A new parameterization describing the health of a sea ice floe and its potential to influence wave fracture

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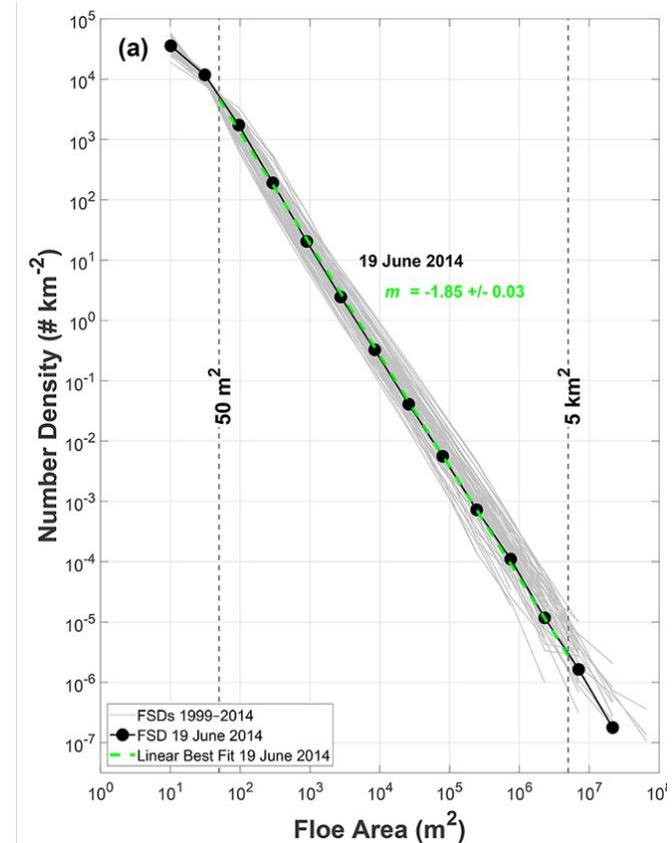[3]Alfred Wegener Institute, Bremerhaven, Germany
[4]NCAR, Boulder, USA

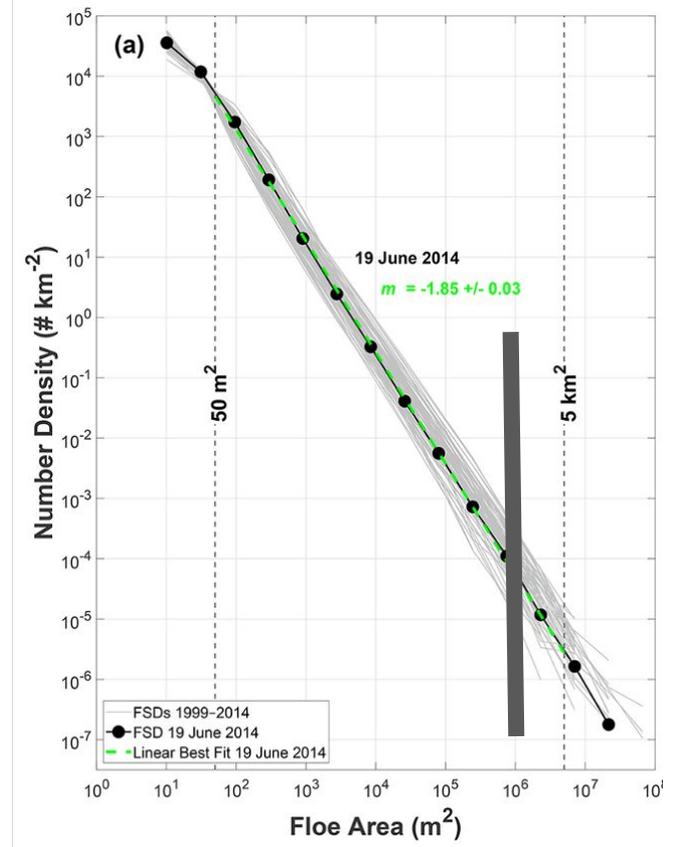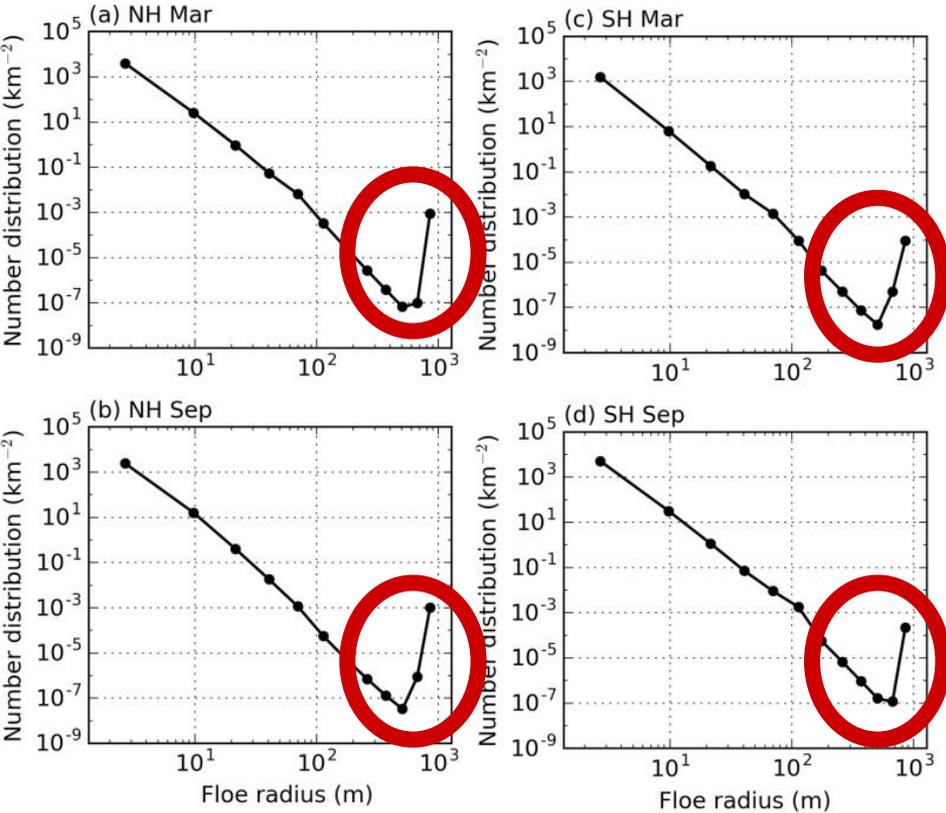Credit: Oceanwide Expeditions

What is the Floe Size Distribution (FSD)?

