Synthesis of Arctic System Science (SASS II)
Summary Table: Projects and Investigators

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* Collaborative Projects

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Climate Response to Future Changes in Arctic Snow Cover and Sea Ice: A New Perspective from the High-Resolution NCAR CCSM3	**Clara Deser**, University Corporation For Atmospheric Research cdeser@cgd.ucar.edu #0629300
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Synthesis of Arctic System Science (SASS II)
Project Abstracts

Collaborative Research: The Roles of Clouds and their Accomplices in Modulating the Trajectory of the Arctic System

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Award #0629360
PI: Axel Schweiger, Polar Science Center, Applied Physics Laboratory/University of Washington

The overarching objectives of the proposed effort are to identify and evaluate relationships between cloud properties, surface radiation fluxes, horizontal heat and moisture transport, large-scale circulation patterns, sea ice extent, and melt onset in past conditions when Arctic change was moderate, and in the future, which models project will be characterized by dramatic loss of permanent ice. Certain cloud-related interactions that were insignificant in the past may play more mid-latitude-like roles as the Arctic's ice disappears, such as exerting an overall cooling rather than warming influence. The proposed effort is aligned with the new directions of the ARCSS program, as it will improve our understanding of linkages among components of the Arctic system, build upon previous work and integrate existing data sets, address cross-cutting questions, investigate causes of spatial and temporal variability, and investigate relationships among components in a range of space and time scales. Data products are not expected from this study, thus a specific plan for data archival is not included.

Intellectual merit: Existing data sets and reanalysis products will be combined with global climate model (GCM) simulations to identify and evaluate important factors affecting downwelling surface radiation fluxes, and how these influences vary: 1) in the past during large-scale and large-magnitude shifts in the climate system; 2) among model simulations of the past; 3) owing to local and remote variability; 4) seasonally; 5) and in model projections of future conditions. The expected outcome is a more complete understanding of processes and conditions affecting Arctic cloud properties, the ability of GCMs to simulate observed relationships among cloud properties and factors that influence them, which cloud-related parameters exert either enhancing or dampening effects on Arctic ice loss, and how those effects can be expected to evolve in the future as the Arctic system continues on its trajectory toward a new state.

Broader Impacts: By its very nature, this project is interdisciplinary and cross-cutting. It focuses on relationships and interactions among various components of the climate system, both within and outside the Arctic, and how these relationships might change in the future. The relationships initially targeted encompass a variety of spatial and temporal scales. The broader impacts of the work, consequently, are naturally extensive across the scientific community. Graduate students at three universities will participate directly and/or indirectly in the project -- one explicitly at the University of Wisconsin -- and the methodology and results will provide new fodder for courses related to climate change. Ultimately the findings should contribute to better informing policy makers, which

will benefit society as a whole. The Polar Science Center at the University of Washington has just completed its first annual Polar Science Weekend hosted by the pacific Science Center in Seattle. A combination of exhibits, demonstrations and lectures brought various aspects of polar research to approximately 5,000 participants, including K-12 classes and the general public. A module based on the roles of clouds in Arctic change will be developed for the events planned for 2008 and 2009.

Collaborative Research: Toward Reanalysis of the Arctic Climate System - Sea Ice and Ocean Reconstruction with Data Assimilation

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Award #0629312
PI: Jinlun Zhang, Polar Science Center, Applied Physics Laboratory/University of Washington
Co-PI: Ronald Lindsay, Polar Science Center, Applied Physics Laboratory/University of Washington

Award #0629311
PI: Gleb Panteleev, International Arctic Research Center, University of Alaska Fairbanks

Award #0629400
PI: Dmitri Nechaev, Department of Marine Science, University of Southern Mississippi

The PI's propose to develop an integrated set of assimilation procedures for the arctic ice-ocean system that are able to provide gridded data sets that are physically consistent and constrained to the historical observations of sea ice and ocean parameters. Building on their past research activities in sea ice and ocean data assimilation, they propose to make some first steps toward the creation of an Arctic Climate System Reanalysis that uses modern four-dimensional variational data assimilation methods employing new data assimilation procedures to maximize the integration of model results with observations. They will focus their attention on three distinct periods, each representing a different state of the Arctic climate. The first period is 1972-1978 when the Arctic was relatively cold and there is a large quantity of hydrographic data available, the second is 1989-1996 when large changes begin in the Arctic Ocean circulation, in its hydrographic structure, and in sea ice conditions, and the third is 1997- present when substantial amounts of open water begin to appear in the late summer. Comparison will be made with new reanalysis products with fields obtained by AOMIP models to validate AOMIP model results. After obtaining the reconstructed solutions with the best fit to the observations, they will focus on the analysis of the sea ice, water circulation, and ocean hydrography during these periods.

