ICEPACK: ESSENTIAL PHYSICS FOR SEA ICE MODELS

Icepack, a new modular software package, represents crucial sea ice processes including thermodynamics, ridging, biogeochemistry, and associated area and thickness changes. The software can be ported easily to a wide variety of models for sea ice prediction and earth system simulation.

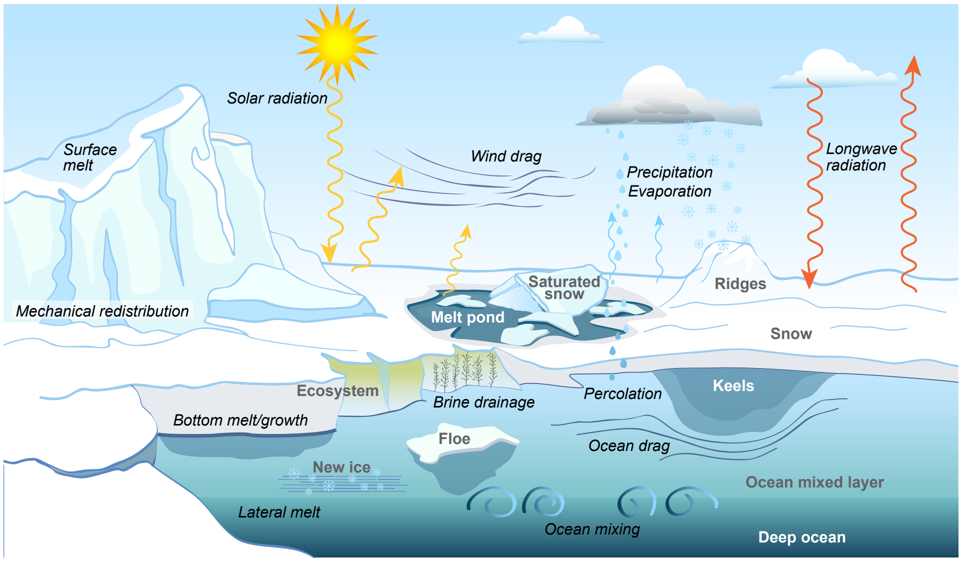

Figure 1. Icepack incorporates column-based physical processes that affect the area and thickness of sea ice.

COMPREHENSIVE REPRESENTATION OF VERTICAL PROCESSES

Sea ice consists of a mixture of ice crystals, liquid brine, air, and other constituents of the ocean water from which the ice forms. A highly complex combination of thermal, radiative, kinematic and mechanical processes determines the composition, structure, and volume of sea ice. Heat tends to flow upward, from the warm ocean toward the colder atmosphere, impelling most thermodynamic sea-ice processes to operate in the vertical direction.

For instance, pockets of salt water migrate vertically through the ice, carving out conduits for draining brine and meltwater from the upper layers of the ice as it freezes and melts. These brine channels also deliver nutrients from the ocean to the ecosystem within the sea ice. Recent model upgrades feature full vertical biogeochemistry with algae, nutrients, and particulates represented, as well as related effects due to increased solar heating in biologically colored ice.

In addition to thermodynamic processes within the ice, evolution of the snowpack and liquid water on top of the ice also influence ice volume, and boundary layers above and below the ice regulate turbulent heat and momentum fluxes. Convergent motion causes sea ice to mechanically deform, creating ridges and keels which contribute to drag.

Modern implementations of sea ice models often use fundamentally different horizontal grids, requiring flexible approaches for referencing information in neighboring grid cells. However, much of the physics in sea ice models can be described in a single vertical column and is referred to as the column physics (figure 1). The column physics code is executed for each grid cell or other discrete element, such as an ice floe.

The column physics code within the Los Alamos Sea Ice Model, CICE, has been separated into a modular software package known as Icepack, which is easily shared among sea ice models having different horizontal structures, enabling faster model development and validation.

