3 Model Components

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3.1 Discretization and initialization of the ice thickness distribution

3.1.1 Discretization of the ITD

Module : ***iceini.F90***
Subroutine : **lim_itd_ini**

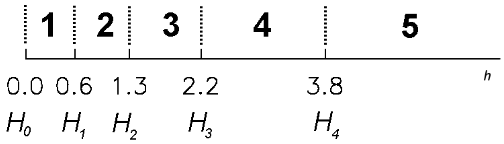

FIGURE 3.1 – Boundaries of the model ice thickness categories (m) for 5 thickness categories.

The thickness distribution function $g(h)$ is numerically discretized into several ice thickness categories. The numerical formulation of the thickness categories follows Bitz et al. (2001) and Lipscomb (2001). A fixed number M of thickness categories with a typical value of $M = 5$ is imposed. For some variables, sea ice in each category is further divided into N vertical layers of ice and one layer of snow. In the remainder of the text, the $m = 1, ..., M$ index runs for ice thickness categories and $k = 1, ..., N$ for the vertical ice layers. Each thickness category has a mean thickness h^i_m ranging over $[H^\star_{m-1},\, H^\star_m]$. $H^\star_0 = 0$, while the other boundaries are chosen with greater resolution for thin ice (see Fig. **??**), using :

$$H^\star_m = H^\star_{m-1} + \frac{3}{M} + \frac{30}{M}\left[1 + tanh\left(\frac{3m-3-3M}{M}\right)\right]. \tag{3.1}$$

$$\tag{3.2}$$

Each ice category has its own set of global state variables (see Table **??** for a list). The global ice state variables are extensive variables (e.g. concentration, volume per unit area, ...). The global state variables are used by all but thermodynamic model routines, in which they are, when necessary, converted into equivalent state (intensive) variables (i.e., thickness, temperatures, ... ; see Table **??** for a list).

TABLE 3.1 – Sea ice global (extensive) variables in LIM3.

Symbol	Description	Units
u	Sea ice velocity	$[m.s^{-1}]$
g^i_m	Concentration of sea ice in category m	[-]
v^i_m	Volume of sea ice per unit area in category m	$[m]$
v^s_m	Volume of snow per unit area in category m	$[m]$
$e^i_{m,k}$	Sea ice enthalpy per unit area in category m and layer k	$[J.m^{-2}]$
e^s_m	Snow enthalpy per unit area in category m	$[J.m^{-2}]$
M^s_m	Sea ice salt content in category m	$[‰.m]$
O_m	Sea ice age content in category m	$[days.m]$

TABLE 3.2 – Equivalent variables in LIM3.

Symbol	Description	Units
$h^i_m = v^i_m/g^i_m$	Ice thickness	$[m]$
$h^s_m = v^s_m/g^i_m$	Snow depth	$[m]$
$q^i_{m,k} = e^i_{m,k}/(h^i_m/N)$	Ice specific energy of melting	$[J.m^{-3}]$
$q^s_m = e^s_m/h^s_m$	Snow specific energy of melting	$[J.m^{-3}]$
$T^i_{m,k} = T(q^i_{m,k})$	Ice temperature	$[K]$
$T^s_m = T(q^s_m)$	Snow temperature	$[K]$
$S^i_m = M^s_m/v^i_m$	Ice salinity	$[‰]$
$o^i_m = O_m/v^i_m$	Ice age	$[days]$

3.1.2 Initialization of the ITD

Module : ***limistate.F90***
Subroutine : **lim_istate**

At the first model time step, if no *a priori* information is available, the state variables have to be initialized for each category. In LIM3, two quantities are prescribed for each hemisphere in the namelist : the ice thickness H^i (average over the categories) and the total concentration A^i (summed over the categories). The product $V^i = A^i H^i$ is the volume of ice per unit area in the grid cell.

First, we initialize the ice thickness (h^i_m) and concentration (g^i_m) into each category. We want g^i_m and h^i_m to respect area and volume conservation :

$$A^i = \sum_{m=1}^{M} g^i_m, \tag{3.3}$$

$$V^i = \sum_{m=1}^{M} g^i_m h^i_m. \tag{3.4}$$

Another constraint is that ice thickness has to be within the category bounds for the first $M-1$ categories, therefore we impose :

$$h^i_m = \frac{H^\star_m + H^\star_{m-1}}{2} \quad i = 1, ..., M-1. \tag{3.5}$$

In this context, there remains $M+1$ constants to be evaluated : h^i_M and g^i_m, $m = 1, ..., M$. Area and volume conservation provides two constraints, therefore we need $M-1$ additional equations to close the system.

In order to to this, we attempt to construct a gaussian distribution for concentrations. First, we decide that the maximum concentration is $A^i/\sqrt{M}$ and falls into the the category m_0, which is such that $H^\star_{m_0-1} < H^i < H^\star_{m_0-1}$. This ensures that H^i represents the most probable thickness into the grid cell. For the other categories, we use an gaussian formulation. Therefore, initial ice concentrations read :

$$g^i_{m_0} = A^i/\sqrt{M} \tag{3.6}$$

$$g^i_m = g^i_{m_0} exp\left[- \frac{h^i_m - H^i}{H^i/2} \right]^2 \quad \forall m \neq m_0 \text{ and } m < M \tag{3.7}$$

$$\tag{3.8}$$

Those provide the $M-1$ required constraints. Area and volume conservations are then used to compute the last two parameters :

$$g_M^i = A^i - \sum_{m=1}^{M-1} g_m^i, \tag{3.9}$$

$$h_M^i = \left(V^i - \sum_{m=1}^{M-1} g_m^i h_m^i \right) \Big/ g_M^i. \tag{3.10}$$

Finding such a gaussian distribution is not always possible for small values of H^i and can lead to potential problems, such as :

- Violation of area or volume conservation
- Thickness of the last category out of bounds : $h_M^i < H_{m-1}^\star$
- Negativity of one of the concentrations

If that is the case, we prescribe the concentration in the last category to be zero and restart the operation for the $M - 1$ categories, and so on, until a suitable distribution is found.

3.1.3 Initialization of the other state variables

Ice salinity and snow depth are also prescribed from the namelist but have no category dependence. Ice age is set to 1 day. Surface, snow and ice temperatures are set to 270K. The remainder of the variables (ice volume, heat contents, ...) can then all be derived from the previously defined variables.

3.2 Horizontal transport

3.3 Transport in thickness space

3.4 Ridging and rafting

3.5 Ice dynamics and rheology

3.6 Ice thermodynamics

3.7 Ice dynamics and rheology

Besides ice thickness and concentration, the other important variable to diagnose the sea ice mass balance is the velocity vector. It is assumed in LIM that all