Using CICE6 to map the Antarctic winter marginal ice zone

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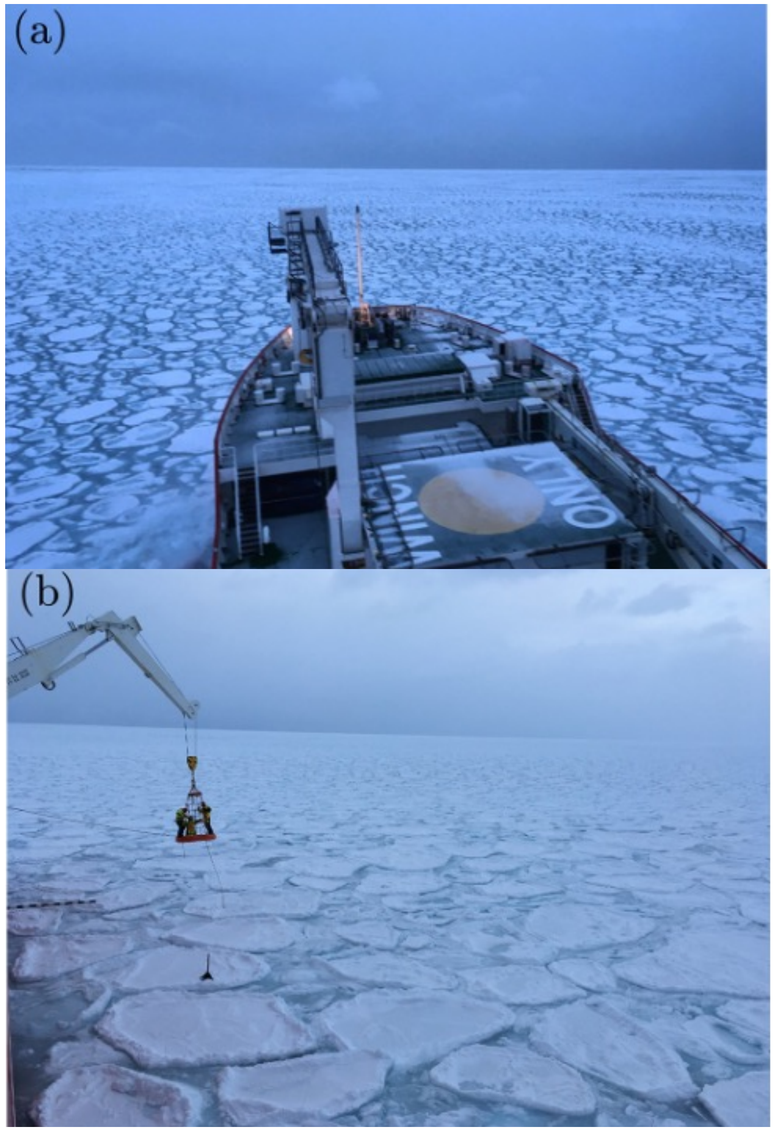
Marginal ice zone (MIZ)

- The marginal ice zone is the interface between the open ocean and the inner pack
- During winter ocean surface waves promote the formation of pancake ice in the marginal ice zone
- Pancakes can become highly dynamic and move the ice edge rapidly [1,2], or consolidate and expand the inner pack