- The FSD quantifies the probability of finding a floe of a given size over a given region
- CICE models the FSD with 12 bins
- CICE prognostically models five processes that affect the FSD:
  - New ice creation
  - Lateral growth
  - Lateral melt
  - Welding
  - Wave fracture
- We introduce <u>floe deformation</u> and <u>"floe health"</u> to tackle homogeneity in the Arctic

(a)
19 June 2014
m = -1.85 +/- 0.03
50 m^2
5 km^2

FSDs 1999–2014
FSD 19 June 2014
Linear Best Fit 19 June 2014

Number Density (# km^{-2})
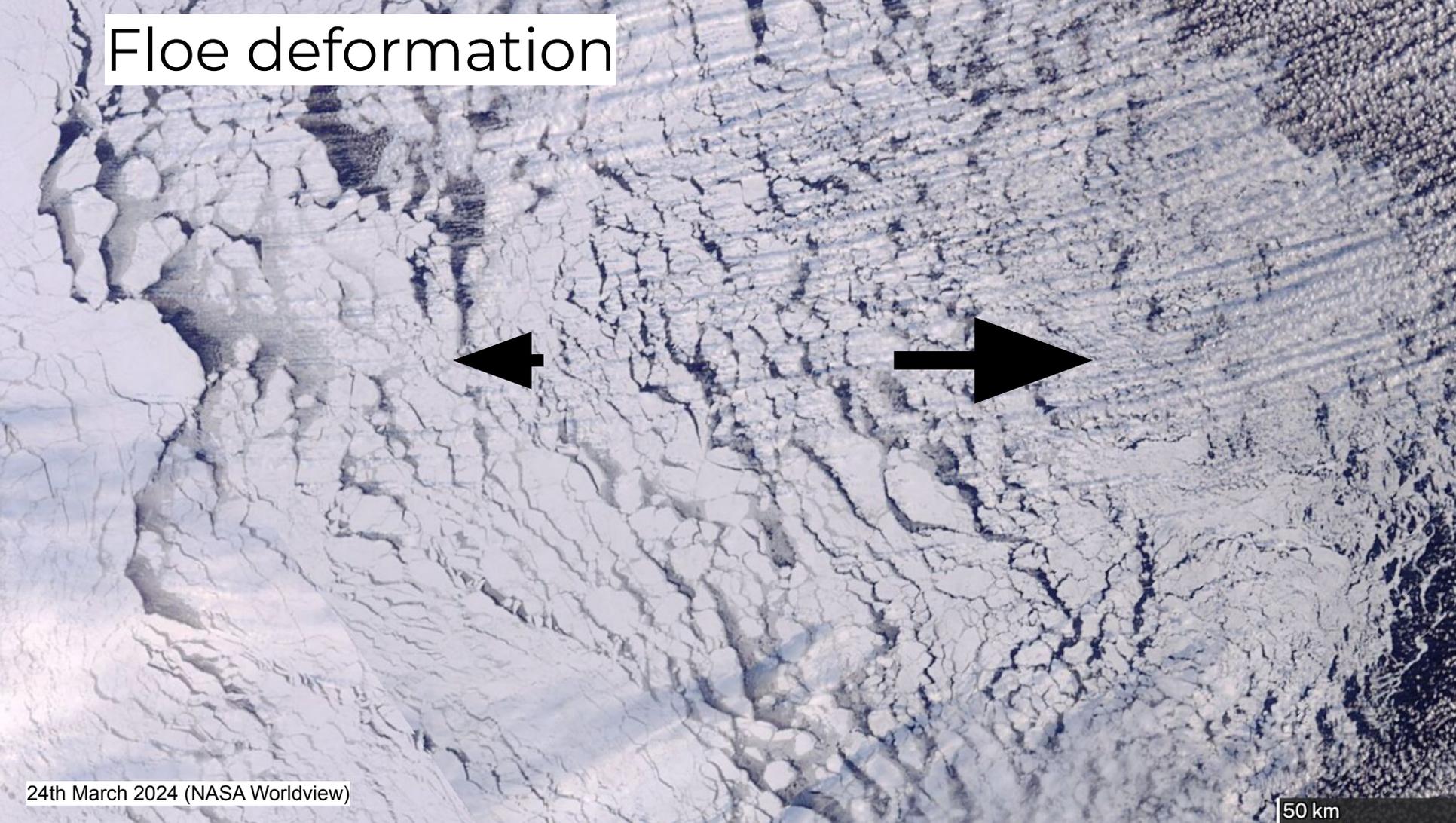Floe Area (m^2)

Denton and Timmermans, 2022

The mismatch between CICE and observations

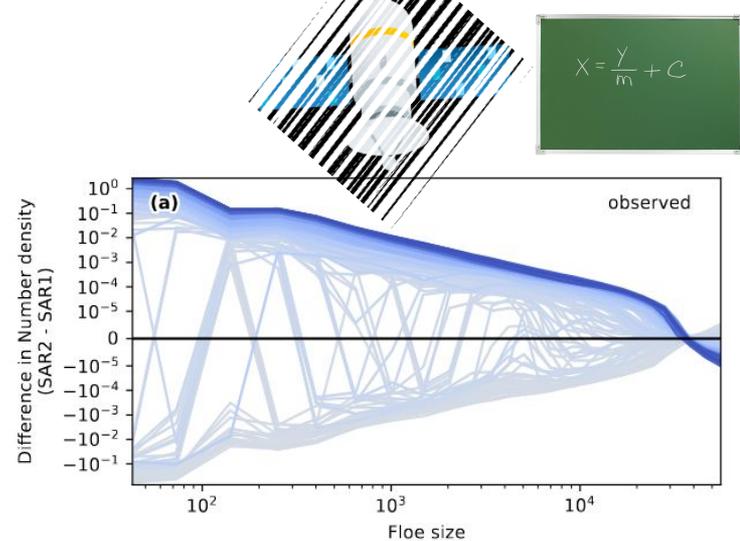Roach et al., 2018; Denton and Timmermans, 2022

Floe deformation

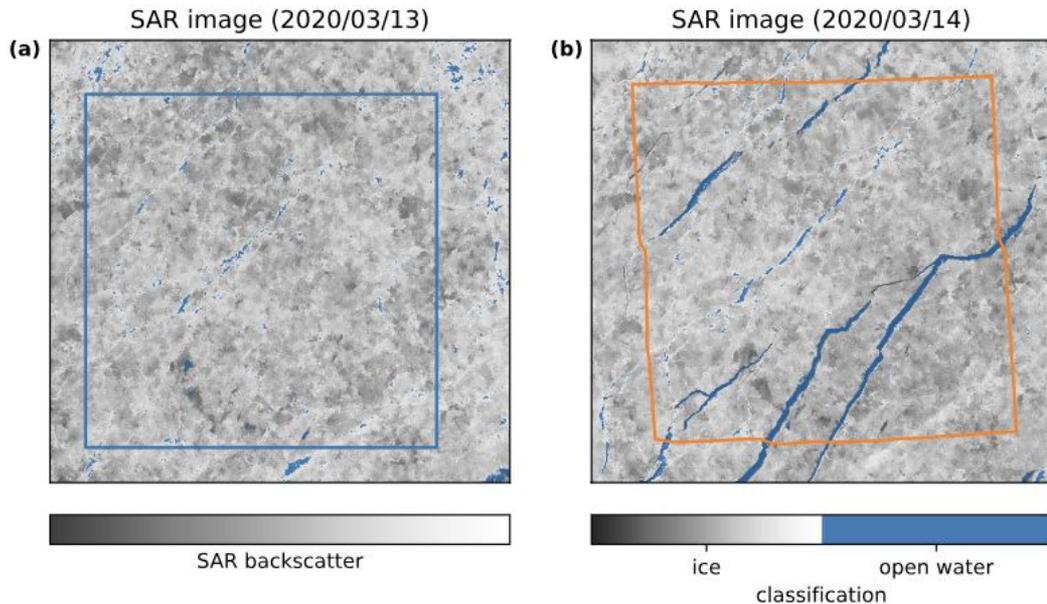24th March 2024 (NASA Worldview)

50 km

Modelling floe deformation

SAR image (2020/03/13)

