GLOBAL CLIMATE CHANGE AND HUMAN HEALTH: INFORMATION NEEDS, RESEARCH PRIORITIES, AND STRATEGIC CONSIDERATIONS

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Introduction

The U.S. Global Research Plan (Committee on Earth Sciences, 1989) and the International Geosphere-Biosphere Programme (IGBP, 1988) were created to assess the effects of global climate change but have not been able to devote much attention to the consequences climate change will have on human health and welfare. Although researchers and policy makers recognize that climate change will have complex effects on resources (Fig. 1), in general, the social and medical sciences have not received appropriate international attention under the banner of global change. To address this imbalance, the public health research community needs to launch a international coordinated effort so that the social and medical sciences are as fully represented as other scientific disciplines. At this time, the social sciences have gained a foothold primarily through policy and socioeconomic analyses, yet little attention is paid to public health. Indeed, funding for public health research is low even in comparison with support for other social sciences.

The scientific community's low interest in and lack of acceptance of public health studies is unfortunate because public health issues are a major challenge for global climatology. In 1985 the U.S. Department of Energy (DOE) produced a series of reports on global climate change. One characterized the additional information required to understand and deal with climate change. The report covered various resources, such as fisheries, water, forest, and agriculture. In addition, it included a solitary chapter on human health, which was extremely difficult to develop (White and Hertz-Picciotto, 1985). At that early stage in the investigation of global climate change (about 1983), the challenges posed by that chapter demonstrated how difficult it is to address public health issues in a global context.

The difficulty arises from three deficiencies in our understanding and advancement of public health science: lack of recognition of and consensus on the relevant questions and research directions that should be pursued, lack of comprehensive models of health-related processes, and lack of worldwide data on health problems. When these shortcomings are successfully addressed, public health science will be able to measure the human dimensions of global climate change.

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Needed Analyses

White and Hertz-Picciotto (1985) identified a number of questions about the effects on human health of changing climate:

Would a warmer climate affect human thermoregulation, acclimation, or adaptation?

Would it produce any changes in human physiology or biochemistry?

Would it increase or decrease the incidence of birth defects?

Would heat waves, storms, lightning, and floods take higher tolls?

Would more extreme climates increase worldwide morbidity and mortality?

Would warmer, moister climates enhance the breeding and spread of bacteria, viruses, fungi, or pollen?

Would more turbulent air movement and more extreme temperatures and humidity spread airborne diseases more effectively?

Would diseases carried by humans become more prevalent and widespread?

Would vector-borne viruses, rickettsia, and bacteria be spread more readily?

Would parasitic diseases thrive better in a warmer climate?

Would climate affect agricultural production, the availability of food for humans, human nutrition, human resistance to disease, and human health?

What interactions between disease and nutrition might occur?

Might air pollution be affected by changes in temperature, in precipitation, in wind speed, and in land cover?

Would climate change affect the quality and quantity of outdoor recreation the human population might enjoy, and if so, with what results in terms of health?

Needed Models

Specific answers to these questions are not immediately forthcoming. Indeed, we do not yet know all the questions that should be asked about the health-related impacts of global climate change. Public health researchers need more sophisticated tools to perform these analyses with reliability. Researchers currently use statistical or simulation models and small-scale information (information derived from a small sampling of a large population or from an intensive sampling of a geographically small area) to produce an analysis of public health risk on a global scale.

