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ARCTIC RESEARCH
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About the Journal

The journal *Arctic Research of the United States* is for people and organizations interested in learning about U.S. Government-financed Arctic research activities. It is published semi-annually (spring and fall) by the National Science Foundation on behalf of the Interagency Arctic Research Policy Committee (IARPC) and the Arctic Research Commission (ARC). Both the Interagency Committee and the Commission were authorized under the Arctic Research and Policy Act (ARPA) of 1984 (PL 98-373) and established by Executive Order 12501 (January 28, 1985). Publication of the journal has been approved by the Office of Management and Budget.

Arctic Research contains

- Reports on current and planned U.S. Government-sponsored research in the Arctic;
- Reports of ARC and IARPC meetings; and
- Summaries of other current and planned Arctic research, including that of the State of Alaska, local governments, the private sector, and other nations.

Arctic Research is aimed at national and international audiences of government officials, scientists, engineers, educators, private and public groups, and residents of the Arctic. The emphasis is on summary and survey articles covering U.S. Government-sponsored or -funded research rather than on technical reports, and the articles are intended to be comprehensible to a nontechnical audience. Although the articles go through the normal editorial process, manuscripts are not refereed for scientific content or merit since the journal is not intended as a means of reporting scientific research. Articles are generally invited and are reviewed by agency staffs and others as appropriate.

As indicated in the U.S. Arctic Research Plan, research is defined differently by different agencies. It may include basic and applied research, monitoring efforts, and other information-gathering activities. The definition of Arctic according to the ARPA is "all United States and foreign territory north of the Arctic Circle and all United States territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering, and Chukchi Seas; and the Aleutian chain." Areas outside of the boundary are discussed in the journal when considered relevant to the broader scope of Arctic research.

Issues of the journal will report on Arctic topics and activities. Included will be reports of conferences and workshops, university-based research and activities of state and local governments and public, private and resident organizations. Unsolicited nontechnical reports on research and related activities are welcome.

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Front Cover

This colorful image shows a portion of the North Slope of Alaska and adjacent Beaufort Sea. It was acquired on August 16, 2000, using the Multi-angle Imaging SpectroRadiometer's nadir (vertical-viewing) camera aboard the Terra satellite. The swirling patterns apparent on the Beaufort Sea are small ice floes driven by turbulent water patterns, or eddies, caused by the interactions of water masses of differing salinity and temperature. By this time of year, all of the seasonal ice that surrounds the north coast of Alaska in winter has broken up, although the perennial pack ice remains farther north. The morphology of the perennial ice pack's edge varies in response to the prevailing wind. If the wind is blowing strongly toward the perennial pack (that is, to the north), the ice edge will be more compact. In this image the ice edge is diffuse, and the patterns reflected by the ice floes indicate fairly calm weather.

The Canning River flows north about halfway between the center and left side of the image, and the U.S.–Canadian border is near the right edge of the image. The two permanent human settlements within the image area are Kaktovic (near the tip of the large rounded peninsula) and Arctic Village (south of the Brooks Range, which crosses from the lower left corner to the middle of the right side). The area represented by the image is approximately 380 × 540 kilometers. The image was produced by the MISR team from NASA's Jet Propulsion Laboratory.

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SPECIAL ISSUE ON THE NATIONAL SCIENCE FOUNDATION'S ARCTIC SYSTEM SCIENCE PROGRAM

An Overview of the Arctic System Science Program

This article was prepared by Neil Swanberg, Director, Arctic System Science Program, Office of Polar Programs, National Science Foundation, and Jonathan T. Overpeck, Director, Institute for the Study of Planet Earth, Department of Geosciences, University of Arizona, and Chairman of the ARCSS Committee.

The Arctic System Science (ARCSS) program's goal is to understand the physical, geological, chemical, biological, and sociocultural processes of the Arctic system that interact with the total Earth system and thus contribute to, or are influenced by, global change. This understanding is being developed to advance the scientific basis for predicting environmental change on a seasonal-to-centuries time scale and for formulating policy options in response to the anticipated impacts of global change on humans and societal support systems.

