Testing a Sea Ice Model

Specifically a new melt pond scheme in SI^3

David Livings Danny Feltham David Schroeder

University of Reading

EGU General Assembly
30 April 2021
Revision 1.2

SI^3

SI^3 (Sea Ice modelling Integrated Initiative) is the sea ice engine of the NEMO ocean model (`https://www.nemo-ocean.eu`). It incorporates elements of three sea ice models that have been used with NEMO in the past: CICE, GELATO, and LIM. It takes account of sea ice dynamics, thermodynamics, brine inclusions, and subgrid-scale thickness variations.

Melt Ponds

A process that has historically been poorly represented in sea ice models is the formation and evolution of melt ponds. These ponds accumulate on the surface of sea ice during the melt season and affect the heat and mass balance in various ways, the most important of which is a reduction in albedo.

A new melt pond scheme has recently been added to SI^3, based on the ideas of Flocco et al (JGR, 2010). This scheme attempts to represent the influence of ice topography on lateral meltwater transport.

This document reports the results of testing this new scheme.

Initial Results

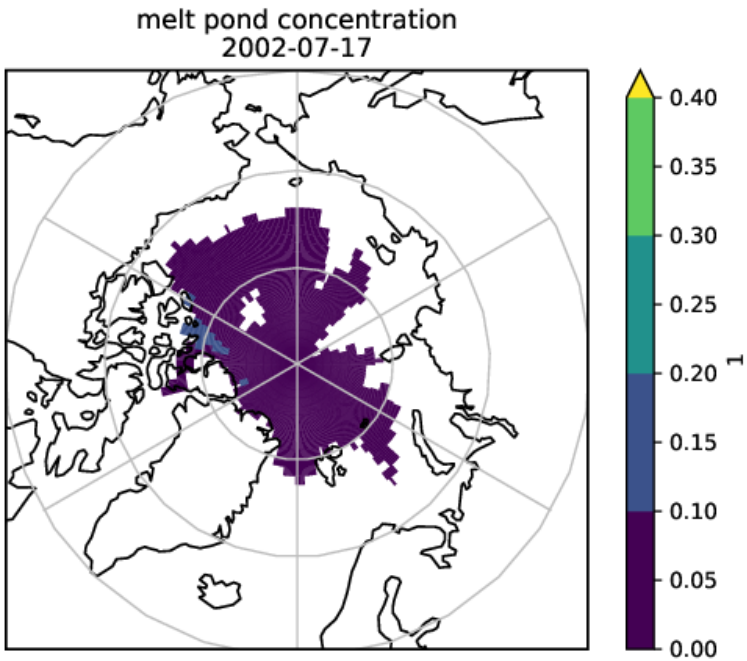
Melt pond concentration and surface v bottom melt

As expected, the new topographic melt pond scheme shows a higher melt pond concentration (as fraction of grid cell area) than the old level melt pond scheme, but the initial results showed a lower concentration than expected.

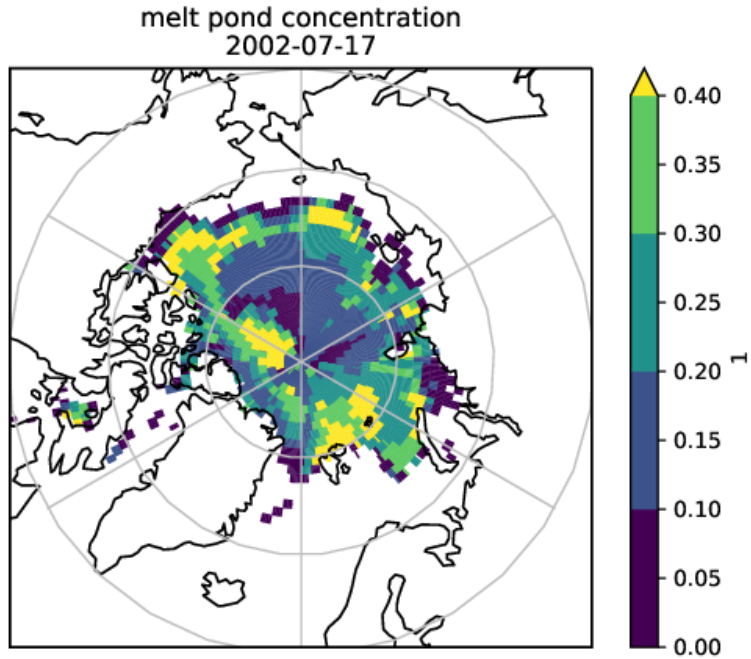
Also unexpected in the initial results was a summer ice bottom melt that was much stronger than the surface melt.

