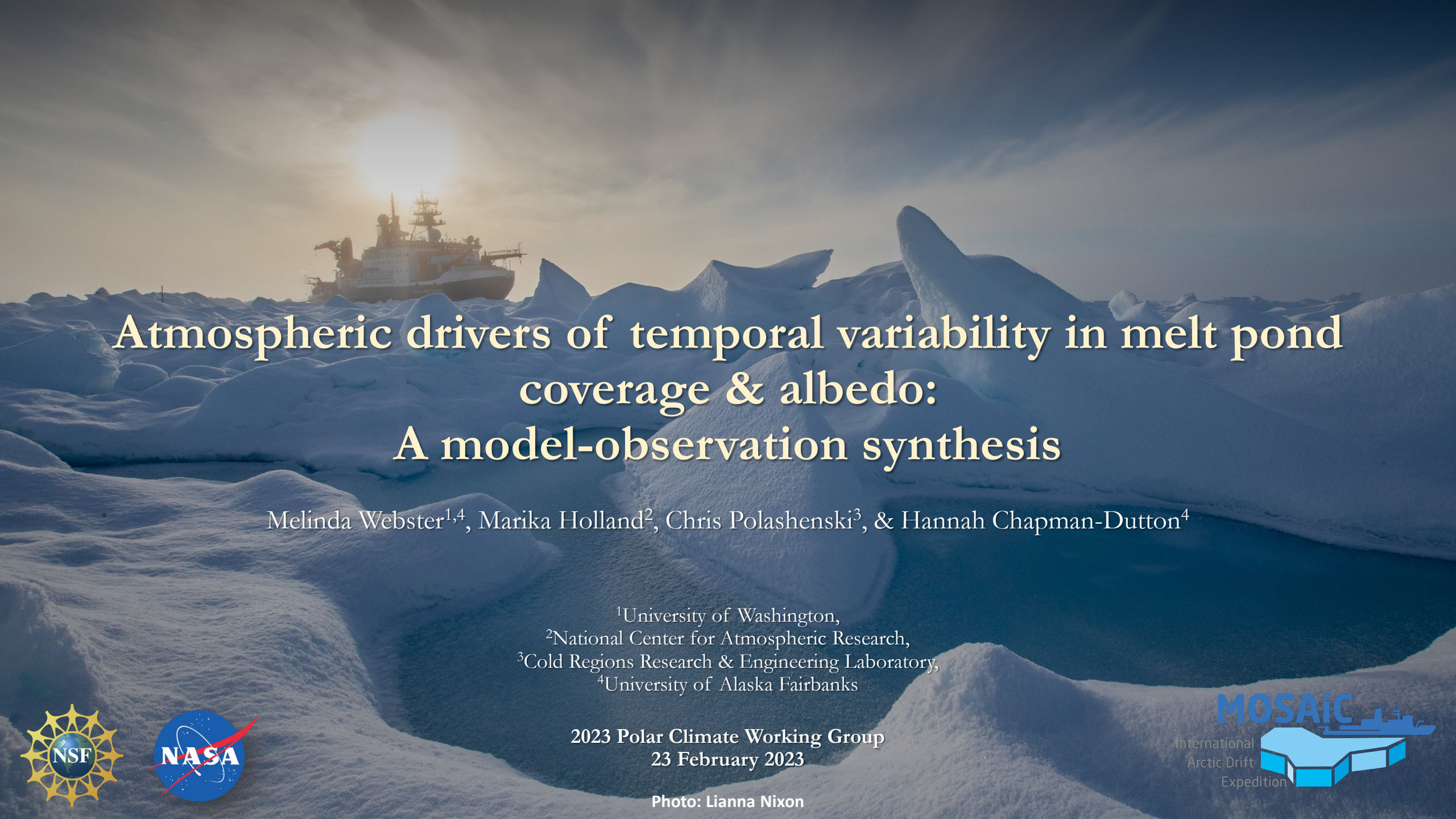

Atmospheric drivers of temporal variability in melt pond coverage & albedo: A model-observation synthesis

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2023 Polar Climate Working Group
23 February 2023

Photo: Lianna Nixon

Melt ponds

- Govern the surface albedo of Arctic sea ice.
- Knowing their areal extent is important…
- But knowing <u>when</u> they are present is equally important.
- Melt pond coverage can be highly temporally variable → drainage, refreezing

