Snow on sea ice in the ACME earth system model

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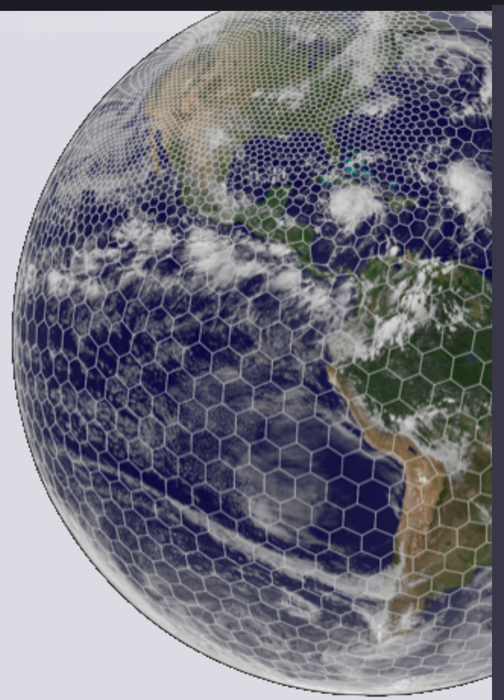
Introducing MPAS
A new framework for earth system models



The Model for Prediction Across Scales (MPAS) is the ocean and ice component of the DOE´s premier climate model, the Accelerated Climate Model for Energy.

The MPAS framework features:
- full coupling of land, sea, and atmospheric models
- an unstructured variable-resolution Voronoi mesh for increased resolution in sensitive regions
- incremental remapping and C-grid discretization to handle advection with minimal loss of accuracy [1]

Modeling sea ice in MPAS

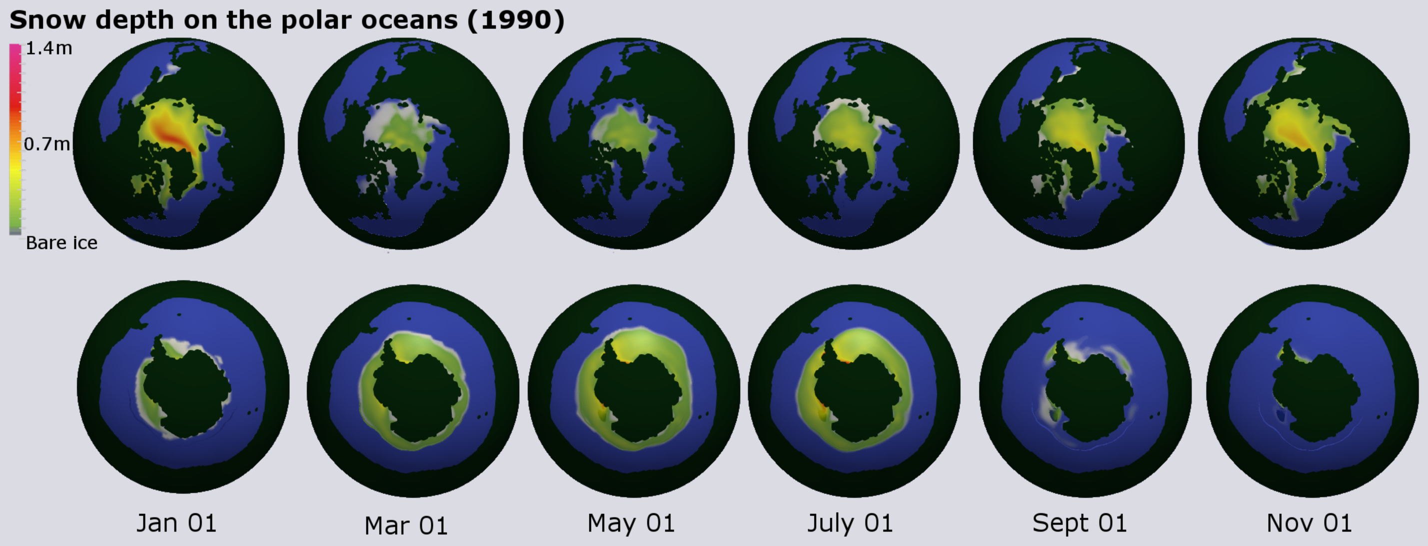
MPAS-seaice extends a leading sea-ice model, the Los Alamos Sea Ice Model (CICE), into the MPAS framework.

CICE is used for shipping forecasts in both the Arctic and Southern Oceans [2]. It has also been used to estimate the extent and nature of sea ice during periods when observation is not feasible (for example, during the polar winters, when the poles are dark and the sea ice is impenetrable to all but the most modern icebreakers).

