will initially link the many distributed catalogs. Eventually, it would be extremely useful if distributed data sets, databases, and models could be linked so that they could work dynamically with each other. In addition to catalogs, directories, and inventories, a successful EOS program will require analysis tools, information about algorithms, information on the processing history of all data, extensive browse capabilities, help files, documentation and bibliographies.

To enable researchers to access these data and information, network connectivity must be reliable, of sufficient bandwidth to allow browsing of images, and exist on an international scale that includes lesser developed countries. Interoperability of hardware and software will be a high priority, and the current lack of international standards will make this a very difficult goal to achieve. Different national regulations regarding telecommunications, and the tendency of many nations to regard the importation and exportation of data as something suspect or threatening, will require very creative solutions. The same is true in collecting and providing seemingly non-controversial information. For example, population and demographic information is considered a state secret in many countries.

The information technology issues that CIESIN must solve that are different from the other EOSDIS sites are the result of the need to understand the problems associated with integrating human and earth sciences data, and providing data and information to the various decision makers and resource managers, educators and the general public. CIESIN will be creating, collecting, and incorporating social and health science data (Levels 0-5). CIESIN will also be creating and incorporating distilled data (Level 5) from the EOS earth sciences, as well as synthesizing Level 5 data from both the social and earth sciences into information that is usable and understandable by its diverse audiences.

CIESIN must tackle many formidable, unanswered questions about appropriate techniques to integrate social and remote sensed earth science data. At present, very few analytical tools exist for this type of integrated social and physical data. In addition to these difficulties, there is a serious lack of interdisciplinary data dictionaries for the social sciences.

The CIESIN ADC will be providing access to EOSDIS by a much broader audience than the traditional earth science researcher. This audience will include a large segment that can be considered non-technical and unfamiliar with remote sensing terminology. This audience is also likely to include many interdisciplinary (physical and social) research groups. CIESIN will also need to enable knowledge transfer to many different sectors: policymakers (all levels), resource managers, educators, students, advocacy groups, the media, and the general public. This will require innovative and carefully thought out approaches to human factors and user interfaces, emphasizing visual presentation, wide use of graphics, icons, multi-lingual considerations, knowledge-based database navigation, etc.

Through the early pilot projects, CIESIN will begin addressing many of these issues. For example, many pilot projects emphasize use by the international community, especially lesser developed countries. Early contributions to the catalog and data collections will be made by the pilot projects. Various techniques in data integration will be tried. Interactions and collaboration with EOSDIS, DAAC's, ADC's, US federal agencies, and other GCRP/IGBP organizations will be required.

The CIESIN information technology staff will also be working on various projects that focus more exclusively on human factors and user interfaces, database techniques, and collaboration techniques. All of these activities are intended to help determine the specifications for a CIESIN ADC.

Physical/Social Science Interface

Various pilot projects have been initiated to gain understanding of the appropriate level of interaction among physical, biological and social scientists. We also need to develop methodologies for the merging of disparate data sets. Thus, interdisciplinary research has been emphasized, especially earth and social science. We have especially encouraged projects that will investigate the possible use of remotely sensed data in the social sciences; this is an area in which there has been virtually no research.

It is important to note that these projects extend beyond those of typical research proposals. It must be demonstrated that the results generated are necessary for a particular decision-making process, but there is a further need to demonstrate how the results would be transferred, in appropriate form, to the decision makers.

The pilot projects have been chosen to emphasize a particular interdisciplinary problem; for example, ozone depletion and human health. It has been demonstrated that stratospheric ozone is indeed decreasing, which should lead to an increase in ultraviolet radiation reaching the surface of the earth, which would lead to increased risk of skin cancers, cataracts, and perhaps infectious diseases. There are various locations where long-term health data (20 years) exist, as well as monitoring of ultraviolet radiation. The health data are being merged with the ultraviolet data to see if there is a correlation between health and ultraviolet radiation. Whether or not such a correlation can be ascertained, the methodology for the collection of health data expressed in a form that will be useful to decision makers is a major goal of this study. The ultraviolet radiation will also be predicted from knowledge of the atmospheric ozone from TOMS (Total Ozone Mapping Spectrometer), and corresponding atmospheric data. An overall goal will be to predict the ultraviolet radiation reaching the surface of the earth on a global basis, and to compare those projections with worldwide health data.

Another example concerns industrial degradation of the environment. One region of Central Europe which is particularly stressed is the Bohemian Massif region of Czechoslovakia, Germany, and Poland. This region, which is home to more than 15 million people, has been and is currently mined extensively for high sulphur content lignite coal which is subsequently burned in nearby power generation stations and steel mills. The mining process results in extensive river acidification because sulphur leaches from the mines and then makes its way as runoff into the water supply. Likewise, when the coal is burned for its energy, the resulting SO_2 emissions return to earth as acid rain, which has been identified as a major cause of deforestation and reduced agricultural yields in the region.

Fortunately, approaches to many of the environmental problems faced in the Bohemian Massif region are fairly well known. However, switching fuel supplies, energy conservation, smoke-stack scrubbers and revised mining practices all require extensive capital investment. The problem facing the decision makers of the region is knowing how to invest extremely scarce capital resources in order to get the highest ecological and economic benefits. CIESIN proposes to enhance the process of transferring the information and analysis techniques that can help regional authorities develop well-founded approaches to resource allocation issues and expand the range of policy and investment options being considered to address the environmental problems of the Bohemian Massif region.

