Emerging Global Water and Energy Initiatives—An Integrated Perspective

A brief report from the
Global Energy and Water Cycle Experiment (GEWEX) Panel
Climate Research Committee
Board on Atmospheric Sciences and Climate
Commission on Geosciences, Environment, and Resources
National Research Council

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This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

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While the individuals listed above have provided constructive comments and suggestions, it must be emphasized that responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Emerging Global Water and Energy Initiatives—An Integrated Perspective

The Global Energy and Water Cycle Experiment (GEWEX) Panel of the National Research Council (NRC) was tasked by the U.S. Global Change Research Program (USGCRP) to provide a rapid and succinct assessment to relevant agencies on the general merit of the GEWEX America Prediction Project (GAPP), as well as the Coordinated Enhanced Observing Period (CEOP). In addition, the panel was asked to provide guidance to the agencies on the relationships between the agencies' newly proposed hydrologic research activities (see below), GAPP, and CEOP (see Appendix A). Providing this guidance is critical, in part, because the federal agencies tend to have somewhat differing priorities across the wide span of GEWEX activities.

In recent years, awareness of the importance of water and energy cycling and water resources has grown substantially. This is manifested in a number of different types of incipient and evolving activities, recommendations, and research plans within the United States, including:

- GAPP,[1]
- the National Aeronautic and Space Administration (NASA) Global Water and Energy Cycle (GWEC) research plan,[2]
- the National Science Foundation (NSF) GEO-2000 plan,[3]
- the National Association of State Universities and Land Grant Colleges (NASULGC) National Water Initiative,[4]
- the U.S. GEWEX Program Office (see Appendix B),[5] and
- the USGCRP Global Water Cycle program element.[6]

Internationally, there is also strong and growing interest manifested, for example, in the proposed GEWEX CEOP.[7]

The objectives of these various activities are consistent with several recent NRC reports that highlight the need for strengthened efforts in hydrologic research and applications. The *21*st Century Report[8] identifies "Improved understanding of the hydrological cycle and much better measurements of atmospheric water (in all phases). . ." as one of the emerging ". . .developments that, on the basis of [its] intrinsic value and potential economic and societal payoff, should be given high priority in the coming decades." Similarly, because "water is at the heart of both the causes and effects of climate change," the *Pathways Report*[9] rates the water cycle as one of the highest priorities for research and observations. This sentiment is also echoed in the NRC GEWEX Panel's *GEWEX Continental-Scale International Project* (*GCIP*) *Report*.[10]

An impressive foundation for water and energy cycle research has been built in the United States by GCIP in the last nine years.[10] GCIP was the first regional GEWEX project to bring together the hydrologic and meteorological science communities for a common research goal focused on water and energy cycling in the coupled land-atmosphere system. This interdisciplinary concept was adopted soon thereafter by several other international hydrometeorological projects (Mackenzie GEWEX Study (MAGS), Large-Scale Biosphere-Atmosphere Study in Amazonia (LBA), Baltic Sea Experiment (BALTEX), and GEWEX Asian Monsoon Experiment (GAME)). In addition, GCIP interacts and coordinates planning with the other international GEWEX experiments through its participation in activities under the purview of the GEWEX Hydrometeorology Panel. Building on GCIP advances, the NRC's *GCIP Report* made several recommendations that, to the extent possible, have been implemented in the final phases of GCIP.

Nevertheless, much work remains to be done to approach the ultimate objectives of GEWEX.[11] It has been proposed, therefore, that as GCIP is phased out in 2001–2002, GAPP continue the advancement of U.S. hydrometeorological research applications. The tentative plans for GAPP draw upon the recommendations of the NRC *GCIP Report* to expand GCIP to the U.S. Southwest, and to develop strong linkages with the water resources management community, while continuing to pursue the core research and observational objectives of GCIP.[12] In addition, GAPP proposes to continue to transfer the new regional modeling techniques, developed within GCIP and other international hydrometeorological research efforts, to global research and

operational models. While still in a draft phase, the initial plans for GAPP appear to be soundly constructed. The emphases of this program address several critical needs that have been articulated previously by the NRC. **We strongly recommend that this initiative continue to be pursued.**