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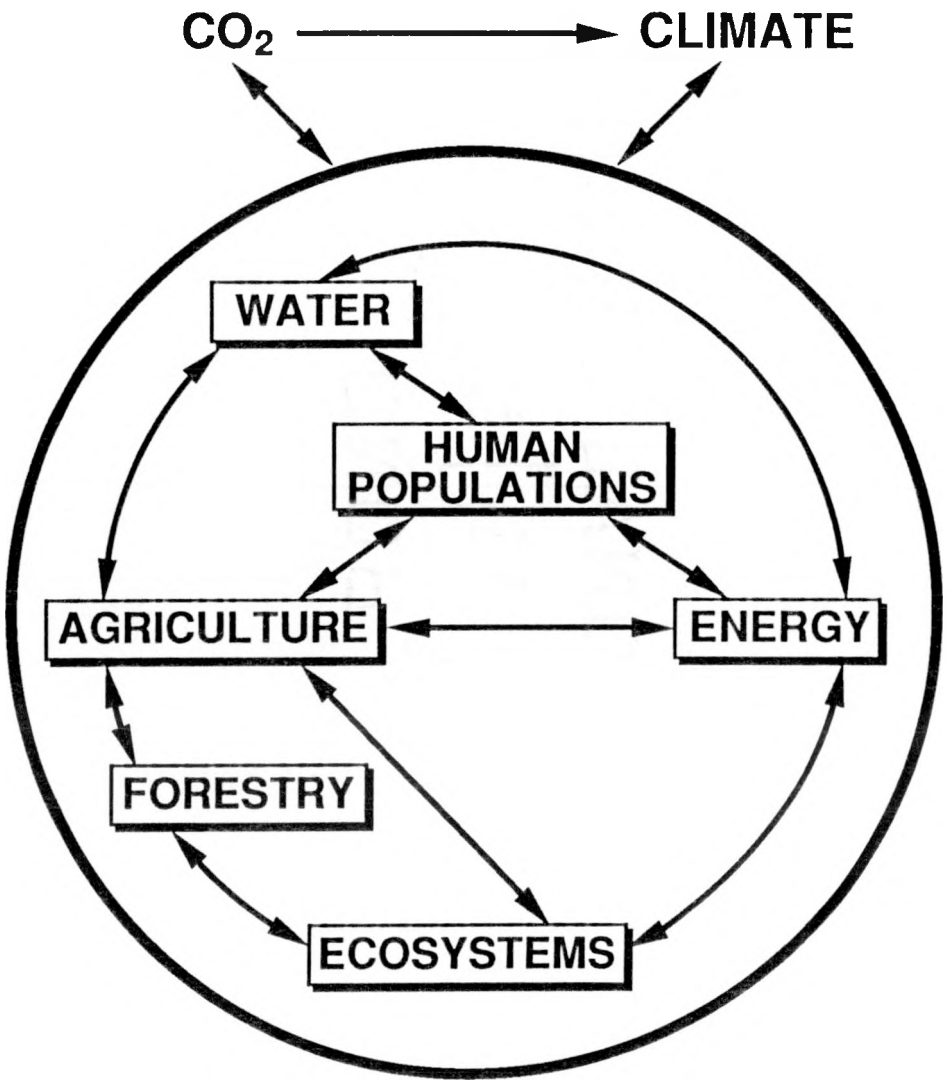
Resource Interactions Important In Global Change



To carry out such predictive analyses successfully, researchers need new simulation models that can account for relationships between or among entities or processes. Such quantitative models would be very unlike the conceptual models that public health professionals have used so successfully to eliminate smallpox and to control polio. The current conceptual models, unfortunately, are not robust and cannot deal with problems like global climate change because a large number of variables and large uncertainties are involved.

As a result of their lack of robustness, the health care/sciences' conceptual models and their results have not been fully accepted by the scientific and policy-making communities that deal with global change. To gain acceptance, the health care/sciences need to develop a quantitative approach that can address uncertainties and successfully model the processes involved. To develop such a model, however, researchers must first thoroughly analyze the processes. Once the processes are analyzed and modeled, regional statistics can be entered into the model. Then public health researchers can perform quantitatively based global analyses.

Needed Data

The lack of depth in the available data will severely hamper public health research into global climate change. Public health researchers frequently do not have enough information available to understand current conditions, let alone predict the future. Other areas of scientific inquiry into the causes and probable effects of global climate change are much more mature than public health studies. For example, not only do thousands upon thousands of data points and hundreds of journal articles describe the chemistry of the carbon cycle, but many reviews of the global carbon cycle tell us exactly what we do not know, why we do not know it, and what resources are needed to develop a fuller understanding. Such self review is vital to the development of science. Thus, similar analyses are needed for public health issues.

Public health officials and researchers should not despair, however; similar shortcomings have existed in almost every other resource area addressed to assess the secondary impacts of climate change. There is hope. On-line bibliographic data bases, directories of numeric data bases, and referral services like the National Environmental Data Referral Service are certainly helpful and often necessary. Yet in order to assess what the real problems are, researchers need to assemble and compile masses of raw data. For a while, analysis within national boundaries will probably suffice, and the work will entail expanding such studies as the St. Louis Study (this volume) or performing studies of regional corridors. Soon, however, national studies and global analyses (city by city and region by region) will have to be performed.

Such efforts will produce a tremendous amount of data, all of which will need to be collected, stored, uniformly formatted, assessed for quality, made available to the scientific community, and distributed to researchers and policymakers (health care and ministructures). Tasks like these have historically been carried out by centralized data centers funded by the government, academic institutions, professional organizations, and private corporations. As for global change issues, we should recognize that analyzing global-scale issues will require data bases that are much larger than those currently produced. Also, because the data collected must come from a multiplicity of disciplines, public health data will need to be correlated with data on climate, agricultural production, populations, and water resources, among many other types of data. This cross-disciplinary exchange of data/information will produce a cross-fertilization of ideas. Data, or the lack of it, will ultimately

be a potential problem to be addressed by public health researchers.

The amount and diversity (in both subject matter and source) or the traditional information clearinghouse of data that will be produced in assessing global problems will overwhelm a traditional data center and outstrip its capabilities. The study of global public health issues will require a data management system that can provide not only the vehicle for exchanging extant, acquired information but also the mechanisms for adding value to and stimulating their use of existing information, synthesizing new data sets, and initiating networking within the research community and stimulate their use. What will be needed is an Information Analysis Center (IAC) (Fig. 2).