Melt ponds

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- Knowing their areal extent is important…
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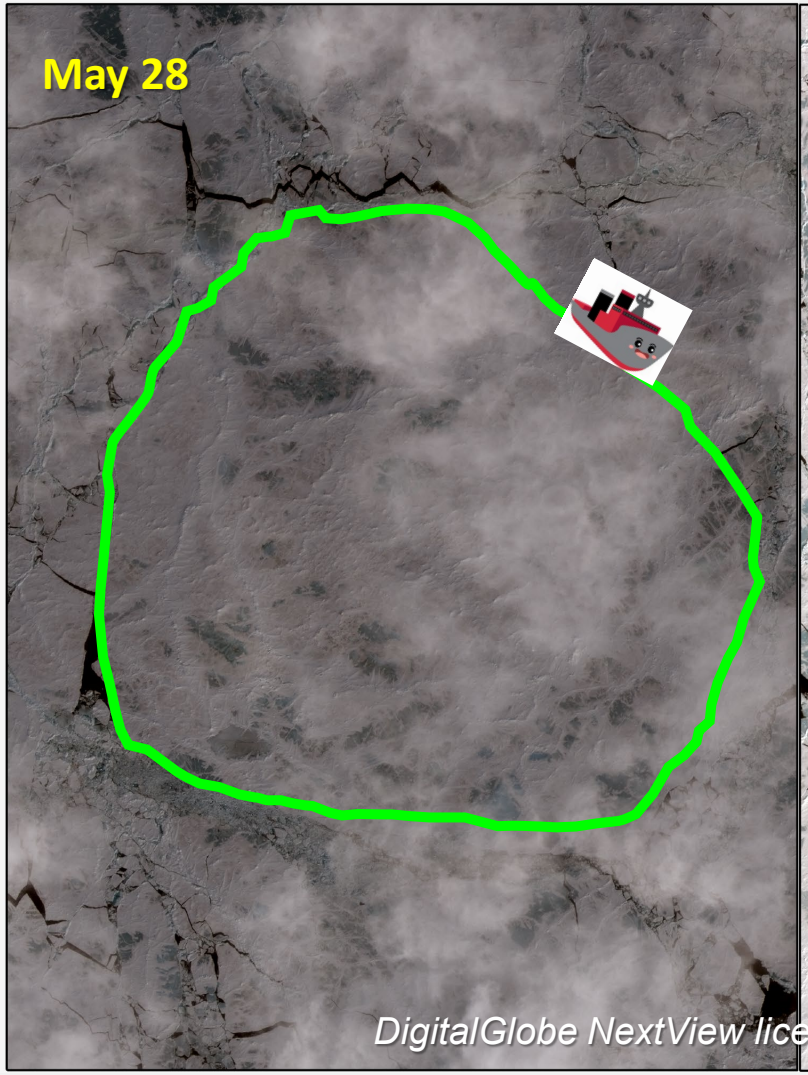
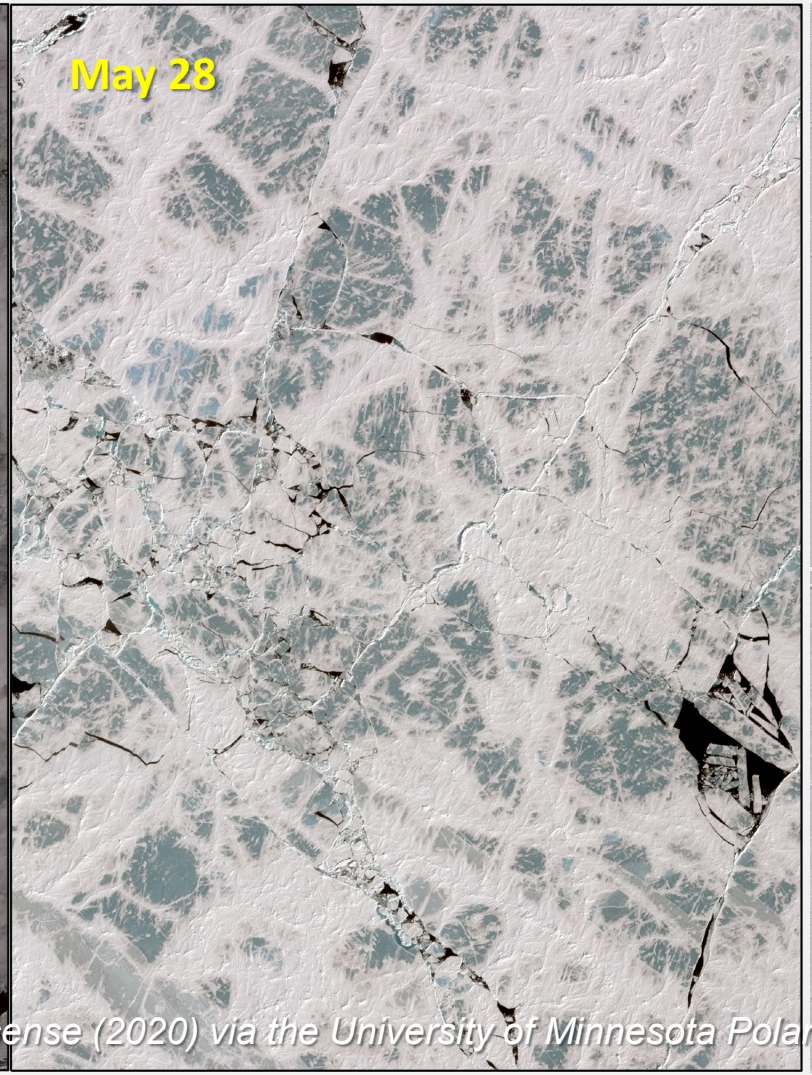
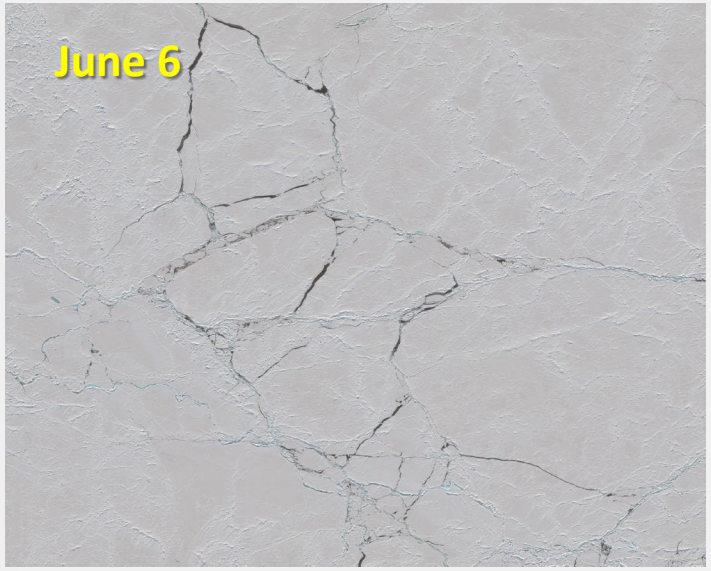
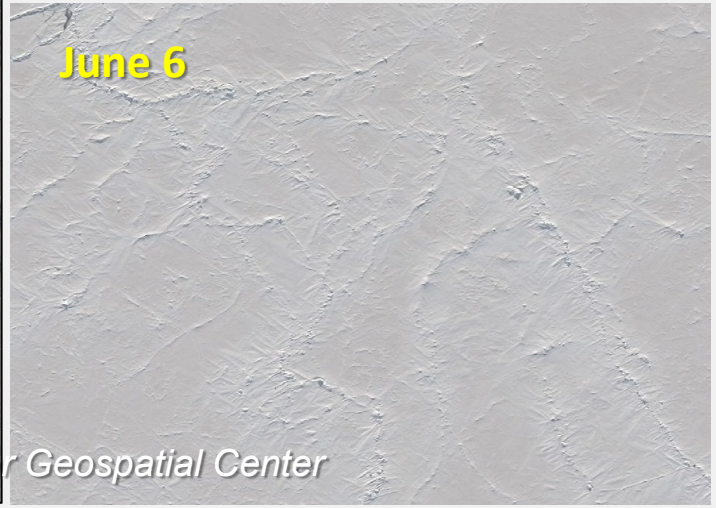








