U.S. DEPARTMENT OF ENERGY

Office of Science

CLIMATE, OCEAN AND SEA ICE MODELING PROGRAM

Simulating wind redistribution of snow on sea ice

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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)

Snow Model Schematic

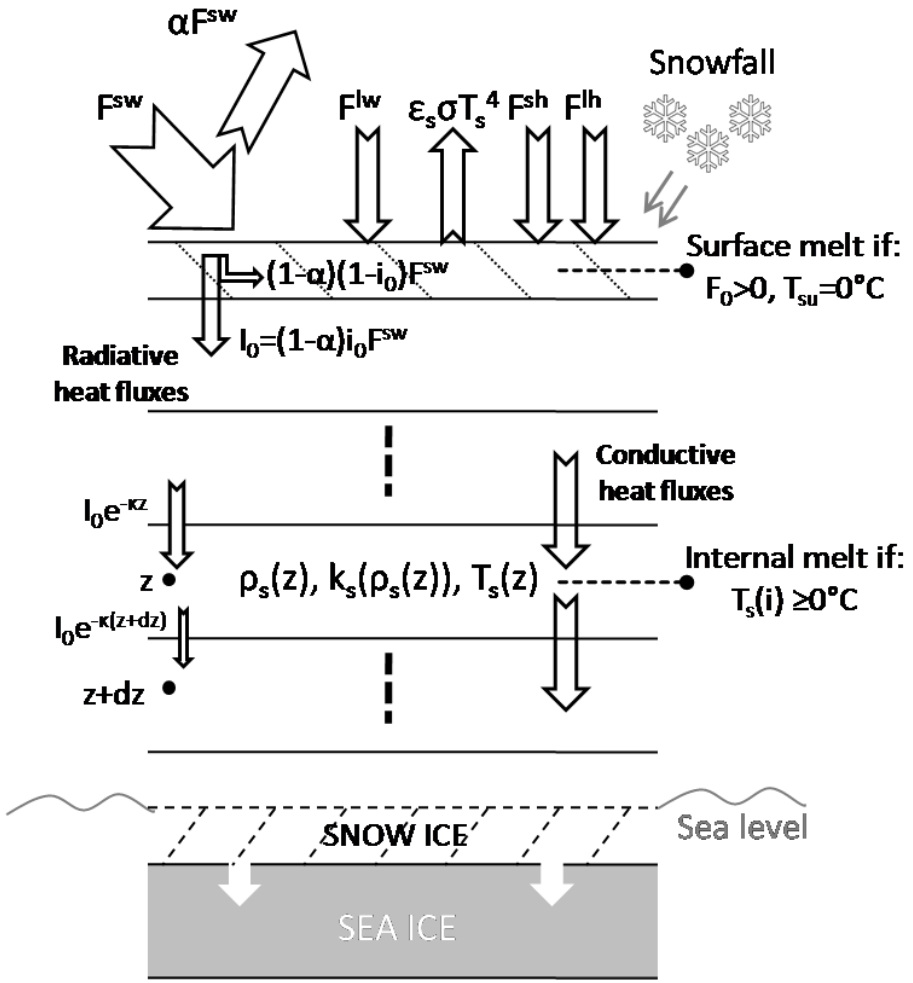

Figure 2.1: Schematic of LIM1D's new snow module.

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

Sturm & Holmgren Recommendations for Climate Modelers

JGR 2001

- Need synoptic weather data to capture discrete storms
- Evolve depth hoar using ∇T, but ...
- Wind slab and depth hoar resist further densification
- Wind slab prevents further snow drifting
- Snow characteristics can be tied to ice type (thin, etc)
- Lateral variability is closely tied to melt pond features
- Snow depth can be treated as a normally distributed random variable with the mean and standard deviation set by ice type

ACME Snow-on-Sea-Ice Model Development

- Increase vertical resolution of the snow column
- Use daily precipitation data to capture discrete storms
- Model snow metamorphism (wet and dry)
  - effective snow grain radius
  - mass of liquid water in snow
  - mass of ice in snow
- Model wind effects on snow
  - wind slab
  - loss to leads
  - radiative effects of snow redistribution

ACME Snow-on-Sea-Ice Model Development

This talk:

- Increase vertical resolution of the snow column
- Use daily precipitation data to capture discrete storms
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  - effective snow grain radius
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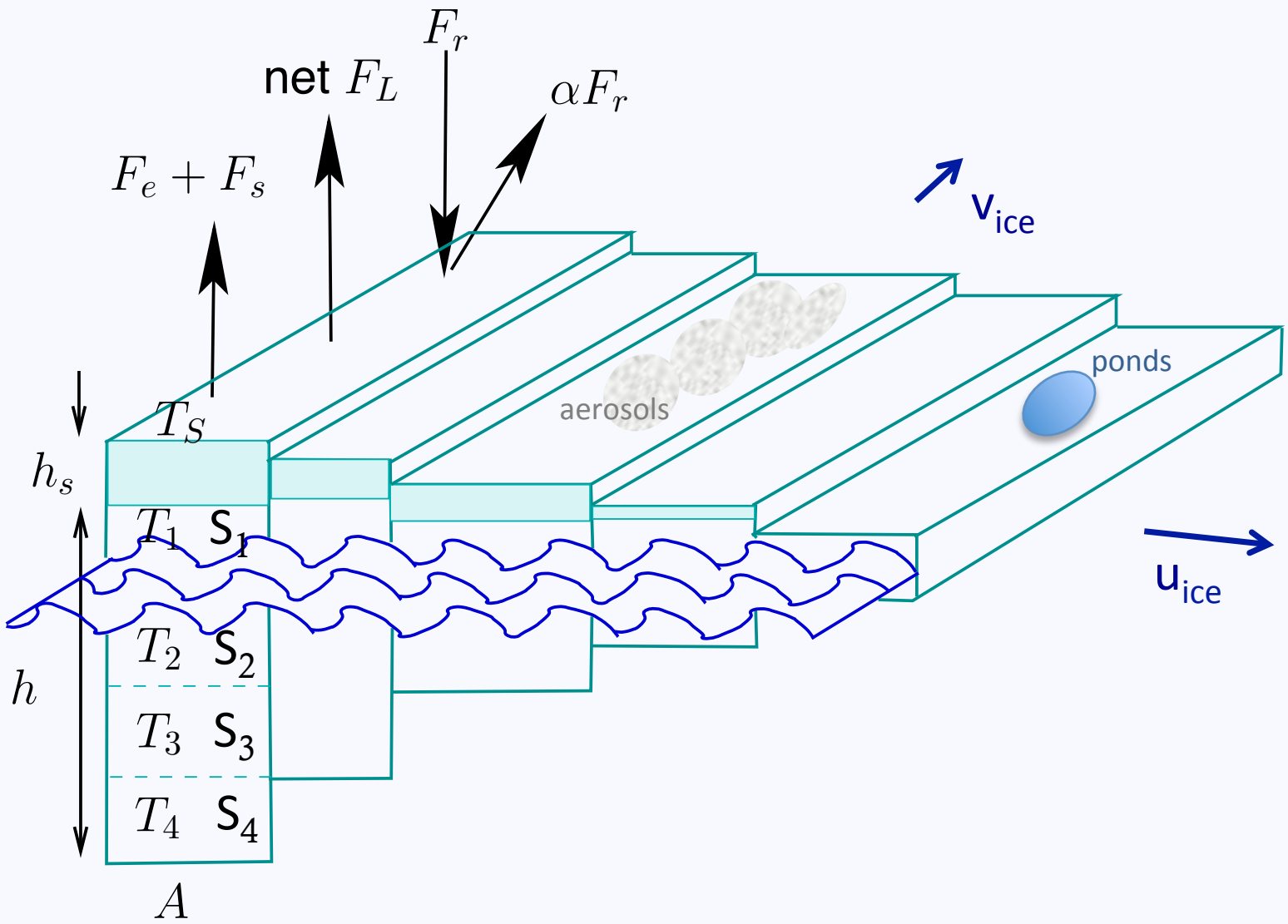
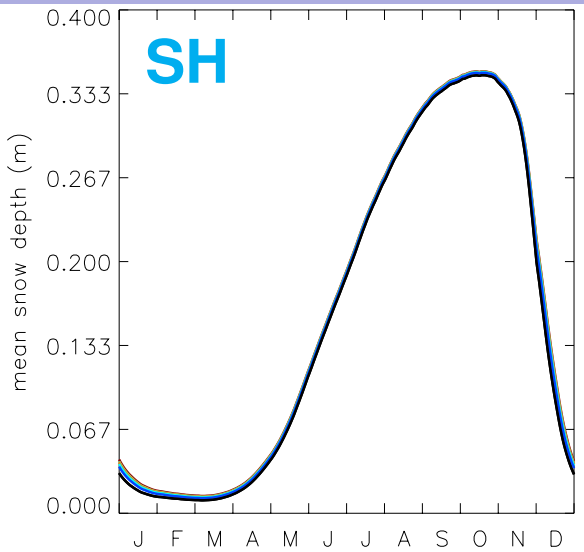
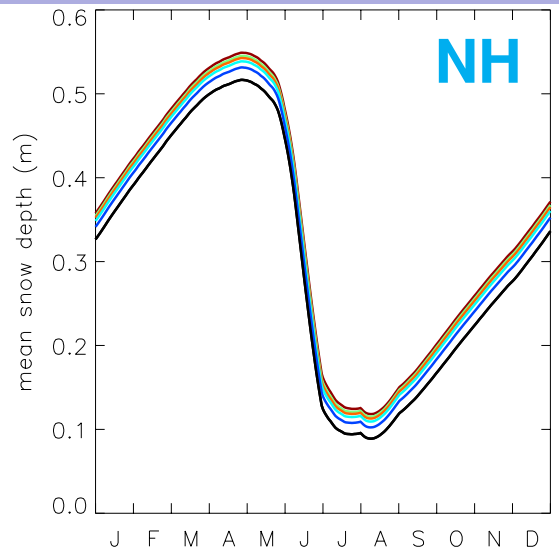
Resolution


F_r
net F_L
αF_r
$F_e + F_s$
v_{ice}
aerosols
ponds
T_S
h_s
T_1 S_1
u_{ice}
T_2 S_2
h
T_3 S_3
T_4 S_4
A

