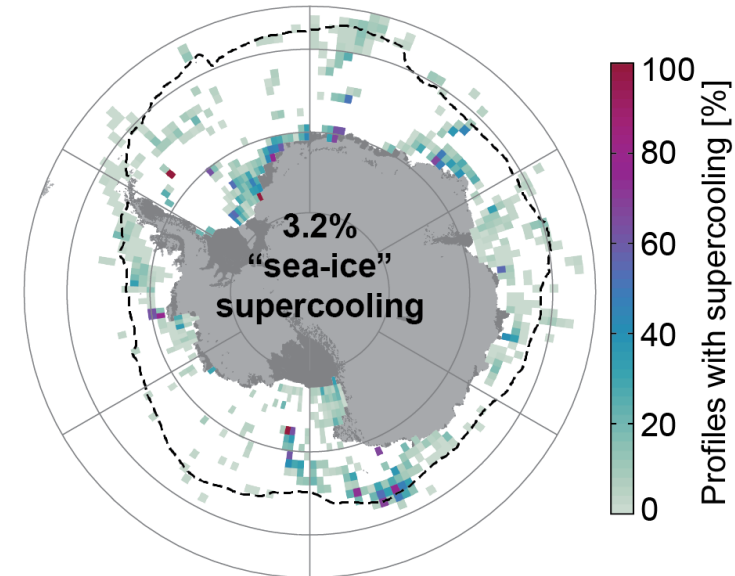


Supercooled Southern Ocean Waters

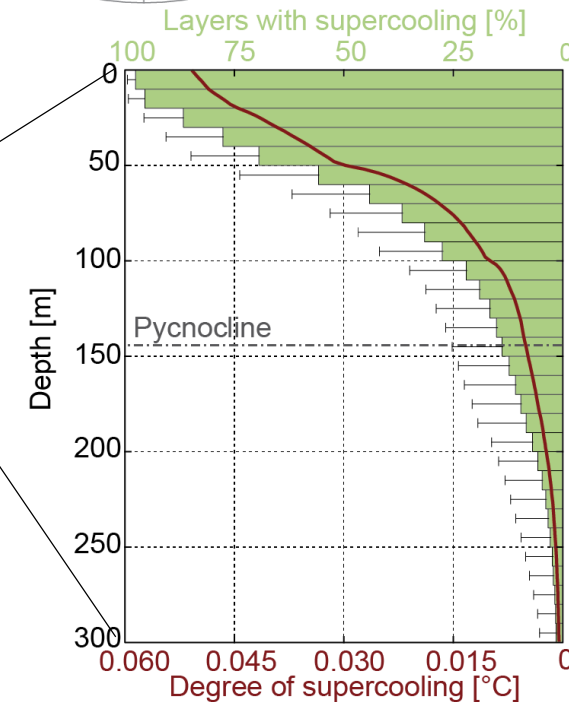
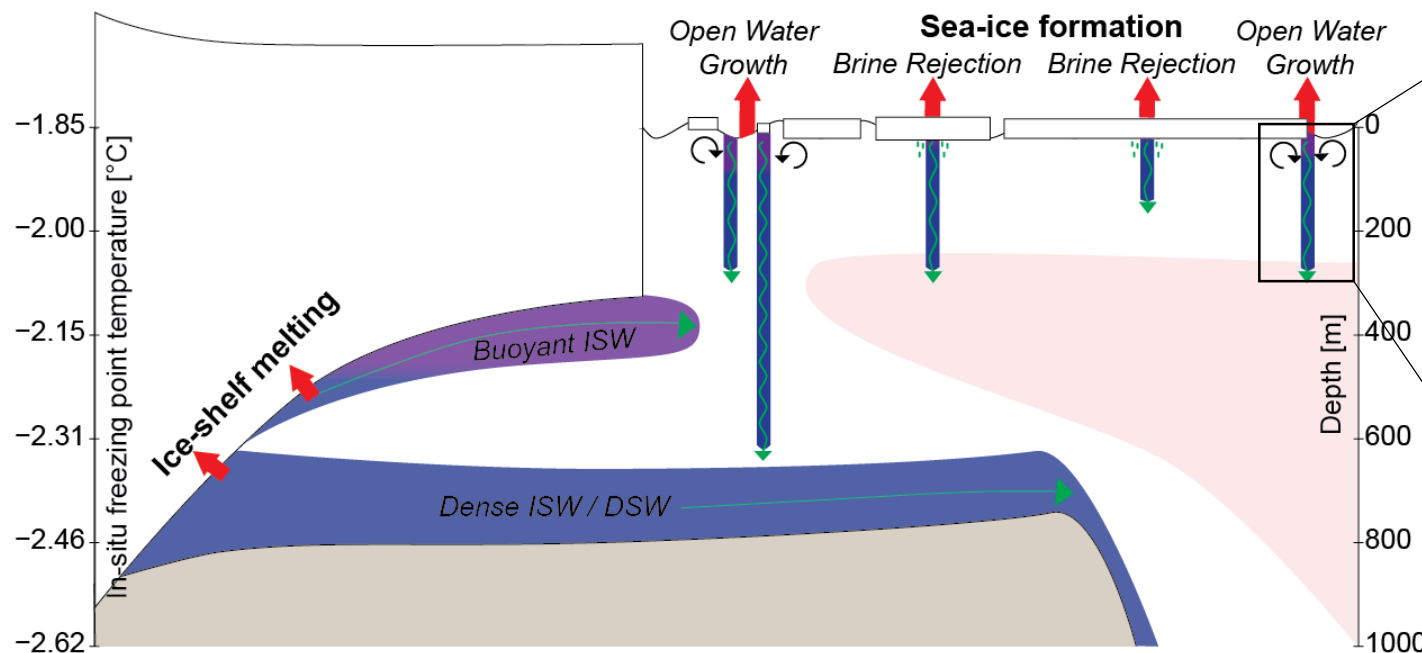
Key points:

- Potential and in-situ supercooling occurs in large parts of the Southern Ocean seasonal sea-ice zone (Argo, MEOP, and ship-board observations)
- Deep coastal supercooling from below 100 m to the ocean bottom is associated with melting ice shelves and dense shelf water formation
- Shallow supercooling is associated with sea-ice formation and can penetrate as deep as the permanent pycnocline



Implications:

“Sea-ice” supercooling could be an important process for extracting heat from deeper layers and for the vertical transport of salt, carbon, oxygen, and nutrients



