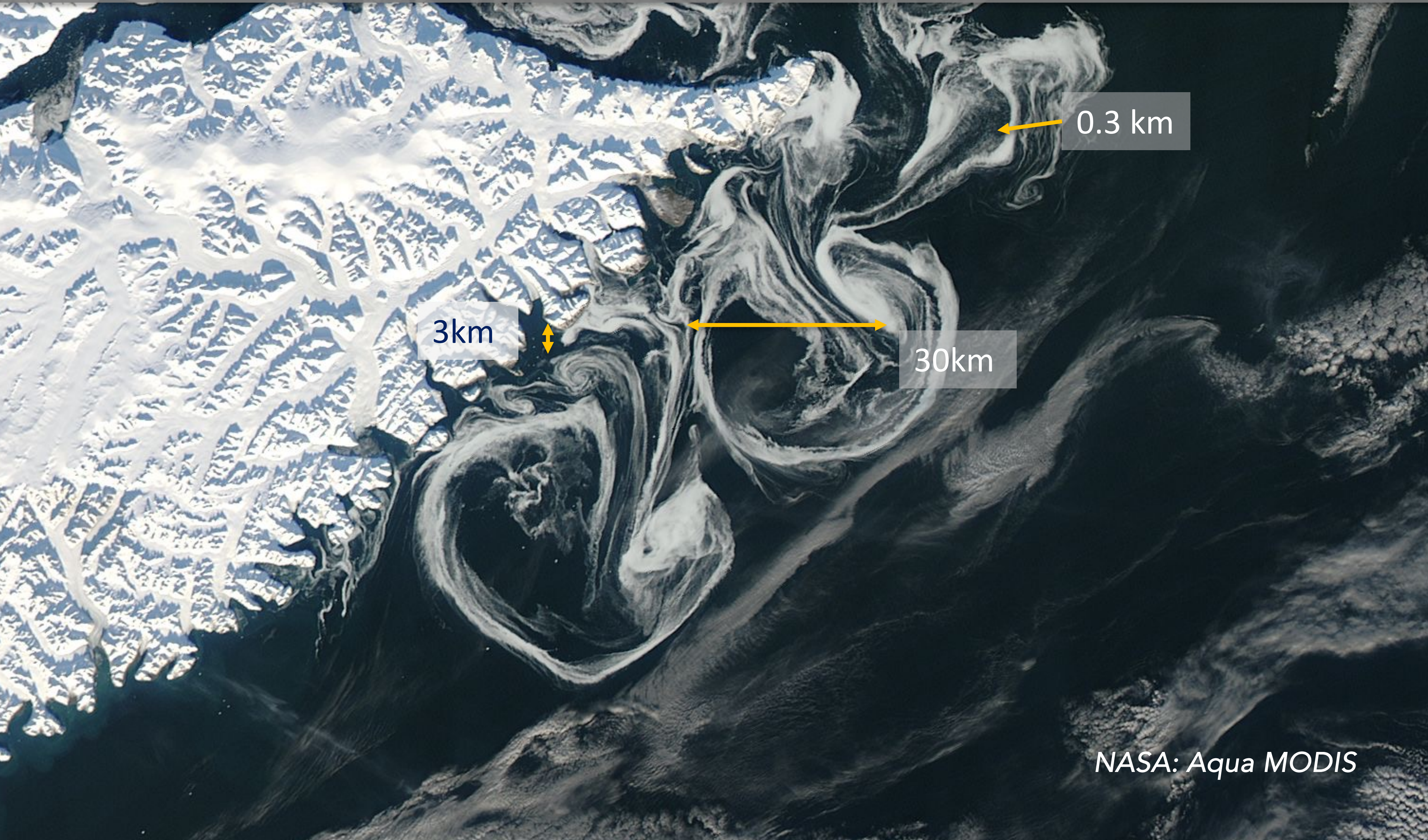
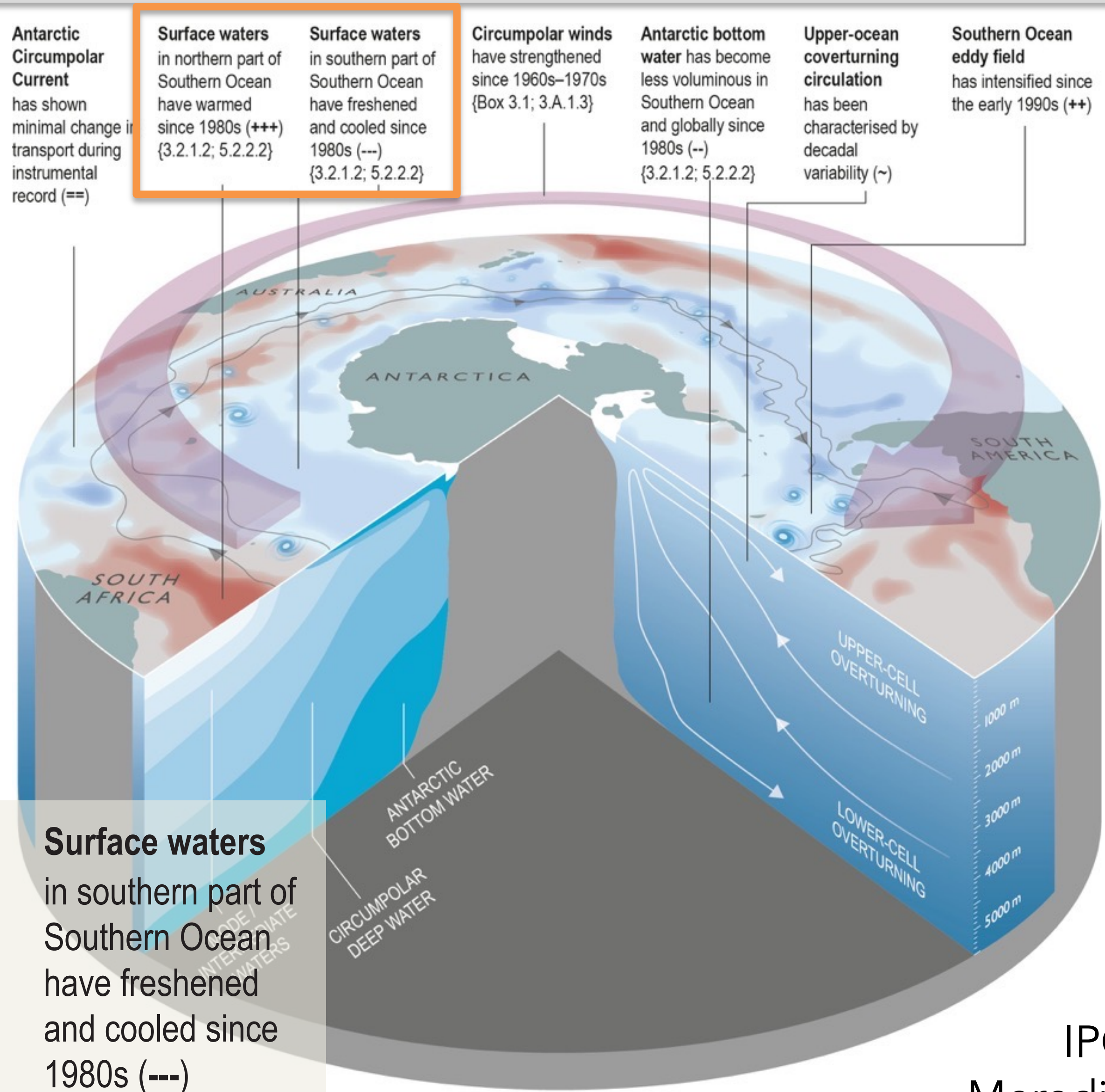
Glider-observed submesoscale fronts in the Southern Ocean and links to air-sea fluxes

