

Sea Ice Sensitivities in the 0.72° and 0.08° Arctic Cap Coupled HYCOM/CICE Models

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LONG-TERM GOALS

Perennial Arctic ice extent, which corresponds to the sea ice that remains during the summer minimum, has decreased over the years 1979–2007 by more than 10% per decade (Comiso et al., 2008). The decline has been faster over recent years, leading to very low ice concentration in the summers of 2007 and 2008 (Goosse et al. 2009) with the lowest observed sea ice extent in the satellite record (1979-present) occurring in September 2012 (Perovich et al. 2012). Further reduction in perennial ice extent will likely lead to the inception of new shipping lanes through the Arctic bringing both opportunities for commerce and the need for heightened defense scrutiny. Prediction of future Arctic sea ice conditions, on both short and longer-term time scales are dependent on the capability of the component models in integrated Arctic and global models. The long-term goal of this project, therefore, is to improve the performance of the sea-ice model used in the Navy's coupled ocean and sea-ice prediction system. The models comprising this system are the Hybrid Coordinate Ocean Model (HYCOM) and the Los Alamos National Laboratory (LANL) CICE model.

OBJECTIVES

The objectives of this project are to:

- 1) Optimize the realism of Arctic sea ice in a forced low-resolution (0.72°) global configuration of coupled HYCOM/CICE using sensitivity testing and skill assessment.
- 2) Assess the skill of an existing forced high-resolution (0.08°) global HYCOM/CICE simulation in regard to its depiction of Arctic sea ice. No data assimilation is taking place during this run.

APPROACH

To optimize the depiction of Arctic sea ice in coupled HYCOM/CICE, sensitivity testing of sea-ice is taking place using the computationally inexpensive low-resolution $\sim 3/4^\circ$ global HYCOM/CICE setup known as GLBt0.72. GLBt0.72 was first configured and run by A. Wallcraft (NRLSCC). It was initialized from a Generalized Digital Environmental Model 4 (GDEM4) ocean state and 3-m ice and was run for five years using climatological atmospheric forcing. It was then forced with 3-hourly Navy

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Operational Global Atmospheric Prediction System (NOGAPS) forcing for the years 2003-2012; NOGAPS is run on a 0.5° horizontal resolution grid. Consistent NOGAPS forcing is not available before 2003. We reran this set-up in FY13 and established a baseline skill assessment of the Arctic sea ice cap by comparing it with observations.

We are now exploring sensitivities to atmospheric forcing, the choice of the parameterization of shortwave radiation transfer in ice and snow, and sea surface salinity restoring using GLBt0.72. Skill assessment is carried out using sea ice observations such as ICESat ice thicknesses, ice drift speeds from ice buoy data, and ice concentration and ice edge location from the Special Sensor Microwave/Imager (SSM/I).

A recent high-resolution (0.08°) global HYCOM/CICE simulation (non data-assimilative), also forced with NOGAPS for 2003-2012, was made available to us by A. Wallcraft to make a baseline skill assessment of the Arctic cap at this higher resolution. The results from our sensitivity runs, together with the skill assessment of this high-resolution simulation, can be used to inform future set-ups of HYCOM/CICE.

WORK COMPLETED

A GLBt0.72 simulation, forced with Coordinated Ocean-Ice Experiment 2 (CORE2) interannually varying fluxes (IAF), is close to completion. CORE2 fluxes of momentum, heat, and freshwater and their components are available globally from 1948-2009; the input data is based on 6-hourly National Centers for Environmental Prediction (NCEP) analysis only for the near-surface vector wind, temperature, specific humidity and temperature, and on a variety of satellite based radiation, sea surface temperature, sea-ice concentration, and precipitation products. All fluxes are computed from 1984 onwards, but radiation prior to 1984 and precipitation before 1979 are given only as climatological mean annual cycles (Large and Yeager, 2009). CORE2 is on a T62 (roughly equivalent to $2^\circ \times 2^\circ$ degrees) grid. A. Bozec (FSU) and A. Wallcraft (NRLSSC) supplied this version of the HYCOM/CICE code to us. We worked with A. Bozec (FSU) to convert HYCOM from its native grid onto a standard set of z -levels as part of the model run and we have started to convert the Community Earth System Model (CESM) ocean model diagnostics package to accept HYCOM output. This tool will provide a systematic approach to skill assessment.

We adjusted albedos used in the empirical parameterization (“CCSM3”) that controls the shortwave radiation transfer through snow and ice to enhance the realism of sea ice thickness. The more advanced multiple radiation scattering parameterization known as “Delta-Eddington” (Briegleb and Light, 2007) is now being tested in a subsequent sensitivity run. We are using weak sea surface salinity restoring with an effective timescale of about 4 years to limit model drift. A sensitivity run will be carried out with stronger salinity restoring to explore its impact on the Arctic ice cover.

