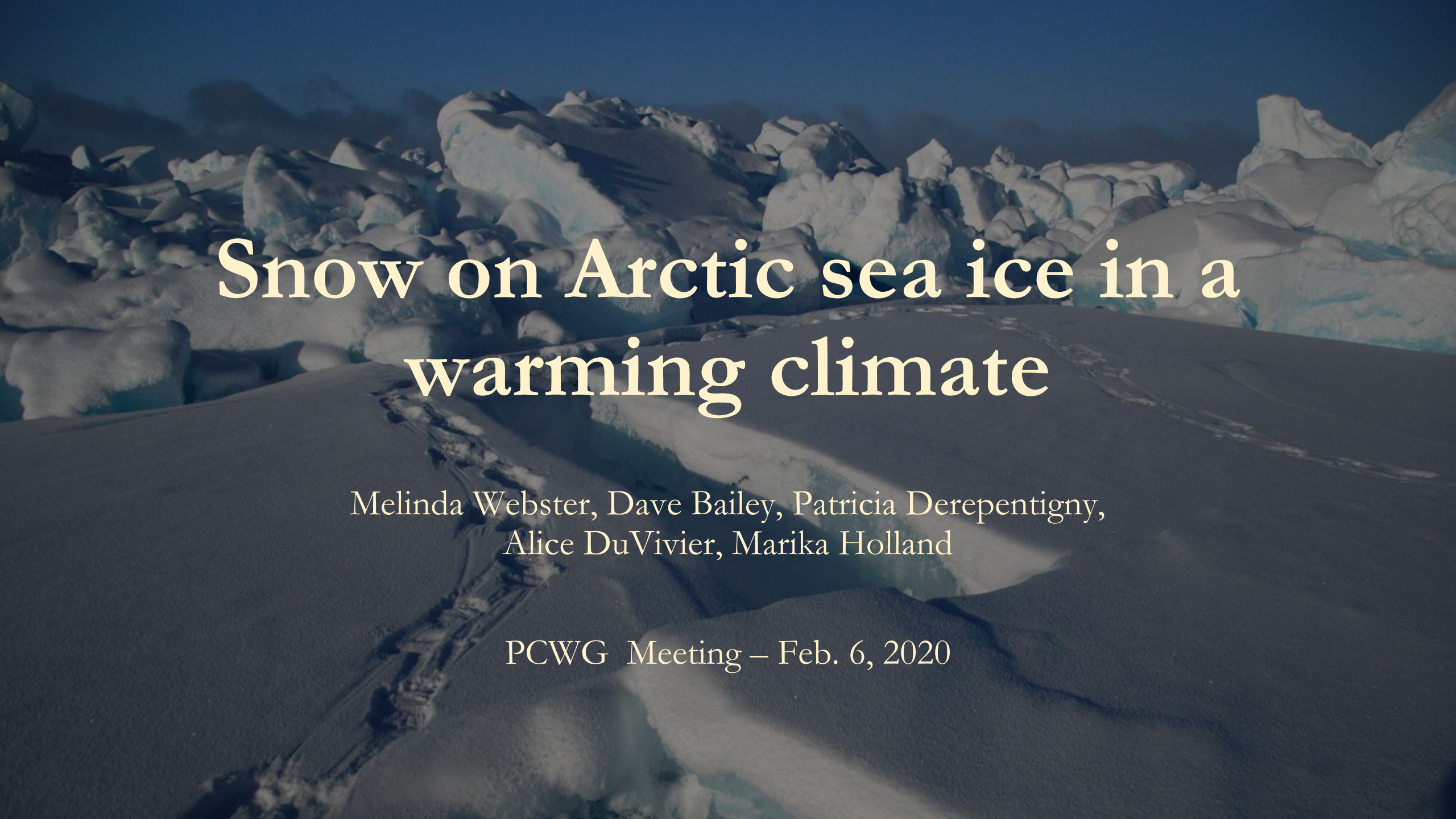
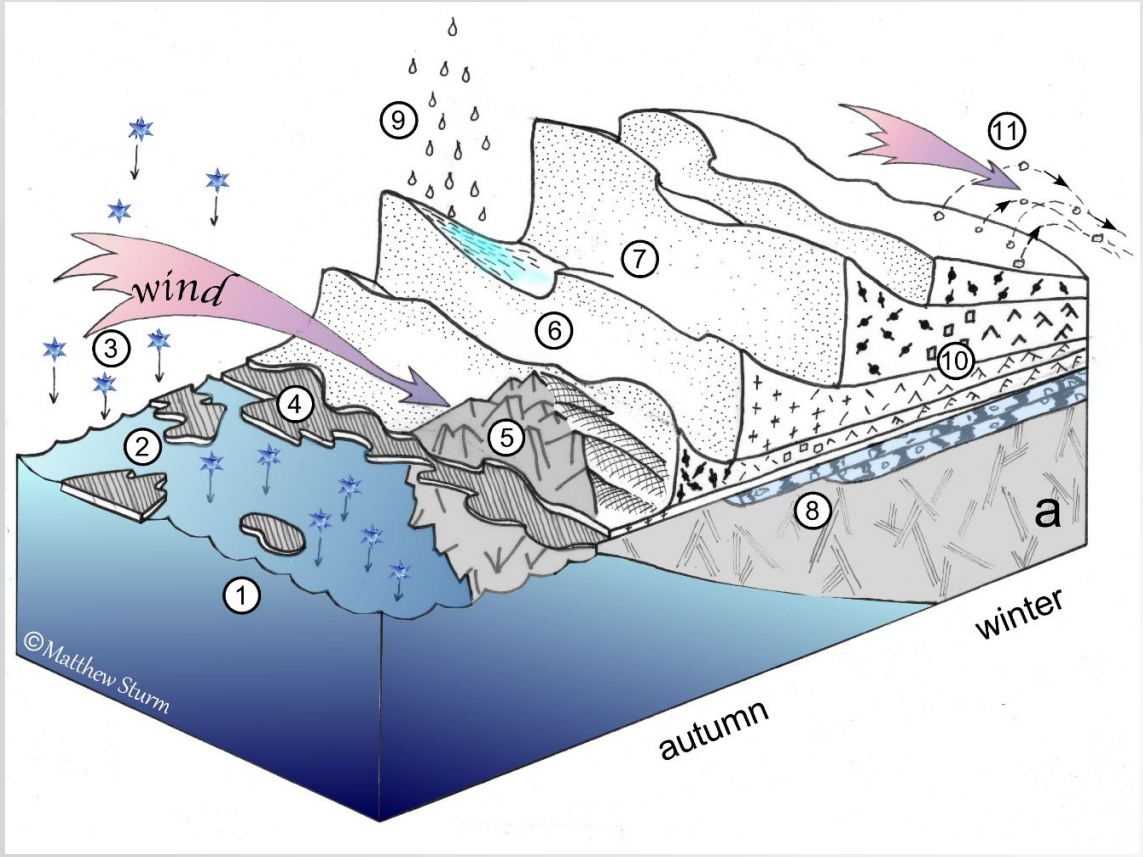
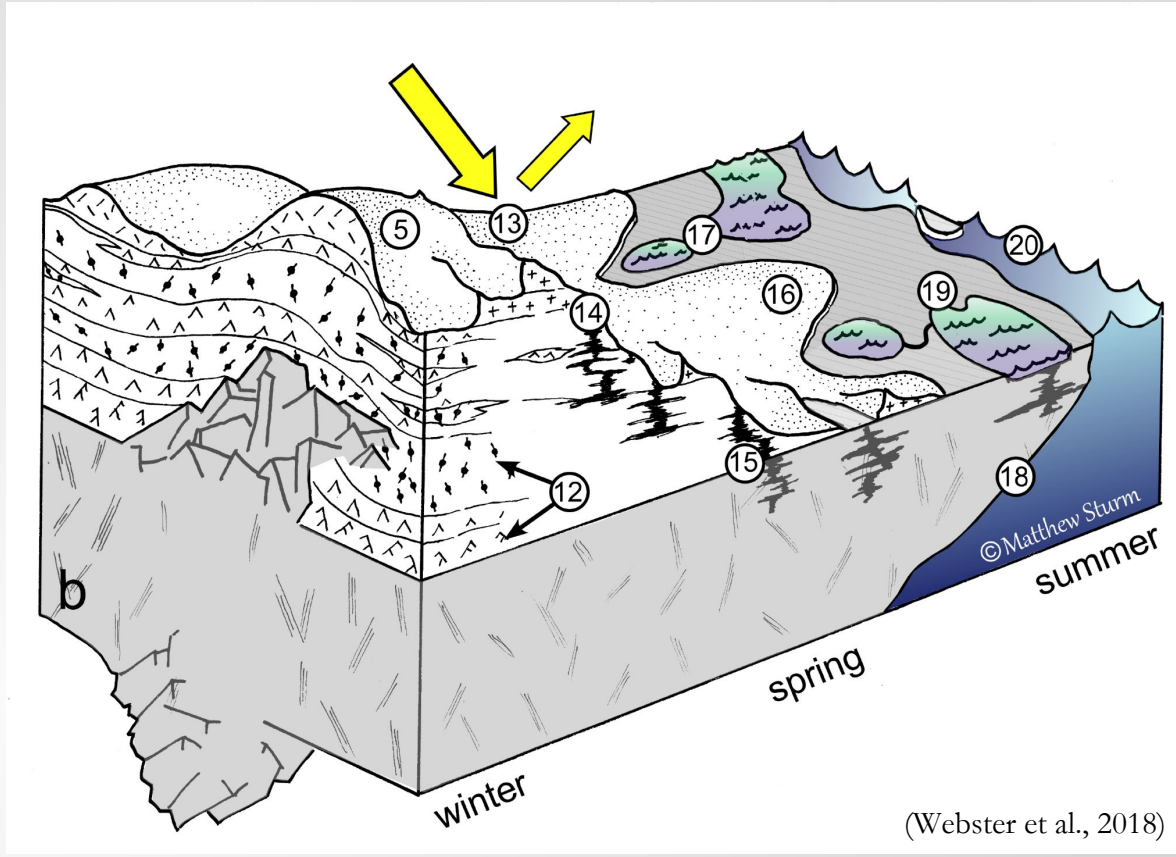