Initial Results: Melt Pond Concentration

Level Scheme

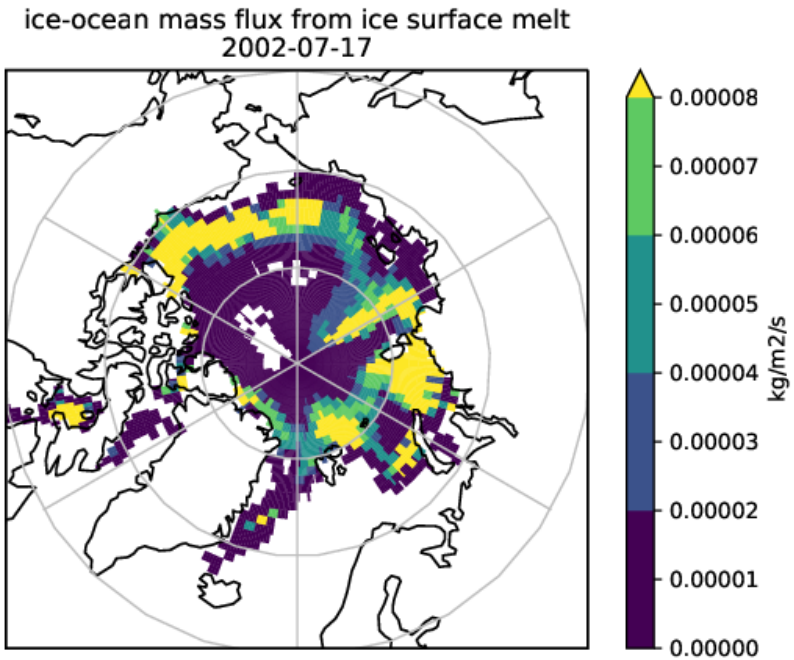


Topographic Scheme

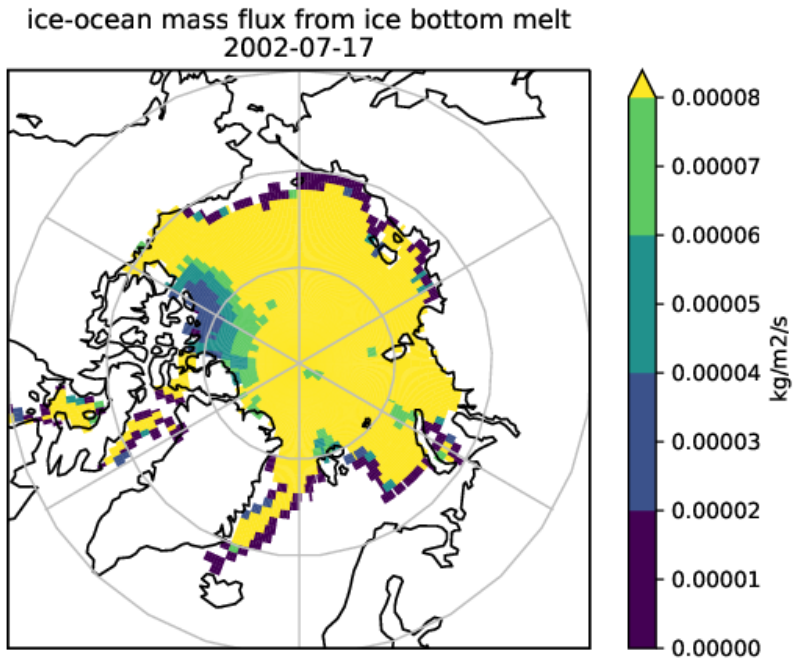


Initial Results: Surface Melt v Bottom Melt

Surface Melt



Bottom Melt



Plots are with no melt pond scheme, but the picture with melt ponds is the same.

