Challenges and Opportunities in Water Resources Research and Education

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A 2012 NRC report, done under the auspices of the Water Science and Technology Board (WSTB) and commissioned by the NSF, presents advice about research needs in hydrologic sciences.

- NSF Earth Sciences officials requested that the WSTB organize a study to (1) review the current status of hydrology and its subfields and their coupling with related geosciences and biosciences, and (2) identify promising new opportunities to advance hydrologic sciences for better understanding of the water cycle that can be used to improve water resources and environmental engineering and management.
Opportunities in the Hydrologic Sciences

The publication of the “Blue Book” in 1991 was a watershed event for the hydrologic sciences.

This highly influential report of a committee chaired by Peter S. Eagleson, Massachusetts Institute of Technology, envisioned hydrologic science as a distinct geoscience and set forth a corresponding research agenda for the field.
CHALLENGES AND OPPORTUNITIES IN THE Hydrologic Sciences

Committee on Challenges and Opportunities in the Hydrologic Sciences

National Research Council

George Hornberger, Committee Chair

Dissemination Video: 
http://www.youtube.com/watch?v=1Nr31_9jJY0
Statement of Task

This study will identify the challenges and opportunities in the hydrologic sciences, including:

(1) a review of the current status of the hydrology and its subfields and of their coupling with related geosciences and biosciences, and

(2) the identification of promising new opportunities to advance hydrologic sciences for better understanding of the water cycle that can be used to improve human welfare and the health of the environment.
Committee Membership

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The Hydrologic Sciences

• What is hydrologic science and how has hydrologic science evolved?

• Technologic and Scientific Advances
  – Chemical Analytical Instrumentation
  – Remote Sensing and Geophysical Techniques
  – Computation and Hydrologic Modeling
  – Sensor Revolution

“Over the past few decades and accelerating in time, leaps in technology have enabled unprecedented measurement, observation and fundamental advances in the conceptual understanding of hydrologic processes.”

• The Interdisciplinary Interface

“Hydrologic science is a central element for many environmental disciplines that are neighbors to hydrologic science…”, “Hydrologic science is central to all of these fields and, in being so, is becoming itself redefined and enriched.”
The signature of a scientific challenge is that it is compelling, both in the domain of intellectual curiosity as well as in the domain of consequences for human and ecosystem welfare.

The Water Cycle: An Agent of Change
Understanding the physical role of water in the past, present, and future of the Earth’s system has been the backbone of the field of hydrology since its inception.

Water and Life
The central theme is the idea of bidirectionality (i.e. water affects life, which affects water).

Clean Water for People and Ecosystems
Many research questions fall within the scope of promoting clean water for the planet, confronting not only hydrologists, but hydrologists collaborating with biogeochemists, environmental engineers, and chemists.
Evaporation, transpiration, and groundwater fluxes interconnect the water, energy, and biogeochemical cycles and are conditioned by human impacts on the water cycle.

What types and mixtures of remote sensing measurements, ground-based measurements, and modeling can be designed that can yield estimates of evaporation and recharge fields at the landscape, regional, and continental scales?

How are groundwater fluxes coupled to surface landscapes and waterscapes?

Monthly water changes over the Amazon and neighboring regions.
Theory and mechanistic field studies are needed to guide the protection, redesign, and restoration of ecohydrologic functions on landscapes.

The processes that determine transitions in ecosystems are not well characterized or understood; yet the viability of ecosystems as localized communities and as part of the global co-evolution of water and life depends critically on these transitions.

What will make wetlands restoration work?

What will make river restoration work?

Numerical modeling demonstrates the possibility of land building to restore the Mississippi River delta.
Clean Water for People and Ecosystems
The Future of Water Quality in a Hot, Flat, Crowded World

As Earth’s human population moves toward 9 billion, as resource use intensifies, and as climate changes, maintaining adequate water quality will rely on new knowledge.

How do changing flow paths as a result of urbanization correspond to changes in water quality?

What new hydrological knowledge is needed to enable agriculture and silviculture to be sustainable with respect to water quality?

How can the hydrologic sciences inform solutions to the “water-energy nexus”?