UNIVERSITY OF GOTHENBURG

Sebastiaan Swart, Marcel du Plessis, Isabelle Giddy, Johan Edholm,
Sarah Nicholson, Louise Biddle, Karen Heywood, UW-APL (IOP) & others!



Southern Ocean in a changing climate

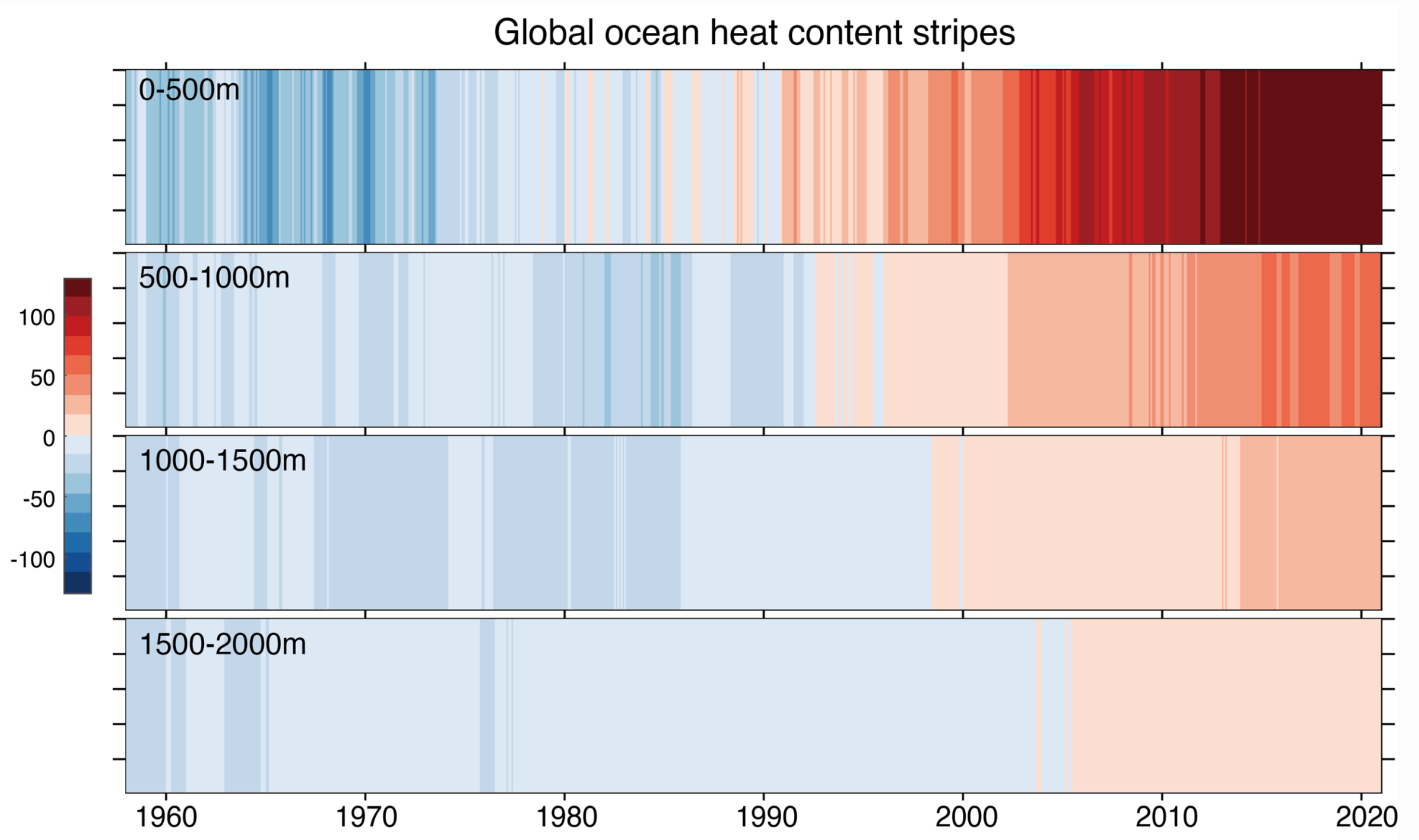


Surface waters in northern part of Southern Ocean have warmed since 1980s (**+++**) {3.2.1.2; 5.2.2.2}

Surface waters in southern part of Southern Ocean have freshened and cooled since 1980s (**---**)