Alternative Surface Transmission Scheme

SI^3 has two parameterisations of the transmission of solar radiation through the surface scattering layer.

The default scheme is based on the work of Lebrun (2019) and uses a fixed transmission coefficient of 0.3. This is combined with different radiation attenuation coefficients in dry and melting snow.

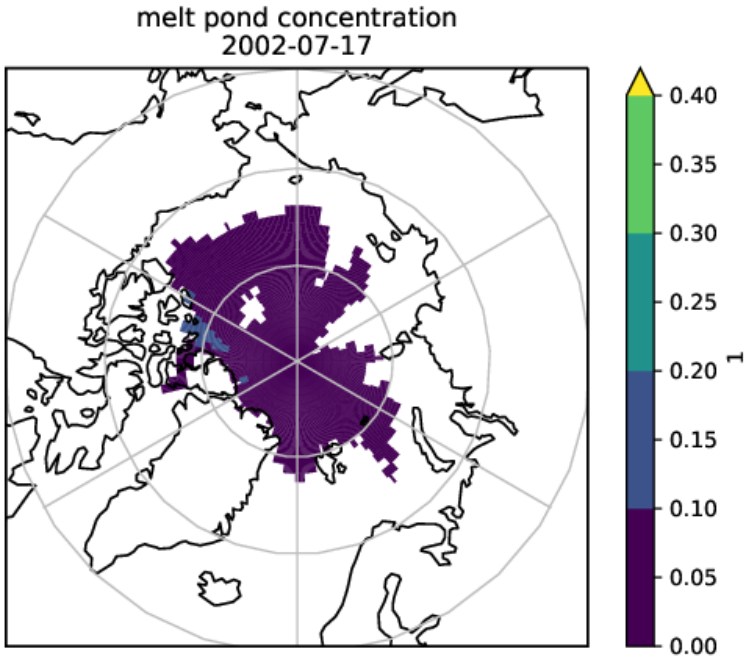
The alternative scheme is based on the work of Grenfell and Maykut (1977). The transmission coefficient varies with cloudiness and is zero wherever there is snow. There is a single radiation attenuation coefficient for all snow types.

Switching to the alternative scheme increases the melt pond concentration and makes the summer ice surface melt more like the bottom melt.

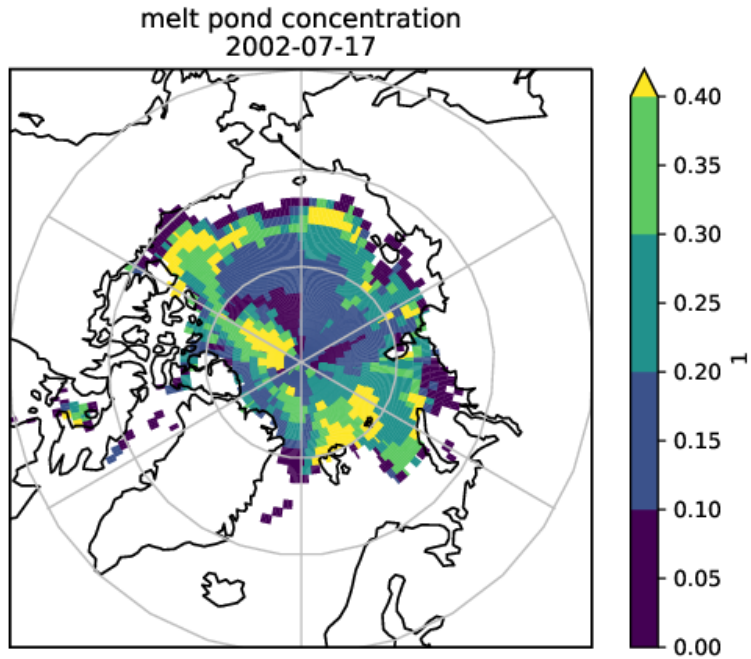
Melt Pond Concentration

Default transmission scheme (repeat of p5)