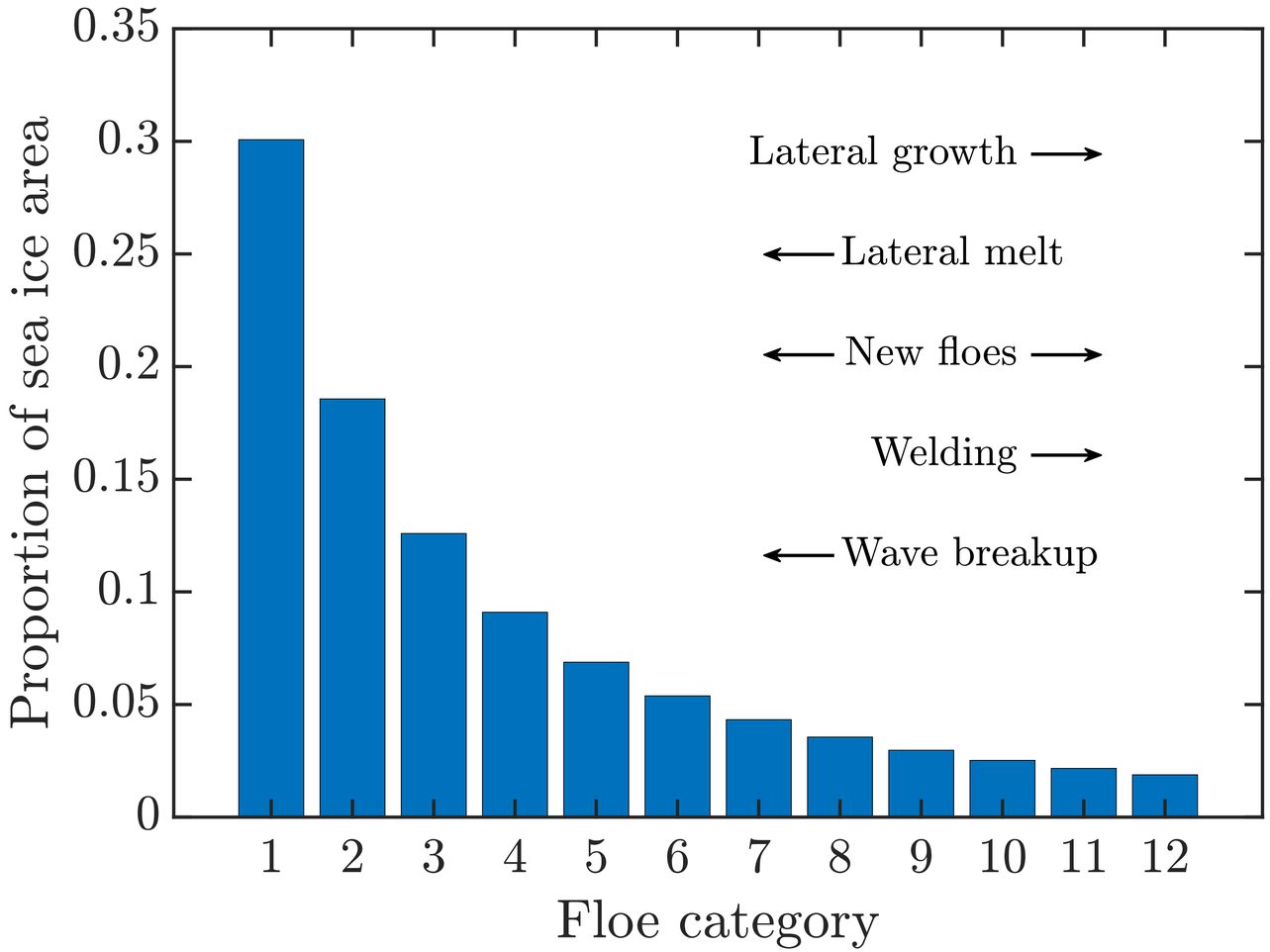
Pancake ice in the Antarctic winter marginal ice zone [2].

[1] Vichi et al., Geophys. Res. Lett, (2019).
[2] Alberello et al., JGR, (2020).

Floe size distribution (FSD)

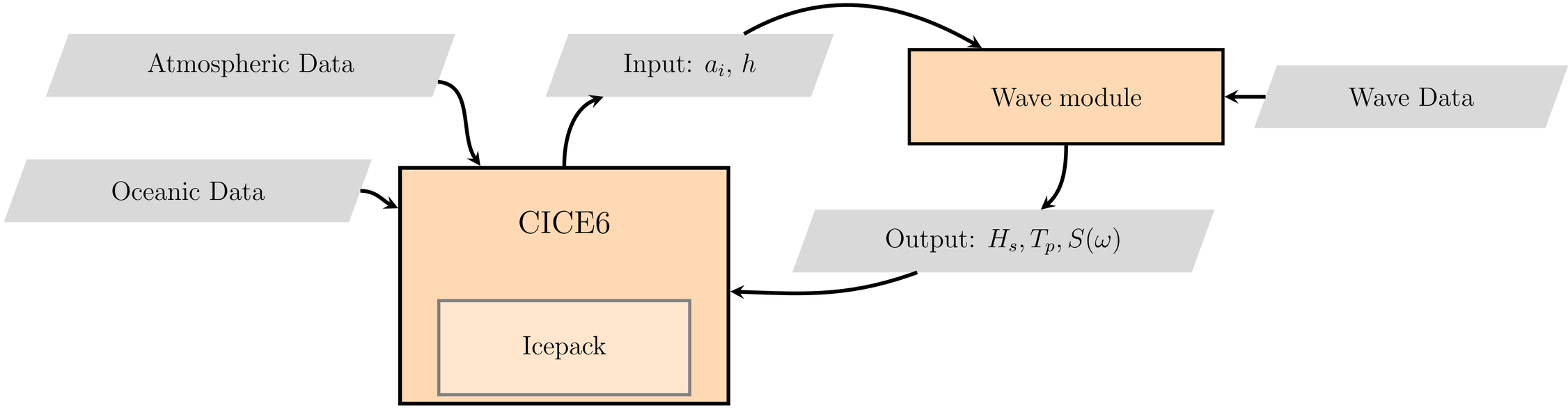
- We chose CICE6 as it includes a prognostic joint floe size and ice thickness distribution
- This allows us to simulate floe size processes such as:
  - Lateral growth and melt
  - The size of newly formed floes (pancakes, nilas, etc)
  - Welding between floes
  - Wave-induced ice breakup