IPCC, 2022
Meredith et al., 2019

Southern Ocean in a changing climate

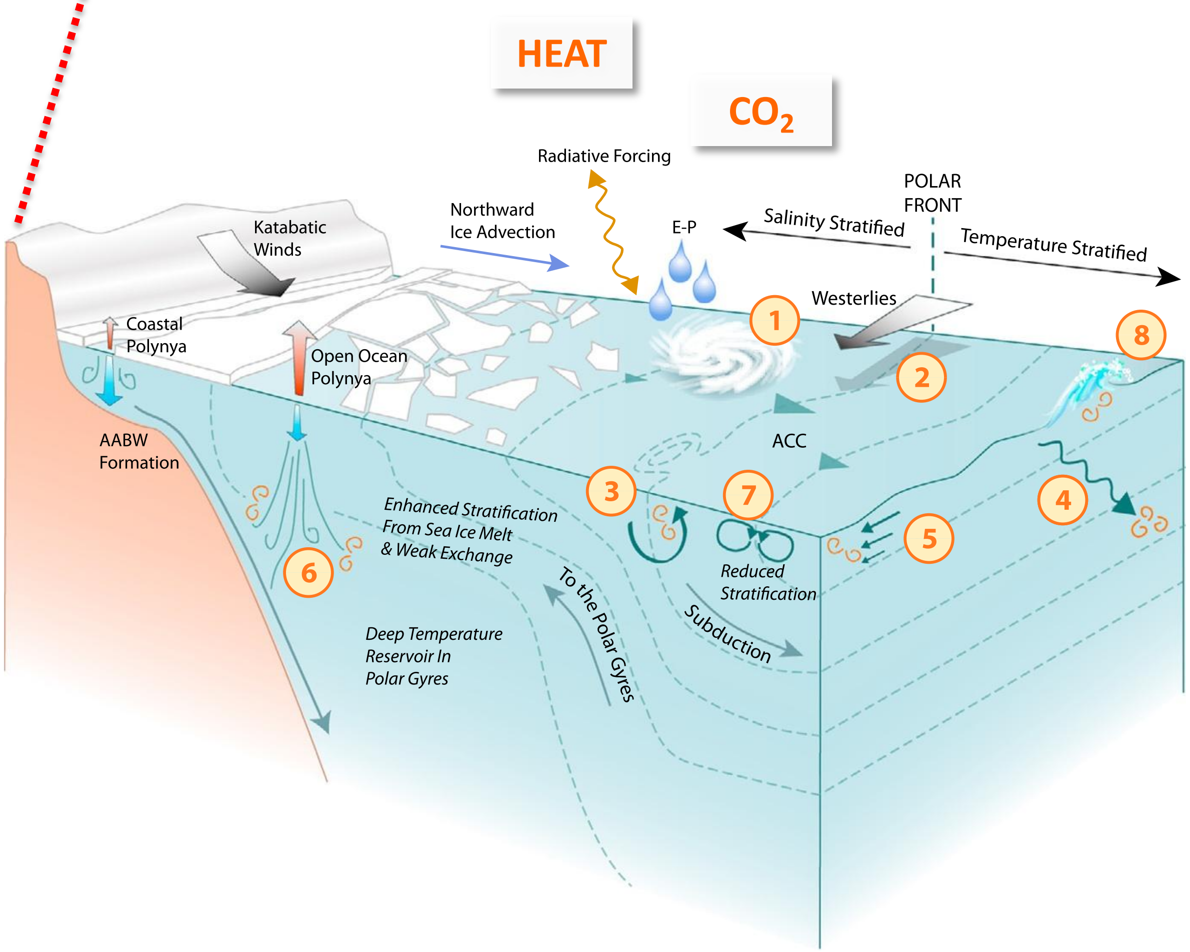


Surface waters in northern part of Southern Ocean have warmed since 1980s (**+++**) {3.2.1.2; 5.2.2.2}

Surface waters in southern part of Southern Ocean have freshened and cooled since 1980s (**---**)

Cheng et al., 2022

Extremely few observations for such a complex system!!