The IAC as a Tool

An IAC would not be just a place to store and distribute data. Such a center would apply innovative approaches to managing research data, thereby increasing the number and diversity of information resources and producing enhanced data and information products to support a broadly defined user community. Justifiable under the purview of an IAC would be such activities as compiling bibliographies, conducting user-defined customized bibliographic searches, publishing newsletters, sponsoring workshops, and producing directories of researchers and policy makers. Its functions might include (but not be limited to) the following:

- Acting as the central data hub for a research program, providing program management with a clearinghouse for sorting available information and data, and serving as the conduit for both the distribution of data generated by the program and the acquisition of external data needed by the program.

- Setting standards not only in the format and transfer of information but also in the overall quality and usefulness of data to be included in the center, the depth of documentation, the extent and type of quality assurance needed, the type and breadth of data distribution, and the methods of archiving.

- Identifying what data are most needed by the general research community and deciding which data should be obtained, processed, distributed, and archived.

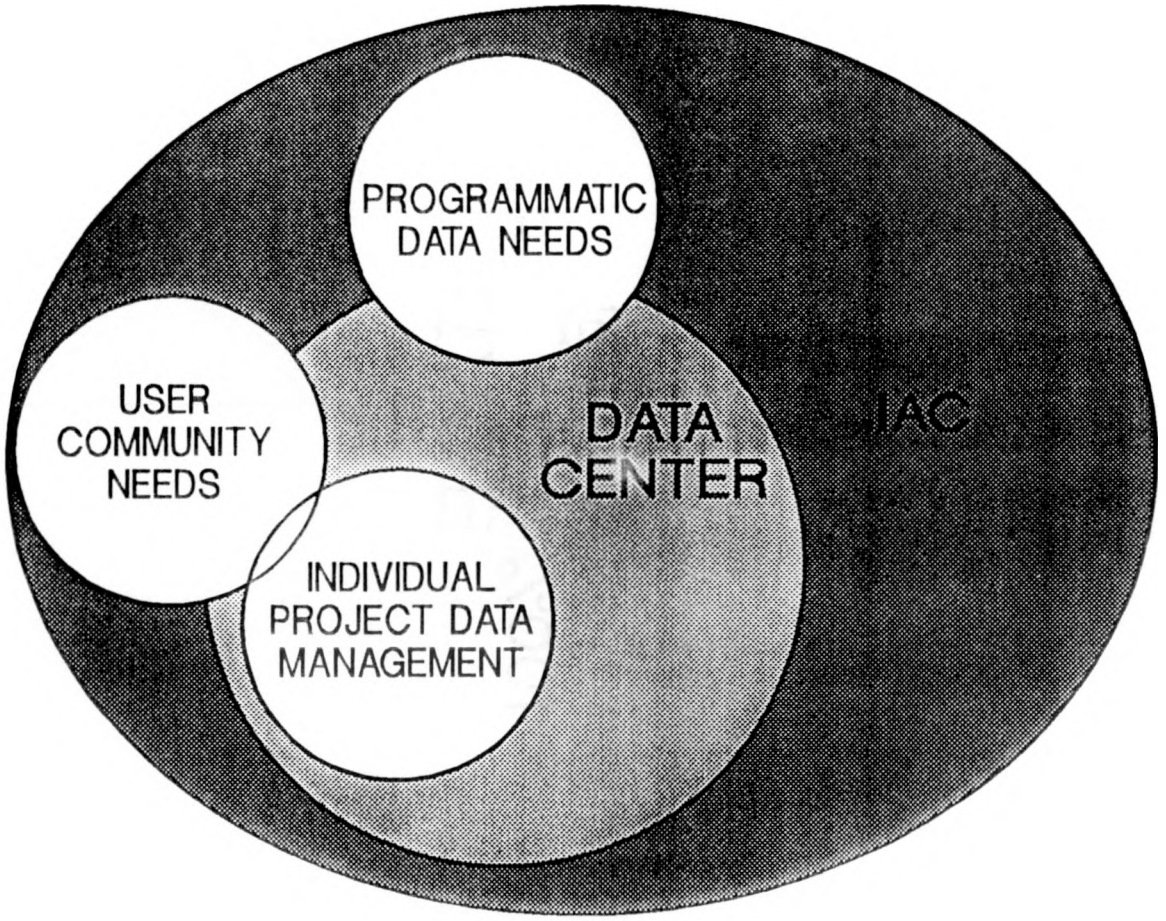
- Taking an active interest in providing data to address issues at hand by assembling information from multiple sources or by producing larger, more numerous, and higher-level data products that are not of the type normally produced by researchers or policy makers.

- Providing quality assurance that greatly increases confidence in reliability: for data sets, such quality assurance includes checking completeness, identifying unreasonable values or inconsistent correlations, and culling questionable observations; for computer models it includes analyzing the computer codes for errors and sensitivity. All quality assurance would be accomplished in close consultation with, and approval by, the original data supplier.

- Documenting data so that someone not familiar with the data could fully understand and use the data 20 years from now solely on the basis of the documentation.