Level Scheme



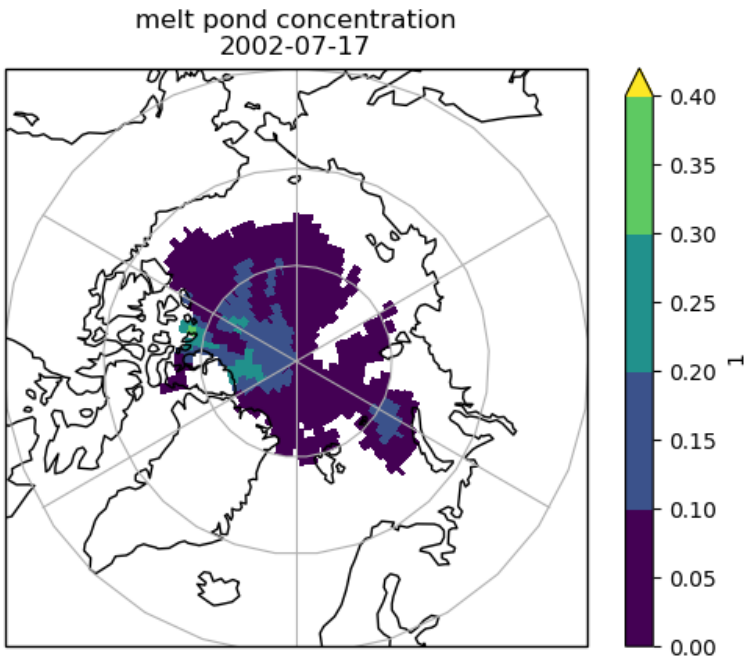
Topographic Scheme



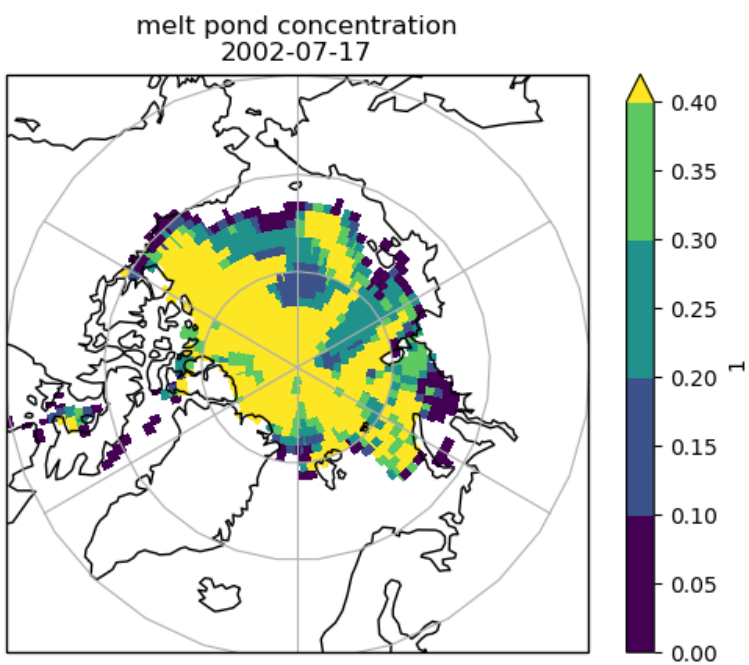
Melt Pond Concentration

Alternative transmission scheme