Human societies generally observe and learn from the world around them and then use the information they gather to plan for the future. What happens to this ability if things change in unpredictable ways? Societies thrive if the changes are beneficial—for example, an improvement in climate for growing or supporting increased populations of fish or animals. However, when changes are negative, such as the disappearance of key resources or environmental features, then the consequences can often be profound. The degree to which a society is able to adapt or move may determine whether it perishes or flourishes.

We are now seeing changes in the Arctic that extend well beyond our recent human experience. The peoples of the Arctic tell us that their world is now unlike any they have known for thousands of years, according to their traditional knowledge. A good analogy for those of us who live in lower latitudes might be that spring just never came: the almanac of our traditional knowledge would become useless, and one would not know when to plant seed nor whether there would be food for newborn calves. As harsh as it seems to us, many of the peoples of the north depend on the features associated with the predictability of winter, and the platform provided by its ice, to help sustain them and the animals on which they depend. Now there is less sea ice, it is thinner and has shifted its location, the permafrost that supports the foundations of buildings and stabilizes the shoreline is melting, the timing of fall freeze-up and spring thaw has shifted by weeks in some places, and the amount of snow cover has changed, or snow has even turned to rain.

Some of these changes have obvious direct impacts on the residents of the Arctic; others act more indirectly through mechanisms such as changes in vegetation, shifts in populations of fish, migrations of land animals, or the patterns and timing of the whale migrations. All of these outcomes affect the residents of the Arctic, but there are also other, less obvious Arctic changes that may have effects that extend far beyond the Arctic. The amount of ice residing in the Arctic basin has changed, along with the surface salinities and the front between the Pacific and Atlantic water in the Arctic Ocean, and there has been a general freshening of the waters in the surface of the Beaufort Sea, all changes that could affect the deep water formation in the North Atlantic, with possible influence on global heat flux and climate.

The global change science community believes that more global change is coming, but the Arctic research community has documented change that is among the most dramatic yet observed. We need to determine whether these changes are due to natural variability or are part of some long-term trend, whether induced by human activities or not. While most of the scientific community agree that carbon dioxide and other anthropogenic greenhouse gases are the likely culprits driving this change, there is also an underlying understanding that at some level the source of the problem is secondary—we are confronted by a problem that is real, and we have an acute need to understand the system in which we live so that we can identify the scope of what to expect next. This is all made more difficult because a complex of factors affect the environment we see. The challenge is to extract understandable patterns of change.

The most troubling concern for the future may be the specter of unanticipated large-scale abrupt climate change. Although our understanding of ice-age inception is still not complete, there is little chance of a new ice age within the next several thousand years. More troubling, however, is the possibility of abrupt Arctic melting, complete with the development of a seasonally ice-free Arctic Ocean and rapidly wasting Greenland Ice Sheet. Indeed, some believe that the recent record summer sea ice retreat and thinning of Arctic sea ice could be the first signs of wholesale Arctic melting such as occurred during the last time the Arctic was warmer than present, approximately 130,000 years ago. The global impacts of such a change would be profound, including a sea level rise of up to six meters and perhaps a major shift in ocean thermohaline circulation.

The NSF ARCSS program was constructed on the premise that to understand this change we need to understand how the Arctic works as a system and how that system fits into the Earth system. This article describes how the ARCSS vision of the Arctic system has been reflected in the efforts undertaken by ARCSS, how that view has matured, and where it is leading both the program and our understanding of the Arctic system.

The Structure of ARCSS

ARCSS as a Leader

There are large international efforts underway to examine global patterns of change and the processes driving them. Programs such as the International Geosphere–Biosphere Programme (IGBP) and the World Climate Research Programme (WCRP) have tried to reduce research on global change problems to manageable levels, more or less along disciplinary lines (hydrology, ecology, paleoclimatology, oceanography, etc.).

