PCWG Winter Meeting - Mar 2025

Fracture of sea ice by ocean surface waves in CESM3

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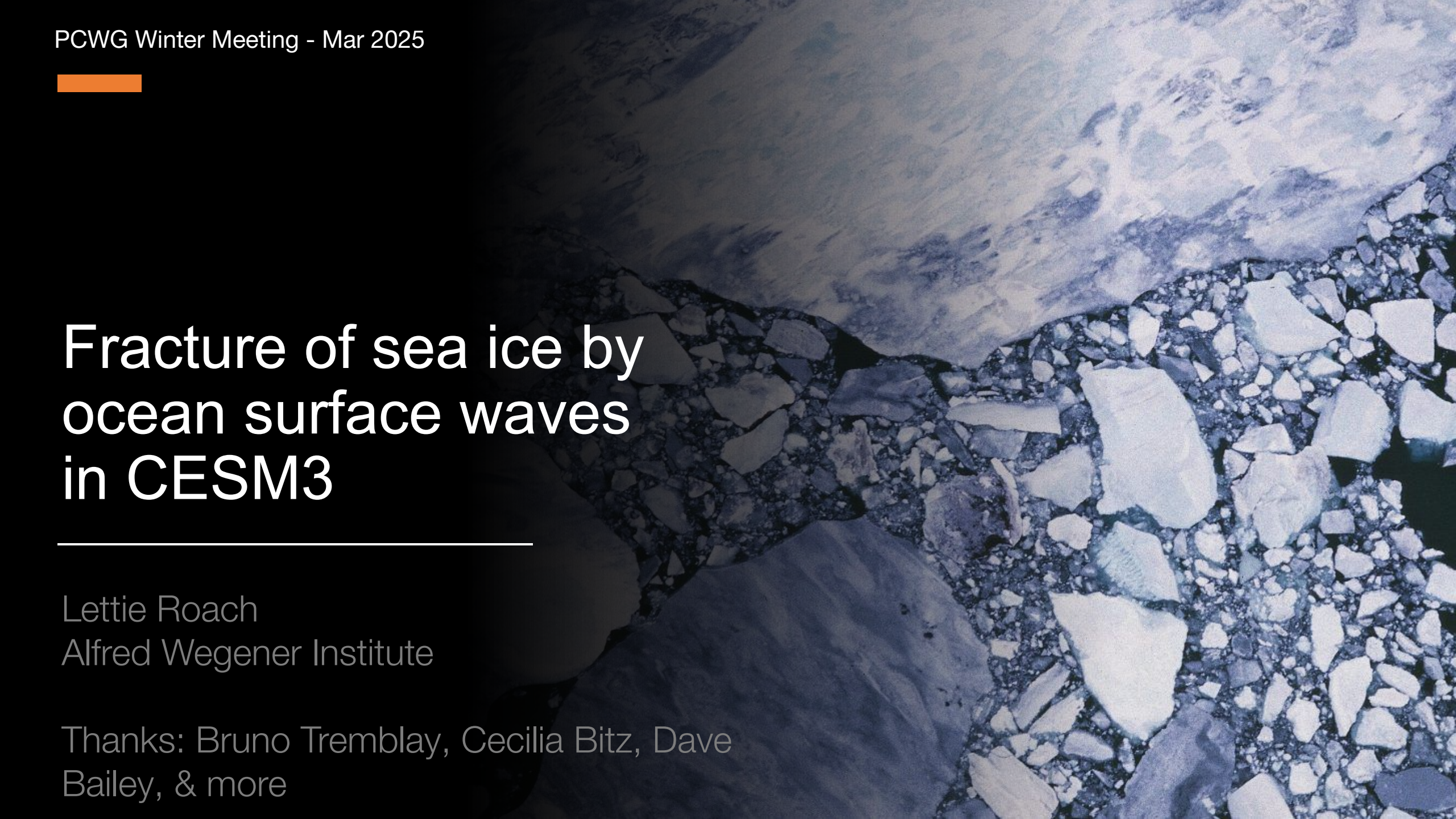
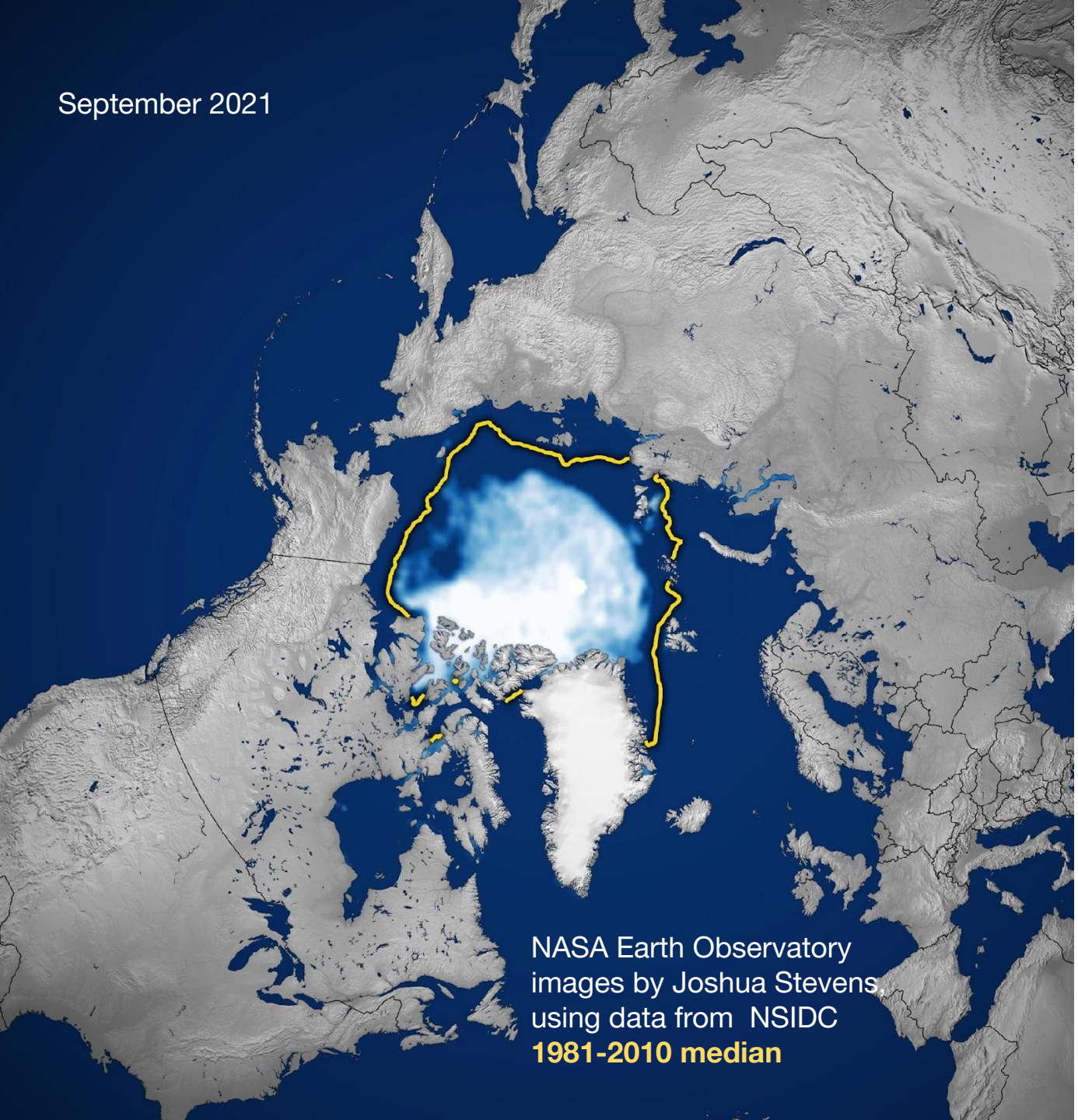
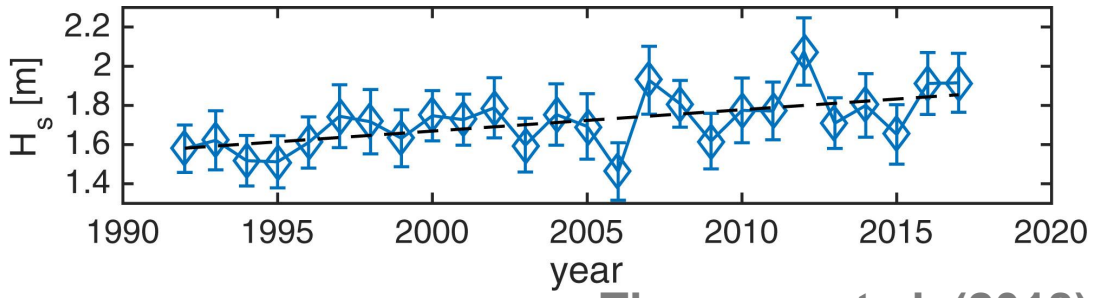
Thanks: Bruno Tremblay, Cecilia Bitz, Dave Bailey, & more