Level Scheme



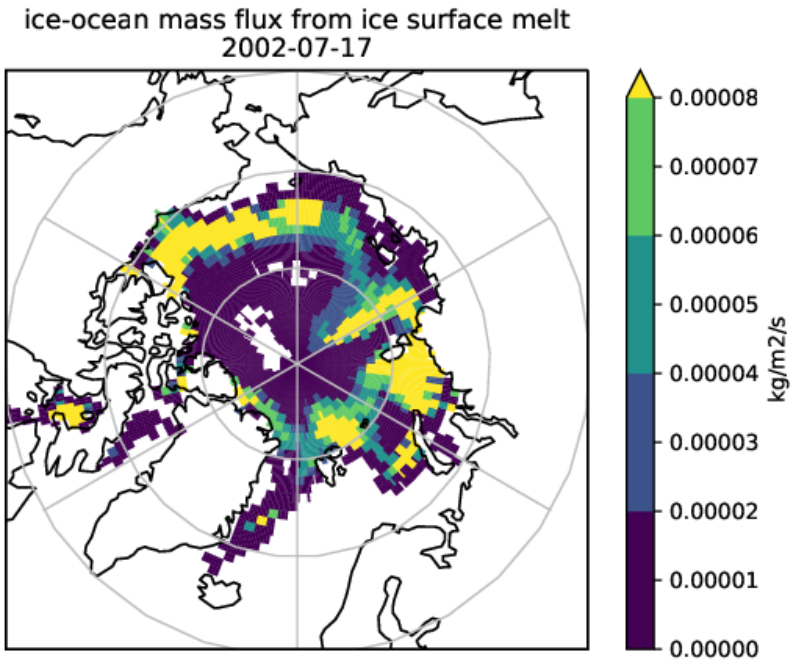
Topographic Scheme



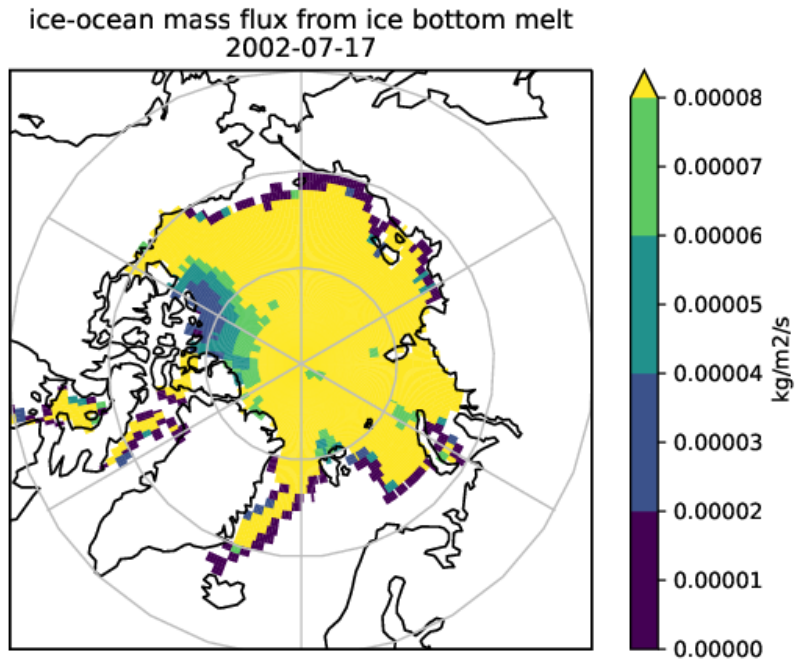
Surface Melt v Bottom Melt

Default transmission scheme (repeat of p6)

