Sea ice sensitivity to snow parameters in the CICE v5.0 sea ice model

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Outline

- Snow processes affecting sea ice.
- Numerical experiments to examine sensitivity of sea ice to snow processes.
- Sensitivity of sea ice to snow density, grain size, thermal conductivity, and snow survival during ridging.
- Summary and conclusions.

Sensitivity of sea ice to snow processes

- Reduction of sea ice melt due to high snow albedo.
- Reduction of sea ice growth due to insulation effect .
- Snow-ice formation due to flooding.
- Reduction of surface albedo over melt ponds.
- Restratification of the upper ocean due to melt water runoff.

Model Setup

CICE v5.0 is run in stand alone mode forced by CORE atmospheric reanalysis and climatological ocean state. Model is spun up for 17 years and then run from 1975-2005.

Parameter choices in Control Run		
Standard dev. parameter for snow grain size	Rsnow	1.5
Snow density	rhos	330 Kg m^{-3}
Snow conductivity	ksno	0.30 W m^{-1} °K^{-1}
Snow fraction surviving ridging	fsnowrdg	0.5

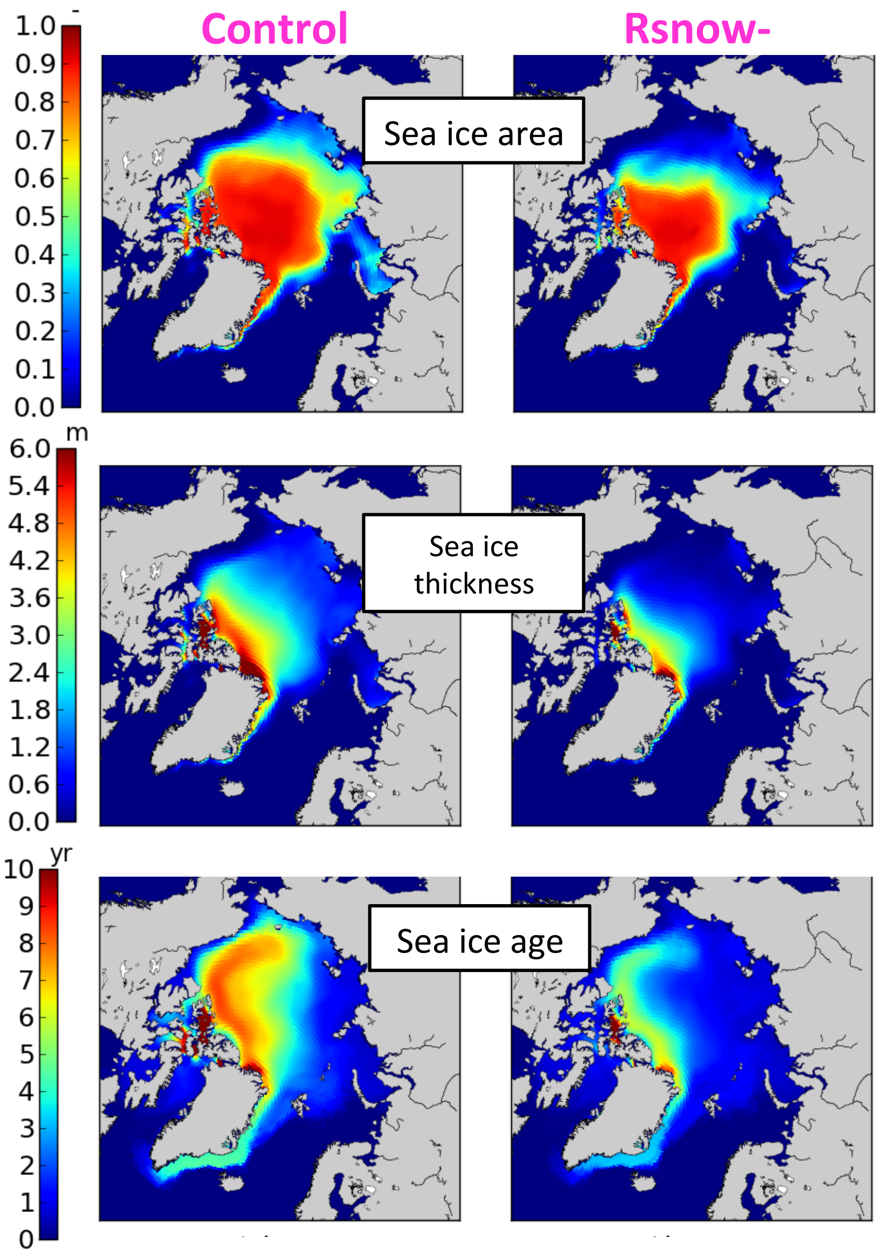
Delta Eddington radiation scheme (Briegleb and Light, 2007).

Ridging scheme including snow survival during ridging (Flato and Hibler, 1995; Liscomb et al., 2007).