Snow on Arctic sea ice in a warming climate

Melinda Webster, Dave Bailey, Patricia Derepentigny,
Alice DuVivier, Marika Holland

PCWG Meeting – Feb. 6, 2020





(Webster et al., 2018)

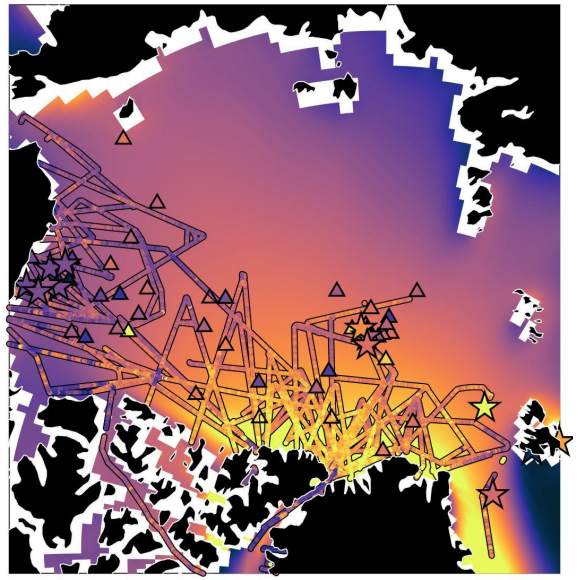
CESM simulates:

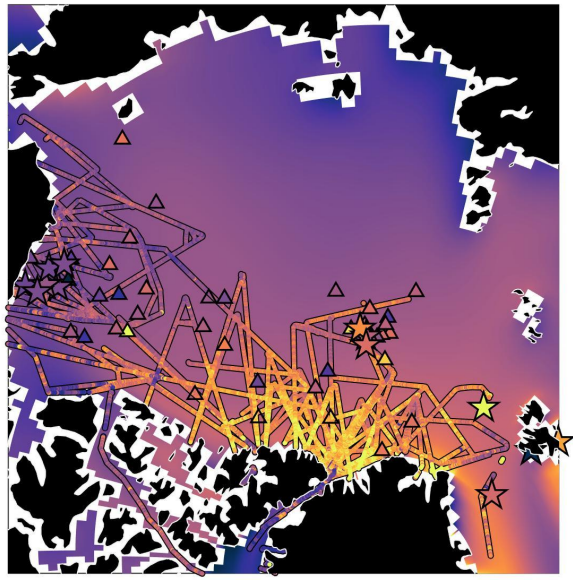
- (#1) Effects of timing of sea-ice formation.
- (#2) Snow accumulation.
- (#8) Snow lost to snow-ice formation.
- Snow lost to ridging (not shown).
- Sublimation and condensation (not shown).