- Widely notifying potential users that data are available, copying and sending data to researchers,

The Information Analysis Center Encompasses Many Functions



policymakers, and educators in a usable form, and providing input-output routines for that medium, as well as including summary statistics with the data.

- Archiving data in a way that ensures its integrity and usability as storage technology advances and as older equipment and media become obsolete.

- Promoting interaction between individual researchers, organizations, data centers, and other IACs, ensuring that any entity can directly receive information from or provide information to any other entity through newsletters, conferences, workshops, direct contacts, participation in bilateral and multilateral agreements, and physical and electronic mail exchange of requests and data (Fig. 3).

Thus an IAC links many communication activities within the scientific community and serves many of the information needs of researchers (Fig. 4).

The CDIAC Model

The Carbon Dioxide Information and Analysis Center (CDIAC) has served the international research community since 1982 under the guidance of the U.S. Department of Energy. CDIAC covers a very small part of the scientific spectrum: the three general areas of climate and weather records, the carbon cycle (including both oceanic and vegetative components), and vegetation. Currently, CDIAC distributes 35 data bases to businesses, universities, and government agencies. Figure 5 shows how CDIAC shares and contributes to the research process.

Our most important product is data bases that have undergone a rigorous quality assurance process. We review the data base, cull questionable data points, reformat it for distribution and use, document it, and perhaps use it in demonstration analyses. However, the data base is not released to the public until the principal investigator signs an approval expressing agreement with the final product (Fig. 6). Indeed, we do not adopt a data base unless we have the full cooperation of the principal investigator, even though the data base might be very critical. Such authority over the data is very important because the data belong to and reflect on the person who produced the information.

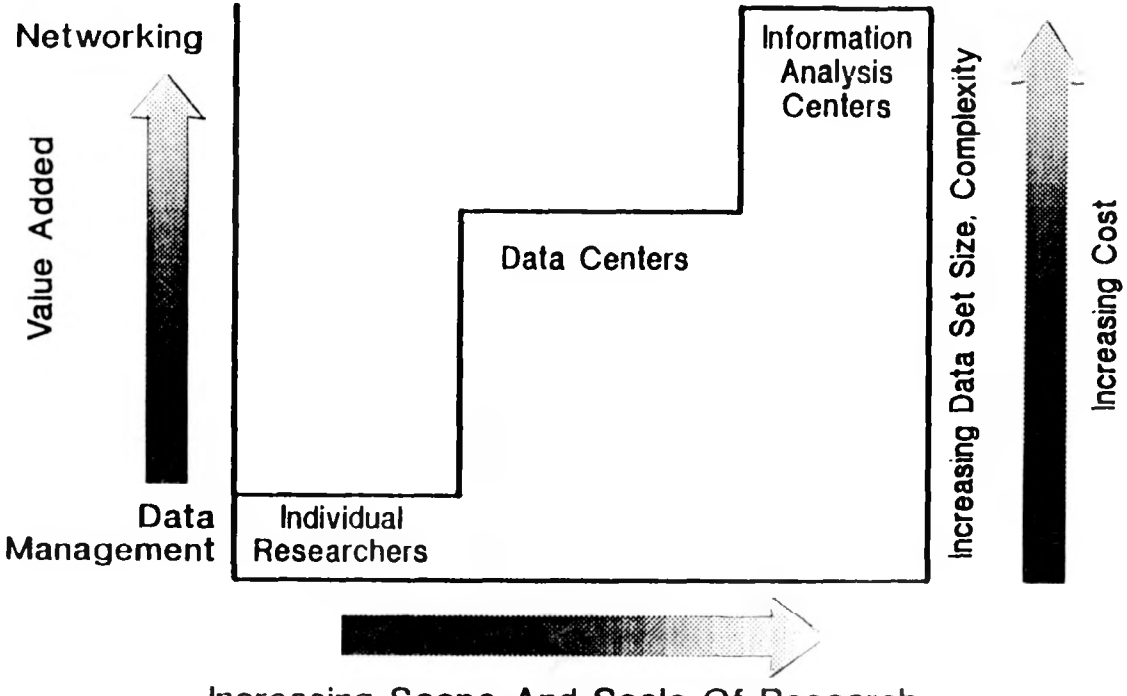
The data base is then 'beta tested'. In this process, the data base is sent to a research site, where specialists work intensively with it for a few months to discover any inconsistencies. Once we are assured that the data are reliable, the data base is permanently archived so that it can be requested and obtained by any researcher. As an additional quality check, we survey the people who request and use the data, asking them "Did you find any problems? What can we do to improve the data base?" and so on. If any error is discovered in the data base, we notify the user community, or we correct the error and announce that a new version of the data base is available.

Quality Assurance, A Special Concern

With data bases of this size and from this diversity of sources, the quality of the data is bound to vary. As a result, the problem of quality assurance has to be given special attention. Variations in data quality arise from two major shortcomings in the way science is conducted.

