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A Comprehensive Modeling Approach Towards Understanding and Prediction

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A Comprehensive Modeling Approach Towards Understanding and Prediction of the Alaskan Coastal System Response to Changes in an Ice-diminished Arctic

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LONG-TERM GOALS

Our research combines state-of-the-art regional modeling of sea ice, ocean, atmosphere and ecosystem to provide a system approach to advance the knowledge and predictive capability of the diverse impacts of changing sea ice cover on the bio-physical marine environment of coastal Alaska and over the larger region of the western Arctic Ocean. The focus of this project on seasonally ice-free Alaskan coasts and shelves is in direct support of the 'Coastal Effects of a Diminished-ice Arctic Ocean' and littoral studies of interest to the U.S. Navy.

Given the continued warming and summer sea ice cover decrease in the Arctic during the past decades, this research will have broader and long-term impacts by facilitating studies of the potential increased exploration of natural resources along the seasonally ice-free northern Alaskan coasts and shelves and of the use of northern sea routes from the Pacific Ocean to Europe. Such activities will change the strategic importance of the entire pan-Arctic region. The research will allow a better understanding and planning of current and future operational needs in support of the continued US commercial and tactical interests in the region.

OBJECTIVES

The main science hypothesis to be addressed in this project can be formulated as follows. The recently observed dramatic decrease of summer sea ice cover in the western Arctic Ocean is driven by two main, primarily local factors: (i) the oceanic heat advection of summer Pacific Water via the Alaska

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Coastal Current and (ii) the positive ice-albedo feedback. To understand physical processes and air-sea-ice interactions involved in these two driving factors, detailed studies, including historical and new observations and very high-resolution modeling, of the Alaska coastal environment are required. The following five specific science goals are proposed to address those requirements in support of the main hypothesis of this project:

1. Explore feedback processes among sea ice, ocean and atmosphere leading to recent and possible future summer decreases of sea ice cover in the Western Arctic Ocean;
2. Quantify impacts of oceanic and atmospheric forcing on regional sea ice cover and its variability;
3. Determine effects of changing sea ice, ocean dynamics and atmospheric circulation on the Alaskan coastal ecosystem (due to temporal and spatial variability);
4. Establish numerical requirements for an optimal hindcast and prediction of environmental conditions in the Alaskan coastal system;
5. Provide guidance for optimal design of an integrated observing system of the Alaskan coastal environment.

APPROACH AND WORK PLAN

We argue that the oceanic heat flux into the western Arctic Ocean is one of the main driving forces of environmental Arctic change. It modulates the state of sea ice cover and determines regions of net growth/melt of sea ice and variability in multi-year and first-year ice distribution, together with the heat and buoyancy fluxes from the atmosphere at the surface, the local river runoff, and dynamic wind forcing. The removal of sea ice along the Alaskan coast for prolonged periods of time increases oceanic effects along the coast, including air-sea exchange, biological forcing, and coastal erosion.

This work builds on a wealth of Arctic modeling expertise and progress at the Naval Postgraduate School, University of Colorado, and University of South Florida to develop state-of-the-art, regional ocean, sea ice, atmosphere and ecosystem models satisfying requirements for studying this coastal system (Maslowski et al., 2007a, 2007b; Maslowski et al., 2004; Maslowski and Lipscomb 2003; Maslowski and Walczowski, 2002; Maslowski et al., 2001; Maslowski et al., 2000; Clement et al., 2005; Clement et al., 2007; Cassano et al., 2001; Cassano et al., 2006a, 2006b, Cassano et al., 2007; Walsh et al., 2004; Walsh et al., 2005). This effort will use available historical and new data for validation or initialization.

Ice-Ocean Modeling: The NPS personnel led by Dr. W. Maslowski is responsible for physical and numerical improvements in ocean (POP) and sea ice (CICE) models, including tidal forcing, land-fast ice parameterization, and eddy resolving model configuration. The first step currently underway is to implement and test the proposed model physical improvements using 9-km model. Next step, which is also in progress, is to develop bathymetry, initial and forcing fields for an eddy resolving configuration. Then multiple decadal simulations will follow with varying atmospheric forcing, including ERA40 and regional atmospheric model output from the University of Colorado. Finally we will perform extensive analyses and validation with available data of all model runs towards an integrated synthesis of the entire project.