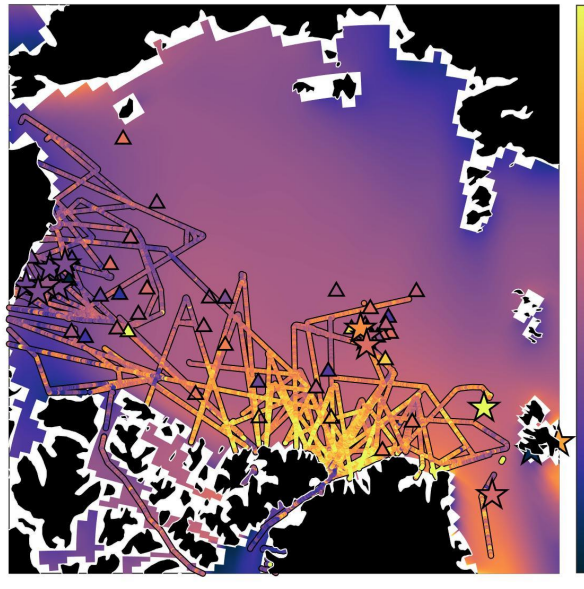
CESM1-CAM

CESM2-CAM

CESM2-WACCM



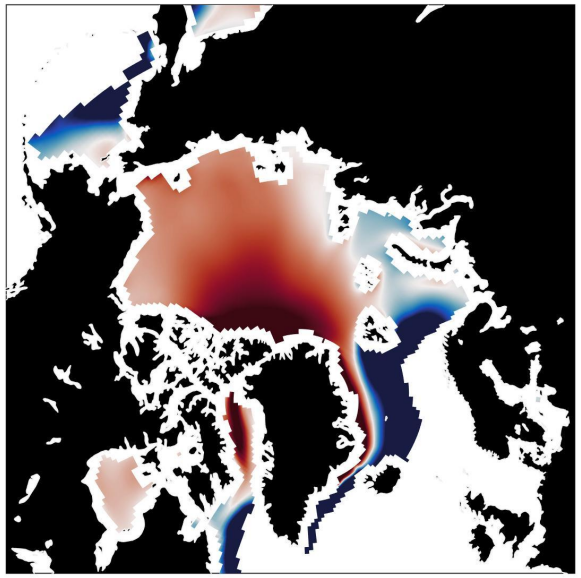


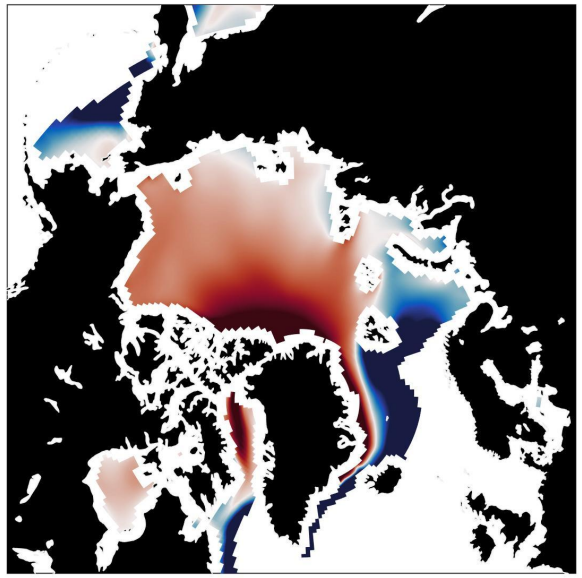


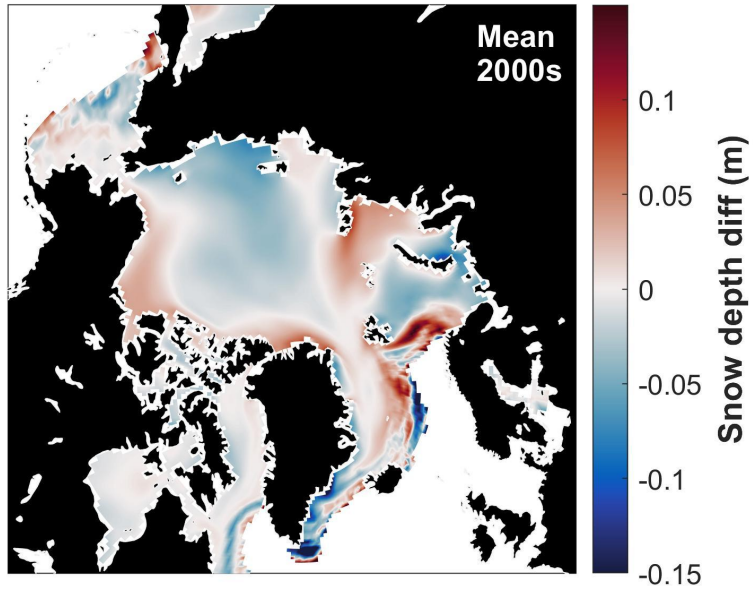
C1CAM – C2CAM

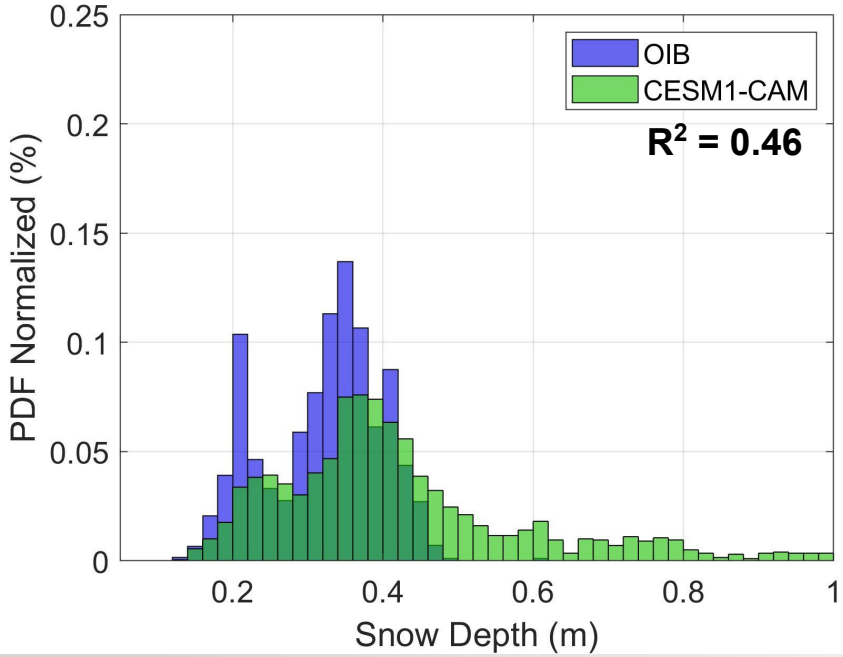
C1CAM – C2WACCM

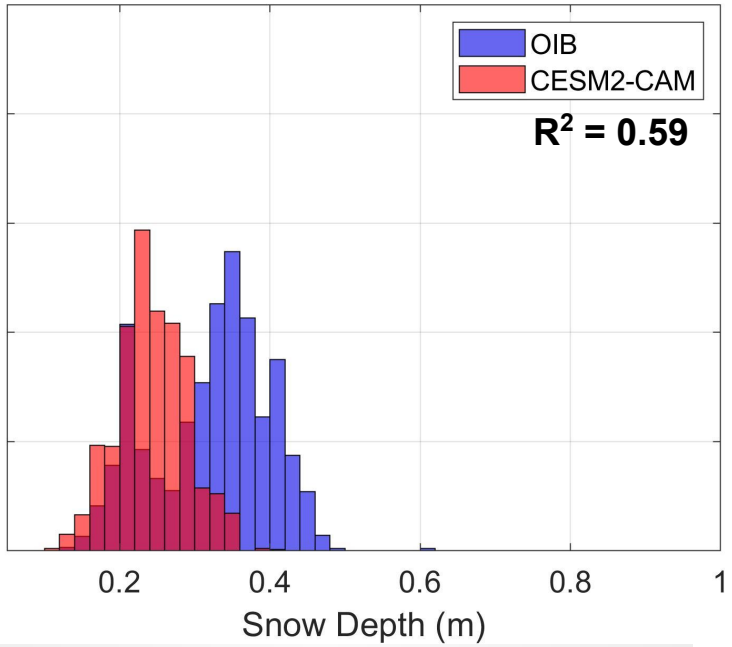
C2CAM – C2WACCM

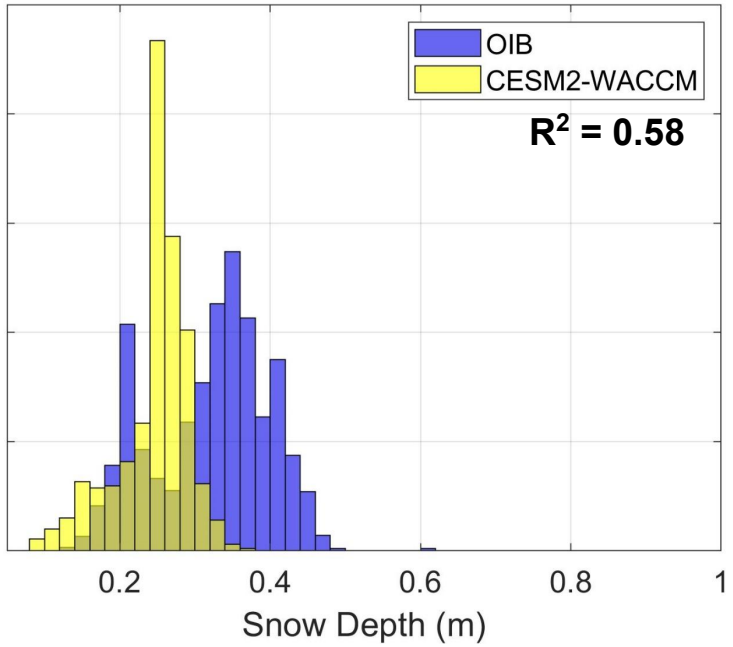




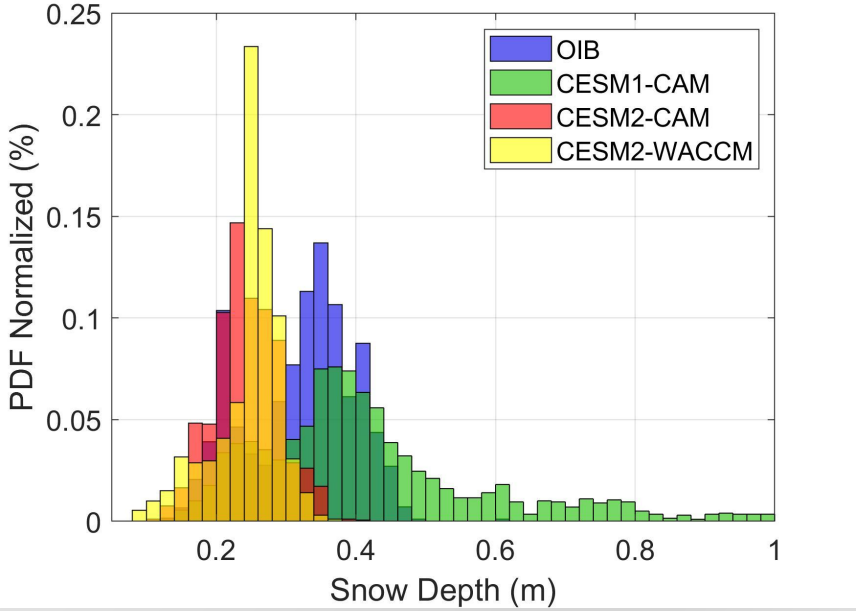




