A New Arctic Ice-Ocean Prediction System

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LONG-TERM GOALS

The long term goal of the project is to produce a new operational Arctic ice-ocean prediction system that improves on the earlier PIPS 1.0 and PIPS 2.0 systems, as measured in terms of forecasting skill.

OBJECTIVES

The objectives are to better represent important sea-ice features such as the ice edge and orientation of leads, to better represent currents which affect ice motion, to improve the initialization of ice forecasts, and to implement the models on microprocessor-based parallel computers for use at Fleet Numerical Meteorology and Oceanography Center (FNMOC).

APPROACH

The approach starts with the coupled ice-ocean model developed by Yuxia Zhang and Wieslaw Maslowski at the Naval Postgraduate School. The ice model employs basic Hibler (1979) viscous-plastic dynamics and two-level thermodynamics; and the ocean model is a multi-level primitive equation model based on the GFDL formulation of Bryan and Cox -- thus, the coupled model has the same dynamics as the earlier PIPS models. The ocean model has more advanced numerics following Dukowicz and Smith (1994); it is called the Los Alamos Parallel Ocean Program (POP).

What is new about the models is their higher resolution already with 18-km grid spacing, as well as their adaptation in advance to the new US supercomputing architectures. The approach proceeds from this advanced status to include the following important new features:
(a) 9-km grid spacing, which will predispose the models to form oriented leads even before an isotropic rheology is included;
(b) anisotropic rheology along the lines suggested by Hibler (1999) as a further step toward realism in forecasting ice deformation;
(c) multi-level thermodynamics using well-tested modular code additions of Bitz and Lipscomb

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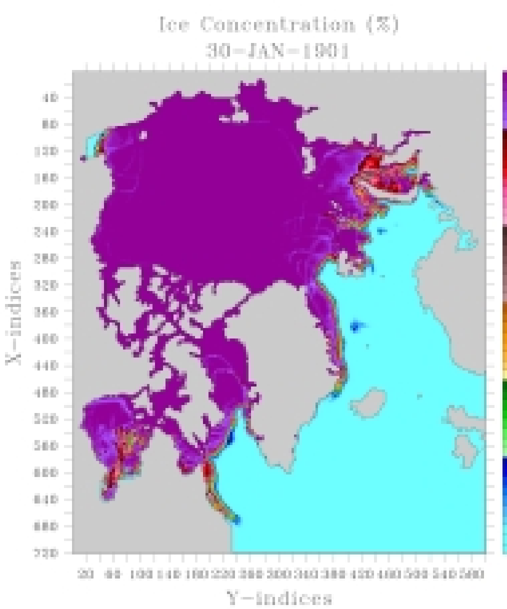
(1999), to better represent ice properties such as the location of the ice edge and areas of significant ridging;
(d) expanded ocean domain, with horizontal grid size near the radius of deformation and better vertical resolution (up to 45 levels);
(e) addition of physics improvements from other PIPS investigators;
(f) inclusion of an optimal interpolation method for assimilating satellite derived ice velocities using a method of Meier et al. (1999);
(g) integration of the 9-km model with ECMWF high-quality atmospheric forcing fields from 1979-98 and evaluation against Arctic ice and ocean observations, particularly during selected periods to improve forecast skill.

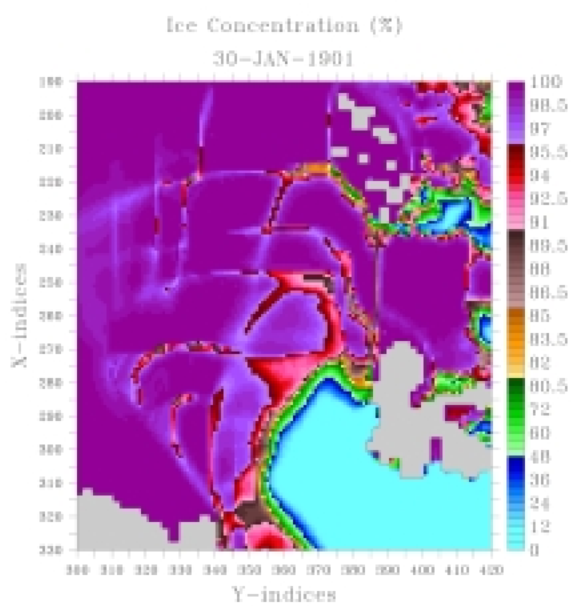
WORK COMPLETED

Of the above-mentioned topics, features (a), (c), and (d) are essentially complete. The coupled 9-km model is running over the expanded domain; and test runs with the multi-level thermodynamics have been made. The anisotropic rheology (b) has been discussed with Hibler as an easily implemented change in the present code. Further physics upgrades (e) will be coordinated with other PIPS PIs. Part (f) has progressed to the point of having algorithms in house to diagnose ice motion from SSM/I satellite data and to assimilate them into the dynamical model. Part (g) has begun with successful test integrations of the fully coupled 9-km model on DoD parallel microprocessor machines nearly identical to those coming to FNMOC. In addition to the NPS project PIs of Zhang, Maslowski, and Semtner, Dr. Don Stark is working full-time on PIPS development and data assimilation at NPS; and LCDR Douglas Marble is a full-time PhD student working on the ocean model. Peter Braccio provides web and data support.