Enhanced ocean surface wave activity in the new Arctic



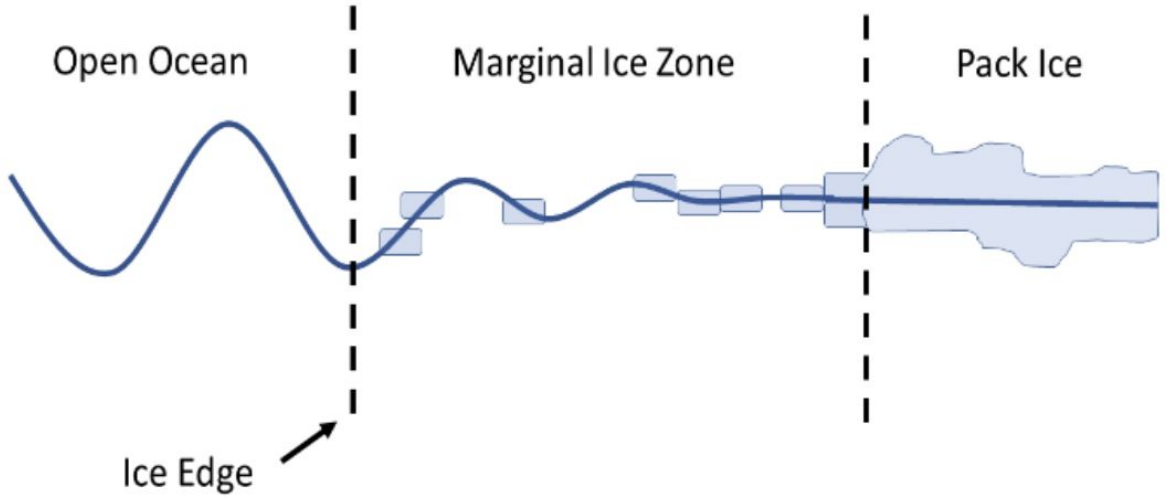
Thomson et al. (2018)