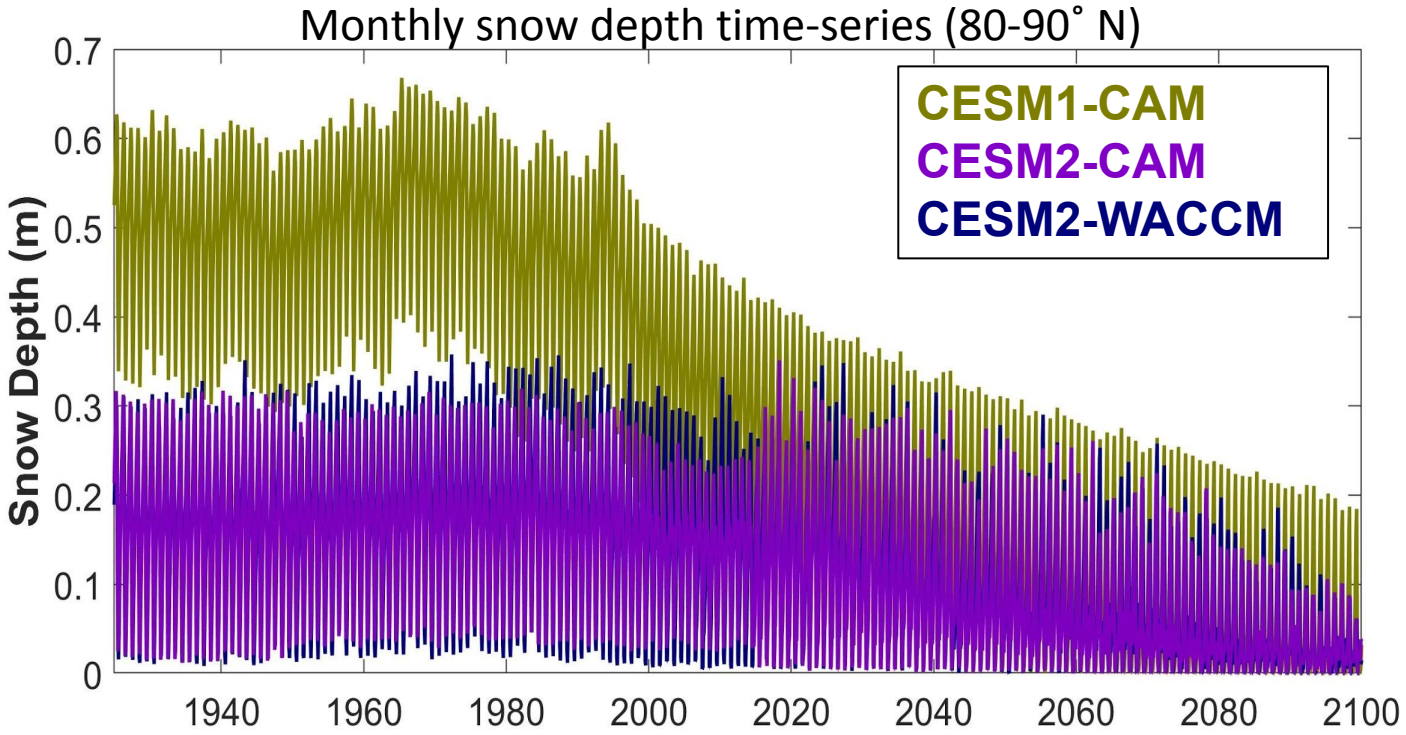


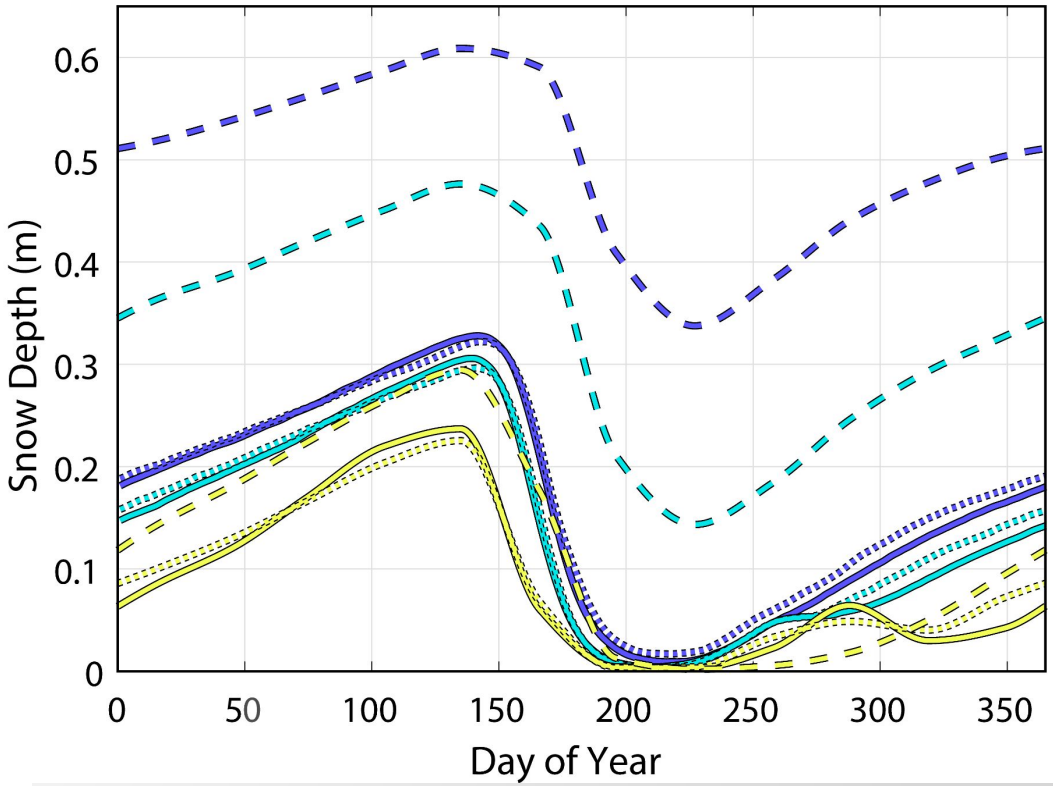


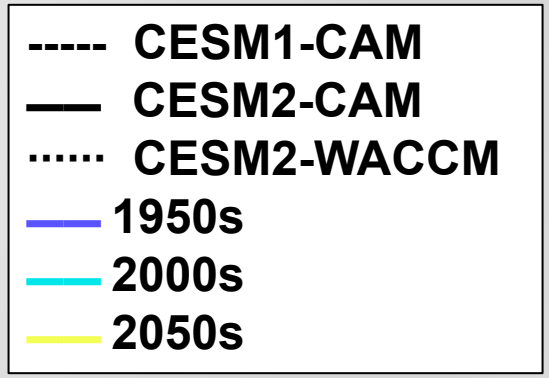
- Ensemble mean of 2000s.
- OIB data averaged where n > 100 in a grid cell.
- Doesn't matter which "n" used or taking larger areal averages…
  - CESM1 has bimodal distribution and deeper snow.
  - CESM2 underestimates snow and misses bimodal peak at ~35 cm.