The MPAS framework provides high resolution in sensitive areas, such as coastlines. Unlike most previous models, which use latitude-longitude grids, it is seamless across both poles.

Example output from MPAS-seaice, for both the Arctic (upper row) and Antarctic (lower row), is shown below.

Snow depth on the polar oceans (1990)



Continents and temperate oceans are masked in black. Sea ice extent is shown in white, and the depth of snow is indicated in yellow and red.

The right-hand side of this poster shows ongoing work to improve the accuracy of MPAS-seaice by addressing its largest source of uncertainty: the snow.

References

[1] W. Lipscomb, E. Hunke (2004). ´Modeling Sea Ice Transport Using Incremental Remapping´, Monthly Weather Review 132(6) p1341-1354.
[2] E. Hunke et al (2015). ´CICE: the Los Alamos Sea Ice Model Documentation and Software Users Manual´. Los Alamos National Laboratory, NM.
[3] J. Urrego-Blanco et al (2016). ´Uncertainty quantification and global sensitivity analysis of the Los Alamos sea ice model´. J. Geo. Res.: Oceans 121 (4) p2709-273.

Computing resources are provided courtesy of the ACME program's COSIM allocation on LANL's TriLab Linux Capacity Cluster (TLCC), wolf. Title photo by Robert Simmon, based on Landsat-7 data and provided by NASA Earth Observatory.

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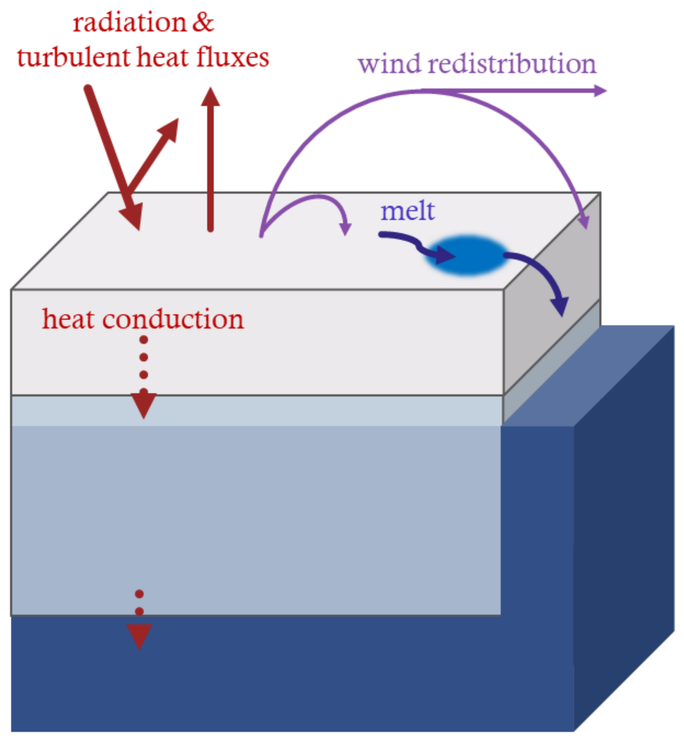
Designing a snow model for MPAS-seaice



1. Uncertain thermodynamics

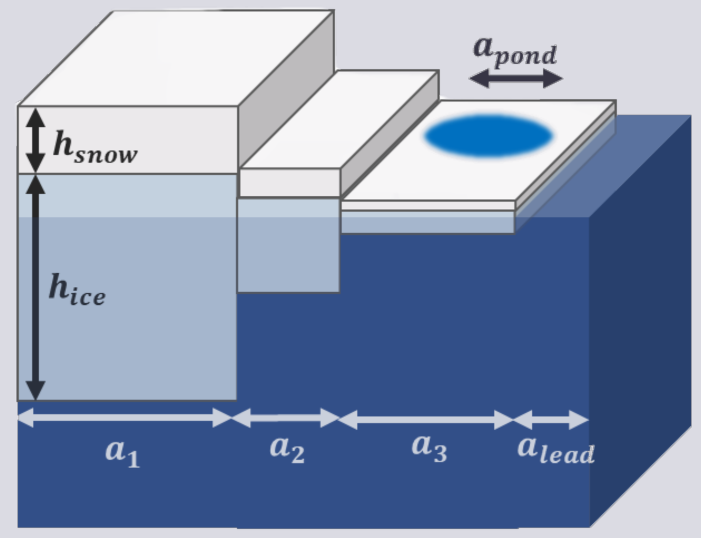
MPAS-seaice maps climate inputs (solar radiation, air temperature, wind speed, and ocean currents) to sea-ice outputs (ice movement and growth rates, wind drag, and outgoing radiation).

The largest source of uncertainty in MPAS-seaice is the thermal conductivity of the snow [3].