ARCSS set out from an early stage to view the world in a manner that reflects its physical structure. Thus, there were ocean and land components established, with the task of planning projects that focused on key domains (land, sea, air) and their interfaces with other parts of the Arctic system. To these were added paleoenvironmental and social components that sought to put the other efforts in perspective of time and to relate them to human activities. Under this structure efforts were launched to examine fluxes of heat, carbon, energy, and (newly) water through all or parts of the system. In recent years some of the global change programs have begun to migrate towards a view that resembles some of the approaches taken in ARCSS. Thus the structure IGBP is proposing for its new incarnation looks much like ARCSS has looked for years, with components related to land, sea, and air and with themes such as carbon fluxes and the water cycle to guide thinking. Moreover, there is increasing recognition in the global programs that while a global view is important, the regional view is essential to the human stakeholders and probably has considerable physical significance.

People

One of the essentials of viewing the Arctic as a system has been the recognition that humans are an inseparable part of it. This is important not only from the standpoint of how human impacts on the global system affect the Arctic, and how impacts in the Arctic affect the rest of the globe, but also because there are significant numbers of humans living in the Arctic. Moreover, people of the Arctic tend to live closer to the environment than people do in many other parts of the world. Subsistence fishing and hunting are far more common among the Native communities in the Arctic than they are in most other areas of the world. As a result, these human societies are highly susceptible to environmental changes. Where people in the rest of the world can insulate themselves to avoid environmental changes, societies that are mostly dependent on what the environment provides cannot. If seal hunts depend on seasonal ice as habitat for seals, then when the ice does not arrive they are impacted heavily. ARCSS constructed the Human Dimensions of the Arctic System (HARC) in an effort to organize research in the broad area of how humans interact with their environment and how we might help reduce vulnerability to environmental change.

The activities of this group are described beginning on page 59. The article outlines efforts to plan and coordinate social science research in ARCSS and presents brief results of some successful HARC projects. Among these are analyses linking ocean and climate changes, marine ecology, fisheries, and the development of human communities in West Greenland and other areas of the Arctic and sub-Arctic Atlantic region. Another study focuses on reindeer herding, the climate factors that influence herding practices, the role of reindeer herding in local economies, the ecological impacts of caribou grazing, and the socioeconomic consequences of losses of reindeer. Other studies included a symposium on sea ice aimed at sharing traditional knowledge and sea ice research knowledge, as well as projects on industrialization in the Kola peninsula and archaeology in Iceland.

This is an exciting area of ARCSS research that is obviously of high relevance to decision and policy making. The HARC group of scientists is attempting to link social science with natural science research. It is developing a community of social science researchers that is preparing to integrate fully with other areas of ARCSS science. The Human Dimensions of the Arctic System will continue to expand as a central part of ARCSS.

The Sea

It is a fact of geography that the Arctic is an ocean surrounded by land, so it is natural that an Arctic system science program would devote considerable effort towards ocean-centered studies. In ARCSS this has taken the form of the Ocean–Atmosphere–Ice Interactions (OAII) component of ARCSS research (page 9), which has sought to understand the Arctic marine environment and its role in climate and global change. Focusing on processes in the oceans and on fluxes from the oceans to the atmosphere, efforts that have emerged from OAII have included the Northeast Water Polynya Study (NEW), 1991–1995; Investigations of the Western Arctic (IWA), 1992–1995; the U.S./Canada Arctic Ocean Section (AOS), 1994–1997; a study on the Surface Heat Budget of the Arctic Ocean (SHEBA), 1995–2003; and the Western Arctic Shelf–Basin Interactions (SBI) program, which is in its field phase.

The SHEBA project was an effort to determine how heat fluxes that couple the atmosphere, sea ice, and ocean produce feedbacks that affect Arctic and global climate. In SHEBA, observations, conducted from a ship frozen in the Arctic pack during 1997-98, established a data set that documents these heat fluxes and related processes with unprecedented accuracy, continuity, and comprehensiveness over a full annual cycle. A major finding was that cloud radiative forcing of the surface heat budget was positive throughout the year. In the final year of SHEBA, project scientists are now applying their new data and understanding to improving local, regional, and global climate models.

