Feedback in the Marginal Ice Zone from Wave-Ice Interactions

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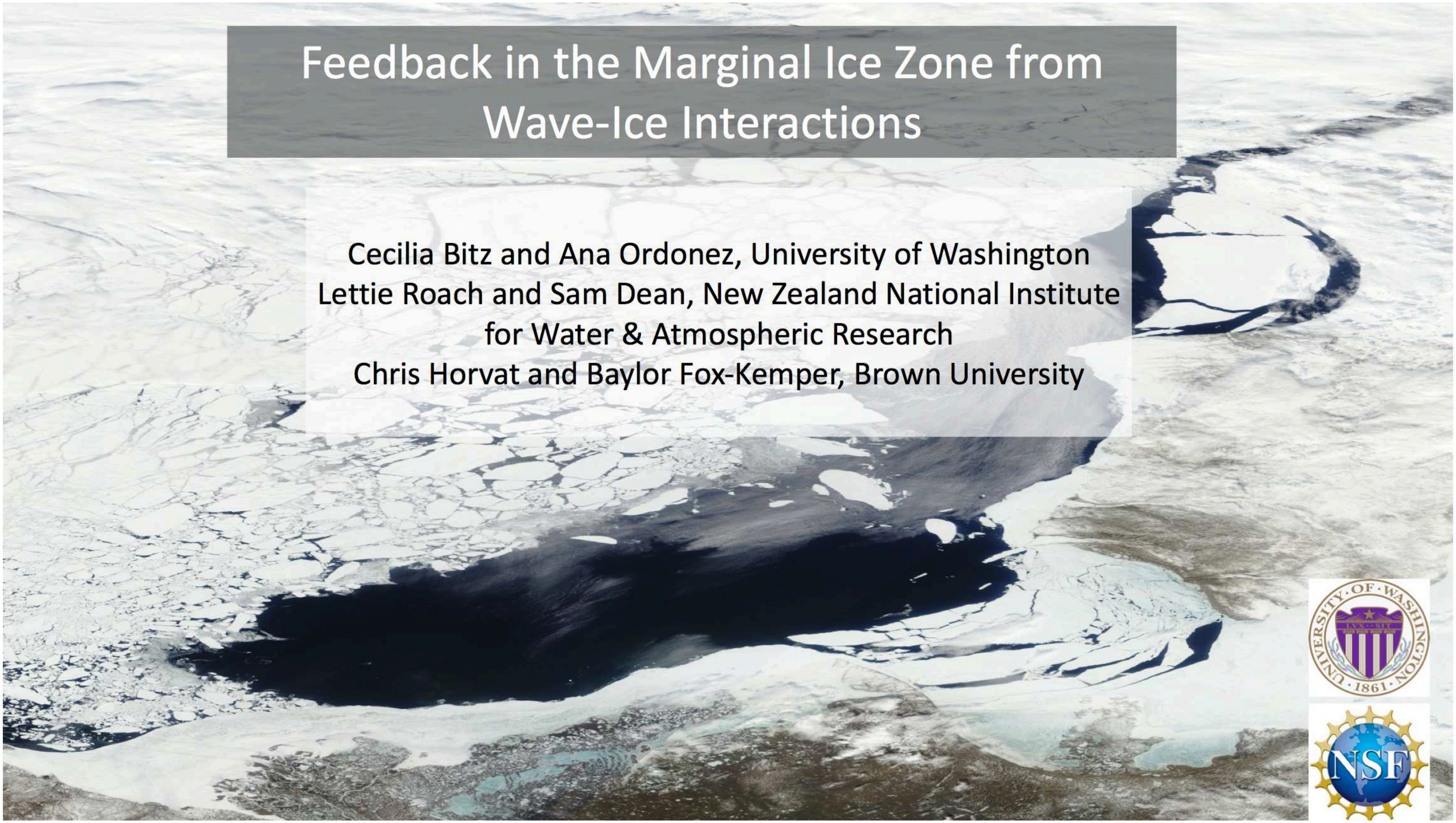
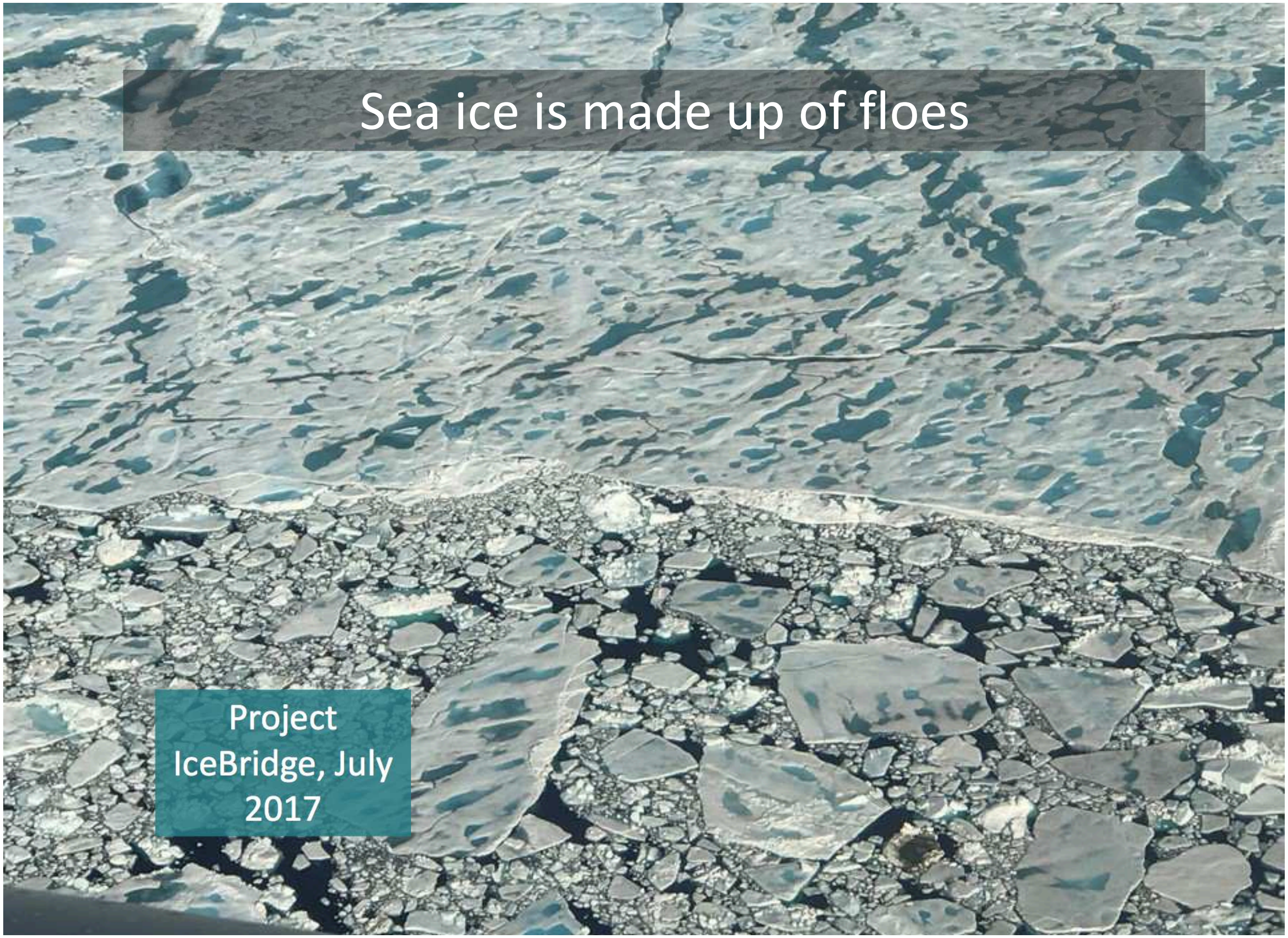
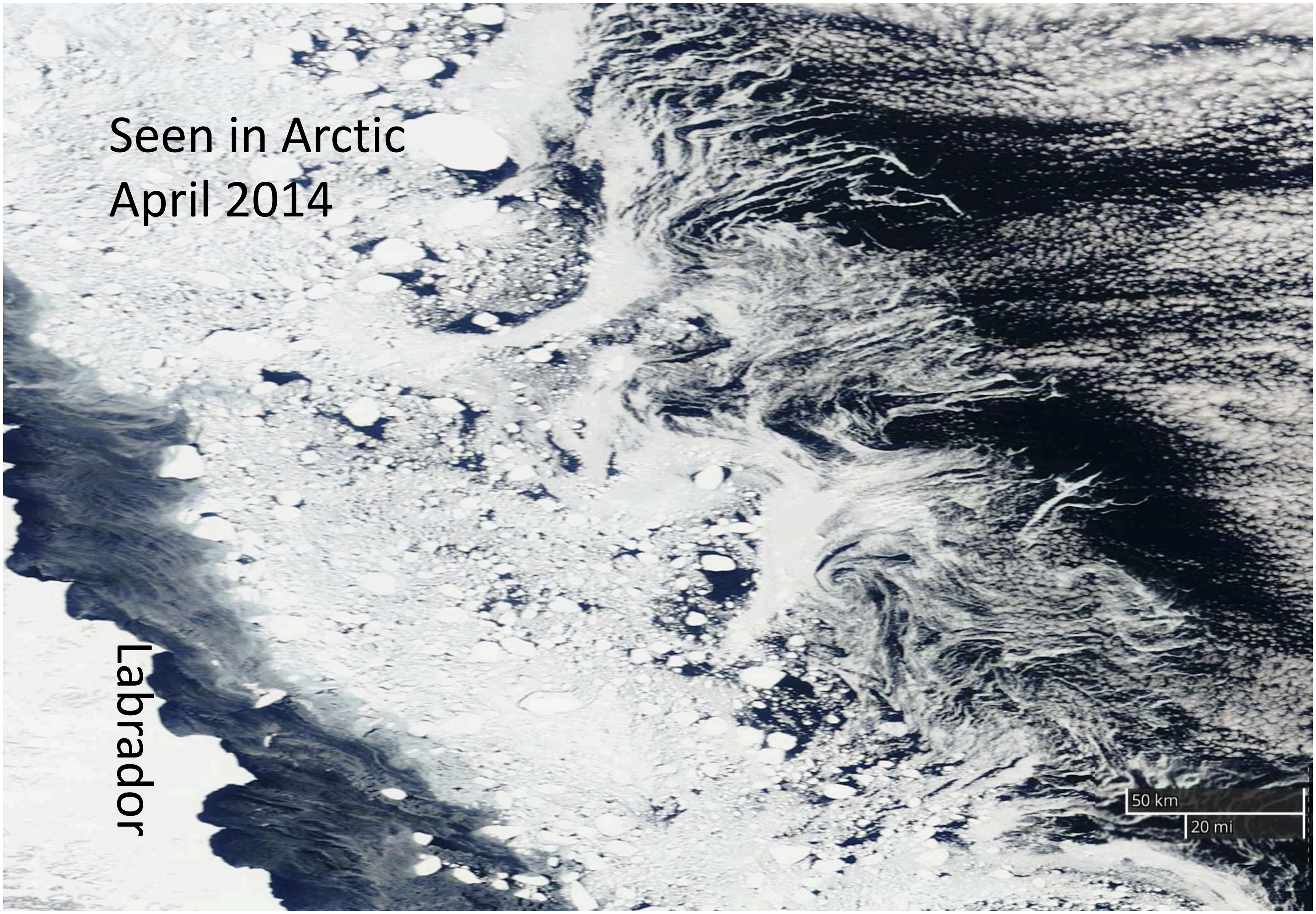
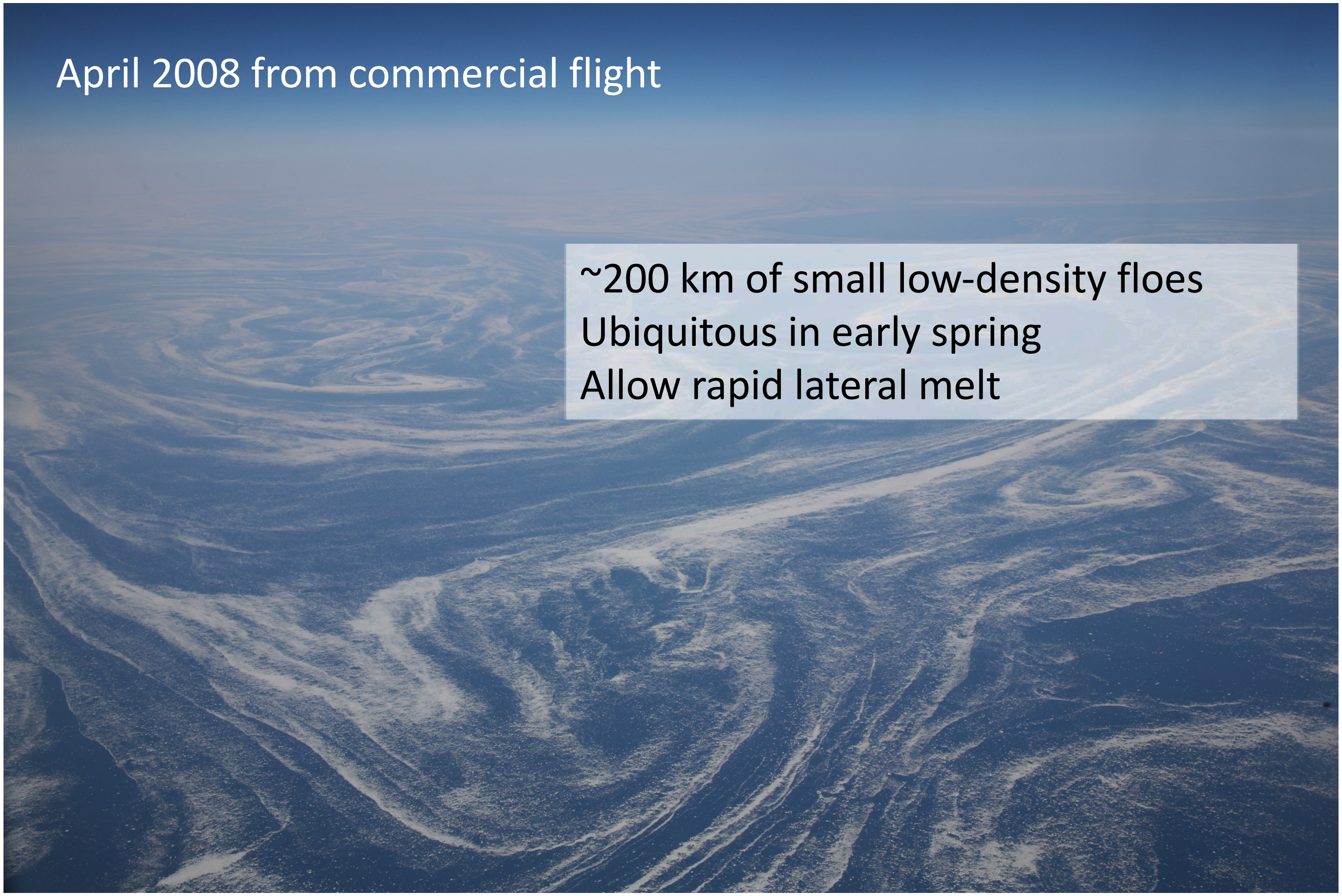