Knowledge Transfer

CIESIN faces some unique challenges. An enormous amount of data relating to global change issues has been and is being collected within the United States and internationally. These data represent the efforts of individuals from diverse scientific disciplines. Much of the data is currently inaccessible or difficult to access. CIESIN's charge is to make these data available to researchers, world wide. Once the researchers have access to the data and make their findings available to the scientific community, then the challenge will be to transfer this information to applied users.

In April 1990, an Issues Identification Panel met in Ann Arbor, Michigan to begin to identify key global change issues. Sixteen top-level people from physical and social sciences, academia, government, industry and information technologies were brought together to identify significant global change issues which need to be addressed over the next decade. They also discussed the societal and political implications of those issues. Among the physical factor issues identified were: Loss of Clean Air; Contamination of the Biosphere; Climate Change; Changes in Quality of Life; Ozone Depletion; Changes in the Land Surface; Loss of Fresh Water Resources; Ocean Changes; and Loss of Biodiversity. In addition to the physical factors, policy issues such as energy, land productivity, health, air and water use were identified. A third category, focusing on human factors, included such issues as population, economics and education. Another result of the Issues Identification Panel was the recognition that physical and social scientists could and should work together in addressing global change issues.

The findings from the Issues Identification Panel were used as the basis for formulating the topic areas of discussion for the Interdisciplinary Task Force. The Interdisciplinary Task Force met in Washington, D.C. during July of 1990 and gathered 120 people representing multi-disciplinary perspectives from the physical and social sciences. These disciplines were represented by political sciences, social sciences, health, policy making, data collection and information technology. They represented federal agencies, academia, and non-governmental organizations from the United States and the international community.

In October 1990, the Knowledge Transfer Symposium was held at Saginaw Valley State University in Michigan. Sixty-two people participated, representing decision makers on local, regional, state and national levels. Decision makers were categorized by three sectors: Education, Public and Media. The Education Sector is the formal education system, i.e., K-12 and Higher Education. The Public Sector consists of groups or individuals involved in the decision-making process associated with translation and transfer of global change information and groups of people or individuals sharing common interests. The Media Sector is composed of groups involved in various mechanisms and procedures dealing with information transfer, including print and non-print communication.

The Symposium participants were asked to address the issues relating to the processes involved in the transfer of global change information. The overall global change knowledge transfer process encompasses translation, transfer and assessment. Translation is the process of putting global change information and issues into terms which are understandable by users within the targeted three sectors (education, public and media). Assessment is the continous determination of the effectiveness of the translation of global change information and its transfer.

The Symposium built upon the findings generated from the Issues Identification Panel and Interdisciplinary Task Force conferences. The objective was to identify procedures and mechanisms for knowledge transfer of global change information by each sector on local, regional, national and international levels so that users will be able to gain a predictive understanding of the interactive physical, biological, and social processes that regulate the Earth system and establish the basis for national and international decisions relating to natural and human-induced changes in the environment. While the charge was also to address international issues of knowledge transfer, the Symposium focused almost exclusively on national concerns. The issues relating to the international transfer of global change presented a complex array of problems. It was decided that, due to the complexity of the issues involved, the international concerns should be addresssed as a future activity.

Key expectations of the Symposium were: to provide CIESIN with a large variety of options which will increase its effectiveness in translating, transferring and assessing its efforts relating to global change information; and to provide CIESIN with a clear understanding of the key issues relating to the translation, transference and assessment of the use of global change information.

Some of the issues which were raised during the Knowledge Transfer Symposium included: the importance of making the global change information easily accessible and usable for specific targeted groups; information should be made relevant for people on local and regional levels, for example, people in the midwest are probably more interested in tornadoes while people on the east coast are probably more interested in hurricanes; CIESIN must maintain quality control over the disseminated information, and at the same time, not be viewed as a filtering mechanism; global change information should become a more significant part of the curricula at all levels of the educational system; users need to understand the scientific process so that they recognize that conclusions are fluid and change with time and new information; CIESIN needs to build a level of trust among the users, who need to understand that exchanges in scientific knowledge do not represent inaccuracies of information; users also need to be comfortable with the belief that the information they are receiving is objective and the best information available.

Another significant issue, which CIESIN will need to address, is the translation of information from one language and culture to others. In order to deal with this issue, one proposal put forth a multi-national organizational model for CIESIN which included an international corporate headquarters with satellite locations within the United States and other participating countries. The satellite sites at the other countries would therefore be responsible for the translation of information into meaningful format for the people in their regions.

CIESIN should employ the latest marketing strategies and employ the most up-to-date technologies. For example, a user-manipulated, hyper-media interactive video access format might be particularly effective. In addition, current avenues of communication such as educational, research, public, private, media and government organizations should be employed in the transfer of global change information. Organizationally, CIESIN can maximize the effectiveness of its staff by drawing expertise from affiliated organizations.

Knowledge transfer pilot projects are designed to demonstrate how global change information can be provided to decision makers on local, regional, state, national or international levels, although no single project is expected to address all of these levels. Knowledge transfer pilot projects are also designed to address one or more of the following process issues relating to knowledge transfer: Translation, Transfer and Assessment. Individual projects are not designed to address all of these processes. Most pilot projects will focus on translation or transfer processes.

All of the conference and pilot project activities are directed at gathering key information for the planning of the CIESIN Center and to facilitate development of CIESIN's organization. The CIESIN Center will have the capacity to make available information on global change to scientific researchers and to transfer the knowledge gained from the scientific research to applied users in the identified sectors worldwide. Planning for the CIESIN Center is expected to take place during 1991 and 1992.