Overview (click to reach section)

Summary

Definitions

Data

Conclusions

Results:

- Spatial patterns of supercooling
- Two types of supercooling
- Sea-ice driven supercooling
- Ice-shelf driven supercooling
- Seasonality of supercooling



Supercooled Southern Ocean Waters

F. Alexander Haumann (alexander.haumann@gmail.com)

Princeton University

Ruth Moorman, Stephen C. Riser, Lars H. Smedsrud, Ted Maksym, Annie P. S. Wong, Earle A. Wilson, Robert Drucker, Lynne D. Talley, Kenneth S. Johnson, Robert M. Key, Jorge L. Sarmiento

Related publication:

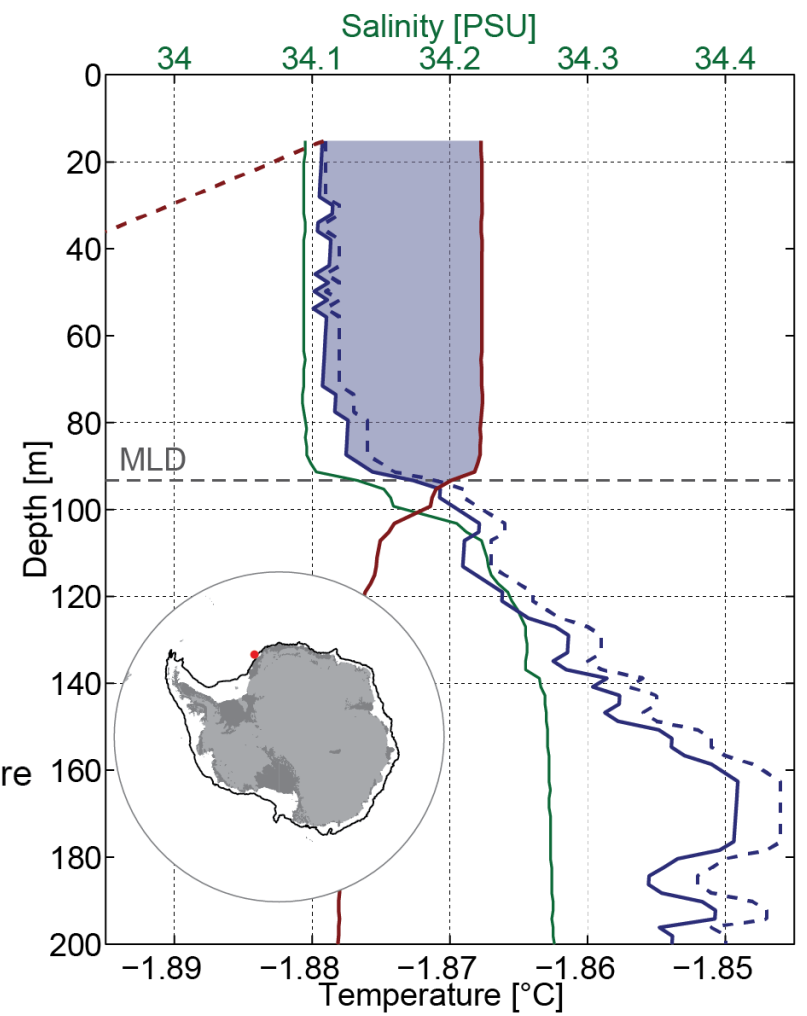
Haumann et al. (2020): Supercooled Southern Ocean Waters. *Geophysical Research Letters*, 47, e2020GL090242. doi:10.1029/2020GL090242.

Definitions of potential and in-situ supercooling

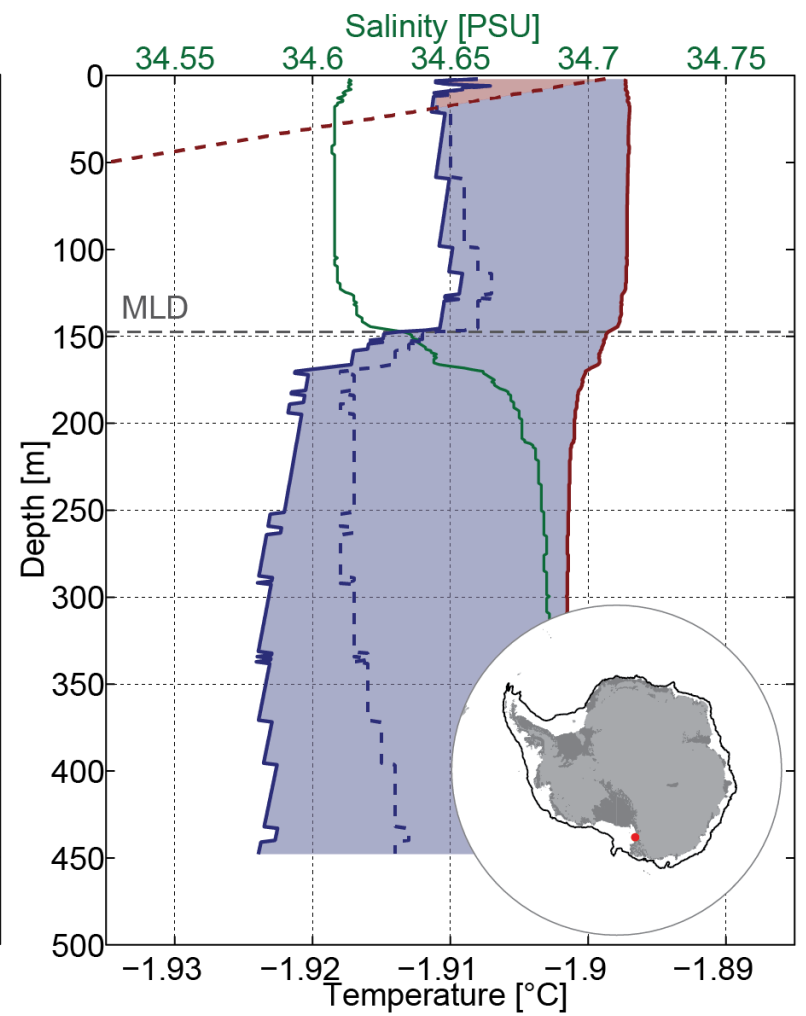
- **Potential supercooling (blue shading in figure):** surface referenced temperature (potential temperature) is lower than surface referenced freezing point temperature
- **In-situ supercooling (red shading in figure):** local temperature is lower than the local freezing point temperature