Impacts of processes on the FSD in CICE6



Model configuration

- We use standalone CICE6.2.0 at 1˚ resolution
- A wave propagation module was added to enable the wave breakup and new floe routines
- The last 5 years (2015-2019) of the 10-year run are used for analysis



Ice concentration (a_i) and mean thickness (h) are passed from CICE to the wave module which calculates significant wave height (H_s) peak period (T_p) and the angular wave spectrum ($S(\omega)$) across the ice cover.

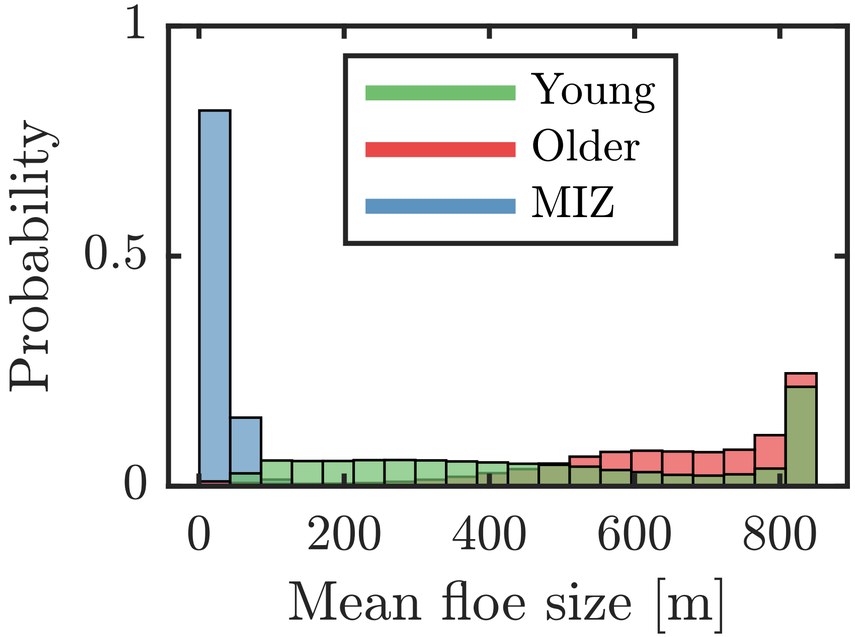
Unsupervised classification of sea ice data

- An unsupervised statistical method (k-means) is used on 8 ice cover outputs from CICE to classify the sea ice into distinct regions

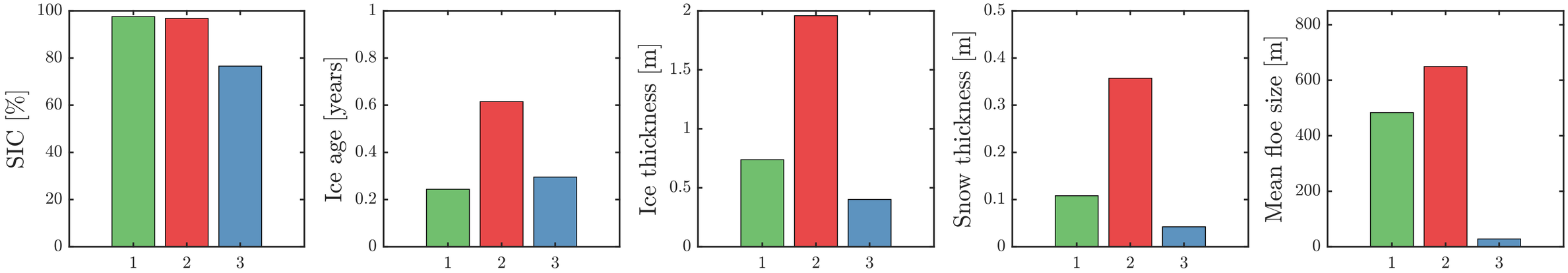
Class 1: Young, thin, large floes (inner pack)