SAR image (2020/03/14)

SAR backscatter

ice — open water
classification

$$\Delta F^N(r, \dot{\epsilon}_I) = a(\dot{\epsilon}_I)\,(2r)^{e\left(\dot{\epsilon}_I\right)}\,\tanh\!\Big(2b(\dot{\epsilon}_I)\,(r_0 - r)\Big)$$

Hutter et al., *in prep*

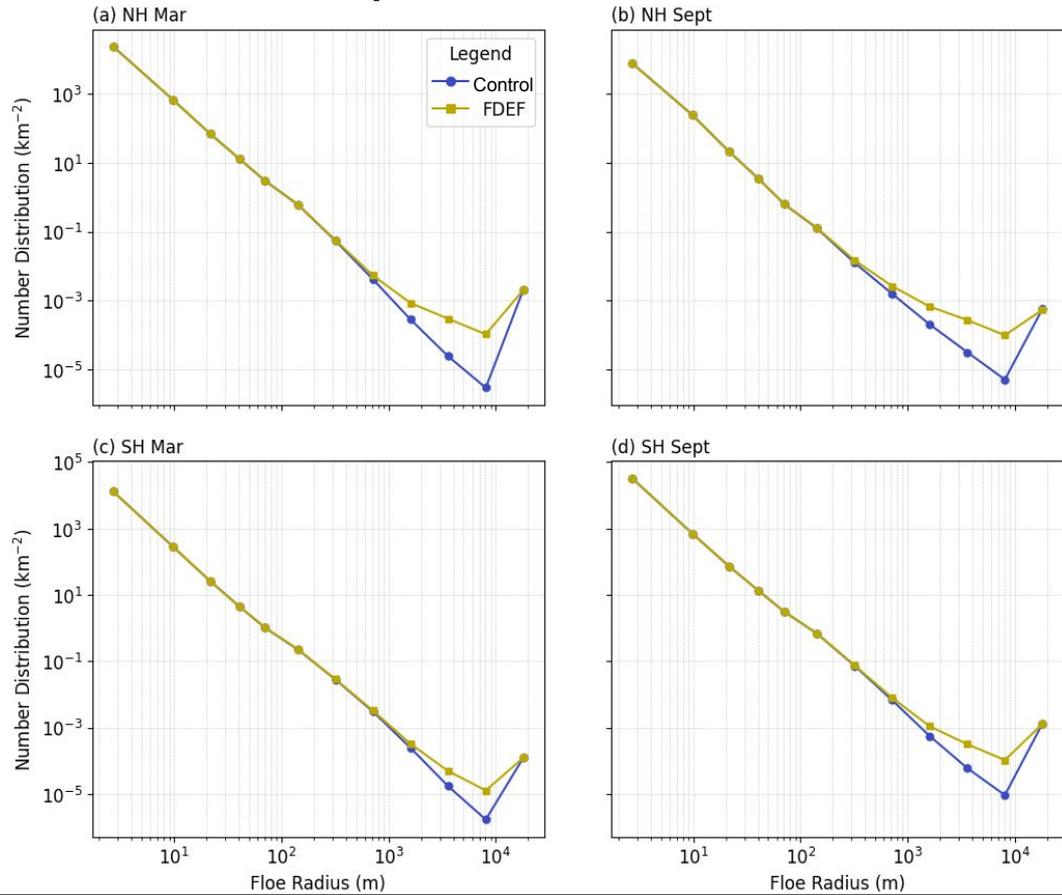# Model setup for floe deformation

- Using CESM
  - Coupled CICE6 🧊 with WWIII 🌊
    - Using extended bounds
  - Prescribed atmosphere (JRA-55)
  - Slab ocean (prescribed Q-flux)
- 40 year run
  - Analysis on last 10 years
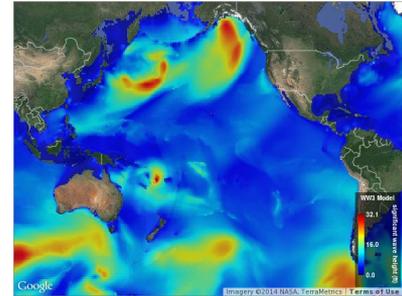
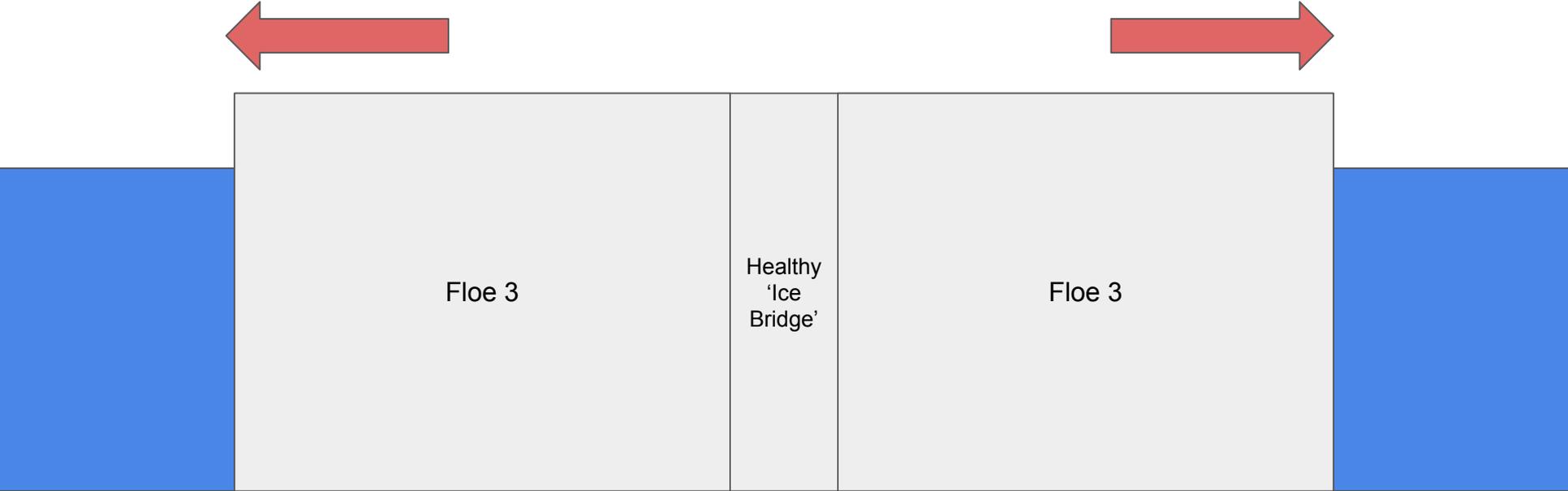# Floe deformation reduces the mean floe radius
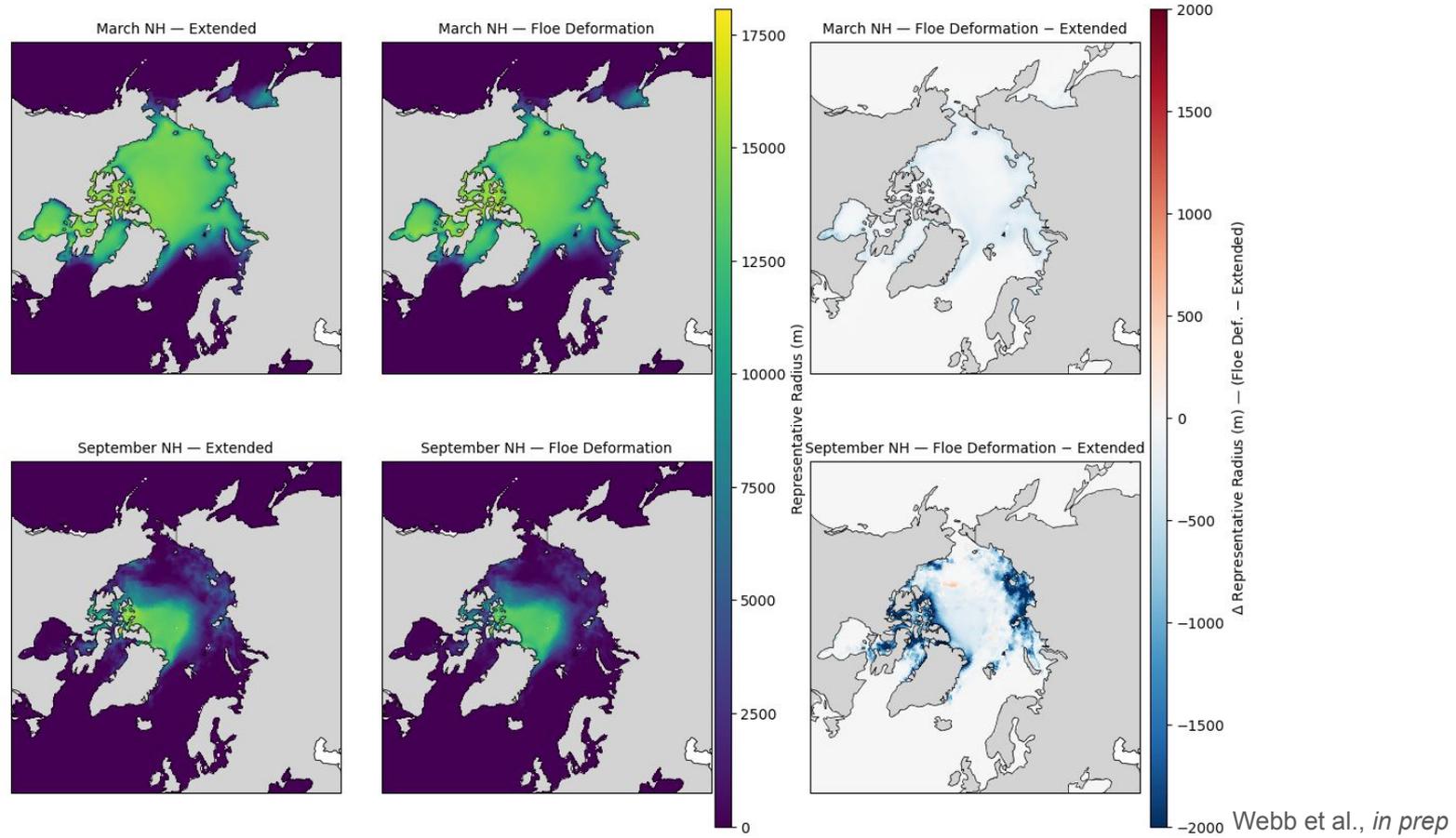
Webb et al., *in prep*