Intellectual Merit: Understanding of the Arctic system and its change is an important goal of the SEARCH program. Accurate gridded atmospheric, cryospheric and oceanic fields consistent with and constrained by point observations are important to understanding the origin of past Arctic changes and are essential for forming accurate budgets of climate variables such as heat and freshwater fluxes. Practical implementation of data assimilation methods is necessary to properly understand and model the climate system, and this project will provide the most accurate results possible with modern techniques. These new simulations will help answer a variety of scientific questions of the SEARCH, SBI, and FWI projects and will significantly contribute to national and international components of ASOF and CLIVAR dealing with climate studies. The algorithms tested and validated in this project could also be applied to a reanalysis of the Arctic Ocean during the 2007-2009 IPY and will be used in existing and planned activities of SEARCH, DAMOCLES, COME, CAME and others.

Broader Impact: Data will be available through a web site that will include links to other relevant projects and data, and will be designed to be useful for a variety of audiences including the scientific community, students, and the general public. Interpretations of the results will be published in scientific and popular journals. Educational activities within the project will include training of graduate and undergraduate students at USM and IARC, as well as integration of the material into courses taught at UW, USM and UAF. Active outreach to grade schools in the Fairbanks and Falmouth area and extensive participation in the Polar Science Weekend at the Pacific Science Center in Seattle will continue.

Climate Response to Future Changes in Arctic Snow Cover and Sea Ice: A New Perspective from the High-Resolution NCAR CCSM3

Award # 0629300
PI: Clara Deser, Climate and Global Dynamics Division, National Center for Atmospheric Research
Co-PI: Michael Alexander, NOAA-CIRES, Climate Diagnostics Center
Co-PI: Robert Tomas, Climate and Global Dynamics Division, National Center for Atmospheric Research

Intellectual Merit: The PI's propose to investigate the impact of projected future changes in Arctic sea ice (extent, concentration and thickness) and snow cover (extent and depth) upon the global atmospheric circulation, the oceans, and surface climate using the new high-resolution (T85) version of the NCAR Community Climate System Model Version 3 (CCSM3).

Their first step will be to investigate the linkages among the atmosphere, ocean, sea ice and snow cover in the 500 year control integration of CCSM3 under present-day greenhouse gas concentrations and in the multi-member ensemble of historical 20th century integrations of CCSM3. These linkages will then be compared to those occurring in the multi-member ensemble of 21st century IPCC integrations of CCSM3 under various greenhouse gas concentration scenarios (e.g., SRES A1B). To isolate the global atmospheric circulation response to projected future changes in Arctic sea ice and snow cover, the PI's shall prescribe (individually and in combination) the changes in Arctic snow extent and thickness, and sea ice concentration and thickness, during 2080-2100 (obtained from the CCSM3 21st century IPCC integrations) relative to the late 20th century as lower boundary conditions to the Community Atmospheric Model Version 3 (CAM3), the atmospheric model component of CCSM3. They will also investigate the coupled ocean-atmosphere response to the sea ice and snow cover changes by means of experiments with CAM3 coupled to the Parallel Ocean Program (POP), the oceanic model component of CCSM3. The proposed work will further understanding of the interactions among Arctic sea ice and snow cover, the global atmospheric circulation, and the oceans under present and future climates.

Broader impacts: The proposed research will benefit society by furthering understanding of how current and projected future declines in Arctic sea ice and snow cover will impact the global atmospheric circulation, with attendant impacts on surface climate, and the oceans. The PI's will engage in synergistic collaboration with other ARCSS and NSF supported researchers. The proposal will support a postdoctoral scientist, and the results will be disseminated broadly by means of web sites, peer reviewed journal articles, and presentations at scientific meetings. The model output generated from this proposal will be delivered to the ARCSS Data Coordination Center (ADCC) at the National Snow and Ice Data Center (NSIDC) before the end of the project and will also be made available to the scientific community via the NCAR CCSM Climate Variability Working Group web page. The proposed research will broaden the participation of under-represented groups as defined by the National Science Board by involving women scientists.