MOSAiC had 2 refreezing events* (that we're aware of): ~June 3 & ~Aug 24

- ~May 28: ponds form (>5%),
- ~June 6: ponds gone! Frozen surface with fresh snow,
- ~Mid-June: ponds return (<5% on June 17; >5% June 21).

*>5% pond fraction change

Different flavors of refrozen pond events?

Ponderings:

- Early melt season: from a cold state → longer-lasting?
- Mid-summer: diurnal freezing → short-lived?
- Late melt season: from a warm state → variable?

Science questions:

- What's normal?
  → When, how frequently, & how long do refreezing pond events occur?
- Are these events important?
  → What are the effects of refreezing ponds on surface albedo & absorbed SW radiation?
- Can these events be realistically simulated?
  → Which atmospheric conditions lead to refreezing pond events?

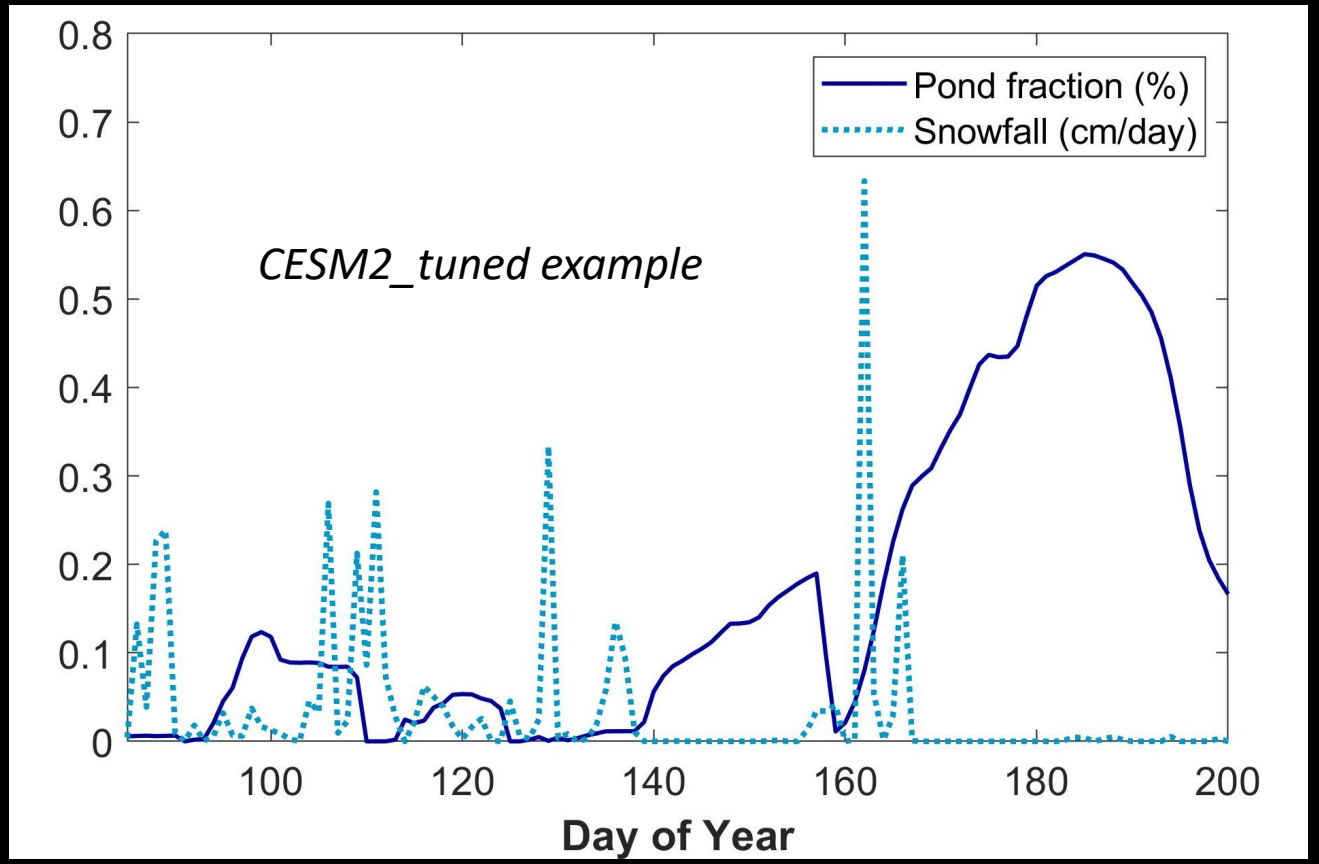
Data & Methods

Community Earth System Model, Version 2 (CESM-2):

- Tuned (Kay et al., 2022):
  - More realistic sea-ice state,
  - 10 ensemble members for 2000-2009

Surface-based & satellite observations:

- MPF: Transect + SkySat + MODIS + Sentinel
- Snow depth: magnaprobe
- Albedo: Kipp and Zonen albedometer



Refreezing pond (RFP) event:

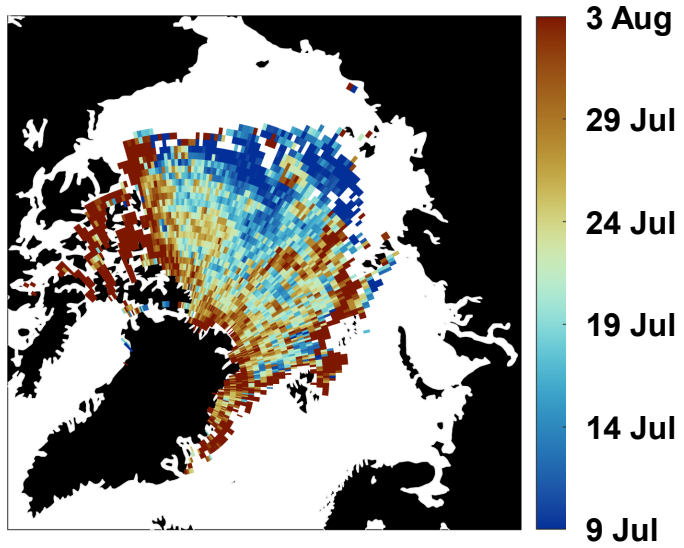
- Pond ice fraction is at least 5%,
- Reduction in pond fraction is at least 5% & eventually (& mostly*) rebounds.

Other notes:

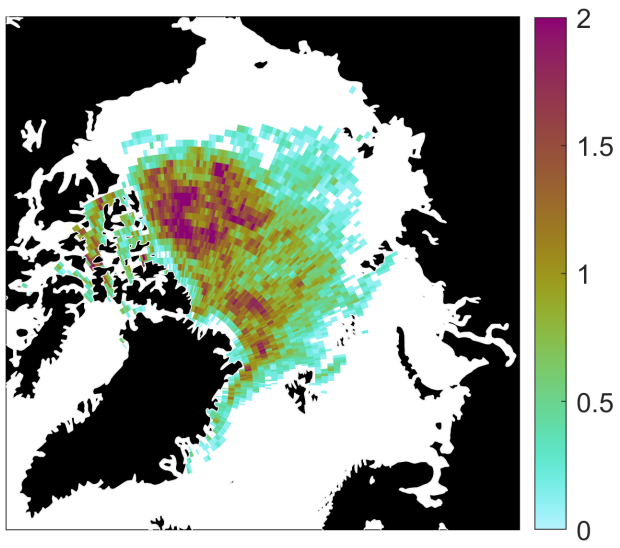
- Evaluating grid cells with >50% SIC year-round,
- Effective ponds – open to atmosphere,
- Ignoring subnivean ponds,
- Not the same thing as summer snowfall events.

When, how often, & how long do refreezing pond events occur?