Additional numerical experiments

Experiment	Parameter
Rsnow-	Rsnow = -1.5
Lrhos	rhos = 280 kg m^{-3}
Lksno	ksno = 0.03 W m^{-1} °K^{-1}
fsnowrdg0	fsnowrdg = 0
fsnowrdg1	fsnowrdg = 1

Sensitivity to increased snow grain size

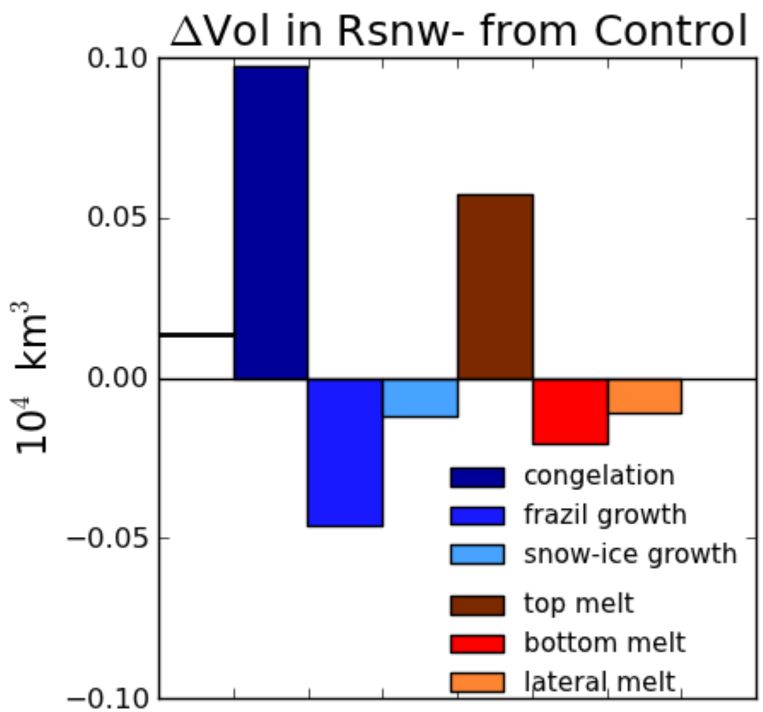


- Albedo calculation using Delta-Eddington scheme (Briegleb and Light, 2007).
- Reduction of sea ice extent.
- Thinning of sea ice in Rsnow-.
- Younger ice with increased snow grain size.

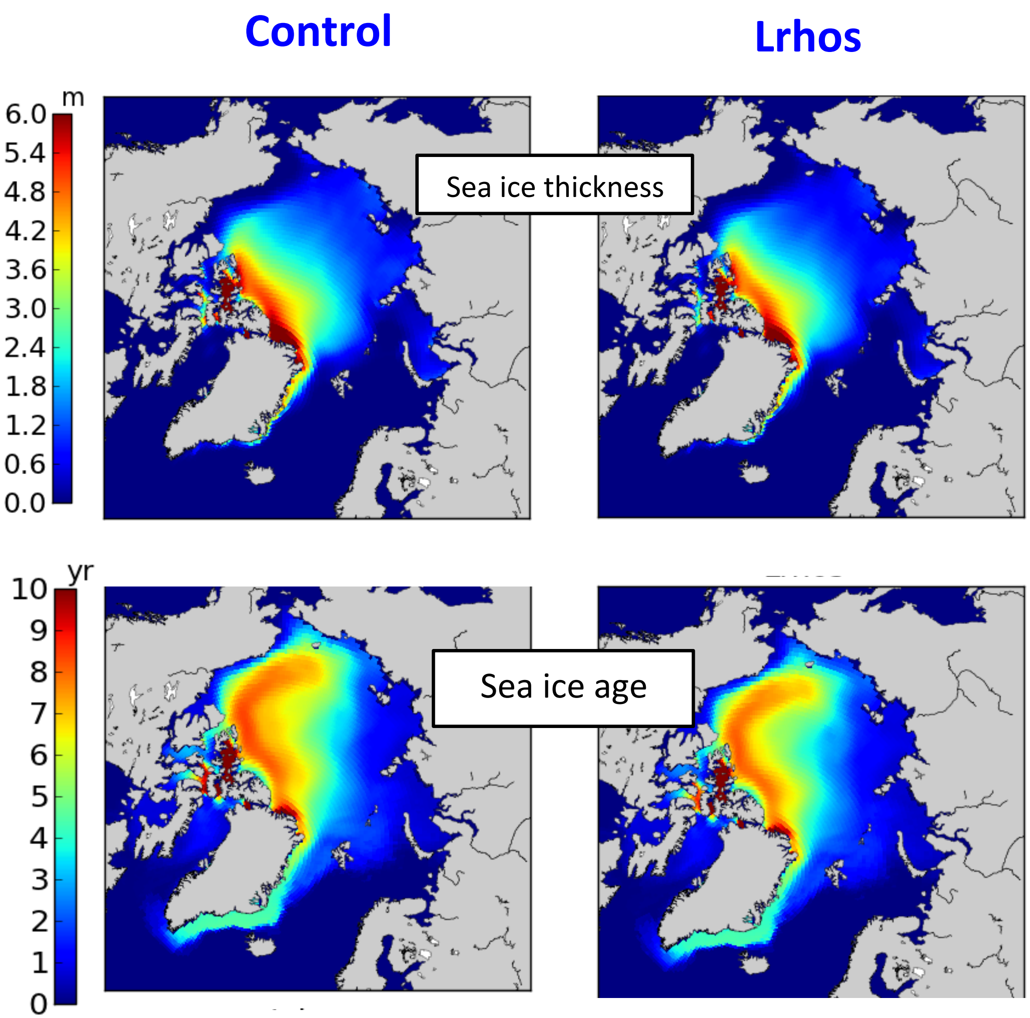
Difference of the mean annual volume terms in Rsnow- from Control Run

Increasing snow grain size reduces albedo:

- Increased snow melting.
- Reduced snow-ice formation.
- Reduced insulation effect of sea ice from atmosphere.
- Increased winter growth rates and summer melt rates.
- Net reduction of sea ice volume and younger ice.

