6 Implementation of Arctic-CHAMP

Arctic-CHAMP must be inclusive and structured to enlist a continuing input of new ideas from the scientific community at large. The initiative also requires a "corporate identity" through which scientists can propose and participate in the monitoring, modeling, and process study components of the initiative. The committee envisions this identity-building to be aided by an Arctic-CHAMP steering committee, an institutional home for the program, research plans, and a workshop series. A successful Arctic-CHAMP should complement, contribute to, and draw from other important NSF, federal agency, and international arctic initiatives. These issues are articulated as a set of specific recommendations to NSF, mapped to the scientific and technical requirements of Arctic-CHAMP identified throughout earlier portions of this report (Box 6-1).

- **This committee recommends that an Arctic-CHAMP Scientific Steering Committee (AC-SSC) be formed to catalyze conceptual development of Arctic-CHAMP and to provide ongoing supervision of its execution.**

The AC-SSC should constitute an interdisciplinary advisory board, with representatives from the fields of land surface hydrology, atmospheric dynamics, sea ice and ocean studies, terrestrial and aquatic ecology, and socio-economics. In addition, membership should include scientists active in executing large-scale synthesis studies, specifically, those developing earth and arctic systems models. A balance between process-level field researchers, operational monitoring agency representatives, and simulation modelers should be sought. The charge of AC-SSC will be to set the science agenda of the overall initiative, to coordinate its research activities, and to ensure that results are disseminated to a broad user community. The AC-SSC should critically assess the initiative's progress and scientific relevancy, as well as provide guidance to NSF-ARCSS on future funding requirements. To ensure continuity across NSF arctic research programs, the AC-SSC should be represented on the ARCSS Committee.

- **The committee recommends that an Arctic-CHAMP science agenda should be more fully developed through an interdisciplinary implementation plan.**

A detailed science plan should go beyond this current document, presenting guidance on the institutional structure for Arctic-CHAMP, its governance, a set of specific scientific investigations and observational campaigns, and coordination with other NSF, national, and international agency efforts. The implementation plan would be augmented through annual reports summarizing progress on Arctic-CHAMP and providing revised plans for future work. Additional documentation of progress would be provided through, first and foremost, peer-reviewed publications by participating researchers. A newsletter, workshop reports, and a frequently updated web page would also help to promote a broad following.

- **The committee strongly recommends that NSF support a set of multidisciplinary, process-based catchment studies.**

Through the normal peer review process, NSF should identify and fund experiments at a core group of field sites aimed at developing a mechanistic view of the hydrology of the Arctic. Integration of hydrology, land-atmosphere interaction, biology, and biogeochemical processes should be a fundamental feature of this research. An emphasis on up-scaling to ensure the relevancy of these studies to the full pan-arctic domain is encouraged.

- **The committee recommends an immediate and major effort to improve our current monitoring of water cycle variables across the pan-Arctic.**

Detecting and interpreting progressive changes to the arctic hydrologic cycle will be impossible without a coherent observational

strategy. This requires immediate attention as well as long-term vigilance. NSF should invest in an expanded, hydrologically oriented monitoring program across the pan-Arctic, coordinating, as required, with U.S. and international agency partners. Enhancing our current capacity will involve data rescue, expansion of current observational networks, and development of new technologies for harsh weather instrumentation. It should also foster development of new interpolation and remote sensing techniques to achieve pan-arctic coverage at high spatial and temporal resolutions.

- **This committee recommends creation of an Arctic-CHAMP Synthesis and Education Center (CSEC) to serve as the institutional focal point for the initiative, open to the entire community of arctic researchers.**

We recommend NSF create a central facility to catalyze ongoing synthesis studies of pan-arctic hydrology. Arctic-CHAMP synthesis models would be developed at CSEC. The center should lead the coordination of modeling, field research, and monitoring efforts within Arctic-CHAMP. Each developmental version of the Arctic-CHAMP models would reside at CSEC, but when sufficiently mature, distributed to the broader research community. In coordination with the National Snow and Ice Data Center (Boulder, Colorado), CSEC would produce a continually evolving Arctic-CHAMP Hydrometeorological Data Archive (HDA) for station-based monitoring data and value-added project outputs emerging from the synthesis work. Arctic-CHAMP science