Collaborative Research: The White Arctic: A Snow-Impacts Synthesis for the Terrestrial Arctic

Award # 0629310
PI: Matthew Sturm, Engineer Research and Development Center, Department of Army Cold Regions Research & Engineering Lab
Co-PI: Donald Perovich, Engineer Research and Development Center, Department of Army Cold Regions Research & Engineering Lab

Award # 0629279
PI: Glen Liston, Cooperative Institute for Research in the Atmosphere, Colorado State University
Co-PI: Christopher Hiemstra, Cooperative Institute for Research in the Atmosphere, Colorado State University

Intellectual merit: A defining feature of the Arctic is a long-lasting snow cover. It persists 7 to 10 months of the year, making white the dominant surface color of both Arctic marine and terrestrial systems. On land, snow impacts the Arctic System in four essential ways: by increasing albedo, by insulating the ground, by affecting mobility and foraging of animals and human transportation and commerce, and by playing a key role in the freshwater cycle. While snow has been discussed in literally hundreds of papers and appears in dozens of models (from process-level to GCM), a comprehensive, snow-centric synthesis has never been undertaken. Current information and knowledge related to snow tends to be compartmentalized by discipline, dispersed throughout the literature, and rarely inclusive. Such a synthesis is needed now more than ever because both the duration and the nature of the arctic snowpack are changing.

In the proposed work, the PI's take a comprehensive approach to snow that will produce a better understanding of how changing snow conditions will affect the Arctic System. The proposed terrestrial snow work completes the suite of synthesis studies on the Arctic System undertaken in the first phase of the SASS Program by combining with an existing study of snow on sea ice, thereby producing a full system-wide assessment of snow impacts. The proposed synthesis is organized into five tasks designed to provide answers to several pressing snow-related questions: 1) collect pan-Arctic datasets, 2) merge tools and models to simulate Arctic snow-related features, 3) produce spatially distributed time evolving distributions of snow properties and characteristics for the terrestrial pan-Arctic System, 4) from these distributions develop a set of integrated indices and derived products that capture the essential snow-related impacts, and 5) use the impact indices to better understand the Arctic System.

Broader impacts: The proposed synthesis will substantially advance our understanding of the complex role of snow in the Arctic System. The datasets and process-oriented modeling produced by this synthesis will be of particular value in advancing large-scale climate models, terrestrial ecology, and atmospheric chemistry. Through interaction with these communities we will provide datasets that can be directly employed to examine problems in a wide range of interdisciplinary studies. To facilitate the transfer of the findings, the PI's will publish a scholarly article describing how best to deal with snow at the system level, and will host an open tutorial workshop in year-3 of this synthesis project. The meeting objectives will be to present synthesis findings and discuss key synthesis questions. They also expect this work to provide direct guidance for the planning of future field research efforts, such as during the International Polar Year and beyond. Synthesis activities within

the group will be fostered by close collaboration and an annual team meeting. The PI's will also participate in synthesis activities planned between other SASS projects and will integrate graduate and undergraduate students into the research, both through direct involvement and by providing opportunities for students working on other Arctic research projects to become involved in our project. This interaction will allow students to visit and work with the different research groups to gain different perspectives on the overall problem. Education and outreach activities aimed at elementary school students are also planned and they will create scientific puzzles regarding the role of snow in the Arctic System.

Collaborative Research: Understanding Change in the Climate and Hydrology of the Arctic Land Region: Synthesizing the Results of the ARCSS Fresh Water Initiative Projects

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Award #0629323
PI: Charles Vörösmarty, Water Systems Analysis Group, University of New Hampshire
Co-PI: Richard Lammers, Water Systems Analysis Group, University of New Hampshire

Award #0629491
PI: Dennis Lettenmaier, Civil and Environmental Engineering Department, University of Washington

Award #0629412
PI: John Cassano, Cooperative Institute for Research in Environmental Sciences, University of Colorado

The climate of the Arctic is changing. According to the Arctic Climate Impact Assessment (ACIA), "Arctic climate is now warming rapidly, and much larger changes are projected". These changes are of concern because of their possible implications for global ocean circulation.