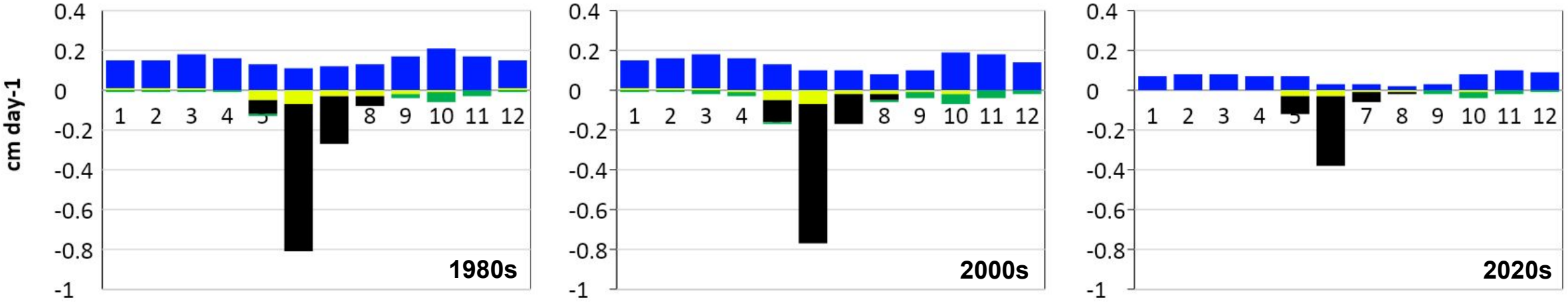
- There are **large** differences in snow coverage for 1920-2100 between CESM1 & CESM2!
  - Stronger spring melt in CESM2 (CAM slightly stronger than WACCM).
  - Snow-free summers (CAM summers less snowy than WACCM summers).
- Differences largely result from differing sea-ice conditions.







CESM2-CAM

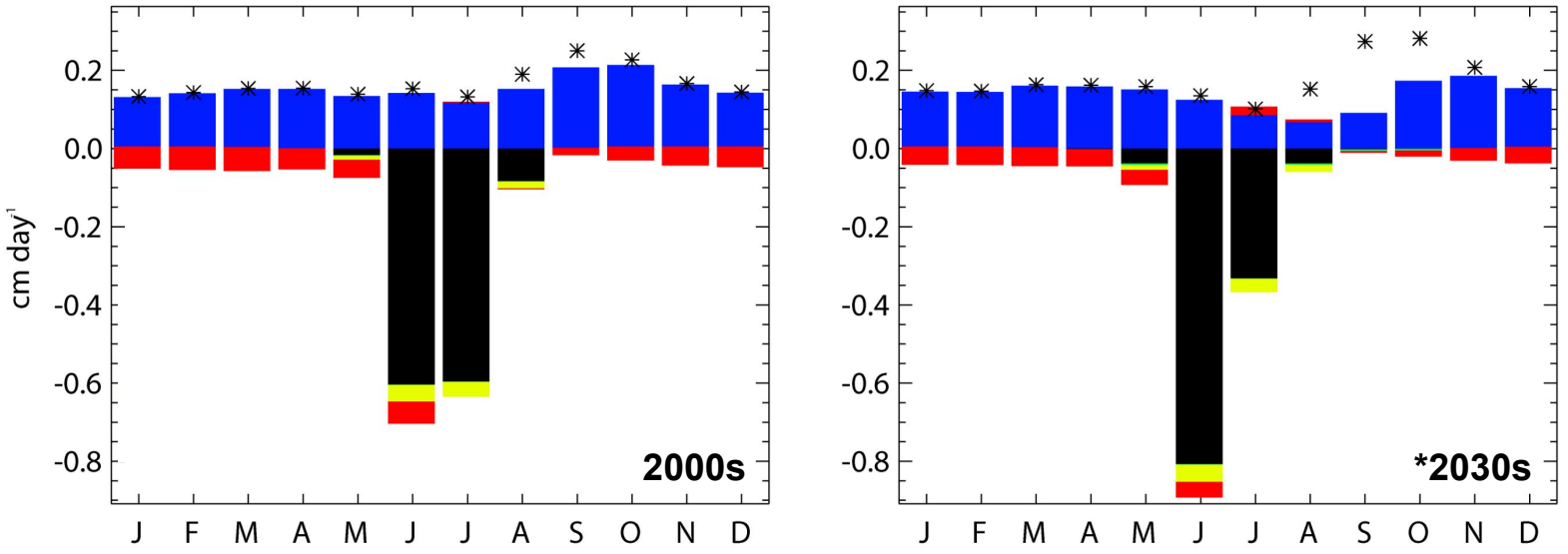


- Snowfall
- Sublimation/Condensation
- Snow-ice
- Melt
- Dynamics

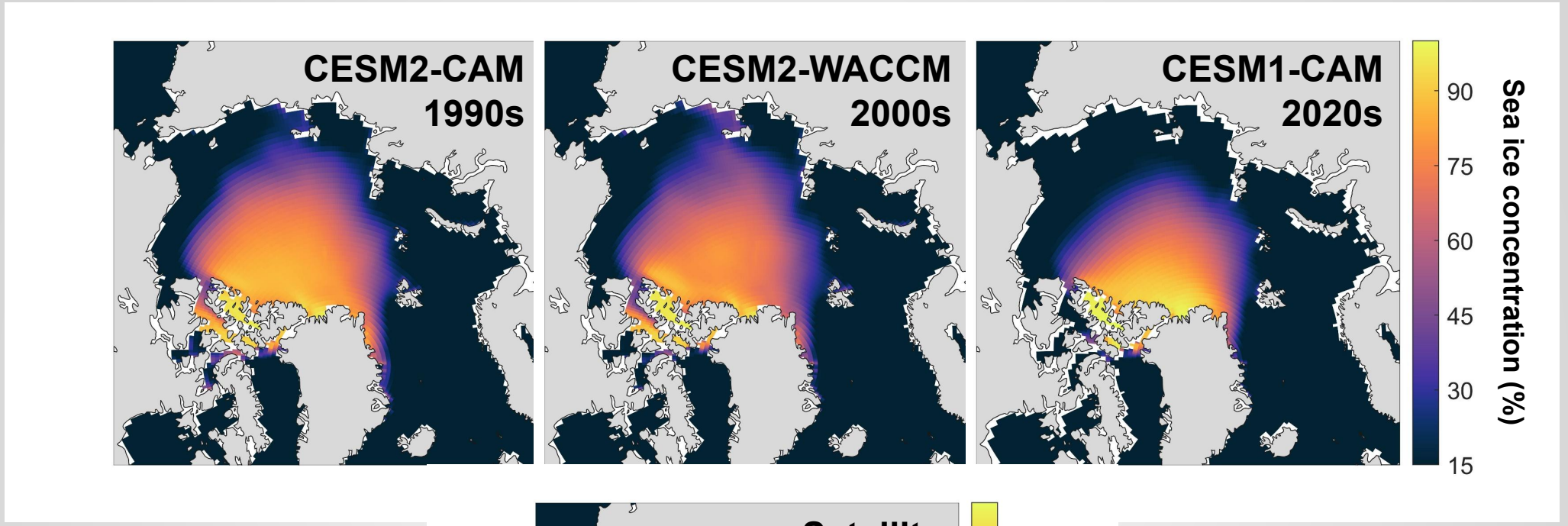
CESM2-CAM (& WACCM) have:

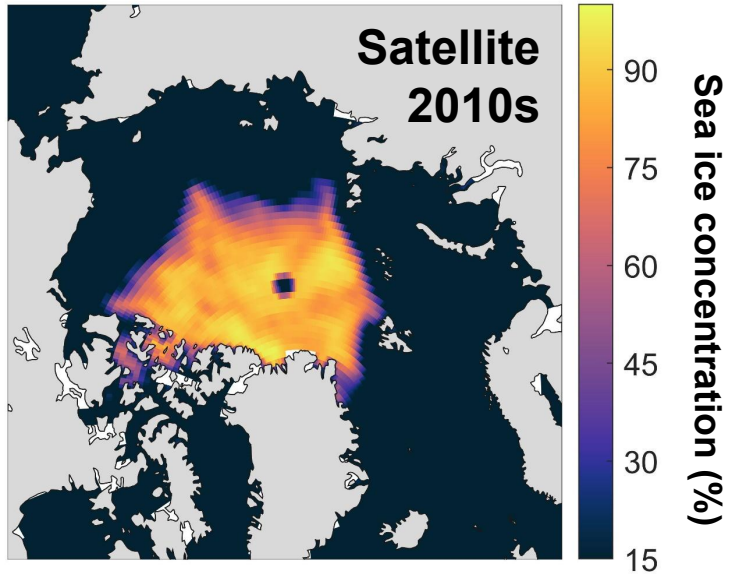
- Less snowfall mass gain.
- More snow-ice loss.
  - CESM2 is thinner.
  - CESM2 snowfall…?
- Stronger, earlier melt.