The Western Arctic Shelf–Basin Interactions (SBI) project (page 24) is investigating the effects of global change on the production, cycling, and shelf–slope exchange of biogenic matter, both seasonally and spatially. It focuses on shelf, shelf break, and upper slope water mass and ecosystem modifications, material fluxes, and biogeochemical cycles as they contribute to shelf–basin interactions within the Arctic Ocean ecosystem. An accumulated body of research indicates that climate change will significantly impact the physical and biological linkages between the Arctic

Recent projects supported by ARCSS

ARCSS Project or Subproject Name	Acronym	Project Web Page URL
Ocean–Atmosphere–Ice Interactions	OAII	http://arcss-oaii.hpl.umces.edu/
Study of Environmental Arctic Change	SEARCH	http://psc.apl.washington.edu/search/
Western Arctic Shelf–Basin Interactions	SBI	http://sbi.utk.edu
Surface Heat Budget of the Arctic Ocean	SHEBA	http://sheba.apl.washington.edu/
U.S./Canada Arctic Ocean Section	AOS	Completed project
Investigations of the Western Arctic	IWA	Completed project
Northeast Water Polynya Study	NEW	Completed project
Land–Atmosphere–Ice Interactions	LAII	http://www.laii.uaf.edu/
Flux Study	FLUX	Completed project
Arctic Transitions in the Land–Atmosphere System	ATLAS	http://www.arts.monash.edu.au/ges/research/climate/atlas
International Tundra Experiment	ITEX	http://www.systbot.gu.se/research/itex/itex.html
Russian–American Initiative on Shelf–Land Environments in the Arctic	RAISE	http://arctic.bio.utk.edu/RAISE/index.html
Paleoenvironmental Arctic Sciences	PARCS	http://www.ngdc.noaa.gov/paleo/parcs/
Greenland Ice Sheet Project 2	GISP2	http://www.gisp2.sr.unh.edu/GISP2/
Human Dimensions of the Arctic System	HARC	http://www.arcus.org/HARC/
Pan-Arctic Community-wide Hydrological Analysis and Monitoring Program	Arctic-CHAMP	Web site pending; 18 new projects

shelves and the adjacent ocean basins. SBI therefore focuses on areas where it is believed that key processes control water mass exchange and biogeochemical cycles and where the greatest responses to climate change are expected to occur. The SBI project conducted its first field year successfully in the Bering Strait region and over the outer shelf, shelf break, and slope of the Chukchi and Beaufort Seas into the Arctic Ocean. The group completed four successful scientific missions in 2002 to the Arctic using three vessels: the USCGC *Healy*, the USCGC *Polar Star*, and the RV *Alpha Helix*. The spring cruise on the new *Healy* icebreaker was the first interdisciplinary research cruise to this region by a science vessel at this time of year. From May through September (and year-round using moorings), the group made a broad array of physical, biogeochemical, and biological measurements that is almost unprecedented in scope for the Arctic.

Another effort to emerge from OAII planning in recent years was the Study of Environmental Arctic Change (SEARCH). SEARCH has grown beyond the intellectual and institutional boundaries of the ARCSS program and is now a very broad effort with some interagency support (see *Arctic Research of the United States*, vol. 15, Fall/Winter 2001). Research is now underway on the Arctic freshwater cycle held under SEARCH auspices with support from ARCSS.

As SHEBA ends and SBI is entering its field phase, the OAII planning component has begun to envisage a future effort that would study chemical processes in the lower atmosphere. Here OAII hopes to inspire research on chemical exchanges between the ocean, ice, land, snow, and lower troposphere. This project idea draws some of its inspiration from the nascent IGBP project called the Surface Ocean Lower Atmosphere Study and would be a bold step in the direction towards true inter-compartmental studies.

The Shore

Much of the coastal Arctic lies in Russia. Recognizing this, and in view of the challenges facing much of the Russian science community, ARCSS researchers saw at an early stage that there was merit in a partnership between American and Russian scientists to study Arctic processes in the coastal zones. The Russian–American Initiative for Land–Shelf Environments in the Arctic (RAISE) was developed, and while it has always been a low-profile activity compared to the large expeditionary efforts of ARCSS, it has achieved considerable successes.