Class 2: Older, thick, large floes (inner pack)

Class 3: Small floes in lower SICs (marginal ice zone)

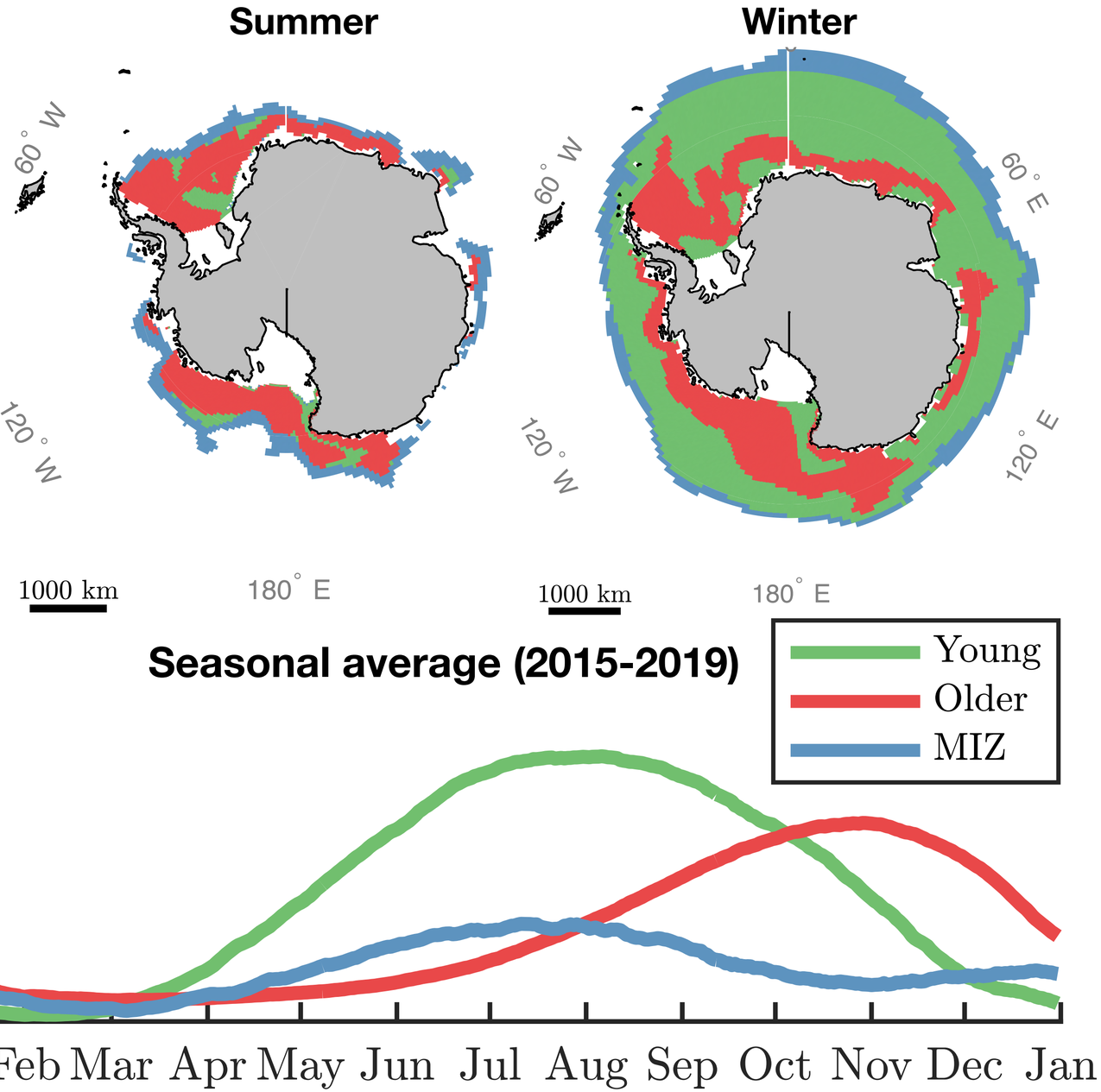


Average values of key variables in each class



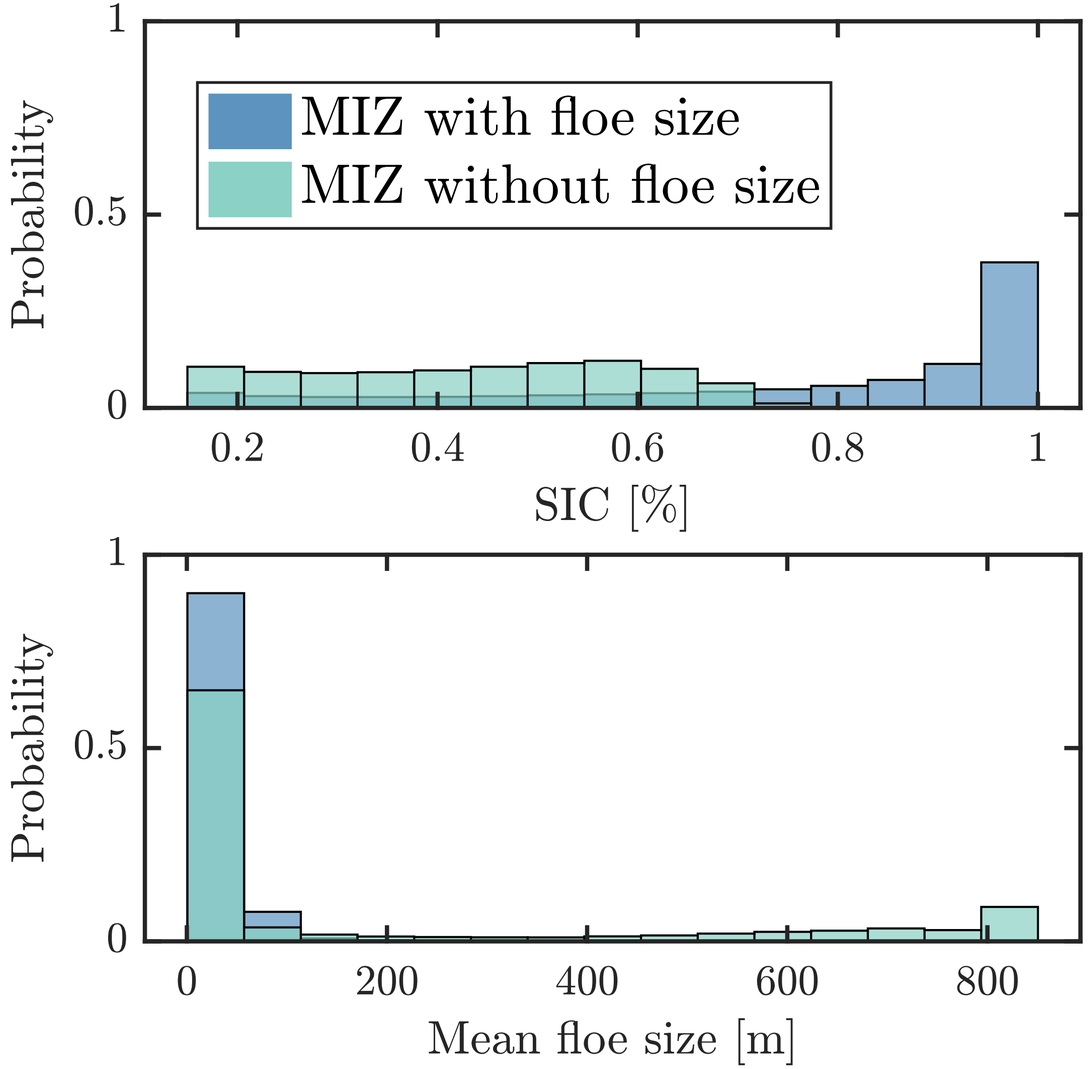
Maps and seasonality of the sea ice classes

- ‘Young ice’ follows a summer-winter cycle
- As winter progresses ice transitions from the ‘young’→‘older’ class
- The MIZ reaches a maximum extent over winter but has a second peak in summer