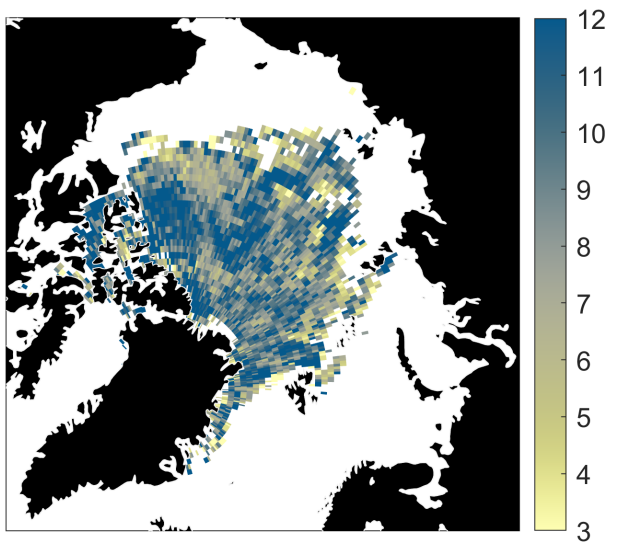
Date: 23 Jul ± 7 days



Frequency: <1 ± <<1 day



Duration: 10 ± 4 days



Timing:

- (1) Early summer in Pacific sector & (2) late summer in MYI region & N. Atlantic.

In general, not many events are simulated.

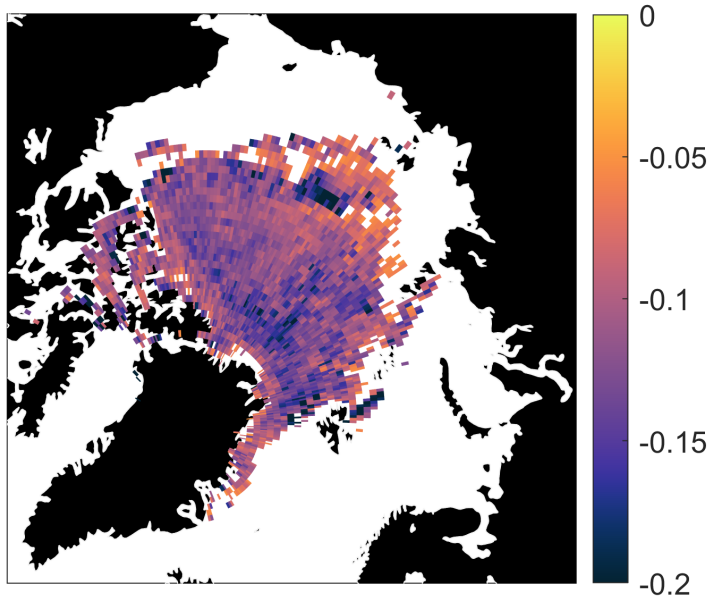
- More events in areas with MYI region.

Duration is spatially variable, averages to 10 ± 4 days.

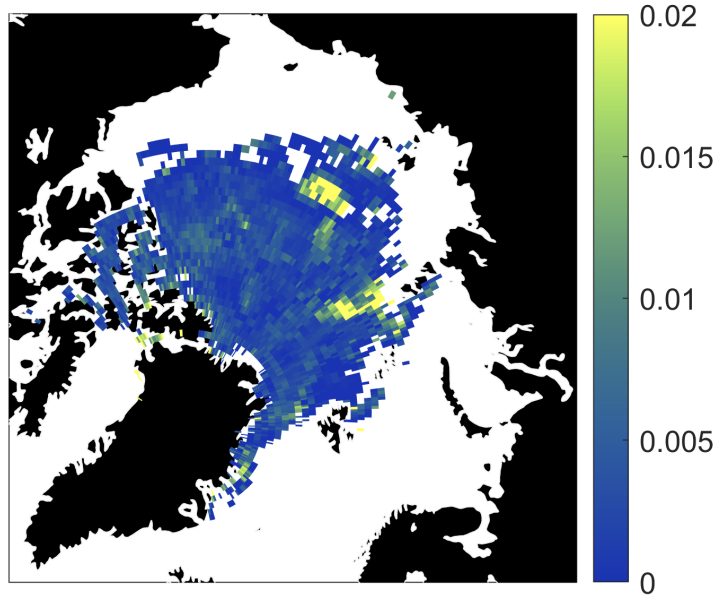
- Are longer-lasting events related to major synoptic events?

What happens to surface conditions when ponds refreeze?

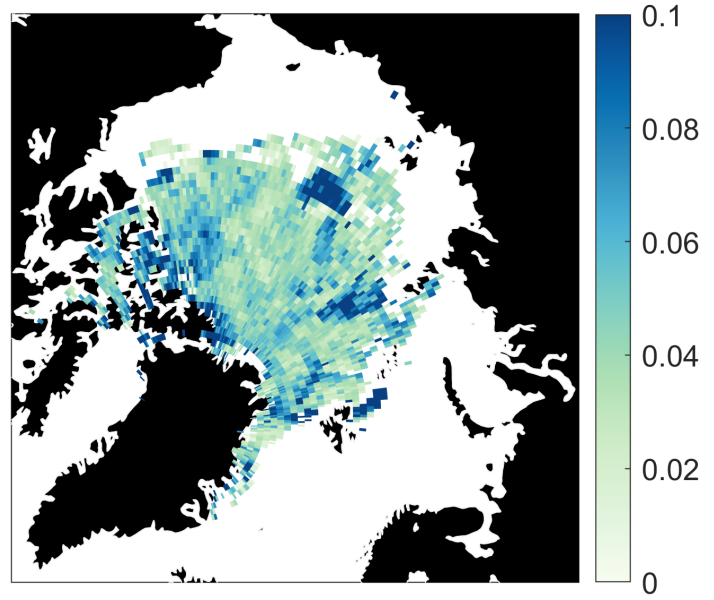
Pond coverage change (%)