The GEWEX CEOP (proposed for the first few years of the next century) is an ambitious international effort to capitalize on an opportunity in which a set of new generation satellites will augment the existing array of meteorological satellites in a common time period. An essential objective of CEOP is to produce a coordinated and enhanced set of globally-distributed, regional, high-resolution observations of energy and water processes linking the land surface and atmosphere. These include observations of land surface hydrology, clouds and precipitation, aerosols, and radiation under geographically diverse climate conditions. The goal is to improve modeling and predictive capabilities pertaining to the land surface and atmosphere hydrologic cycle on time scales from hourly to seasonal—an overarching GEWEX objective. **It is important, however, that, as planning for CEOP progresses, its specific scientific and predictive objectives and benchmarks are clearly defined.**

The simultaneity of the observational and research projects—which were designed on their own merits prior to the proposal for CEOP—constitutes an unprecedented opportunity to expand understanding of the climate system and its predictability at a broad range of time and space scales. With its objective of producing high resolution data sets particularly concentrated on the heat source and sink regions that drive and modify climate, CEOP addresses one of the critical climate monitoring needs outlined in the NRC's *Climate Observing Systems* report.[13] For these reasons, and because it has the potential to be a powerful integrating focus of the diverse hydrometeorological research and observational programs planned for 2001–2002, **the panel recommends U.S. participation in CEOP**, particularly through GAPP. It will be important for U.S. involvement in CEOP to also include collaboration with Climate Variability and Predictability (CLIVAR)/Global Ocean-Atmosphere-Land System (GOALS) investigations. Of particular relevance are those that prominently involve water and energy exchanges among the land, ocean, and atmosphere (e.g., monsoon regimes), such as the CLIVAR programs studying the El Niño-Southern Oscillation, the Austral-Asian monsoon, and the

monsoon and climate of the Americas (Variability of the American Monsoon System (VAMOS) and Pan-American Climate Studies (PACS)). U.S. agencies participating in CEOP (and other international programs) should stress the importance of the free and open exchange of scientific data.[14] It is expected that U.S. involvement in CEOP will be led by the agencies participating in the USGCRP and coordinated by a U.S. GEWEX Program Office and Scientific Steering Committee (SSC) (discussed below).

To maximize the returns from all relevant, ongoing, and proposed initiatives in the hydrosciences, it is vital that each initiative build upon the advances proposed by others and, at the same time, consider its potential value in meeting the needs of others. Although the United States provides major support for a U.S. GEWEX Hydrometeorology Project (GCIP/GAPP) and several GEWEX Radiation and Modeling and Prediction Projects[15] that are central to accomplishing GEWEX's scientific objectives,[11] the interaction between these has not been wholly effective. This is, in part, because proposals seeking funding for U.S. participation in global satellite projects must compete with each other and with GCIP/GAPP, with little coordination. Developing this coordination is especially critical if new observational systems are to feed effectively into an increased understanding of atmosphere-land-ocean-biosphere processes, fluxes, reservoirs, and improved model parameterizations, to ultimately serve diverse climate user and water resource communities (e.g., U.S. Geological Survey, Army Corps of Engineers, Bureau of Land Management, and Department of Agriculture, as well as several international activities). The fact that so many different agencies are responsible for water resource issues, in addition to those responsible for fundamental water and energy cycle research (e.g., NASA, NSF, National Oceanic and Atmospheric Administration (NOAA), and Department of Energy (DOE)), makes it very difficult to coordinate GEWEX-related projects.

Coordination of the aforementioned activities, both within the GEWEX program and with other programs, appears unlikely unless an organizing body is given the mandate to advocate and harmonize such interagency actions in real time. In a previous report,[5] the NRC GEWEX Panel stated that there are sound reasons why a U.S. GEWEX Program Office should be established collaterally with the U.S. CLIVAR Program Office. In response to a USGCRP request for further input on this matter (see Appendix B for the USGCRP request), the

panel considered the pros and cons of co-locating these offices. The panel finds that its original recommendation for common infrastructures is still valid and that co-located offices would be beneficial.[16]

The NRC GEWEX Panel recommends that, in conjunction with the establishment of a U.S. GEWEX program office, a U.S. GEWEX SSC be established, constituted by leaders of the hydrometeorological research and water resource communities. A U.S. GEWEX SSC should advise the U.S. GEWEX Program Office and federal agencies, thereby advocating and better organizing U.S. GEWEX research. Also, a U.S. GEWEX SSC should facilitate more effective interaction with the international GEWEX programs and the developing international and U.S. CLIVAR programs. A particular goal should be to foster greater involvement of the water resources community in GEWEX-related research. In addition, an SSC should help define the national priorities in water and energy cycle research and observations and thereby avoid problems that have befallen other major U.S. climate efforts.[17] The U.S. CLIVAR SSC provides a practical example by which near real-time guidance can be provided to integrate a diverse group of observational and research activities toward a common set of goals.[18] Because so many of the regional and global objectives of these two major programs overlap, a coherent and coordinated approach to U.S. climate research that encompasses both viewpoints needs to be articulated.