- Potential temperature (0 dbar)
- Surface-referenced (0 dbar) freezing point temperature
- Potential supercooling
- - - In-situ temperature
- - - In-situ freezing point temperature
- In-situ supercooling
- Salinity
- - - Vertical mean mixed-layer depth

SOCCOM profile off the continental shelf:
71.34° S, 16.88° W; 5 June, 2019

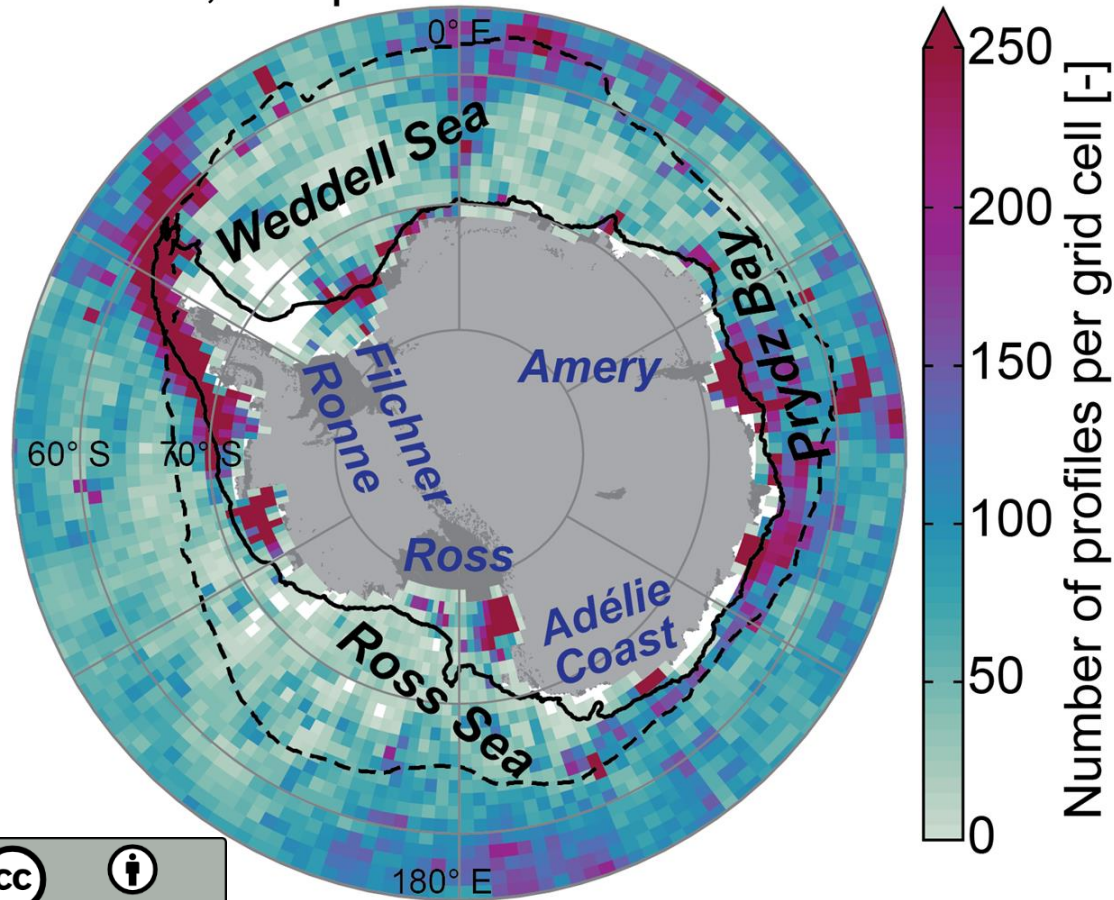


Ship-based measurement in Terra-Nova Bay during PIPERS: 74.97° S, 164.03° E; 11 May, 2017

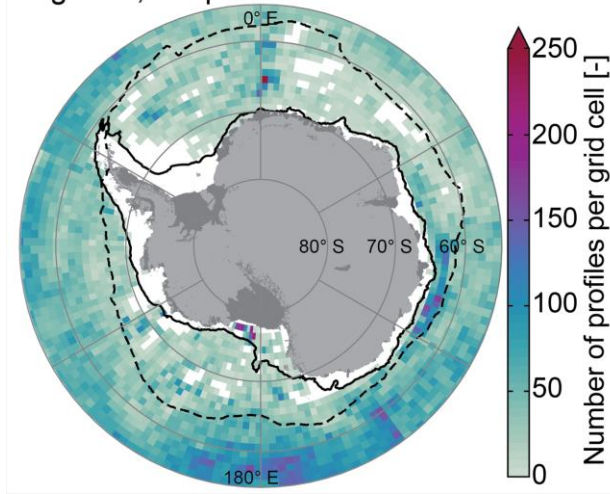


Hydrographic data from the Southern Ocean south of 55°S over the period 1972 to 2020

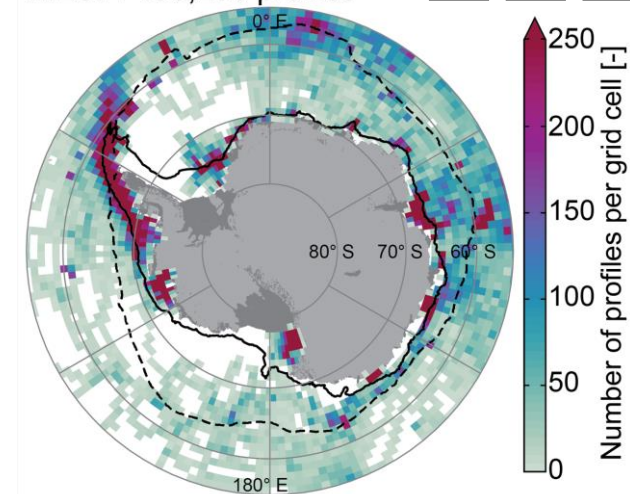
All: 309,387 profiles



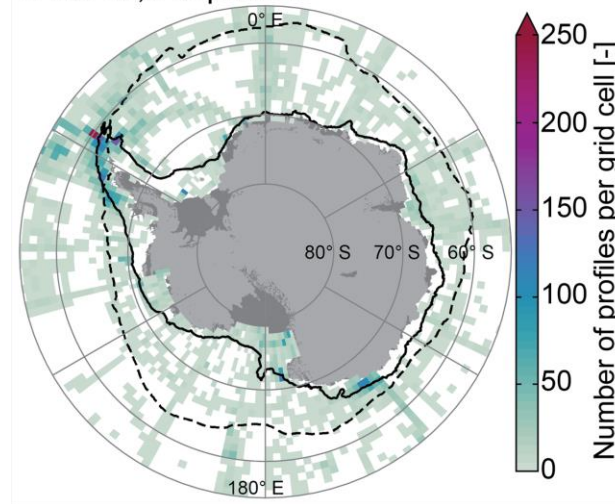
Argo: 99,676 profiles



MEOP: 196,268 profiles



CTD: 13,443 profiles



Data uncertainty (T, S, P):

