

Modeling the Floe-Size Distribution to Improve the Prediction of Sea Ice in the Marginal Seas

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LONG-TERM GOALS

The long-term goal of this project is to improve prediction of sea ice in the marginal seas by simulating the evolution of the floe-size distribution in basin-scale, rheology-type sea ice models. Lateral ablation and sea ice mechanics depend on the size of floes and yet their distribution in present-day models is assumed to be homogeneous in space and constant in time.

OBJECTIVES

The primary objective of this project is to develop a method for predicting the floe-size distribution for a basin-scale models using the PIPS 3.0 model as the basis. An improved representation of lateral (sidewall) ablation in the PIPS 3.0 model is an automatic outcome of predicting the floe-size distribution.

APPROACH

The approach I am taking is to:

1. Incorporate the equation for predicting the floe-size distribution into the PIPS 3.0 model framework. Initial integrations would use a stochastic process for floe breaking.
2. Evaluate the success of simulating the floe-size distribution with observations and high-resolution model results.
3. Develop a more physically based method for simulating floe breaking and welding.
4. Demonstrate the skill of the new model in simulating the ice edge and predicting floe-size distribution.

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5. Collaborate with W. Maslowski to upgrade the PIPS 3.0 model with the new physics.

WORK COMPLETED

I have incorporated the equation for predicting the floe-size distribution into the PIPS 3.0 model framework using a formulation analogous to that used for predicting the ice thickness distribution in the PIPS model. I have investigated the behavior of the parameterization and the sensitivity of the floe-size distribution to the range of variables. In particular I have tested the influence of various functional forms for floe breaking based on the work of Dempsey (1996). With regard to the numbered items listed in the Approach section, I have completed part 1 and I have made significant progress on part 3. I have begun to evaluate the success of the model as described in parts 2 and 4. Further work is needed to complete these portions of the project, and I will devote much of my time in the second year of this project to validating the method. In the latter half of next year, I will work with the PIPS 3.0 model developers (W. Maslowski and D. Stark) to incorporate the new algorithms into the PIPS 3.0 model.

RESULTS

The floe size distribution varies in time owing to lateral ablation and floe breaking. In agreement with observations, when these processes are included in the model, the cumulative number distribution exhibits roughly a power-law dependence for summertime conditions in the marginal seas. Figure 1 shows three simulations of the model for idealized conditions with the floe-size distribution evolving subject to lateral ablation only, floe breaking only, and both processes together. Lateral ablation is simulated based on the work of Maykut and Perovich (1987) and Steele (1992), as in the PIPS 3.0 model; although here the floe perimeter is predicted – not prescribed. Solar absorption in the leads and under the ice warms the ocean surface. When the model simulates the floe size distribution subject to lateral ablation only, floes decrease in diameter and some melt away altogether. Floe numbers are depleted over the whole range of the distribution, as all floes lose area and the smallest floes melt. Figure 1a shows that after 60 days, the smaller floes have suffered a greater loss in numbers.

Figure 1b shows a simulation where lateral ablation is neglected and instead floes evolve due to breaking only. I assume that floes under 10 m in diameter do not break. Above 10 m, the probability for a floe to break increases linearly up to 30 m and then remains constant, based on the work of Schmidt et al. (1995) who showed a jump in the bending rigidity above 30 m. With these assumptions and an initial distribution ranging from 30–800m, floe breaking in isolation increases floe numbers for floes smaller than a few hundred meters in diameter at the expense of the larger floes. The total number of floes increases.

Finally, Figure 1c shows both processes together. In this case, my assumptions meant to be appropriate for the marginal seas have lead to the dominance of lateral melt. Increasing the number of large floes initially or increasing the floe breaking rate can cause breaking to dominate.