Snow depth change (m)



Albedo change

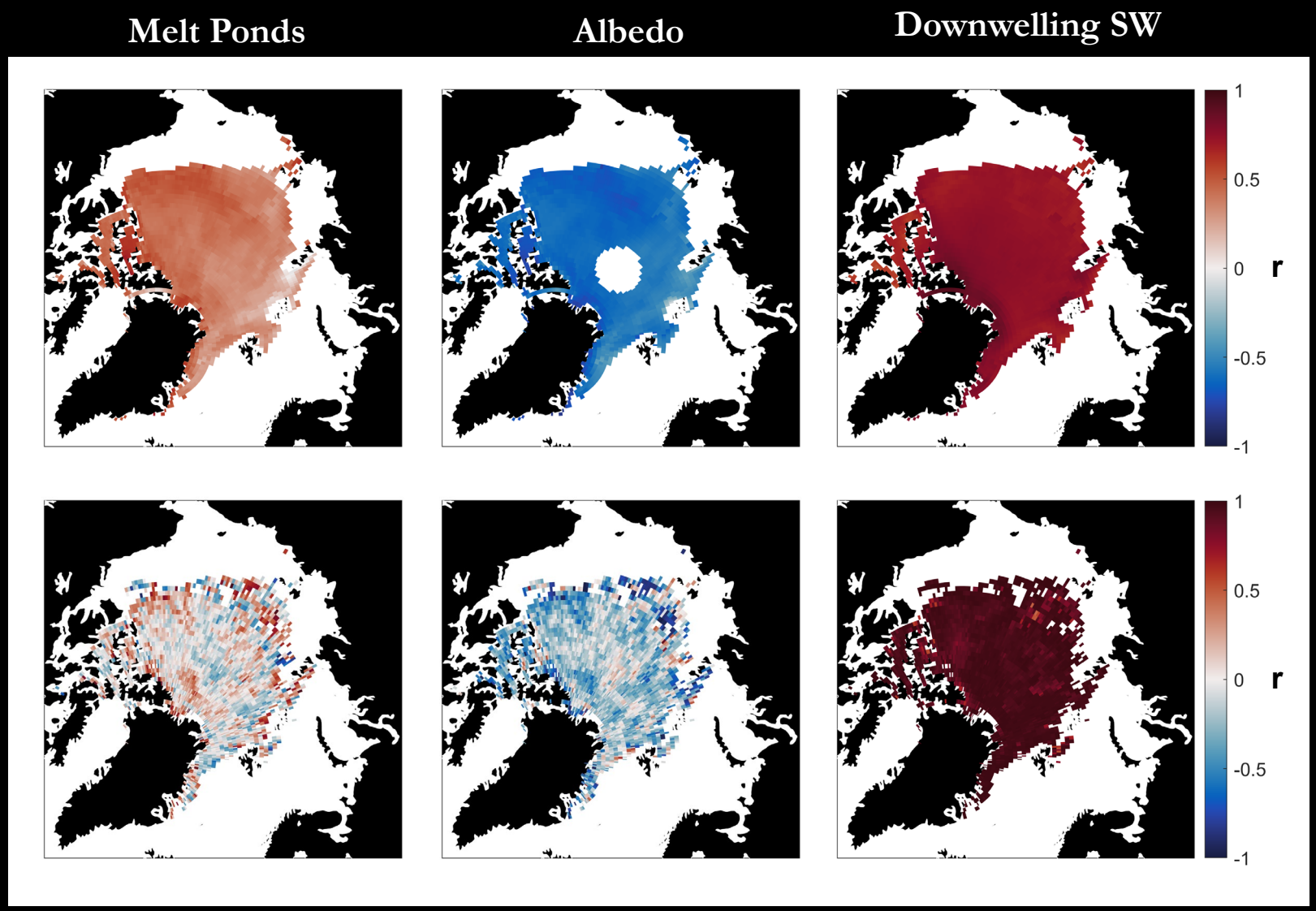


During refreezing pond events:

- Considerable decrease in ponded ice: -12% ± 3%.
- Small increase in snow depth : 4 mm ± 2 mm.
- Considerable increase in albedo: 0.05 ± 0.01

→ Largest increase in snowy areas with large decrease in pond coverage.

Effects of refreezing pond events on the absorbed SW radiation?