Appendix A

OFFICE OF THE US GLOBAL CHANGE RESEARCH PROGRAM
400 VIRGINIA AVENUE, SW SUITE 750, WASHINGTON, DC 20024 Phone: 202-488-8630 Fax: 202-488-8681

April 21, 1999

Dr. Soroosh Sorooshian
Chair, NRC GEWEX Panel
National Research Council HA 466
2001 Constitution Ave. Washington, DC 20418

Dear Soroosh,

In the past six months there have been a number of exciting developments in U.S. GEWEX and other hydrologic research activities. While the future looks quite bright, we need to ensure that the high level of interest amongst the federal agencies in this area is most effectively put to use. In this regard, we ask that the NRC GEWEX Panel provide rapid and succinct guidance on the following issues.

As you know, the GEWEX Continental-Scale International Project (GCIP) will be phased out in 2001–2002. Capitalizing upon the progress made by GCIP, the GEWEX America Prediction Project (GAPP) has been proposed to phase in beginning in 2001. The overall mission of GAPP is to extend and apply the findings of GCIP to develop a capability to make reliable monthly to seasonal predictions of important hydrologic variables (e.g., precipitation, soil moisture, runoff, and evaporation) as part of a global climate prediction system. It has been proposed that GAPP play a role in the GEWEX Coordinated Enhanced Observing Period (CEOP), as well as in related CLIVAR activities such

as the Variability of the American Monsoon System (VAMOS) project. This new interagency initiative being developed under NOAA (OGP)'s guidance is taking place within the context of the newly proposed NASA Global Water and Energy Cycle (GEWEC) and NSF GEO-2000 projects.

It is clear that the potential benefits from this ensemble of initiatives in the hydrologic sciences will contribute substantially to the well-being of society, as well as to the growing body of scientific knowledge, if they are wisely guided. Therefore, the USGCRP requests that the NRC GEWEX Panel provide an overall assessment of GAPP's general merit. In addition, we ask that the panel provide guidance to the relevant agencies concerning the relationships between their newly proposed hydrologic research activities, GAPP, and CEOP. This advice should be rapidly supplied in the form of a letter report, as the planning for these various initiatives is proceeding at a fast pace.

We ask that the GEWEX Panel be aware of the formation of a science working group under USGCRP to aid in development of a U.S. program on the water cycle and global change, as discussed at the last GEWEX meeting. Coordination with such a group will be accomplished through joint membership with relevant NRC bodies.

Sincerely,
David M. Goodrich
Executive Director
USGCRP Coordination Office

cc: Rick Lawford
Peter Schultz
Robert Schiffer

Appendix B

OFFICE OF THE US GLOBAL CHANGE RESEARCH PROGRAM
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March 16, 1999

Dr. Soroosh Sorooshian,
Chair Global Energy and Water Cycle Experiment Panel
Dept. of Hydrology and Water Resources
University of Arizona Tucson, AZ 85721

Dear Soroosh,

This letter is in response to the recent NRC letter report *GEWEX-CLIVAR*: *Coordination of U.S. Activities*. I write as chair of the CLIVAR Interagency Group, a panel of agency program managers who are supporting the U.S. contribution to CLIVAR and who are sponsoring the CLIVAR Science Steering Committee. The NRC interest in this issue and the summary of NRC recommendations in one brief volume is much appreciated.

The matter of interactions between these two WCRP programs has been the subject of much discussion within the Interagency Group and by the CLIVAR SSC. Participation in the upcoming GEWEX Panel meeting and devotion of roughly half of the May CLIVAR SSC to coordination with GEWEX is some evidence of the importance of this issue to the CLIVAR community. Russ Davis, co-chair of the CLIVAR SSC, will be attending the GEWEX Panel meeting and will describe more fully the scientific issues and organization of U.S. CLIVAR.