Floe deformation helps... somewhat

Webb et al., *in prep*

Can using "floe health" help solve truncation

Williams et al., 2016

What is floe health?

Floe 3

Healthy
'Ice
Bridge'

Floe 3

How do we represent health mathematically?

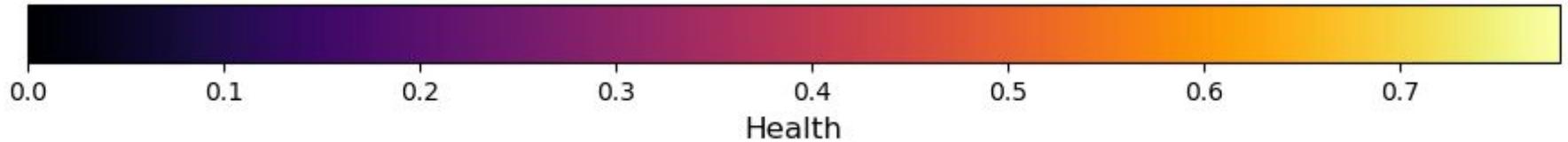$$\frac{dH(r,h)}{dt} = -\nabla \cdot (H\mathbf{V})$$

Flux
Convergence

Tendencies Increasing
Health

Positive
Welding Tendency
Reducing Health

Time
Decay
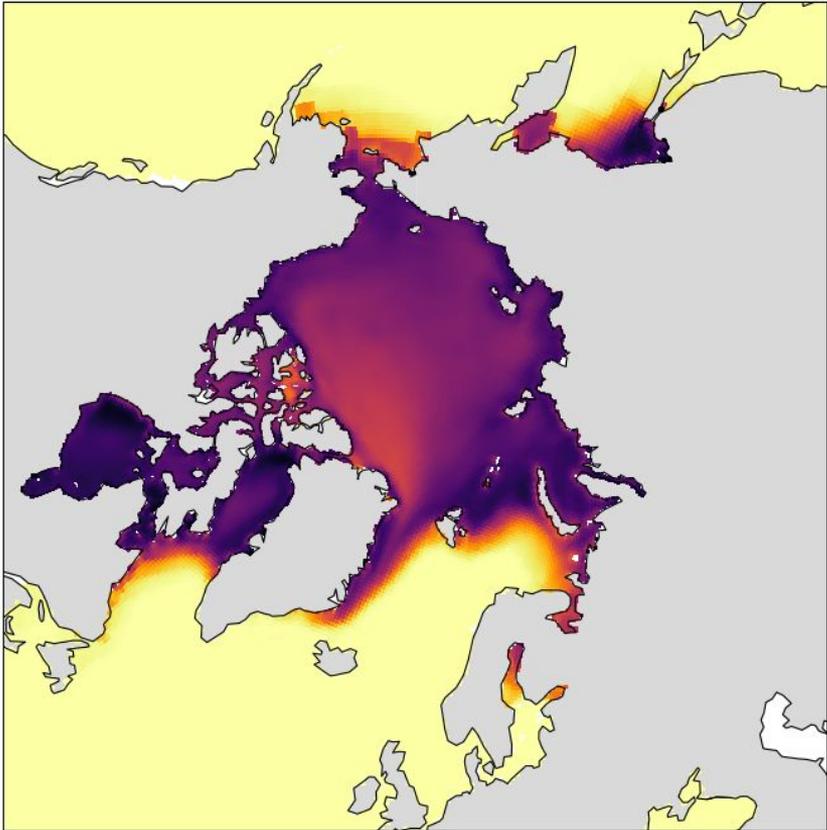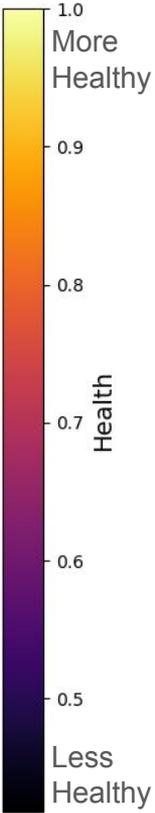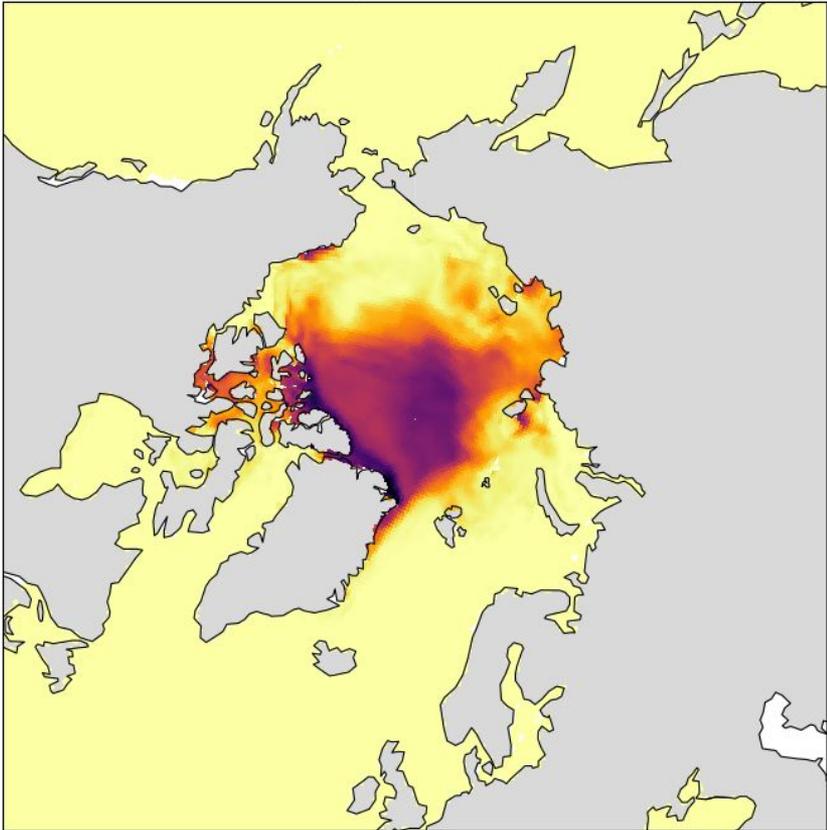
Less Healthy