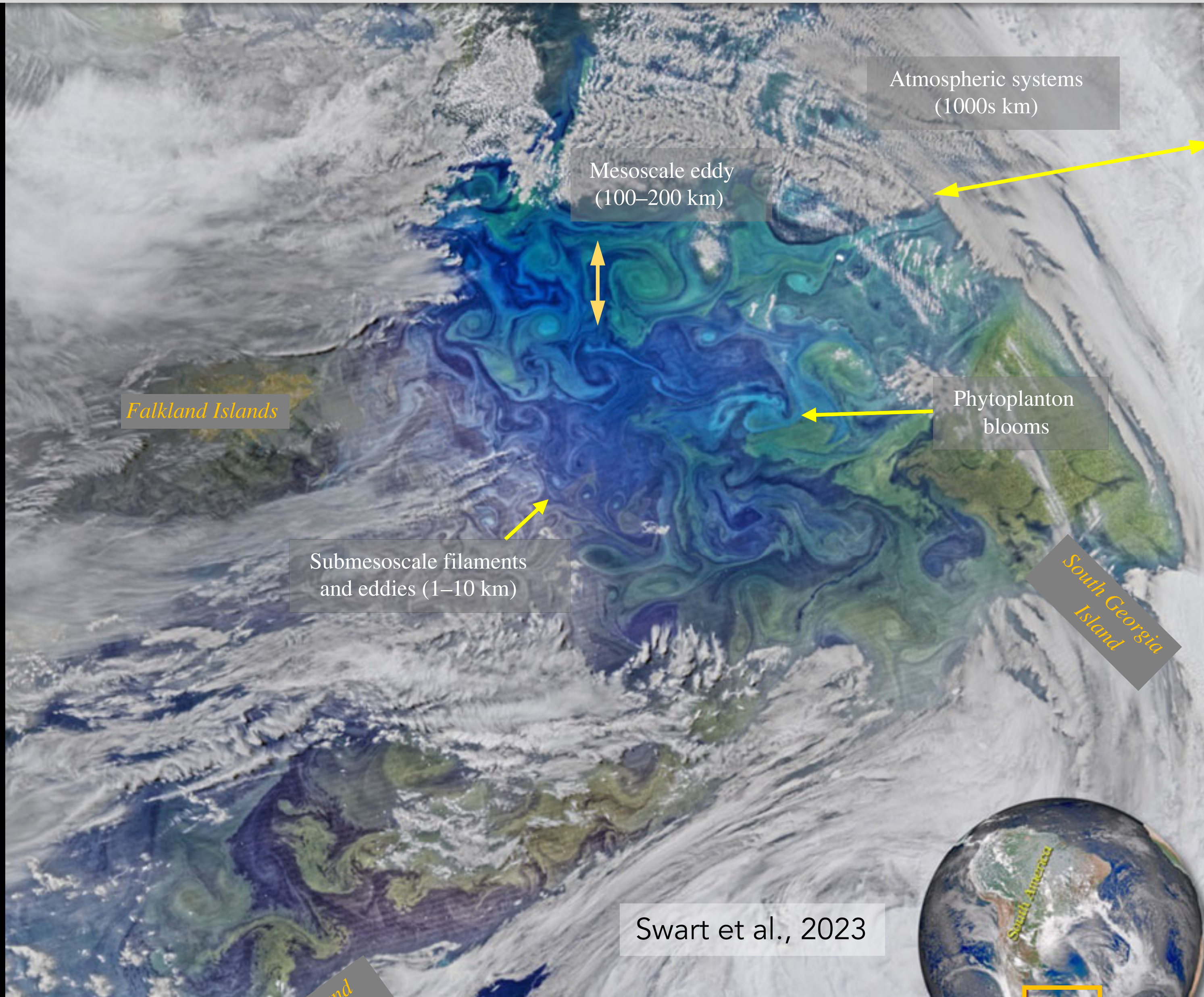


1. Surface forcing from storms *O(10 km-1000 km)*
2. Wind-front interactions *O(1 km-100 km)*
3. Submesoscale eddies & jets *O(100 m - 10 km)*
4. Downward propagating internal waves *O(10 m -100 m)*
5. Near surface shear & mixing *O(10 m -100 m)*
6. Heat loss, brine rejection & deep convection in polynyas & leads *O(10 m -1000 km)*
7. Langmuir Circulation *O(10 m - 100 m)*
8. Wave breaking *O(1 m - 10 m)*

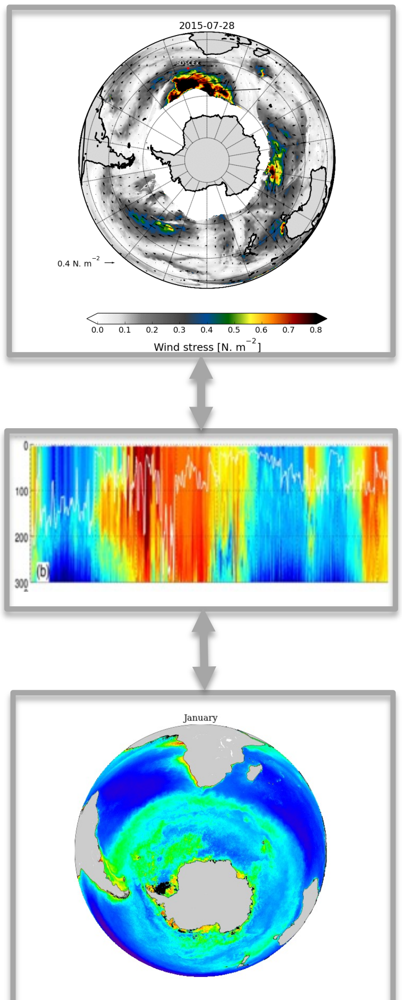
Southern Ocean Mixing Processes

Gille, Sheen, Swart & Thompson, 2022 – Mixing in the Southern Ocean, chap. In Ocean Mixing

The fine-scale ocean impacts its boundaries - we can’t yet fully observe or quantify



Multi-layer simultaneous observations needed:
ML physics, air-sea & BGC processes



ATMOSPHERE

OCEAN

BIOGEOCHEM

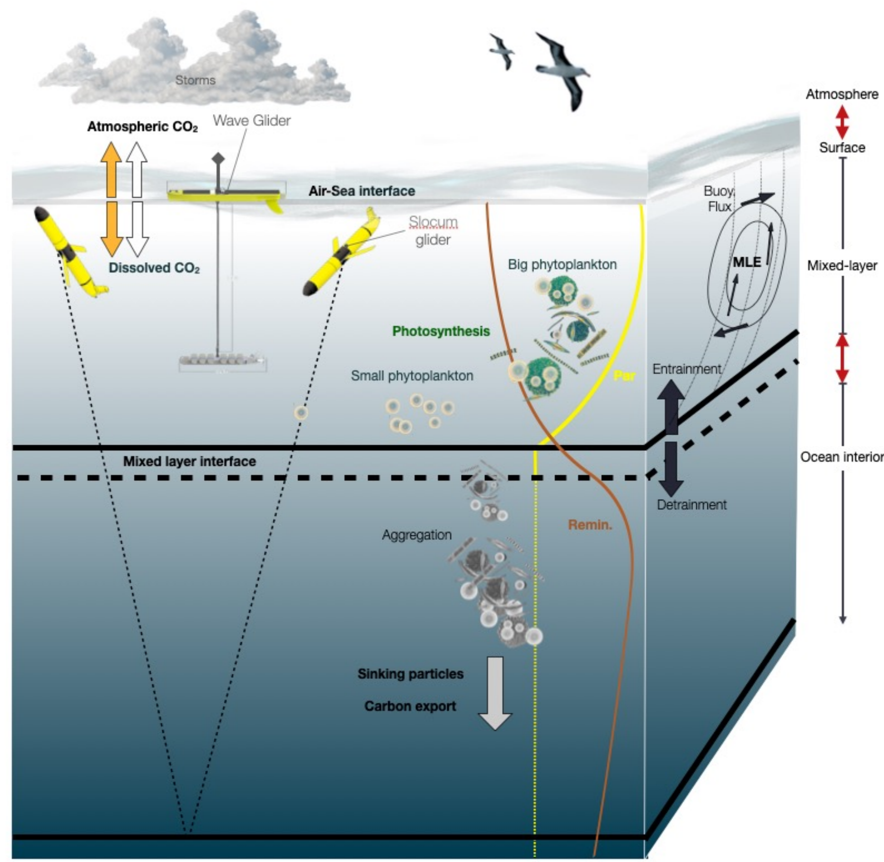
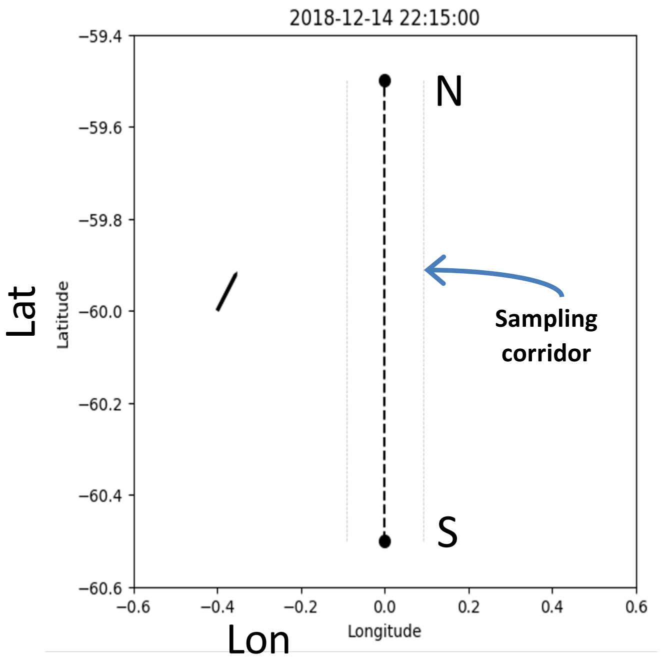