Argo $\pm 0.002^{\circ}\text{C}$, ± 0.01 PSU, ± 2.4 dbar

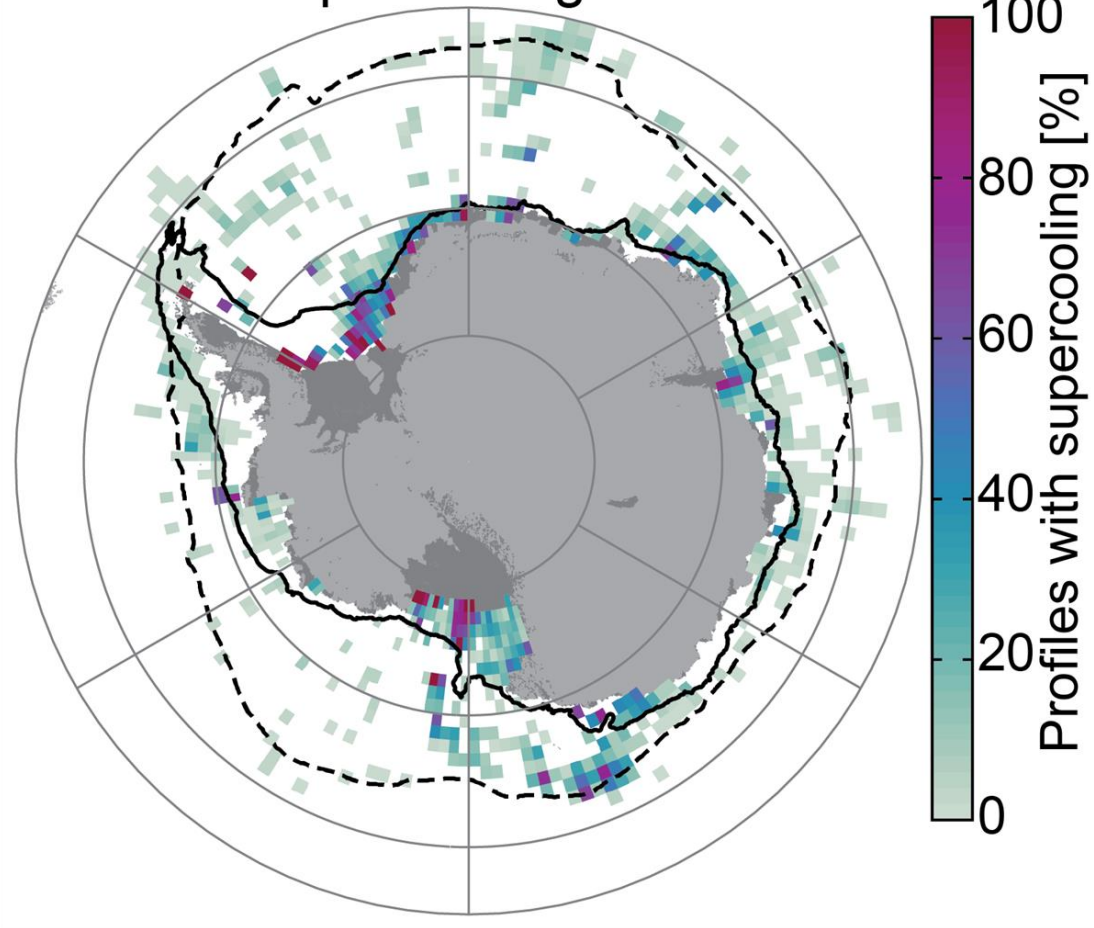
MEOP $\pm 0.02^{\circ}\text{C}$, ± 0.03 PSU, ± 3 dbar