More Healthy

| 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 |

Health

Can using "floe health" help solve truncation

Mean Health Climatology

March NH

September NH

More Healthy

Less Healthy

Health

Can using "floe health" help solve truncation

Wave fracture feedback

$$\epsilon_{FB} = (1 - \lambda_w(1 - \bar{H}))\epsilon_{crit}$$

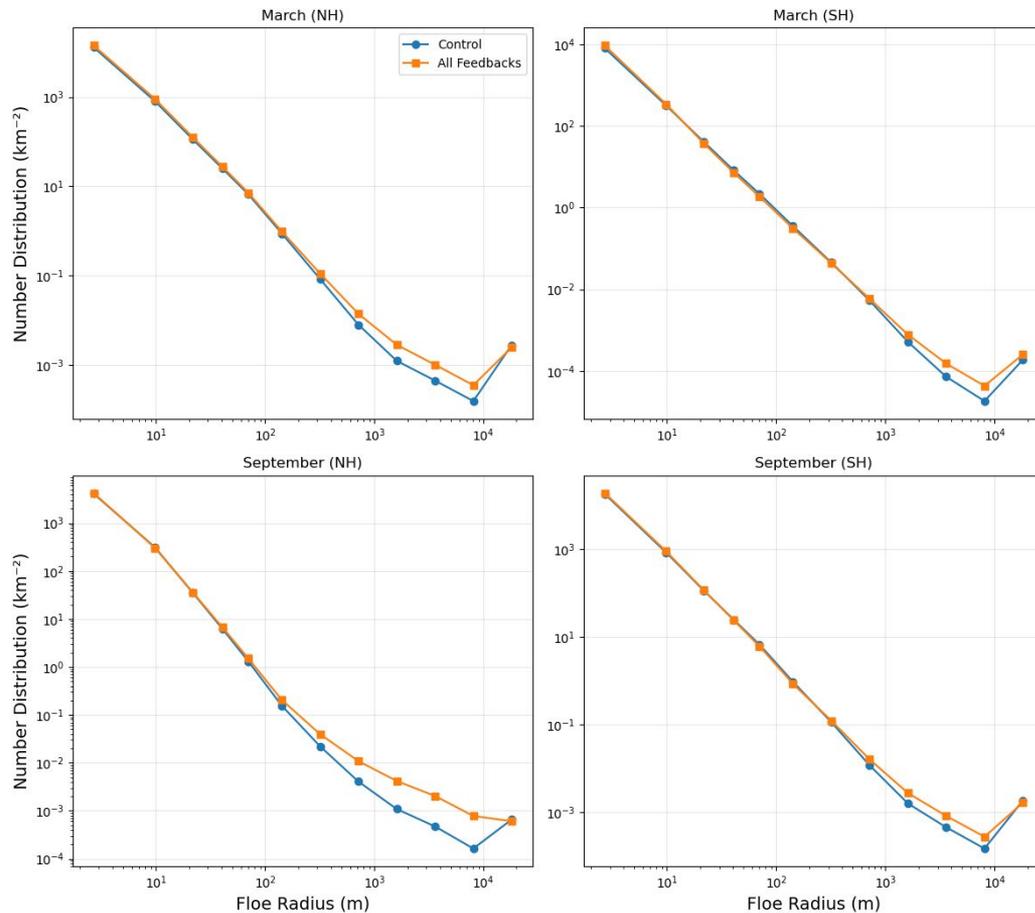Can using "floe health" help solve truncation