The article on RAISE on page 33 describes a number of research areas that have been successful. One important area was the launching of a number of data recovery projects involving both U.S. and Russian scientists. These data represent an important legacy that needs to be saved because they can provide important long-term records. An example of their importance is the use of historical hydrographic records from the Soviet era in syntheses of river runoff data. Recently published results found that the average annual discharge of fresh water from the major Eurasian rivers to the Arctic Ocean increased by 7% from 1936 to 1999. These discharges correlated with changes in the North Atlantic Oscillation and with increases in global mean surface air temperatures. This could mean that the large-scale change in freshwater influxes to the Arctic have important implications for ocean circulation and climate. Another example of the success of RAISE has been the proliferation of ideas into other scientific communities. Many projects inspired by RAISE involve teams of Russian and U.S. investigators who were funded recently through the Freshwater Cycle competition (see below) as part of an Arctic Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP).

Other foci in RAISE are described beginning on page 34, such as studies of the extent to which ice sheets were present at the time of the Last Glacial Maximum in northeastern Siberia and their extent in the Northern Hemisphere. As ARCSS moves towards more integrative efforts, RAISE has begun to evolve, and planning has proceeded towards a coordinated Land–Shelf Interactions (LSI) project that would focus on the pan-Arctic coastal zone and support land-, river-, and sea-based research. This emerging research effort would attempt to cross the traditional geomorphic boundaries separating marine and terrestrial lines of inquiry in Arctic system science.

The Land

In a manner complementary to OAII's, the Land–Atmosphere–Ice Interactions (LAII) component of ARCSS has sought to develop projects that improve our understanding of the interactions between land, atmosphere, and ice in the Arctic. To date, much of LAII research has focused on

Alaska and has comprised a major contribution of land-based data to U.S. global change research in the Arctic. The LAII Flux study, funded from 1993 through 1997, investigated the processes controlling the fluxes of CO_2, CH_4, water, nutrients, and energy between Arctic terrestrial ecosystems and the atmosphere. Under LAII's guidance there sprang from this effort a project called Arctic Transitions in the Land–Atmosphere System (ATLAS). ATLAS's goal was to develop an understanding of the role of the Arctic terrestrial system in global climate change by studying the interactions and feedbacks in the land–atmosphere system critical to impacts of high ecological and social importance. As ATLAS progressed, ARCSS supported a parallel effort to simulate impacts of climate change on tundra vegetation as a contribution to the International Tundra Experiment (ITEX).

Some of the key results to emerge from a decade of LAII research are highlighted in the article beginning on page 43. The Flux study and ATLAS found that the warming in the Alaskan Arctic has been associated with warming of permafrost, expansion of shrubs, and a temporary increase in CO_2 efflux. They also found that winter is a more important period of biological activity than had been previously appreciated and that vegetation changes can have a significant positive feedback to regional warming. ITEX found that experimental warming initially increases growth in most Arctic plants but that the growth response to warming diminishes over time. The Circumpolar Active Layer Monitoring (CALM) study found that the active layer depth of the permafrost responds sensitively to summer climate. Others found that spruce began to invade tundra throughout Alaska after 1850 and that spruce invasion of permafrost-affected tundra depends on the melting of permafrost in some sites. Still others found that the duration of lake ice cover (seasonal or multi-year) is a dominant control on the biogeochemistry of Arctic lakes and that this can be traced in the sediments.

LAII researchers have begun to work in the Russian Far East, and like OAII, LAII has teamed up with other ARCSS researchers to create a vision for a new effort that would follow on the heels of ATLAS and ITEX. Dubbed Pan-Arctic Cycles, Transitions, and Sustainability (PACTS), this project would explore the connected biophysical, biogeochemical, and social systems as engines of change in the Arctic by focusing on the interaction of physical and living systems.