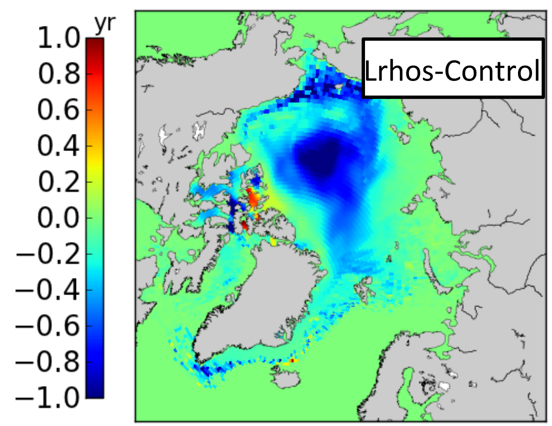


Sensitivity to reduction in snow density



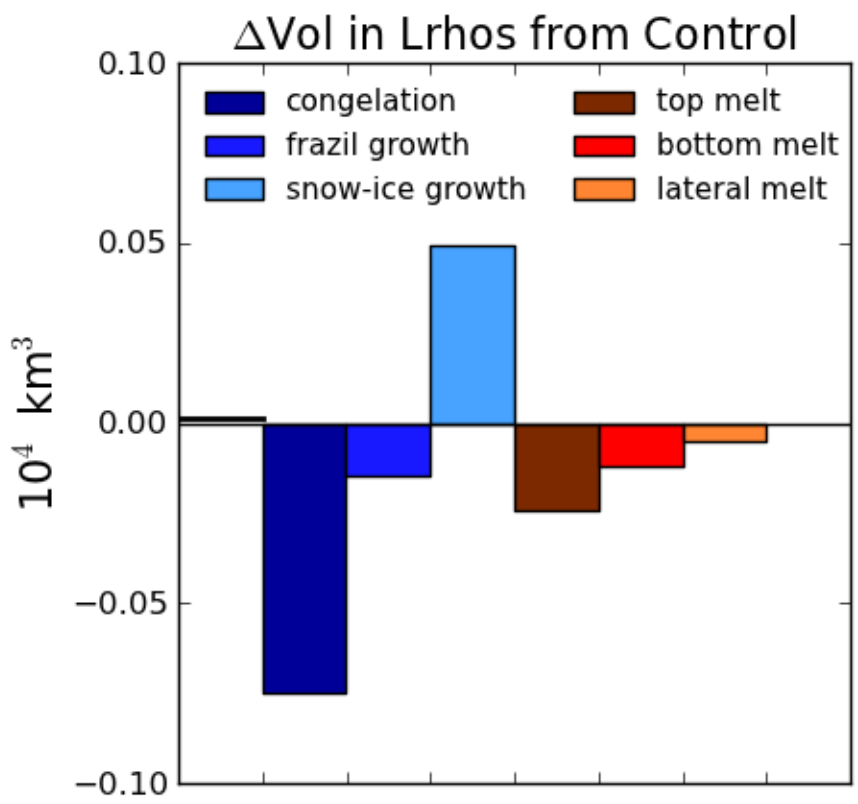
- Sea ice thickness and extent not sensitive to reduction in snow density.
- Sea ice age is reduced in Lrhos in comparison with Control Run.