Surface Melt



Bottom Melt

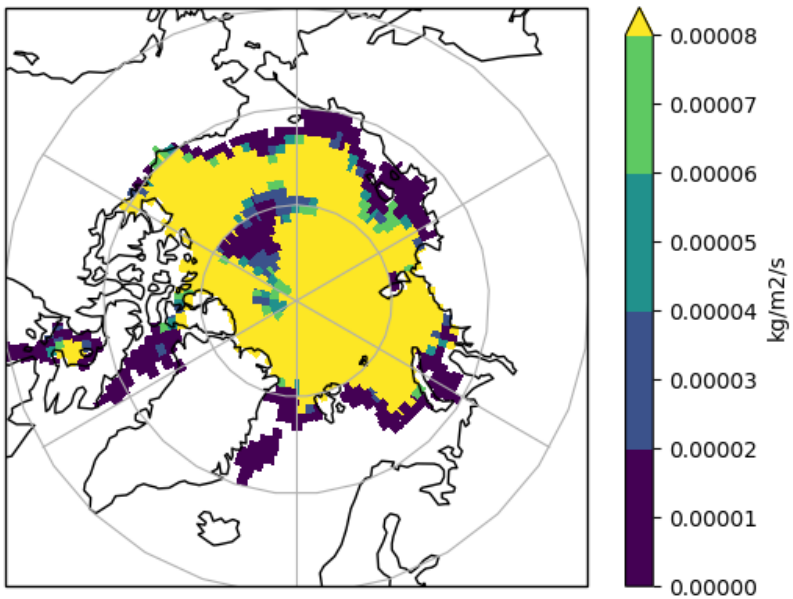


Plots are with no melt pond scheme, but the picture with melt ponds is the same.

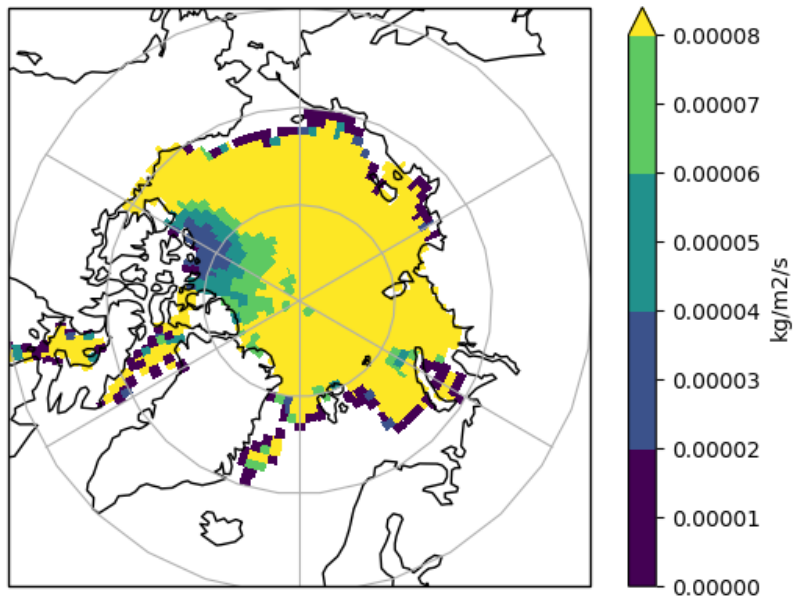
Surface Melt v Bottom Melt

Alternative transmission scheme

Surface Melt



Bottom Melt



Plots are with no melt pond scheme, but the picture with melt ponds is the same.

Conclusions 1

Using the alternative surface transmission scheme increases the realism of the melt pond concentration from the topographic melt pond scheme.

It also equalises the summer ice surface melt and bottom melt.

The bottom melt is still unexpectedly high, however.

Albedo of Thin Ice

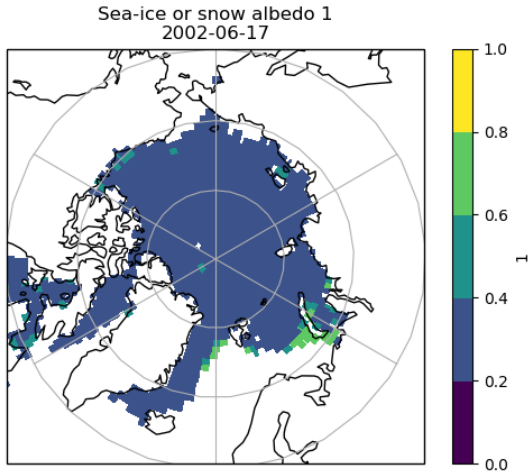
Even after switching to the alternative transmission scheme, a further problem remained: the albedo of the lowest ice thickness category was too low. It was dominated by a large area of albedo in the range 20–40%, whereas values in the range 60–70% were expected.

