A new snow thermodynamic scheme for the Louvain-la-Neuve sea Ice Model (LIM)

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Introduction

The Louvain-la-Neuve sea Ice Model (LIM) is a three-dimensional global model for sea ice dynamics and thermodynamics that has been specifically designed for climate studies. Its latest version LIM3 (Vancoppenolle and others, 2009) is fully coupled with the oceanic general circulation model (GCM) OPA on the modelling platform NEMO. In the framework of the Work Package 4 of the European project COMBINE (Comprehensive Modelling of the Earth System for Better Climate Prediction and Projection), a new one-dimensional snow model has been developed for the thermodynamic component of LIM and some results from the validation is described hereafter. An outlook of the upcoming works with regard to the global model LIM3 is also presented.

Snow Model Description

Snowfall

Because snow properties on sea ice mainly depend on the wind speed at the time of precipitation, density of fallen snow is parameterized as in Jordan and others, 1999: $\rho_s = \max\{150, 20u^2\}$, where $u$ is the wind speed in m.s$^{-1}$ and $\rho_s$ is in kg.m$^{-3}$.

Heat conduction in the snowpack

The heat conduction equation in snow is treated:

$$\frac{\partial T}{\partial t} = c_v\frac{\partial}{\partial z} \left[ \frac{\partial T}{\partial z} + \frac{\sigma T^4}{\rho c_p} \right]$$

where $c_v$ is the specific heat capacity, $\rho$ and $c_p$ are the density and specific heat capacity of snow, respectively, $\sigma$ is the Stefan-Boltzmann constant, and $T$ is the temperature.

Snow stratigraphy

When the freeboard is negative, sea water infiltrates the snow/ice interface and refreezes to form snow ice.

When snow has entirely melted away, the resulting liquid water remains on the sea ice and the depth of water is used to compute the albedo of the ID-meltpond.

Results from the Validation at Point Barrow – 2008 & 2009:

Map of Point Barrow neighborhood. The “CS” dot represents the Chukchi Sea sampling site, where the data we use were collected.

Data:


Forcing:

Relative humidity and air temperature are also available in the snow and ice data. Snowfall, wind speed and radiative fluxes are taken from ECMWF ERA-Interim reanalyses and forecasts (Simmons and others, 2007).

Run configuration:

On the examples on the right, the model runs from mid-January to June 2008 and 2009, with a time step of 6 hours and 6 layers of snow.

- Results & Conclusions:

  - The model performs better than the former thermodynamics in simulating snow and ice temperatures, with approximately 25% more correlations higher than 0.8 between simulated and modelled temperature profiles.
  - Model performances in simulating the internal temperature profiles are highly sensitive to the number of snow layers in the model. The correlations observed between modelled and measured temperature profiles improve with the snow layer number set in the model. However these correlations do not increase indefinitely but stop after a threshold layer number is reached, and this threshold is different for each of the model setups tested so far.
  - Snow and sea-ice thicknesses are well represented, with average deviations between simulated and observed thicknesses of -3 cm for snow and -6.5 cm for sea ice (-7 cm for 2008 and -2.2 cm for 2009).
  - Large maximum errors are observed in snow depth (until -9 cm), but still in the expected range of variability.

- As expected, wintertime sea-ice bottom accretion rate and maximum ice thickness are sensitive to the thermal conductivity of snow. None of the three tested formulations for snow heat conductivity gave better results than the others in every cases.

- On the other hand, during the summer period, the snow thermal conductivity parameterization hardly influences the sea-ice bottom ablation rate. This is due to the fact that snow absorbs almost all surface temperature variability and makes the sea-ice internal conductive heat fluxes small and steady.

Upcoming works...

The validation of LIM1D has shown the importance of the snow stratigraphy in models and suggests that the representation of processes driving snow properties, lacking in global-scale models, must be compensated by at least a good representation of snow density distributions. Studies like Nicolas and others (2009) identifying typical patterns of snow distribution on various ice types (see figure on the right) may therefore give a relevant solution for a better representation of snow and its impacts on sea ice in GCMs.

This is why the next step will be the implementation LIM1D into NEMO-LIM3 with snow density and thickness categories. As a first approach, the distribution functions of density and thickness will be prescribed and built from observations.

References


Data collection by the Floating Ice Group of the University of Alaska Fairbanks (UAF).

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