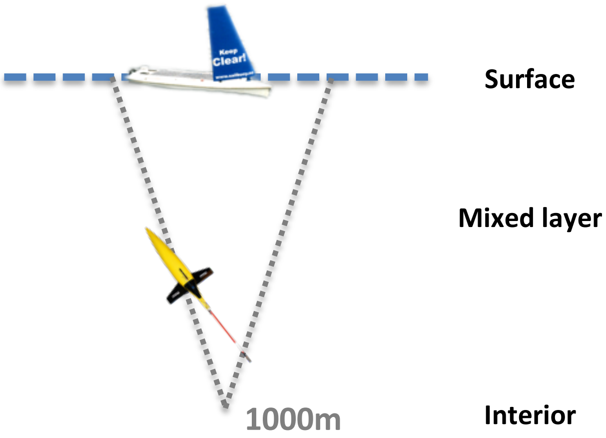
Photo: Emma Bone

MIZ fine-scale observations
(60°S; 0°E)
(15 Dec 2018 – 21 March 2019: 3.5 months)

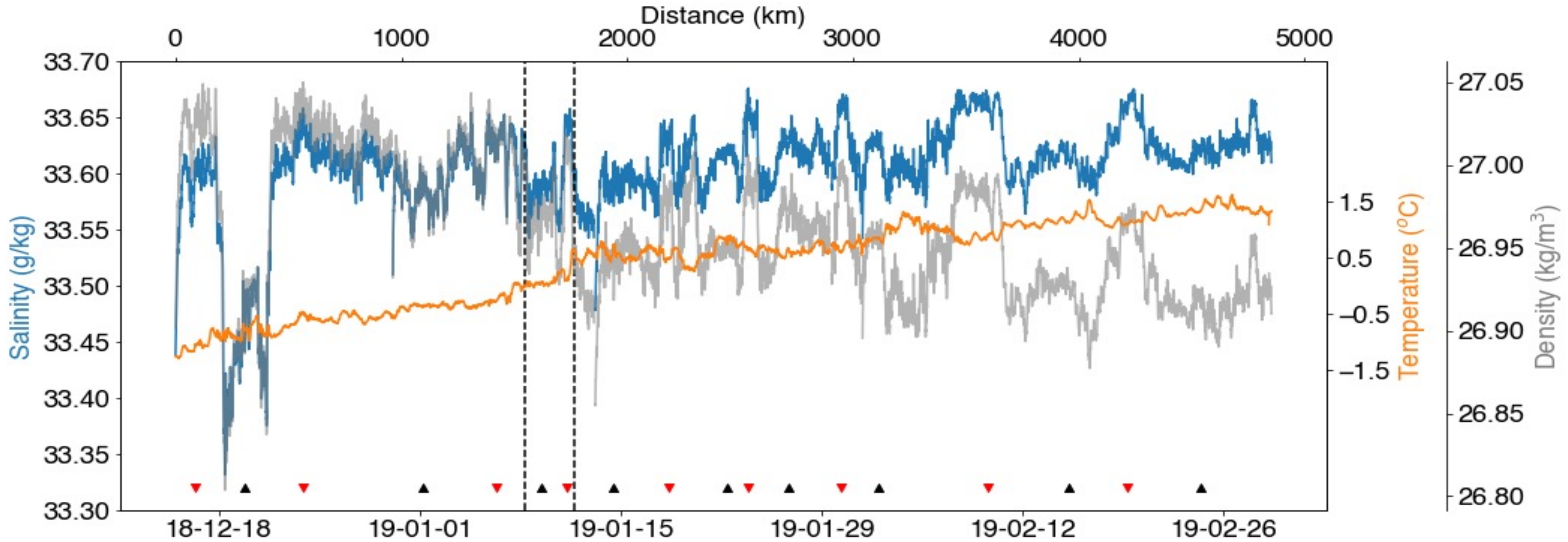
Sailbuoy

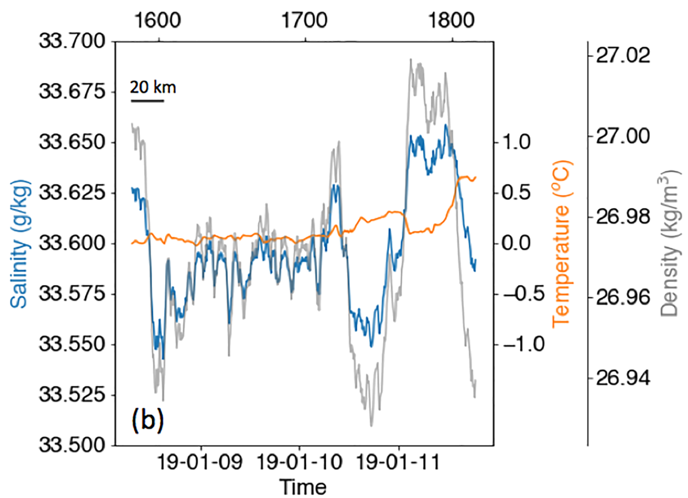
Seaglider



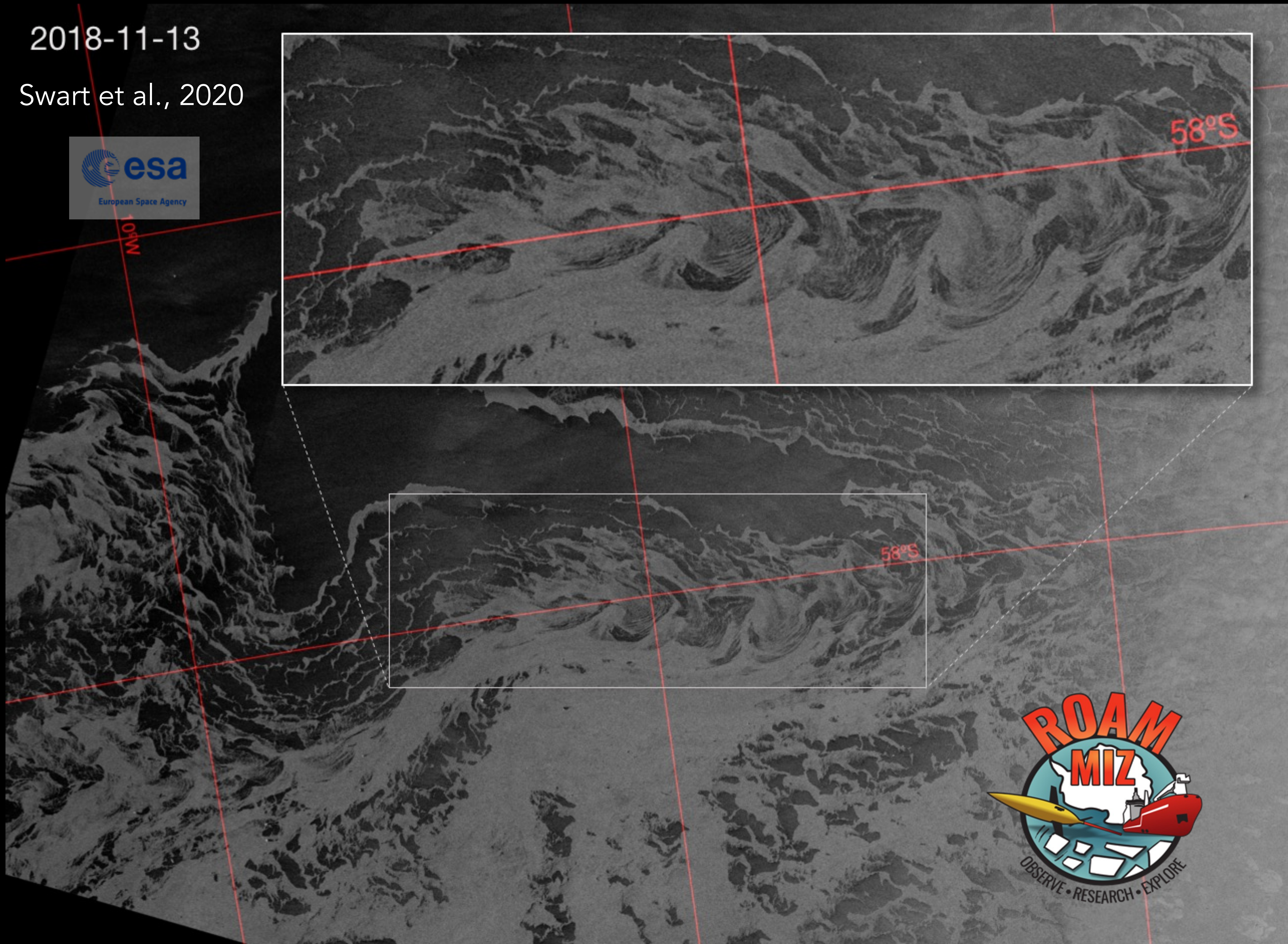