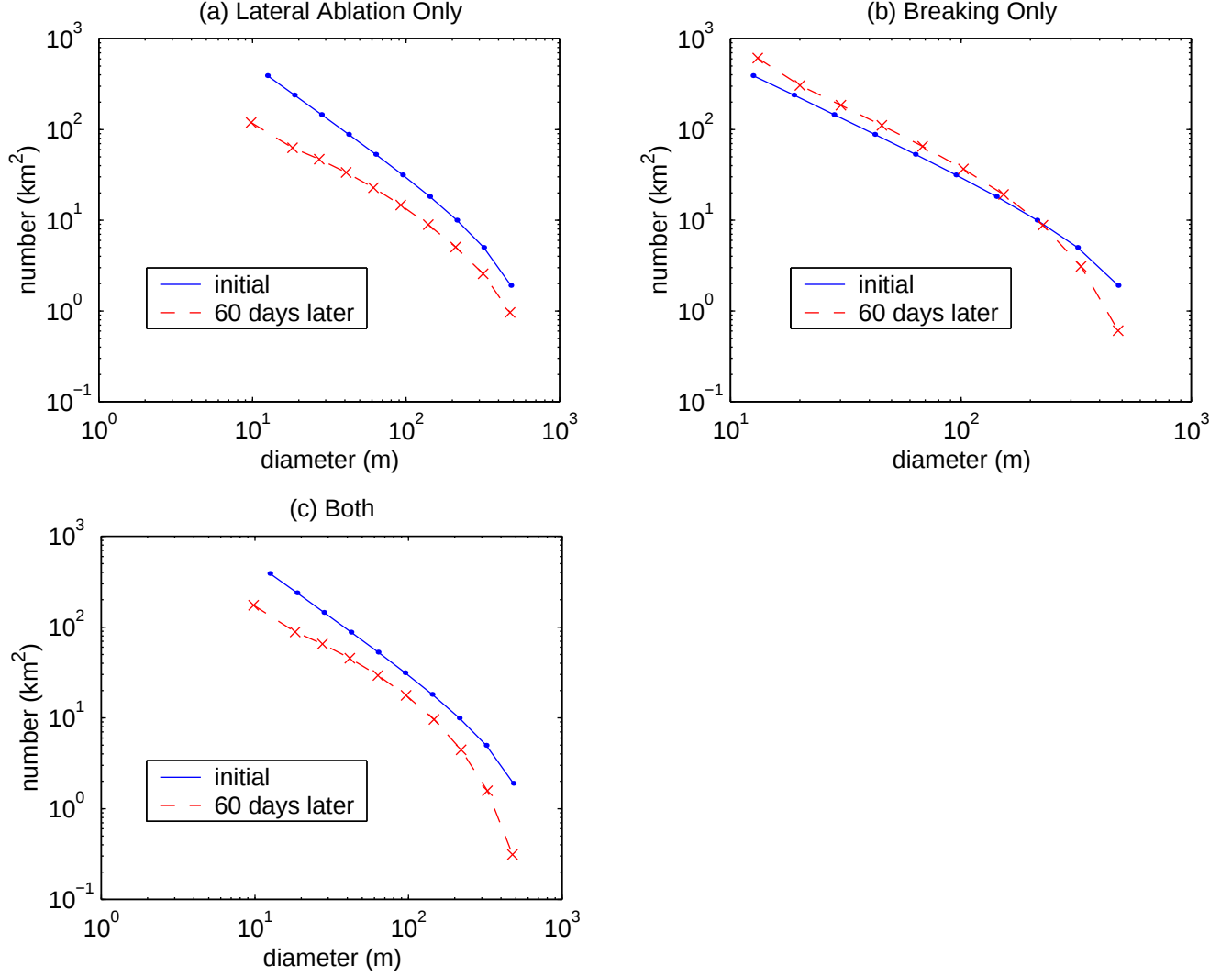


Figure 1. The Simulated Cumulative Number Distribution

IMPACTS/APPLICATIONS

Modeling the floe-size distribution has the potential to improve the prediction of sea ice, particularly in the marginal ice zone. Presently only discrete-element models (e.g., Hopkins, 1996) explicitly keep track of floes. Because this approach actually resolves the floe-scale, it is computationally expensive and can only be used for short simulations. In contrast my method for modeling the floe-size distribution is designed as a sub-gridscale parameterization for a continuum mechanics type of sea ice model (i.e., the type of model widely used for operational forecasting and climate modeling, including the viscous-plastic rheology of Hibler, 1979), which necessarily use scales above ~ 10 km. My approach increases the computational expense of a sea ice model like that used for PIPS 3.0 by less than 30%.

TRANSITIONS: None as yet.

RELATED PROJECTS

I have also helped develop an open-source sea ice model called the Community Sea Ice Model (CSIM) as part of the Community Climate System Model, lead by the National Center for Atmospheric Research. CSIM uses many of the same algorithms and code structure that are used in the PIPS 3.0 model. To date the community of CSIM users have developed further model improvements that can easily dovetail into the PIPS 3.0 model. For example, CSIM already makes use of a second-order accurate method for advecting the sea ice thickness distribution in thickness space following the work of Lipscomb (2001). This method reduces the inaccuracy from taking long time steps that J. Lewis (personal communication) described at the June 2001 PIPS meeting. CSIM is downloadable and well documented at <http://www.ccsm.ucar.edu/models/ccsm2.0/>.

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