Atmospheric Modeling: The Polar Climate and Meteorology Group at the University of Colorado (co-PI J. J. Cassano) is responsible for conducting regional atmospheric model simulations to address the science goals listed above. In particular the group at CU will complete a suite of varied horizontal resolution atmospheric model simulations (50, 25, 10, and 5 km) over a model domain centered on the Alaskan north slope using ERA40 initial and lateral boundary conditions and sea ice extent from satellite observations. All simulations will be nested within one or more coarser resolution regional atmospheric model domains that cover a larger portion of the Arctic, such that the change in resolution between any domain forcing data (either from global reanalyses or coarser resolution atmospheric

model domains) and that domain's horizontal resolution is no greater than a factor of 5. In addition to this basic suite of atmospheric model simulations we will perform an ensemble of simulations at 50 km horizontal grid spacing to assess the model sensitivity to the source of lateral forcing data, by using global NCEP/NCAR reanalysis data, and to the choice of atmospheric model by using Polar MM5 and Polar WRF. Sensitivity to lower boundary conditions will be explored by running atmospheric model simulations with 5 km horizontal resolution using 9-km SST/ice and 1-2-km SST/ice in addition to the control 5-km simulation that will be forced with satellite observations of sea ice extent. All model output will be freely shared with our project collaborators at the Naval Postgraduate School.

Ecosystem Modeling: research is led by Dr. John J. Walsh at the University of South Florida. The milestones of this project involve completion of the following four tasks:

1. Modify the existing 9-km bio-model of Walsh et al. (2004, 2005) to allow decadal integrations
2. Develop a biological (N-P-Z) model at eddy-resolving resolution and over the same domain as the ocean-ice model
3. Complete two decadal simulations (configured at increasing spatial resolution) of the biological model forced with high-resolution ice-ocean and atmospheric model output
4. Analyses (inter-comparison of various model runs and validation with historical and new data) of results to address the main science goals

WORK COMPLETED

This project has started late summer of 2007 with the subcontract awards for the first year of the project finalized in fall of 2007. The currently ongoing work includes the implementation and testing of the proposed ocean and sea ice model physical improvements using 9-km model. Next step, which is also in progress, is to develop bathymetry, initial and forcing fields for an eddy resolving ocean model configuration. Some atmospheric model simulations have started. The regional ecosystem model is being modified to run decadal integrations forced with prescribed oceanic and atmospheric forcing. A project-dedicated web site is being developed to distribute results and communicate finding of this work to larger audiences including general public.

RESULTS

No results are yet available to report – see the explanation above.

IMPACT AND APPLICATIONS

National Security

The focus of this project on seasonally ice-free Alaskan coasts and shelves is in direct support of the ONR focus on 'Coastal Effects of a Diminished-ice Arctic Ocean' and littoral studies of interest to the U.S. Navy. Given the continued warming and summer sea ice cover decrease in the Arctic during the past decades, this research will have broader and long-term impacts by facilitating studies of the potential increased activities along the seasonally ice-free northern Alaskan coasts and shelves. Such activities will change the strategic importance of the entire pan-Arctic region. The research will allow a better understanding and planning of current and future operational needs in support of the continued US tactical interests in the region.

Economic Development

Understanding and prediction of environmental conditions under a diminished-ice Arctic Ocean will have broader and long-term impacts by facilitating studies of the potential increased exploration of

natural resources along the seasonally ice-free northern Alaskan coasts and shelves and of the use of northern sea routes from the Pacific Ocean to Europe. The research will allow a better understanding and planning of current and future operational needs in support of the expanding US commercial interests in the region.

Quality of Life

This research, by advancing the knowledge of the past, present and future environmental conditions along the northern Alaskan coasts and shelves, will facilitate an improved planning and protection of natural environment including marine life and rural communities, which depend on it for subsistence.

Science Education and Communication

The project involves undergraduate, graduate, and postdoctoral education in research. The postdoctoral and graduate students will receive practical training in environmental modeling and/or analysis of model output and observational data. All PIs will present results of this research in undergraduate and graduate classes, at scientific meetings and in peer-reviewed literature.

RELATED PROJECTS

This grant is funded by the Office of Naval Research's National Oceanographic Partnership Program (NOPP), and builds on work done under the two following programs funded by NSF:

1. Study of Northern Alaska Coastal System (SNACS): Maslowski and Cassano (co-PIs)
2. Western Arctic Shelf Basin Interaction (SBI): Maslowski and Walsh (co-PIs)

More information about the two projects is available at www.oc.nps.navy.mil/NAME/name.html

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