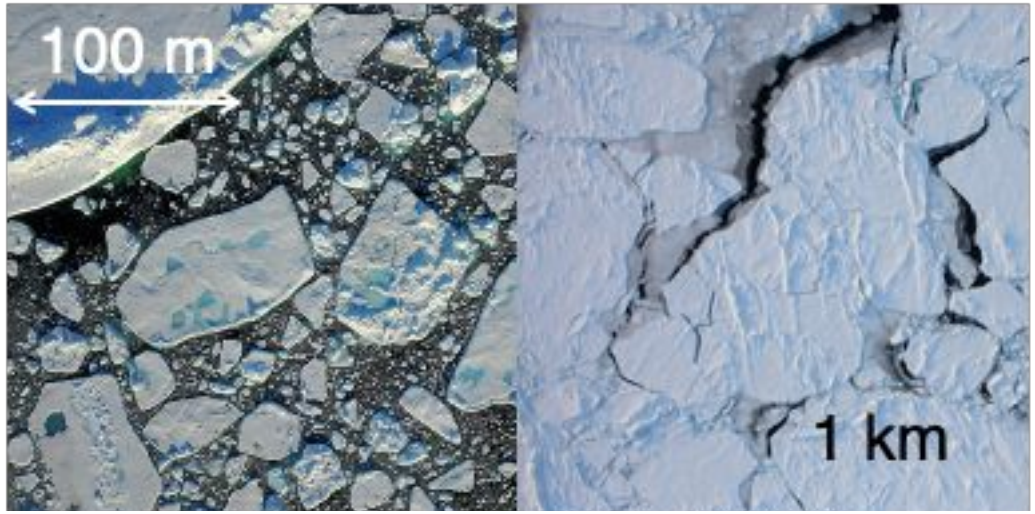
Direct impacts on Arctic communities – storm surge, coastal erosion

Antarctic sea ice subject to large swells

Potential wave-ice feedback

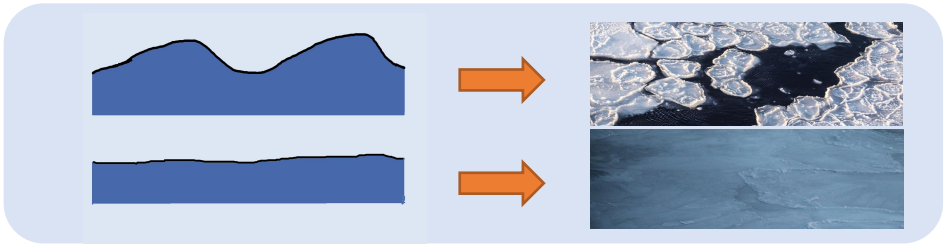
1. Waves travel through sea ice
2. Waves fracture sea ice
3. Fragmented sea ice melts faster
4. More waves



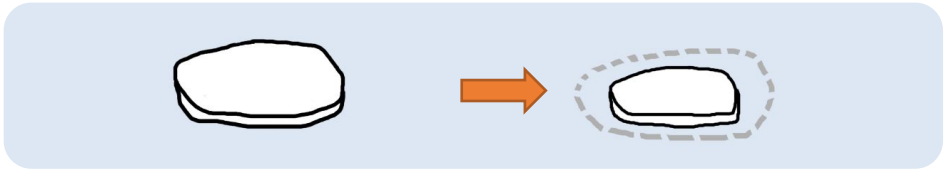


e.g. Asplin et al. (2014)

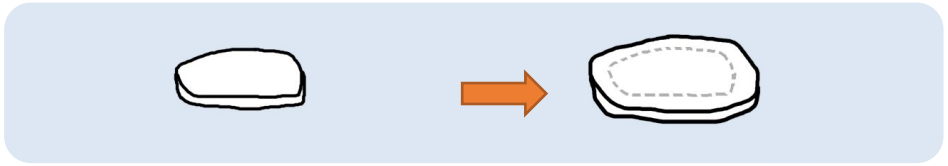
Challenge #1: many processes affect ‘fragmentation’