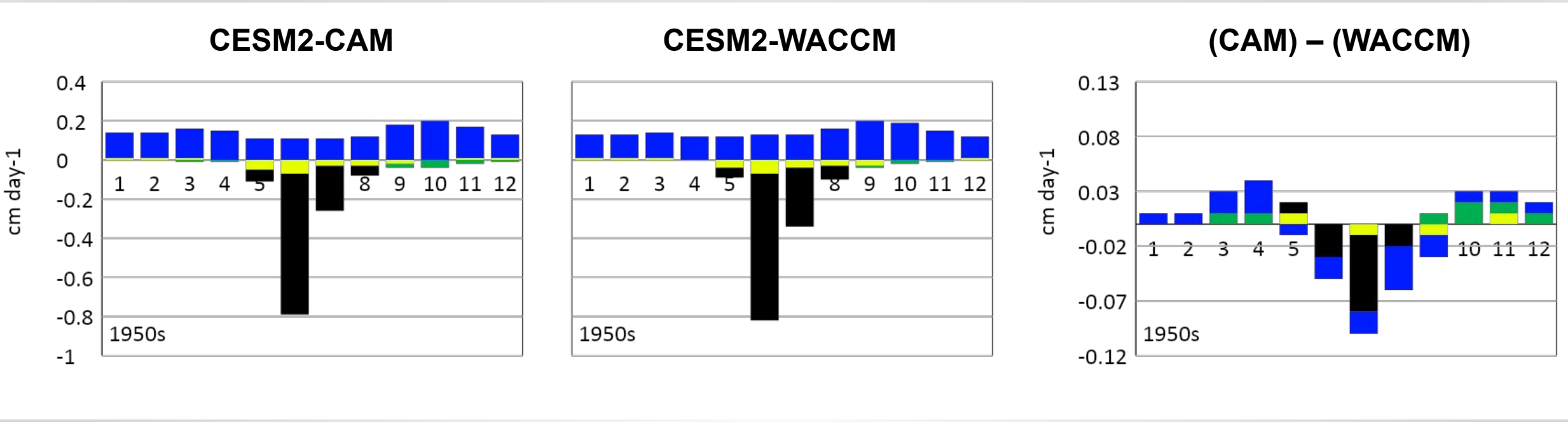
CESM1-CAM



How can snow processes be compared between models with such different sea-ice conditions?



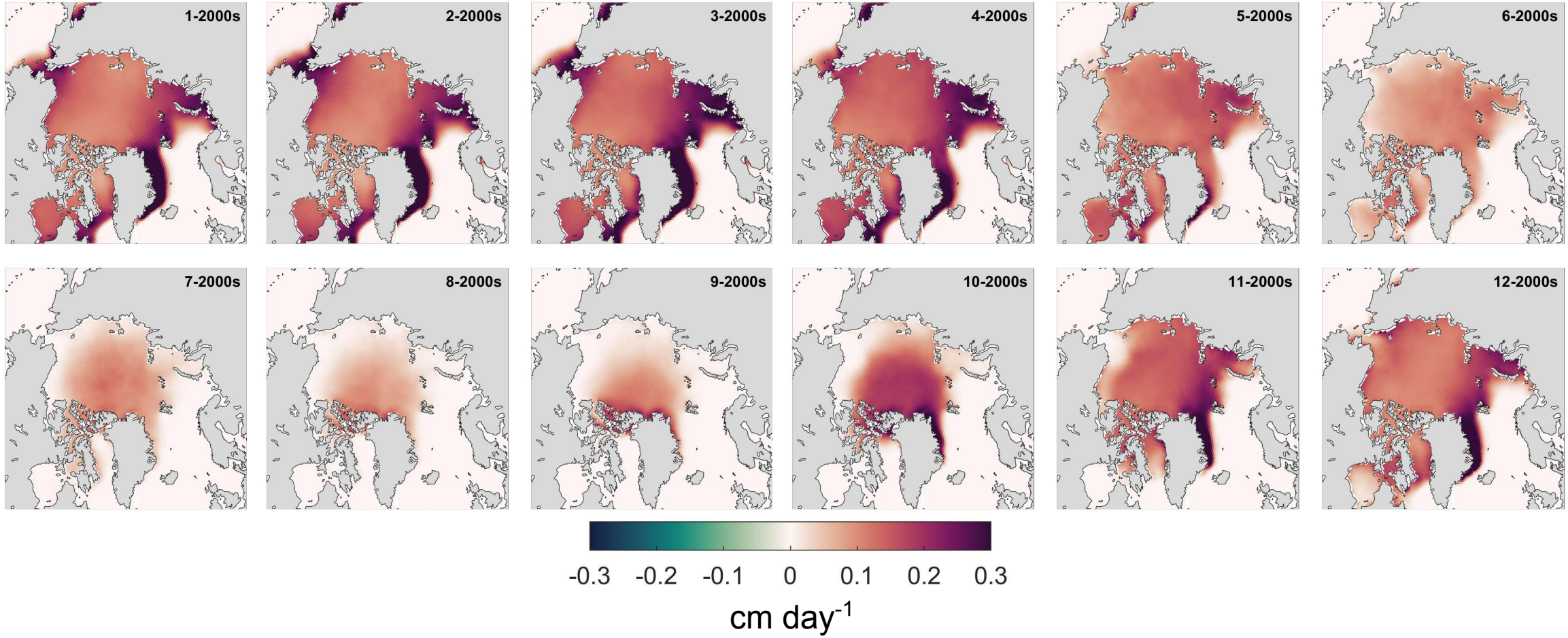




For 1950s historical state, CAM has:

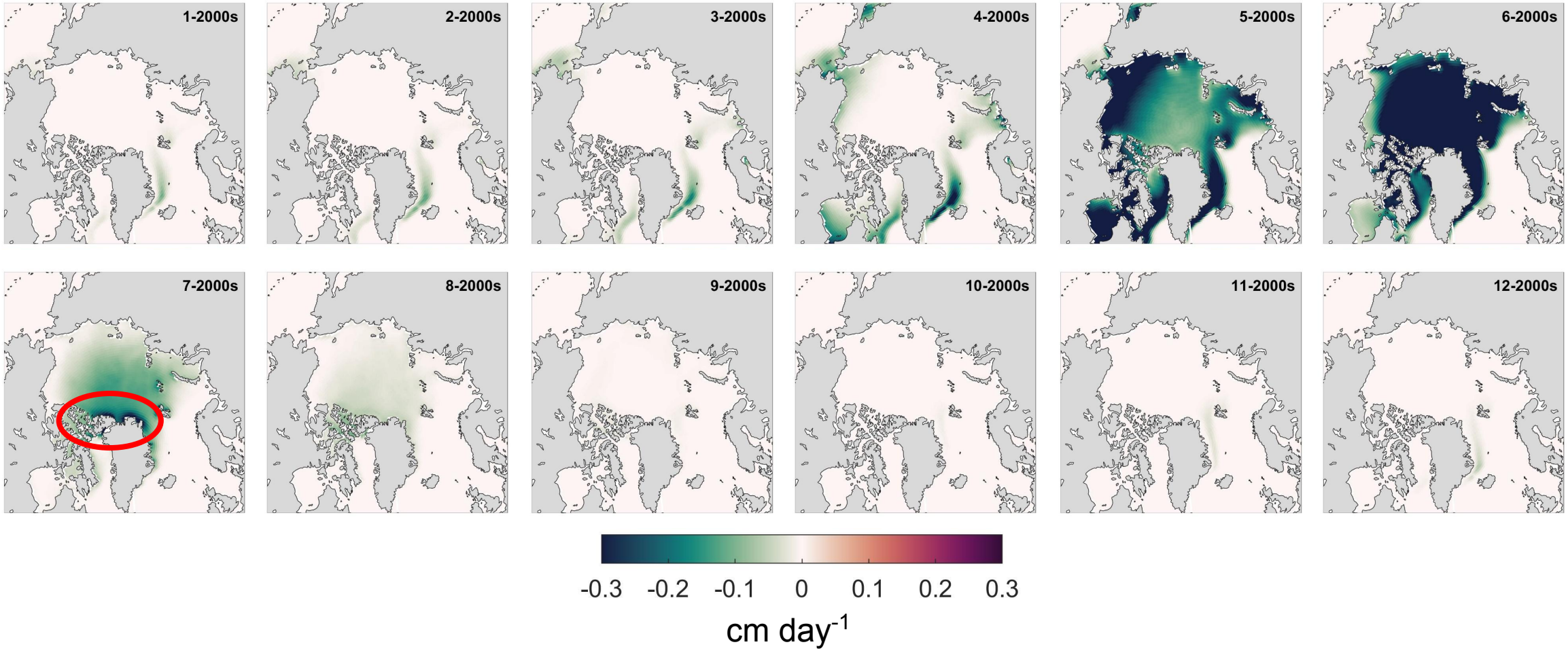
- Slightly less <u>total</u> snowfall mass gain.
  - More in winter-spring.
  - Less in summer.
- A LOT less melt.
  - WACCM's "snowier" summers likely due to greater summer snow accumulation.
- More snow-ice formation.

Snowfall (mass gain):



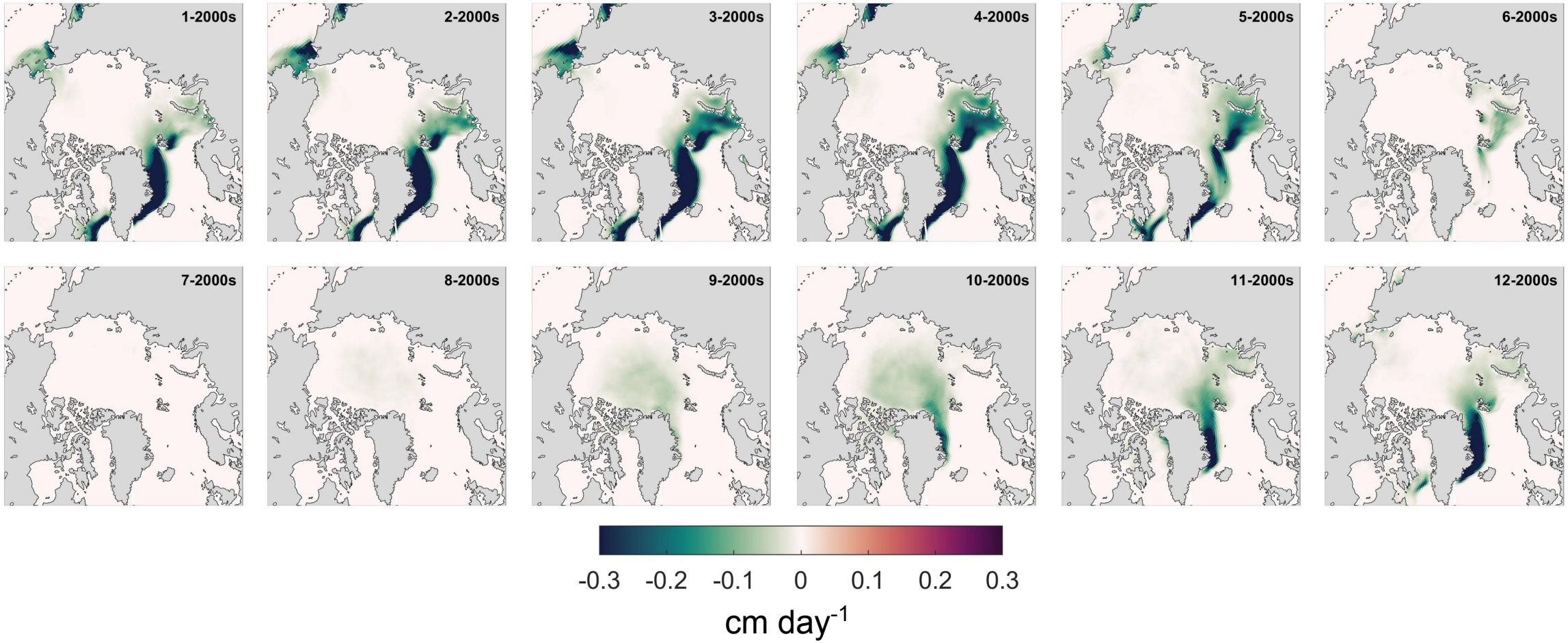
- It's snowing year-round!
- What do the (limited) observations show?
  - Peak in Sept. (1954-1991 climatology); peak in Oct. (2000 – 2018 IMBs).
  - CESM2 & observations indicate snow accumulation begins in August (1954-1991 climatology; IMBs; high-res. satellite imagery; albedo data).

Snow melt (mass loss):



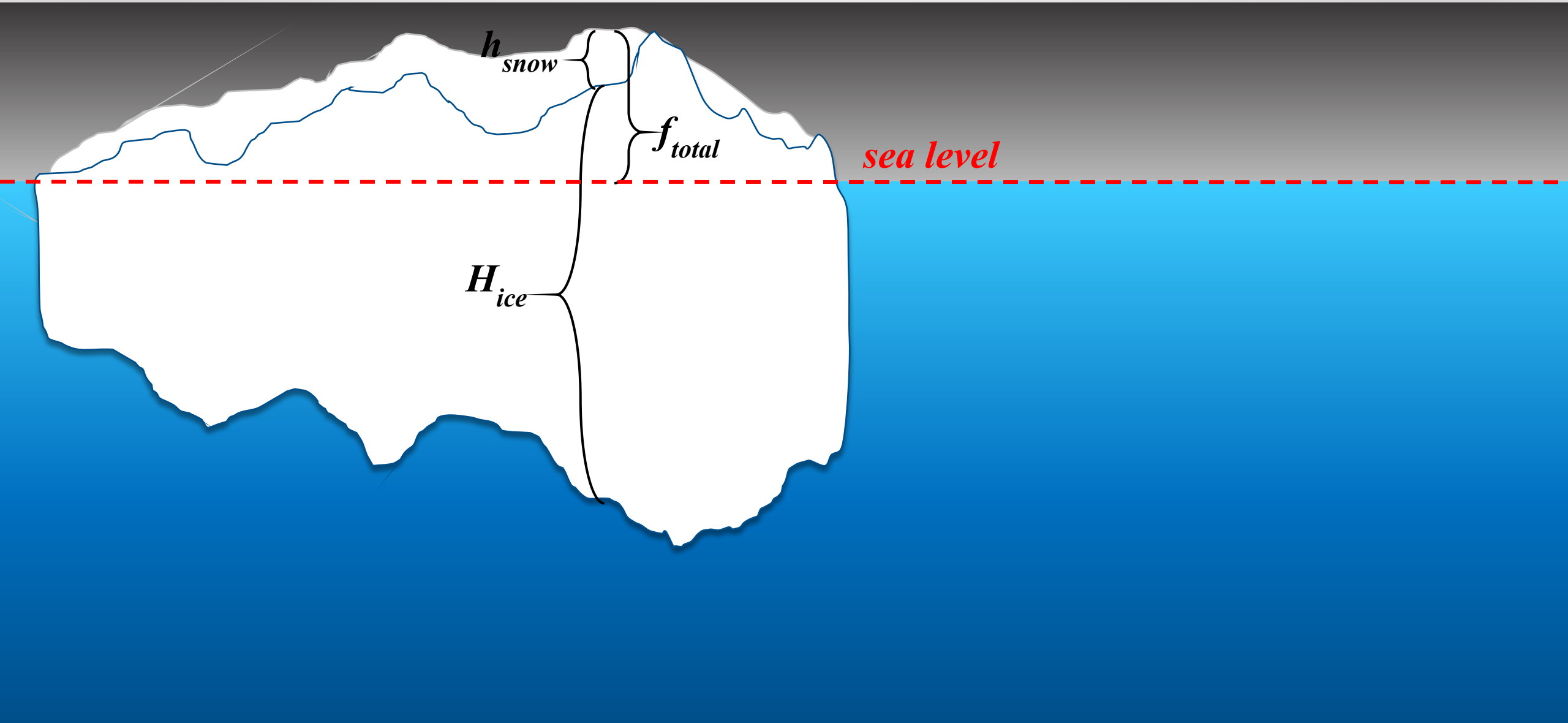
- Qualitatively, patterns seem reasonable.
  - To be compared with IMB snowmelt rates.
- Odd feature in July, north of Greenland.