Increasing annual flow weighted dissolved organic nitrogen concentration (DIN, μM) with increasing residential area (A) and impervious surface (B).

What might be the effects of climate change on fresh water quality?
The committee does not intend the report to be an exhaustive compendium of all of the important research questions that need to be addressed. The sum of the chapters in the report is not an exhaustive list spanning the entire range of hydrologic and related research. Rather, it is intended to enumerate some of the most challenging concepts and to indicate some of the most important areas of research for promoting progress in the field.

A link to the report can be found on the WSTB web site:

http://dels.nas.edu/wstb
Distribution Funding among Directorates for FY 2012 (735 water proposals, total $424 Million)
Collaborative Research: WSC-Category 3 - Toward Sustainability of the High Plains Aquifer Region: Coupled Landscape, Atmosphere, and Socioeconomic Systems
Figure 7. Representative problem/opportunity spaces in water for energy.
Figure 8. Representative problem/opportunity spaces in energy for and from water.
Research priorities identified by the working groups included assessments of the impact of chemicals or materials used in the preproduction or production stages on water quality, the variability of stray methane in well water, the fate of fluids that remain in the subsurface, and potential problems with naturally occurring radioactive material in wastewater and solid waste. Longitudinal studies on long-term processes and the impacts of shale gas production on water quality would yield information that could help the public differentiate between perceived and actual risk.
**Charge.** The Special Scientific Committee will review the potential human health, ecological, environmental, and social impacts of unconventional gas and oil development in the Appalachian Basin and use the review to develop a priority-based Strategic Scientific Research Plan for better understanding these potential impacts. The research plan ideally will be used by regulators, oil and gas developers, environmental and public health experts, and other interested parties to better understand the implications of ongoing and future unconventional gas and oil development.

http://www.healtheffects.org/UOGD/UOGD.htm
Agriculture and Food Research Initiative - Water for Agriculture

NIFA initiates a new challenge area to address critical water resources issues such as drought, excess soil moisture, flooding, quality and others in an agricultural context. Funding will be used to develop management practices, technologies, and tools for farmers, ranchers, forest owners and managers, public decision makers, public and private managers, and citizens to improve water resource quantity and quality. NIFAs approach will link social, economic, and behavioral sciences with traditional biophysical sciences and engineering to address regional-scale issues with shared hydrological processes and meteorological and basin characteristics.
Smalley Institute (Rice University) Grand Challenges: Top Ten Problems Facing Humanity Over the Next 50 Years

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism & War
7. Disease
8. Education
9. Democracy
10. Population

http://cnst.rice.edu/content.aspx?id=246
Resource issues will gain prominence on the international agenda. Unprecedented global economic growth—positive in so many other regards—will continue to put pressure on a number of highly strategic resources, including energy, food, and water, and demand is projected to outstrip easily available supplies over the next decade or so.

www.dni.gov/nic/NIC_2025_project.html
TABLE 2  Technological and Nontechnological Opportunities to Meet or Maintain Water, Food, and Energy Resource Security

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<th>Resource</th>
<th>Nontechnological</th>
<th>Technological</th>
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| Water    | - Encourage behavioral changes to consume less water  
          - Implement strict building standards for water use | - Use energy-efficient or water-efficient energy technologies  
          - Encourage efficient and diverse water-use technologies (e.g., rainwater harvesting and storage) |
| Food     | - Encourage best management practices in irrigation (e.g., no till) | - Use efficient irrigation technologies (e.g., drip irrigation, reclaimed water, capture nutrients, and recycle) |
| Energy   | - Encourage behavioral changes to conserve water and food | - Use energy-efficient or water-efficient water technologies (e.g., dual flush toilets) |

GEO PRIORITIES
2014 – 2019

(from a presentation by Roger Waikomoto at AC-GEO meeting, October 2014)
Food, Energy, Water System

- Why and why NSF?
  • Population growth and movement is stressing food, energy, and water resources (e.g., playing out now in California)
  • Climate change & variability and disruptive events add to the stress and coupling
  • Fundamental knowledge of these three interconnected coupled systems is lacking
- What?
  • Interdisciplinary approach to integrated research and modeling of the food-energy-water system
  • Engineering solutions, data integration and smart technologies
  • Science and engineering research to address sub-elements of the nexus
  • Equip workforce through education and engagement to address this system

