Snow on Sea Ice

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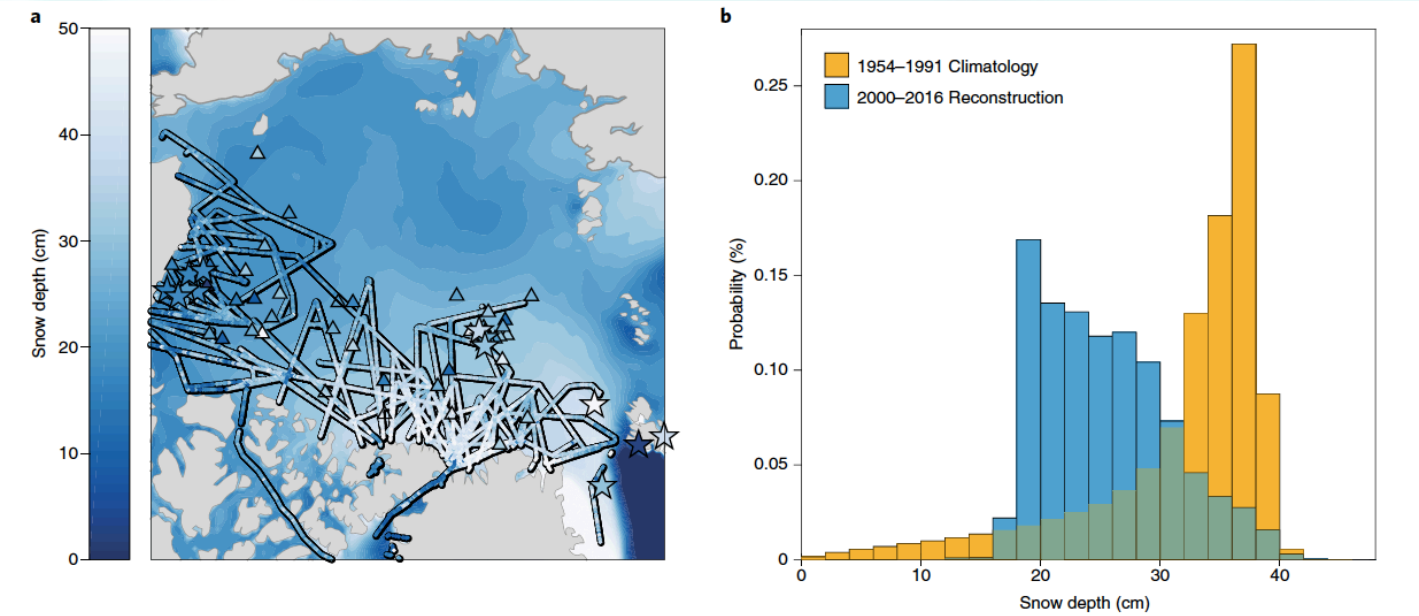
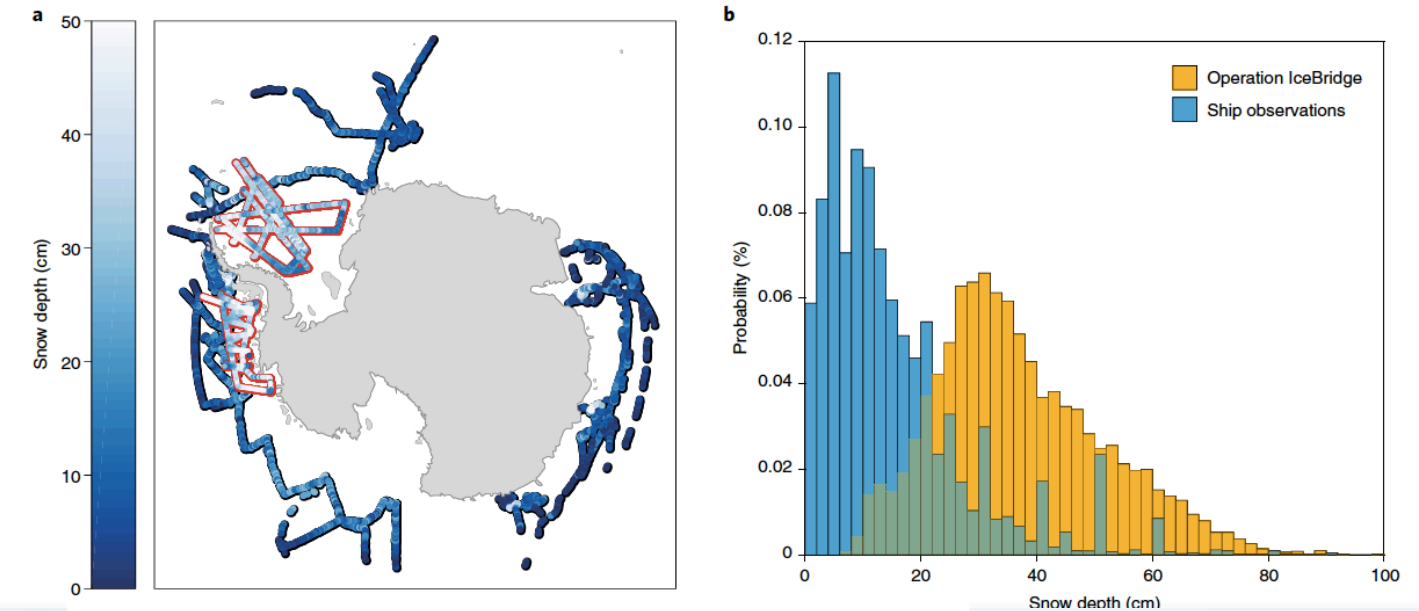
Snow in the Changing Sea Ice System

