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Inclusion of a multi-layer thermodynamic snow scheme in a large scale sea-ice model

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In both hemispheres, the sea-ice snow cover is a key element in the local climate system and particularly in the processes driving the sea-ice thickness evolution. Because of its high reflectance and thermal insulating properties, the snow pack inhibits or delays the sea-ice summer surface melt. In winter however, snow acts as a blanket that curtails the heat loss from the sea ice to the atmosphere and therefore reduces the basal growth rate.

Among the processes controlling the snow state on sea ice, snowfall, wind and temperature changes are probably the most important. Though very heterogeneous horizontally, owing to the transport of snow by wind, sea-ice dynamics (ridging and rafting) and variability in the sea-ice thickness distribution, the snow cover is nonetheless stratified. Each layer carries a signature of past weather events, for relatively recent snow, and metamorphic pathways that older snow may have been through. In a simplified model, this snow stratigraphy can be represented by its vertical density profile, while the other snow properties are assumed to be computationable from density.

In this study, we analyse the importance of the snow density profile in both one-dimensional and full versions of the thermodynamic-dynamic **L**ouvain-la-Neuve Sea-**I**ce **M**odel (LIM3), which is part of the ocean modelling platform NEMO (Nucleus for European Modelling of the Ocean, IPSL, Paris). Our sensitivity study showed that a non-uniform density profile (with a vertical mean value ρ^*) leads to $\pm$ 10% ice thickness at the end of the growth period, as compared to a uniform profile prescribed to ρ^*. We also show that the sea-ice growth rate is more sensitive to density changes near the surface than at the snow base, an expected result given that the snow surface layers undergo the largest temperature gradients due the sharp state variations of the atmospheric lowest levels.

This one-dimensional snow scheme was included into LIM3. For memory and computational cost reasons, it includes only 3 layers but the vertical grid is refined in thermodynamic routines. The same sensitivity tests are performed to show that also in a large scale sea-ice model, calculating the mean snow density on a grid cell is insufficient, and keeping information about density profile is crucial.