CTD $\pm 0.002^{\circ}\text{C}$, ± 0.002 PSU, ± 3 dbar

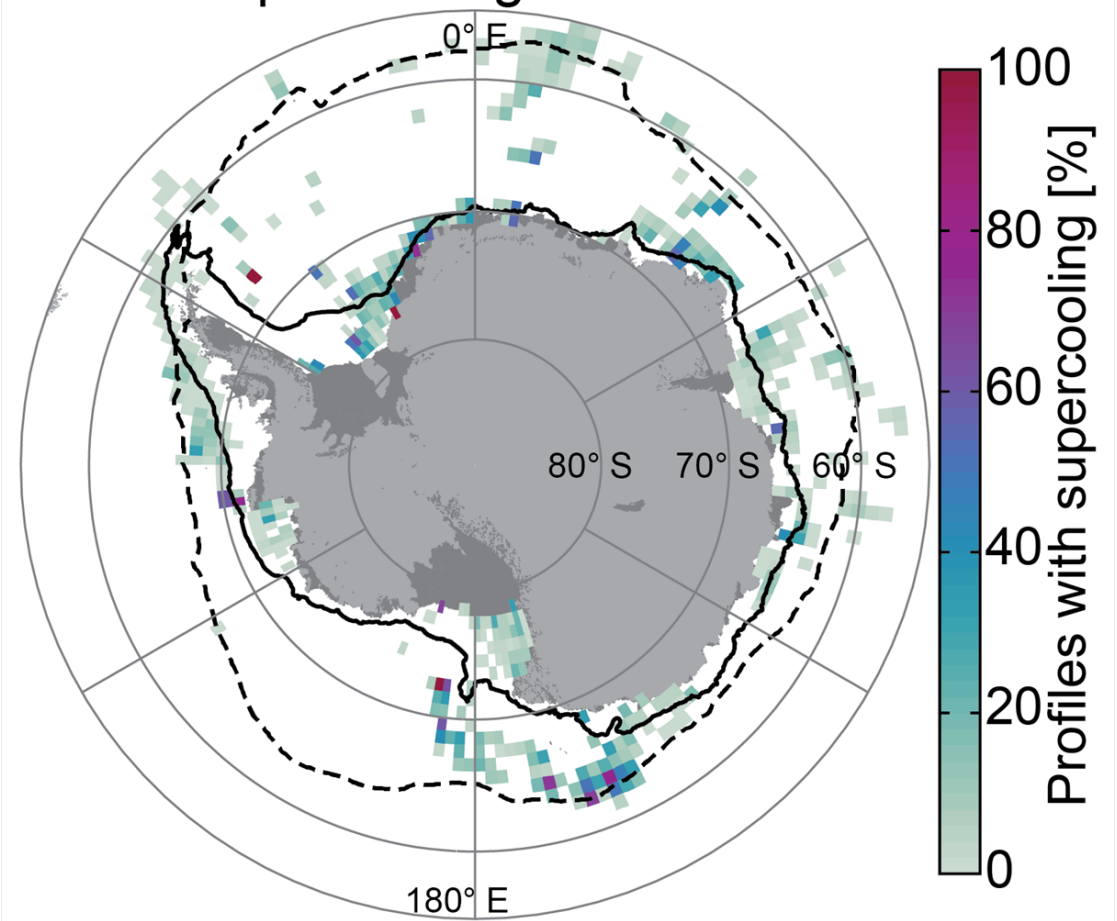
Potential and in-situ supercooling



Potential supercooling: 5.8%



In-situ supercooling: 2.6%

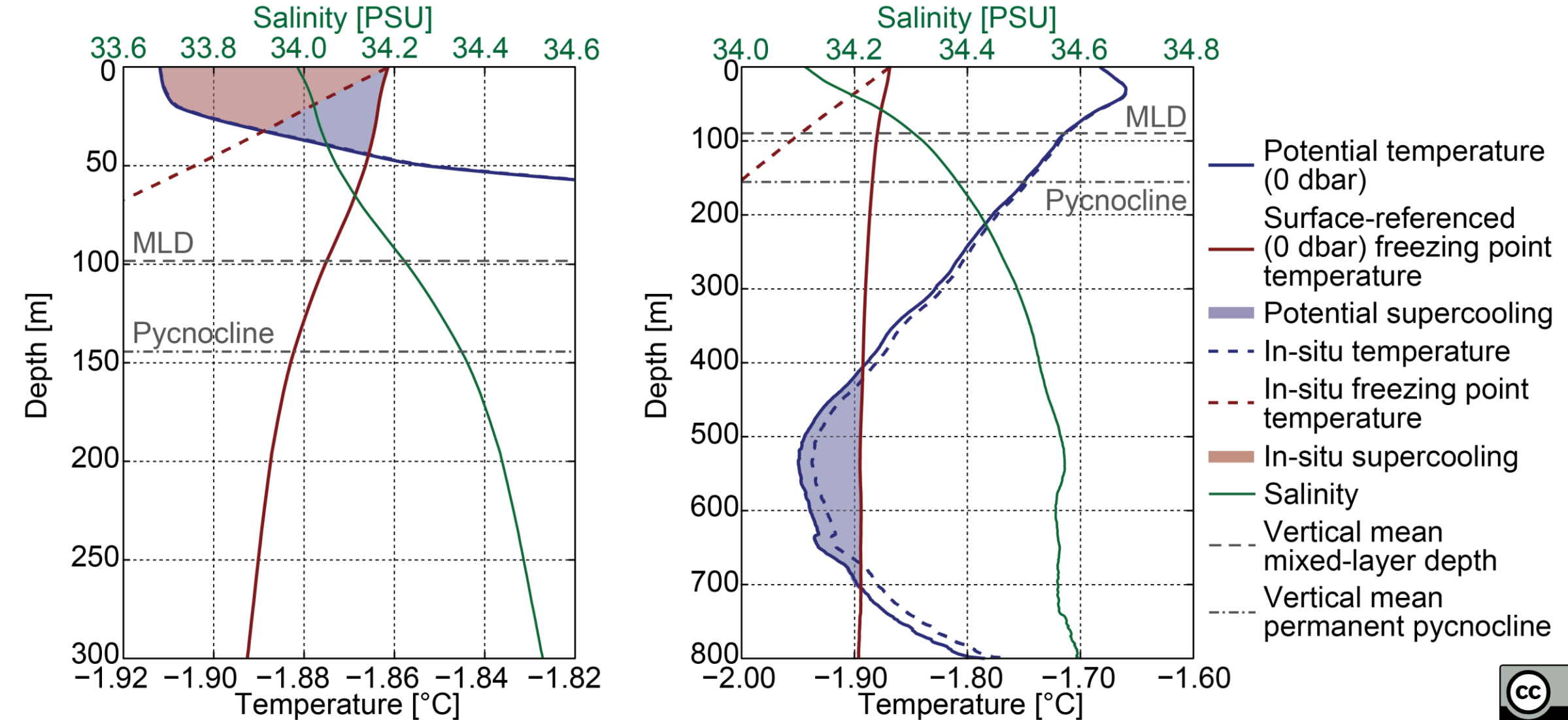


- 5.8% of all profiles (10.4% if uncertainties are ignored)
- 2.6% of all profiles (5.9% if uncertainties are ignored)

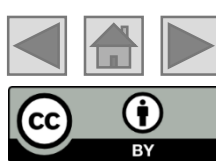
Two different types of supercooled profiles