Sea ice age difference

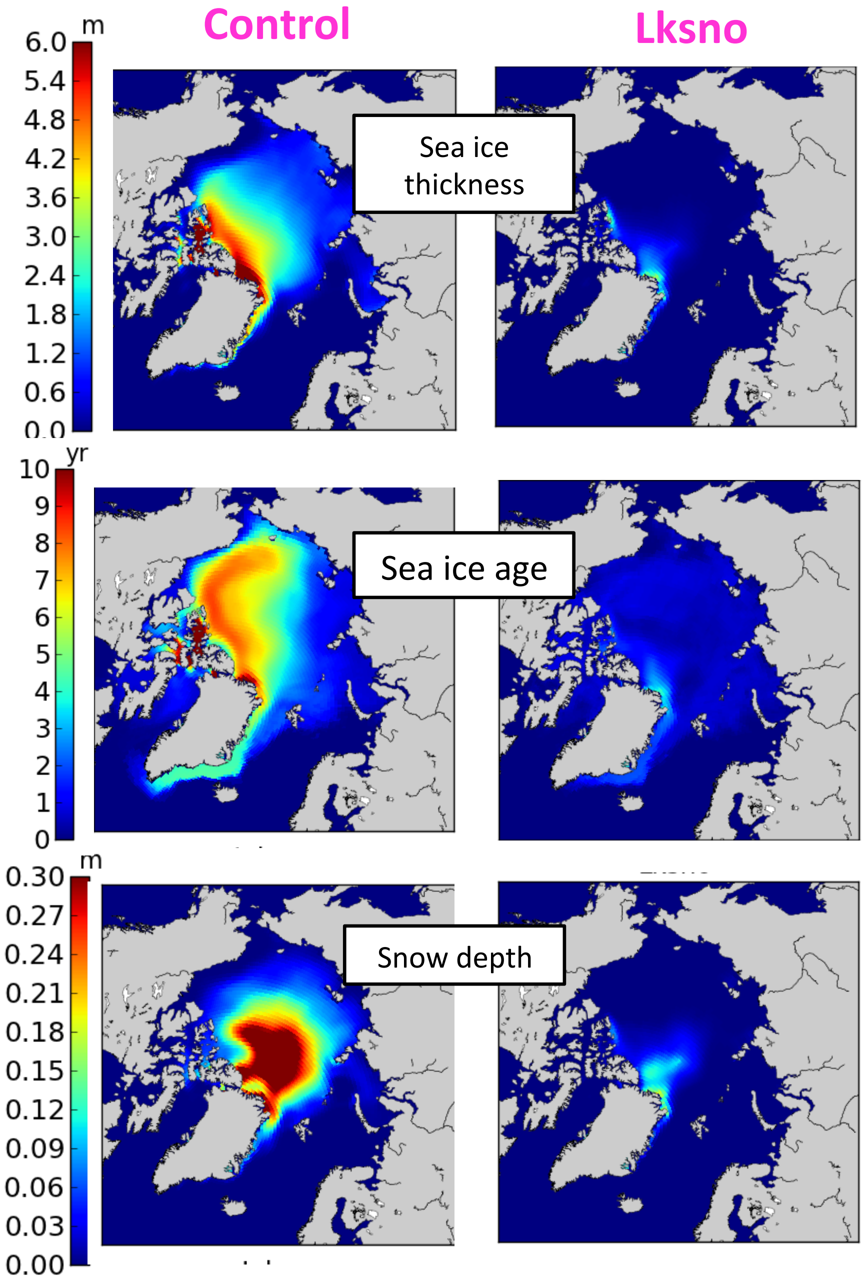


Difference of the mean annual volume terms in Lrhos from Control Run

- A reduction in snow density leads to more snow-ice growth: snow-ice is heavier because larger content of brine.
- Larger insulation effect due to larger snow depths.
- Less basal growth of sea ice.
- Less penetration of solar radiation into the snow pack leading reduced melt rates.
- Feedbacks might be responsible for similar thickness and coverage in the two experiments.



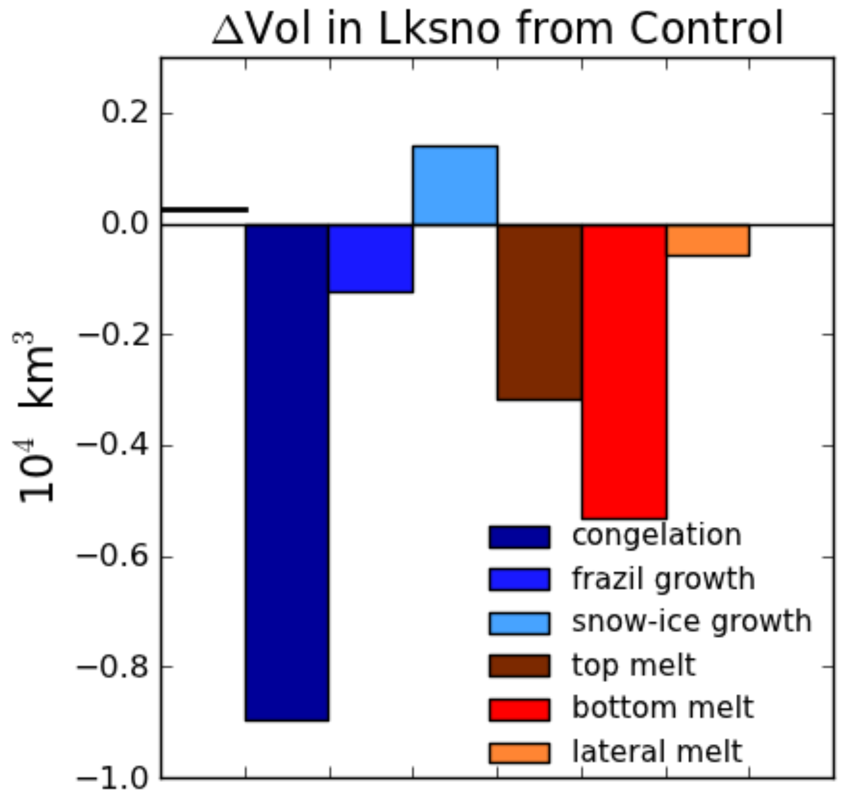
Sensitivity to reduced snow conductivity



- Thermal conductivity of snow can range between 0.03-0.65 (Sturm et al., 1997)
- Severe reduction in snow conductivity
- Severe reduction of sea ice area and thickness
- Younger ice regime

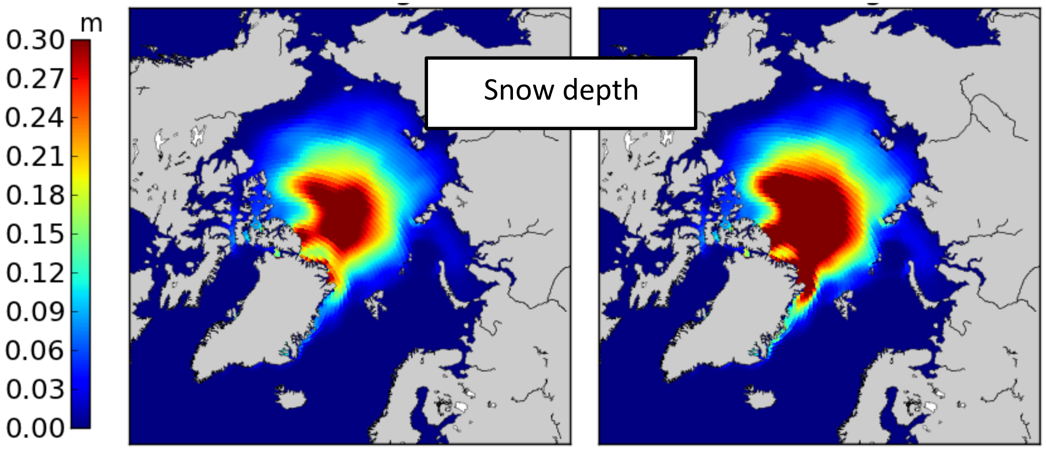
Incremental difference of the mean annual volume terms in Lksno from Control Run