Your report was written prior to the December International CLIVAR Conference in Paris, and many of the issues are described in the attached U.S. CLIVAR Position Paper prepared for the conference. Several areas of potential collaboration deserve highlighting:

- The letter report recommends the coordination of GOALS [CLIVAR] process studies with those of GEWEX. The position paper cites a strong U.S. CLIVAR interest in expansion of studies concerning the American monsoon. The development of a new GEWEX American Prediction Project, focused on the Southwest, and CLIVAR interest in extension of American monsoon studies to the Pacific cold tongue and stratus region, appear to be fruitful areas for collaborative efforts. The position paper states: "Consideration of the role of land-surface processes and orography on the climate variability associated with the American monsoon will be included and would most appropriately be incorporated by partnership with GEWEX."
- From the U.S. CLIVAR perspective, extending ENSO studies to the Asian-Australian monsoon has a high level of interest; however, its current status in the U.S. from the programmatic point of view is less well-developed than the American monsoon. Interactions and collaboration with the GEWEX Asian Monsoon Experiment (GAME) community is expected to enhance understanding of the relative importance of ocean versus land heating in the interannual variability of the Asian-Australian monsoon.
- Potential CLIVAR participation in the Coordinated Enhanced Observing Period (CEOP) has been discussed at the last CLIVAR SSC meeting. CLIVAR expects to have considerable in situ observational deployments during the 2001–2002 period, and the use of the resulting data sets with those from new satellite measurements and from GEWEX hydrometeorology projects could result in unprecedented global climate data sets. However, definition of scientific goals and resolution of formidable data assimilation questions remain as issues.

A particular topic of discussion regarding CLIVAR-GEWEX coordination is the development and location of a U.S. GEWEX Project Office, and whether it should be co-located with a U.S. CLIVAR Project Office. At the moment, it appears likely that the latter will be located here in Washington, in the same building as our USGCRP Office.

Advantages of co-locating a U.S. GEWEX Office here are cited in your NRC report: ensuring that advances in one program feed into the other; minimizing duplication of effort; and promoting the most efficient mechanisms for progress.

However, interagency discussions cited significant disadvantages as well. A Washington location would not have the close ties to the academic community that a university-based project office might have. And, while co-location with CLIVAR might enhance coordination, the perception of CLIVAR activities coming to dominate GEWEX planning was cited as a potential drawback. It would be useful for agencies to get a sense of the views of the GEWEX Panel on this issue. In the meantime, development of a CLIVAR Office will allow room for potential expansion of a GEWEX Office, so as not to foreclose any options.

We look forward to working with you and with the GEWEX community, and anticipate productive discussions at the GEWEX Panel Meeting in Irvine.

Sincerely,
David M. Goodrich
Executive Director
USGCRP Coordination Office
Attachment: U.S. CLIVAR Position Paper

Notes

1. GEWEX Continental-Scale International Project (GCIP) Office, 1999. *A Prospectus for the GEWEX America Prediction Project (GAPP)*. Draft of July, 1999.

The prospectus outlines GAPP as follows:

"A highly successful GEWEX Continental-Scale International Project (GCIP) will be completing its observational phase in March 2001. Although many of the shorter-term objectives of GCIP have been realized, its mission of 'developing a capability to predict variations in water resources on time scales up to seasonal and interannual as an integral part of a climate prediction system (NRC, 1998. [*GCIP Report*])' remains a challenge that will only be addressed through the development of a new understanding of land surface processes and the exploitation of new technologies. The program outlined in this prospectus extends the GCIP approach to other climate regions of the USA and also ***shifts the program focus from analysis to prediction*** in order to better position the science community to achieve the GCIP mission. To bridge the gap between the current understanding and capabilities of the climate community, and the requirements for a prediction capability that fully incorporates the controls of land surfaces on the climate system, appropriate components of the atmospheric and hydrologic research communities will develop science and implementation plans for the **GEWEX America Prediction Project (GAPP).**"

"In order to achieve its overall mission, GAPP will pursue the two following primary objectives:

• develop and demonstrate a capability to make reliable monthly to seasonal predictions of precipitation and land surface hydrologic variables as part of a global climate prediction system.

• interpret and transfer the results of improved seasonal forecasts to appropriate agencies and organizations for the optimal management of the nation's water resources."

Specific U.S. agency plans for participation in GAPP have not yet been formulated.

2. NASA is currently in the process of drafting a plan for its future Global Water and Energy Cycle research activities.

3. NSF's Geosciences Directorate is in the process of creating a long-range plan for its activities through 2010, termed GEO-2000. A draft of the GEO-2000 vision statement can be found at:*http://www.geo.nsf.gov/adgeo/geo2000/*.