Salinity fronts in Southern Ocean MIZ

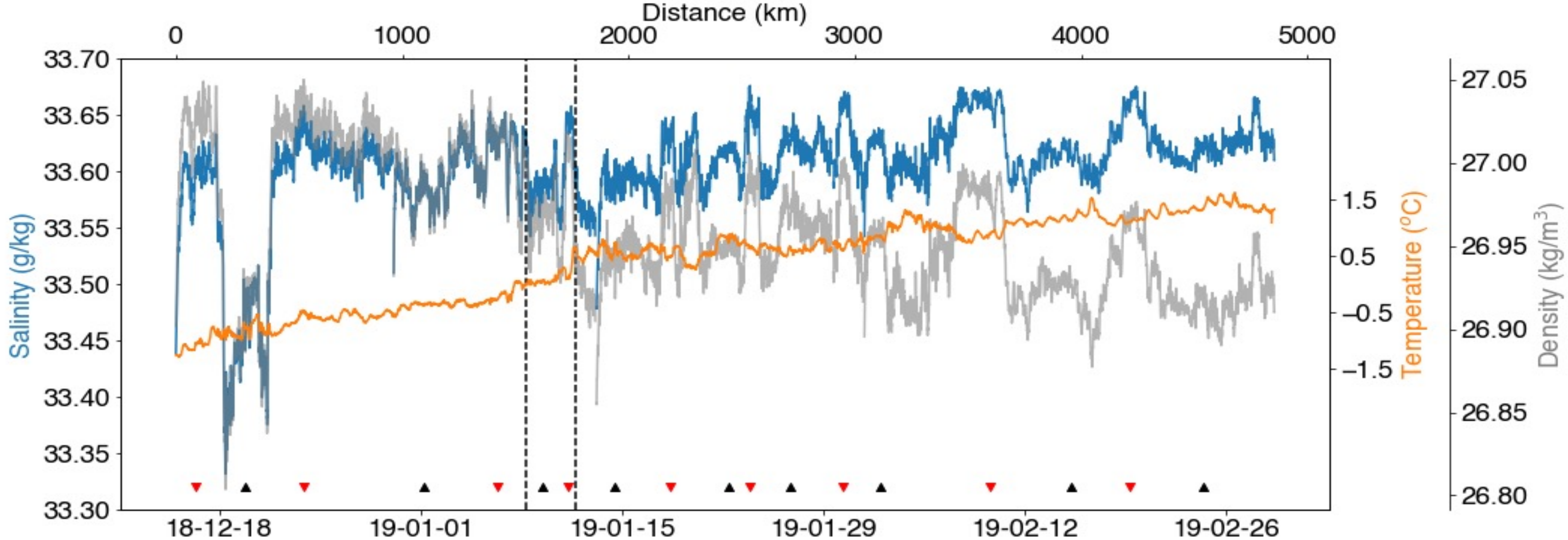


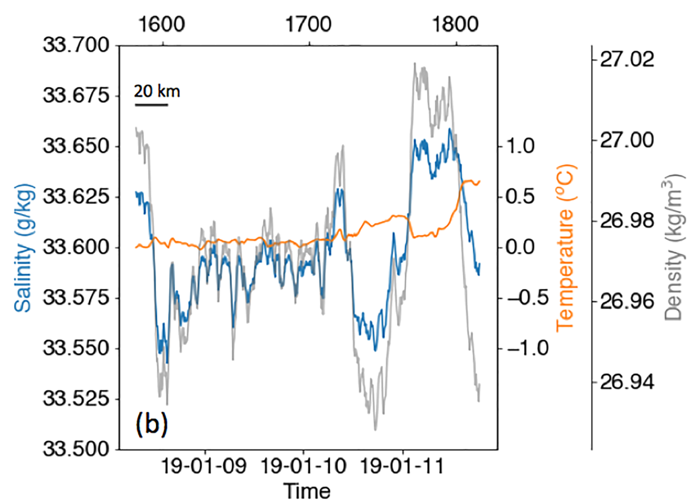


Swart et al., 2020


2018-11-13
Swart et al., 2020
esa
European Space Agency
10ºW
58ºS
58ºS
ROAM
MIZ
OBSERVE • RESEARCH • EXPLORE