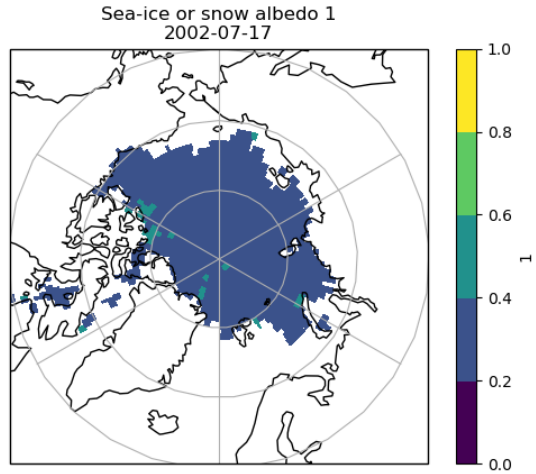
By default, SI^3 reduces the albedo of ice thinner than 150 cm. This can serve to simulate the effect of melt ponds on albedo when melt ponds are not directly simulated.

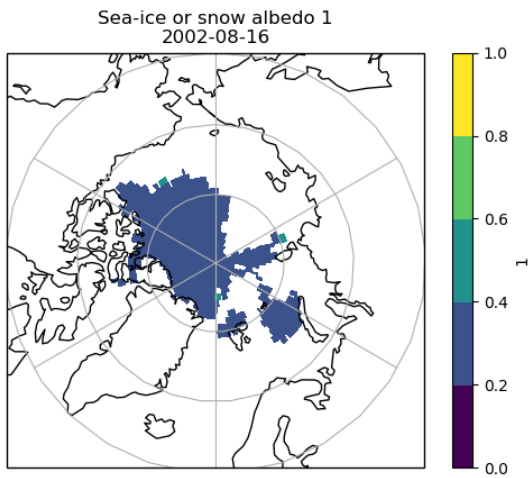
Turning off the albedo reduction when the topographic melt pond scheme is active gives albedo values closer to those expected. It also increases the late-summer sea ice extent, which was smaller than expected before.