Sea ice is made up of floes
Project IceBridge, July 2017

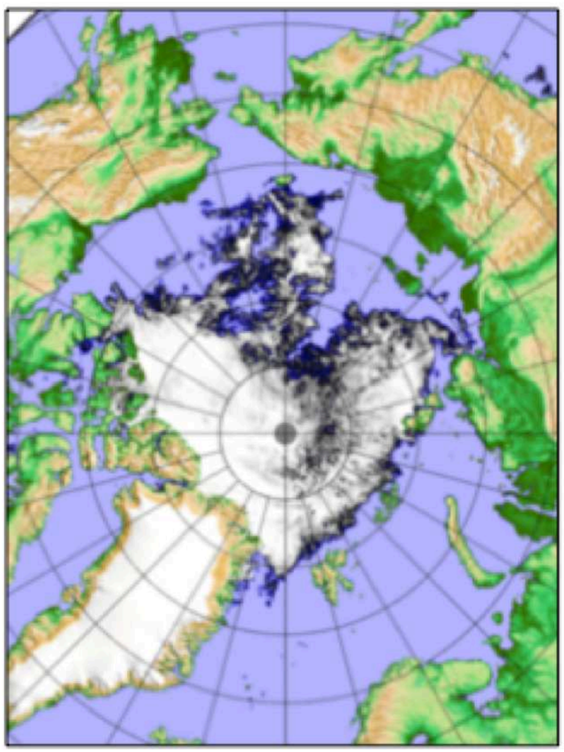

Seen in Arctic
April 2014
Labrador
50 km
20 mi



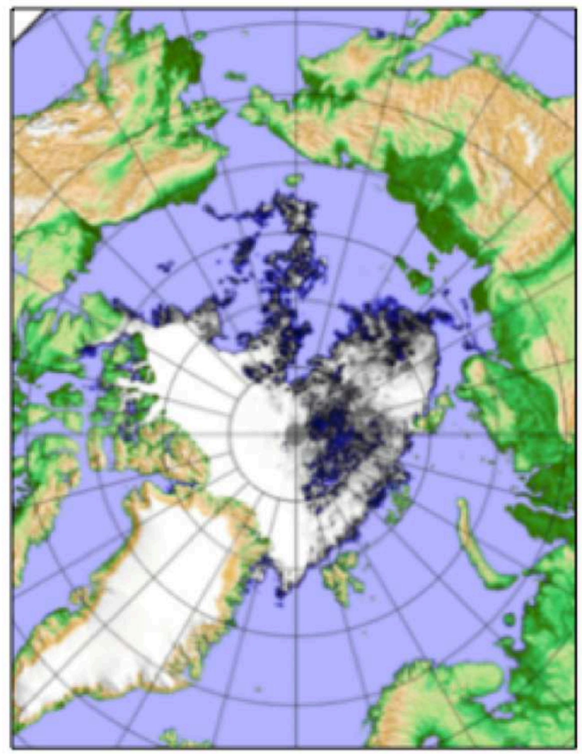
http://blogs.discovermagazine.com/imageo/2013/04/25/on-the-edge-redux/#.WceTMjOZNE4
Photo from Daniel Schwen

