the world. State and local school boards across the U.S. are considering these standards as models in developing their own K-12 science programs. Both sets of standards are available online at http://www.project2061.org/tools/benchol/bolframe.html and http://books.nap.edu/books/0309053269/html/.

Both the AAAS *Benchmarks* and the NRC *National Science Education Standards* include Earth and space sciences as integral components of the overall science curriculum. In making the case for why AGU should pursue a position statement, CEHR noted that many school boards are under pressure to limit or eliminate the teaching of Earth and space sciences. Some of the pressure stems from groups that object to the teaching of evolution and other scientific theories on the age of the Earth and origin of the universe. Equally prominent are those who express concerns about a curriculum already overcrowded with traditional content in physics, chemistry, and biology.

AGU's Committee on Public Affairs (COPA), which is responsible for evaluating whether position statement proposals fall within the Union's guidelines for advocacy, engaged CEHR to more fully develop the rationale for writing a policy statement on the topic, given that the AGU membership is primarily concerned with research at the university level. That rationale includes an acknowledgment that success in advancing the geophysical sciences, a Union goal, depends measurably on the preparation of well-educated students and on a public that understands and appreciates the value of Earth and space sciences.

The panel intends to finish its work this spring; thus, your comments will be most helpful if they are received by mid-March. You can write, e-mail, or fax comments to Peter Folger, Manager, Public Affairs, AGU, 2000 Florida Ave., NW, Washington, D.C. 20009; E-mail: pfolger@agu.org; Fax: 202-328-0566.

John Snow of the University of Oklahoma, Norman, Oklahoma, chairs the panel. Other panel members include:

Marvin Geller, SUNY Stony Brook, Stony Brook, N.Y., USA;

Carl Katsu, Fairfield Area School District, Fairfield, Penn., USA;

Margo Kingston, USGS (retired), Reston, Va., USA;

Randall Richardson, University of Arizona, Tucson, Ariz., USA; and

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# G E O P H Y S I C I S T S

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## In Memoriam

**Alvin Seiff** died on December 16, 2000, at age 78. He had been a member (Atmospheric Sciences) since 1976.

## Honors

**Ann Pearson** and **Gary Kleiman** were both awarded the Rossby Award for the most outstanding thesis submitted to MIT's Program in Atmospheres, Oceans, and Climate.

Pearson's thesis is titled "Biogeochemical Applications of Compound-specific Radiocarbon Analysis." Her study presents the first comprehensive set of compound-specific carbon isotopic ($\delta^{13}C$ and $\Delta^{14}C$) data for lipid biomarkers isolated from marine sediments.

Kleiman's thesis is titled "Measurement and Deduction of Emissions of Short-lived Atmospheric Organo-chlorine Compounds." His objective was to measure and deduce the emissions of some trace short-lived reactive organochlorine gases that have health and environmental implications.

## Recent Ph.D.s

### Hydrology

Scour in low gradient gravel bed streams: Patterns, processes, and implications for the survival of salmonid embryos, **Paul E. DeVries**, University of Washington, Stephen J. Burges, March 2000.

The frequency and extent of hydrologic disturbances in the Puget Lowland, Washington, **Christopher P. Konrad**, University of Washington, Derek B. Booth and Stephen J. Burges, December 2000.

Aspects of boreal forest hydrology: From stand to watershed, **Bart Nijssen**, University of Washington, Dennis P. Lettenmaier, December 2000.

Trees, snow and flooding: An investigation of forest canopy effects on snow accumulation and melt at the plot and watershed scales in the Pacific Northwest, **Pascal Storck**, University of Washington, Dennis P. Lettenmaier, March 2000.

### Solid Earth Geophysics

Electrical potential changes and acoustic emissions generated by fracture and fluid flow during experimental triaxial rock deformation, **Oswald C. Clint**, University College London, Peter Sammonds, Shingo Yoshida, and Phillip Meredith, February 2000.

# FORUM

## Global Water Data: A Newly Endangered Species

PAGES 54, 56, 58

Water science finds itself at an interesting and critical crossroads. Sophisticated atmospheric modeling, remote sensing, and Internet-based exchange of data enable exciting new synergies to develop among scientists, policy-makers, and the private sector. Paradoxically, we find it evermore difficult to validate products from these high-technology tools and to exploit their full potential due to a severe and sustained decline in available hydrologic data sets.

