THE CICE CONSORTIUM MODEL FOR SEA-ICE DEVELOPMENT

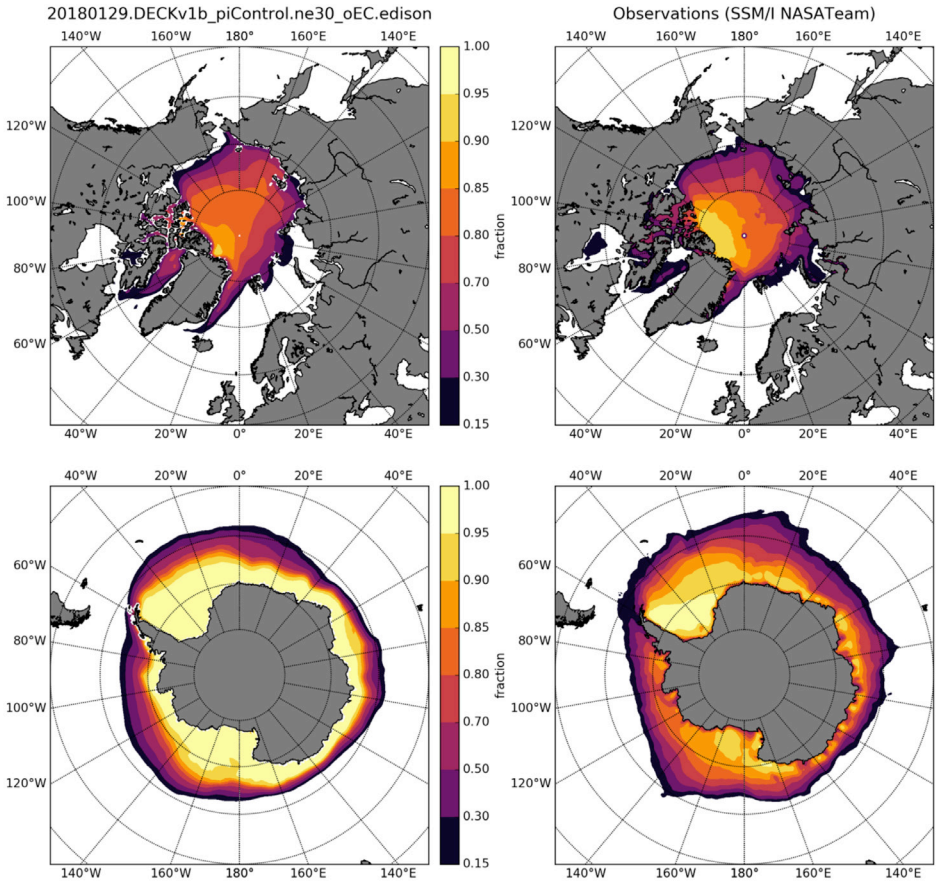
In 2016, a group of primary developers and users of a preeminent sea ice model known as CICE founded a consortium, whose mission is to foster collaboration on sea ice model developments for earth system research as well as operational applications.

LONGSTANDING MODELING EFFORTS

CICE is a computationally efficient model for simulating the growth, melting, and movement of polar sea ice.[1] Designed as one component of coupled atmosphere-ocean-land-ice global climate models (GCMs), today's CICE model is the outcome of more than two decades of effort led by scientists at Los Alamos National Laboratory. The model's development and maintenance have been led and coordinated by the Department of Energy (DOE) since the early 1990s[2].

A CICE submodule, known as Icepack, also recently has been developed. Icepack contains the single-column physics and biogeochemical aspects of CICE, such as ice ridging, thermodynamics, and hydrology. With these features now independent of mesh and dynamics, it is easier for a greater number of modeling groups to use and contribute. Icepack also includes a stand-alone driver and automated testing protocols.

CICE/Icepack has demonstrated an ability to accurately simulate the characteristics of sea ice. For example, the figure on this page displays a simulation of Arctic/Antarctic sea ice by DOE's E3SM earth system model, which uses Icepack, compared with observational estimates.



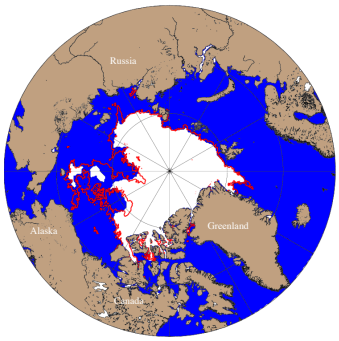
Arctic summer and Antarctic winter climatologies of sea ice concentrations simulated by an adaptation of CICE/Icepack in the E3SM (left panels), compared with observational estimates derived from measurements by the Special Sensor Microwave Imager (SSM/I) satellite instrument (right panels).