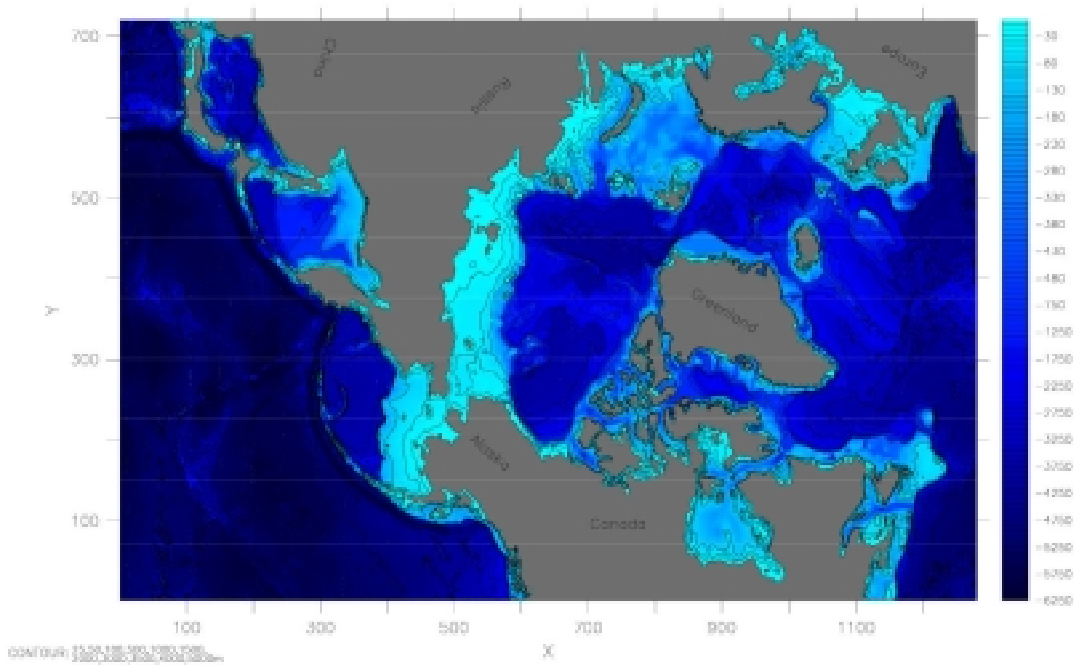
RESULTS

To give a brief view of sea ice as simulated with a 9-km version of the multicategory model, figures 1 and 2 show the ice compactness in percent over a large domain that included the central Arctic Ocean, and the Greenland-Norwegian Seas, as well as a closeup in the area of Fram Strait which show prominent leads similar to the elongated features seen in observations.





To give a brief view of ocean results, figures 3 and 4 show a map of model bathymetry and an instantaneous predicted height field from the 9-km expanded-area coupled model. The representation of both fields is a significant improvement in this model relative to earlier PIPS models that had a rigid-lid formulation. Many realistic features of high-latitude ocean circulation are apparent in figure 4.



1/12-degree PIPS 3.0 Model Bathymetry (m)

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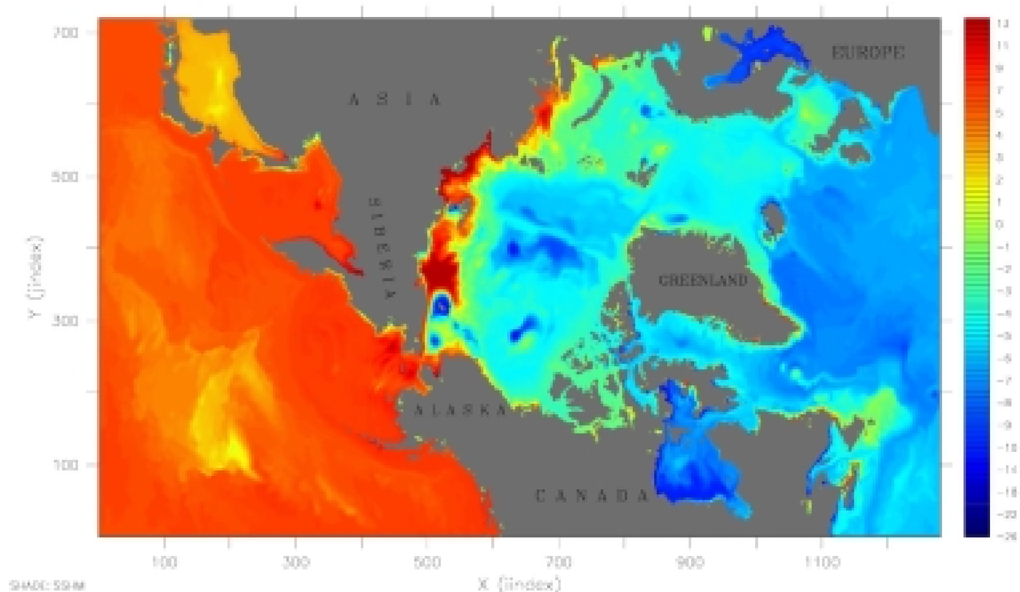

Figure 2. Sea Surface Height (cm) after 6-month spinup – PIPS 3.0

IMPACT/APPLICATIONS

The application of the model will result in significant improvements in knowing the ice conditions for operational military and civilian activities in the Arctic. The use of the model will supplement observations for nowcasting information and provide improved forecasts using the atmospheric forcing fields from the Navy Operational Global Atmospheric Prediction System (NOGAPS).

TRANSITIONS

The model under development will be transtioned in FY2000 to Stennis Space Center, where experienced personnel under Dr. Ruth Preller will bring the model into full operational status with 6.4 funding.

RELATED PROJECTS

PIPS model development efforts are ongoing at the University of Alaska (Dr. William Hibler) and the University of Washington (Dr. Jinlun Zhang). Dr. Walter Meier of the University of Colorado and the National Ice Center continues his research on assimilating satellite-derived ice velocities. Dr. Ruth Preller heads a group at Stennis Space Center to ready the model for operational use. Other ONR investigators are investigating new ice rheologies and better prescriptions of boundary layer processes.

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