The first shortcoming is that researchers generally are not rewarded for producing high-quality

Derivation Of An Information Analysis Center



Spatial	Site	Regional	Global
Organizational	Individual	Multidisciplinary	Interdisciplinary
Temporal	Months To Years	Years To Decade	Multi-Decades

Increasec Need For An IAC

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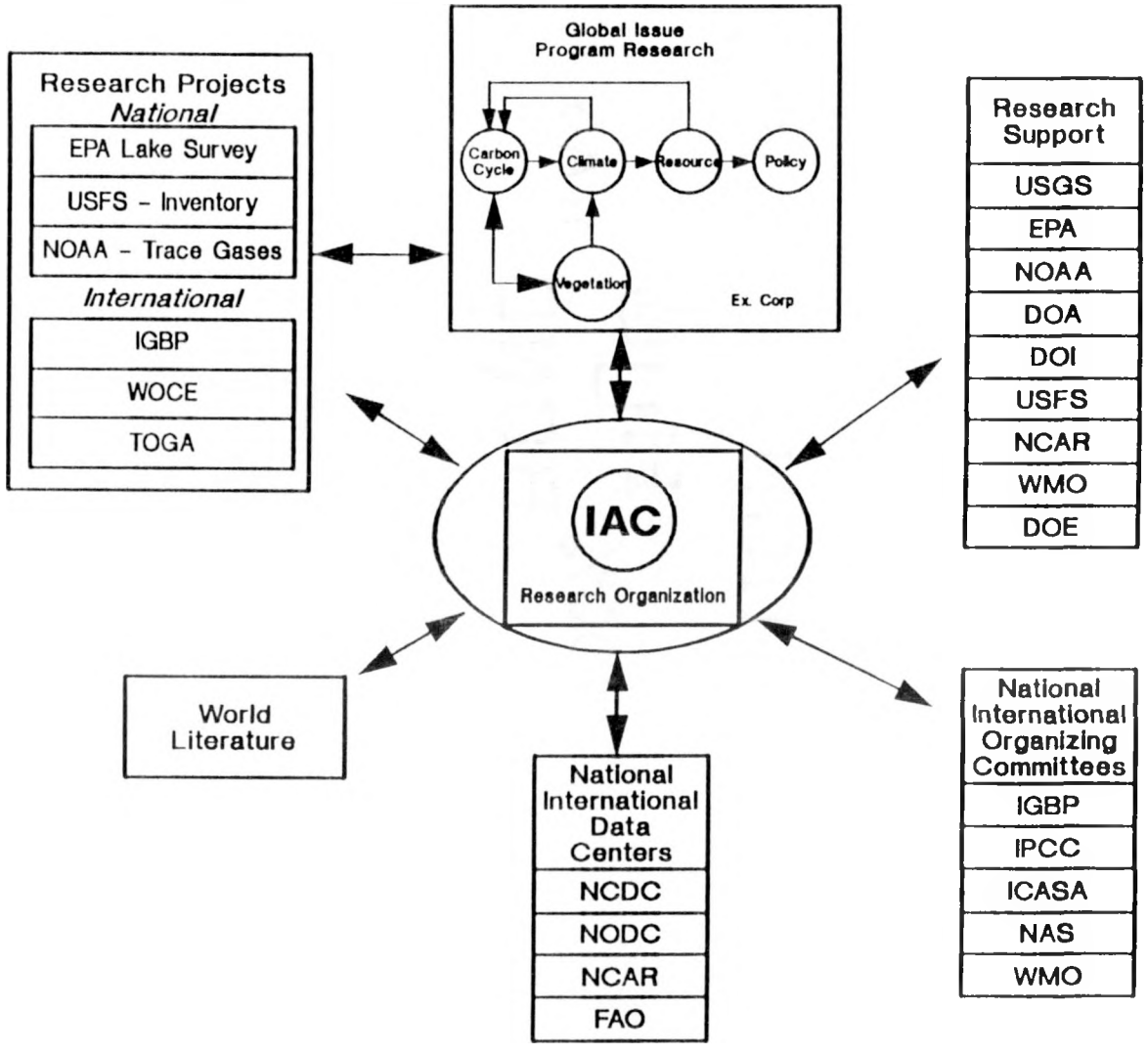
The IAC Is A Gateway Linking Many Activities And Serving Many Needs