The impact of floe size on MIZ classification

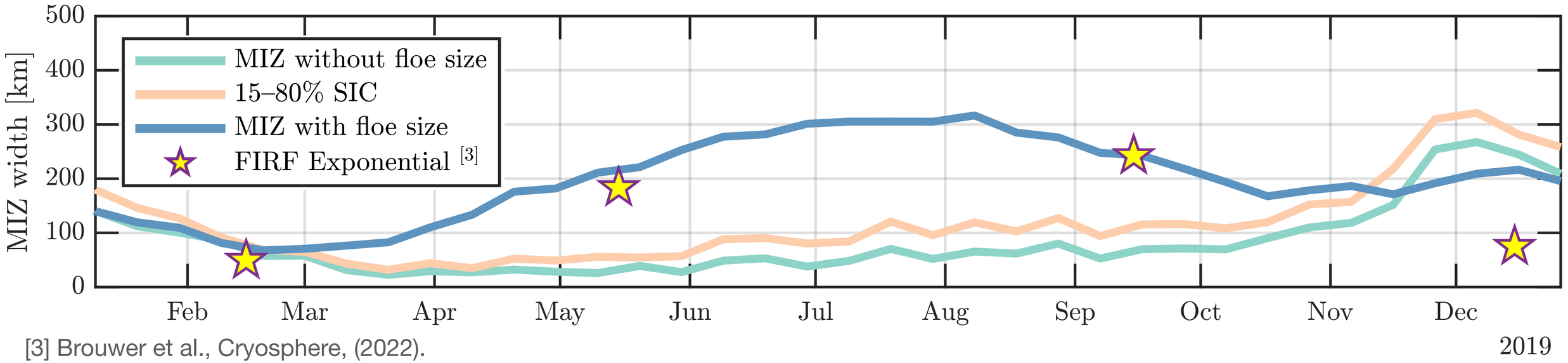
- We excluded ‘mean floe size’ from our dataset to test the impact of floe size
- The classification method was repeated on the remaining 7 variables
- The MIZ without floe size information is driven by sea ice concentration instead of floe size



Widths of different MIZ definitions

- By including the floe size in our definitions we obtain a much larger winter marginal ice zone which agrees with a wave height MIZ definition from satellite data [3]

- Removing floe size information results in a MIZ that follows the traditional sea ice concentration definition of 15—80% [4]



[3] Brouwer et al., Cryosphere, (2022).
[4] Strong et al., JTECH, (2017).

Conclusion

- We used an unsupervised classifier to measure the extent and seasonality of the Antarctic marginal ice zone with and without the inclusion of floe size data
- Removing floe size information from the classification produces a sea ice concentration driven definition for the marginal ice zone
- Including mean floe size in the classifier produces good agreement with a wave height based marginal ice zone definition

Supporting slides
References

1. Vichi, M. *et al*. Effects of an Explosive Polar Cyclone Crossing the Antarctic Marginal Ice Zone. *Geophysical Research Letters* **46**, 5948–5958 (2019).

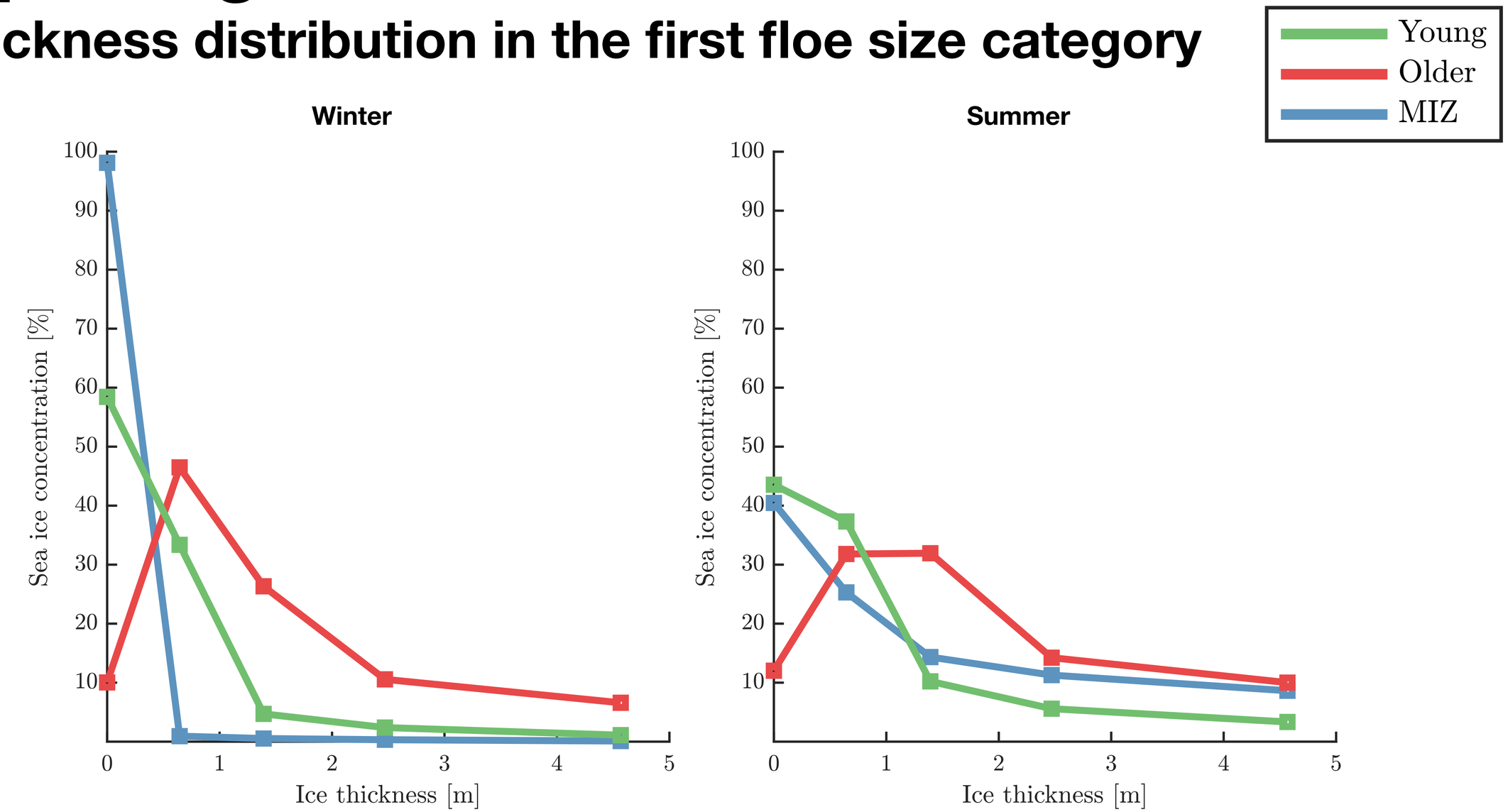
2. Alberello, A. *et al*. Drift of Pancake Ice Floes in the Winter Antarctic Marginal Ice Zone During Polar Cyclones. *Journal of Geophysical Research: Oceans* **125**, e2019JC015418 (2020).