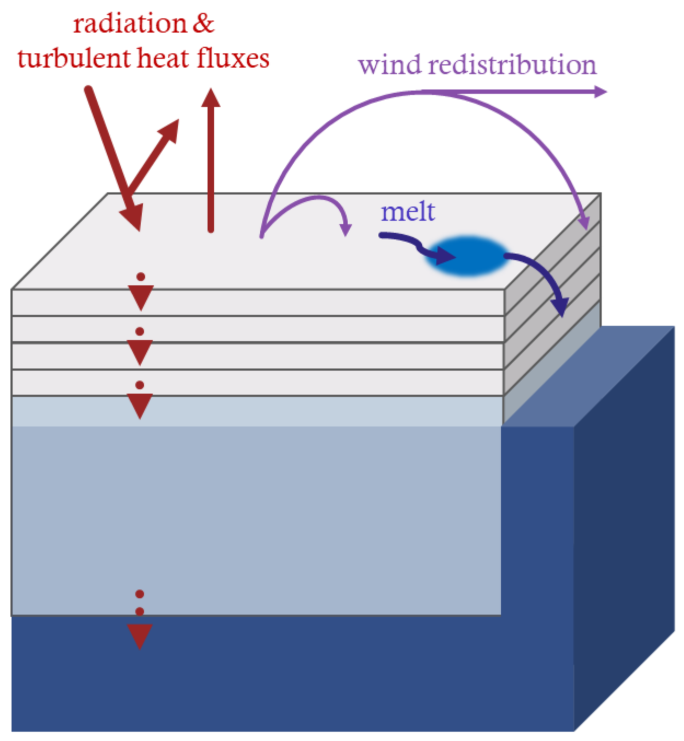
The modeled snow thermodynamics currently contain several major simplifying assumptions. These include a linear temperature gradient; a constant thermal conductivity (0.300 W/m/K); a constant snow density (0.300 kg/m^3, and a flat snow cover.

The following sections of this poster describe ongoing. work to improve the accuracy of MPAS-seaice by relaxing these simplifying assumptions.

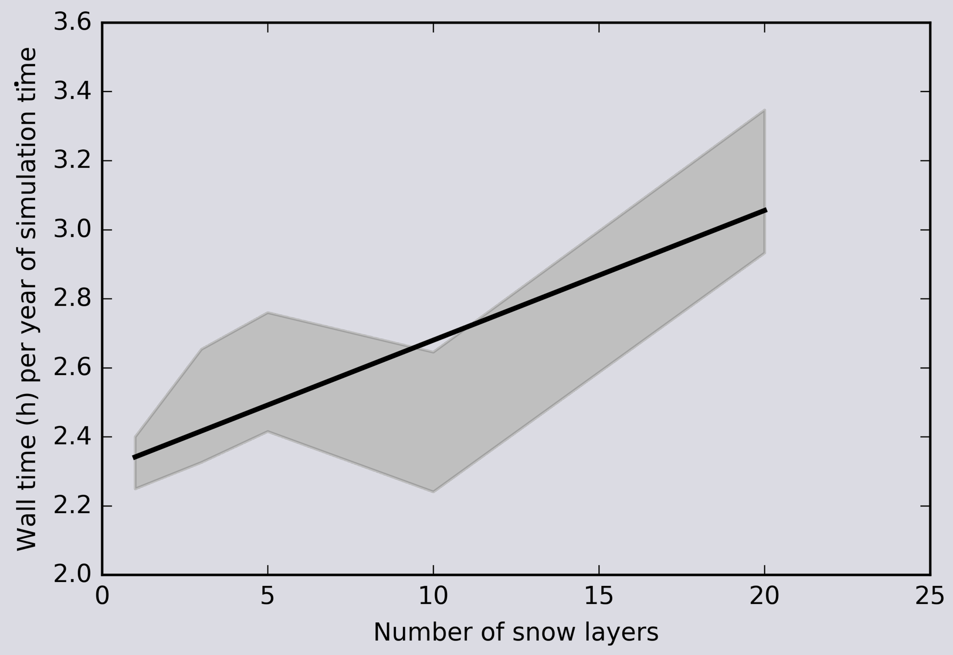
MPAS-seaice models several ice thickness categories within each grid cell. These allow the model to represent a variety of ice types, such as ridged ice, multiyear ice, pancake ice, and slushy frazil. Each category holds a single snow layer.