Box 6-1. Arctic-CHAMP Scientific and Technical Needs

Several specific research needs aimed at improving our current understanding of the arctic water cycle and its sensitivity to change were identified throughout the text, setting the scientific stage for Arctic-CHAMP. In response to the integrative nature of the arctic water cycle, these issues will need to be addressed in a systematic and comprehensive fashion. A synthetic view of the entire pan-arctic hydrologic system, based on focused process, feedback, and sensitivity studies, will be critical to ensure the necessary transfer of knowledge between fine and large scale studies and between campaigns dedicated to observation and process understanding. Specific activities that are required to develop such an integrated view of the entire pan-arctic system include:

- **maintenance of existing and establishment of new, long-term, and coherent monitoring programs for key hydrological and biogeochemical variables, including both water itself and the constituents it supports;**
- **enhancement of the current generation of field programs to support process-based understanding of arctic hydrology;**
- **development of methods to bridge the gap between process-level studies, point-scale monitoring, and the hydrodynamics of the pan-Arctic through combined field-based measurements, remote sensing, and modeling;**
- **design of a strategy to achieve synthesis and water budget closure over the full water cycle, encompassing interactions across atmospheric, land surface, and oceanic components with links to the larger earth system;**
- **determination of the links between water-related changes, ecosystem dynamics, biogeochemical cycling, and trace gas emission which feed back to the hydrologic cycle and climate system;**
- **assessment of the vulnerability of humans to arctic water cycle changes;**
- **full-system feedback and sensitivity studies, including human systems, in response to global change; and**
- **implementation of a viable administrative structure and mechanism to promote full pan-arctic system integration.**

A more exhaustive listing of recommended actions representing the views of a broad cross-section of the arctic science community is presented in a collection of position papers (Hinzman and Vörösmarty 2001). Appendix 2 offers a summary listing of these issues.

activities will serve as an important application of state-of-the-art technologies and should be coordinated with relevant activities of the NSF Information Technology Research Program.

Researchers and their students and post-docs would be chosen through a competitive fellowship program attracting the most highly qualified applicants. CSEC would bring together observationalists, process-level scientists, and modelers in a collaborative physical setting to share insight and to cross-fertilize ideas. Research would be performed by graduate students and post-doctoral fellows on site, but supervised by contributing researchers from several parent institutions. A useful model for CSEC is that of the NCEAS (National Center for Ecological Analysis and Synthesis in Santa Barbara, California). To inform the public of the need to study the otherwise distant Arctic and its role in environmental change, direct links to the NSF Interagency Education Research Initiative are advised. A vigorous K-12 effort could be mounted through the CSEC.

- **This committee recommends that funding be committed to an Arctic-CHAMP Workshop Series and Open Science Meetings to provide ongoing intellectual support for the overall initiative.**

Arctic-CHAMP would serve as an excellent focal point for working groups seeking to execute field programs, create and implement community-based models, and interpret specific observational data sets. A major initial effort should be directed toward understanding the changing contemporary condition of the pan-arctic water cycle. Other workshops in the series could focus on historical/paleo and future settings. Biogeophysical and human dimension issues should be jointly addressed. Periodic Open Science Meetings should also be convened to solicit input from the broader research community.

- **The success of Arctic-CHAMP will depend on a purposeful integration across other programmatic elements of the National Science Foundation and allied federal agencies, and the committee strongly advises that steps be implemented to foster this collaboration.**

A primary goal of the current NSF-ARCSS Program (Box 6-2) is to promote an understanding of the impacts of global change on the physical, biological, and human resources of the Arctic (ARCUS 1998). The issue of feedbacks across the pan-Arctic is an important emphasis of the future ARCSS Program and thus integrates well with the concept of an Arctic-CHAMP. This interdisciplinary perspective is driven not only by scientific curiosity but as well by the needs of the policy community, which seeks response strategies to impending climate change that transcend the domains of traditional disciplines (e.g., U.S. National Assessment 2000).

By their very nature, multiagency efforts such as the U.S. National Assessment and SEARCH would serve as important sources of information and would be served, in turn, by the unique set of hydrologically oriented results emerging from Arctic-CHAMP. As a good example, remote sensing for freeze-thaw dynamics, envisioned as a NASA post-2002 mission (Cline et al. 1999), would provide an enormously important data set for hydrological studies across the entire pan-Arctic. Coordination with Arctic-CHAMP field studies could provide critical ground-truth, while Arctic-CHAMP simulation studies would constitute an immediate hydrological application for this satellite system. Arctic-CHAMP studies on biological and biogeochemical feedbacks in response to global change would directly support the central scientific concerns of the NSF Biocomplexity Program. A coordination is clearly needed to avoid duplication of effort and to optimize the use of federal research dollars. Appendix 3 lists several specific opportunities for collaboration within the U.S. Arctic research community.