3. Brouwer, J. *et al*. Altimetric observation of wave attenuation through the Antarctic marginal ice zone using ICESat-2. *The Cryosphere* **16**, 2325–2353 (2022).

4. Strong, C., Foster, D., Cherkaev, E., Eisenman, I. & Golden, K. M. On the Definition of Marginal Ice Zone Width. *Journal of Atmospheric and Oceanic Technology* **34**, 1565–1584 (2017).

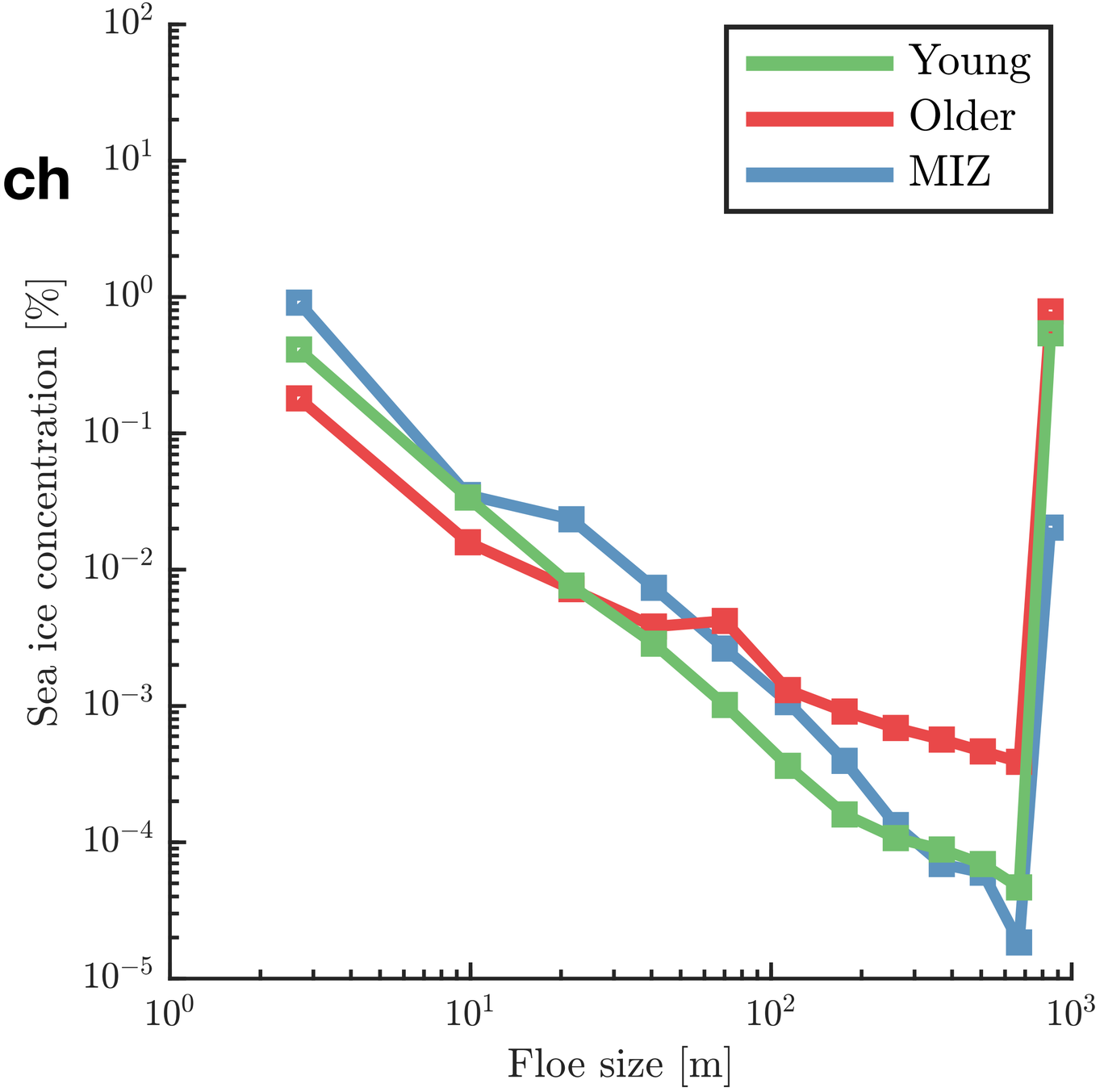
Supporting slides