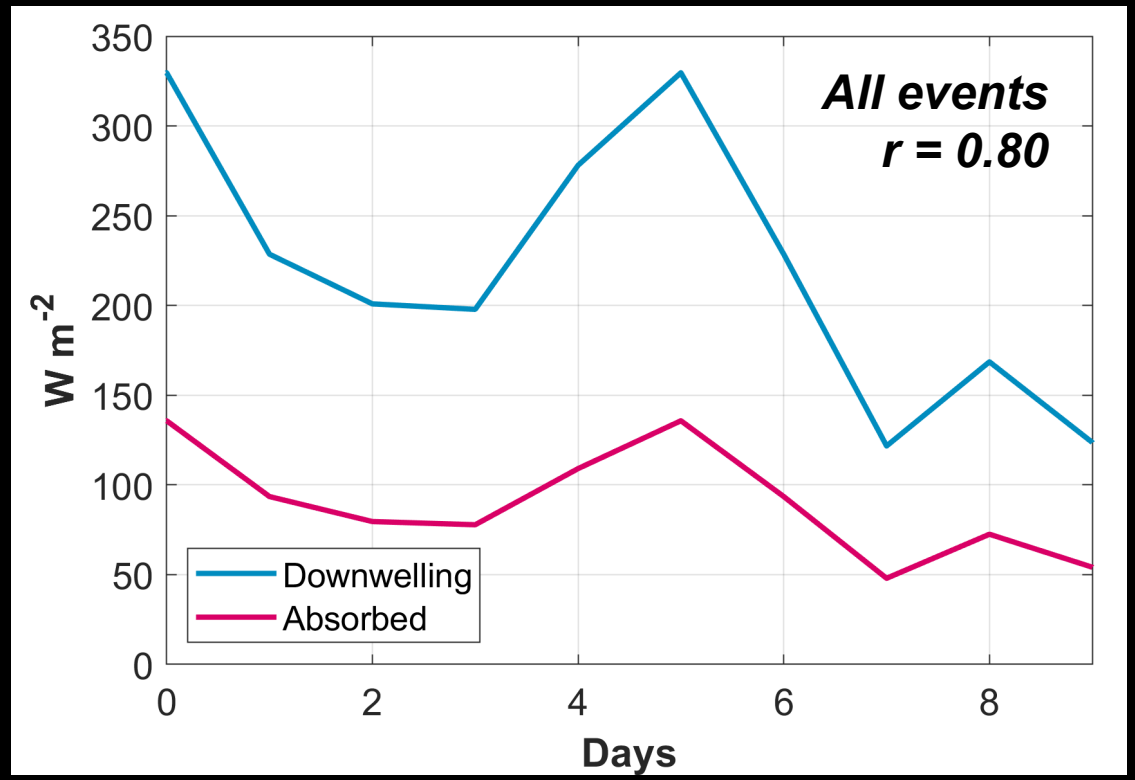


During RFP events, correlations are:

- Weaker with pond coverage & albedo,
- Stronger with downwelling SW radiation…

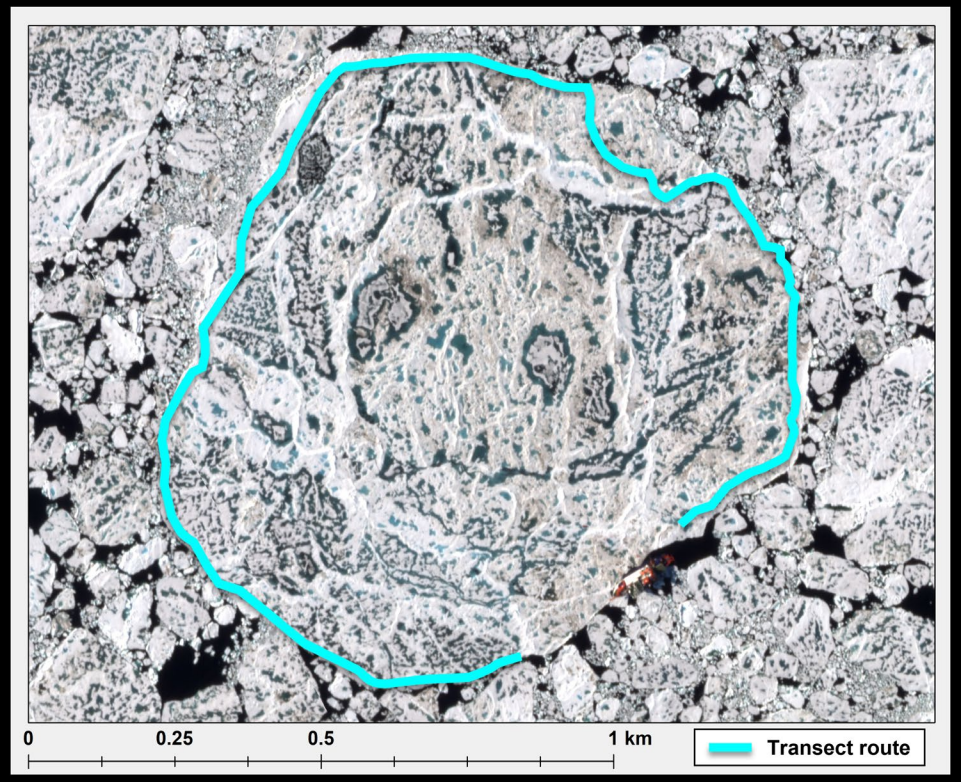
SW absorption decreases primarily due to downwelling SW radiation decreasing…