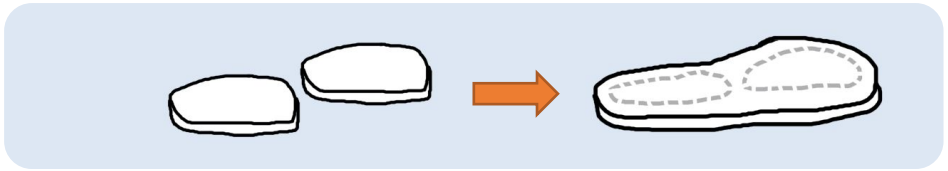
- New ice formation



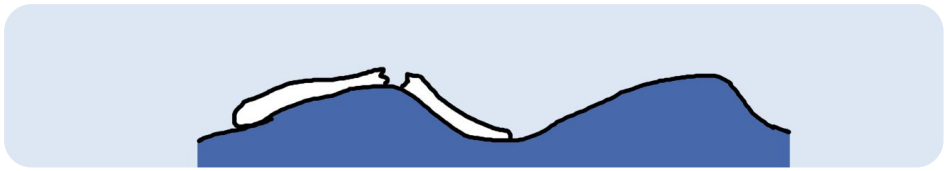
- Lateral melt



- Lateral growth



- Floe welding



- Wave fracture

Challenge #2: observations are limited

- Difficult to span spatial & temporal scales
- Hard to tune basin-scale models
- Aim to develop physically-realistic process representation

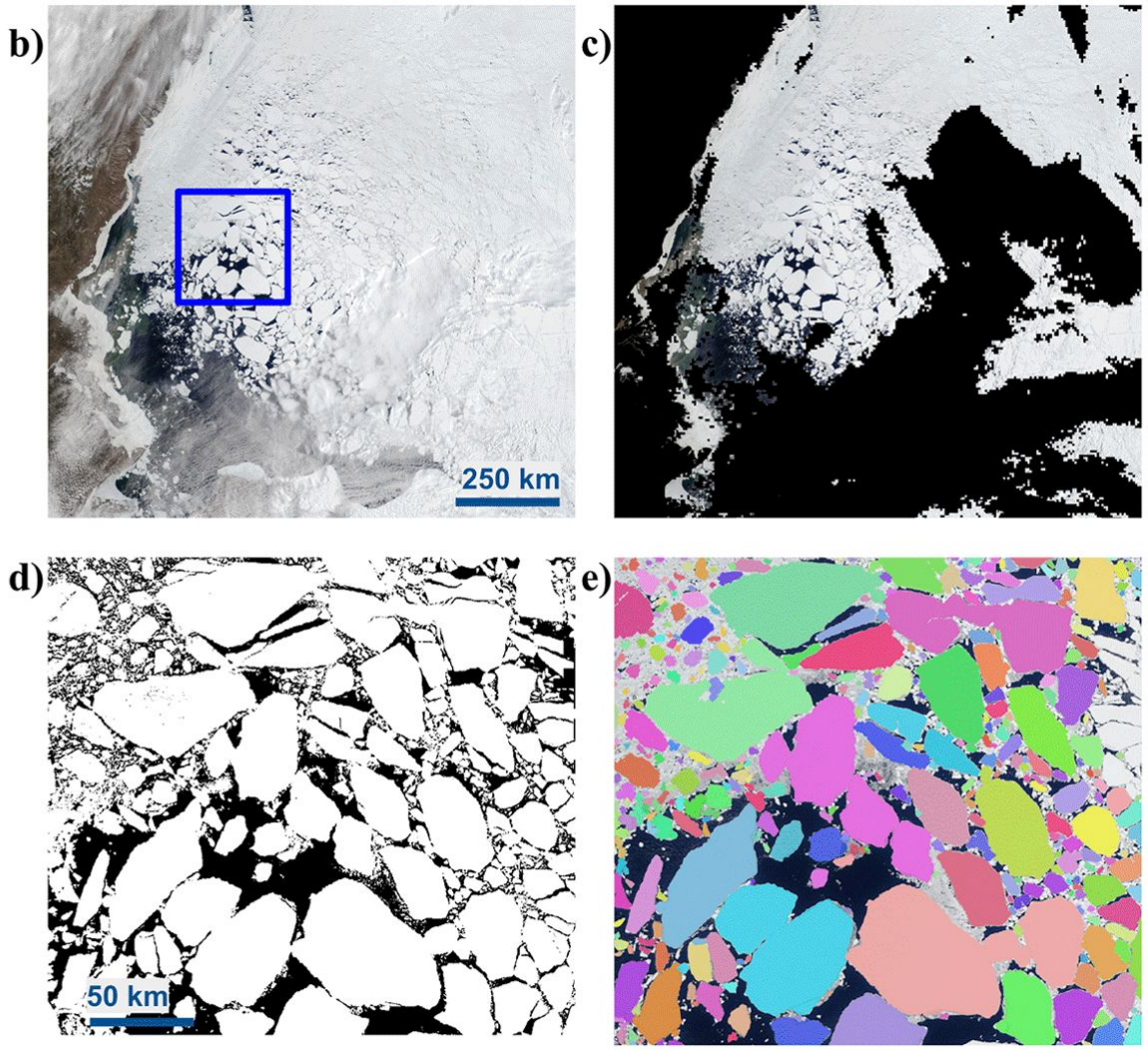
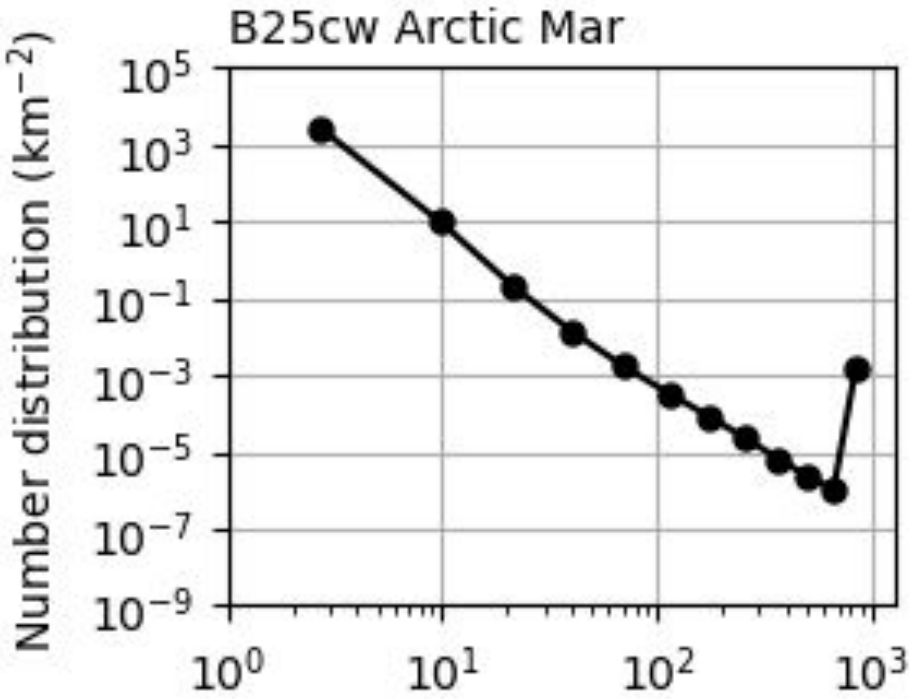