The ARCSS Freshwater Integration Study (FWI) was designed to address the scientific basis of many of these broader issues that are related to the arctic freshwater cycle, especially over land. In particular, FWI has the objective of addressing "... key, unresolved issues ... [that are] fundamentally cross-disciplinary and synthetic in nature". Three of these issues deal directly with the coupled implications of arctic climate and the water and energy balances of the region. NSF funded a group of 18 FWI projects in 2002, which together with subsequent ARCSS projects were intended to address the FWI questions outlined above. However there is a need for synthesis activities to exploit more fully results of the FWI projects.

This work will utilize research results from the FWI projects that have a substantial land surface activity, and will incorporate the results in a synthesis activity that will document and attribute observed change in the arctic hydrologic cycle, both for the climate of the region, and the global climate system. The primary synthesis mechanism will be a coupled regional land-atmosphere model (either polar WRF or MM5), and (more limited use) of a global model of medium complexity of the ocean-land-atmosphere system.

The overarching science question to be addressed is: How do changes in arctic land processes affect the climate of the region, what are the implications of these changes for the arctic hydrologic cycle (including coupling and feedbacks with the atmosphere), and what are the impacts of changes in the arctic freshwater system on global climate? The research will address two supporting science questions: 1) How can the results from the FWI studies be used to better understand the hydrologic processes affecting observed change in the freshwater balance of the pan arctic land system? and 2) To what extent are the observed changes in Arctic terrestrial hydrologic cycle due to imported change from other regions (via atmospheric processes), and to what extent are the observed terrestrial hydrologic changes exported to the atmosphere and to the global ocean system? The first question

leads to attribution questions regarding which hydrologic processes have contributed to observed change, and will be addressed using a strategy of uncoupled, partially coupled, and fully coupled land-atmosphere modeling at the pan-arctic scale. Addressing the second question will require documenting the effect of hydrologic change on global climate (via changes in the oceans). It will be addressed through use of a coupled GLOBAL land-ocean-atmosphere model of medium complexity (University of Victoria ESCM climate model).

To date our understanding of change in the Arctic region and its broader role in global climate has been limited. This research seeks to provide a comprehensive view of key hydrological processes within the Arctic system and how they interact regionally and with the global system via oceanic and atmospheric pathways. It is expected that this will result in a better understanding of how hydrologic processes have contributed to observed change and the contribution from extra-Arctic processes. Detailed analysis of these interactions and feedbacks will provide valuable information to the climate community for understanding the role of the Arctic in climate variability and change.

Collaborative Research: The Impact of Changes in Arctic Sea Ice on the Marine Planktonic Ecosystem - Synthesis and Modeling of Retrospective and Future Conditions

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Award #0629095
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Significant changes in arctic climate have been detected in recent decades. One of the most striking is the decline of sea ice concurrent with changes in atmospheric circulation and increased surface air temperature. This arctic warming trend is likely to continue into the future, leading to a diminished arctic sea ice cover that will significantly impact the arctic marine ecosystem and ultimately arctic and subarctic human communities. It is therefore critical to understand how changes in sea ice influence the marine ecosystem. To this end, this work will investigate the historical and contemporary changes of arctic sea ice, water column, and aspects of the marine ecosystem as an integrated entity, and project future changes associated with a diminished arctic ice cover under several plausible warming scenarios. The focus will be on the marine planktonic ecosystem.

The scientific objectives are: 1) Synthesize the historical evolution of the arctic biology/ice/ocean system from 1979 to the present to understand the large-scale changes that have occurred in the sea ice, upper ocean, and marine planktonic ecosystem over this period. 2) Identify key linkages and interactions between the sea ice, the upper ocean, and the planktonic ecosystem to understand how changes in sea ice affect biogeochemical processes and food-web dynamics. 3) Project a diminished ice cover with several warming scenarios to explore the functioning of the planktonic ecosystem in an ice-diminished or summer ice-free Arctic Ocean.