Large storms can rapidly take out ice

16 August 2016



29 August 2016



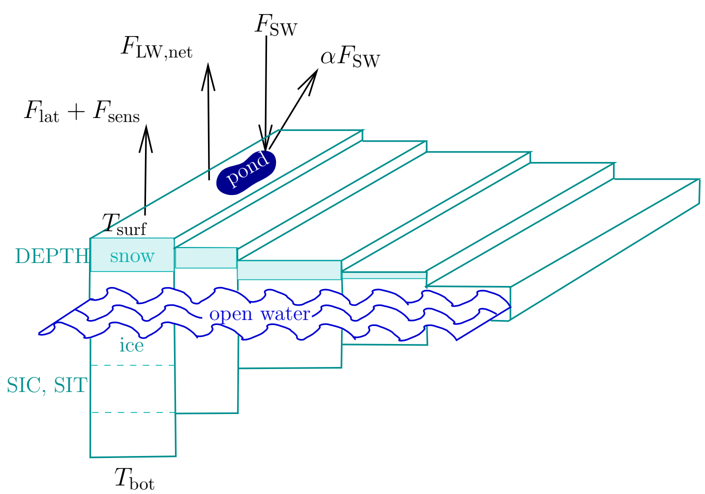
AWI sea ice data portal

Potential Influence of Floes on Sea Ice & Climate

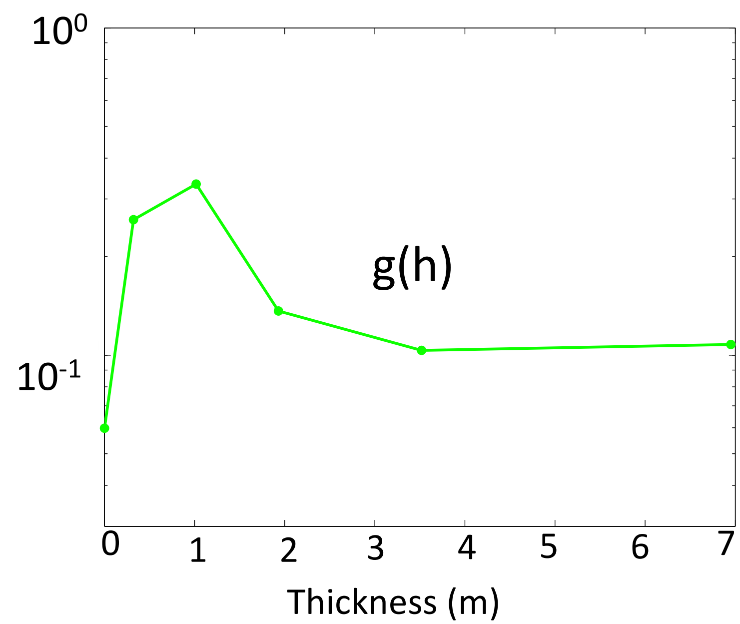
- Smaller floes have relative more lateral area than basal area
- So smaller floes melt away faster and enhance ice edge retreat
- Could lead to very rapid sea ice loss events (vRILEs)
- Coupled to ocean surface waves and ocean mixing

Sea ice models have simulated the ice-thickness distribution for a few decades

A grid cell has these variables in **each** thickness category



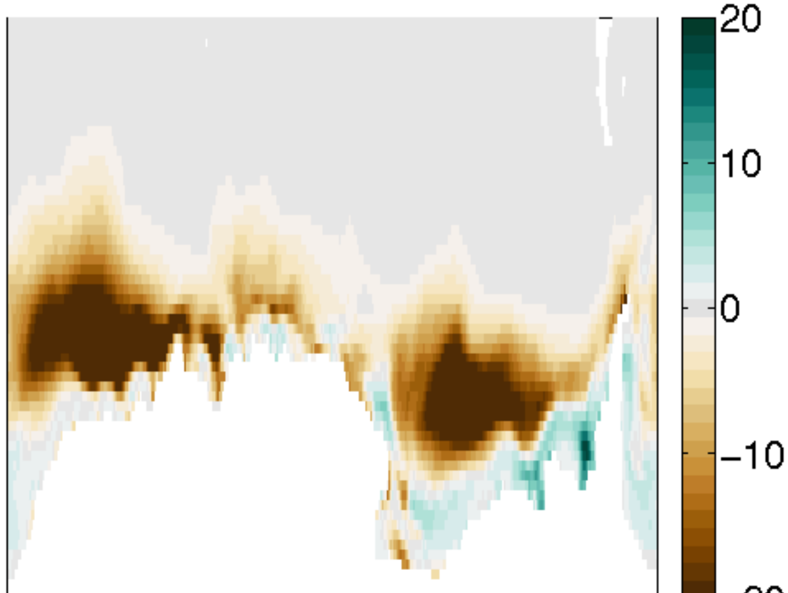
Schematic from Notz and Bitz (2017)



Each Category has a fraction of the ice cover, giving this example distribution

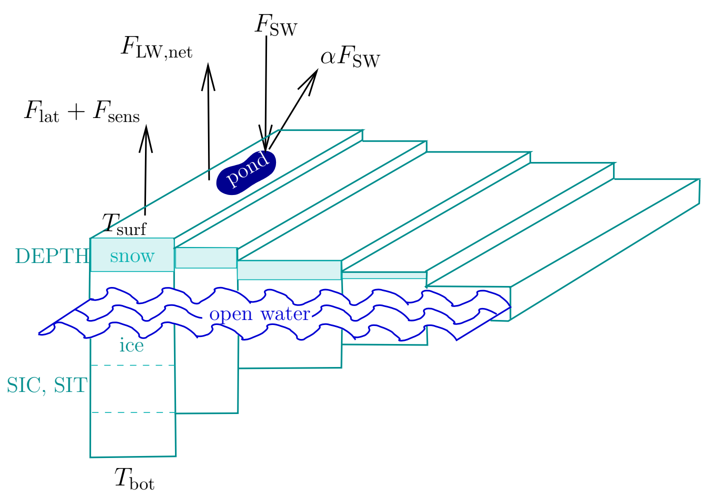
Test of CCSM4 (no wave or floe size model). All floes were 300 m in diameter, and I simply set them to 3m.

In February, Antarctic sea ice concentration is 10-20% less and there is overall 20% less sea ice area.



Sea ice models have simulated the ice-thickness distribution for a few decades

A grid cell has these variables in **each** thickness category

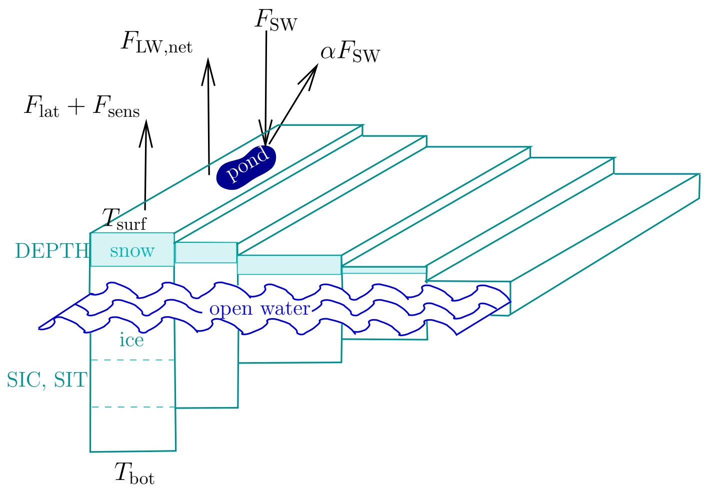


Schematic from Notz and Bitz (2017)