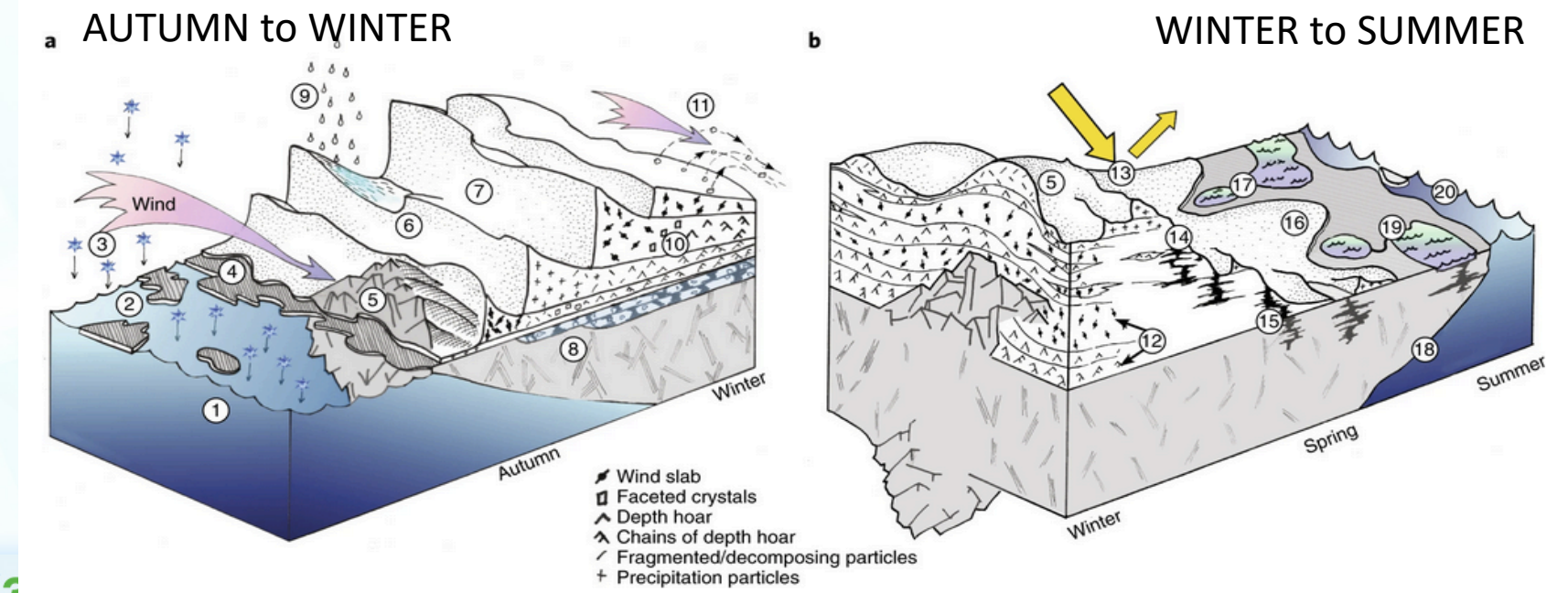




Webster et al, 2018. Nature Climate Change

- AUTUMN-WINTER: Snow fall, wind redistribution + ice deformation, snow-ice formation and flooding of the ice surface, metamorphic snow grain/density layers ➔ enhanced heterogeneity

- WINTER-SUMMER: Snow heterogeneity is keyed to ice deformation state, depth hoar (good insulator, large grain size) and wind slab (dense, hard, poor insulator), meltwater percolation coarsens grains, flushes sea ice, refreezes, melt-pond forms adjacent to dunes ➔ dynamic surface albedo



Webster et al, 2018. Nature climate change

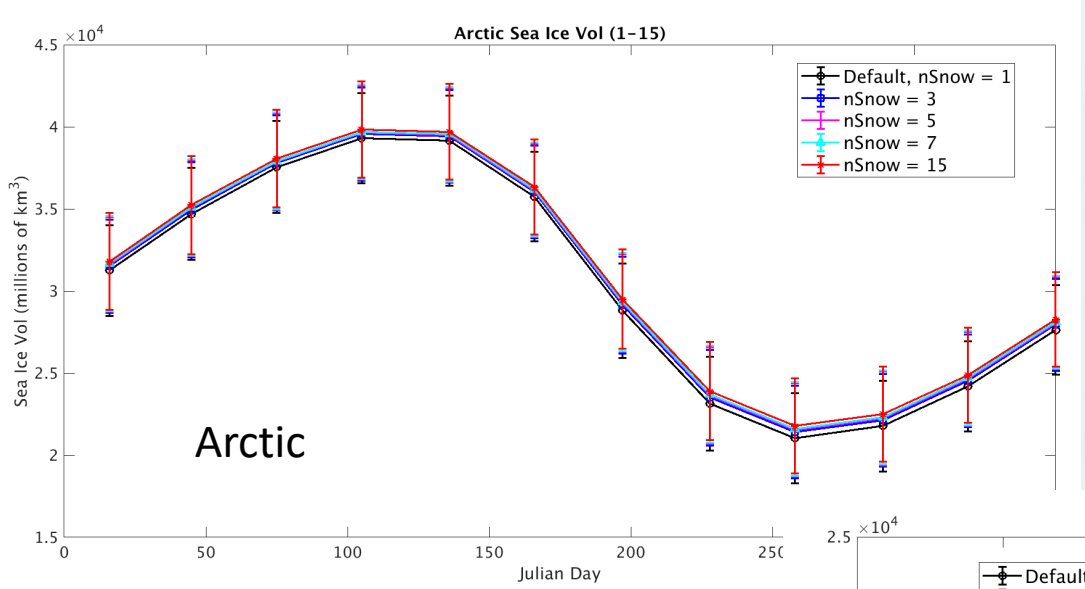
MPAS-seaice v1

- 1 snow layer for thermodynamics
- 2 radiation layers
  - Includes snow, bare ice and pond fraction
- Snow may fall in leads but no wind redistribution
- Fixed snow density
- Optical properties depend on effective snow grain radius, locally parameterized (no memory) as
  - If Tsfc <= -1.5^{o}C, Rsnw = 125 um
  - If Tsfc >= 0°C, Rsnw = 1500 um
  - For -1.5 < Tsfc < 0, linear increase (tunable parameter R_snw = 1.5).

MPAS-seaice v2

- Increased number of snow layers in thermo and radiative calculations (5 and 6, respectively)
- Dynamic effective snow grain radius (snow pack has memory). Adds 3 snow tracers
  - Temperature gradient metamorphism (depth hoar formation, same as land model snow)
  - Snow ages (grain size increases) with liquid content from rain and melt .
- Wind redistribution: 30%, 30%sw, ITDsd, ITDrdg
- Evolve snow density but do not feed back into physics (no wind slab or density heterogeneity). Based on wind slab production and liquid/ice content *