At the same time, climate change, population growth, and economic development all add to the urgency of securing a clear understanding of the global water system. Control of the land-based water cycle will remain a major preoccupation of human society well into the future. Environmentally, socially, and financially sound management of water resources requires investment in long-term and consistent hydrologic monitoring. Given the current state of hydrologic information, are we well-prepared to anticipate the impact of global change on the terrestrial water cycle and to manage future challenges to our water resource infrastructure?

### Essential Data for the Water Sciences

A coherent view of the terrestrial water system is virtually impossible without long-term, continuous, and spatially consistent data sets that can be readily exchanged among water researchers. The central role of water in the Earth system means that progress in many sub-disciplines of the water sciences—operational weather forecasting, atmospheric dynamics, land surface hydrology, and water quality assessment—depends heavily on reliable hydrologic data that can characterize the properties, distribution, and circulation of water in the atmosphere (vapor flux, precipitation), on the land (soil moisture, snow water equivalent, groundwater), and in surface waters (lake/reservoir/wetland storage, runoff).

In this article, we focus on data sets that describe the state of surface and groundwaters. We also include water-related socio-economic statistics; in particular, information on water use. Such data provide essential calibration and validation targets for models and statistical analysis of the hydrosystem.

Hydrologic information is also essential to the safe, cost-effective design of water facilities. Over the last two decades, 73% of water works in the developing world were over-designed due to unavailable or unreliable hydrologic information (C. Fernandez-Juaregui, UNESCO, Montevideo; G. Matthews, The World Bank, Washington D.C.; personal communications, 1999). And, despite substantial investment in hydraulic engineering, we continue to suffer from devastating floods and drought with great loss of life and property. The basic source of information for designing water resource infrastructure remains the land-based monitoring network.

### Decline in Available Water Monitoring Information

A growing number of constraints conspire to limit the availability of in situ hydrologic data. The historical commitment of participating countries to initiatives such as the International Hydrological Decade (1965–1974), which helped to establish baseline water resource conditions worldwide, is no longer evident.

Today, data collection efforts focus more on individual development projects, spawning a patchwork of data sets of short time duration, restricted spatial coverage, and limited availability. The decline has been most marked in Africa, where the density of discharge gauges in most countries falls far below World Meteorological Organization (WMO) guidelines [*Rodda*, 1998]. In the last 5 years alone, there has been a 90% reduction in the number of stations reporting discharge to the WMO Global Runoff Data Center (GRDC) (W. Grabs, WMO, Geneva; personal communication, 2000). In Russia, we see a 25–30% decline in operational capacity since 1985, and losses from 15% to 60% across the other former Soviet states (I. Shiklomanov, SHI, St. Petersburg; personal communication, 1999).

Even in the data-rich parts of the world, substantial losses in monitoring capacity have been documented. Canada, for example has seen a 25% reduction in the number of discharge stations since 1990 (B. Goodison, Environment Canada, Downsview, Ont., personal communication, 1999). In the United States, more than 100 river gauges with long-term records are lost each year [*Lanfear and Hirsch*, 1999].

Delays in data reduction and release–in many countries amounting to several years–greatly exacerbate the problem. Large quantities of otherwise reliable data exist in difficult-to-use paper formats, warehoused for years and in grave risk of damage. Global electronic data holdings for discharge show a peak in the mid-1980s, with a dramatic decline thereafter. Of the approximately 3000 stations in the GRDC archive, fewer than 700 are technically appropriate for constructing reliable global runoff fields [*Fekete et al.*, 1999]. Water chemistry data are even more fragmentary [*Fraser et al.*, 1995]. A major effort is needed to assemble a simple inventory of global data holdings and to create meta-data links to available electronic archives.