We've added a floe size distribution to each thickness category, giving a joint thickness floe-size distribution

Sea ice models have simulated the ice-thickness distribution for a few decades

A grid cell has these variables in **each** thickness category

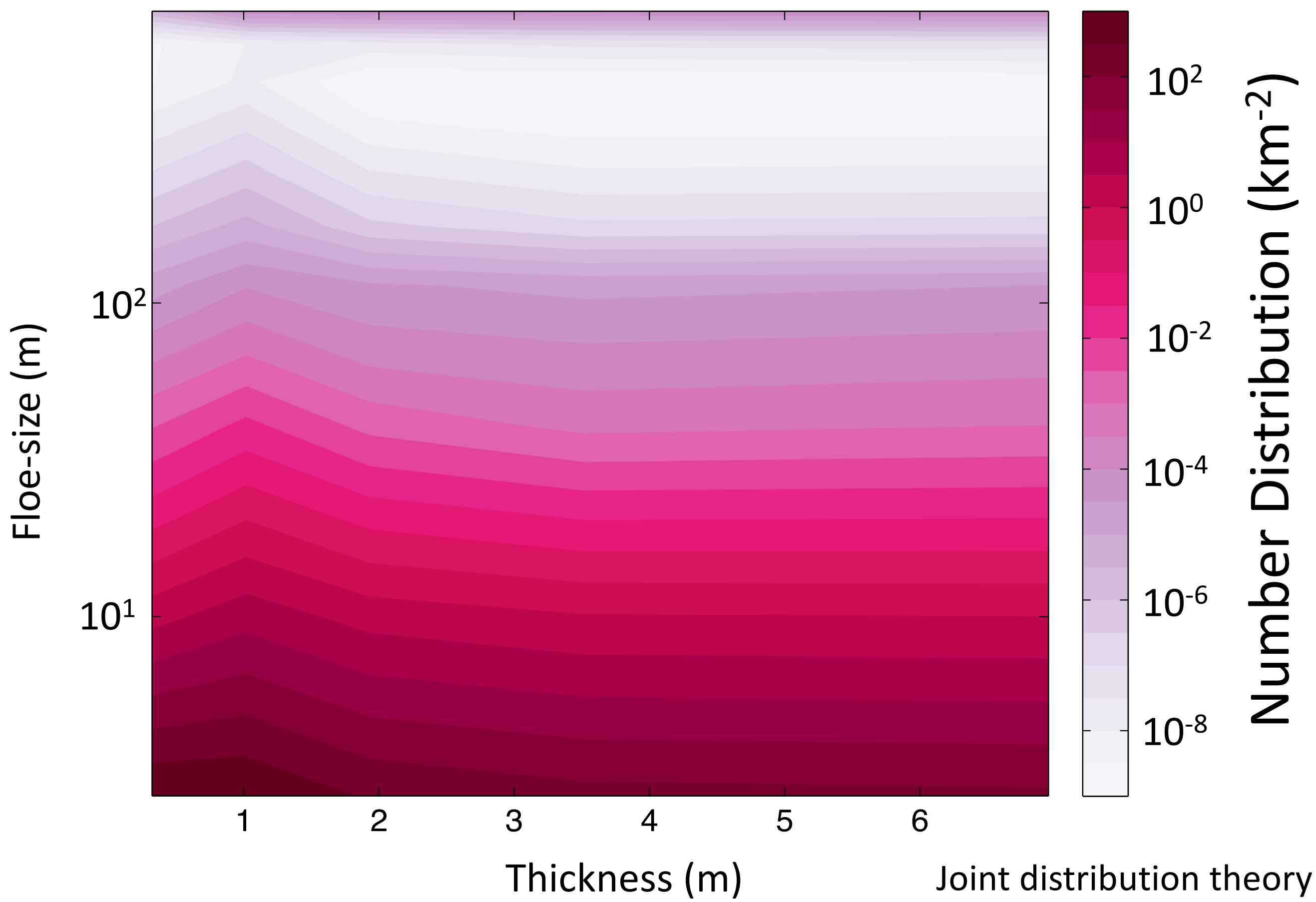


Schematic from Notz and Bitz (2017)

We've added a floe size distribution to each thickness category, giving a joint thickness floe-size distribution

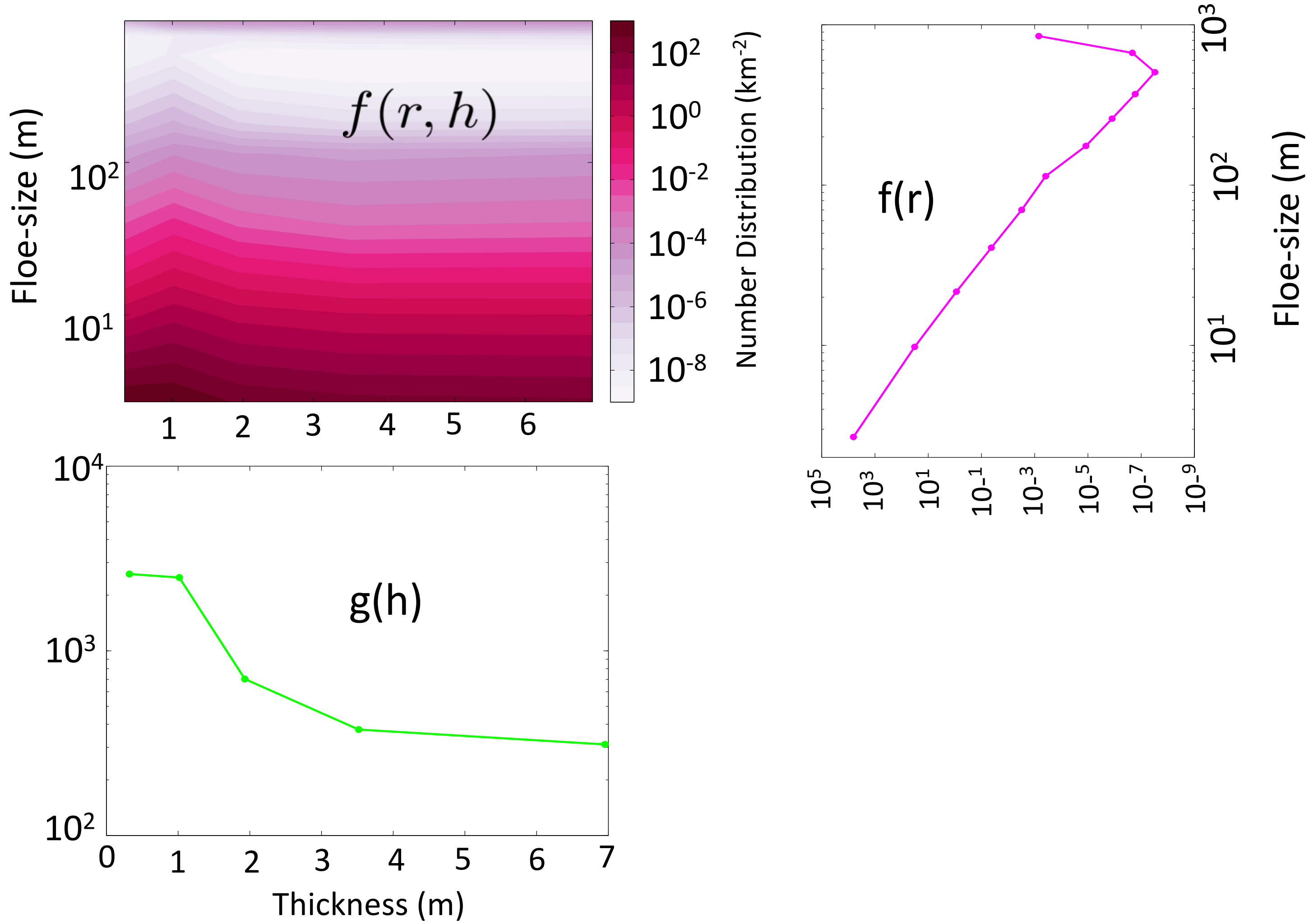
We coded it up in CICE5 in the CESM2 codebase