Snow-ice formation (mass loss):

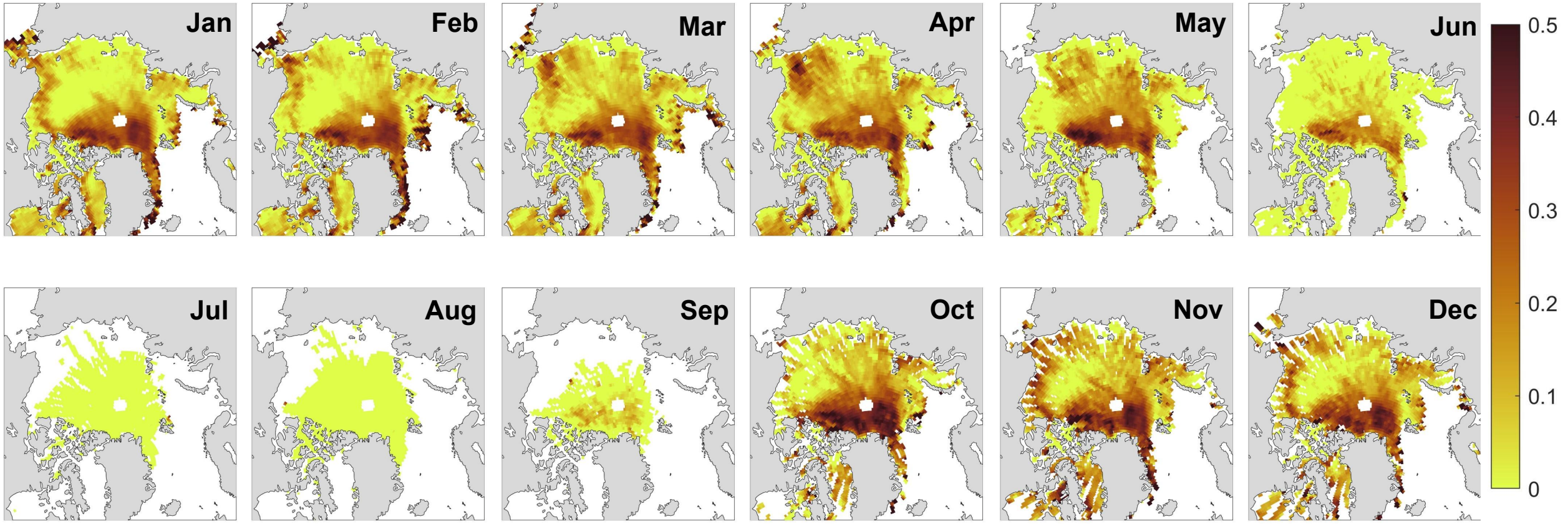


- Snow-ice has been observed in Fram Strait (1987), Bering Sea (2018-2019), Fram Strait/Laptev Sea (2015).
  - Snow-ice in peripheral seas may be spatially representative (Laptev?). Magnitude?
- Wide-spread Central Arctic snow-ice formation possibly not realistic, particularly in MY ice areas.

Exploring CESM snow using ICESat-2 data…

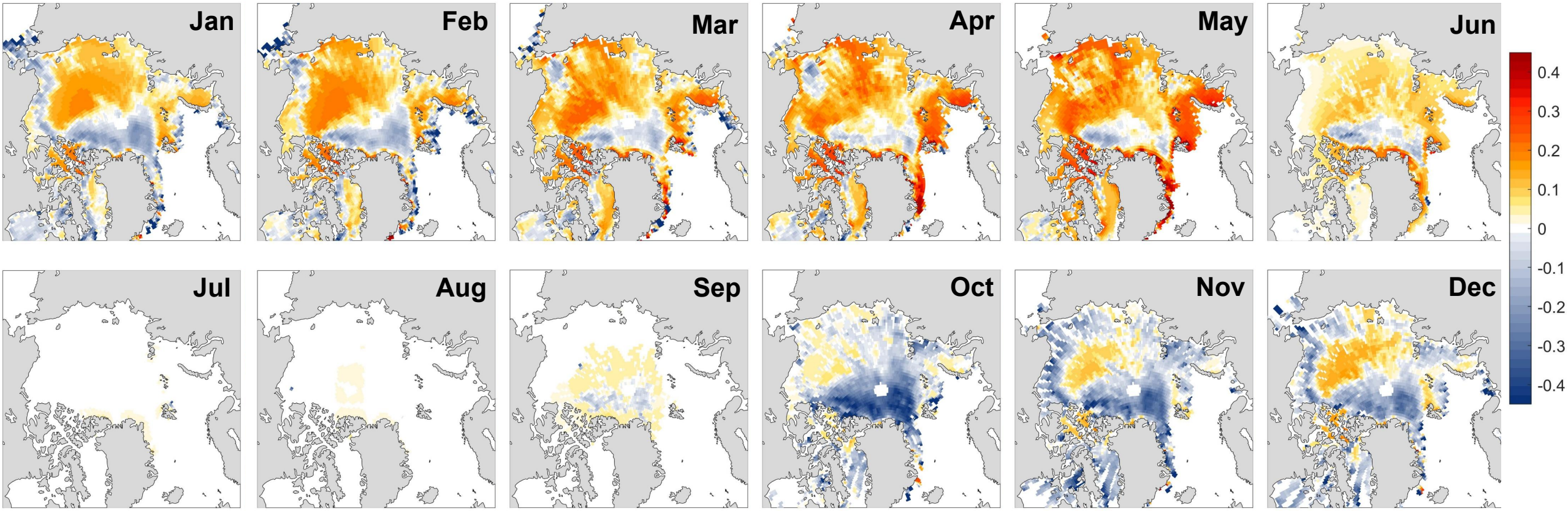


CESM2-WACCM/ICESat-2 derived monthly snow depths



Greater spatial variability that better matches sea-ice conditions.

(WACCM snow depth) minus (ICESat-2-derived snow depth)



CESM2-WACCM has:

- Deeper snow in eastern Arctic; starts diverging in December.
- Thinner snow on MY ice.
  - See “tongue” of MY ice in Beaufort/Chukchi seas.

Next steps?

- Complete analysis with IMB data to assess seasonal cycle, & rates of accumulation & melt.
- Date of snow-free conditions & snow-cover duration.
- Snowfall rates.
- Ratios: Freeboard-to-snow depth & snow-to-ice thickness ratios.
- Bonus: Rain-on-snow frequency.

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