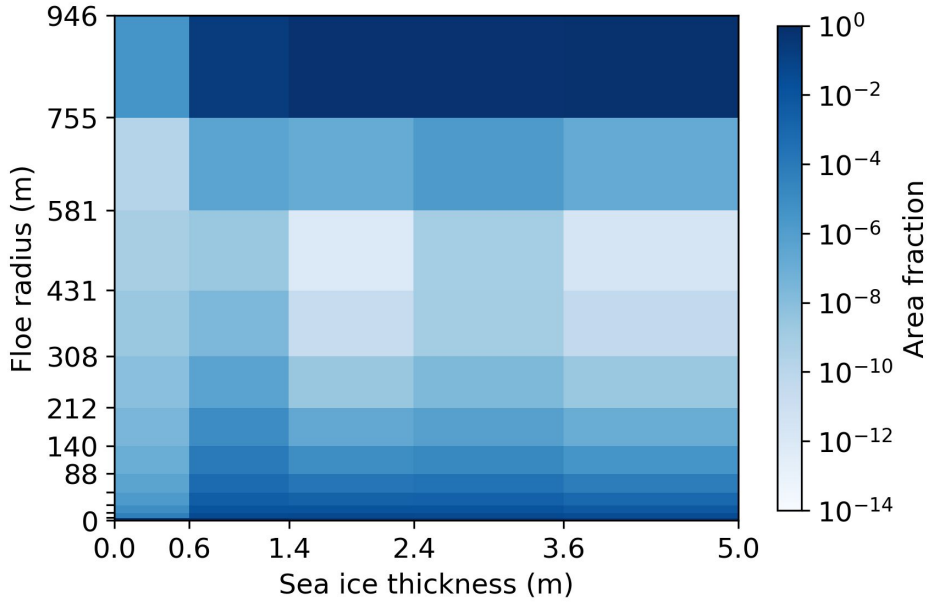
Figure: Buckley et al. (2024)

Floe size distribution in CICE

- Floes are near-circular
- Represented as a distribution with discrete size classes

