Rising to the Challenge: The Role of the Information Sciences

Abstract

As the monitoring and measuring of global change proliferates data, the information sciences will be maximally challenged by the photogrammetry and remote sensing experts. This commentary examines three areas of note that must be addressed to successfully meet the challenge. The approach addresses the access to remotely sensed data, integrating pertinent remotely sensed data with other applicable data, and the extraction of information and the generation of knowledge from the integrated data. An overriding theme of this commentary is that the experts in the natural, social, and remote sensing sciences must work together to meet these extraordinary challenges to better understand the issues of global environmental change and its effects on our society.

Introduction

The discoveries and ingenuity of experts in the field of photogrammetry and remote sensing, coupled with scientific advancements and evolutionary technology, are enabling the world community to see an entirely new view of our Home Planet. Their contributions have moved us into an unprecedented era of space-based Earth observational capabilities. We have experienced an extraordinary extension of our senses and yet our thirst for knowledge of the Earth and our environment seems unquenchable. Only the first steps have been taken. However, achievements in deploying advanced sensors and space systems will be a forgotten legacy if we do not act now to put in place the information management resource base necessary to guide the treasury of incoming data and measurements into the workstations and applications of the global change community. We must consider some of the emergent and urgent challenges before us as we endeavor to cope with the torrent of information which awaits us just over the horizon.

We are living at a special time in human history in which we can make a global contribution of lasting value. Convergence of three key factors is helping to create this opportunity; knowledge of the threat, demonstration of a technology to monitor the Earth system, and the public will and national resolve to act in response. The challenge for those of us engaged in the information sciences is to develop and implement strategies and achieve results that seize this opportunity for action. While our progress to date has been rewarding, our contributions to life on Earth will be insignificant if we do not rise to the challenges.

Few could argue that remote sensing imagery is not today a part of popular culture. Striking, cloud-free images of Earth adorn the corridors of our workplace and the walls of our children's classrooms. These images are powerful motivators for environmental stewardship and sensitivity. Unfortunately, what the popularization of remotely sensed images has failed to convey to date, is how extremely powerful these images are as informational tools.

As pilot for the Skylab 3 mission and commander of the Space Shuttle Columbia, I had the opportunity to see, first hand, what many people will only be able to see through the eyes of sensors and satellites. From space, you can see all the colors of Earth: the blues of its oceans, the whites of its clouds and snow on the mountains, the green and brown patchwork of farm fields, and the painted deserts in all their living hues of red and brown and purple. From such a vantage point, you don't see the boundaries that divide us culturally, politically, or economically. All you do is realize how profoundly you care for this place, our Earth.

You wish you could convey the wonder, the marvel, and the awe of this exquisite blue and white sphere, suspended in a sea of blackness, appearing unified and tranquil. Seeing Earth from space is a powerful, expansive experience that makes you feel impatient with the relative pettiness that so often preoccupies and confounds us.

As it orbits our planet every 90 minutes, the Space Shuttle, one of the most sophisticated expressions of human knowledge and technical skill, passes over millions of people suffering from wars, hunger, ignorance, and disease. The urgency to employ technology in the service of humankind becomes so very apparent as you watch the daily struggle of life on Earth from hundreds of miles overhead.

The Challenges for Information Sciences

Today, many of our colleagues would say our technological advancement provides us the opportunity to make a global contribution of enduring value. I submit this is not merely an opportunity but an obligation. Specifically, there are three critical challenges that I believe establish a framework for understanding the role of information science; data access, data integration and information extraction, and knowledge generation.

We currently suffer from an embarrassment of riches with respect to data. Given the rich pool of data resources at hand, we must deploy appropriate technology for *access* to those resources by the global community of researchers and applied users worldwide. Once ubiquitous, unimpeded access to these data resources becomes a reality, we must not fail to develop the capacity to *extract meaningful information* from this resource base. Finally, given the capacity for data access and information extraction, we must continually *develop and improve* our understanding of the Earth system through modeling of the observed phenomena. These challenges are in consonance with three principal goals of the U.S. Global Change Research Program (US-GCRP), that is, to document, analyze, and understand.

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Access to Remotely Sensed Data

The first challenge, providing access to data resources, has a number of facets. It is widely accepted that we have amassed a rich pool of data resources. This is substantiated by any cursory analysis of existing and planned programs for collection. For example, NASA's Earth Observing System (EOS) and other remote sensing systems will create unprecedented volumes of data. There is also *in-situ* information from ground stations, ships, and airplanes which complements remotely sensed data sources. Finally, there are diffuse, albeit crucial, data pertaining to human actions, such as demographics, economics, industrial metabolism and productivity, energy consumption, public health, and so forth.

To meet the challenge of providing data access, information scientists must enable the capture of data in a viable information system. The EOS Data and Information System (EOSDIS) represents the promise of such a robust, evolutionary architecture which can stand the test of time in management of long time-series data sets envisaged for the US-GCRP. However, there is a concern that the volume of existing and future data will push against the outer boundaries of current database management technologies. In addition, the nodal development of national and international databases may demand an inherently distributed system architecture.

Information scientists must enable access to data by the international, interdisciplinary community of users. This is just one factor driving the requirement for interoperable directory systems with cost-effective browse capability, interoperability with multiple system sources, and implementation of the highest standards of data quality and integrity. Also, information scientists must exploit new distribution technologies and media, and extensive use of networking.

The technology now exists to access, catalog, and store tremendous volumes of data and to distribute it on very high speed networks with global reach. The challenge here is to bring into balance the data collection and data management components of our Earth observations programs.