This is one of the Imperatives for GEO in the forthcoming strategic plan.
Leadership of the Directorate for Geosciences at the National Science Foundation (NSF) will update the community on the latest GEO programmatic and budget information. This town hall will also include introductions of new division directors in Atmospheric & Geospace Sciences, Earth Sciences and Ocean Sciences. Following short presentations, NSF would like to hear from the community about their questions and concerns regarding geoscience research support.
Interdisciplinary research (IDR) is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice.

Interdisciplinary Challenges in Studying Social-Ecological Systems: Partnerships across the Natural and Social Sciences
ADAPT-SL: Agricultural Decision Making and Adaptation to Precipitation Trends in Sri Lanka
Sri Lanka: Overview

• Undergoing rapid economic, political & cultural transition.

• Agricultural production: Significant and prioritized
  – 12% of GDP
  – 41% of total land area
  – Employs ~66% of nation

• Dominated by rice production (61% of farmers)
Big picture:

Research questions:

– Is the water picture changing?

– When & why do farmers adopt water-efficient cultivation?

– How do behaviors vary across social, institutional, hydrological settings?

– How can results relevant to decision-makers be developed and presented?
First principal component of drought indices represents the northeast monsoon. Cross wavelet transformations of the principal component of drought indices and Niño 3.4 data during 1980-2000 show a consistent anti-phase lag relationship between in the 4-8 period range. This indicates a weakening of NEM during El Niño years in recent decades.

What decisions made at a large scale influence water use?
Sigiriya had some of the most complex irrigation systems of the ancient world. Some open channel systems and sluice gates built during the Anuradhapura era (4th century BC to 11th century AD) are still functional.

**Mahaweli Project:** a system of reservoirs, open channels, and tunnels diverting water from the water abundant upper watershed in the central highlands, providing irrigation water to 3,650 sq.km.
Hydropower-irrigation tradeoffs

Legend:
- Mahaweli River
- Other River
- Reservoir
- Hydroelectricity Plant
- Key Diversion Point
- Irrigation systems

Mahaweli Complex

Rice

Power

Reservoir

Mahaweli River

Reservoir

Power

Reservoir

Power

Reservoir

Power

Halani

Others
1. What is the opportunity cost of each additional unit of water diverted north? What is social “value” of each unit of water kept in the Mahaweli?

2. What diversions (% diverted to Polgolla, % diverted to Bowatenna) provide highest economic benefits?

3. How does the picture change with System of Rice Intensification (SRI)?

“Besides increasing funding for interdisciplinary work and revising university evaluation and reward structures as means of lowering the costs and risks of interdisciplinarity, there is a much less discussed third strategy: making it easier to talk to colleagues from other disciplines. ….. It is a critical strategy, for even if foundation and governmental funding for interdisciplinary work were plentiful and institutional reward structures properly adjusted, disciplinary cultures and habits of mind would continue to result in high, sometimes prohibitively high, start-up and ongoing costs for interdisciplinary collaboration.”

Engaging in interdisciplinary projects has large up-front costs. For example, Lucy Shapiro reports that in starting Bio X, a large interdisciplinary institute at Stanford that combines biology, physics, engineering, and medicine, the four faculty founders needed to meet weekly for two years before they understood one another’s work well enough to begin collaborative initiatives.

Epistemological worldviews, methodological orientations, and interpersonal norms vary across disciplines in dramatic ways. These differences can compromise projects before they are even off the ground. It is critical to have a forum, such as a weekly seminar, where scholars can build relationships and grapple with these cultural factors prior to launching a formal collaboration. Collaborations will often emerge naturally from this process, and researchers may have a clearer understanding of the types of research questions a potential colleague is prepared to address and how.

At VIEE, we hold a weekly forum where scholars discuss news, emerging issues, and nascent ideas for research.

VIEE sustaining energy and environment through collaboration
So, as the sun sets over beautiful Sri Lanka....

Thank You.

Questions, comments, discussion?