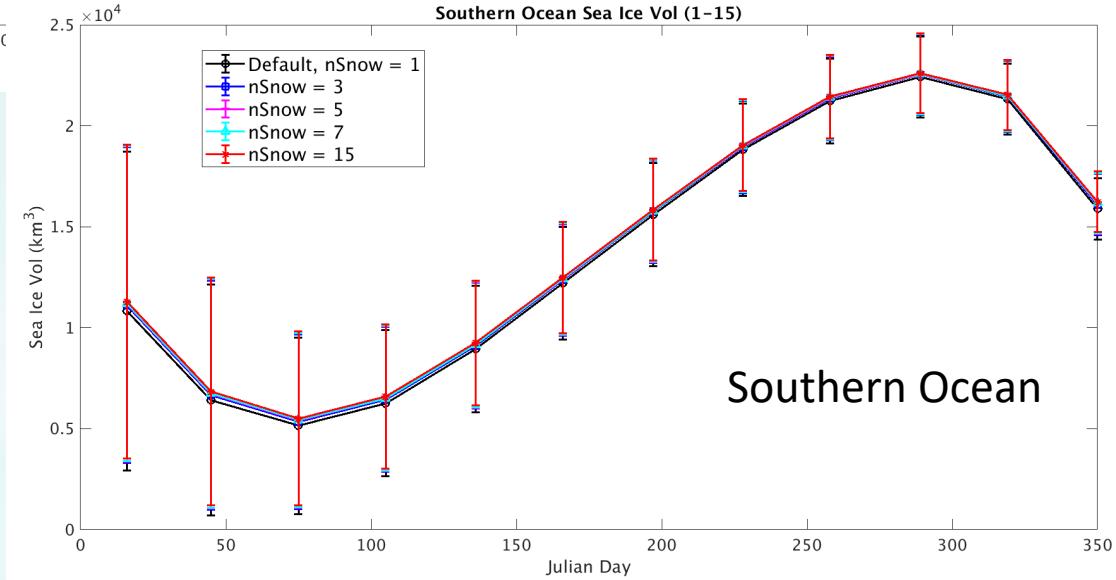
Sea Ice Volume

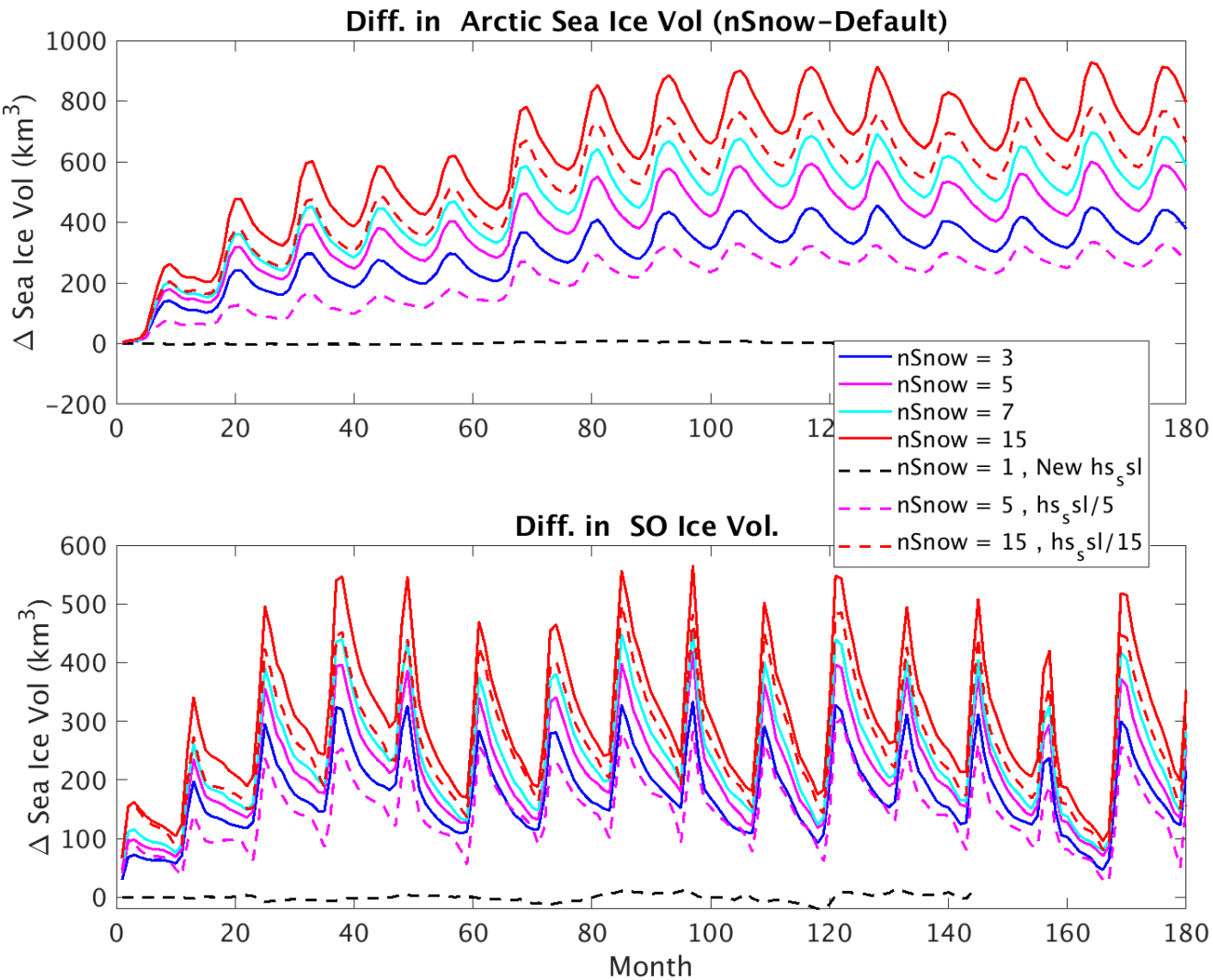


Changing the number of Snow Layers

Default is nSnow = 1

Sea Ice Volume (years 1-15 of JRA-55)



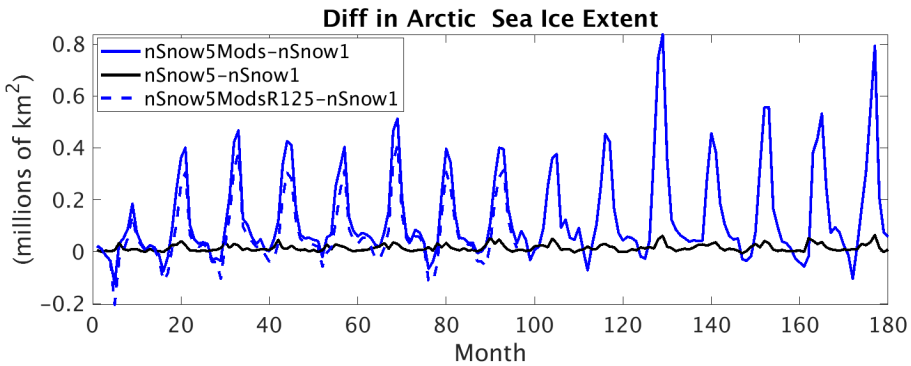


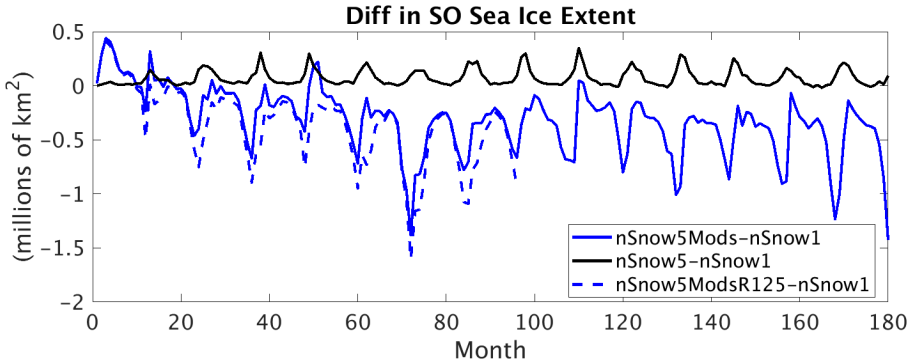
1. Increase Ice volume with increasing number of snow layers (nslyr).