The Past

An understanding of the past is essential to interpreting the environmental data we receive and determining where we are in the full range of past changes. An effort to develop such an understanding was first organized under the PALE (Paleoclimates from Arctic Lakes and Estuaries) and GISP2 (Greenland Ice Sheet Project Two) components, which have evolved into a more circum-Arctic Paleoenvironmental Arctic Sciences (PARCS) component. PARCS taps a community of researchers studying past climates and environments of the Arctic and sub-Arctic. This component is not uniquely an ARCSS effort but has been assembled in collaboration with the Earth System History program at the National Science Foundation.

PARCS research (page 50) aims to develop an understanding of the range of natural environmental variability in the Arctic, explore the impact and cause of "surprises" in Arctic climate system behavior, define the sensitivity of the Arctic to altered forcings, document the history and controlling mechanisms of biogeochemical cycling of nutrients and radiatively active species, and evaluate the realism of numerical models used to predict future change. PARCS does this with a focus on acquiring and analyzing paleoclimatic and paleoenvironmental records, linked with climate model experiments, to determine the causes and consequences of past warm episodes in Arctic climate. PARCS also uses paleoclimatic records of high temporal resolution to determine the natural modes of climate variability that have impacted the Arctic over the past 2000 years.

PARCS researchers have shown that there have been periods lasting from hundreds to thousands of years when the climate in the Arctic was several degrees Centigrade warmer than it has been for the past 100 years. This information is evidence of the natural range of Arctic thermal variability and gives insight into how the Arctic system responds to prolonged and pronounced warming. PARCS has also documented Arctic climatic variability and fluctuations on decade to century time scales over the last 20,000 years and has shown how some of these variations have impacted people (for example, the Norse of Greenland at the onset of the Little Ice Age). Scientists have reconstructed the postglacial history of the northern boreal forest treeline across Eurasia and have shown how the observed changes reflected changing summer temperatures due to natural variations in the Earth's orbit and the warming of the Nordic seas.

One of PARCS' goals has been to integrate paleoenvironmental records to foster the reconstruction and analysis of climatic change. To this end, PARCS has produced an online data atlas for the research community and collated paleoclimatic records of summer temperature from a variety of sources to produce a circum-Arctic record of climatic change over the past 400 years. The latter work demonstrated just how unusual late-twentieth-century warming appears to be.

The Future of ARCSS

The ARCSS program has a decade of research behind it, and the scientific results of the program have increased considerably our understanding of Arctic processes. ARCSS has employed disciplinary scientific projects in a wide array of efforts targeting portions of the Arctic system. However, it has not yet made a concerted attack at the level of the whole Arctic system nor over all time scales important to human concerns. The holistic system understanding has remained an elusive goal, not only for ARCSS but also for most of the global change programs around the world. It is a difficult task, made more so because most researchers were educated in a discipline, and even if they appreciate the needs for interdisciplinary understanding, it does not come readily or through obvious paths. The ARCSS program is taking a two-pronged approach to addressing this problem. The first is to engage more fully in the use of themes that by their very nature cut across the disciplinary boundaries imposed by science. The second approach is to assemble the thematic understanding of the system into a synthesis.

Examples of the integrative themes may be found in the flow of energy through the system, the biogeochemical cycles of carbon and nutrients and other important chemical constituents, and of course the hydrological cycle in its broadest sense, including atmospheric transport and deposition, land surface hydrology, and oceanography. Other, less-obvious themes, such as information content and flow in systems, evolution, scales of time, system memory, even system complexity, could eventually help increase our understanding of the system, but our thinking about the Arctic system is not sufficiently developed now to employ such approaches.

ARCSS has studied pieces of the energy flow story in SHEBA, and of carbon flow in ATLAS and SBI, but not yet assembled the pieces fully into a system-wide understanding. Ultimately these themes need to be linked. For example, the flow of energy is highly coupled to the hydrological cycle, and both influence the flow of carbon, though the biologically mediated component of the carbon cycle is highly regulated by organisms and thus by the information content held in the biodiversity of the system. Before we can link these themes, we need to understand more about each of them and how they cut across the various compartments of the system. To do this, ARCSS is striving now to move from the compartmentalized research mode of LAII and OAII to a thematic mode.