The objective of GEO-2000 is to "identify exciting prospects for major advances in understanding the interactions among the full suite of Earth system components." As part of NSF's planning, a workshop was convened in Albuquerque, NM (January 31-February 1, 1999) to provide input to the formulation of the hydrologic component of GEO-2000. A summary of the meeting (*http://cires.colorado.edu/hydrology/*) states that:

". . . Researchers have not been able to quantify many fluxes within the water and companion cycles because they lacked tools to collect and analyze data that capture the complexity and scales at which hydrologic systems operate. The problem is particularly critical where water moves through a phase change or from one medium to another at the medium to large watershed scale where multiple disciplines must work together. New observing capabilities (radar, satellite images, isotope tracers, etc.) and new mathematical tools (fractals, random perturbations of dynamical systems, etc.) provide needed technology, but hydrology lacks an integrated observational system. Educational programs do not provide adequate training for this new era. Example issues are 1) measuring precipitation on, evapotranspiration from, recharge into, and moisture storage within watershed reservoirs where studies are stymied by a lack of mass balances for water, sediments, solutes, etc.; and 2) quantifying the heterogeneous properties of soils and aquifers from geologic understanding for water supply which is threatened by pollution plumes. Watershed-scale data can be used to link disparate space-time scales and couple physical, chemical, and biological states. Scientists can be educated to probe these integrated data sets with advanced diagnostics, computational experiments, and analyses of process, pattern, and probability.

The many scientists who interacted in this assessment have firmly concluded that substantive progress requires: 1) Comprehensive, multidisciplinary studies of hydrological systems in critical geochemical, geologic, and ecological settings at field scales. 2) Upgrading geoscience education that trains graduate researchers with emerging tools and K-12 youngsters in basic understanding of geoscience and the water cycle. 3) A 'Hydrologic Observing Facility' to facilitate deployment of cutting-edge instrumentation and organization of data sets for efficient access. A science framework with this vision will produce clear and visible payoffs for researchers, educators, and water managers through a substantially improved understanding of risk, vulnerability, and predictability of water resources under growing environmental stresses."

4. National Association of State Universities and Land Grant Colleges (NASULGC), the Universities Council on Water Resources, and the National Institute for Water Resources, 1999. *The National Water Initiative*. Draft of March 11, 1999.

"The National Water Initiative aims to meet grand challenges facing the nation's water resources in the 21st. Century, increase the nation's adaptability in the face of greater pressure on these resources, and equip citizens and decision-makers with the knowledge necessary to protect, sustain, and manage the nation's waters as vital national assets. The Initiative also aims to contribute to the global base of knowledge increasingly needed for sustainable water management systems worldwide in a variety of landscapes and social, cultural, and economic conditions. . . The nation's waters—coastal and estuarine, rivers, lakes, and ground water—are essential and priceless national assets. Disturbingly, they also face daunting grand national challenges: (i) water, quality, and health; (ii) hydrologic hazards and human-altered hydrologic systems; (iii) environmental and ecosystem services; (iv) environmental remediation and restoration; (v) changing use and competition; (vi) water delivery and use systems, including renovation and rehabilitation; (vii) ground water management, including conjunctive use; and (viii) public understanding for sustainability of national water assets. . . . The National Water Initiative aims to advance research-based knowledge and its timely application to grand challenges to our nation's waters. To do this, the Initiative advocates an 8-part action program: (i) establish a National Partnership to advance and achieve the vision; (ii) develop a Comprehensive Research Strategy to ensure the knowledge base for addressing and resolving grand challenges to the nation's water in a timely manner; (iii) support research—especially fundamental and adaptive studies—through a new, federally-

funded, comprehensive research program whose central element is extramural, merit-based, competitively-awarded research grants; (iv) apply research-based knowledge expeditiously through a national network of centers, with specific attention to grand challenges and their specific problems; (v) establish and sustain National Observing Systems (including present systems), study areas, and tools and methods for continuous assessment of the nation's water systems; (vi) facilitate Collaboration and Integration among members of the national partnership; (vii) sustain a coordinated national program for Education and Communication for publics and professionals on the value of the nation's water resources and need for their prudent stewardship; and (viii) conduct systematic and comprehensive Assessment and Evaluation of the results of the overall Initiative. The initiative is being developed through a National Partnership among federal, state, and other public agencies; private sector users; the public; and the nation's universities and colleges. The Initiative has been endorsed by the National Association of State Universities and Land-Grant Colleges, the Universities Council on Water Resources, and the National Institute for Water Resources. Positive and helpful discussions have been held with senior federal officials. Discussions with private and public sector leaders and workshops are planned for 1999."