### Data Restriction Policies

Several additional factors limit international exchange of water data and the issue requires a complex journey into the realms of law, economics, science, politics and the Internet. Since water data are viewed as having both strategic and economic value, rules governing their release remain highly contentious. Unlike agreements for meteorological data (i.e., WMO Resolution 40/Cg-XII, June 1995), policies for exchanging hydrologic information have been difficult to craft. The needs and perspectives of 185 countries, many with several regional water monitoring services, must be coordinated. Contrasts in hydrological data policy are stark, with some water services supporting free and unrestricted data access, and others effectively closing their archives to outside users.

Given these challenges, it is noteworthy that WMO Congress XIII recently adopted Resolution 25 (Cg-XIII, May 1999), which calls for the free and open exchange of hydrographic data. Although this is an encouraging development, the agreement contains no provision for enforcement.

In many cases, data bank closure results from withdrawal of government subsidies, forcing operational services to recoup costs through commercial sales, often with limited success. This strategy, applied to the U.S. LANDSAT program, yielded no additional net income, yet cut in half the number of data users (R. Jenne; NCAR, Boulder, Colo.; personal communication, 2000). Nonetheless, the selling of hydrological data for intended cost-recovery is now widespread.

Legislative challenges to open data exchange have recently been ratified or proposed, seeking to protect property rights against data piracy [*NRC*, 1999]. A 1995 treaty strengthening exclusive rights of data base producers was submitted to the World Intellectual Property Organization (WIPO), but was not ratified. The 1998 European Union Database Directive prevents unauthorized use of more than insubstantial (not defined) portions of a database for more than 15 years of its creation. Some countries exempt certain research and educational activities, yet many others do not. Similar legislation is under study in the U.S. Congress. A sub-committee of the International Council for Science (ad hoc ICSU/CODATA Group on Data and Information) was recently created to monitor developments and articulate the concerns of scientists.

A virtual data embargo arises from the "digital gap" separating developed and developing world water scientists. It is not surprising that <1% of all Web-based queries to GRDC archives originate from Africa, a stark reflection of its technical isolation.

### Lack of Socioeconomic Information

In addition to information on the physical geography of water availability, socioeconomic data sets are critical to water resource assessments and articulation of the role humans play in the global water cycle. These include statistics on the distribution of urban and rural population, water use by sector, use efficiencies, level of economic development, investment in water infrastructure, land equipped for irrigation, wastewater treatment, water quality, and human health. Data on the operation of reservoir and other engineering works are also necessary.

There is little reliable information on these socioeconomic variables and what is available is highly incomplete and poorly harmonized. As a result, we have typically generated a picture of water surplus or deficit at the scale of individual countries or regions [e.g., *United Nations*, 1997], with obvious problems for characterizing water availability over large, heterogeneous areas. Recent analysis [*Vörösmarty et al.*, 2000] at higher spatial resolution shows one billion more people than previously estimated to be living under severe water stress. A systematic assessment of required data sets and a formal program to collect this information worldwide is critically needed, perhaps patterned after the U.S. water use information program [*Solley et al.*, 1998].

### Positive Developments

The dialogue on threatened hydrologic information has been recently elevated within the larger global change agenda. The U.S. National Academy noted the decline of climate and hydrologic observing systems, and the corresponding difficulties this will inevitably create for assessing global change [*NRC/PCOSS*, 1999]. At the XXII International Union of Geophysics and Geodesy (IUGG) Congress in Birmingham, U.K., two key resolutions (IUGG Resolution on Integrated Global Earth Monitoring Systems; IAHS Resolution on Hydrological Observing Networks) were adopted, specifically addressing this question. The U.N. Conference of the Parties has endorsed the activities of the Global Climate Observing Systems (GCOS), including hydrologic monitoring [*TOPC*, 1997], to support implementation of the Framework Convention on Climate Change.

Major new international initiatives, such as the World Water Vision, the UNESCO-led Hydrology for Environment, Life and Policy (HELP), GCOS, Global Terrestrial Observing System (GTOS), the WMO/UNESCO Inter-national Groundwater Resources Assessment Centre, and the IGBP Water Group provide important institutional frameworks for continued progress in water science and management. Multi-agency efforts such as the Integrated Global Observing Strategy (IGOS) and the Global Terrestrial Network for Hydrology (GTN-H) [*Cihlar et al.*, 2000] have the potential to further catalyze worldwide hydrologic data exchange. These programs have helped mobilize the community against the ongoing loss of monitoring capacity, but it remains unclear to what extent such efforts can ultimately be translated into a wider and more reliable source of global water data.