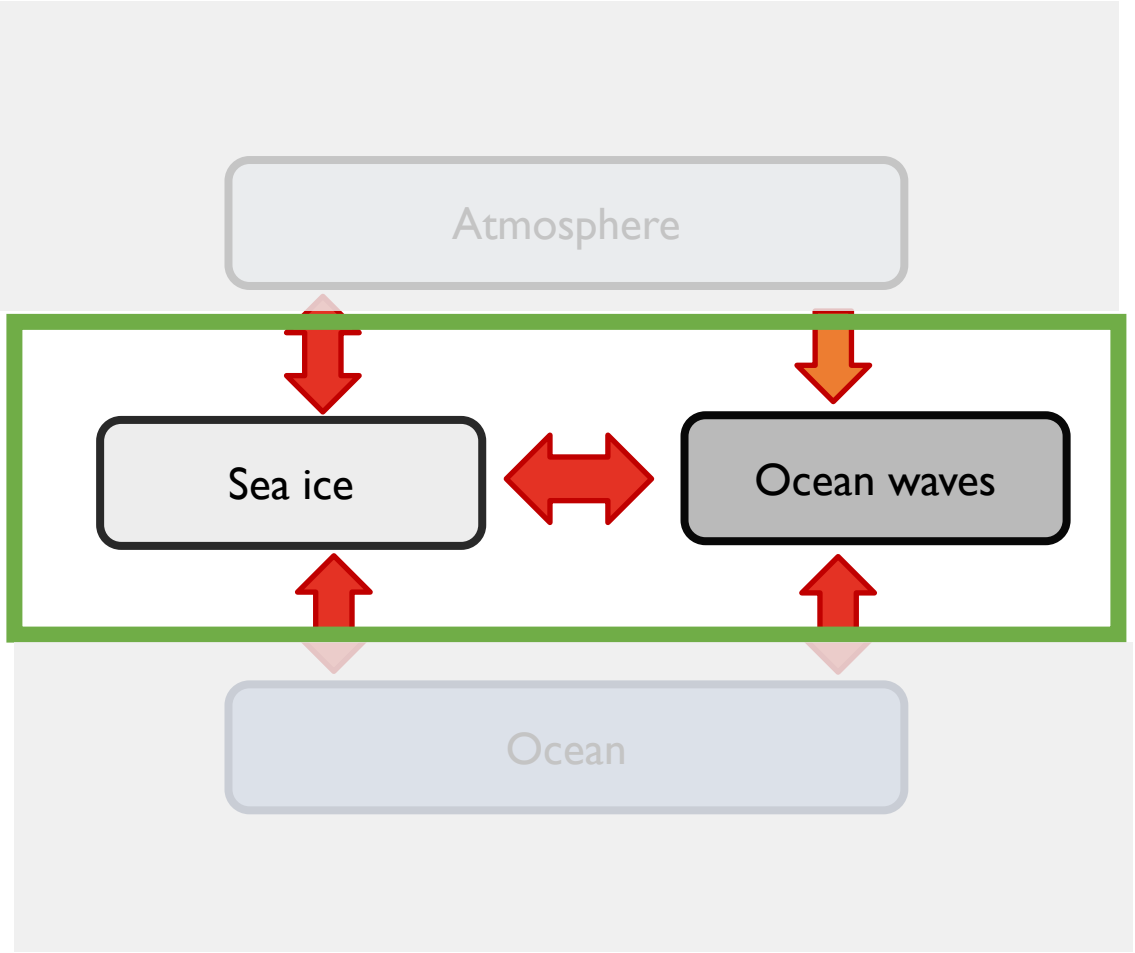
$$\frac{\partial f}{\partial t} = -\nabla \cdot (f(r,h)\mathbf{u}) + \mathcal{L}_T + \mathcal{L}_M + \mathcal{L}_W$$





Horvat & Tziperman (2015)
Roach, Horvat, Dean and Bitz (2018)
Roach, Bitz, Horvat and Dean (2019)

Wave—sea ice coupling via the FSD in CESM3



- Wavewatch III on MOM grid
- IC4M10 attenuation (Meylan et al. 2020)
- Exchange mean floe size, thickness, concentration, wave spectrum
- Tuned floe welding parameter

CICE-WW3 group: Dave Bailey, Cecilia Bitz, Bruno Tremblay, Geraint Webb, Erin Thomas, Alice duVivier

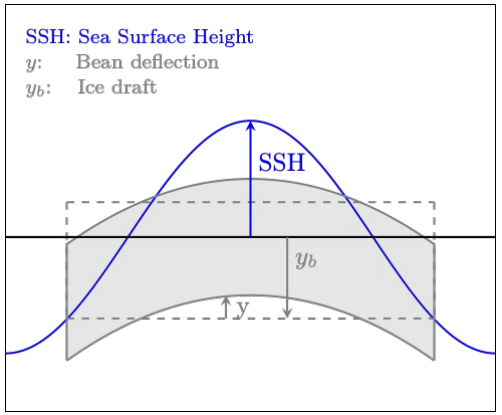
Wave fracture

Tremblay & Roach (in prep)

- Current scheme: Horvat & Tziperman (2015) (HT15)
- Assumes sea ice flexes perfectly with the SSH field
- Calculate strain for 10 km floe
- Find extrema with finite differences

- New scheme: Tremblay & Roach (in prep) (B25)
- No assumption on flexibility or rigidity
- Solving a conservation of momentum equation for a thin elastic plate in hydrostatic equilibrium (Bernoulli-Euler Beam Theory)
    - Takes floe size into account