Northern Hemisphere mean Joint thickness and floe-size distribution in CICE5

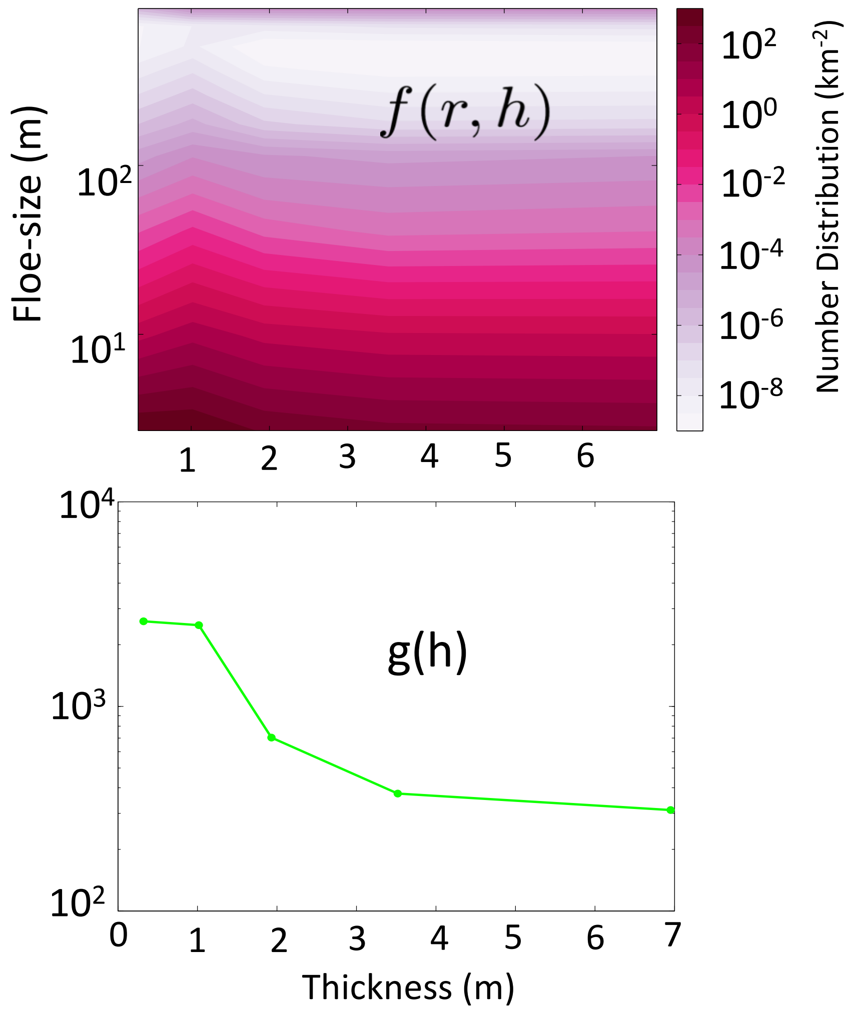


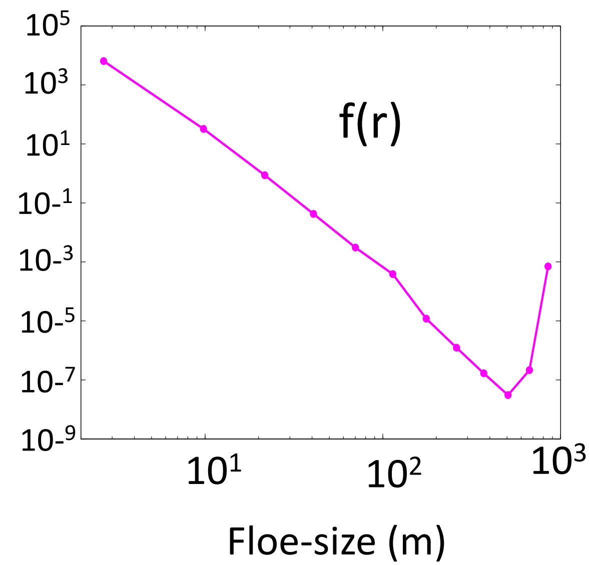
Joint distribution theory was developed by Horvat and Tziperman (2015)

Northern Hemisphere mean Joint thickness and floe-size distribution in CICE5



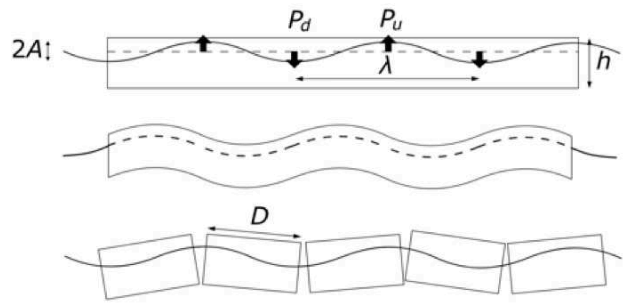
Northern Hemisphere mean Joint thickness and floe-size distribution in CICE5





We have 12 size bins and 5 thickness bins (60 total)
Smallest floe mean size is ~3m

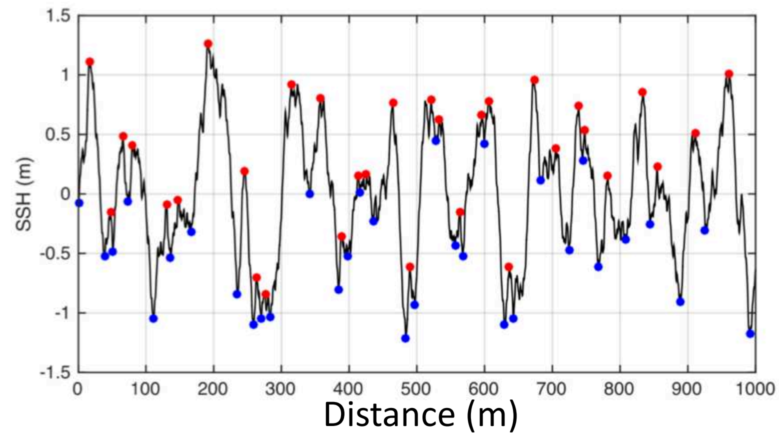
Fracturing is illustrated here:



Dumont et al (2011)

- Sea ice model needs to know wave amplitude spectrum
- We then convert the spectrum into a 1D sea surface height and examine the spacing of maxima using the method of Horvat and Tziperman (2015)

A sample sea surface height:



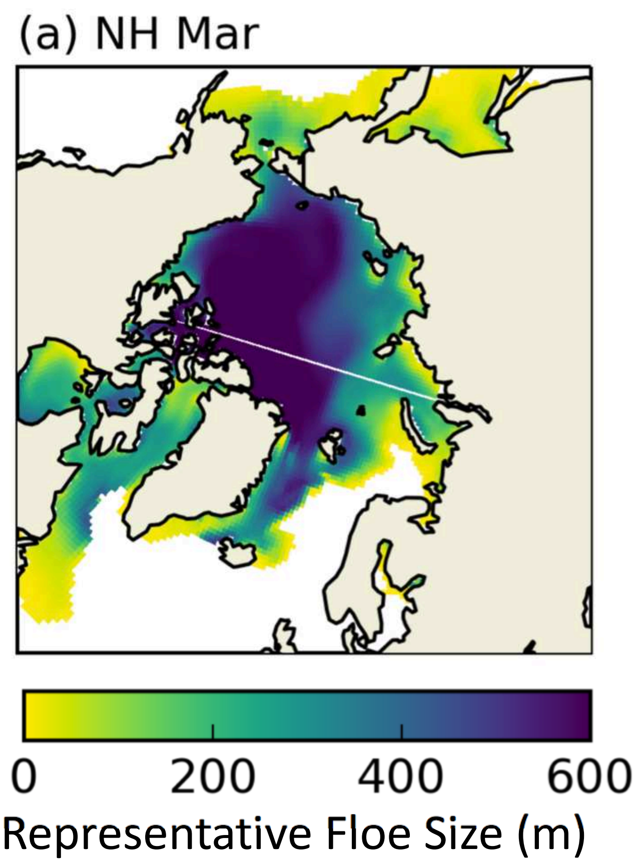
Processes that influence floe size

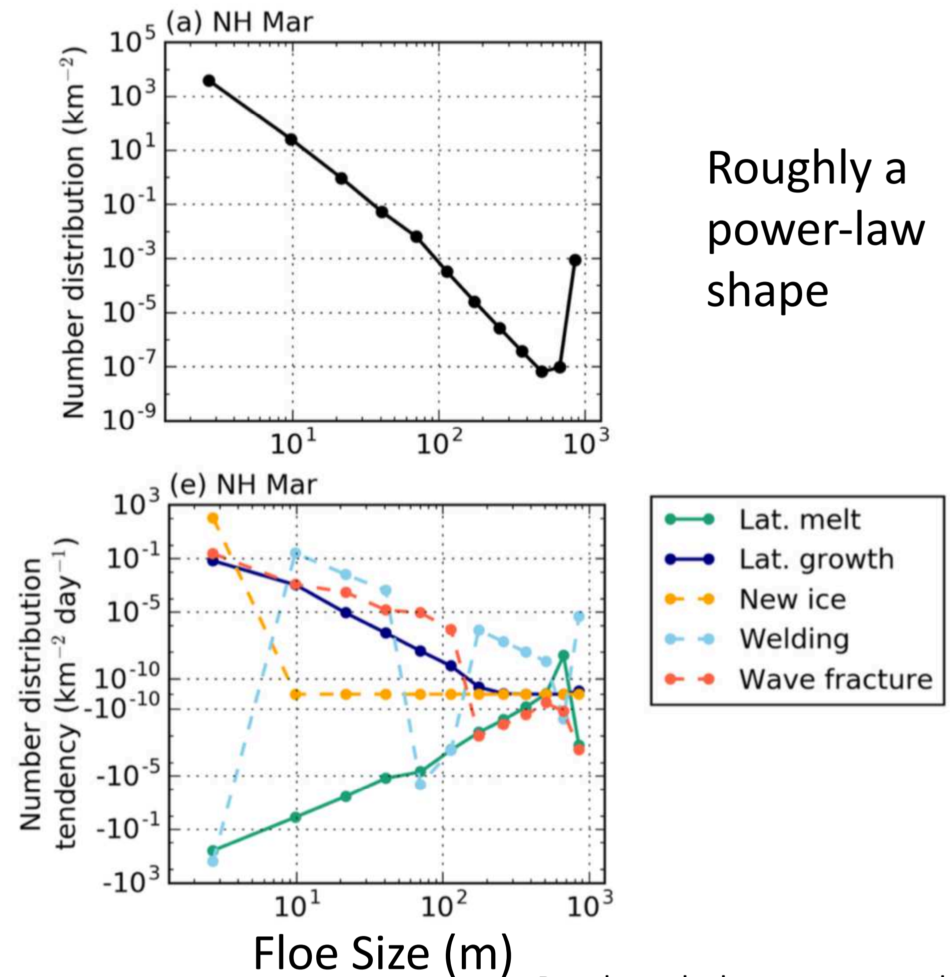
1. Lateral melt
2. Lateral growth
3. New ice growth – assumed to start as pancakes for now
4. Floe merging
5. Wave fracture

$$\frac{\partial f}{\partial t} = -\nabla \cdot (f(r,h)\mathbf{u}) + \mathcal{L}_T + \mathcal{L}_M + \mathcal{L}_W$$

Modeling a Joint floe-size (r) and thickness (h) distribution of sea ice, $f(r, h)$

Prescribing wave spectrum

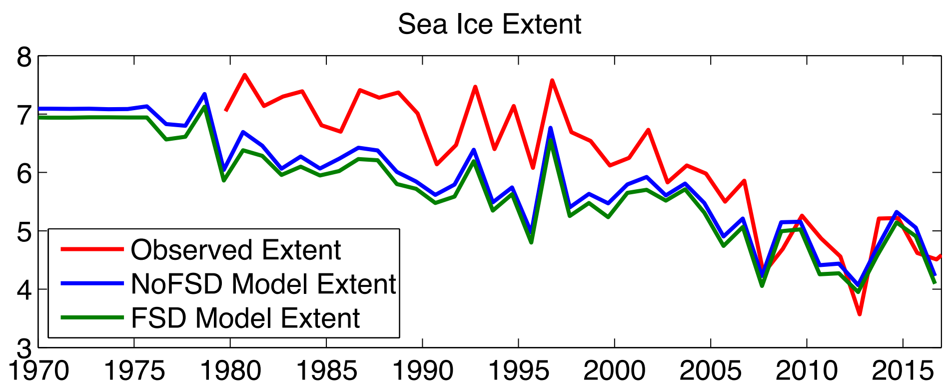


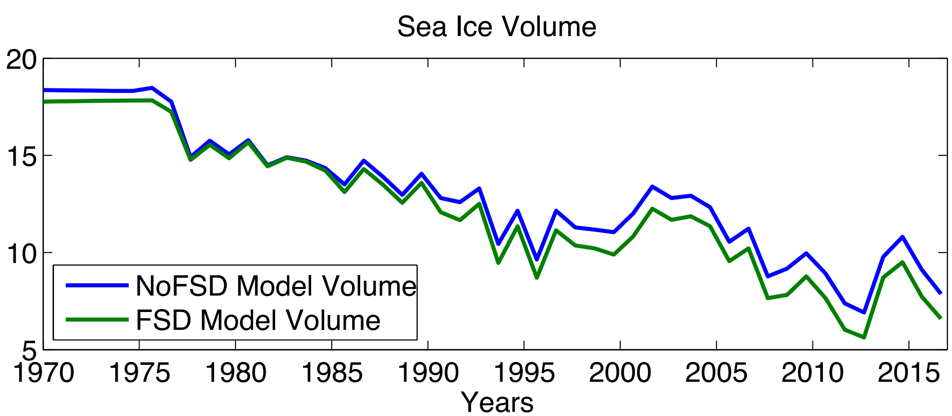


Roughly a power-law shape

Roach et al, close to accepted

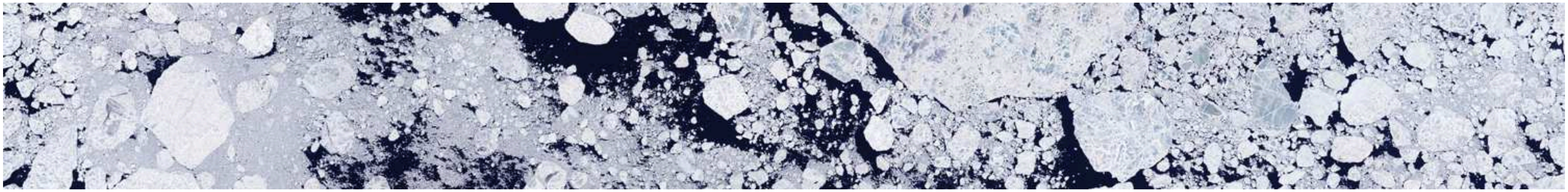
Influence of joint floe-thickness model on September Extent/Volume



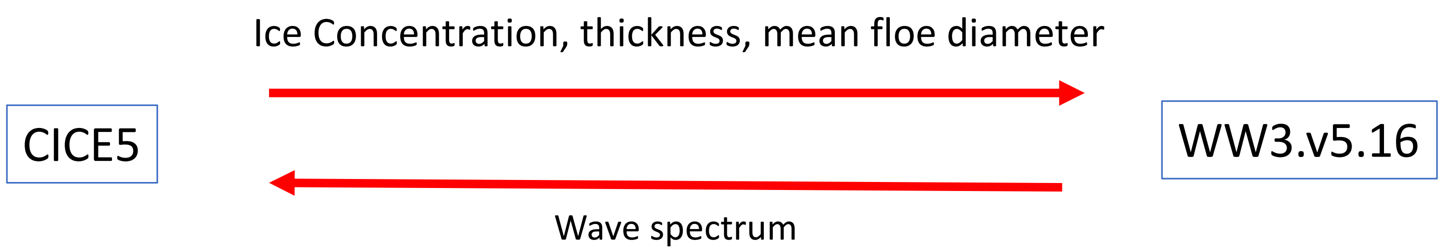


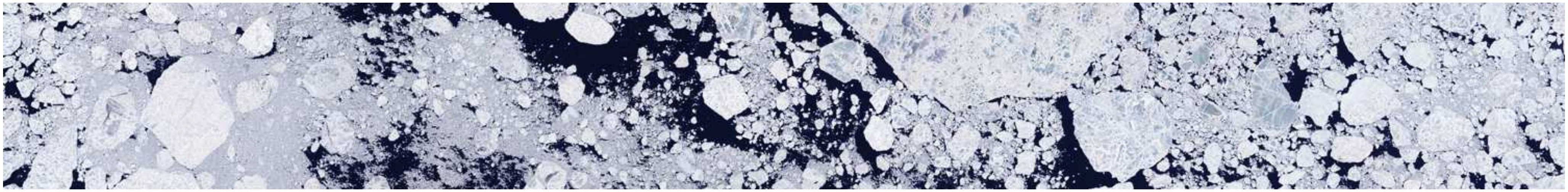
Little influence on September sea ice **extent** because atmosphere is prescribed (bias here is due to slab ocean)

Bigger influence on **volume**



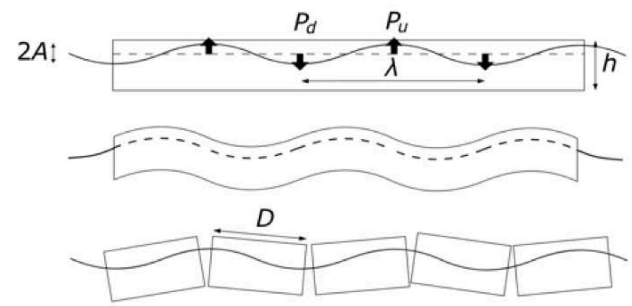
We have coupled CICE5 in CESM2 to WAVEWATCH3 v5.16, which predicts the surface wave spectrum.