Other feedbacks

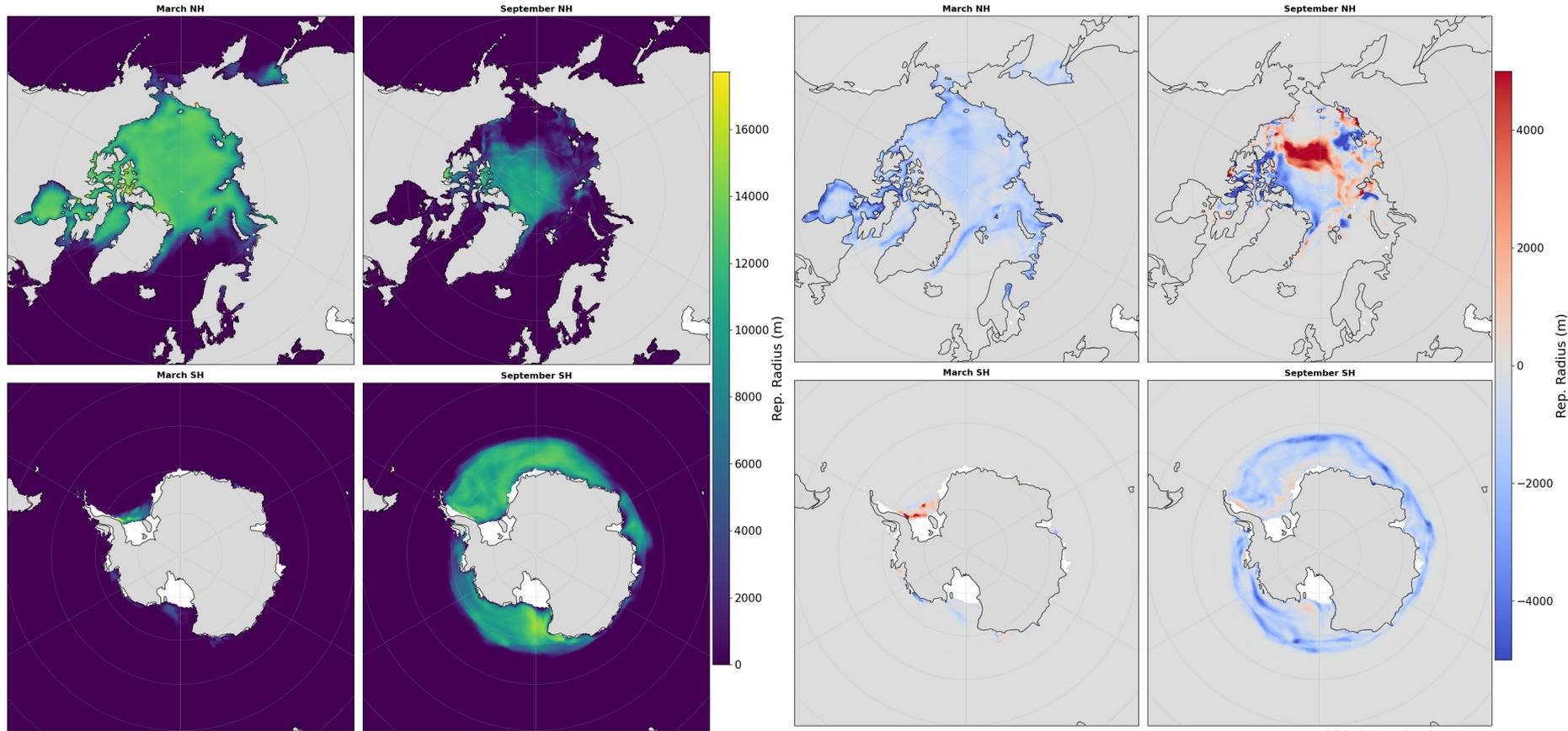$$\beta = 1 + \lambda_d(1 - \bar{H})$$

$$\chi = 1 - \lambda_s(1 - \bar{H})$$

The change in the FSD

Webb et al., *in prep*

A large decrease in the mean floe radius

Webb et al., *in prep*

Future work & Acknowledgements

- Use observations to constrain our model
- Alter parameterization(s) accordingly based on observational constraints and explore model biases
- Consider other thermodynamic effects on floe health

References

Denton, A. A. and Timmermans, M.-L.: Characterizing the sea-ice floe size distribution in the Canada Basin from high-resolution optical satellite imagery, The Cryosphere, 16, 1563–1578, https://doi.org/10.5194/tc-16-1563-2022, 2022.

Roach, L. A., Horvat, C., Dean, S. M., & Bitz, C. M.: An emergent sea ice floe size distribution in a global coupled ocean-sea ice model, Journal of Geophysical Research: Oceans, 123, 4322–4337. https://doi.org/10.1029/2017JC013692, 2018.
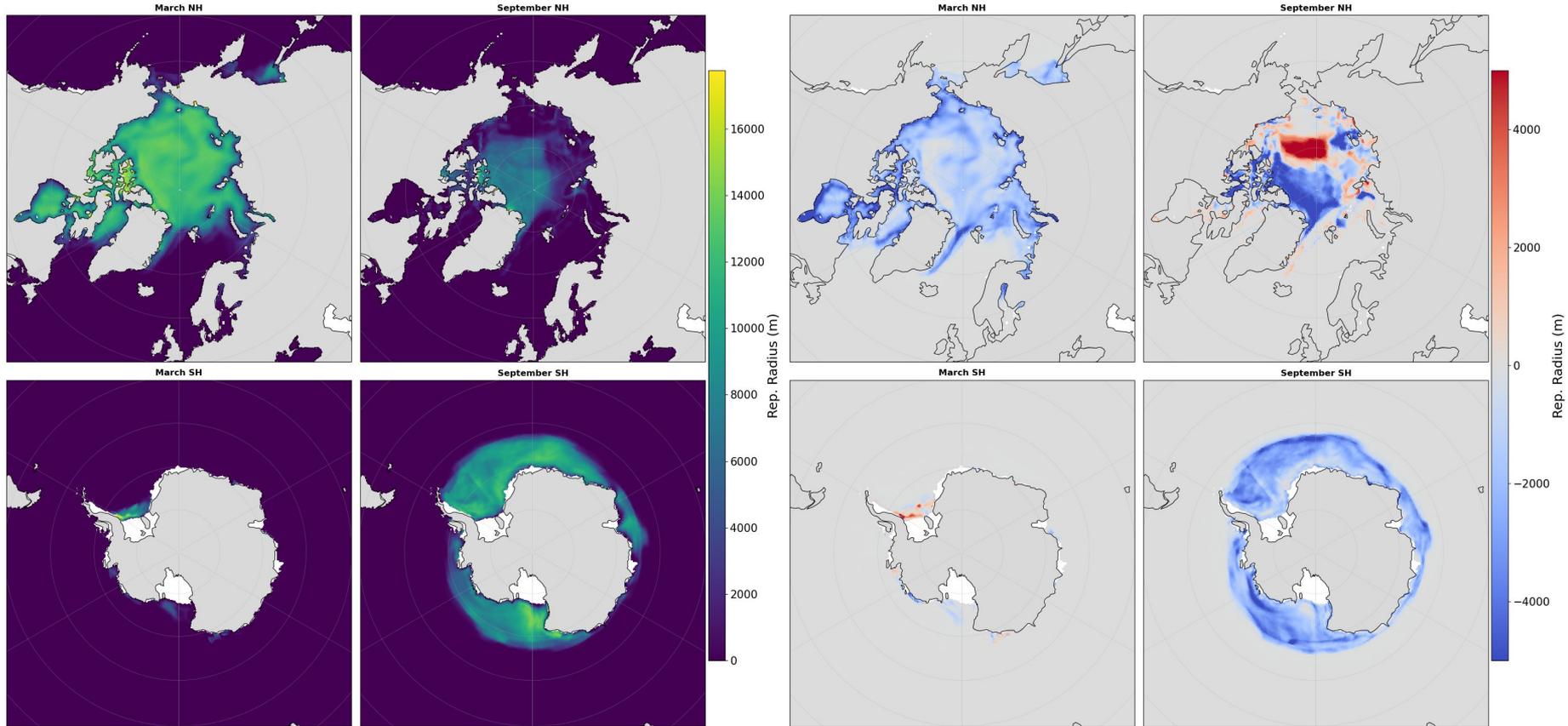
Hutter, N., Bitz, C. M., Linking the evolution of floe sizes to the sea-ice deformation history using SAR imagery, in preparation

Williams, G. D., and Coauthors, 2016: Drones in a cold climate, Eos, 97, 1-6, https://doi.org/10.1029/2016eo043673.