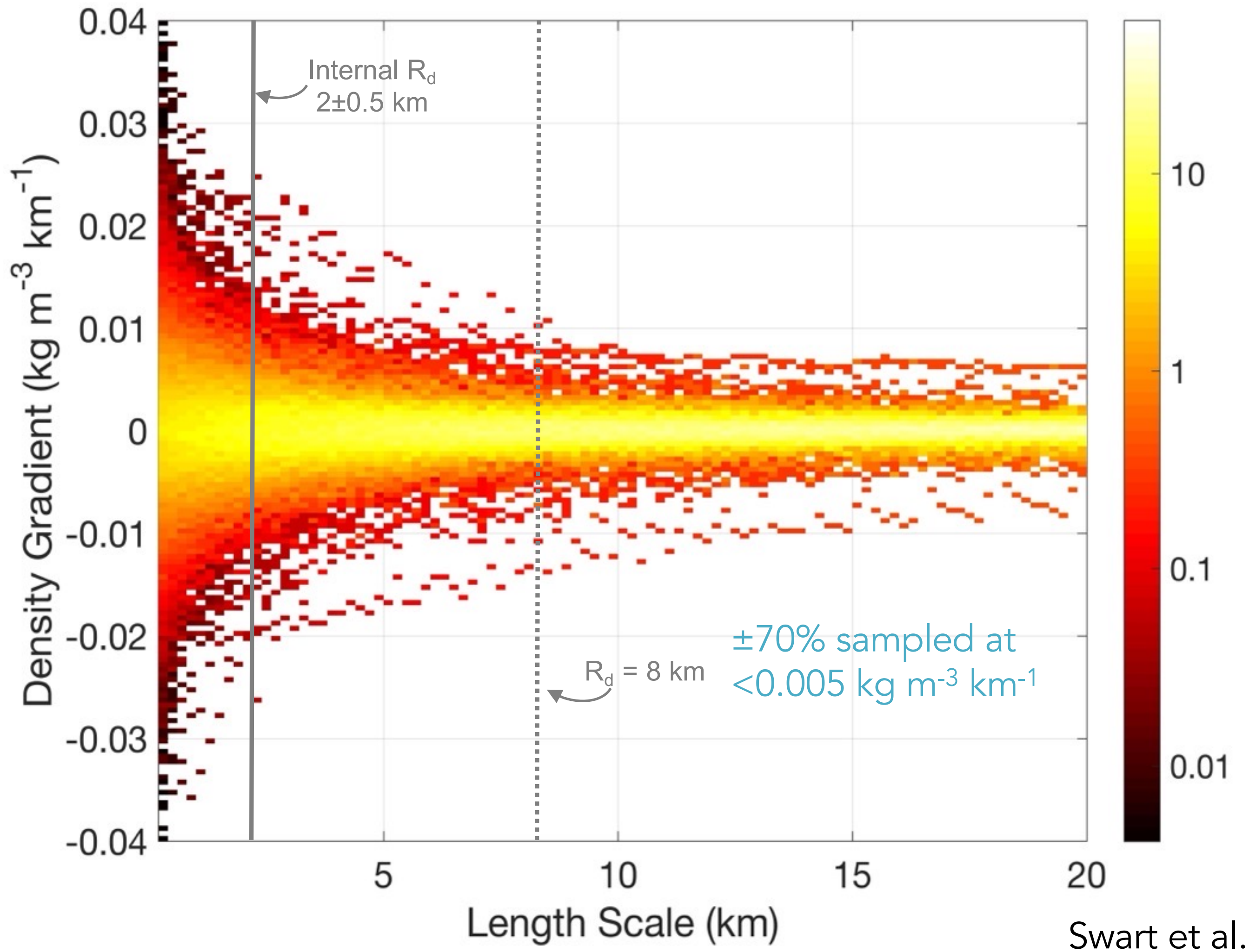
Salinity fronts in Southern Ocean MIZ





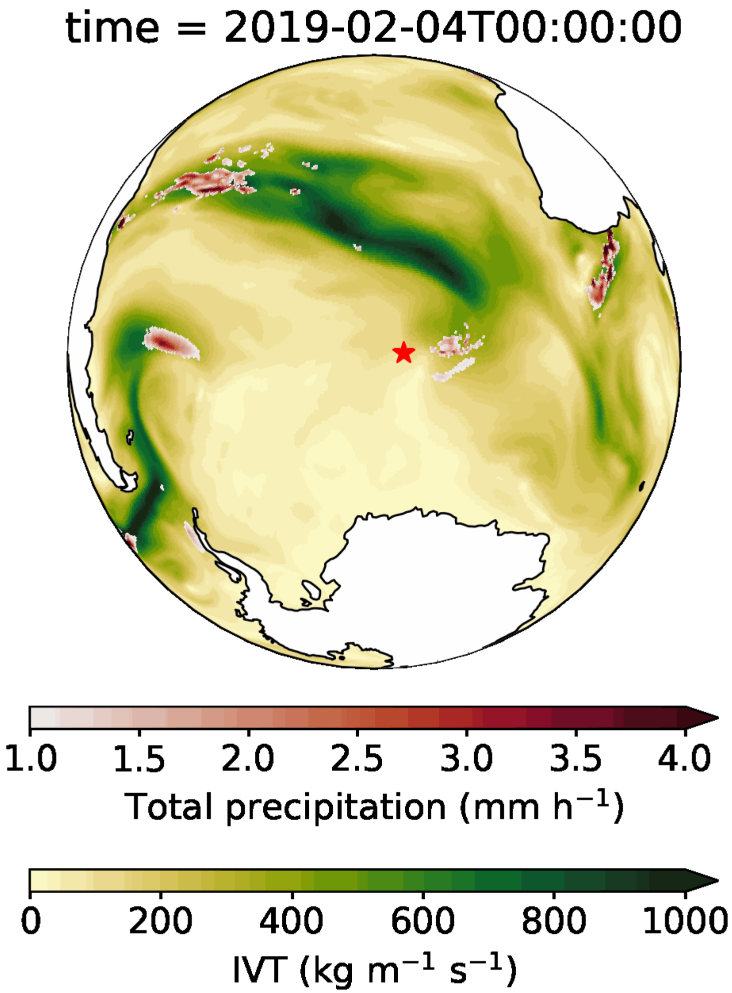
Swart et al., 2020

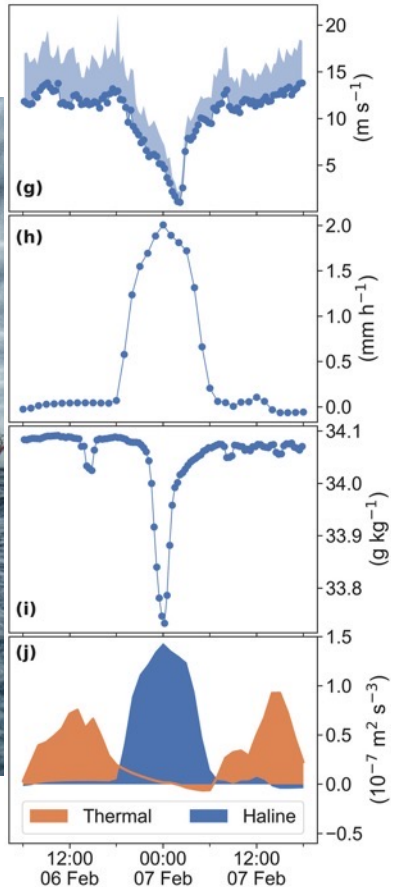
Length-scale of upper ocean fronts



Swart et al., 2020

Impacts of a turbulent atmosphere on the submesoscale



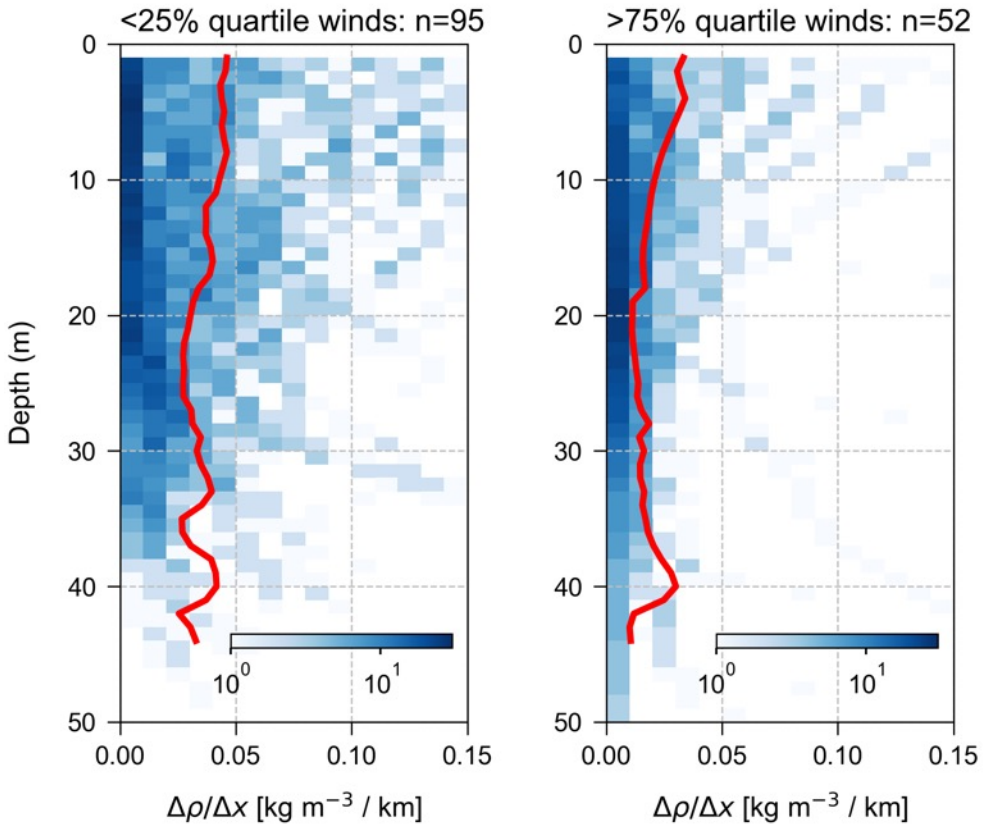