Shallow surface supercooling and deeper subsurface supercooling

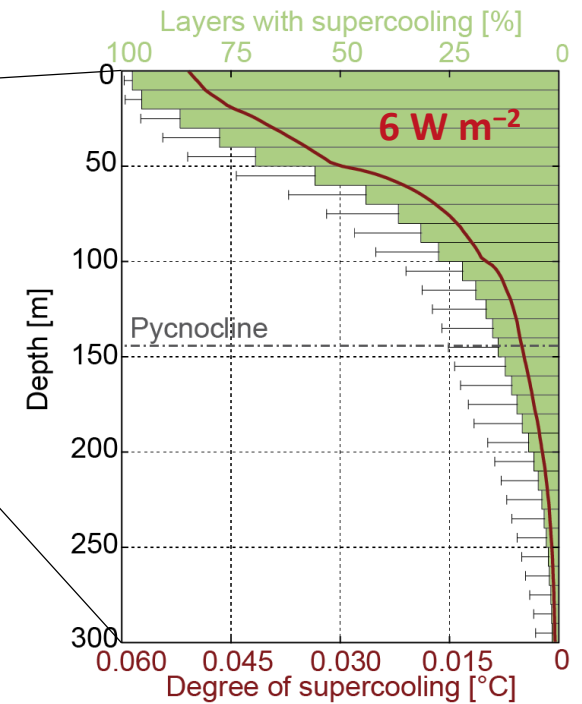
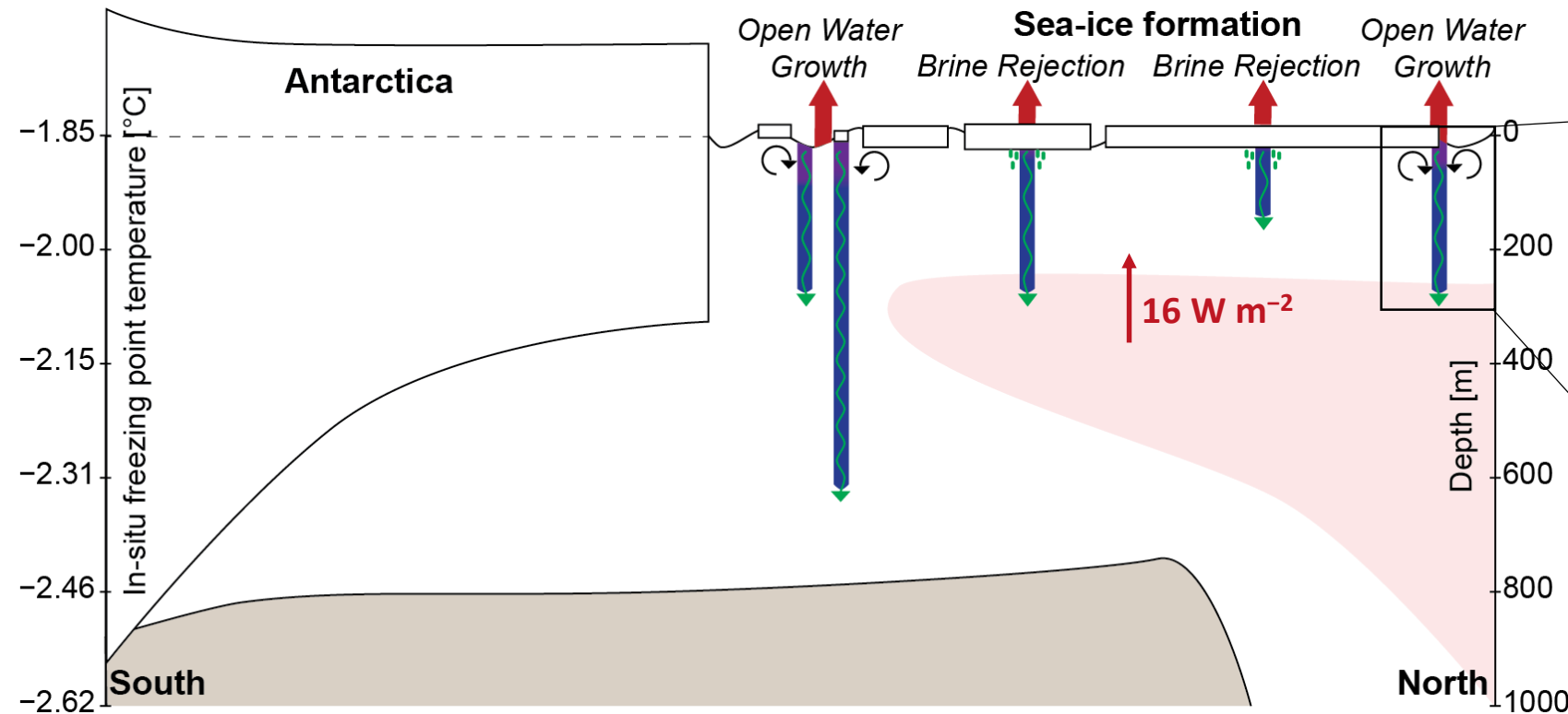
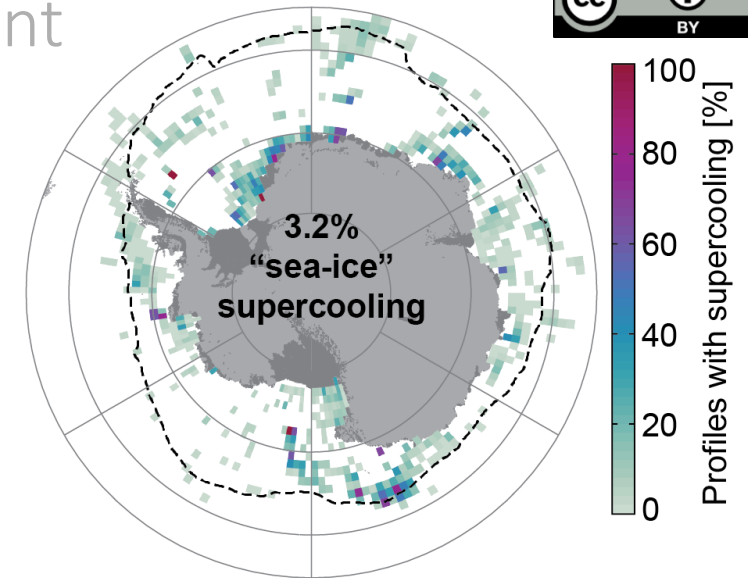


Sinking plumes of supercooled seawater from sea-ice formation

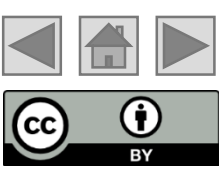


First observational evidence for horizontal and vertical extent of supercooling and convection due to sea-ice formation

- Supercooled sinking plumes could locally account for a large portion of the subsurface heat loss
- They could also be an important process for the vertical transport of carbon