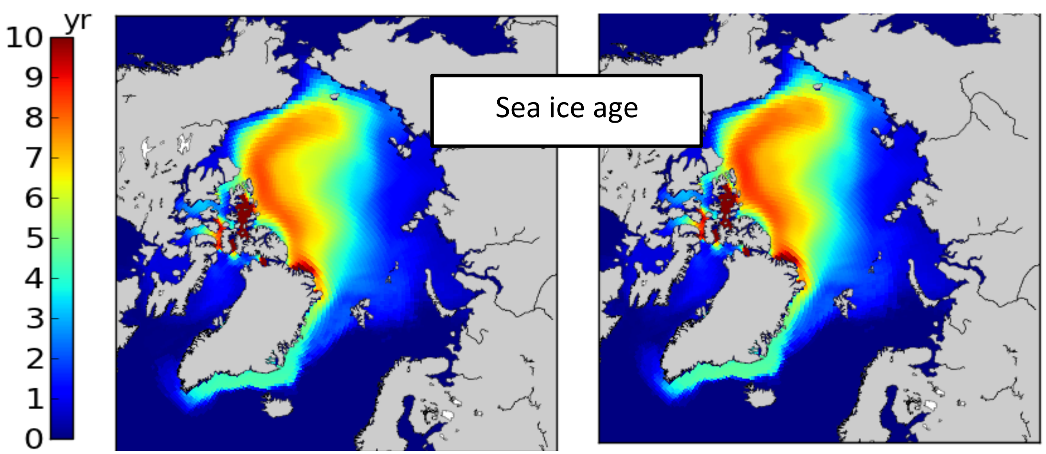
- Increased insulation reduces heat losses in winter and radiation reaching the sea ice pack in summer.
- Snow ice formation increases due to thinner ice.
- Reduced snow depths due to less heat transmitted downwards, used to melt snow pack (earlier onset of snow melting).
- Ice extent minimum occurs in August.



Sensitivity to snow survival fraction during ridging

Frsnow0 (all snow is lost) | **Frsnow1** (all snow survives)

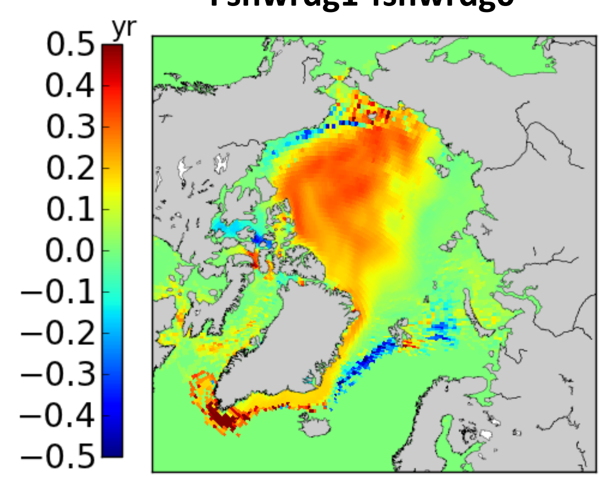




- Sensitivity of sea ice area or thickness is small
- Significant reduction of snow depths when all snow is lost during ridging
- Aging of sea ice when all snow survives ridging

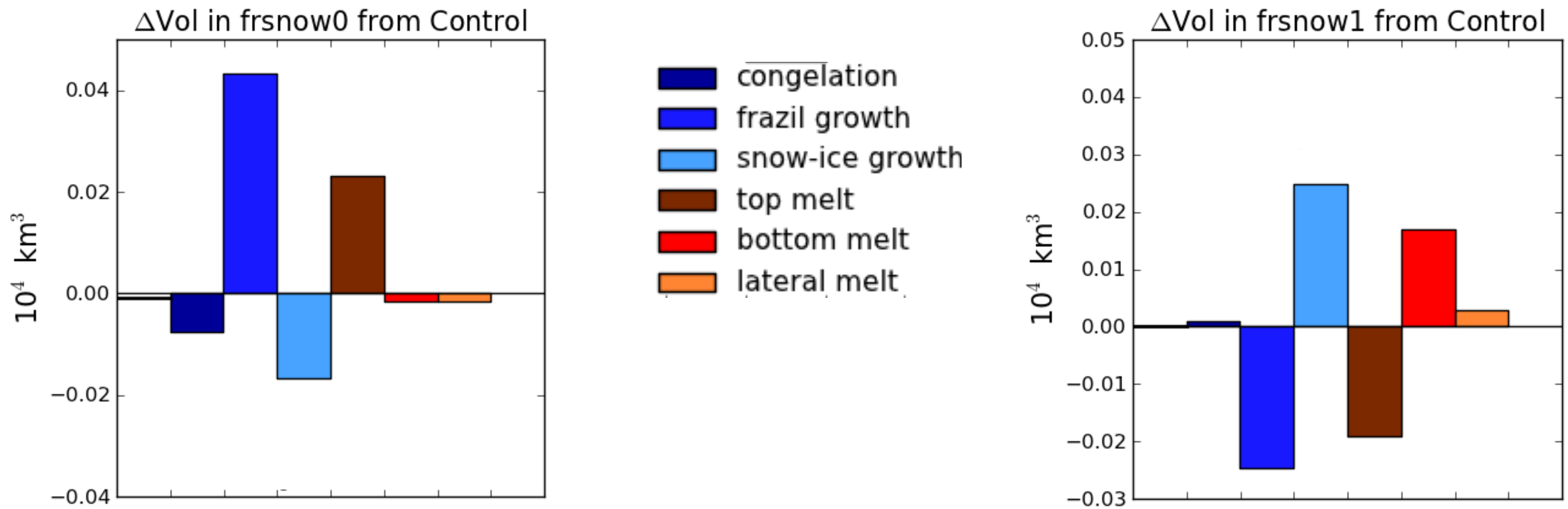
Sea ice age difference

Fsnwrdg1-fsnwrdg0



Incremental difference of the mean annual volume terms in frsnow0 and frsnow1 from Control Run

