Space Techniques Used to Measure Change in Terrestrial Waters

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Discussion of Challenges Facing Water Management in the 21st Century

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Managing water for sustainable use is a complex balancing act that requires significant scientific advice on policy issues, according to experts at a conference, "Water for a Sustainable and Secure Future," held in Washington, D.C. on 29–30 January.

Several speakers called for the need to correct water distribution problems—particularly in developing countries and other regions where many people lack access to clean drinking water and safe sanitation systems—and to re-balance the allocation of water between various human uses, as well as ecosystem needs

Bruce Babbitt, U.S. Secretary of the Interior during the Clinton administration, said that, while there is no absolute shortage of water in the world, distribution problems arise in many areas because of the lack of efficient use and the inability to price water as a valued commodity.

Babbitt also said that scientists need to help policy-makers draw a "bright line" indicating how much water needs to be left in rivers and other water bodies for the use of natural resources and to maintain ecosystem services. "The real challenge is to get hydrologists, geoscientists, and modelers to address the issue of what are the rational, sustainable boundaries of supply."

Robert Hirsch, associate director for water for the U.S. Geological Survey, said, "Many of us who have had training in water look at a river and ask the question, 'how much water can I get out of this river to make for a reliable supply for a city or industry or agriculture?' That's the old question. The new question is, 'how much water do I need to leave in rivers for the species that depend on that water?' That is one of our greatest challenges."

He stressed the importance of having good scientific information to break gridlocks among different water users about the appropriate balance of water allocation, including in more arid regions such as the western United States.

Hirsch outlined a number of key challenges in water management, including the need to have a national assessment of the status and trends of groundwater and surface water use, and the need for improved models and monitoring to understand water availability and use.

Among other concerns he cited are the scientific uncertainty about the impact of the progressive decline in groundwater in some regions, questions about the effectiveness and potential environmental impacts of aquifer injection storage and recovery, the health impacts of low-concentration compounds such as hormones and medicines in water, and the emerging issue of changes in hydrology driven by climate change.

Impact of Climate Change

Other speakers also addressed concerns about the potential impact of climate change on water issues. William Graf, professor of geography at the University of South Carolina, agreed that climate change does present some concerns, but he argued that there are more imminent and known threats to water resources.

"Climate change is an integral part of what we are going to be facing," he said. "But we have already had 5 times the effects that we might reasonably expect from climate change already installed in the ground. Dams that we have built in this country, which number more than 75,000, in many instances have altered flood peak discharges; for example, by 100%. That is much more of an alteration than we will ever reasonably expect from climatic change. It strikes me that we ought be dealing with problems we know and understand first, and then deal with problems of speculating about what is coming down the pike."

However, Peter Gleick, president of the Pacific Institute for Studies in Development, Environment and Security, said that one of the most severe consequences of climate change could be its impact on water resources. "The climate cycle," Gleick said, "is the hydrological cycle."

Gleick also called for a "soft path" to water management that includes conservation, new technologies to reduce water usage, and managing resources for human and ecosystem needs. He contrasted the soft path with the "hard path," which he said included the building of inefficient and environmentally damaging dams, levees, and other infrastructure.

In addition, he said he supports proposed U.S. federal legislation that calls for establishing a national water commission, which passed the House of Representatives last fall. He has proposed that such a commission become involved in efforts to protect national water resources, as well as in providing advice on how to help address the global water crisis.

The conference was sponsored by the National Council for Science and the Environment, a nonprofit group involved with efforts to improve the scientific basis for environmental decision-making.

—Randy Showstack, Staff Writer

MEETINGS

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Terrestrial waters—including snowpack, glaciers, water in aquifers and other geological formations, water in the plant root zone, rivers, lakes, man-made reservoirs, wetlands, and inundated areas—represent less than a mere 1% of the total amount of water on Earth. However, they have a crucial impact on terrestrial life and human needs and play a major role in climate variability.

Land waters are continuously exchanged with the atmosphere and oceans in vertical and horizontal mass fluxes through evaporation, transpiration, and surface and subsurface runoff. Although it is now recognized that improved description of the terrestrial branch of the global water cycle is of major importance for climate research and for inventory and management of water resources, the global distribution and spatial-temporal variations of terrestrial waters are still poorly known because routine in situ observations are not available globally. So far, global estimates of spatial-temporal change of land water stored in soils and in the snowpack essentially rely on hydrological models, either coupled with atmosphere/ocean global circulation models and/or forced by observations.

Concerning surface waters, in situ gauging networks have been installed for several decades in many river basins distributed non-uniformly throughout the world. In situ measurements provide time series of water levels and discharge rates, which are used in studies of regional climate variability and in socio-economic applications; for example, water resources allocation, navigation, land use, hydroelectric energy, and flood hazards. Gauging stations, however, are scarce or even absent in parts of large river basins due to geographical, political, or economic limitations. Moreover, since the beginning of the 1990s, numerous in situ networks have declined or ceased operations because of political and economic factors.