5. The rationale for the establishment of a U.S. GEWEX Program Office and collateral infrastructure with a U.S. CLIVAR Program Office is discussed in a previous report of this panel: NRC, 1998a. *GEWEX-CLIVAR: Coordination of U.S. Activities*. National Academy Press, Washington, D.C., 22 pp. This report states that: "There is no interagency mechanism within the United States to ensure that this type of coupling [between GEWEX and CLIVAR] will occur, nor is there one to ensure that the individual GEWEX activities within the United States are coordinated. A high degree of coordination between GEWEX- and CLIVAR-related activities would help ensure that the advances in one program directly feed into the other, minimize duplication of effort, and promote the most efficient avenues for progress. Despite the somewhat higher infrastructural burden that may come with enhanced coordination, the reality is that programs such as GEWEX and CLIVAR cannot work collaterally without having collateral infrastructures. One practicable vehicle for bringing about the necessary inter- and intra-program coupling may be the establishment of a U.S. GEWEX Program Office that parallels and is closely integrated with the one being discussed for CLIVAR." Following the publication of this report, this set of issues was discussed at length at the March 18–19, 1999 NRC GEWEX Panel meeting in Irvine, California. For a summary of the discussion at this meeting, see: *http://nationalacademies.org/basc*.

6. USGCRP, 1999. *Our Changing Planet. The FY2000 U.S. Global Change Research Program Implementation Plan and Budget Overview*. A report by the Subcommittee on Global Change Research, Committee on Environment and Natural Resources of the National Science and Technology Council, pp. 100.

"USGCRP Program Elements include:

. . . 6. The Global Water Cycle, with a focus on improving our understanding of the movement of water through the land, atmosphere, and ocean, and on how global change may increase or decrease regional water availability."

". . .The study of the global water cycle is the unifying theme that can bridge the gap in the spatial-scale spectrum between atmospheric and hydrological sciences. This issue is in its first year and will be implemented through coordinated U.S. and international programs. Planning is underway to develop joint interagency programs in the U.S. and coordination with international programs [e.g., the Global Energy and Water Cycle Experiment (GEWEX), the Program on Climate Variability and Predictability (CLIVAR), Biological Aspects of the Hydrologic Cycle (BAHC), and potentially a more fully coordinated international Hydrology and Water Cycle Program]. The primary goal of this research is a greater understanding of the seasonal, annual, and interannual mean state and variability of water and energy cycles at continental-to-global scales, and thus a greater understanding of the interactions among the terrestrial, atmospheric, and oceanic hydrosphere in the Earth's climate system. This understanding will be achieved through a combination of observations, modeling, and analysis at a range of spatial and temporal scales, and will provide the foundation for understanding the relationship between weather and climate. . . . An important element of the research program is a quantitative assessment of the improved understanding for weather prediction and for water and environmental management. In addition, advances in understanding the relationships between hydrologic processes and climate will lead directly to better inferences regarding climate change and its subsequent hydrologic impacts at regional-to-global scales."

7. International GEWEX Project Office (IGPO), 1999. *Scientific Plan for the Coordinated Enhanced Observing Period (CEOP): An Overview from a*

GEWEX Hydrometeorology Panel Perspective. Working Draft of April 29, 1999.

"ABSTRACT

The [international] GEWEX Hydrometeorology Panel (GHP), through its five Continental Scale Experiments (BALTEX [Baltic Sea Experiment], GAME [GEWEX Asian Monsoon Experiment], GCIP [GEWEX Continental-Scale International Project], LBA [Large-Scale Biosphere Atmosphere Experiment in Amazonia], and MAGS [Mackenzie GEWEX Study]) is initiating a cooperative effort for a Coordinated Enhanced Observing Period (CEOP) in the 2001–2002 time period to take advantage of the first opportunity to compile continental data sets on a global scale derived from a new generation of satellites [e.g., EOS AM-1, Landsat-7, Envisat, ADEOS-2, EOS PM-1, and NOAA K/L/M]. The GHP perspective given in this overview is particularly focused on the land surface-atmospheric interactions and their impacts on the regional and larger scale climate systems as part of an overall scientific objective for CEOP:

To understand and model the influence of continental hydroclimate processes on the predictability of global atmospheric circulation and changes in water resources, with a particular focus on the heat source and sink regions that drive and modify the climate system and anomalies.