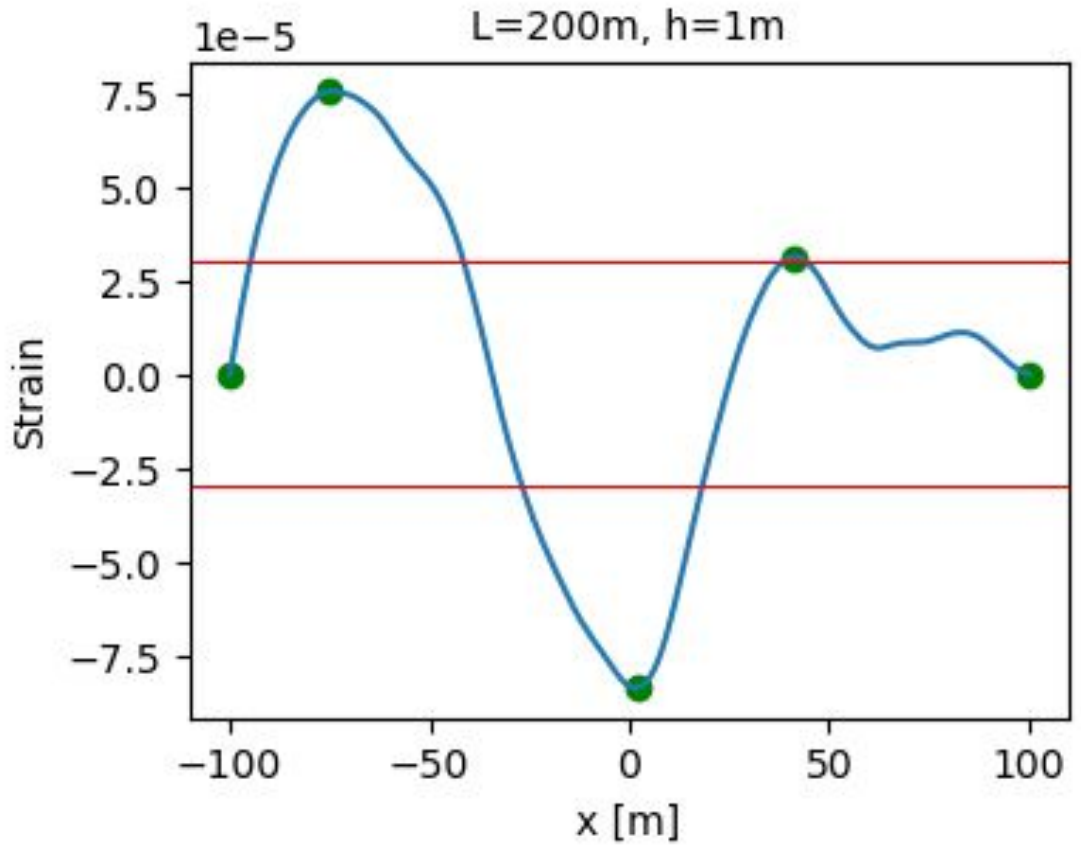
- Find locations where strain exceeds critical strain
- Fractures at these points



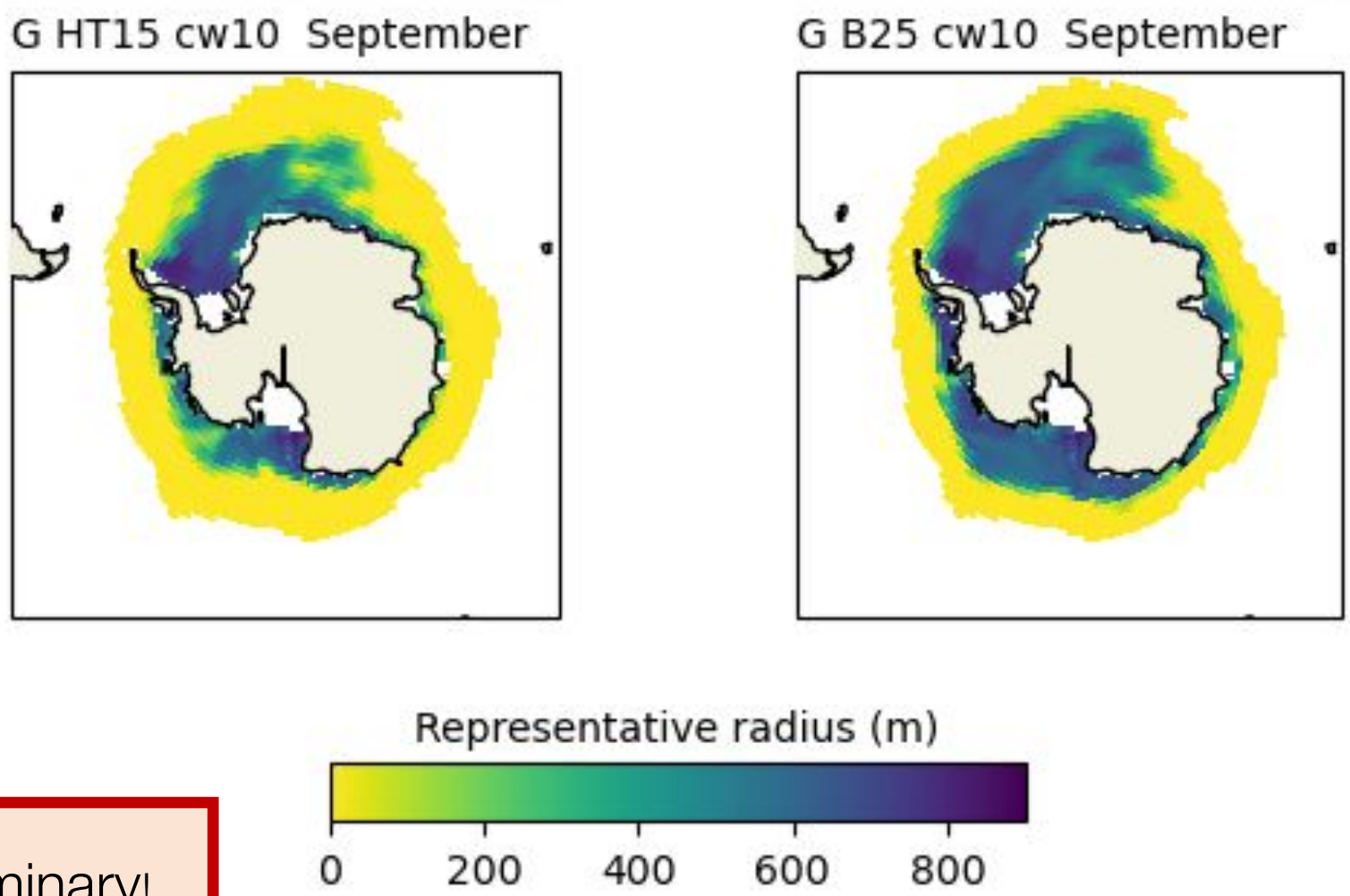
New scheme

Tremblay & Roach (in prep)