Vertical Resolution





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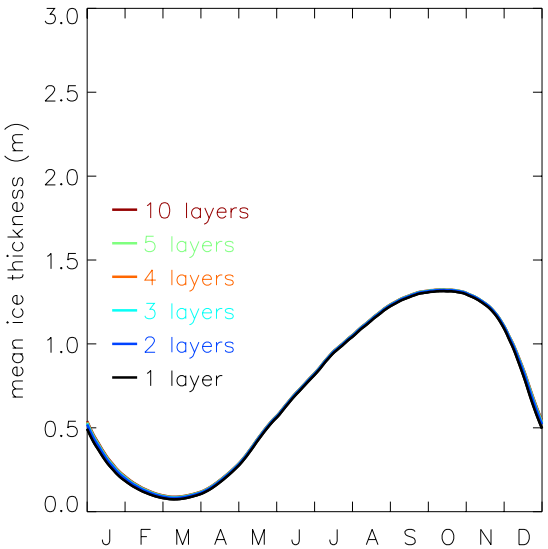

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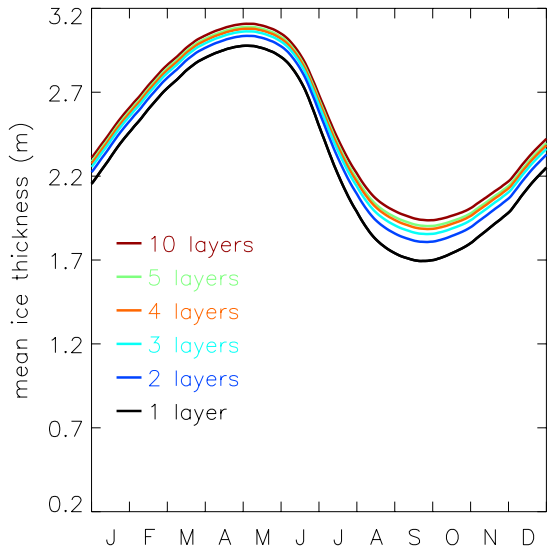
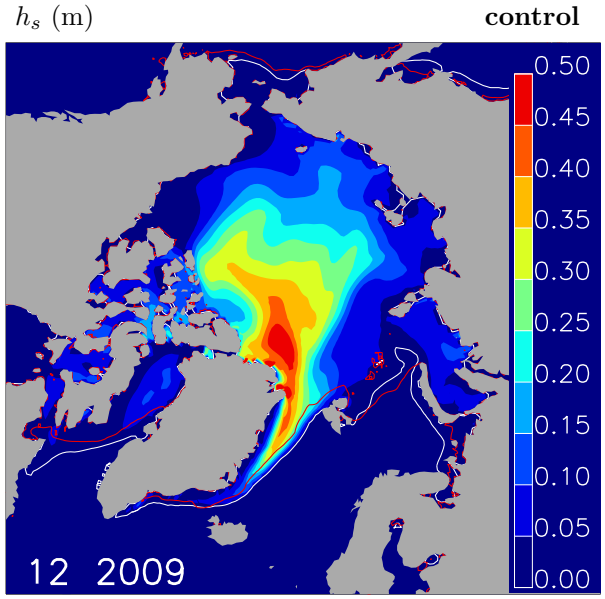
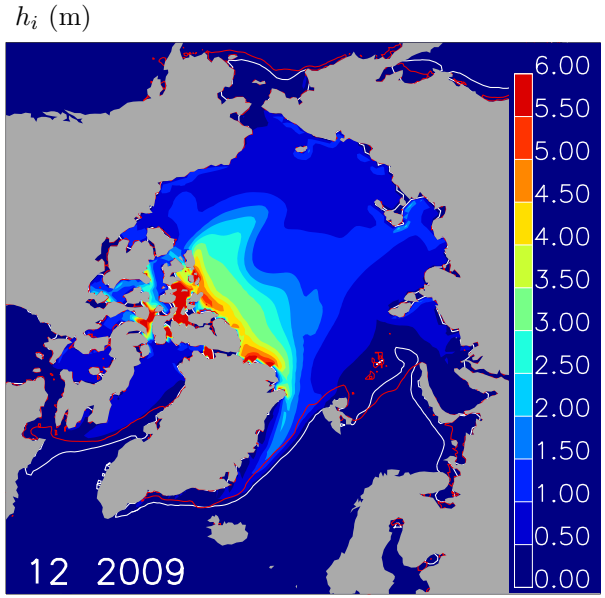