This GHP perspective on CEOP can be much broader through cooperative efforts, which include the oceanographic community, the large scale climate modeling community, and Arctic researchers. Planning for these cooperative efforts is now in process and will be included in an updated version of this plan."

8. NRC, 1998b. *The Atmospheric Sciences Entering the Twenty-First Century*. National Academy Press, Washington, D.C., 364 pp. The full reference to hydrologic research is as follows: "We have identified a number of emerging basic research, technique, and technological developments that, on the basis of their intrinsic intellectual value and/or potential economic or societal payoff, should be given high priority in the coming decades. Here, these key developments are summarized, and specific recommendations based on them are offered. . ." ". . .5. *Improved understanding of the hydrologic cycle and much better measurements of atmospheric water*: Ongoing advances in understanding the control of atmospheric water (in all phases) will lead to

much improved understanding of and ability to predict a variety of dynamical systems. Critical physical processes include the control of water vapor by convection and cloud microphysics, and the coupling of the atmospheric boundary layer with the underlying surface. Improved understanding of these processes, together with the advent of much improved techniques for measuring soil properties, atmospheric water vapor, and condensed water, is essential for solving the difficult problem of quantitative precipitation forecasting and will be necessary for adequate modeling of climate as well."

9. NRC, 1998c. *Global Environmental Change: Research Pathways for the Next Decade, Overview*. National Academy Press, Washington, D.C., 69 pp. On page 24 the report states: "Similarly, water is at the heart of both the causes and effects of climate change. It is essential to establish rates of and possible changes in precipitation, evapotranspiration, and cloud water content (both liquid and ice). Additionally, better time series measurements are needed for water, runoff, river flow, and, most importantly, the quantities of water involved in various human uses. This crosscutting initiative can clearly build upon the progress made by the Global Water and Energy Cycle Experiment (GEWEX) in the World Climate Research Program and the Biospheric Aspects of the Hydrological Cycle (BAHC) project of the International Geosphere-Biosphere Program."

10. NRC, 1998d. *GEWEX Continental-Scale International Project (GCIP): A Review of Progress and Opportunities*. National Academy Press, Washington, D.C., 93 pp.

The GCIP report recommended "that GCIP focus its efforts in the following areas:

- Develop accurate quantitative precipitation estimates based on high-resolution weather radar observations.
- Develop improved large-scale estimates of soil moisture consistent with large-scale estimates of precipitation, evaporation, and runoff.
- Further improve the coupling between atmospheric and land surface hydrologic models.
- Develop and apply coupled land data assimilation systems.
- Prepare data archives to facilitate future reanalyzes.
- Foster active dialogue between GCIP and the water management community.

From a wider national perspective, GCIP does not address hydroclimatic phenomena that are characteristic of the semi-arid U.S. Southwest, a region where the availability of water is a critical resource issue as well as a challenging scientific problem. Applying the methodologies and technical facilities developed for GCIP to a study of the Colorado River basin and surrounding mountain regions is a challenge for the future."

The impressive foundation for water and energy cycle research that has been built in the United States by GCIP is outlined in the Executive Summary of the NRC *GCIP Report* and described in more detail at the end of each of the report's chapters.

11. Objectives of the GEWEX Program:

• Determine the hydrological cycle and energy fluxes by means of global measurements of atmospheric and surface properties.

• Model the global hydrological cycle and its impact on the atmosphere, oceans, and land surfaces.

• Develop the ability to predict the variations of global and regional hydrological processes and water resources, and their response to environmental change.

• Advance the development of observing techniques, data management, and assimilation systems for operational application to long-range weather forecasts, hydrology, and climate predictions.

12. Objectives of GCIP:

• To determine the time and space variabilities of the hydrologic and energy budgets over a continental scale.

• To develop and validate macroscale hydrological models, related high resolution atmospheric models, and coupled hydrological-atmospheric models.

• To develop and validate information retrieval schemes incorporating existing and future satellite observations coupled with enhanced ground-based observations.

• To provide a capability to translate the effects of future climate change into impacts on water resources on a regional basis.

13. NRC, 1999. *Adequacy of Climate Observing Systems*. National Academy Press, Washington, D.C., 51 pp.

Climate monitoring principle #7: ". . .Give the highest priority in the design and implementation of new sites or instrumentation within an observing system to data-poor regions, poorly observed variables, regions sensitive to change, and key measurements with inadequate temporal resolution. . ."