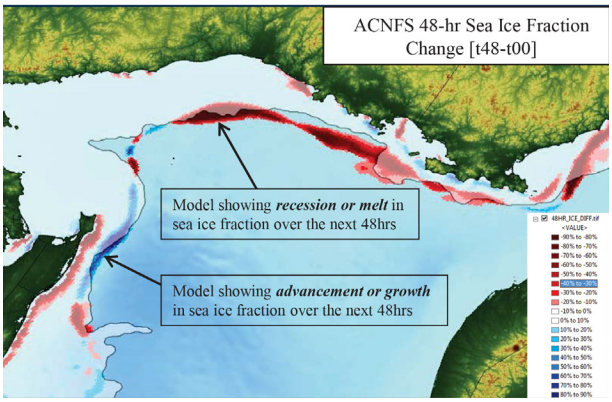
A COMMUNITY RESOURCE

CICE holds a prominent position in the international GCM community, having been adopted by research and operational organizations in more than twenty countries. These include numerous climate modeling groups such as E3SM, CESM, and GFDL in the United States, as well as forecast centers operated by the National Weather Service, United Kingdom Meteorological Office, the Danish Meteorological Service, and the U.S. Navy. The Navy disseminates daily sea ice forecast products to the National Oceanic and Atmospheric Administration (NOAA) and to the multi-agency National Ice Center (NIC), while also using the model for special missions.

Get CICE and Icepack

CICE Version 6 (Copyright LACC-06-012) and Icepack Version 1 codes can be accessed at **https://zenodo.org/communities/cice-consortium**





Left: This figure from September 10, 2016, shows U.S. Navy's Arctic Cap Nowcast/Forecast System (ACNFS) forecast of nearly record-low sea ice extents. The year's minimum sea ice extent is shown in white, and the red line represents the ACNFS's forecasted 15 percent ice area contour. Right: Change in fractional coverage is a National Ice Center (NIC) product that is useful for ship captains. *Figures courtesy of the Naval Research Laboratory Stennis Space Center and the National Ice Center.*

FOUNDING A CONSORTIUM

In 2016, the international CICE Consortium[3] was founded to promote further scientific research and development (R&D) of sea ice modeling, and to accelerate the transfer of these innovations to operational arenas. The Consortium formalizes an existing collaborative alliance that produced CICE. It functions as a coordinator of sea ice modeling R&D efforts for a large group of participating universities, government agencies, and affiliated institutions.

The Consortium does not perform R&D tasks itself, however. Instead, it maintains the CICE model for current users, while providing a mechanism for testing R&D innovations and sharing these within the broad sea-ice modeling community. A key goal is to facilitate incorporation of these improvements into operational models, such as those used by civilian and military weather prediction centers.

A noteworthy operational application of CICE is the U.S. Navy's Arctic Cap Nowcast/Forecast System (ACNFS) sea ice prediction. The ACNFS couples the CICE model to an ocean data-assimilation system, where atmospheric forcing is provided by the atmospheric model.

TESTING MODEL INNOVATIONS

The Consortium continues to incorporate new developments from the sea ice modeling community. To provide a sound basis for member agencies to decide whether to include R&D innovations in their GCMs, the Consortium coordinates confidence and acceptance testing of the associated code. For example, a Consortium team has devised a statistical approach for testing whether new code that does not produce identical simulation results will significantly change the modeled climate.

This novel method uses a two-stage, paired statistical t-test to identify false positives, and a quadratic skill-compliance test to verify the high correlation and similar variance of the alternative solutions.[4] Such a testing procedure is currently implemented for simulations by the Naval Postgraduate School's Regional Arctic System Model, which includes CICE.

SETTING AN EXAMPLE

The multi-agency, international CICE Consortium incorporates both a governance mechanism and intellectual property protection within an open software development environment. It thus provides a positive example for other R&D/operational alliances that are now developing within the U.S. climate and weather prediction communities.

SUPPORT

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[1] *CICE User's Guide* **http://readthedocs.org/projects/cice-consortium-cice/**

[2] *The CICE Consortium*: About Us **https://github.com/CICE-Consortium/About-Us**

[3] *CICE History* **https://github.com/CICE-Consortium/About-Us/wiki/History**

[4] A. Roberts, E. Hunke, R. Allard, D. Bailey, A. Craig, J.-F. Lemieux, M. Turner. Quality Control for Community Based Sea Ice Model Development. *Phil. Trans. Royal Soc. A*, submitted 2018)