Control Run

h_{snow}



h_{ice}



CICE v5

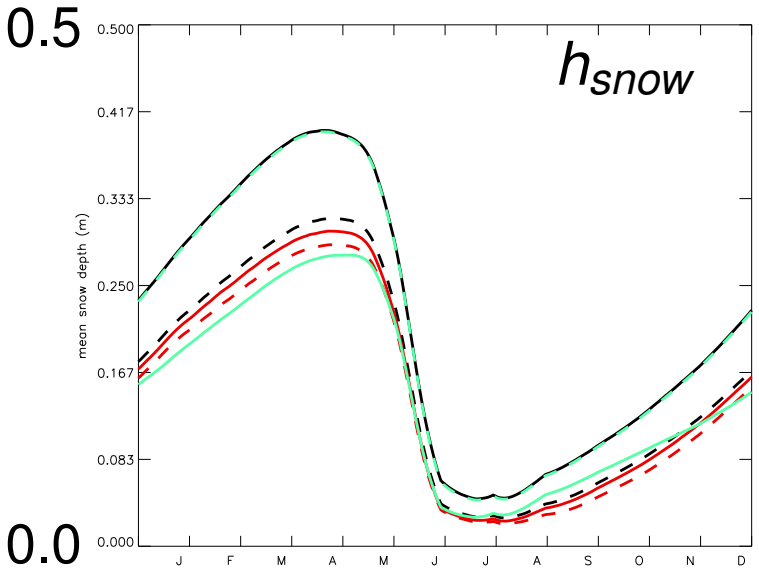
1° global displaced pole grid

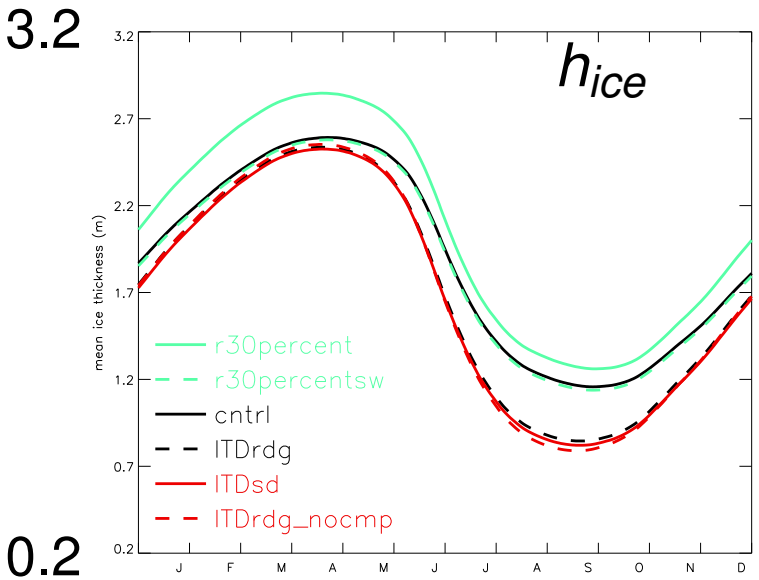
Modified CORE II forcing

Slab mixed-layer ocean

Control	1958 – 2009
Experiments	1980 – 2009

30% Rule: Loss to Leads / Redistribution



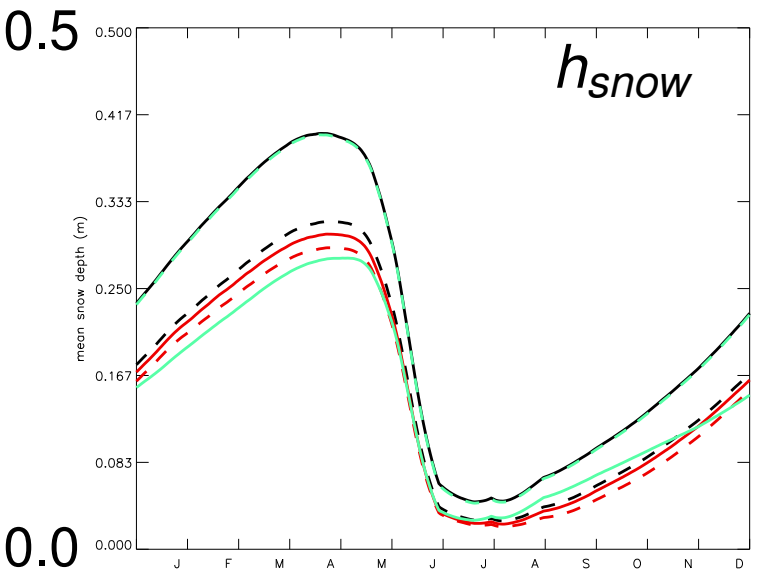


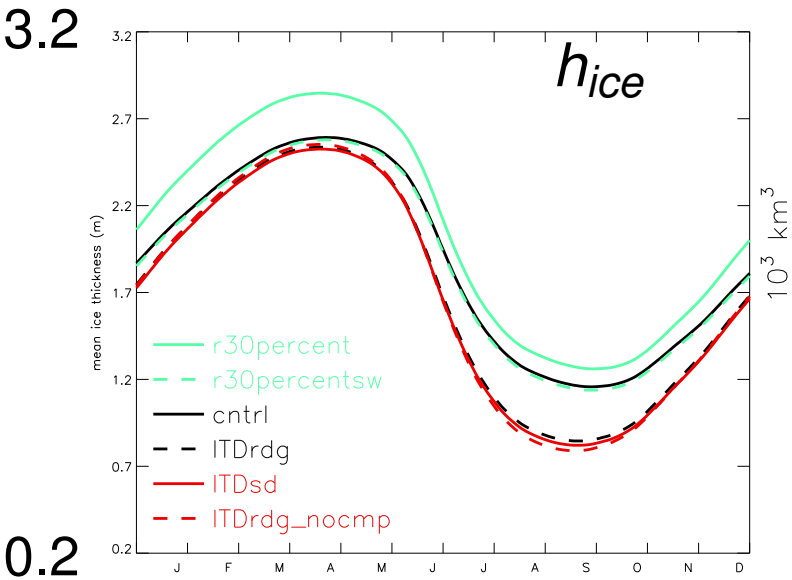
control

move snow from level ice to leads

move snow from level ice to deformed ice (radiation)