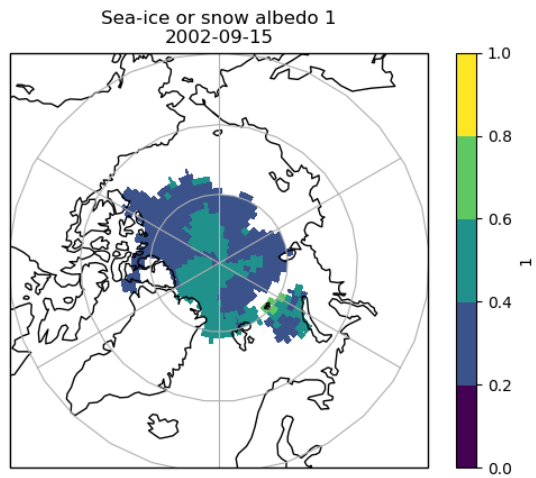
Albedo of Lowest Ice Thickness Category

Default albedo reduction for thin ice



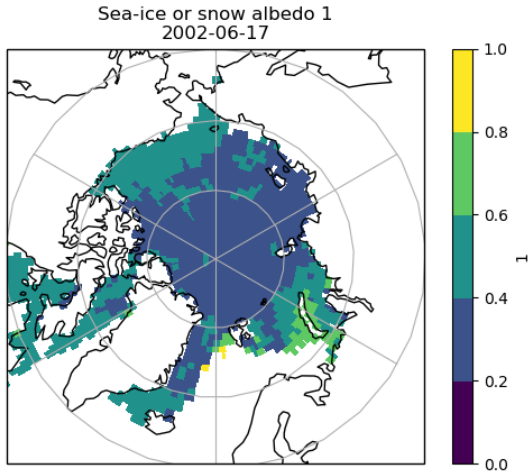


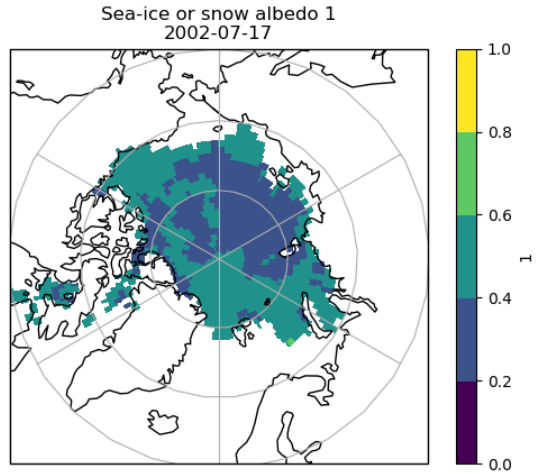


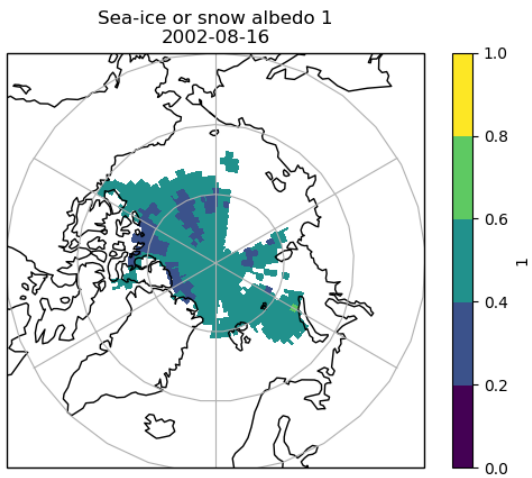


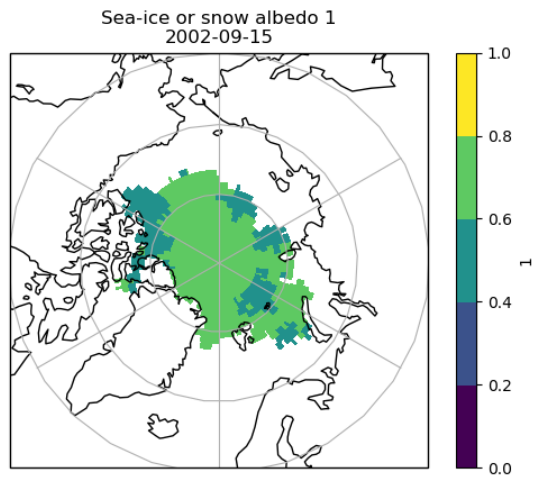
Albedo of Lowest Ice Thickness Category

No albedo reduction for thin ice









Conclusions 2

Turning off the reduction of albedo for thin ice when the topographic melt pond scheme is active increases the realism of the albedo of the lowest ice thickness category and the late-summer sea ice extent.

Further Work: Conservation Properties

It was originally intended to test the effect of the topographic melt pond scheme on the conservation of fresh water and heat in SI^3.

This turned out to be trivial in the context of the wider system because the current implementation does not simulate the delayed release of meltwater to the ocean through its storage in melt ponds. Instead, all meltwater is considered to run off into the ocean immediately it is formed. Similarly, the melt pond scheme does not currently intervene in the heat budget of the wider system.

Work is ongoing to test the internal freshwater budget of the scheme for consistency.

Further Work: Mixed-Layer Ocean Model

It was also originally intended to perform these tests by running SI^3 with a mixed-layer ocean model as an intermediate complexity alternative to running with the full NEMO ocean model or forcing with saved ocean fields.

A mixed-layer model has indeed been implemented as a modification of the existing NEMO standalone surface scheme (SAS), but it has some unexplained features that require further investigation. In particular, runs of SI^3 with the mixed-layer model give sea ice that is thinner than runs with the full ocean model, which is surprising because runs with the SAS give sea ice that is thicker than runs with the full ocean model.

The results in this presentation were all created by running SI^3 with the full ocean model.

Further Work: Objective Comparisons

Assessment so far has depended on comparison with values expected from past experience. It would be good to make a more objective comparison of SI^3 with the results from other sea ice models (such as CICE) and with observations.

Acknowledgements

This work was funded by CMEMS, CPOM, and IS-ENES.