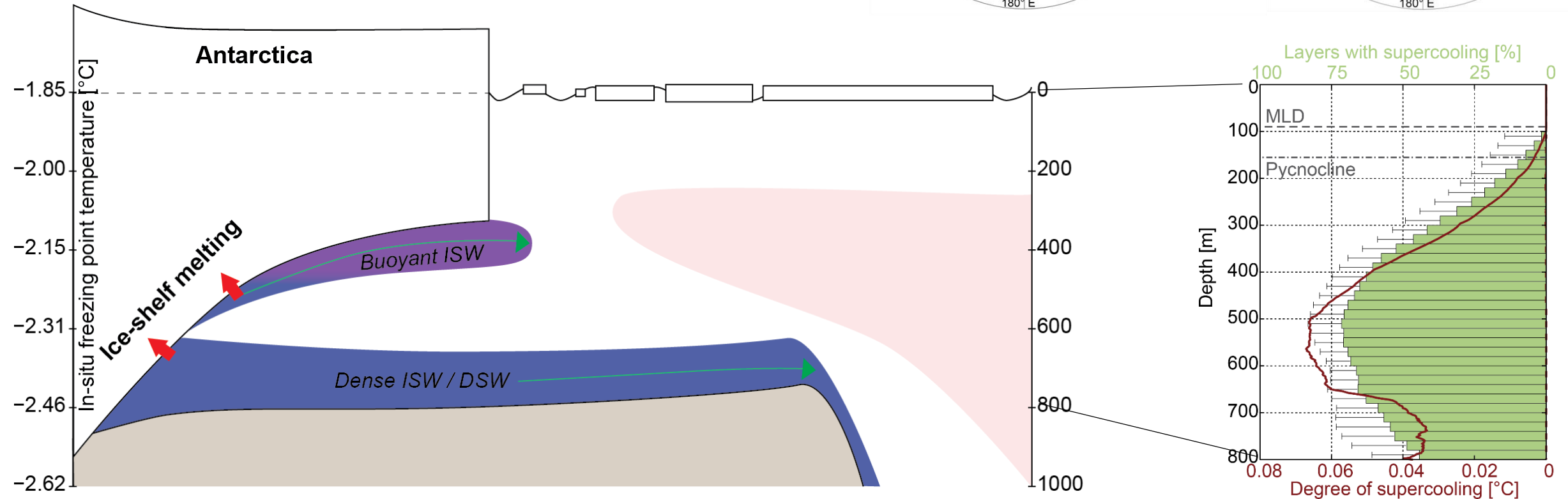
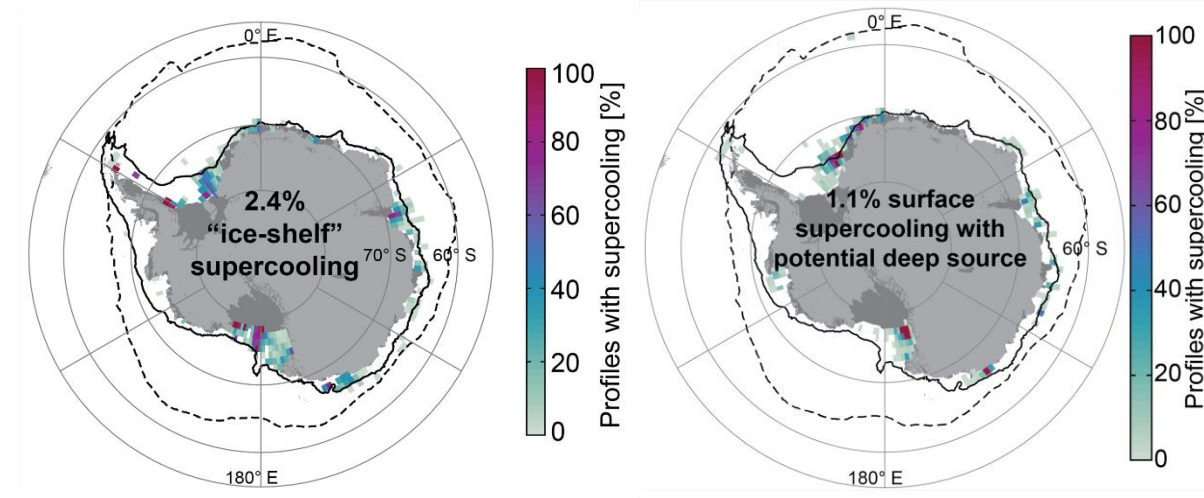