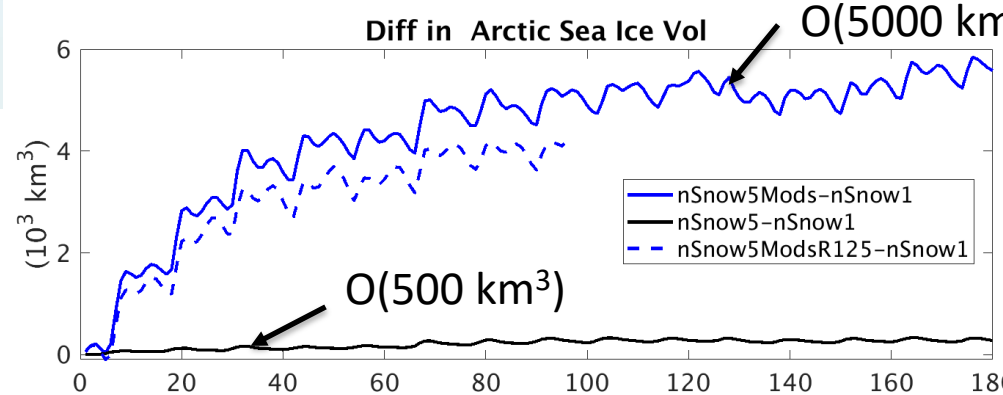
2. Evaluation of the snow surface layer (SSL) in the radiation calculation is dependent on nslyr

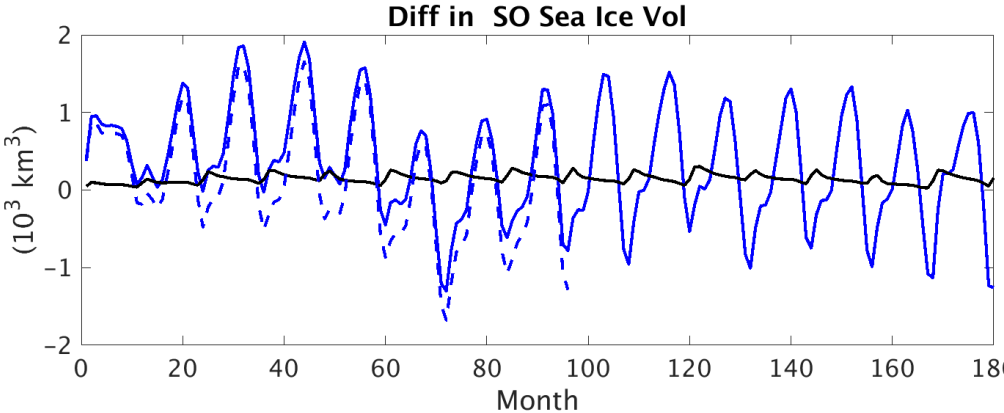
Dashed lines show SSL scaled by nslyr

How do changes from snow layer number (black line) compare with changes from improved physics (blue lines)?