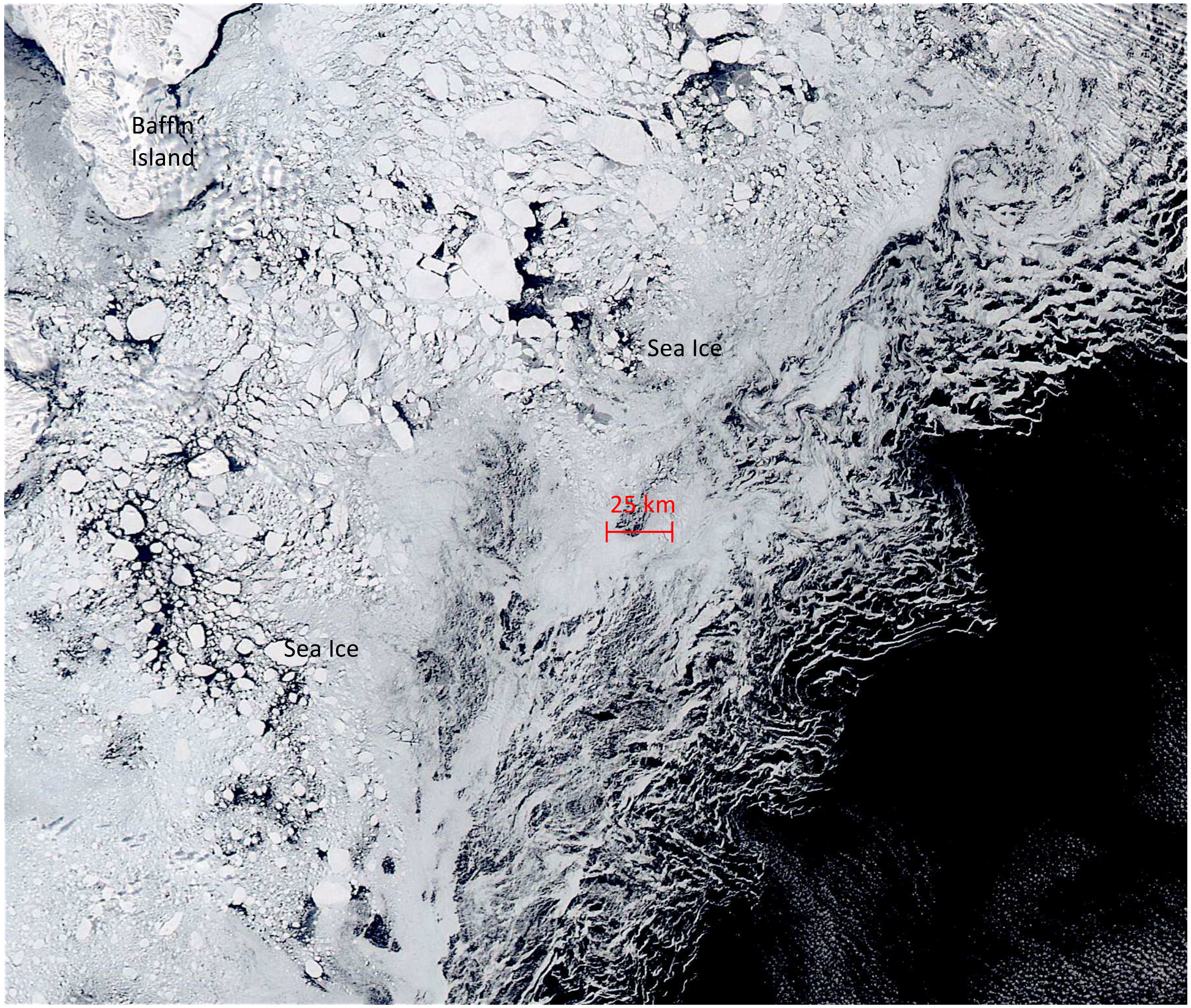
What does sea ice do to waves?

- Sea ice damps waves as waves deform the ice, damping wave energy
- Sea ice also scatters waves, redirecting wave energy

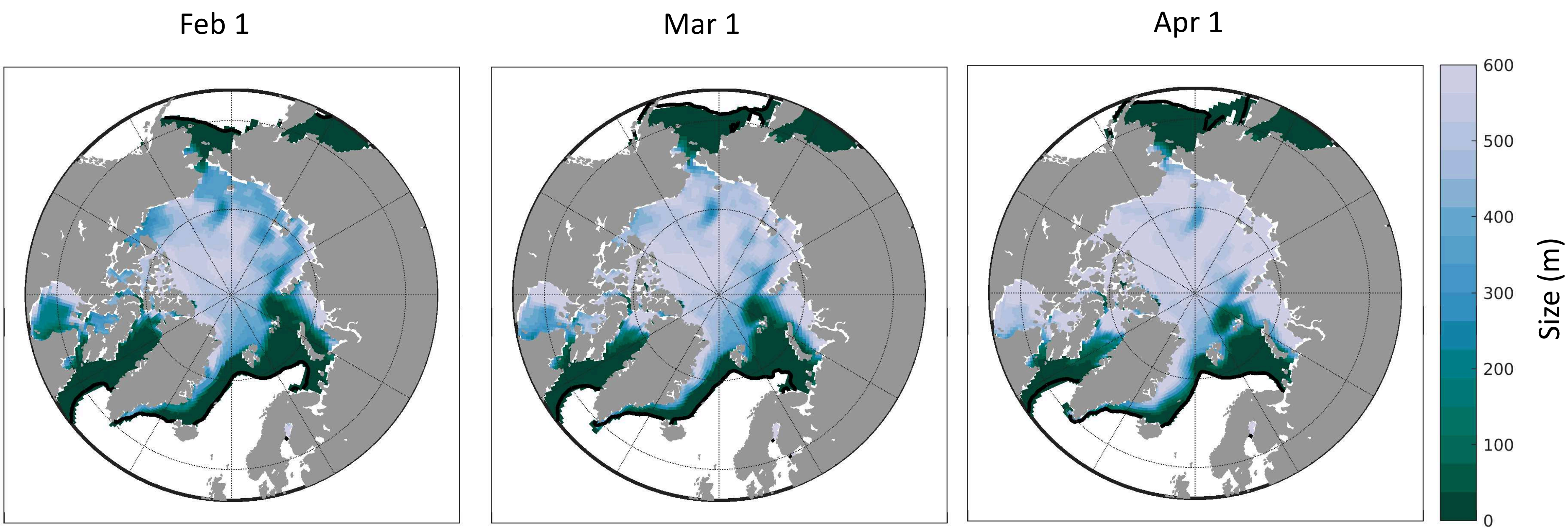


Dumont et al (2011)