Ice thickness distribution in the first floe size category



Supporting slides

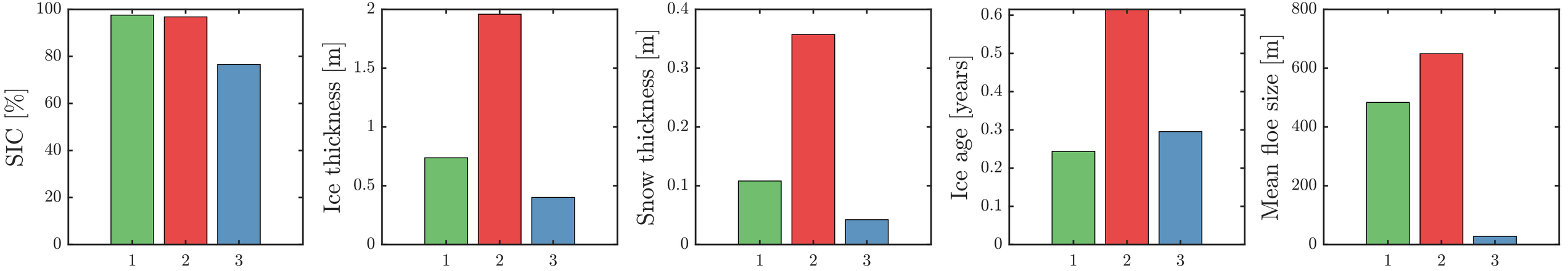
Floe size distribution of each class



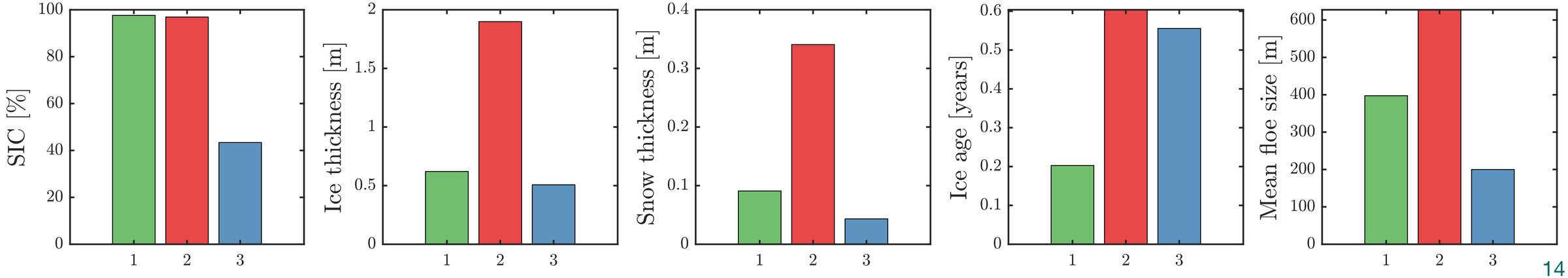
Supporting slides

Mean values with and without floe size

With floe size in classification



Without floe size in the classification



Supporting slides

Maps of classification without floe size