- **There are several ideal opportunities for international collaboration in arctic hydrological research. The committee urges an active linkage of these ongoing programs with Arctic-CHAMP.**

Arctic-CHAMP's treatment of coupled water dynamics across the entire pan-Arctic will enlist the interest and involvement of the international research community. There are several well-established experimental, monitoring, and analysis programs in place to which Arctic-CHAMP should be linked, with the aim of providing synergistic benefits not otherwise achievable through each individual effort. These involve significant ongoing as well as new initiatives organized around scientific and

monitoring activities. Box 6-3 summarizes several noteworthy efforts. Among these are major arctic field campaigns over a variety of spatial scales, routine environmental monitoring, intercomparison modeling studies, remote sensing, numerical weather prediction and reanalysis, data archiving activities, and policy-relevant assessments. Bilateral agreements involving the U.S. and other arctic scientific partners should be fostered, in particular with Russia to help sustain its scientific infrastructure and human resources.

- **The Arctic, as a harbinger of global climate change, will continue to be an important focal point for ongoing research and international policy formulation. It is recommended that a policy arm of Arctic-CHAMP be established to disseminate scientific findings to the environmental management community.**

Box 6-2. NSF ARCSS Program Elements

As a consequence of its ambitious mandate, ARCSS has been organized into a series of more manageable programmatic components:

- **Land-Atmosphere-Ice Interactions (LAII);**
- **Ocean-Atmosphere-Ice Interactions (OAII);**
- **Paleoenvironmental Studies (Greenland Ice Sheet Project Two [GISP2], Paleoclimates from Arctic Lakes and Estuaries [PALE]), both part of Paleoenvironmental Arctic Sciences (PARCS);**
- **Human Dimensions of the Arctic System (HARC); and**
- **Russian-American Initiative on Shelf-Land Environments (RAISE).**

The LAII Flux Study in Alaska, North American Tundra Experiment (NATEX), Arctic Transitions in the Land-Atmosphere System (ATLAS) program, and U.S. contributions to the International Tundra Experiment (ITEX) provide important observational components to the overall ARCSS effort. These studies have supported a broad array of observational programs, process-based studies, modeling efforts, and environmental assessments. Several have been high profile and highly successful (e.g., Greenland Ice Sheet Project, SHEBA), both scientifically and in raising public awareness of the importance of the Arctic in global change. While these programs provide important new science, synthesis across these efforts has yet to be achieved. Integration and synthesis is emphasized as part of the new ARCSS research agenda.

It is noteworthy that ongoing IPCC assessments include a polar regional analysis, due to the many years of research indicating a high sensitivity of the Arctic to greenhouse warming. Integrative, pan-arctic understanding of hydrologic interactions and feedbacks in response to global change—of the type envisioned for Arctic-CHAMP—provides critical scientific support to U.N. Framework Convention activities. The international diplomacy issues associated with arctic system change are enormous. The contributions of Arctic-CHAMP toward articulating the diverse physical, biological, and human vulnerabilities to this change provide an important impetus for international cooperation in wisely managing this critical part of the arctic and earth systems.

Box 6-3. International Programs Sharing the Scientific, Observational, and Policy-Oriented Objectives of Arctic-CHAMP

Several opportunities are apparent for mutually beneficial collaboration, taking advantage of existing infrastructure and ongoing investment in these programs. The listing below shows some major representative programs and is not meant to be exhaustive.