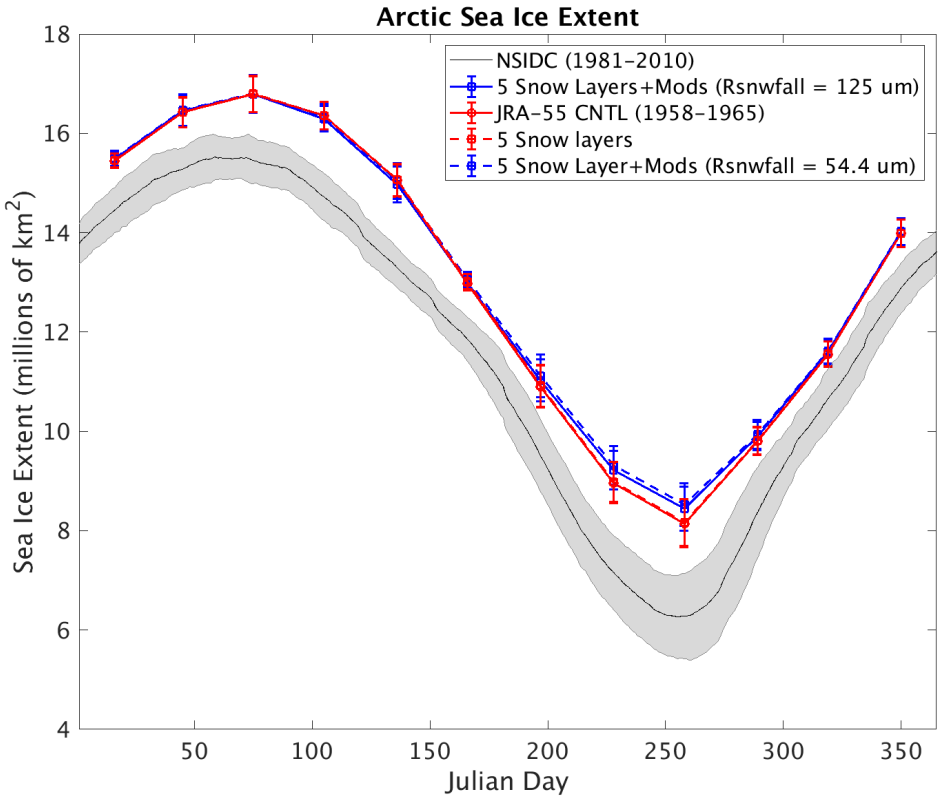


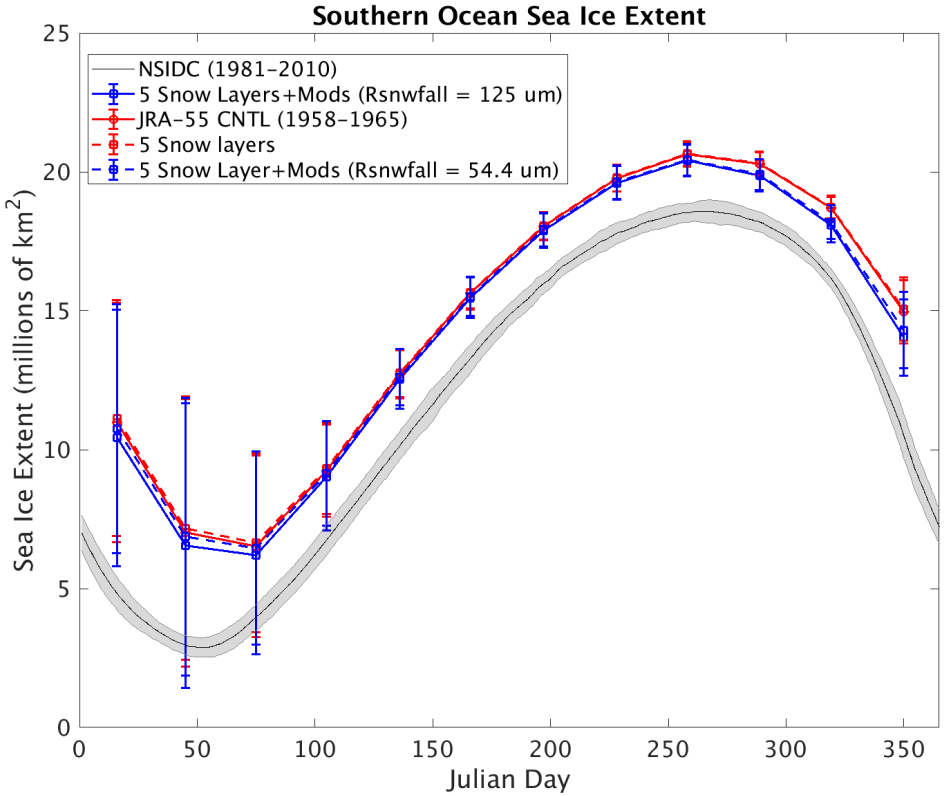




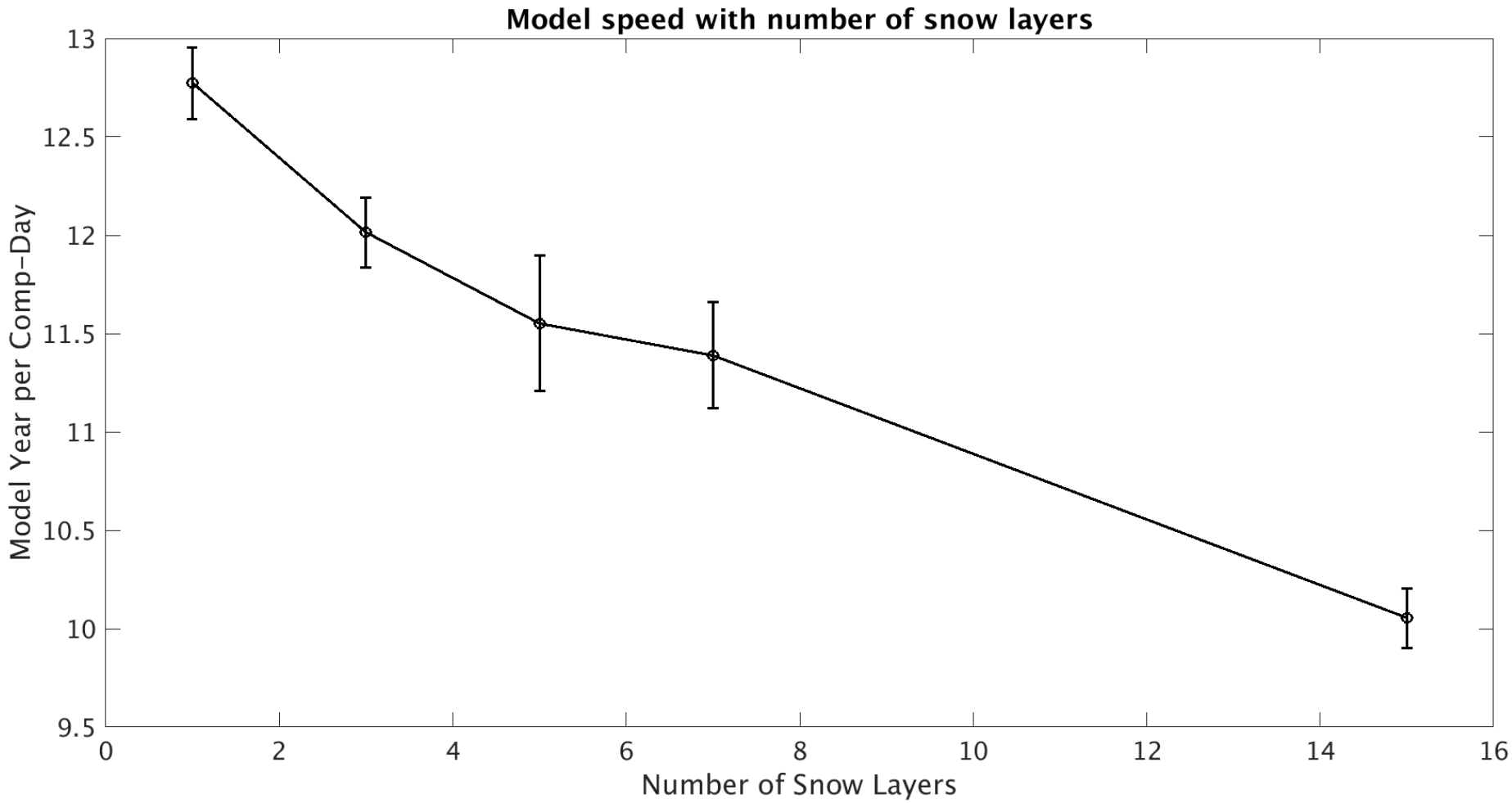


Sea Ice Extent

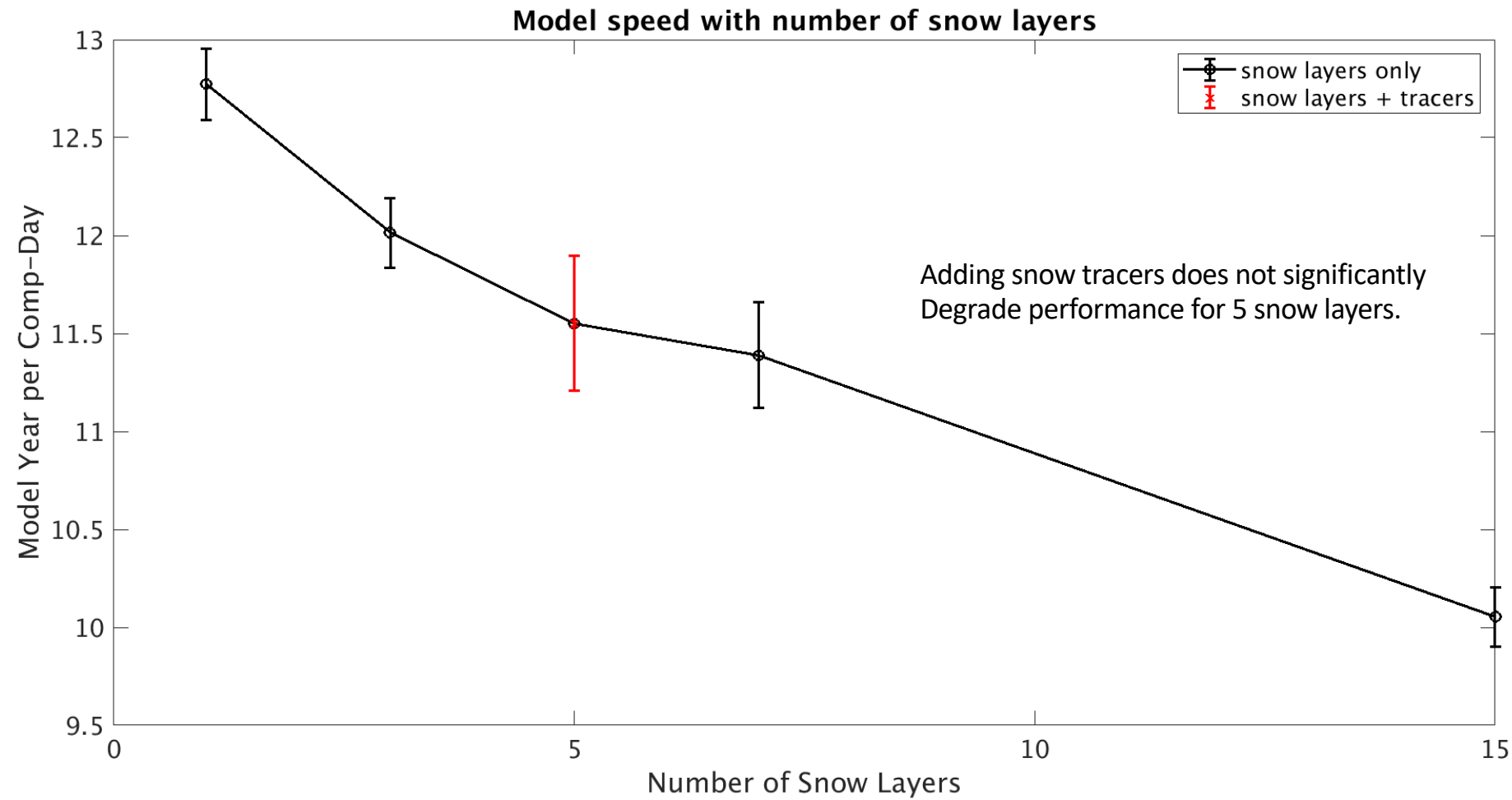




Computational Expense



Computational Expense

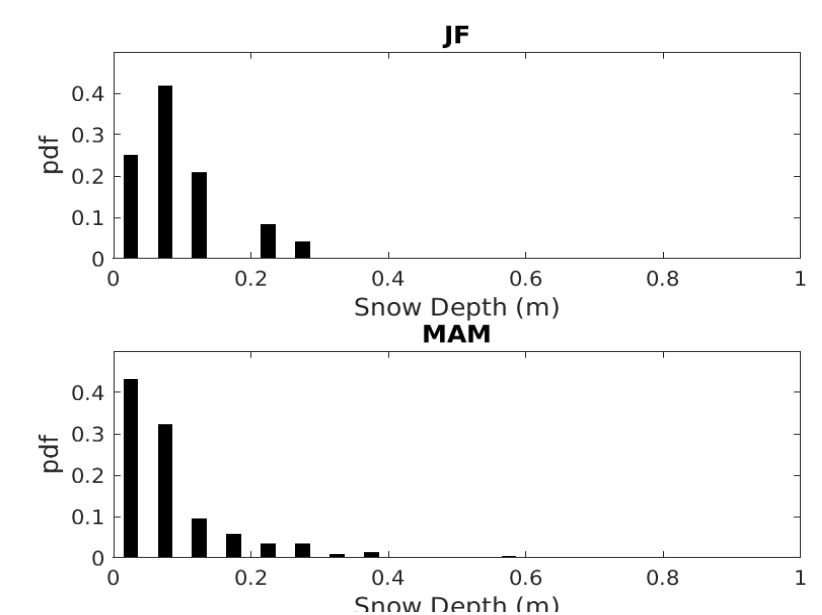


Simulation Experiments for Snow Redistribution and Aging (G-CASE)

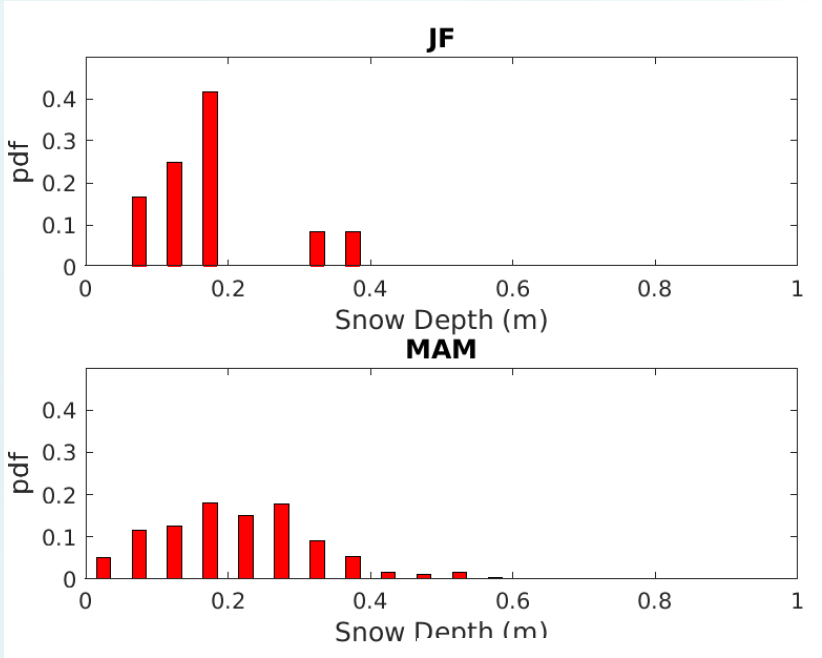
- JRA-55 with original snow model (nsnowlayers = 1). v1
- JRA-55 with all snow mods (nsnowlayers = 5, rsnw_fall = 125 um) + 30% rule. 30%. (Sturm and Holmgren 2001)
- Branched from year 25 of CNTL-30%.
  - all snow mods + 30% rule with shortwave Feedback. 30%sw
  - All snow mods + snow redistributed among ice categories based on wind speed, density, and standard deviation of ice thickness distribution ITDsd. (Lecomte et al. 2015; LIM)
  - all snow mods + snow redistribution among level/ridged. ITDrdg
  - all snow mods but no snow redistribution. NONE
  - all snow mods but rsnw_fall = 54.526 um and ITDrdg. rsnw54ITDrdg

Russian Drift Data (1983-1990s)