RESULTS

Our results focus on the realism of the sea ice thickness simulated by HYCOM/CICE. The original NOGAPS-forced GLBt0.72 simulation produced too thick sea ice in the Beaufort and Chukchi Seas (see Fig.1, lower panel). A difference field with ICESat observations showed a thickness bias of up to 2-3 m (not shown) in these locations. The sea ice thickness from the CORE-forced GLBt0.72 in the 1970s (Fig.1, upper panel) does not show this excessive bias, and it is expected that the sea ice

thicknesses in the 2000s from the CORE-forced run will be even lower. Further sensitivity testing with the snow/ice solar radiation transfer parameterization will fine-tune this result. Once we have settled on the optimal set-up based on these sensitivity runs, we will restart from the same initial condition as used in the NOGAPS run, producing a comparative simulation for the 2000s.

We also show ice thickness for the 2000s from 0.08° global HYCOM/CICE together with that from ICESat observations. This simulation was also forced with NOGAPS, but does not show the same excessive ice thickness as in GLBt0.72 in the Beaufort and Chukchi Seas. In February and March 2004-2008, the difference field between the model and the observations shows that ice thicknesses are reasonably realistic in the Chukchi and Beaufort Seas, but are too thin to the north of the Canadian Archipelago. In October-November 2003-2007, the ice thickness is too low throughout the Arctic. Exploration of the causes of these low biases is underway.

IMPACT/APPLICATIONS

Improved realism of sea-ice in the Navy's operational coupled ocean/sea-ice prediction system should reduce uncertainty in predictions and provide increased confidence in projections for decision making.

RELATED PROJECTS

“Optimized Infrastructure for the Earth System Prediction Capability”; Celicia DeLuca (PI). A goal of this project is to incorporate HYCOM into CESM. As a first step, A. Wallcraft (NRLSSC), A. Bozec (FSU), and E. Chassignet (FSU) have modified HYCOM so that it can be forced stand-alone with CORE2 fluxes, the data atmosphere used in CESM. We are using their code in our project.

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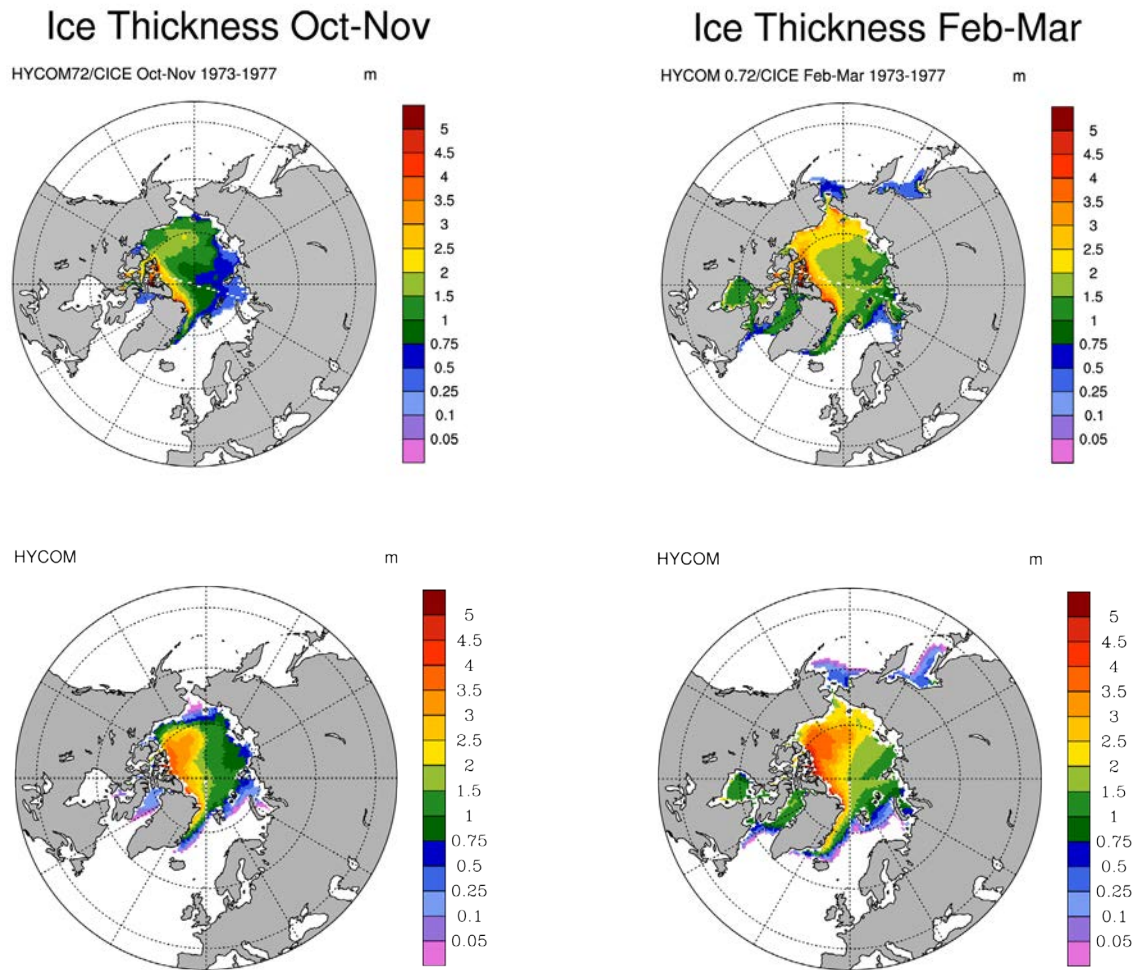