INTERNATIONAL PROGRAM	PRIMARY GOALS/ACTIVITIES
Major International Science Initiatives	
1. World Meteorological Organization's World Climate Research Program (WMO/WCRP)	
(a) Global Water and Energy Experiment (GEWEX)	Coupling studies of land-atmosphere for regional and global modeling; Continental-Scale Experiments (CSE's) include Baltic Sea (BALTEX), Mackenzie GEWEX Study (MAGS), GEWEX Asian Monsoon Experiment (GAME) for Lena River; organizing major Coordinated Enhanced Observation Period (CEOP) for 2001–02.
(b) Climate Variability and Predictability Study (CLIVAR)	Understanding climate variability on a months-to-decades time frame.
(c) Climate and Cryosphere (CliC)	Broad set of cryosphere/atmosphere interactions (snow, ice, land, sea ice, oceans); Arctic as harbinger of global change; strong monitoring component including WMO meteorology and hydrology networks; follow-on to existing Arctic Climate System Study (ACSYS).
2. International Geosphere-Biosphere Program and Subsidiary Program (IGBP) Elements	
(a) Past Global Changes (PAGES)	Response of earth system to change over numerous time domains including rapid climatic shifts; analysis of sea ice, salinity, thermohaline circulation under current versus glacial maximum conditions, paleoclimatic reconstructions along Pole-Equator-Pole (PEP) transects; paleoclimate modeling including dynamic vegetation; human dimension issues during the Holocene.
(b) Task Force of Global Analysis, Interpretation, and Modeling (GAIM)	Development of linked models of the complete earth system, integrating dynamic atmosphere, ocean, biosphere, and biogeochemical models; feedback studies and system sensitivity to global change.
(c) Biospheric Aspects of the Hydrological Cycle (BAHC)	Enhancements of land surface-atmosphere transfer schemes; design and execution of large-scale field experiments; monitoring of carbon, water and energy fluxes at instrumented sites; constituent transport across drainage basins; dynamic vegetation and its role in regulating climate.
(d) International Global Atmospheric Chemistry (IGAC)	Biosphere-atmosphere exchanges of trace gases, including arctic wetlands; development of new gas emission instrumentation.

INTERNATIONAL PROGRAM	PRIMARY GOALS/ACTIVITIES
Intercomparison Studies	
(a) GEWEX/ACSYS Project for Intercomparison of Land Surface Parameterization Schemes (PILPS-2e)	Improve arctic land surface transfer schemes through multiyear, spatial comparisons of participating model results; explore alternative treatments of snowpack, soil, permafrost, frozen lake, wetland dynamics.
(b) International Association of Hydrological Sciences Snow Model Intercomparison Project (SNOWMIP)	Improve understanding of snow/hydrology process-level linkages.
(c) WMO Commission for Instruments and Methods of Observation: Solid Precipitation Measurement Intercomparison	Correction of well-known biases in precipitation measurements.
(d) IGBP Paleo-Model Intercomparison Project (PMIP)	Assess relative performance of models contrasting glacial maximum (20K years before present) to Holocene altithermal (6K bp).
(e) European Ice Sheet Modeling Initiative (EISMINT)	Test, compare, improve upon numerical ice-sheet, ice-shelf, and glacier models.
(f) ACSYS Sea Ice Model Intercomparison Project (SIMIP)	Improve understanding of freshwater dynamics associated with growth, transport, and decay of Arctic Ocean sea ice.
(g) Arctic Ocean Model Intercomparison Project (AOMIP) of ACSYS-CliC	Understand processes influencing Arctic Ocean climate and how to best represent and forecast these in numerical models.
Existing Field/Process Study Sites	
(a) U.S. and International Long-Term Ecological Research Network (LTER/ILTER)	Two LTER sites with integrated research, intensive monitoring, and experimentation. Two other sites beginning to develop long-term and integrated research.
(b) International Tundra Experiment (ITEX)	MAB-NSN initiative (Man-And-the-Biosphere, Northern Sciences Network); provides systematic meteorological station data, monitoring of permafrost in collaboration with IPA, snow cover and lake ice data, and analysis of permanent plot studies.
(c) Northern Hemisphere Climate-Processes Land-Surface Experiment (NOPEX)	Long-term catchment studies, soil-plant-atmosphere monitoring, regional climate surveys, use of remote sensing for data inputs to models, development of cold-weather measurement techniques.
(d) BOREAS	Major U.S.-Canadian initiative to develop improvements in understanding of land surface-atmosphere exchanges of energy, water, carbon, and other biogeochemical fluxes, including trace gases; bulk of field effort ended in mid-1990s, analysis continues.
Remote Sensing	
(a) Glacier Inventory of the Commission on Glaciation, International Union for Quaternary Research (INQUA)	Based on Landsat-7 data, provides benchmarks for future change in freshwater stocks trapped on land as "permanent" ice.