Dense and buoyant ice-shelf water along the continental shelf

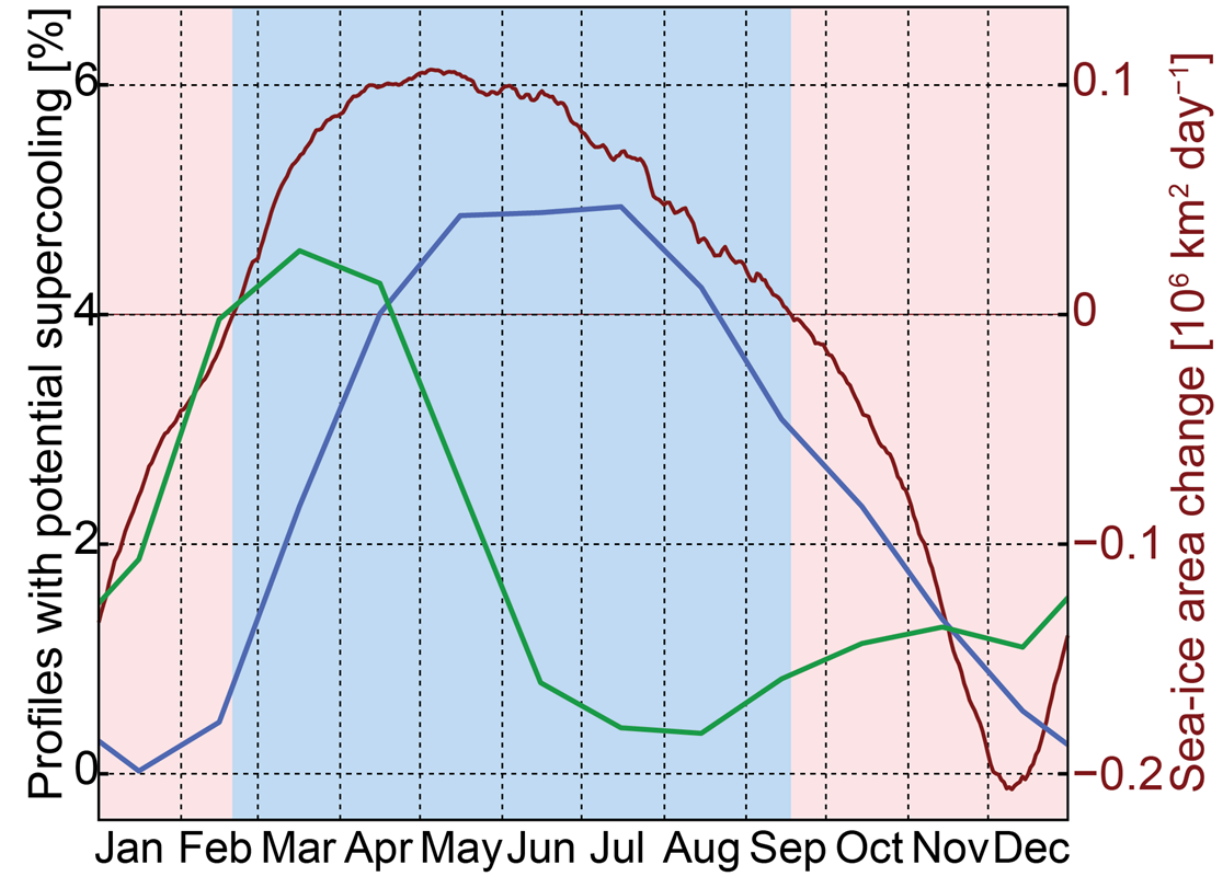


Expanding previous picture of the occurrence of Ice-Shelf Water from melting Antarctic glaciers

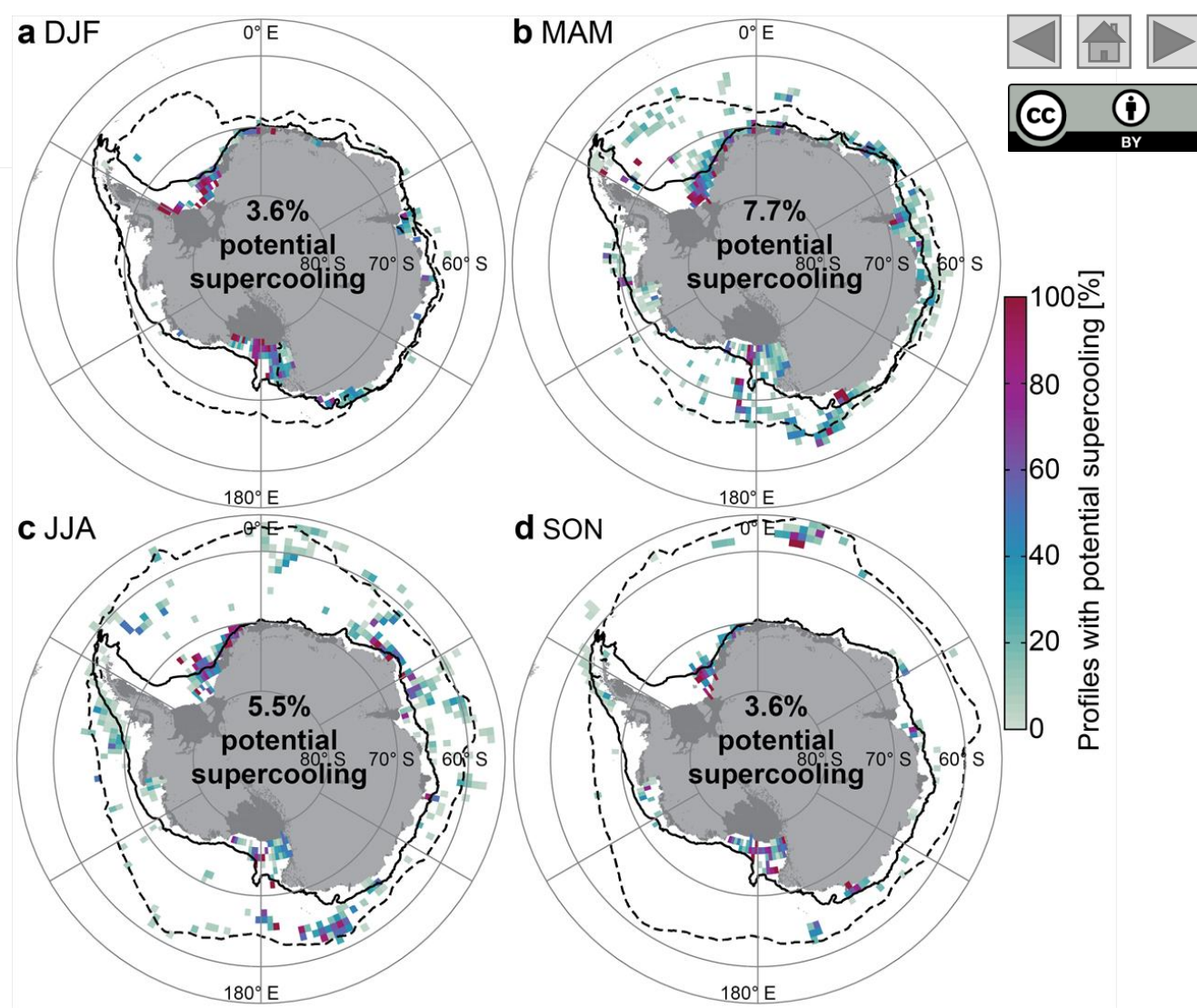
- Large occurrence of sinking, dense ISW in regions known to form AABW
- Possible rising, buoyant ISW in regions known for platelet ice formation



Seasonal cycle of supercooling



- “Sea-ice” potentially supercooled profiles
- “Ice-shelf” potentially supercooled profiles
- Sea-ice area change
- Sea-ice growth
- Sea-ice melt



- Sea-ice potentially supercooled profiles approximately follows with a slight delay the seasonal cycle of sea-ice growth and decay
- The seasonal cycle of ice-shelf supercooled profiles peaks at the end of the austral summer



Conclusions and implications

- Potential and in-situ supercooling occurs in large parts of the Southern Ocean seasonal sea-ice zone
- Deep coastal supercooling from below 100 m to the ocean bottom is associated with melting ice shelves and dense shelf water formation
- Shallow supercooling is associated with sea-ice formation and can penetrate as deep as the permanent pycnocline

“Sea-ice” supercooling could be an important process for extracting heat from deeper layers and for the vertical transport of salt, carbon, oxygen, and nutrients

Haumann et al. (2020): Supercooled Southern Ocean Waters. *Geophysical Research Letters*, 47, e2020GL090242. doi:10.1029/2020GL090242.