Integration: The Freshwater Cycle

The first major move in the direction of thematic integration is being developed through the ARCSS Freshwater Cycle effort, for which the major focus is to study the hydrologic cycle and heat balance of the Arctic and sub-Arctic atmosphere, landmass, and ocean. Scientific questions address the physical, chemical, and biogeochemical character of the Arctic freshwater system and its connections with the subpolar oceans and Arctic environmental change. The inspiration for this new focus came from the international Arctic/Sub-Arctic Ocean Fluxes (ASOF) group, the new Arctic Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP) group within ARCSS, and the Study of Environmental Arctic Change (SEARCH) effort that sprang from OAII and is now coordinated across most Federal agencies working in the Arctic.

Other efforts are expected to emerge that cut across disciplinary boundaries. An example of one being discussed now in ARCSS is the Pan-Arctic Cycles, Transitions, and Sustainability (PACTS) project. Devised to explore the connected biophysical, biogeochemical, and social systems as engines of change in the terrestrial Arctic by focusing on the interaction of physical and living systems, this effort could serve as a template for a way of looking at the Arctic system with some of the less-obvious themes mentioned above, such as information flow and biodiversity. Work is anticipated in other subject areas, such as the interaction of energy flux and chemistry. Another area for significantly higher efforts is human dimensions research. Up to now, this has been a separate effort in ARCSS, but it may become much more heavily integrated into all aspects of ARCSS research.

ARCSS Synthesis

ARCSS has long had an element called Synthesis, Integration, and Modeling Studies (SIMS) that to date has been mostly a vigorous data management effort aimed at assuring the assembly, public release, and responsible archival of data (ADCC, page 79) and improving data exchange between principal investigators, particularly in field efforts and expeditions such as ATLAS, SHEBA, and SBI (JOSS, page 70). SIMS had the initial intent, however, of feeding and driving the synthetic thinking in the program, and through it ARCSS has engaged in some synthesis efforts in its individual projects (see SHEBA and ATLAS). ARCSS is now launching a new effort that will move the program towards more Arctic-system-wide synthesis.

The words “integration,” “synthesis,” “review,” and “analysis” are often cast about almost as if they were synonymous. A review is a study and restatement of material previously studied. Analysis is the separation of a whole into its component parts; in the case of science it is an examination of a complex, its elements, and their relations. Integration is the process of forming or combining information into a functioning or unified whole, and synthesis is the combining of diverse ideas into one coherent theory or system. Analysis and integration play key roles in a synthesis. Reviews and summaries are also important building blocks towards synthesis, but the key concept in a synthesis is the struggle towards new insights and a higher level of understanding through considering research results on various facets of an overall theme.

The synthesis effort on which ARCSS is launched is still being defined, but there have already been some ideas expressed in the community. The goal being discussed is describing the whole Arctic system in an integrated fashion that would include non-ARCSS research, data sets, and people. It will certainly be a substantial research effort to collect our knowledge of the components of the Arctic system and how they fit together. The synthesis will reach down to the disciplinary level to address problems that emerge as essential to achieving the full-system understanding. The first phase of the synthesis effort is to take place in 2003.

ARCSS Program Structure

The focus of the synthesis effort will be the intellectual content of the program, not a programmatic reorganization. However, among the more valuable things likely to emerge from a synthesis will be the identification of what new research needs to be done. Thus, while the synthesis effort does not necessarily mean a major change or restructuring of the ARCSS program, it should guide the direction of the future ARCSS.

The organizational structure of ARCSS is viewed as a tool that fosters scientific learning, so if our approach to the science changes, the structure would also be expected to change. The OAII and LAII components are scheduled to end, and we expect a new structure to emerge from discussions ongoing in the ARCSS community and from the synthesis. Beyond that, there are no preconceived notions about the shape of a future ARCSS that are driving this process. It is highly likely that ARCSS will continue to study Arctic processes on the land, sea, ice, and air, that it will look to the past as well as the future, and that it will address issues relating to human dimensions.