Billions of dollars have been invested in the collecting, cataloging, and archiving of key environmental data over the past three decades. That investment must be maintained and optimized. Clearly, the advent of such initiatives as NASA's Mission to Planet Earth will stimulate further investment in archiving strategies and storage technologies because the Earth Observing System itself is projected to transfer data to the ground at an estimated rate of 1.1 Terabytes per day.

Integration of Remotely Sensed Data

Data access alone is not enough. The second challenge, data integration and information extraction, is of equal or greater importance. A number of issues face information scientists as they attempt to meet this challenge. Disparate types of data will need to be integrated if we are to be able to derive the maximum benefit from our data resources. Technologies such as Geographic Information Systems will face new challenges, such as relating Earth and human science data in meaningful, georeferenced information products. Furthermore, visualization technologies must cope with four-dimensional data streams.

The extraction of information from data includes, of course, the development of algorithms that extract, from a multi-dimensional array of data, the important nuggets of information that address problem solving. A related issue is the need for information extraction tool kits that are readily adaptable to a wide spectrum of problems and are at the same time accessible to a broad range of users.

Recently, the National Space Council promulgated National Space Policy Directive 7 (National Space Council, 1992), which underscores the need for interoperability and integration of ground based data and information systems supporting a Space-based Global Change Observing System, or S-GCOS. This directive should give pause to those who feel there may be a lack of substantive support for enhancing the ground systems infrastructure. All federal agencies involved are explicitly directed to "participate with other USGCRP agencies in planning for the Global Change Data & Information System (GCDIS) with a goal of maximizing the system's interoperability."

Owing to concerns over the proper balance between data collection and data analyses, the United States Congress itself took bold action in 1989 to address this issue when it directed a study be conducted to determine the adequacy of plans and programs to address the anticipated data management milieu of the 1990s and beyond (House of Representatives, 1989).

Knowledge Generation

The third challenge facing information scientists is best characterized as knowledge generation. This involves the development of models through which an understanding of observed phenomena are derived over time. This improved understanding must be achievable, not merely by the traditional enclaves of Earth scientists, but also by a much broader community of users.

The premises underlying the characterization of knowledge generation as a critical challenge are the understanding of phenomena fundamental to developing the parameters of global change, and the conveyance of that understanding to applied users.

The information technology issues undergirding these premises are threefold. The first issue at hand is the need to map and document observed fundamental natural and human processes over time, implying the need for consistent documentation to enable comparative understanding and monitoring over a period of many years. Second, there is a requirement for the development of modeling frameworks and systems that enable comparative and parametric evaluation at global and regional scales, that is, to understand the science of global change. Third, the conversion of the science to decision support systems that look at the problem from the perspectives of applied users, such as policy makers.

We have fallen short in matching the vigor of data collection with the rigor of data management and integration. Access to, use, and understanding of our existing data and information resources begs for improvement. Improvements in these areas are crucial when one recognizes the new reality that the traditional user community of remotely sensed information (i.e., remote sensing scientists and photogrammetrists) is no longer an exclusive user constituency.

We need to address our own adaptability to support the growing field of interdisciplinary researchers who seek to integrate remotely sensed data in ways few dreamed of only years ago. The implications of interdisciplinary studies are particularly important, especially those pathfinding efforts in the high risk wilderness of integrating the social and natural sciences. Considerable work, such as that of the NASA Earth System Sciences Committee (1988), has been accomplished in the past decade toward understanding the interactions among natural processes that influence global change. The conceptual model of Earth system processes, also known as the Bretherton Diagram, recognizes that information and data from one system or discipline, such as the physical climate system, is needed to evaluate processes in another system, for example, in biogeochemical cycles.

There has been a growing emphasis on the need to not only understand the Earth and the interrelationships of its natural systems, but also to begin to understand the human dimensions of global and regional environmental changes. To do so requires an interdisciplinary approach to researching global change that will draw upon, as never before, both the social and natural sciences. We need to erase traditional boundaries between the natural and social sciences, each with its discrete lexicon, methodologies, and analytical tools. We need to find common platforms on which these knowledge domains can be brought together to create meaningful georeferenced information products for decision makers and applied users who impact our environmental management and development processes.

Conclusions

I am drawn to the words of ASPRS past President, Dr. Vincent Salomonson, who reminded us that this is "a very prominent society with a highly warranted reputation for and a rich history in the development and utilization of photogrammetry, remote sensing, and technology for educational, scientific, and practical purposes" (Salomonson, 1992). These practical purposes are at the heart of the applied users that must now be served.

We cannot deny the irreversible trend toward integration of a multiplicity of scientific domains. We cannot shrink from the information sciences challenge presented; we must rise to this challenge and move to develop and deploy appropriate, evolutionary, and revolutionary technologies in support of the global environmental change community.

The information science community must be committed to directing engineering and scientific expertise toward improving our ground-based information infrastructure to ensure that our priceless data, the currency of science, is archived, handled, and distributed to the broadest possible interdisciplinary research and applications user base.

We must reach out to new and non-traditional users, and work to make their exploitation of remote sensing data and information successful and productive. We must understand the unique data exploitation needs and foster dialogue between natural, social, and health scientists with economists, demographers, civil engineers, and architects.

From initial observation to decision making, it is the information sciences that provide the enabling mechanisms for us to measure, analyze, and understand global change. I envision a framework anchored in the three fundamental challenges of information sciences presented to you.

As you engage your colleagues, I encourage you to be mindful of the historical role you have had in enabling the human race to visualize our home planet. I urge you to recognize the challenge and the unprecedented opportunity we have before us. I urge you all to promote the full utilization of Earth observation technology from measurement to enlightenment.

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