Get Icepack

Icepack Version 1 (doi 10.5281/zenodo.1213462):
https://zenodo.org/communities/cice-consortium

U.S. DEPARTMENT OF ENERGY | Office of Science

A FLEXIBLE, COMMUNITY RESOURCE FOR APPLICATIONS

Because of its highly reflective surfaces, sea ice contributes critically to Earth's energy budget, and its motion alters the distribution of salt within the oceans via melting and freezing. Understanding and predicting the evolution of sea ice–a mutable, moving, semi-solid material composed of ice, water, salt, gases, and other chemical constituents–poses a formidable challenge for both research scientists and prediction centers.

Sea ice change affects multiple U.S. national security interests in the Arctic, including military and defense operations, strategic resources, trade routes and infrastructure, along with subsistence hunters and wildlife. For these reasons, both civilian and military operations demand accurate simulations of sea ice thickness, concentration, and velocity on daily to centennial timescales.

The sea ice physics in Icepack has been developed with the support of the U.S. Department of Energy (DOE) since the early 1990s as part of CICE, which is used by numerous modeling centers around the world for a wide range of such applications. Icepack is now developed and maintained by the CICE community, including DOE, through the CICE Consortium. Icepack's many comprehensive physical process representations are used in different combinations by modeling centers, providing flexibility for applications.

Icepack consists of three independent parts: the column physics code, a driver that supports stand-alone testing of this code, and scripts that build and test the Icepack model. Thus, scientists can adjust Icepack to meet their needs: it can be used for developing and testing sea ice parameterizations, and its column physics can be implemented within diverse numerical models for both research and operational applications.

Because it is independent of the mesh and dynamics that are specific to a given modeling center, Icepack further enables community collaboration for sea ice physics model development.

SEA ICE MODELING AT DOE

In addition to CICE, the Department of Energy currently supports two other sea ice models that utilize Icepack:

1) An unstructured-grid model based on the Model for Prediction Across Scales (MPAS) framework, which is incorporated in DOE's E3SM, the **Exascale Earth System Model** (figure 2) and
2) A model still under development, the Discrete Element Model for Sea Ice (DEMSI).

Instead of representing the pack ice as a continuum that is approximated numerically on a mesh, DEMSI utilizes a Lagrangian (flow-following) approach for modeling collections of discrete sea ice floes interspersed by leads (areas of open water).

This approach promises to represent sea ice behavior more realistically at high spatial resolution. DEMSI also will exploit new computer architectures for which discrete calculations provide optimal throughput, thus advancing sea ice modeling into a future exascale computing era.

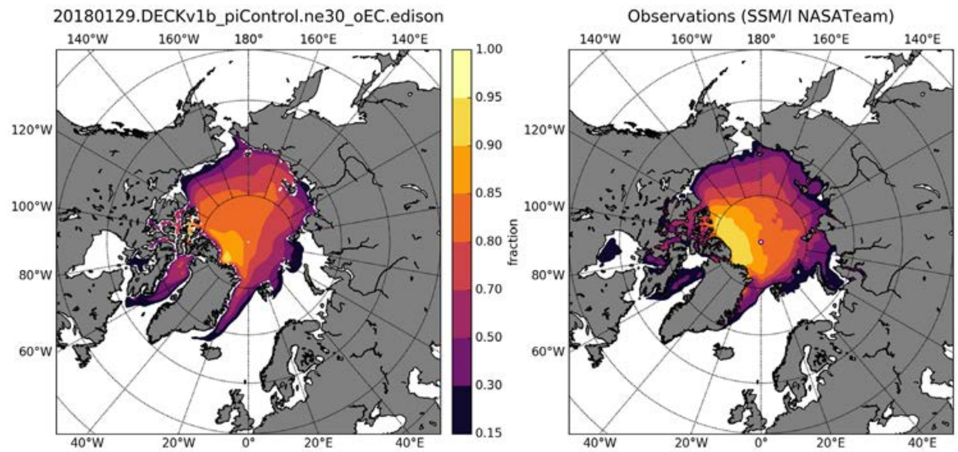

Figure 2. Arctic summer climatologies (1988 to 2007) of fractional sea ice concentration simulated by an adaptation of CICE/Icepack in the E3SM (left panel), compared with observational estimates derived from measurements by the Special Sensor Microwave Imager (SSM/I) satellite instrument (right panel).

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