### Conclusion

We submit that in the face of rapidly accelerating global change, the urgent goals of sustainable development, food and international security, and adequate health care will be impossible to realize without an essential collection of baseline, high-quality water data sets. The ongoing deterioration of monitoring networks constitutes a global problem, but one that is most acute in the developing world. Donor countries must therefore be willing to make a commitment to water sciences capacity-building by funding operational monitoring, data rescue and update, and training of water scientists in the developing world. Given the international dimension of emerging water resource issues, the commitment and support of the entire global change community is required to reverse the ongoing decline of critical water data sets.

For further information and a directory of global water data sets, see www.watsys.sr.unh.edu/metadata/ and www.wlu.ca/~wwwiahs/ on the World Wide Web.

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# SECTION NEWS

## GEOMAGNETISM & PALEOMAGNETISM

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## The Old Ways Worked

PAGES 54, 59

Most people working in paleomagnetism today have access to a high-speed computer, a fast and sensitive magnetometer, and sophisticated data-reduction programs. Until very recently, this was not true.

This increased efficiency should have made our lives simpler, but, of course, it hasn't. Work expands to fill the time available to do it, as everyone knows; hence, our enhanced paleomagnetic efficiency has propelled a substantial increase in the number of steps used in routine demagnetization, in order to make use of principal component analysis [PCA; *Kirschvink*, 1980]. In most cases, one hopes, all this extra work is rewarded by "better" results. But, as this note will demonstrate, sometimes it isn't.

During the first three decades of paleomagnetism, nearly every aspect of the work was so slow that it was commonplace to use what today would be regarded as unacceptable "shortcut" methods. In the earliest days (late 1940s to mid 1950s), paleomagnetic poles were based on natural remanent magnetizations (NRMS) alone; no magnetic cleaning was done. This soon gave way to "blanket demagnetization," in which each sample was demagnetized at a number of (usually quite low) levels, and Fisher [1953] statistics calculated at each level. Paleomagnetic poles for such studies were based on the demagnetization level that yielded minimum scatter; for alternating-field demagnetization, this was usually 15, 20, or 25 mT. Later (late 1960s into the early 1980s), a common procedure was to choose one or more pilot samples from an NRM plot for each site for systematic demagnetization, using perhaps a half-dozen steps. The step at which pilot directions stopped changing (the "stable end point," judged from a stereoplot and/or orthogonal diagram) then was used to demagnetize the rest of the site. We call this "blanket demagnetization by site."

Many of the paleomagnetic data available today were acquired by these earlier methods.

No doubt many of these studies would have been better (more precise; more "reliable")— if they had been done using modern methods—but they weren't. A serious question then arises: Should these "old" results be used at all? From our personal observations, and from communications with other paleomagnetists in the over-50 subset, many practicing paleomagnetists would

Table 1. Paleomagnetic data for Miocene volcanic rocks from Lesbos, as compiled by different techniques.

| # | Method | N | Dec | Inc | k | Mean $\alpha_{95}$ |
|---|---|---|---|---|---|---|
| 1 | PCA | 26 | 6.5 | 46.7 | 11.1 | 4.2 ± 1.7 |
| 2 | Blanket demagnetization by site | 26 | 5.7 | 46.8 | 11.8 | 5.1 ± 2.4 |
| 3 | Blanket demagnetization @ 20 mT | 17 | 5.3 | 51.7 | 9.7 | 4.4 ± 1.9 |
| 4 | PCA on sites of previous calculation | 17 | 5.1 | 51.7 | 9.8 | 4.3 ± 1.6 |
| 5 | NRM | 26 | 5.1 | 49.7 | 12.8 | 10.6 ± 13.7 |
| 6 | NRM* | 23 | 8.3 | 50.0 | 13.0 | 6.0 ± 3.1 |

"Method" described in text. N = number of sites. Dec, Inc = mean declination and inclination. k = Fisher's precision parameter [*Fisher*, 1953]. Mean $\alpha_{95}$ is the mean value of site-mean 95% confidence limit, with standard deviation.