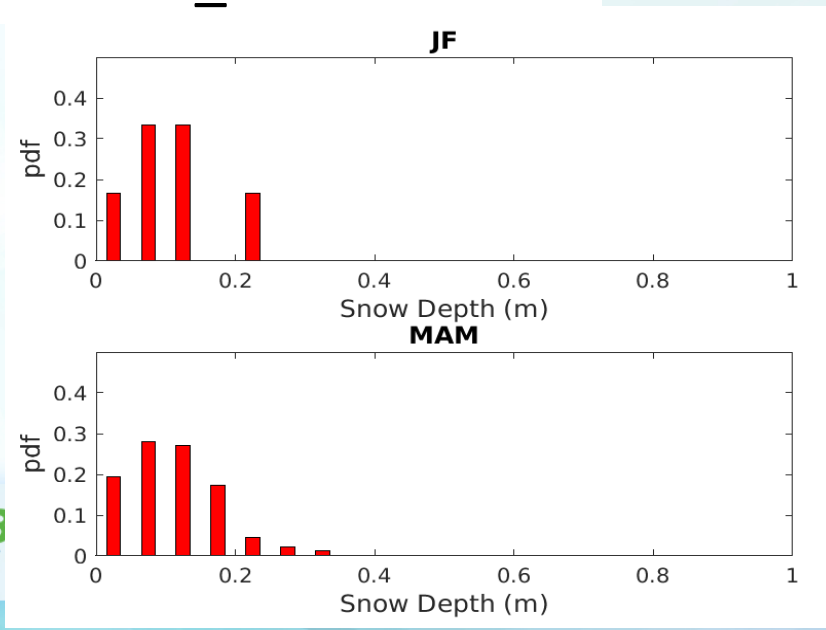
OBS



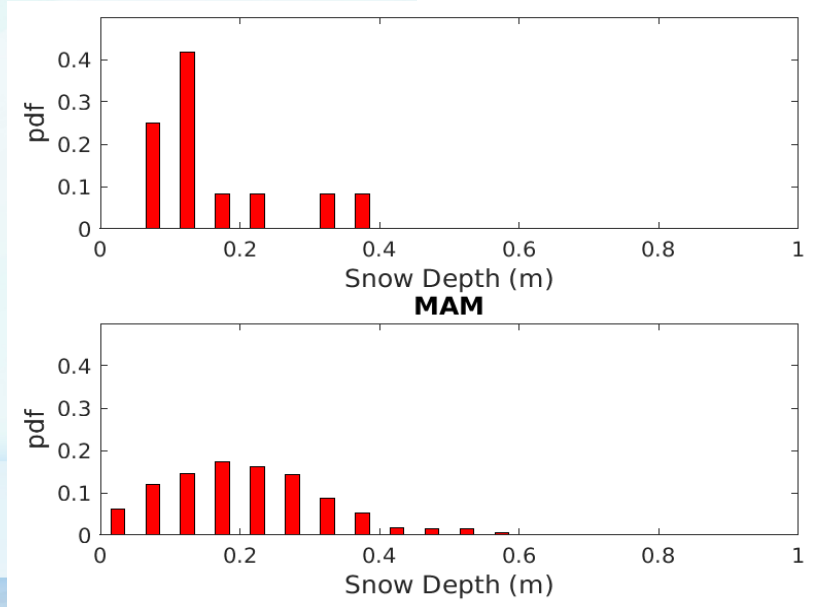
v1

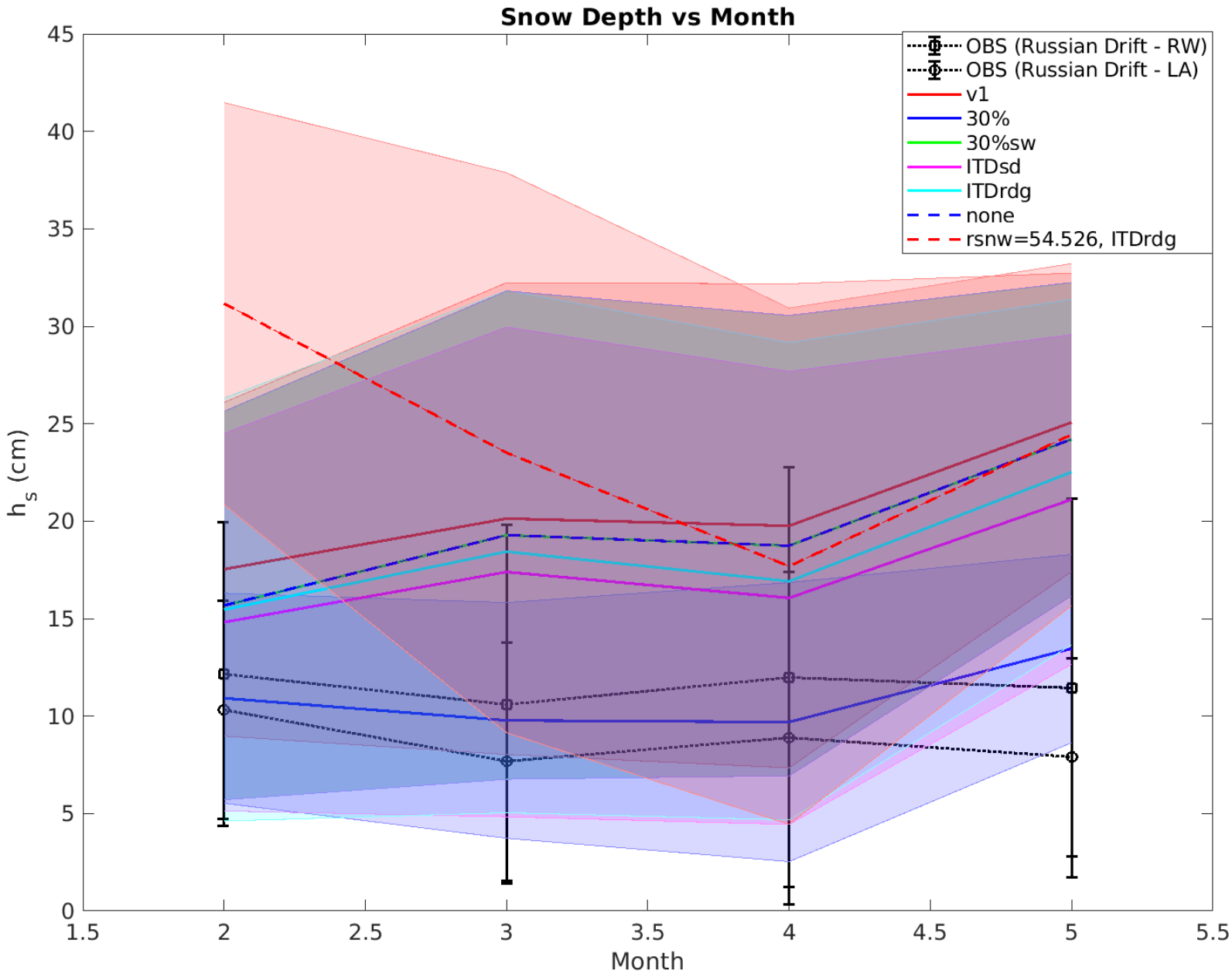


30% + rsnw_fall = 125 um

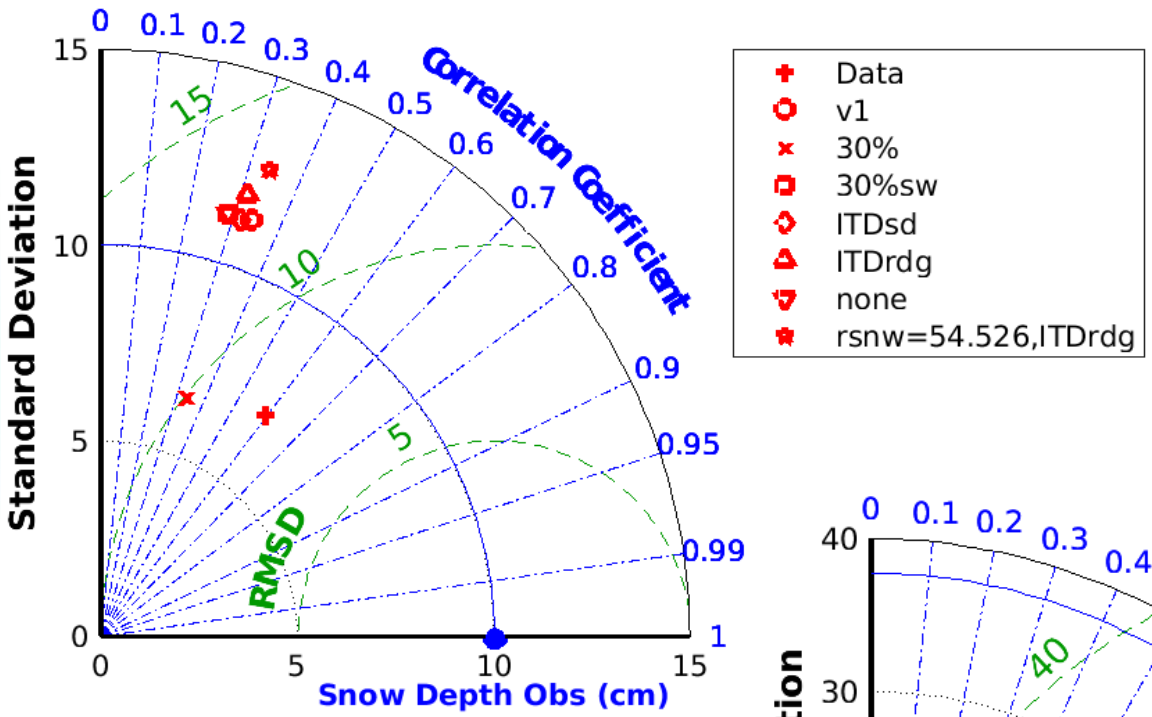


rsnw_fall = 125 um

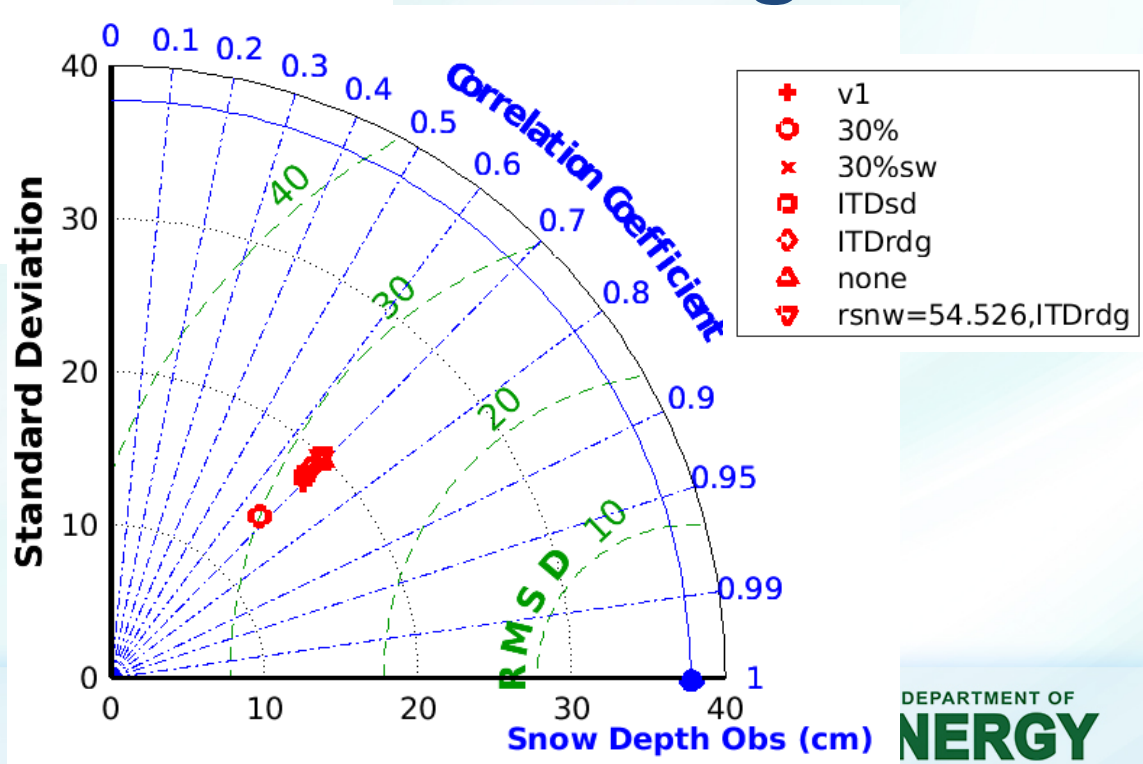



Snow Depth vs Month
OBS (Russian Drift - RW)
OBS (Russian Drift - LA)
v1
30%
30%sw
ITDsd
ITDrdg
none
rsnw=54.526, ITDrdg
h_s (cm)
Month
0
5
10
15
20
25
30
35
40
45
1.5
2
2.5
3
3.5
4
4.5
5