- Strain values generally smaller and closer to observations

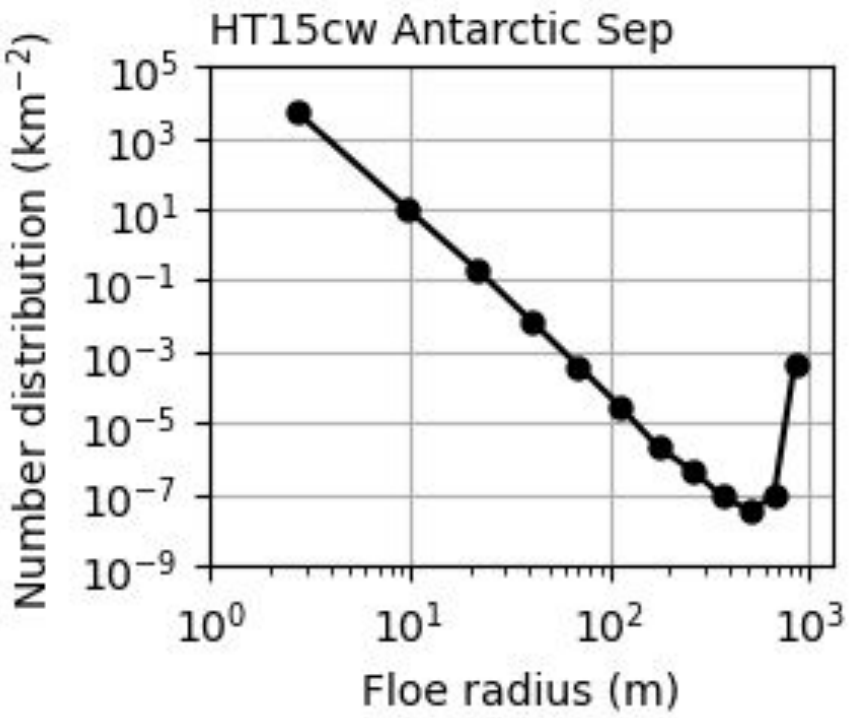


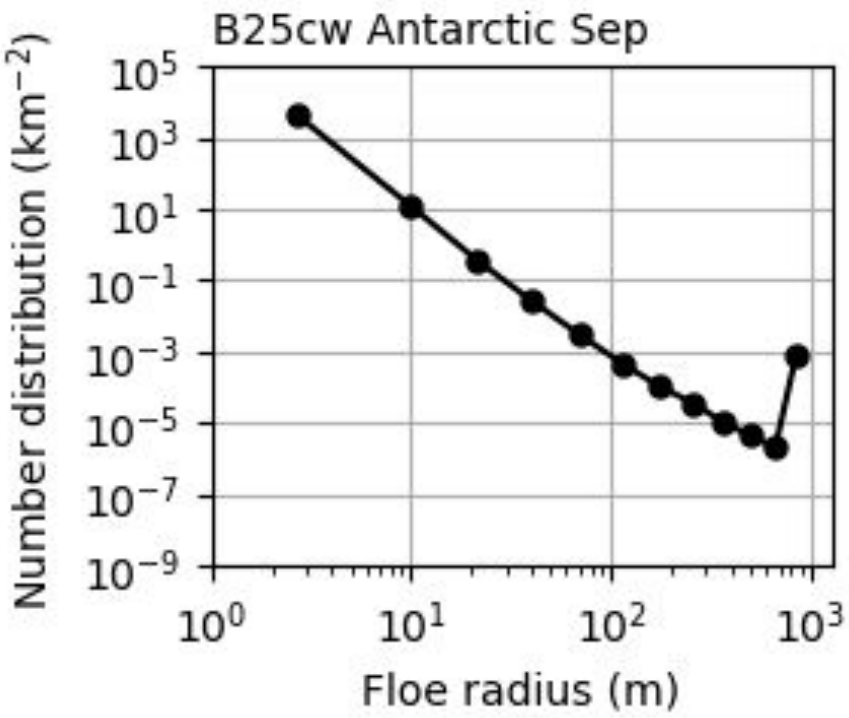
Increases Antarctic floe sizes



⚠ Preliminary!

Increases Antarctic floe sizes





⚠ Preliminary!

Summary

- Coupled wave—sea ice interactions via the FSD are now an option in CESM3
- FSD simulation appears reasonable with minimal tuning
- New wave fracture scheme is more physically realistic and appears to improve Antarctic FSD
- Much more to do!
    - Wave fracture: see where we can simplify and learn
    - Working with fully-coupled CESM3: check impact
    - Evaluate against observations in case study simulations

Questions? Interest in collaborating? lettie.roach@awi.de