CLIMATE, OCEAN AND SEA ICE MODELING PROGRAM

Snow Model Physics in GCM Sea Ice Components

CICE and LIM

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2015

Snow Influences

Sea Ice Dynamics

- mass
- form drag

Sea Ice Thermodynamics

- albedo
- thermal insulation
- melt pond water source
- radiative shield for ponds (infiltration, or on pond ice)
- meltwater flushing, ice salinity
- snow-ice formation

Snow Influences

Ocean

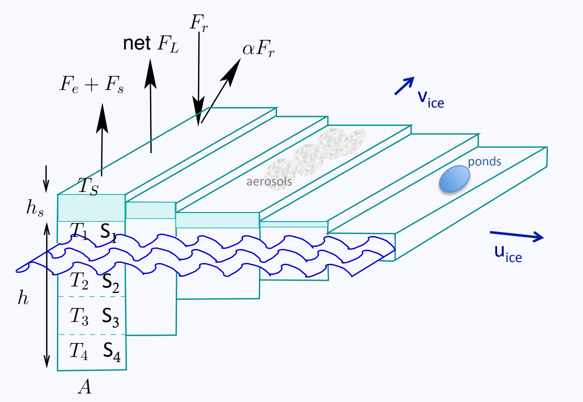
- fresh melt water
- energy content
- transmitted shortwave (if it survives through the ice)

Biogeochemistry

- vertical tracer transport
- tracer scavenging during meltwater flushing
- horizontal tracer transport (incl. fresh water)

Ice Thickness Distribution g

Schematic of model representation of g(H) in five ice "categories"



A=fractional coverage of a category

Slide courtesy Cecilia Bitz, Dave Bailey, Marika Holland

Snow Model Schematic

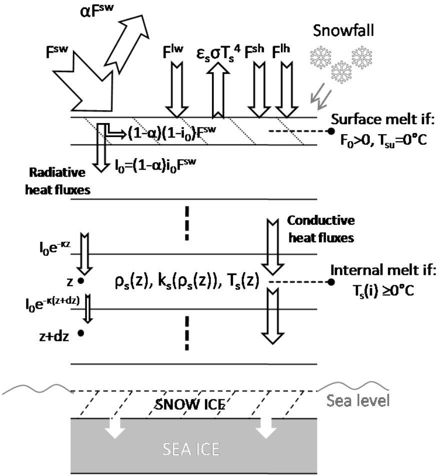


Figure 2.1: Schematic of LIM1D's new snow module.

O. Lecomte, Ph.D. thesis, Université catholique de Louvain, 2014

A Basic Snow Model

- thermodynamic model computes growth/melt rates
- vertical conductive, radiative and turbulent fluxes
- state variables: mass (volume)
  energy (temperature, enthalpy)
- assumed density profile, effective thermal conductivity
- salinity = 0 (unless sea water infiltrates)
- mass changes due to
  - snowfall
  - sublimation/deposition
  - melt
  - snow-ice formation
  - loss during ridging
- vertical discretization with multiple layers
- horizontal advection on top of sea ice

Radiation: CICE delta Eddington

- emissivity = 0.95
- thin snow is patchy
- surface scattering layer and internal layer
- prescribe "inherent optical properties"
  - extinction coefficient
  - single scattering albedo
  - scattering asymmetry
- compute "apparent optical properties"
  - albedo
  - internal absorption
  - transmission to ocean
- tuning parameters
  - snow grain radius (freshly fallen, melting, nonmelting, standard deviation)

Radiation: LIM — Beer's Law

- emissivity = 0.95
- surface scattering layer absorbs all near-infrared
- extinction coefficient
- albedo depends on
    - surface state
    - cloud cover
    - sea ice thickness
    - snow depth

More LIM Features

- prescribes density profiles over first-year, multiyear ice
- after snowfall, merges adjacent layers with $\min(\Delta\rho_s)$
- advects heat content of 3 snow layers, total mass
- also includes
  - superimposed ice formation in saturated snow
  - internal snow melting
  - wind dependence

Wind Dependence: LIM

- density of new-fallen snow depends on surface wind speed (seasonal)
- some snow is blown into the ocean through leads
- transported snow mass flux is
  - proportional to wind speed
  - negatively proportional to snow density
  - inversely proportional to stddev(ITD)
- conductivity depends on snow density, liquid water content

CICE Features in Development

- wind dependence similar to LIM
  - use level, ridged ice topography within categories
  - some snow is blown into the ocean through leads
  - snow compaction depends on wind speed
- dry and wet snow grain metamorphism
  - grain size used in delta-Eddington radiaiton
- effective snow density
  - ice, liquid water content
  - snow compaction

Olivier's wisdom

"... the sea ice model is more sensitive to the snow representation in the Arctic than it is in the Southern Ocean, where the sea ice thickness is not driven by temperature profiles in the snow."

O. Lecomte, Ph.D. thesis, Université catholique de Louvain, 2014