30% Rule: Loss to Leads / Redistribution





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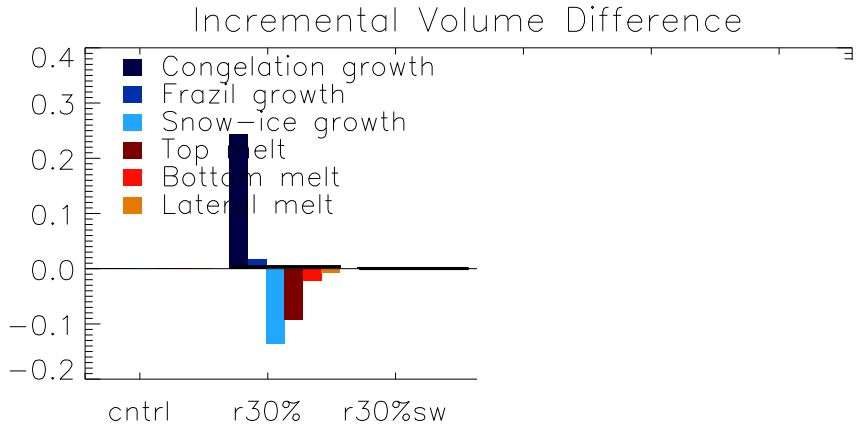

Wind Dependence: LIM

- density of new-fallen snow depends on surface wind speed
- 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

Wind Dependence: LIM
Wind Dependence: CICE

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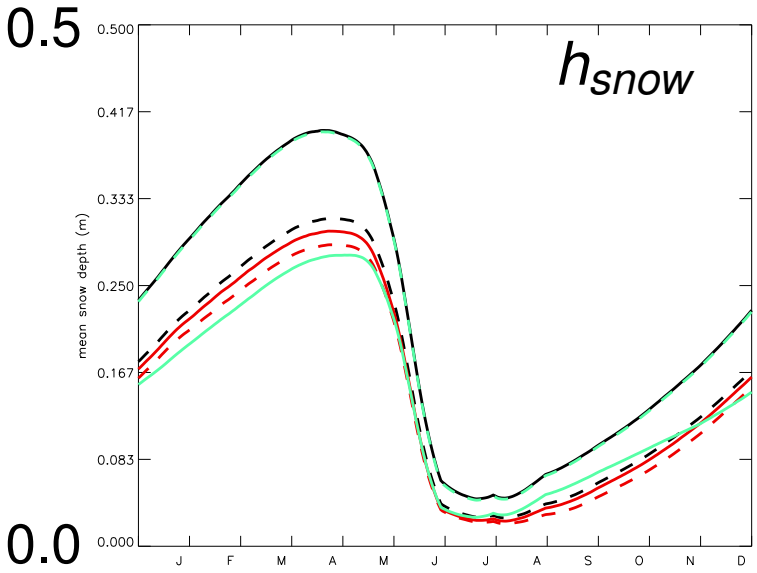
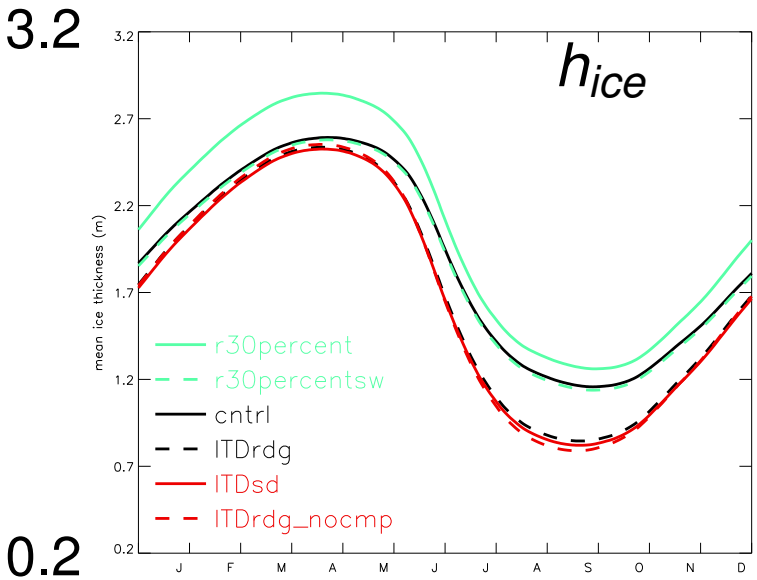
- some snow is blown into the ocean through leads
- transported snow mass flux is
  - proportional to wind speed
  - negatively proportional to snow density
  - inversely proportional to stddev(*level+deformed ITD)*
- conductivity depends on snow density, liquid water content