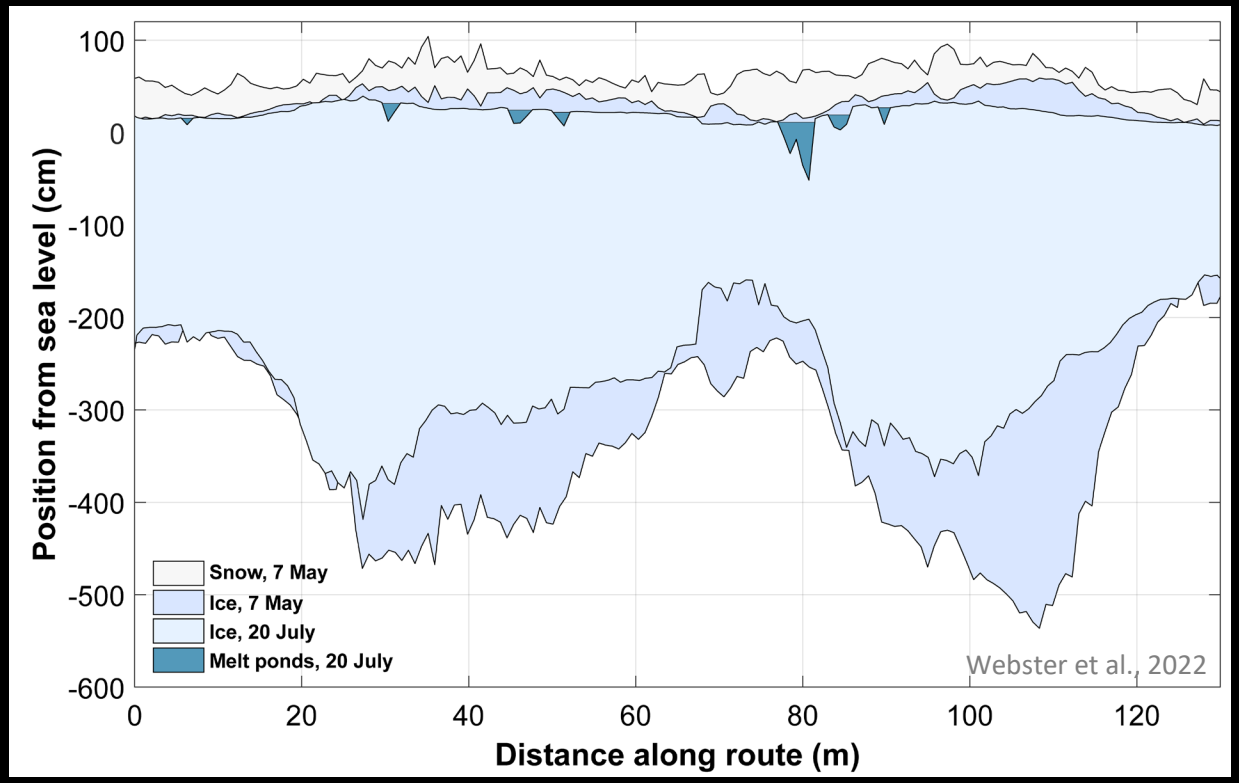
Less downwelling SW radiation? Some speculation:



The albedo boost from refreezing pond events & associated snowfall is masked by clouds (TBD)

How do the model results & MOSAiC observations fit within the context of one another?





	Observations (N = 1) (MOSAiC)	CESM2-tuned (N = 30) (MOSAiC)	CESM2-tuned (N = 30) (Pan-Arctic)
Number:	~1 (Leg4) 1 (Leg5)	<1: 2/30 runs had 1 event <1: 4/30 runs had 1 event	<1 ± <<1 days
Duration:	~20 days 2 days	12 & 20 days 7, 2, 18, & 3 days	10 ± 4 days
Dates:	~1 June 24 Aug	23 July 16 July	22 July
Pond fraction change:	- -10%	-11% -9%	-12 ± 3%
Snow change:	- 60 ± 10 mm	1 mm 6 mm	4 ± 2 mm
Albedo change:	- 0.07	0.05 0.05	0.05 ± 0.01

The CESM2_tuned simulates:

- Much fewer events
- Different seasonal timing of events
- Much less snow accumulation

Preliminary conclusions & next steps

- At MOSAiC, CESM2_tuned simulated fewer refrozen pond events & less snow accumulation than observed.
  - Need to look at larger sampling size, same period, event duration, & seasonal timing to pinpoint potential biases.
  - Are clouds masking the surface albedo boost?
    - Characterize atmospheric conditions during refreezing events: Cloud cover, snowfall events, cyclones, frontal systems, cold air outbreaks, & more.
  - Data/idea suggestions & collaborations welcome! → melindaw@uw.edu
- Expand observational analysis to the pan-Arctic scale:
  - Remote sensing retrievals paired with buoy observations (IABP):
    - Wright et al., 2020, in review; Niehaus et al., in review; Martius et al., in prep; Tavri et al., in prep; Fuchs et al., in prep; Buth et al., in prep; Buckley et al., 2020; Webster et al., 2015; Rösel et al., 2012; & many others.
  - Hoping for MPF retrieval uncertainties better than 5%...
- Extra preliminary: CESM2-LE had even fewer refreezing events & less snow accumulation... more analysis needed.

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Focus period: the sunny season