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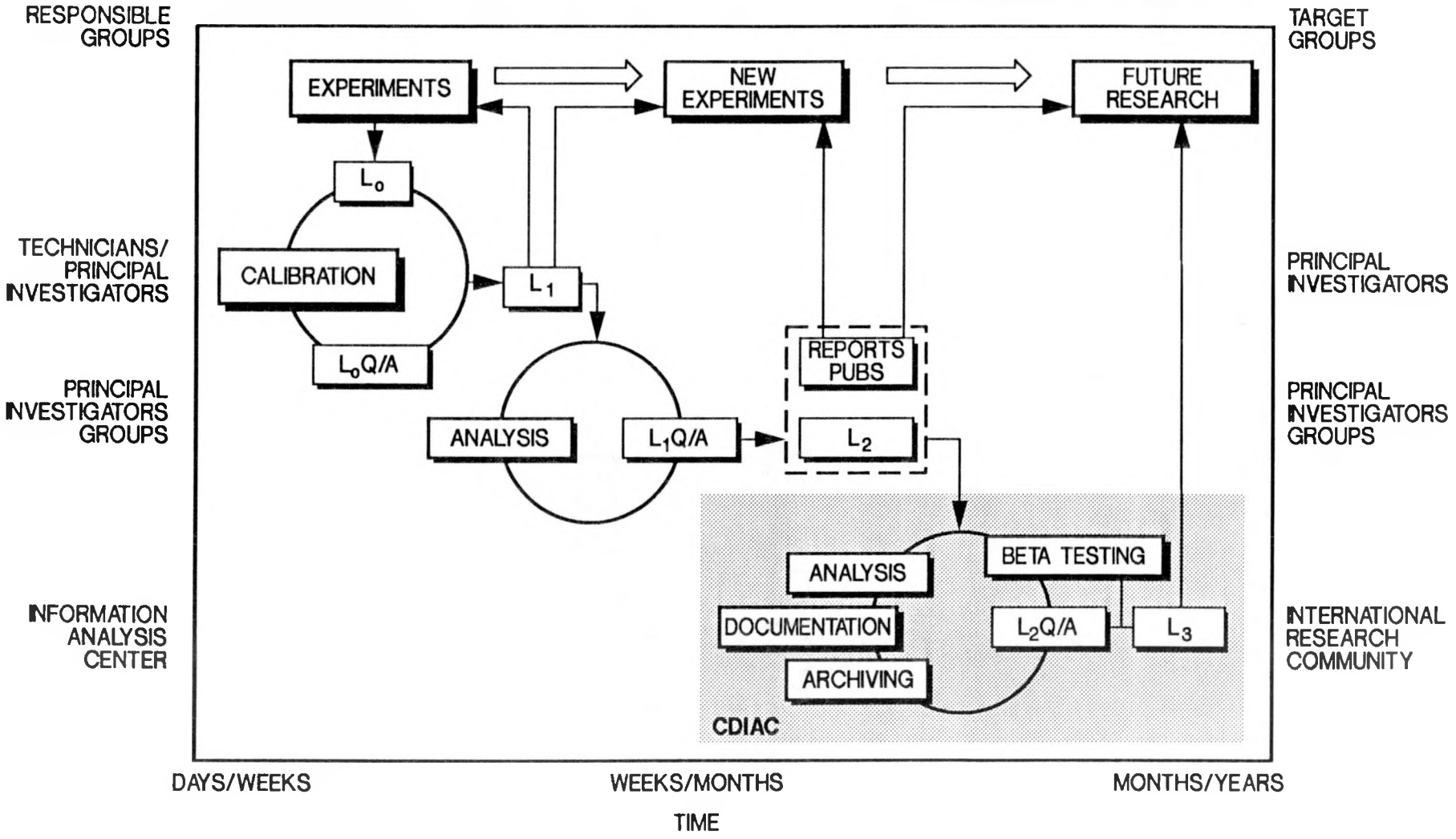
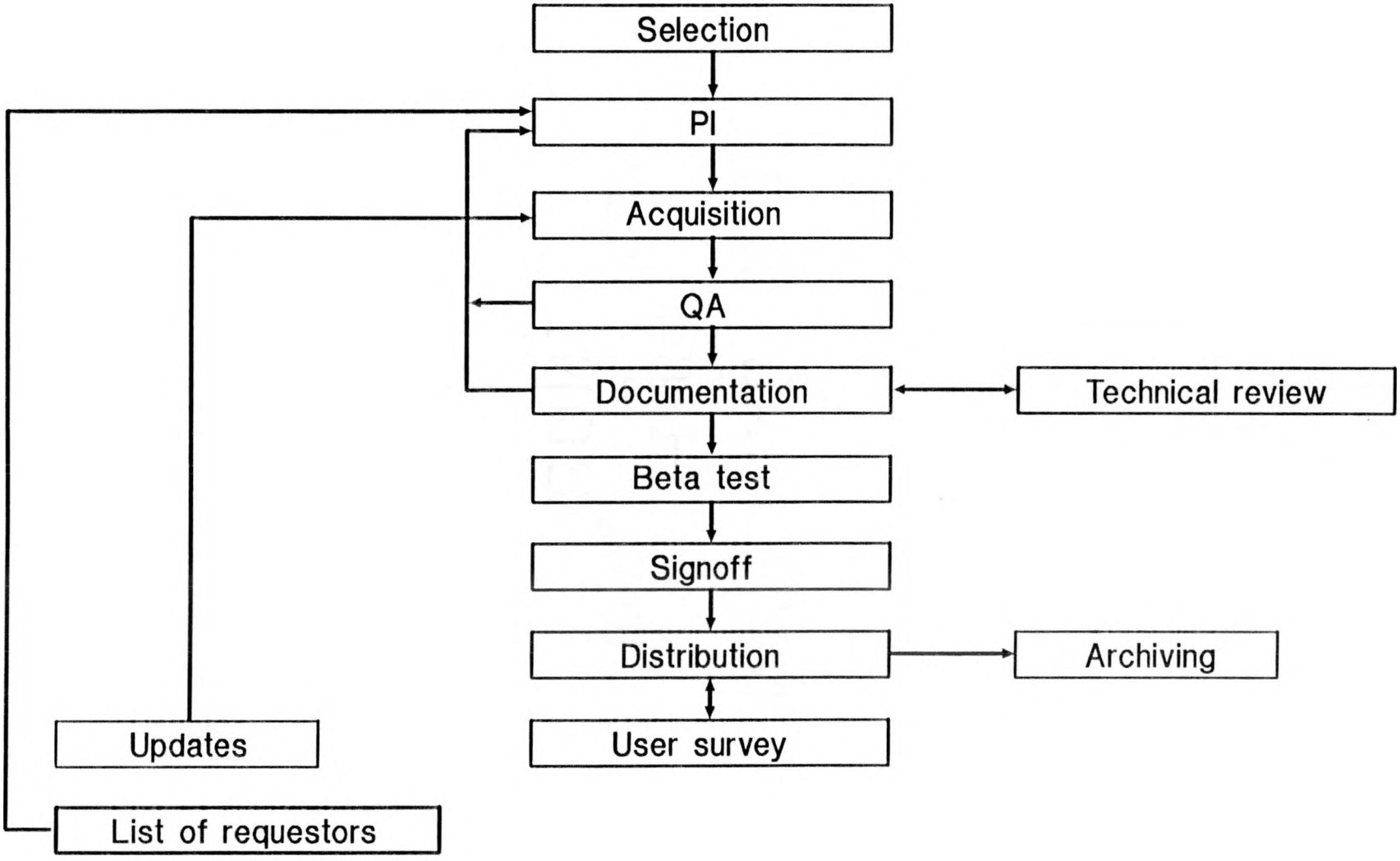
CDIAC'S ROLE IN DATA MANAGEMENT