This is a two-task research project: retrospective investigations and future projections. The first task aims at synthesis and interpretation of the large-scale changes that have occurred in arctic sea ice, upper ocean, and marine planktonic ecosystems over the past three decades. The second aims at qualitatively and quantitatively examining the impact of a diminished ice cover on the structure and functioning of the marine ecosystem. To achieve these, this group will construct a coupled pan-arctic Biology/Ice/Ocean Modeling and Assimilation System (BIOMAS) for synthesis and modeling of the integrated arctic system of ice cover, ocean, and marine planktonic ecosystem. BIOMAS will synthesize physical and biological observations through model parameterization/calibration and data assimilation. This unique system is a significant advance in integrated biology/ice/ocean modeling and assimilation that will provide the best possible estimates of the impact of changes in ice cover on the arctic marine planktonic ecosystem on decadal and pan-arctic scales, both retrospectively and predictively.

Collaborative Research: Producing an Updated Synthesis of the Arctic's Marine Primary Production Regime and Its Controls

Award #0629348
PI: Patricia Matrai, Bigelow Laboratory for Ocean Sciences

Award #0629253
PI: Louis Codispoti, Center for Environmental Sciences, University of Maryland

Award # 0629370
PI: Richard Zimmerman, Ocean, Earth and Atmospheric Sciences, Old Dominion University

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PI: Michael Steele, Polar Science Center, Applied Physics Laboratory/University of Washington
Co-PI: Bonnie Light, Polar Science Center, Applied Physics Laboratory/University of Washington

Primary production provides the energy that fuels the Arctic Ocean (AO) ecosystem, as in all ecosystems. Understanding marine primary production (PP) and its controls is a critical step towards appreciating the Arctic Ocean as a system and allowing diagnostic modeling of its current status as well as prognostic modeling of future change.

The focus of this proposal is to synthesize existing studies and data relating to AO PP and its changing physical controls such as light, nutrients, and stratification, and to use this synthesis to better understand how PP varies in time and space and as a function of climate change.

Specifically, this work will:

-Synthesize estimates of PP, using complementary methods that emphasize different spatial and temporal scales into a consistent pan-AO data set (ARCSS-PP). These methods are: (a) ^{14}C uptake (measured; instantaneous gross to net algal primary production), (b) nutrient, O_2 and inorganic carbon production/consumption (derived; seasonal and regional scale net community production), (c) remote sensing (derived; seasonal, regional, and real-time pan-AO net community production) and (d) bio-physical algorithms (derived; net primary production as a function of physical, chemical and physiological factors).

-Employ ARCSS-PP to test hypotheses regarding the controls of PP and to prepare a marine PP dataset for AO modelers to calibrate biogeochemical numerical models, both in collaboration with existing or proposed ARCSS-funded projects.

-Define functional regions of the AO that operate similarly with respect to PP with similar temporal and spatial variability.

-Investigate potential future changes in PP using analogues from the historical data record.

Collaborative Research: Syntheses of Sea Ice, Climate, and Human Systems in the Arctic and Subarctic (SYNICE)

Award # 0629500
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Award #0629338
PI: Jeffrey Rogers, Department of Geography, Ohio State University

The SYNICE project seeks to improve the understanding of pan-Arctic and North Atlantic climate and human systems through the integration and syntheses of several sea-ice data sets together with information from the physical and social sciences. The project is analyzing data from the past 1000 years, with major emphasis on the period c. AD 1800 to the present.

Five major locations/sea-ice data sets are being considered: i) The sea-ice record from Iceland; ii) The sea-ice record from the Barents Sea area; iii) The record of historical ice conditions around Newfoundland and on the Grand Banks, and in the Gulf of St. Lawrence and the Scotian Shelf; iv) The Odden region of the central Greenland Sea; v) A climate and sea-ice record based on Moravian missionary accounts from Nain, Labrador.

Two other components will investigate local knowledge of sea-ice and other climate changes, specifically in Iceland and Labrador/Nunatsiavut. Deliverables include: i) Development of a new 150-year central Greenland Sea ice-atmosphere dataset; ii) Analysis and modeling of the relationship between ice extent and production in the Central Greenland Sea and the occurrence of deep convection; iii) An interpretation of how Greenland Sea convection has varied over the past 150 years, together with implications of this for the development of ocean changes and marine climate in the Nordic Seas during this period; iv) A homogeneous and reliable long-term sea-ice record for Iceland; v) A synthesis of the sea-ice records with circulation data in order to gain insights into past, present and future natural climate variability of pan-Arctic systems; and vi) a study of the social impacts of changing Arctic and Subarctic environments.