Fig. 1. Sea ice thickness (m) from GLBt0.72 forced with CORE2 fluxes (upper) and NOGAPS (lower) for October-November (left) and February-March (right). The NOGAPS output is from the 2000s while the CORE-forced fields are taken from the 1970s. The CORE-forced run had not yet reached the 2000s at the time of writing this report.

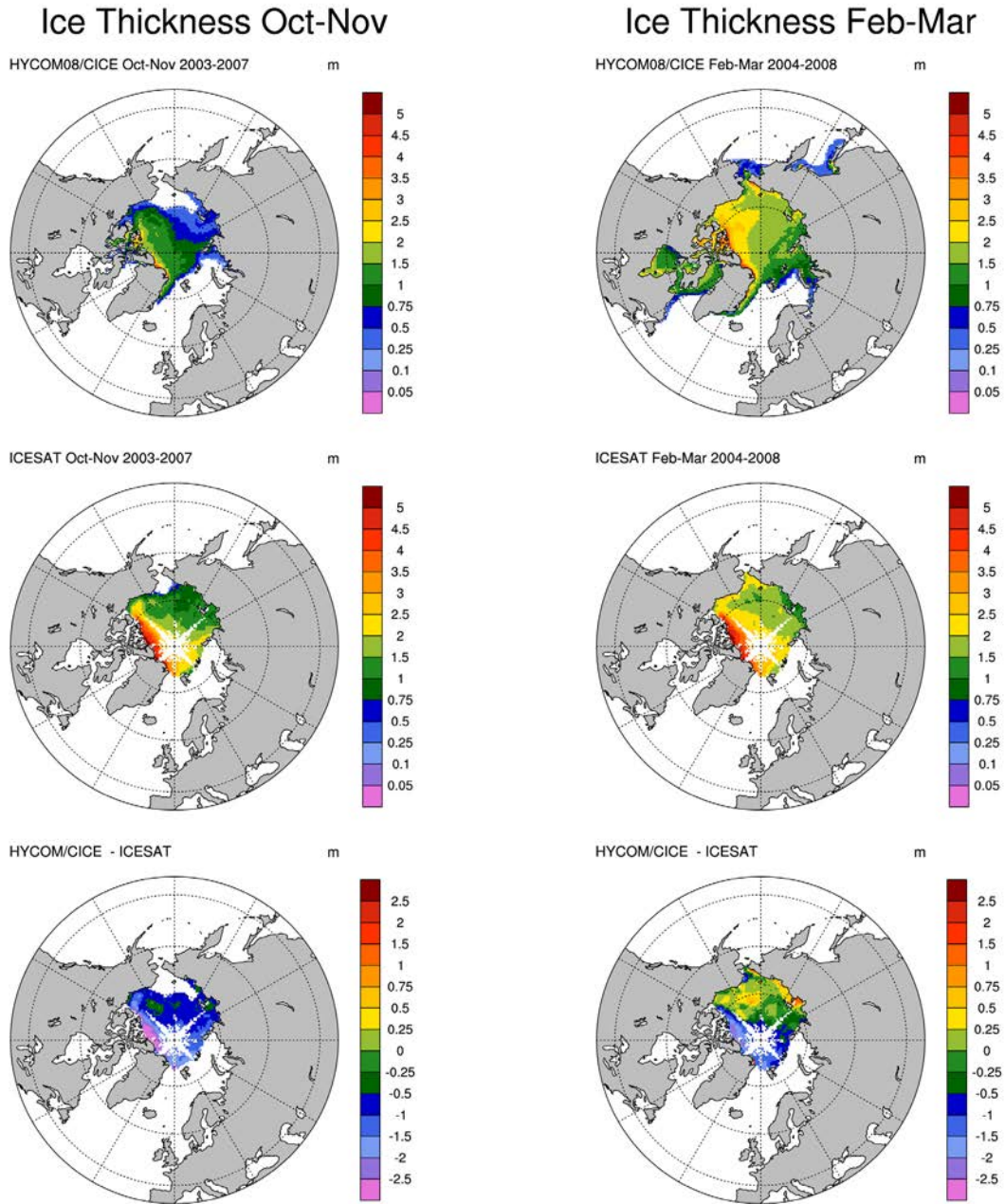


Fig. 2: Sea ice thickness (m) from 0.08° HYCOM/CICE (upper), ICESat (middle), and their differences for October and November of 2003-2007 (left) and February-March of 2004-2008 (right). ICESAT data: <http://rkwok.jpl.nasa.gov/icesat/download.html>