Recently, remote sensing techniques have been used to monitor components of the water balance of large river basins on time scales ranging from months to decades. Among these, two are particularly promising: satellite altimetry for systematic monitoring of water levels of large rivers, lakes, and floodplains, and new space gravity missions for measurement of spatial-temporal variations of total terrestrial water. Other remote sensing techniques, such as Synthetic Aperture Radar (SAR) Interferometry and passive and active microwave observations, also offer important information on land surface waters, such as changing areal extent of large wetlands.

By complementing in situ observations and hydrological modeling, space observations have the potential to significantly improve our understanding of hydrological processes at work in large river basins and their influence on climate variability, geodynamics (for example, sea level change, Earth's rotation, and gravity-field variations), and socio-economics. Unprecedented information can be expected when models and surface observations are combined with observations from space, which offer global geographical coverage, good spatial-temporal sampling, continuous monitoring over time, and the ability to measure water mass change at or below the surface. A grand challenge for the future is to assimilate space-based hydrological products into models; for example, models of global/regional climate and regional water management, as now is done in meteorology and oceanography, for both scientific and operational applications.

To address these issues, a workshop sponsored by the French Centre National d'Etudes Spatiales (CNES) was organized. This 3-day workshop attracted over 80 participants from 12 countries who work in large-scale hydrology, climate modeling, regional hydrology, water resources management, space geodesy, and remote sensing. These scientists heard the respective scientific concerns of others, and discussed how to better understand the terrestrial branch of the global water cycle, how to improve and validate space-based hydrological products, how to exchange data and model results, and how to assimilate data into models.

Future common work plans involving the different communities and specific actions were also discussed. The workshop was organized around several main themes: global hydrological modeling (objectives, state-of-the-art, future requirements, contribution of space observations); global monitoring of total terrestrial water mass from space; applications of surface water monitoring by satellite altimetry; passive and active microwave techniques for observing surface water and snow; the combination of space techniques; and the need for global data of land water mass change in space geodesy.

The workshop concluded with a general discussion led by a few panelists with active participation by the audience. The main questions addressed were: What are the current and future challenges in large-scale hydrology, and how should we face them? Do space observations provide valuable information on land hydrology? And, how can we strengthen the collaboration between hydrologists/climate modelers and space-observation scientists?

From the discussion, two specific recommendations were identified. The first was to create an international project for exchange and evaluation of simulated and remotely sensed hydrologic variables. The project would focus on those variables representing major domains of storage of continental water—snowpack, natural and artificial surface water bodies, soil water, and groundwater—and major fluxes—precipitation, total evapo-transpiration, and river discharge—any of which may be affected by or affect human activities.

Data sets to be contributed would include those derived from remote sensing and those obtained by simulation of hydrologic processes. Evaluation of remote sensing data and model outputs would include comparison with in situ observations; therefore, this proposed international project would have to establish a collaboration protocol, including data exchange with existing in situ networks. Efforts would be made to ensure maximum temporal overlap of contributed data sets. Contributed data sets would be accompanied by documentation sufficient to inform all participants about how they were created.

Consideration will be given to seeking sponsorship of this project by the Global Water and Energy Cycle Experiment (GEWEX) and to using the results of related GEWEX projects (e.g., the second Global Soil Wetness Project and the "Coordinated Enhanced Observing Period") within the proposed project.

Also recommended was the creation of a European Working Group on Hydrologic Observations from Space, under the auspices of the European Space Agency (ESA). The objective of the working group would be to promote the application of existing space observations and near-future missions (for example, CryoSat, Jason-2, and SMOS-Soil Moisture and Ocean Salinity) to problems in hydrology, and to express the requirements for future spaceborne hydrology missions and the ground-based observations necessary to support the validation of spaceborne data products.

Problems in hydrology of relevance to the group would range from the local water management scale to the global scale. Membership would be split more or less equally between scientists concerned with observational processes and those concerned with applications of the data, and it would include scientists whose primary concern is ground-based observation.

The working group would promote cross-border communication on space observations in hydrology within Europe, as well as access for developing countries to hydrologic observations from space, and seek collaborations to share ground- and space-based hydrology observations. The working group would also promote communication between the scientific community and space agencies and communication with relevant working groups at the international level. It would organize scientific meetings with a focus on problems of space observations for hydrology and on ground-based observations necessary to support the validation of spaceborne techniques. The participants in these science working group meetings will be drawn from experts in both spaceborne and ground-based observations, and from modelers assimilating these data.

In the United States, there is the Surface Water Working Group, funded by NASA's Terrestrial Hydrology Program, and created in 2002 [*Alsdorf et al.*, 2003] Its primary objective is to determine observational requirements for global land-hydrology applications using space techniques, in situ observations, and data assimilation. Its ultimate goal is to identify new space-based technologies capable of fulfilling these requirements.

Given the existence and mission of the Surface Water Working Group, the creation of an ESA-related European working group would facilitate the exchange of ideas and information on these topics between the two sides of the Atlantic. It might also eventually lead to a joint mission totally dedicated to land hydrology.

The Workshop on Global Hydrology from Space was held 29 September 29–1 October 2003, in Toulouse, France.

Reference

Alsdorf D., D. Lettenmaier, and C. Vörösmarty, (2003), The need for global, satellite-based observations of terrestrial surface waters, *Eos, Trans. AGU, 84, 29*, 269–280.

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