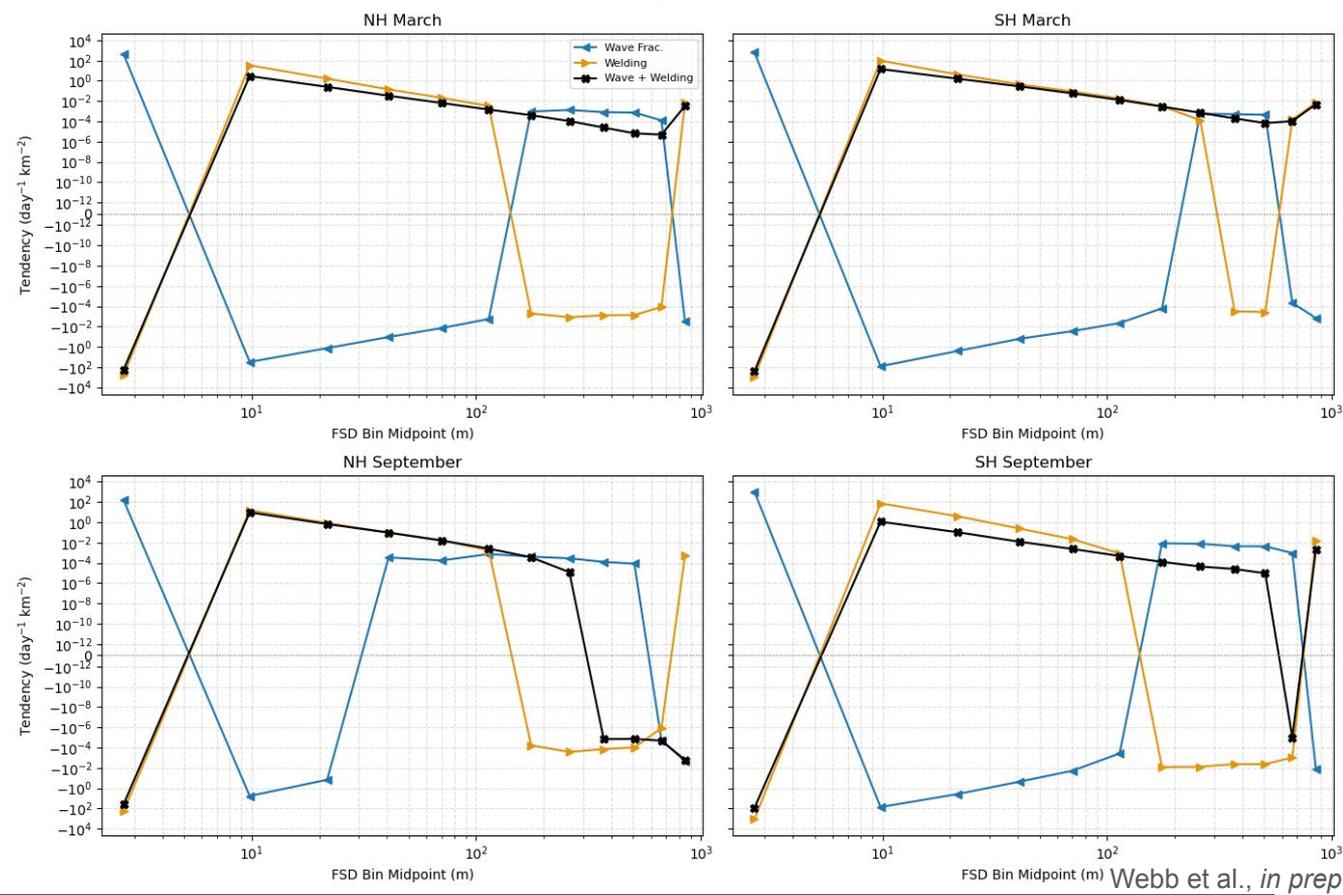# Very strong feedback - FSD
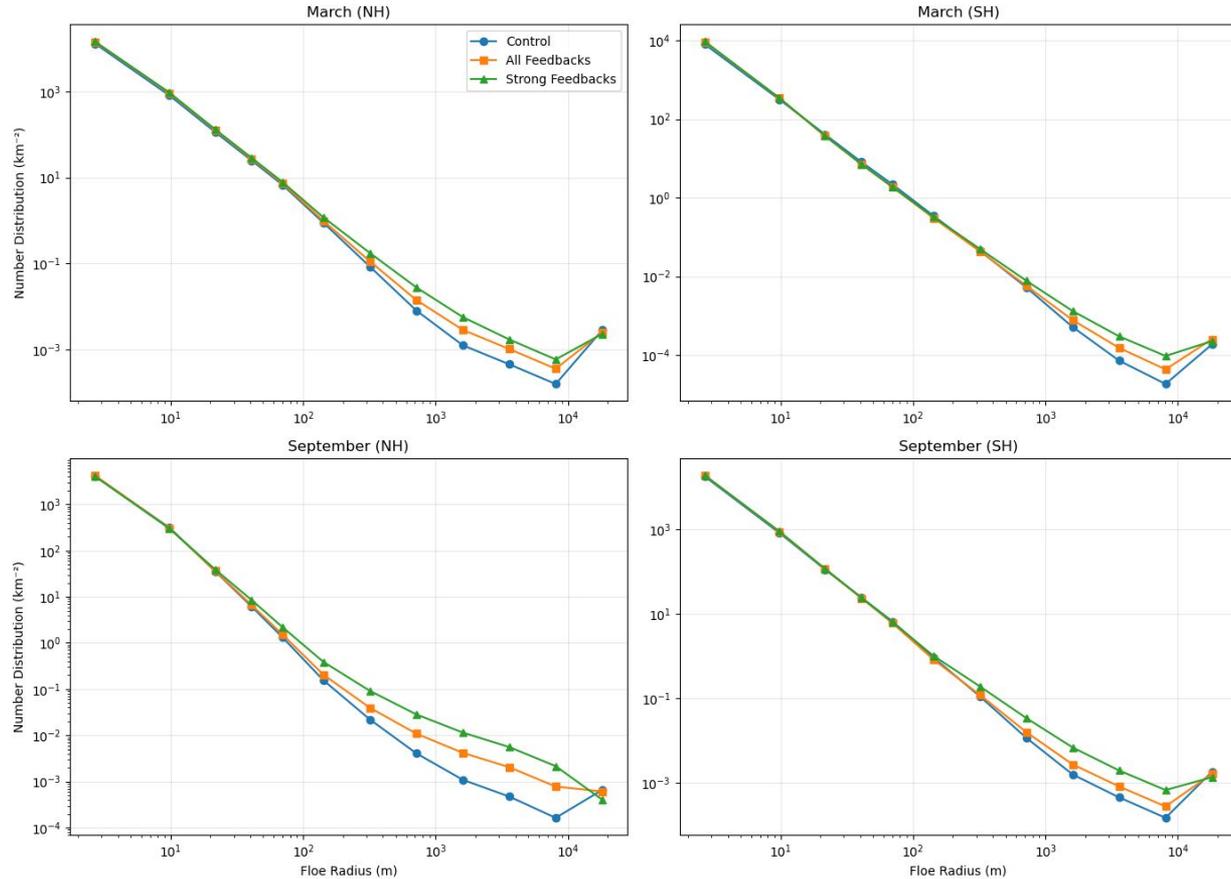
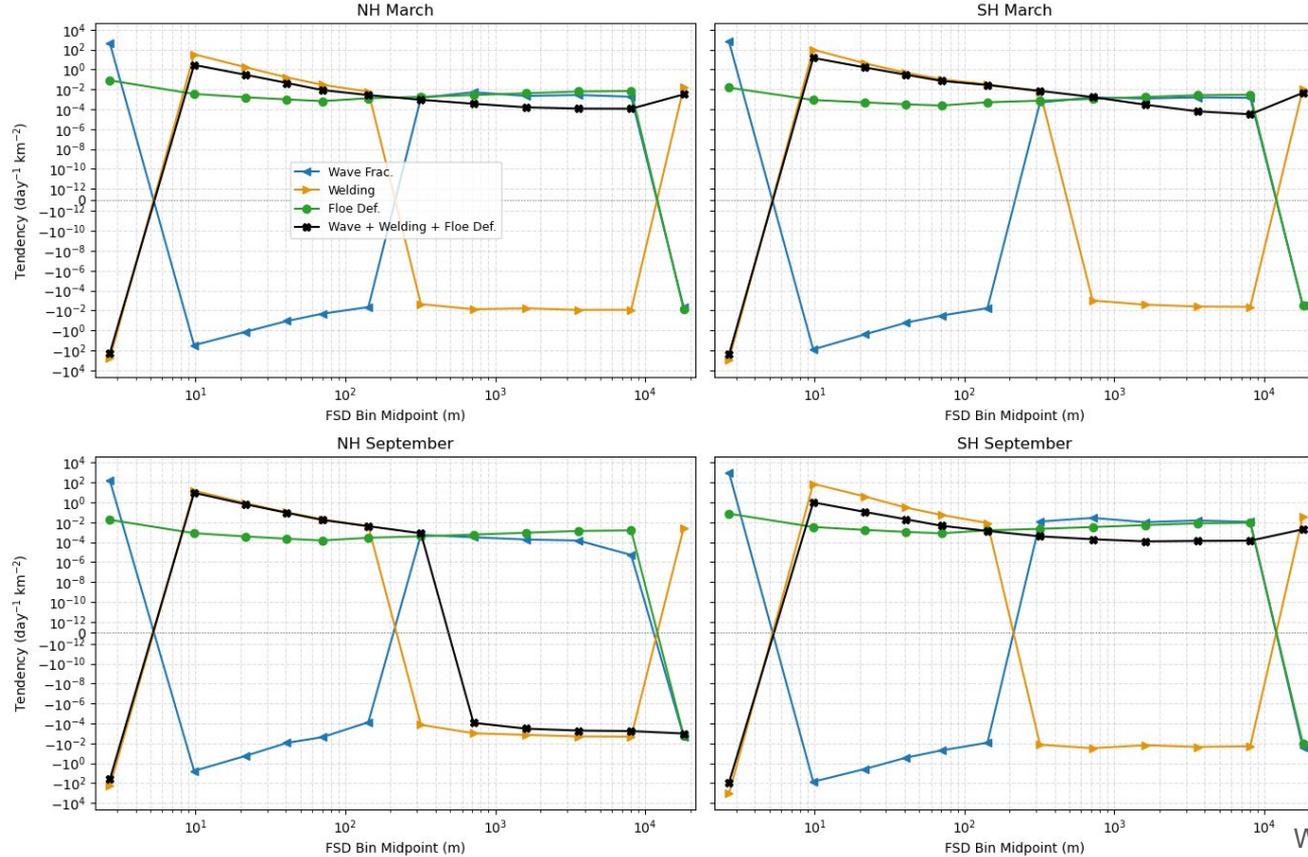# An even larger decrease in the mean floe radius