5.5

Russia Data

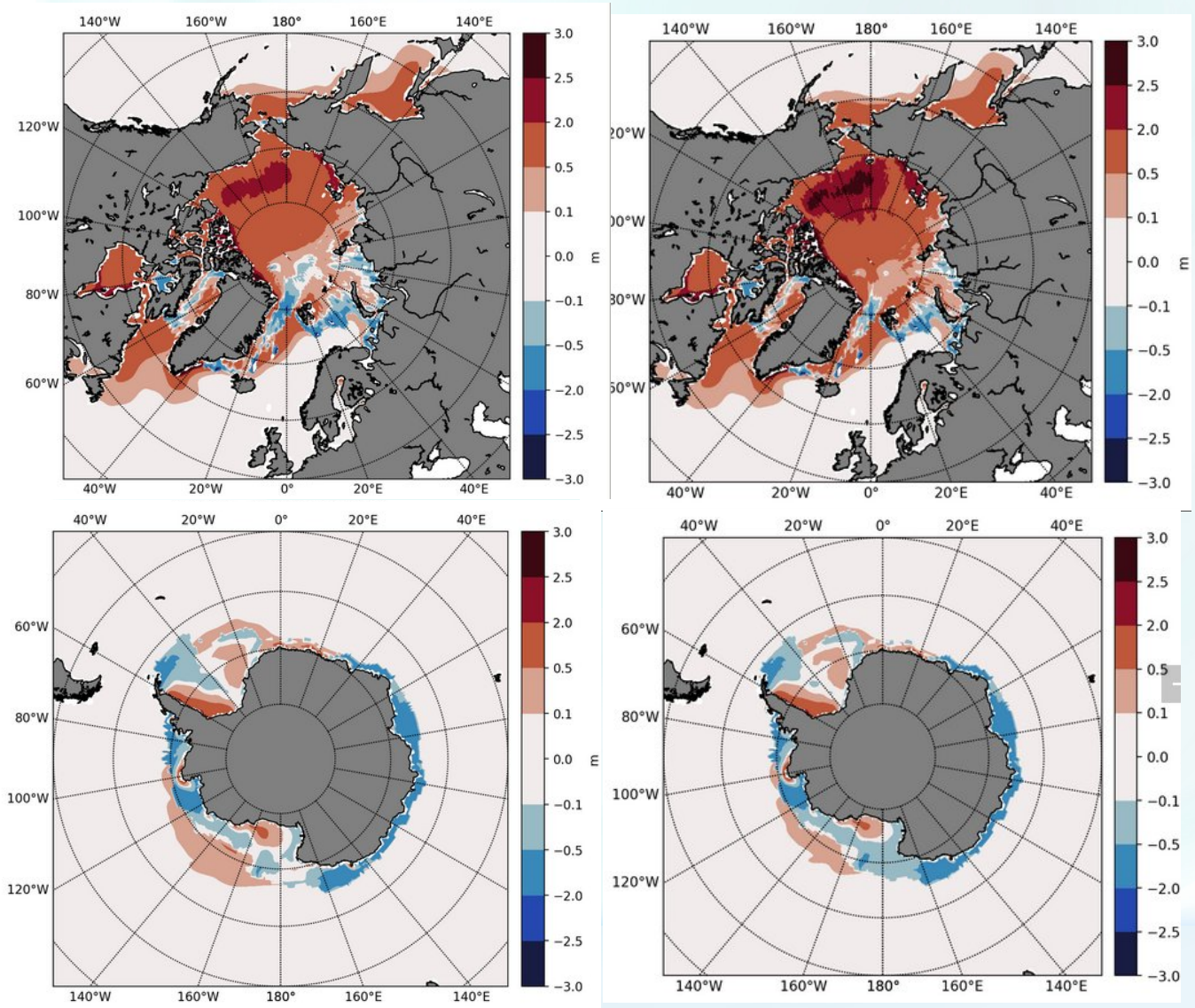


IceBridge Data



Sea Ice Thickness, Model – Obs (FM; yrs 1983-2002 of JRA-55)

E3SM.v1 **v2 SnowMods**



Preliminary results indicate GCASE SnowMods produce

Overall thicker NH Sea ice and generally more extensive, *though not in early spring*

Less extensive SH sea ice, though *thicker* during maximum extent and *thinner* during minimum.

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