Wind Dependence: CICE



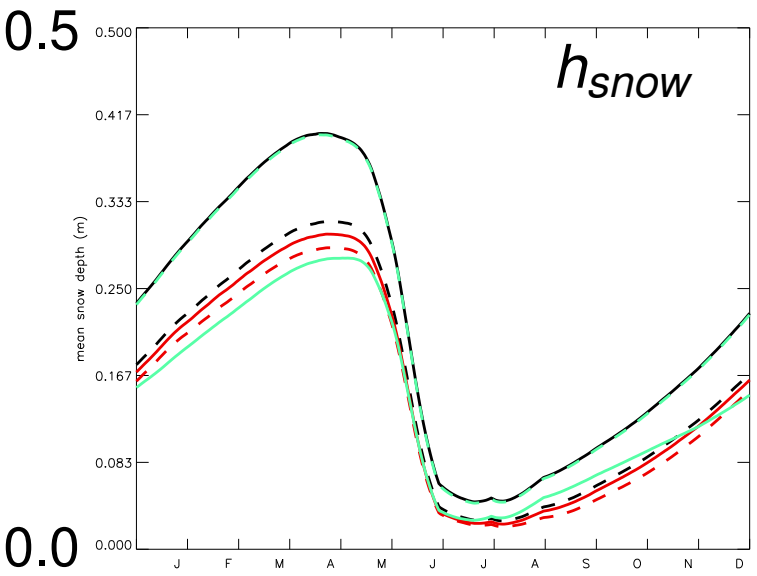


control

Wind redistribution

w/ level+deformed ITD

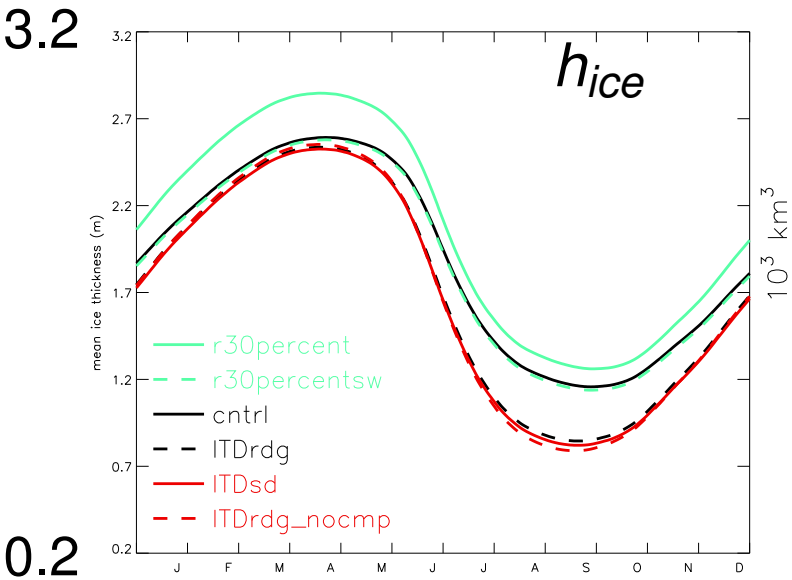
Wind Dependence: CICE

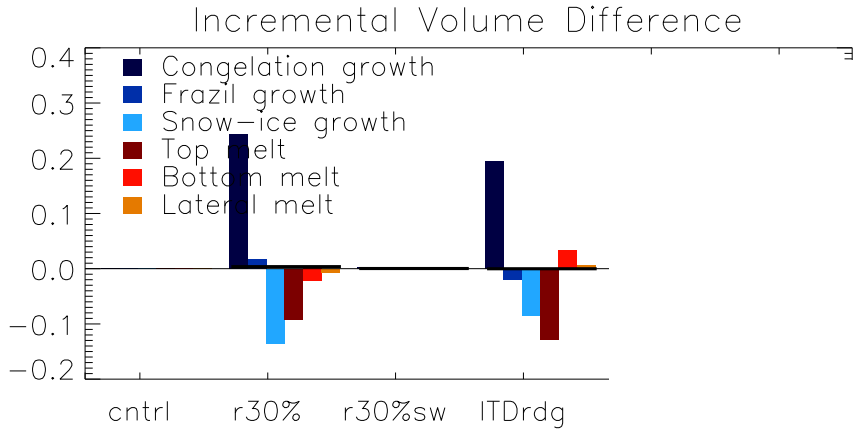


control

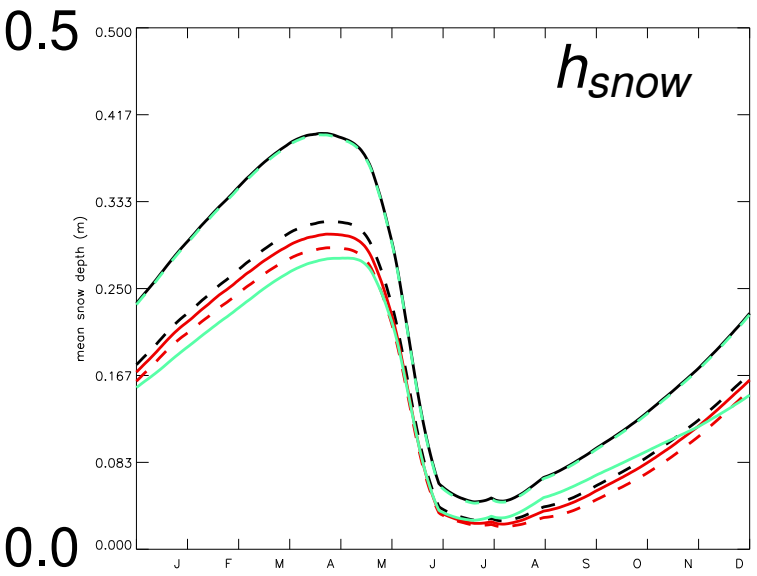
Wind redistribution

w/ level+deformed ITD





Wind Dependence: CICE