INTERNATIONAL PROGRAM	PRIMARY GOALS/ACTIVITIES
(b) Cryosphere System Program (CRYSYS) (Canadian contribution to NASA Earth Observing System)	Develop methods to extract and use cryospheric information from satellite and more conventional data sources.
(c) European Space Agency (ESA) Synthetic Aperature Radars on ERS-1 and ERS-2	Provide altimetry for monitoring changes in glacial ice mass.
(d) ESA's CryoSat	Set for launch in 2003, will fly a radar altimeter to monitor ice sheets and marine ice.
(e) Canada's RADARSAT	Provide synthetic aperature radar (SAR) imagery with high resolutions, from 8 to 100 m; backscattering holds potential for mapping freeze-thaw of surface active layer.
Monitoring and Analysis Programs	
(a) Global Climate Observing System (GCOS)/ Global Terrestrial Observing System (GTOS)	Multiorganizational (WMO/UNESCO/UNEP/ICSU) operational framework for systematic change detection; GCOS Surface Network (GSN) would serve as a global reference network of land surface observational weather/ climate stations; Global Terrestrial Networks (GTN) would include measurements of high relevance to northern polar region including glacier inventories (GTNet-G), hyrology (GTN-H), permafrost (GTNet-P).
(b) World Glacier Monitoring Service	Glacier monitoring providing inventories of glacier numbers, areal extent and in some cases glacier mass balance.
(c) International Permafrost Association (IPA)	Site-specific time series and pan-arctic mapping of permafrost; two international programs constitute IPA observational activities: the Circumpolar Active-Layer Monitoring (CALM) and Permafrost and Climate in Europe (PACE); NSIDC holds the IPA Circumpolar Active-Layer Permafrost System (CAPS) CD-ROM.
(d) Arctic Paleo-River Discharge (APARD)	Multi-disciplinary analysis of modern and ancient circumarctic river discharge, initiated by the Arctic Ocean Sciences Board (AOSB).
Numerical Weather Prediction and Reanalysis	
(a) European Center for Medium-range Weather Forecasting (ECMWF) and National Center for Environmental Prediction (NCEP)	Forthcoming ECMWF ERA-40 global reanalysis will provide long time series (1957–present) of atmospheric variables at 60-km resolution and six-hourly time steps; precipitation, evaporation, net vapor convergence, winds, radiation fluxes, and clouds will be routinely computed; U.S. reanalysis efforts (1948–present) established under NCEP.
(b) ACSYS Panel on Polar Products from Reanalysis Working Group on Coupled Models Numerical Experimentation Group (ACSYS NEG)	Activities to support use of weather prediction and atmospheric reanalysis models with arctic focus; under WCRP auspices.
Data Archives	
(a) National Snow and Ice Data Center (NSIDC)	Clearinghouse for a broad array of data sets supporting polar and high-latitude studies, including historical station time series and remote sensing data sets, several

INTERNATIONAL PROGRAM	PRIMARY GOALS/ACTIVITIES
	directly linked to the arctic hydrologic cycle (e.g., precipitation, snow cover, sea ice extent); serves as NSF-ARCSS, NASA, and ISCU data center for arctic geophysical data products.
(b) Arctic Precipitation Data Archive (APDA)	ACSYS product from WMO Global Precipitation Climatology Center (GPCC).
(c) ACSYS Data and Information Service (ADIS)	Metadata directory of historical or newly available arctic data sets.
(e) Global Observing Systems Information Center (GOSIC)	Data clearinghouse for GCOS/GTOS/GOOS databases.
(f) Arctic Environmental Data Directory (AEDD)	Metadata system; archive nodes at USGS offices in Anchorage, UNEP GRID (Arendal, Norway), Russian Ministry of Environment Protection and Natural Resources (Moscow).
(g) Global Runoff Data Center (GRDC)	Archive of Arctic River Database (ARDB) housed in WMO-GRDC, Federal Institute of Hydrology, Koblenz, Germany.
(h) Pan-Arctic Hydrographic Data Base (R-ArcticNET)	Compendium of time series of runoff and discharge data across pan-arctic domain, conjoining USGS, Russian State Hydrological Institute (SHI), Environment Canada data; a collaboration of the University of New Hampshire and SHI; distributed by NSIDC.
Framework Convention on Climate Change	
(a) Working Group 1 (Science of Climate Change)	Quantitative documentation of progressive environmental changes due to greenhouse warming; Arctic recognized as highly sensitive to global climate change; observational support from GCOS/GTOS.
(b) Working Group 2 (Impacts, Adaptations, Mitigation)	Studies of biogeophysical changes and policy-relevant human dimensions issues.
Other Arctic Assessment Programs	
(a) Arctic Monitoring and Assessment Program (AMAP)	International program case as broad assessment of contaminant pollution across the pan-arctic, with consideration of associated impacts.
(b) Arctic Climate and Impact Assessment (ACIA)	Evaluation and synthesis of climate variability, change, and UV radiation increases; contributes an arctic perspective to IPCC, established under the Arctic Council.
(c) Northern Research Basins (NRB)	Symposium convened every two years to share research results from studies in watersheds dominated by snow, ice, and permafrost.