Packaging Process



data bases in the way they are rewarded for high-quality publications. Indeed, compiling data bases takes time and money away from research. National research programs - such as space, health, and education - have been supportive of data base compilation largely in times of plentiful funding. When money has become scarce, data management has frequently been cut first. Fortunately, such is not always the case. The global change program is an excellent example of a program where, at least in the planning stage, data collectors have become equal partners with scientists.

The second shortcoming is that researchers are not particularly good at assuring the quality of their data; they are slightly myopic. Researchers might, for example, overlook spurious data or outliers. Gaining some distance from the work gives new insight into, and a less impassioned perspective towards, inconsistencies in the data. Quality assurance checks by independent reviewers often find problems in the data that researchers have overlooked.

As a result, IACs can expend a significant amount of their resources on quality assurance. Developing an accurate data base might be a multimillion dollar investment. Yet the amount spent on assuring the data's quality is justified, especially when one considers how much research is represented by that data base and how much could be depending on its analysis.

To gain an appreciation of the amount of culling necessary to ensure high quality in a data base, consider the Historical Climatology Network. CDIAC started with data from ~1219 measuring stations in the United States and applied very rigid quality assurance procedures to that data base. National Climatic Data Center dismissed some climate data records because they did not cover a long enough period, dismissed others because the data-collecting stations were moved, and dismissed yet others for other inconsistencies in the data. Much of this quality control was provided by the National Climate Data Center in Asheville, North Carolina. CDIAC, as the technical liaison, produced the final documentation. At the end of the quality control process, data from only 1200 stations remained for global climate and performed change analysis. Because calculations and predictions made thorough use of upgraded data bases, they will have much greater meaning, reliability, and authority.

An IAC for Public Health

To establish an IAC capability for public health researchers, funds must be solicited and secured. Because of the massive amount of data to be handled, the sheer number of investigators conducting the research, the variety of scientific disciplines represented, and the geographic dispersal of the researchers, no single site will be able to do all the work of the IAC. The work load will have to be borne cooperatively by a variety of organizations, and services will have to be paid for through subcontracts or grants from institutions. It would be reasonable to put sums of money in various sites and to have each site handle a particular aspect of the problem.

To ensure that the approach to the problem remains unified, certain aspects of the program will have to be coordinated centrally, perhaps by the federal government. The provision of centralized program office support is essential because of the scope and range of the enterprise: at CDIAC, we have identified 5000 people in 150 countries who are involved in research on global climate change. The needs of this diverse community cannot be met successfully through the uncoordinated efforts of scores of institutions scattered around the world.

The research community that can contribute to a fuller understanding of public health issues must to be identified. Then information can be addressed to that target group through the educational milieu. For example, at CDIAC, we continuously target 5000 global change researchersand policy/decision makers, asking them for additional research results and giving them the latest available information.