Frsnow0 **Frsnow1**



- No snow survives ridging.
- Ocean cooling due to increased snow melt.
- More heat transmitted onto sea ice pack leading increased top melting.
- Reduced snow-ice formation.
- Younger ice due to enhanced lateral growth

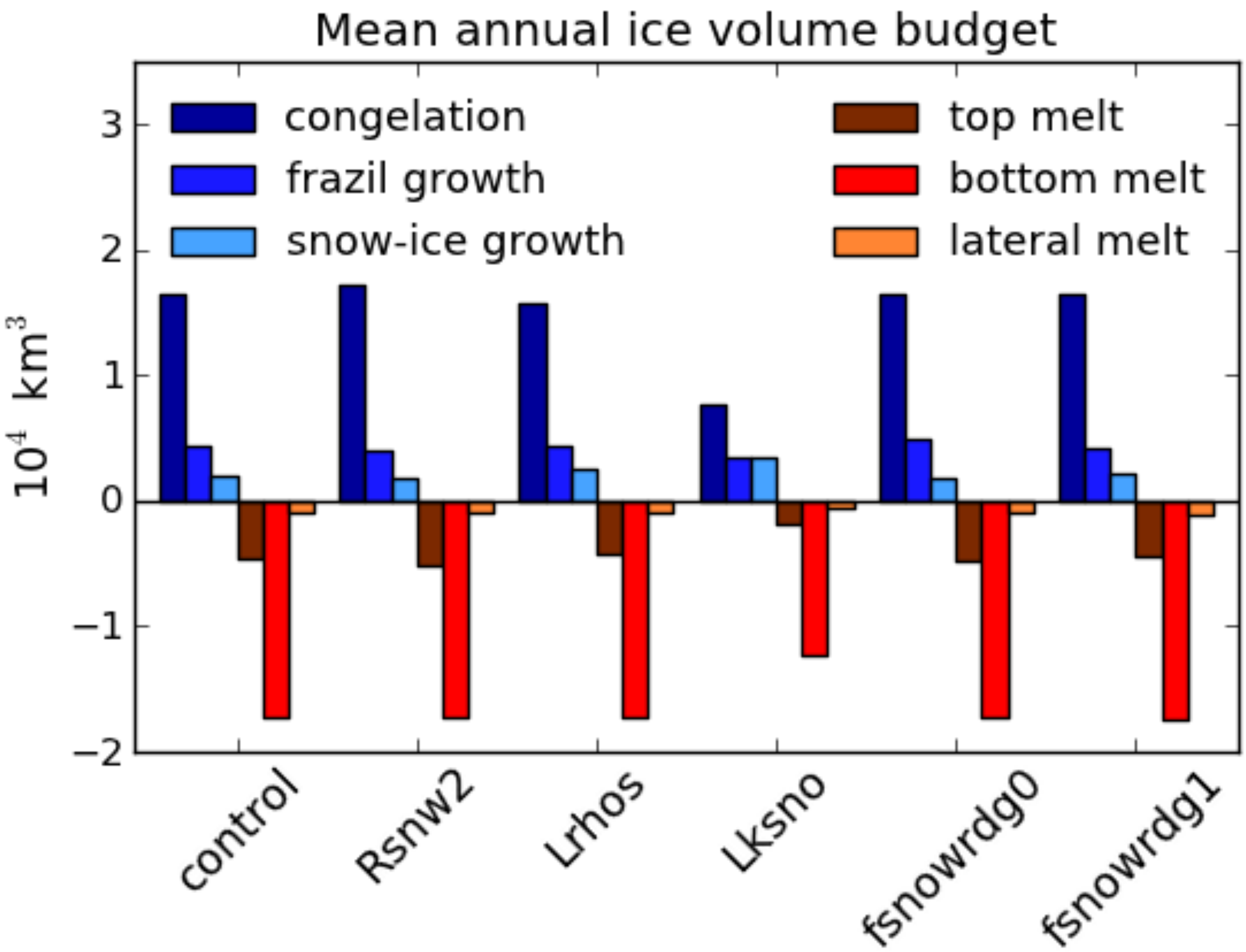
- All snow survives during ridging.
- Less snow melts in the open ocean.
- More snow available for snow-ice formation.
- Larger insulation effect.

Summary

- Sea ice age is sensitive to any change in the snow parameters examined.
- Sea ice thickness and extent are sensitive to snow grain size and thermal conductivity, but less sensitive to snow density and survival during ridging.
- Sea ice volume budget terms are sensitive to the parameters examined, but they can balance each other in some experiments (Lrhos, fsnowrdg0, fsnowrdg1).
- Other snow parameters that need to be examined include:

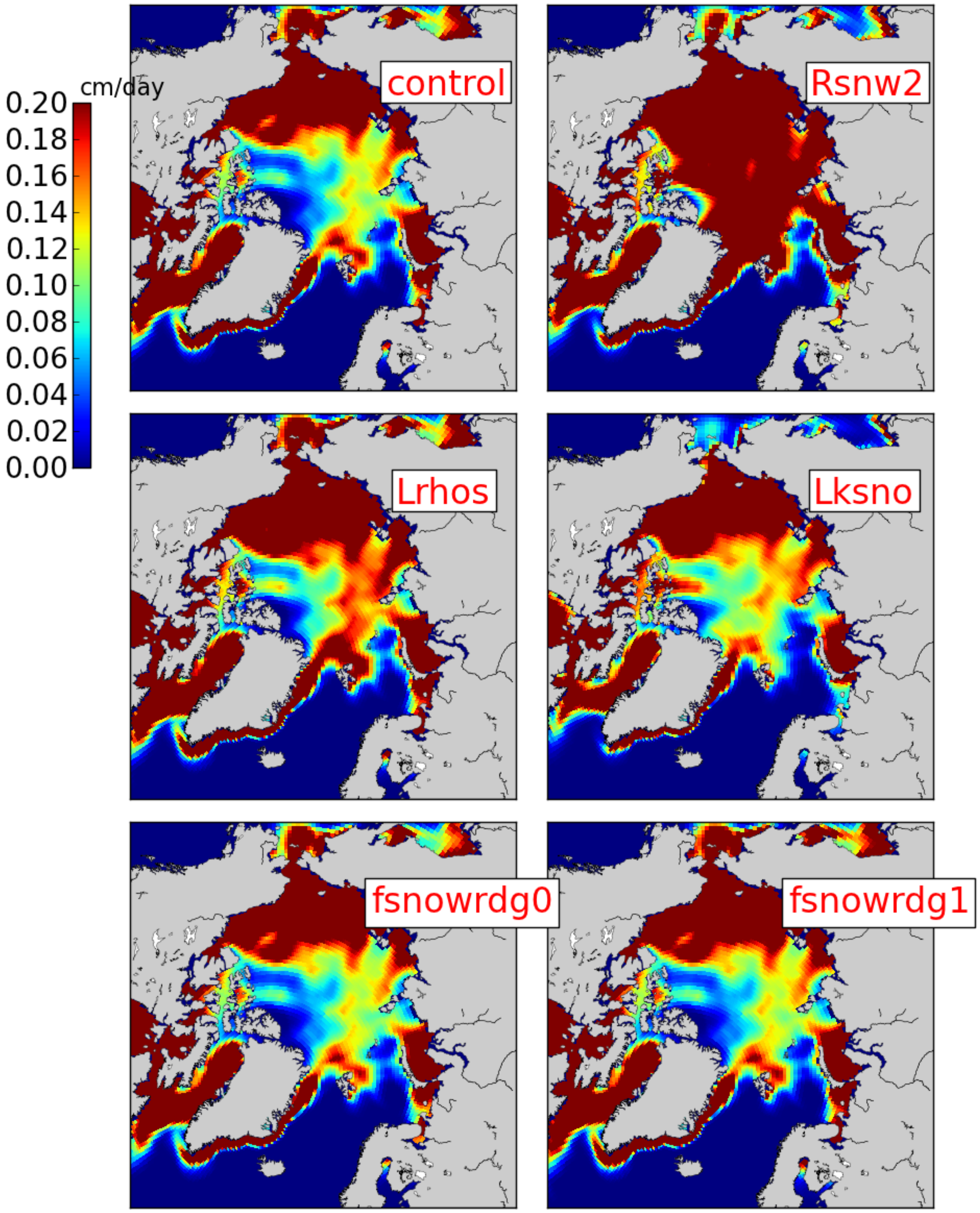
  snow depth transition to ponds, threshold for melting and non-melting snow grain sizes, transition parameter for melting to non-melting snow conditions, thickness of surface scattering layer of snow.

- Critical role of snow cover on the mas balance of ice pack.
- Parameterization of snow processes in sea ice models are uncertain.
- Sensitivity of sea ice simuations to snow processes needs to be better understood.
- Snow parameterizations are critical cause they can control the exchange of energy and freshwater between ice-ocean-atmosphere.
- What parameterziations are new in CICE5?