14. These issues are discussed fully in:

NRC, 1995. *On the Full and Open Exchange of Scientific Data*. National Academy Press, Washington, D.C., 21 pp.

NRC, 1997. *Bits of Power: Issues in Global Access to Scientific Data*. National Academy Press, Washington, D.C., 250 pp.

15. The GEWEX Radiation Projects are the following: Baseline Surface Radiation Network (BSRN), Global Aerosol Climatology Project (GACP), Global Precipitation Climatology Project (GPCP), Global Water Vapor Project (GVaP), International Satellite Climatology Project (ISCCP), and Surface Radiation Budget Project (SRB). The GEWEX Modeling and Prediction Projects are the following: Global Cloud System Study (GCSS), and Project for Intercomparison of Land Surface Parameterization Schemes (PILPS).

16. The panel finds that one of the reasons that have been put forth for not co-locating the GEWEX office in the Washington area—i.e., a Washington location would not have the close ties to the academic community that a university-based Program Office might have—applies equally to both GEWEX and CLIVAR. The other reason that has been put forth—i.e., CLIVAR activities might dominate those of GEWEX—can be alleviated through the selection of a strong leader for the U.S. GEWEX office.

17. One example is the set of problems associated with the absence of a coordinated, national climate modeling strategy. This situation is described in: NRC, 1998e. *Capacity of U.S. Climate Modeling to Support Climate Change Assessment Activities*. National Academy Press, Washington, D.C., 93 pp.

18. **U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE Terms of Reference**

Calling upon the U.S. scientific and technical atmospheric, oceanographic, and climate communities for assistance, the U.S. CLIVAR Scientific Steering Committee should:

(1) Provide overall scientific and programmatic guidance to ensure that U.S. CLIVAR progresses towards achieving its scientific objectives using individual experts or expert groups as necessary.

(2) Develop and update as needed an implementation strategy to prioritize and sequence U.S. CLIVAR activities, and comment on agency implementation of the U.S. CLIVAR Program.

(3) Promote balance within the various elements (theory, modeling, empirical studies, long-term observations, and field campaigns) of the program and identify scientific gaps.

(4) Work with the funding agencies to ensure that U.S. CLIVAR activities are coordinated with international CLIVAR activities and other USGCRP elements.

(5) Provide oversight and coordination of and guidance to U.S. CLIVAR working groups.

(6) In consultation with other advisory bodies, provide advice for the effective transition of sustained observations initiated during CLIVAR to operational entities after they have demonstrated their usefulness for climate predictions.

(7) Keeps the NRC/CRC appraised of the status of US CLIVAR and acts as U.S. liaison to the International CLIVAR SSC.

(8) Provide oversight of and guidance to the U.S. CLIVAR Project Office and its director (if applicable).

(9) Keep the research community and the general public appraised of on-going activities and achievements of CLIVAR, e.g., briefings at major conferences, overview articles, and media briefings.

The SSC reports to the CLIVAR Interagency Group through the U.S. Global Change Research Program Office. Membership: 3-year terms, renewable only once.

Acronyms

BALTEX	Baltic Sea Experiment
CEOP	Coordinated Enhanced Observing Period
CLIVAR	Climate Variability and Predictability
DOE	U.S. Department of Energy
ENSO	El Niño-Southern Oscillation
GAME	GEWEX Asian Monsoon Experiment
GAPP	GEWEX America Prediction Project
GCIP	GEWEX Continental-Scale International Project
GCSS	Global Cloud System Study
GEWEX	Global Energy and Water Cycle Experiment
GOALS	Global Ocean-Atmosphere-Land System
GPCP	Global Precipitation Climatology Project
GVaP	Global Water Vapor Project
GWEC	Global Water and Energy Cycle
ISCCP	International Satellite Climatology Project
ISLSCP	International Satellite Land Surface Climatology Project
LBA	Large-Scale Biosphere-Atmosphere Study in Amazonia

MAGS	Mackenzie GEWEX Study
NASA	National Aeronautics and Space Administration
NASULGC	National Association of State Universities and Land Grant Colleges
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSF	National Science Foundation
PACS	Pan-American Climate Studies
SRB	Surface Radiation Budget Project
SSC	Scientific Steering Committee
USGCRP	U.S. Global Change Research Program
VAMOS	Variability of the American Monsoon System