An IAC in public health research will have a variety of other benefits. Such an IAC will promote networking (as mentioned at this conference) which is a critical need in the public health research community. Networking will allow thousands of researchers from different institutions, agencies, and countries to exchange comments and have input to establishing research priorities. In addition, an administrative program would determine the consensus of the research community about where the research should be directed and who should perform specific tasks. Such a dispersed organization coordinated by a central office will allow the field of public health to formalize the management of data collection, formatting, quality assurance, storage, and use.

Some Strategic Considerations

Set priorities and narrow the focus. Some global problems are long-term propositions (e.g., the accumulation of CO_2 in the atmosphere from the burning of fossil fuels), whereas other problems are relatively acute emergencies (e.g., the destruction of rain forests). Discriminating between long-term and near-term concerns helps researchers define priorities and sharpen the focus of their efforts. Such a distinction is embodied in an analysis recently completed for the U.S. Agency for International Development. In that report, ORNL scientists looked at a list of resources (e.g., fisheries, vegetable crops, agricultural animals, and forests) and considered the effects that global climate change might have on those resources. The effects reflect both long-term and near-term changes (Fig. 7).

Similarly, in discussing public health effects, it might be strategically wise to distinguish between long-term effects and near-term emergencies and consider them separately. Although the public (and their elected representatives) can always doubt and temporarily ignore the long-term effects of climate change, they cannot argue about emergencies. Society must immediately respond to floods, disease, and famine.

Retain a global perspective. Human populations cannot be the sole focus in global analyses. As researchers, we must consider the highly interdependent web of resources, which is subject to a vast number of interactions. Indeed, some interactions only indirectly affect public health (e.g., the interactions between water resources, agriculture, nutrition, and health) (Fig. 1). Although human populations certainly are important, the other interrelationships have not been accorded an appropriate share of the necessary resources: this imbalance must change.

Make global models regionally specific. Regional specificity will be critical to public health. Once the new climate regime in a particular small region is known, the public health effects of that climate will need to be predicted. Global estimates will not predict what will happen to individuals in specific locales. Therefore, the models of global processes must be able to predict changes in public health for regions of meaningful size and scale.

Conclusion

Impacts On Resources

Resource	Impacts	
	Long-Term Change	**Emergencies**
Agriculture	• Crop productivity (increase/decrease) • Salinization • Locations of crop regions	• Increased crop failures and losses • Famine
Water Resources	• Salinization • Management and timing of run-off • Water supply • Flood management	• Drought • Flood • Salinization
Population & Health	• Infectious and parasitic diseases (incidence, range) • Nutrition and sanitation • Air pollution	• Epidemics • Respiratory and cardiac stress • Refugees
Energy	• Hydropower resource changes • Changes in electricity demand	• Supply system failure (e.g., loss of hydropower services, storm damage to supply system)
Forestry, Fisheries, Ecosystems	• Shift in ecological zones • Species composition • Salinization • Productivity change	• Fires • Pests and diseases • Flooding

Research in the social and medical sciences has been sorely neglected in the debate about global climate change. In that debate, much has been said about the environment whereas little has been said about people. Such an oversight is a serious deficiency in our international planning efforts because the effects on people are ultimately what will be important. To rectify the oversight, social scientists as well as medical scientists must become more active in the debate.

Although the public health research community may be tempted to devote increased time, money, and manpower to develop more research projects, the identification and pursuit of specific research projects should not be their sole focus at this time. Public health researchers must also develop a stringent philosophy of data and data management. Under that philosophy, data management and data quality assurance must be equal partners with research. Only then can public health researchers and other scientists fully appreciate each others' potential to contribute to the understanding of both global change and the effects that global change may have on our planet.

Acknowledgment

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Figure 1. Resource interactions important in global change. Climate change will have complex effects on natural resources and the human population.

Figure 2. Data management and user communities. The individual researcher undertaking data management can serve only a small portion of the user community and can rarely serve programmatic information needs. The data center expands this role but falls short of serving the entire user community and the majority of program needs. The information analysis center (IAC) serves the individual researcher, the larger user community, and program-level data needs through its role in data management, its variety of functions, and its value added concept of data management.

Figure 3. Levels of data management. As research needs dictate the analysis of data of increasing scope and scale, spatial, organizational, and temporal characteristics become such that individual and data center approaches to data management become inadequate. At the level of data management needed to address global issues and human health the concept of an information analysis center (IAC) becomes justified.

Figure 4. The information analysis center (IAC). The IAC serves many functions, not the least of which is to act as a hub linking the research community with support and funding agencies and providing a focus for data management at the program level.

Figure 5. Levels of data manipulation, quality assurance, feedback. Note that this is not a depiction of sequential data flow or a data network, but a conception of the processes and feedbacks associated with research data. CDIAC's scope is shown in the shaded area.

Figure 6. Steps in the CDIAC numeric data packaging process.

Figure 7. List of major resources possibly affected by global climate change broken down by impacts from long-term climate change and shorter-term emergencies.

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