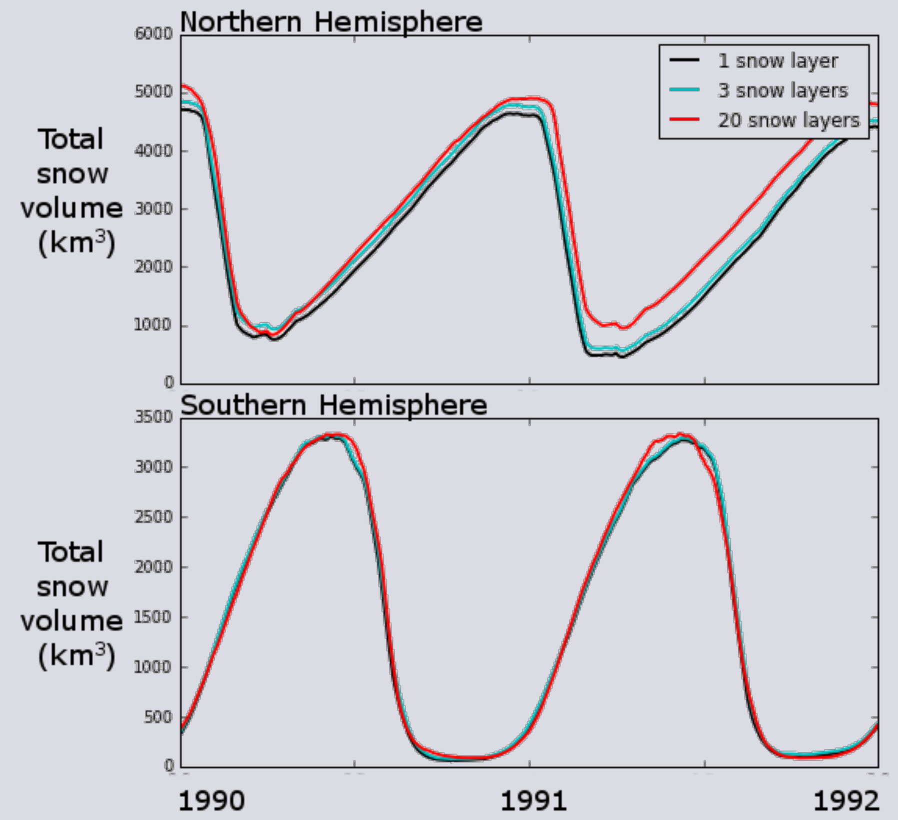
2. Improved vertical temperature resolution



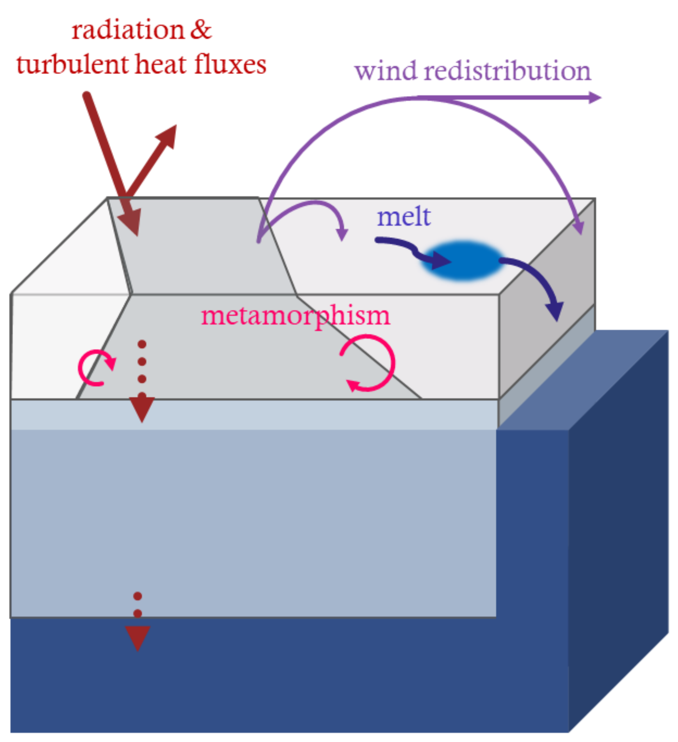
Improving the vertical resolution of the temperature within the snowpack created a small change in outcome, and a significant increase in computational expense. The effects are strongest in the northern hemistphere.



Snow cover and vertical temperature resolution



3. Variable thermal conductivity



The heat flux through snow varies significantly with the metamorphic state of the snow (left) and its spatial distribution (right). On sea ice, snow usually tends towards a mix of large, poorly conductive depth hoar crystals and fine, compacted wind slab, arranged in dunes.

In updates to MPAS-seaice, we intend to track the snow according to its metamorphic content rather than its vertical structure. This will allow us to separate the thermal conductivity of snow into (1) a hand-sample conductivity, which will vary from 0.070W/m/K for depth hoar to 0.500W/m/K for wind slab, and (2) a lateral and convective heat flux, which will increase the total heat flux through the snow by a factor of 1.5.