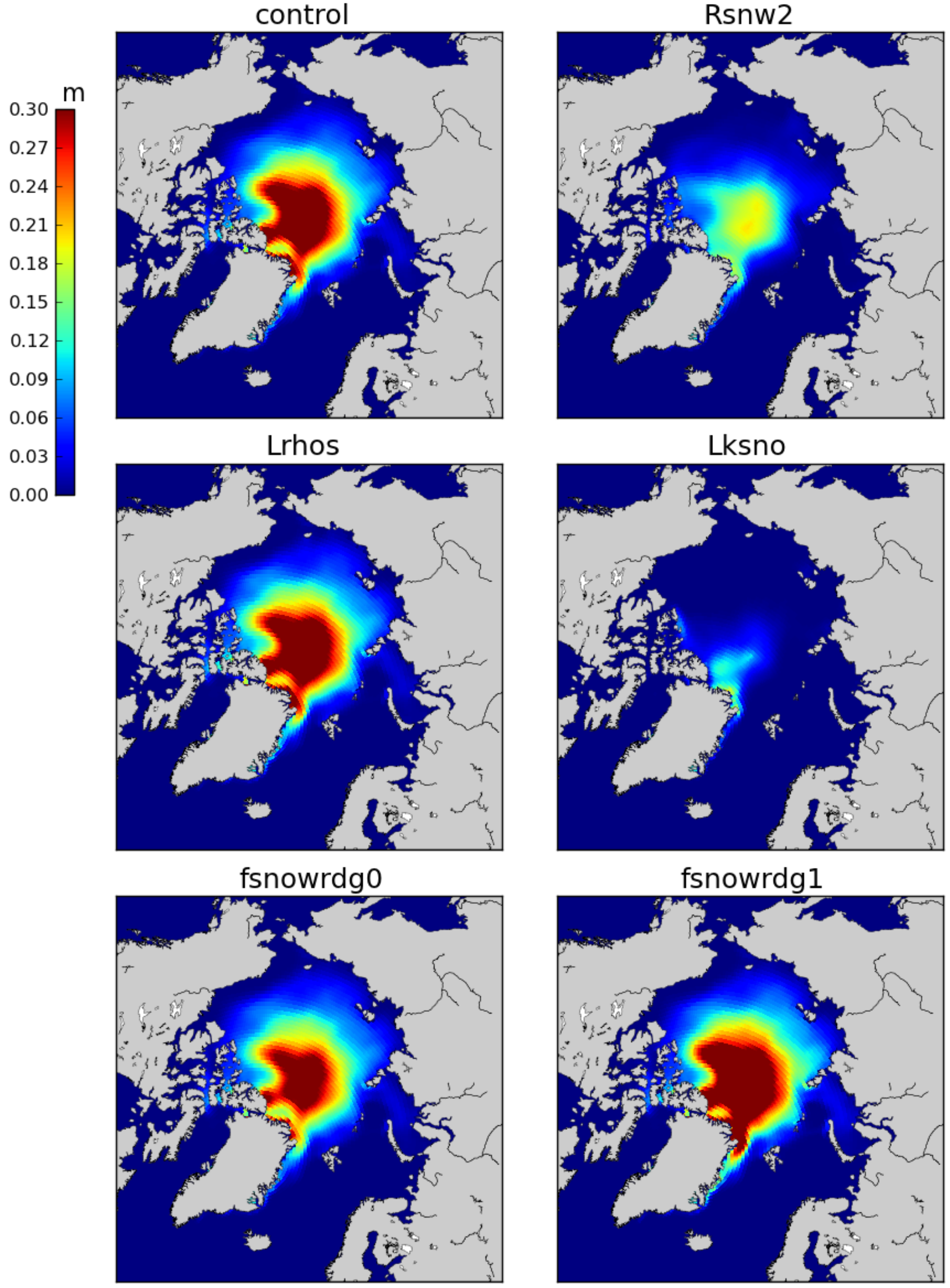


Mean annual ice volume budget
congelation
frazil growth
snow-ice growth
top melt
bottom melt
lateral melt
10^4 km^3
3
2
1
0
−1
−2
control
Rsnw2
Lrhos
Lksno
fsnowrdg0
fsnowrdg1

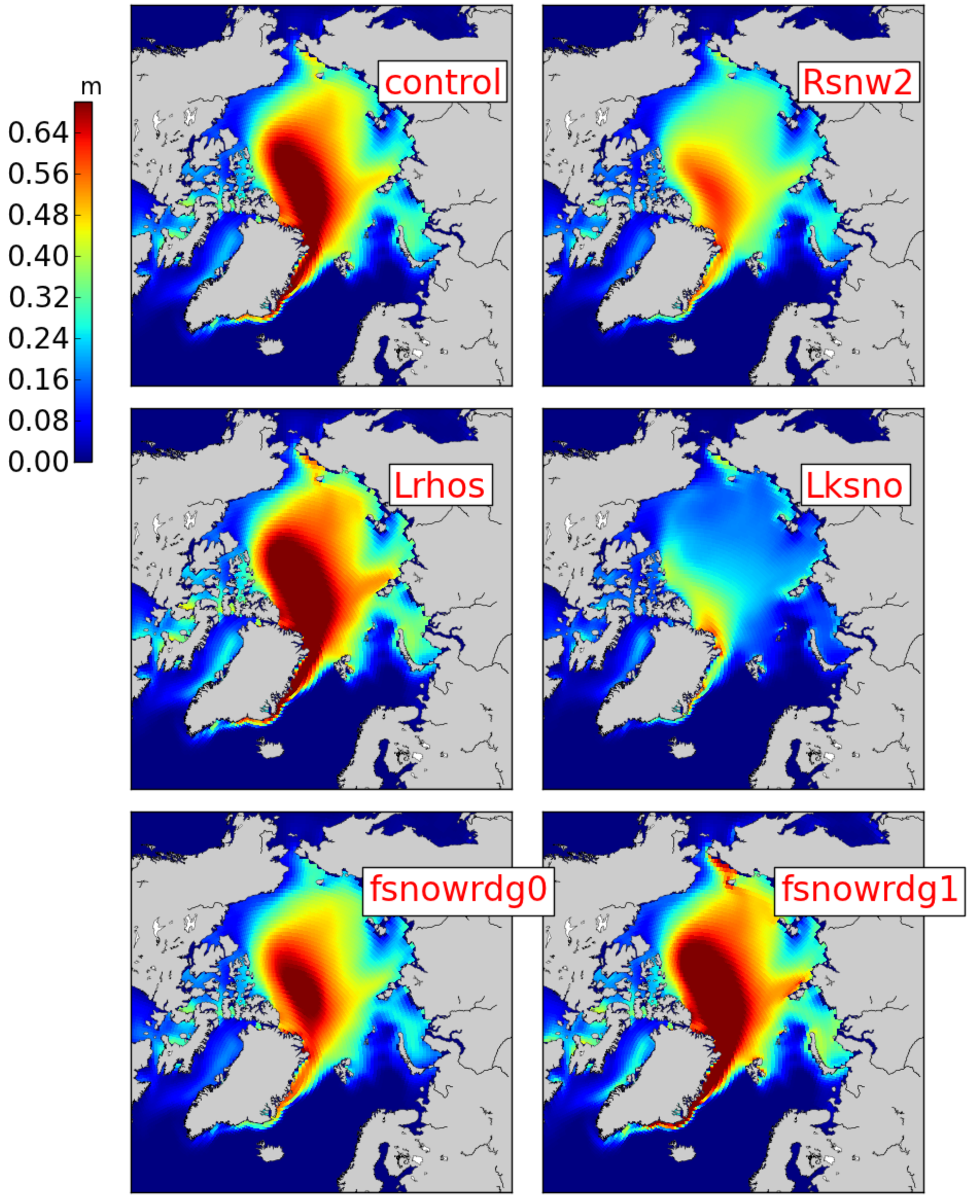
Snow melt


cm/day
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
control
Rsnw2
Lrhos
Lksno
fsnowrdg0
fsnowrdg1

Snow depth (Sep)



Snow depth (May)



Snow melt (May)