30 March 2017
Subpolar Seas

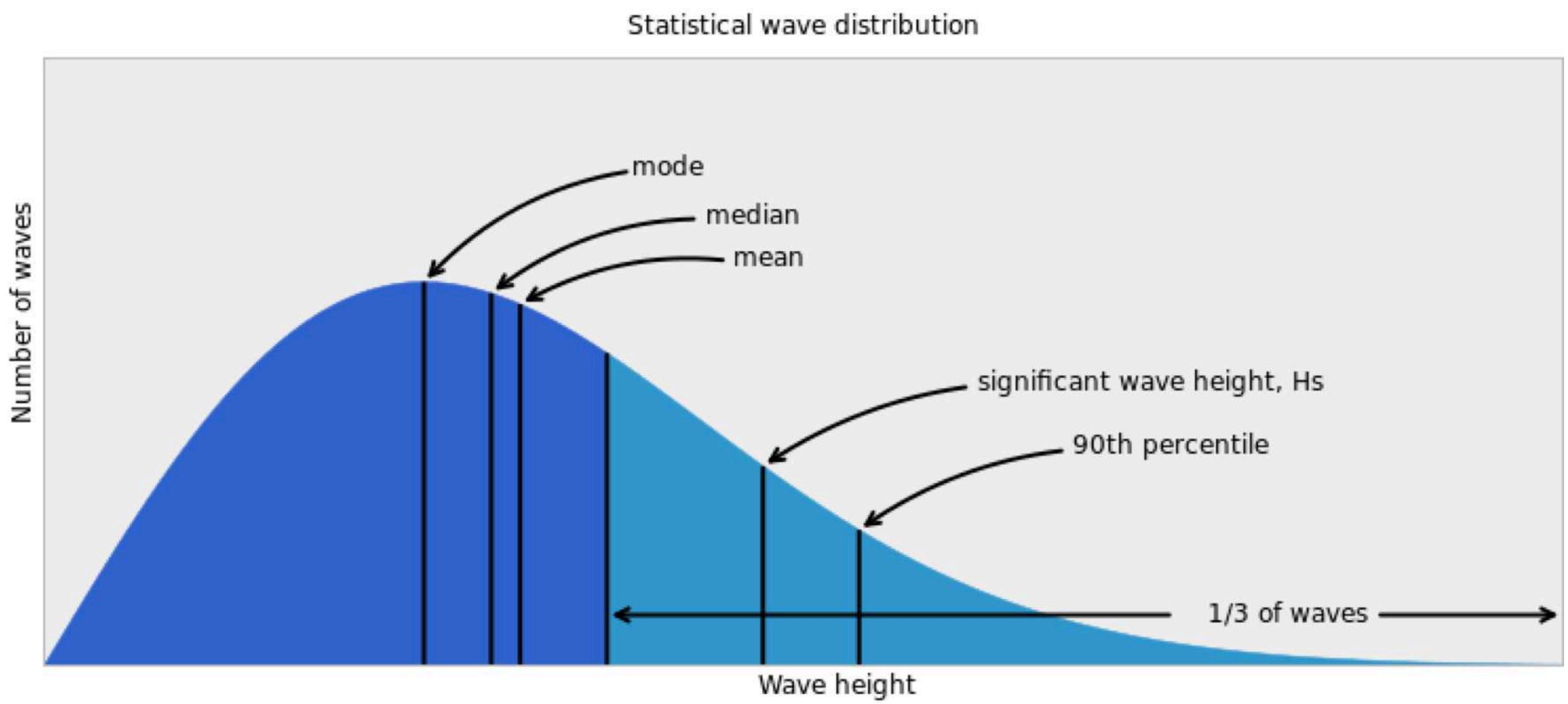


Influence of floe-size model coupled to wave model on “Representative” Floe Size



15% Sea Ice Contour showing sea ice edge is in black

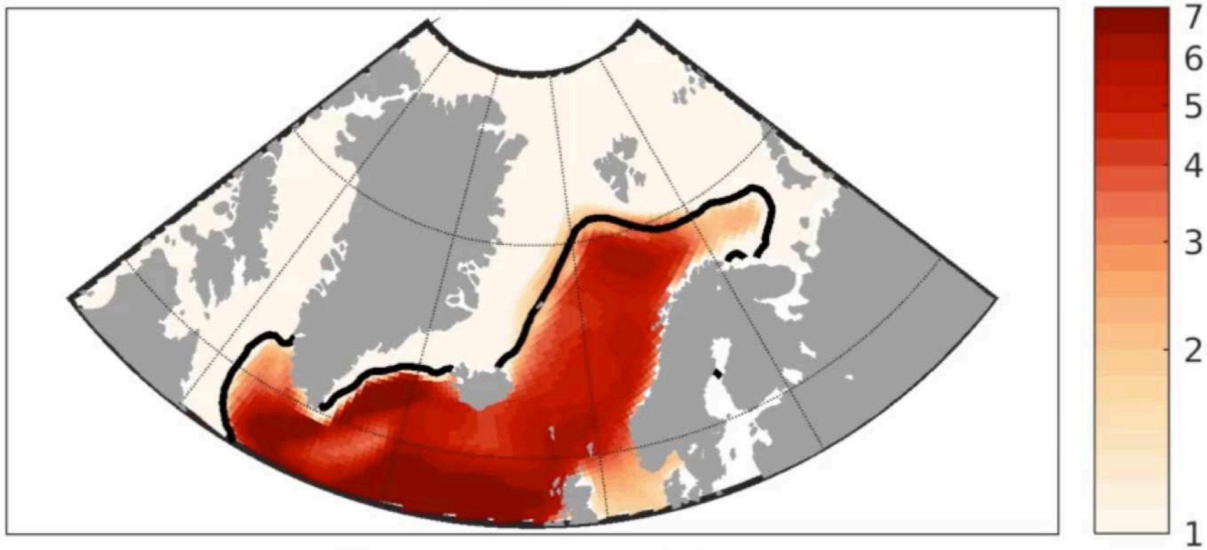
Significant Wave Height, Hs



Wavelength

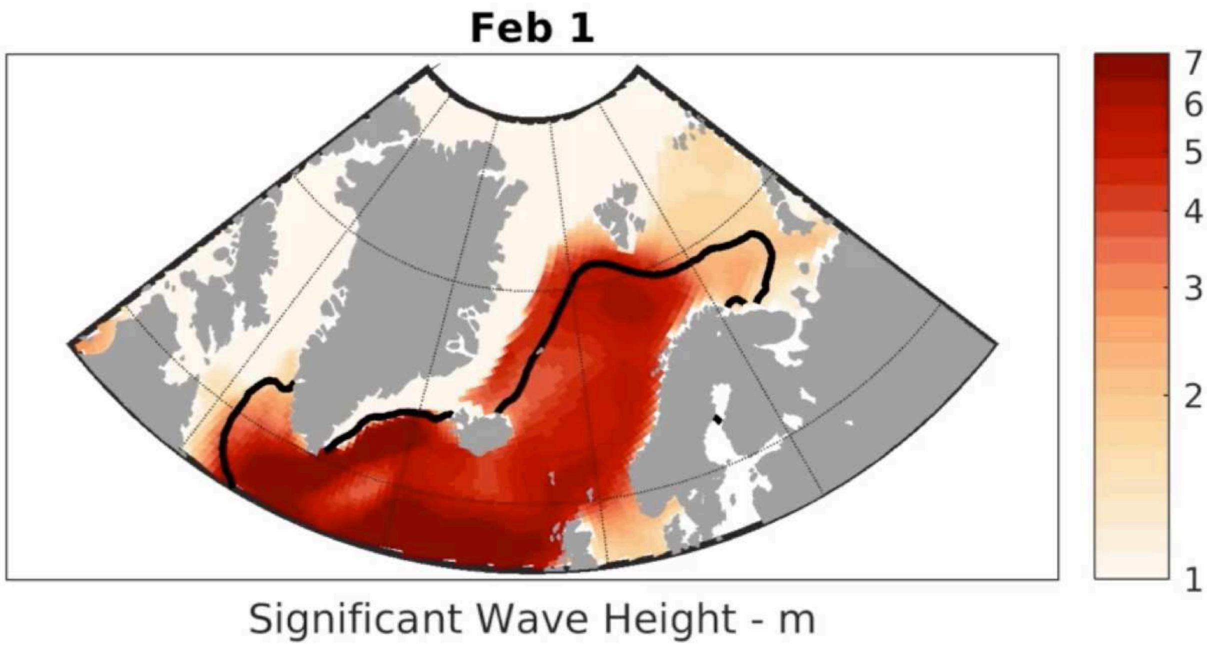
Figure from Wikipedia
WAVEWATCH definition of Hs is 4 (area under curve)$^{0.5}$

Feb 1



Significant Wave Height - m

In this experiment, all floes damp waves
(this is an animation when given live)



In this experiment, only floes >6m damp waves,
So waves travel much further into the sea ice!

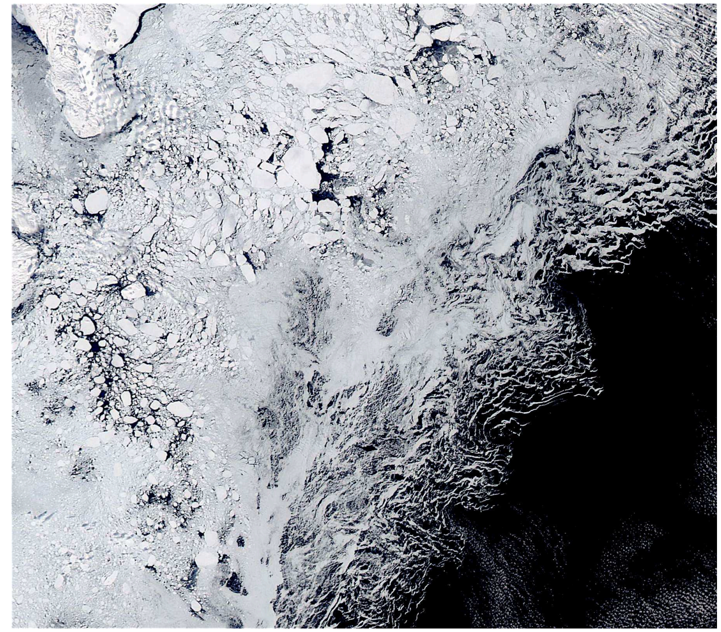
What’s next?

Run coupled wave-sea ice model for recent extreme cases

Turn on atmosphere and ocean when CESM2 is released

Work on constraining with observations

Conclusions



First joint floe-thickness distribution for climate simulations and first coupled floe-wave model

All five processes have a strong influence

Floe-Wave coupling causes abrupt spatial edge in wave height and floe size