Webb et al., *in prep*

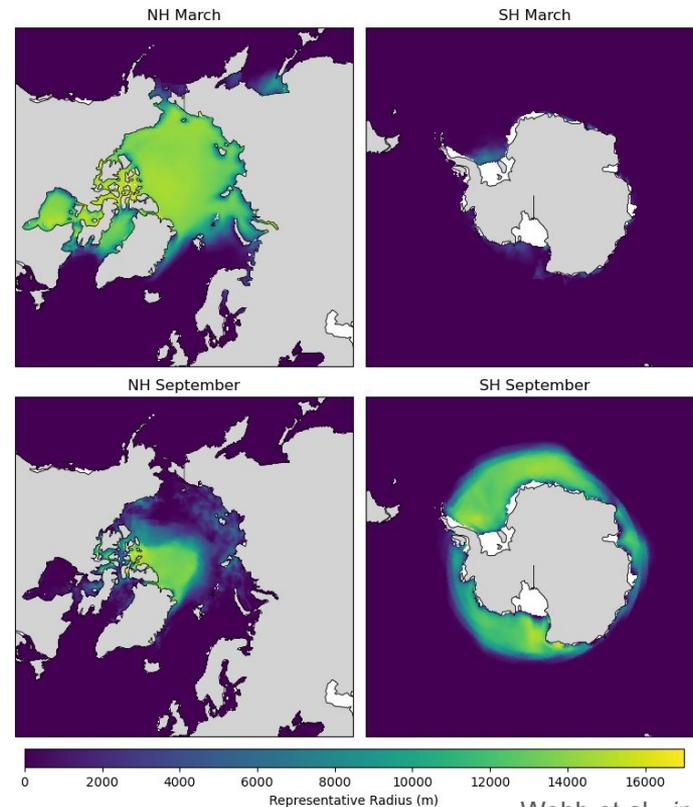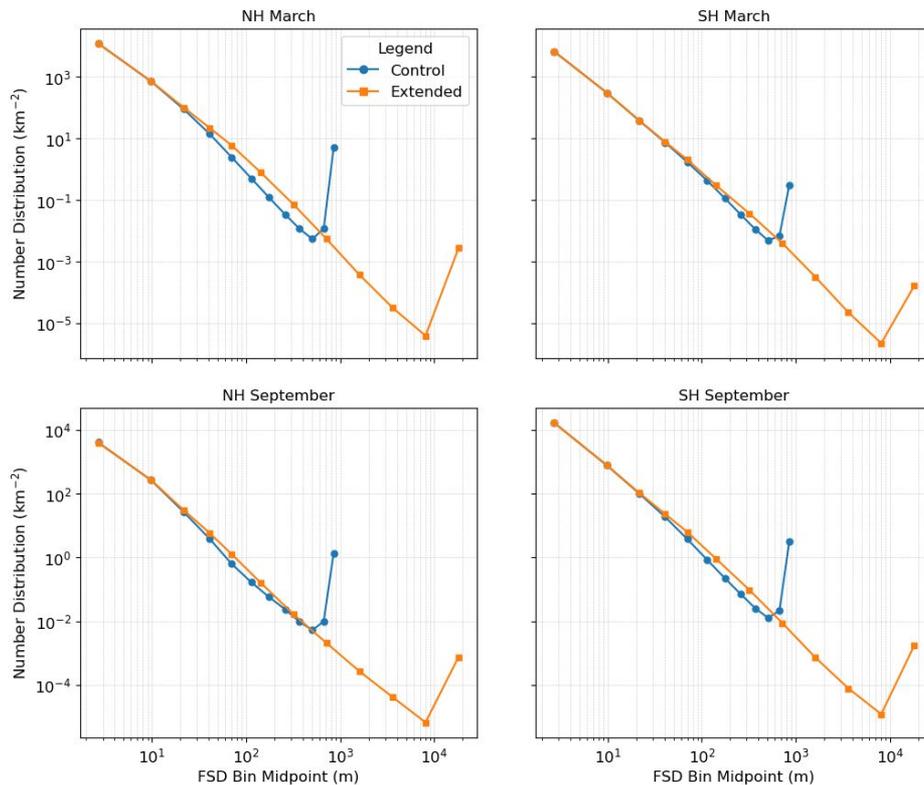# The dichotomy between welding and wave frac.

Webb et al., *in prep*

The dichotomy between welding and wave frac.

Webb et al., *in prep*

The FSD in models - extending resolved floe sizes

Webb et al., *in prep*