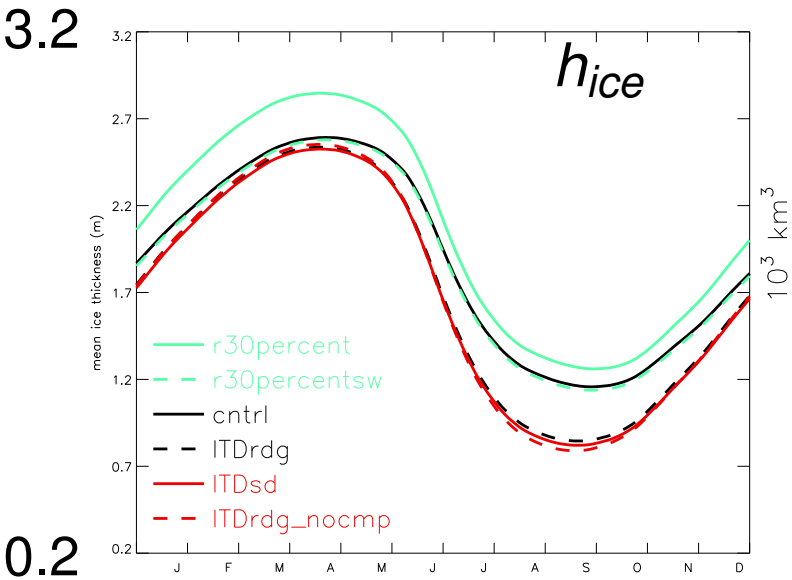
control

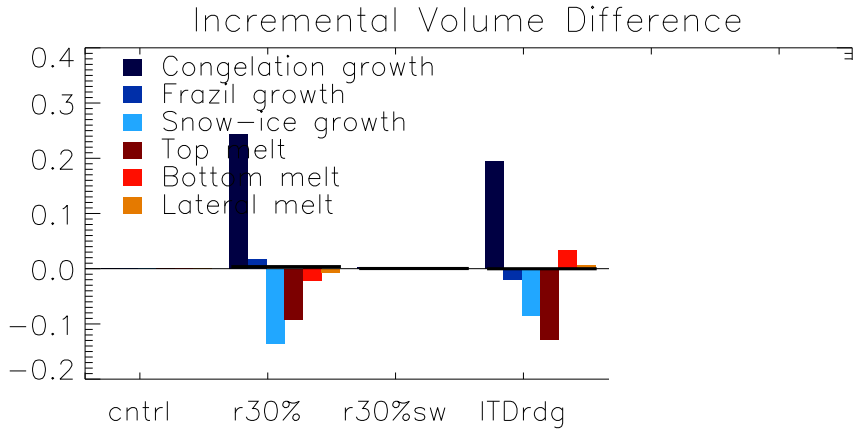
Wind redistribution

w/ level+deformed ITD

w/ std ITD

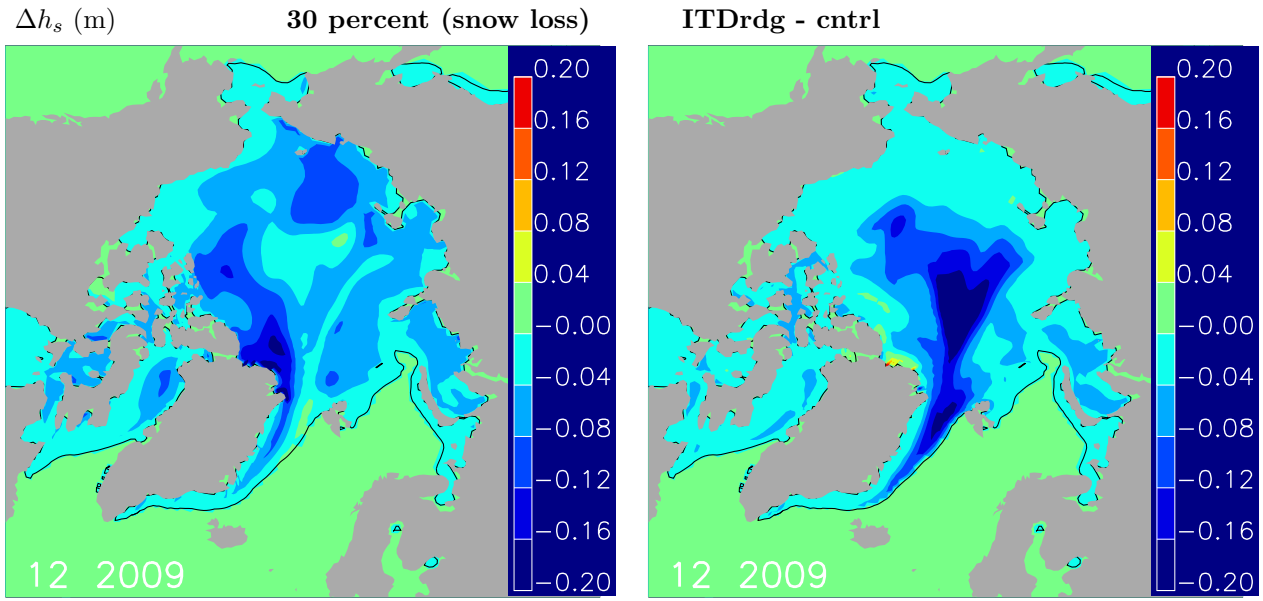
w/ no compaction



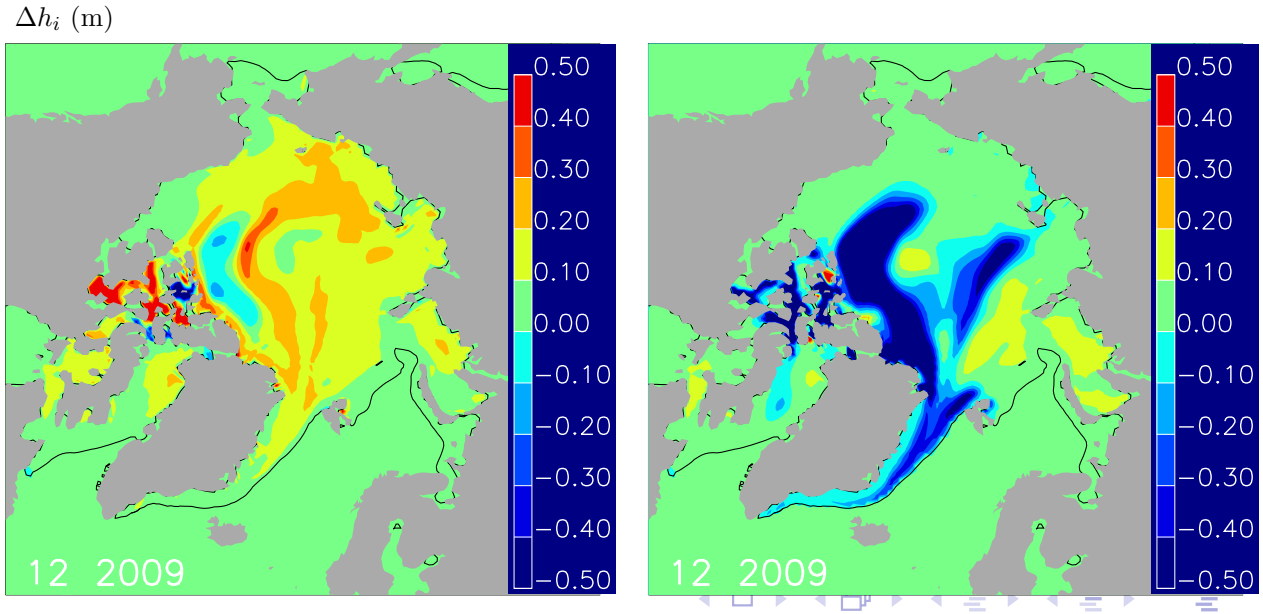


Experiments - Control

Δh_{snow}

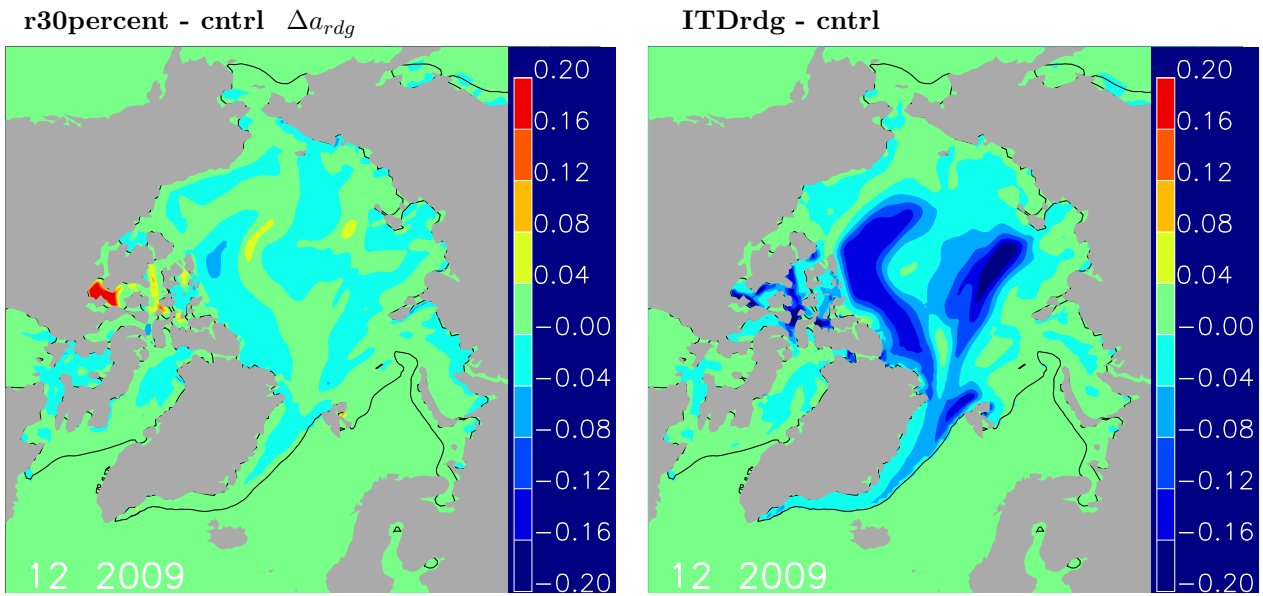


Δh_{ice}



Change in Deformed Ice Area

Δa_{rdg}



Preliminary Results

- need at least 3 snow layers, preferably more
- snow loss to leads is critical
- feedback with deformed ice needs to be explored
- snow metamorphism likely to have bigger radiative impact
- new developments include varying snow density
- effects of synoptic precipitation need to be explored

Experiments - ITDrdg

Δh_{snow}

Δh_{ice}