ARs produce 50% precipitation
= 10% of surface buoyancy

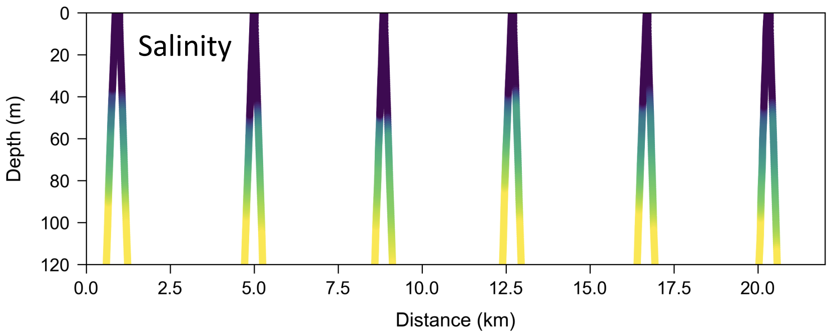
Edholm et al., GRL, 2022

Glider wind-front interactions at submesoscales

Glider density gradients during different wind regimes



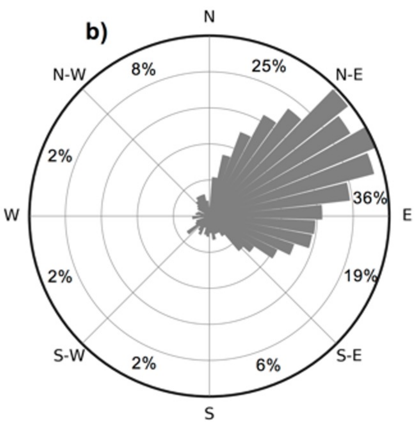
Glider climb-dive phases



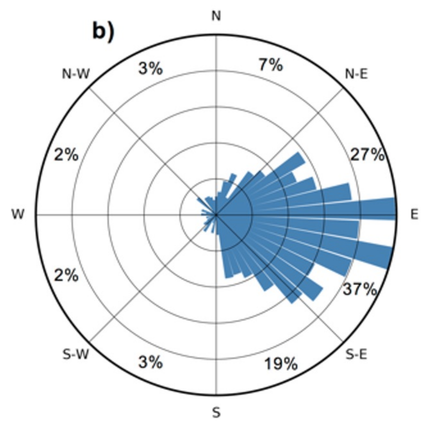
Swart et al., 2020

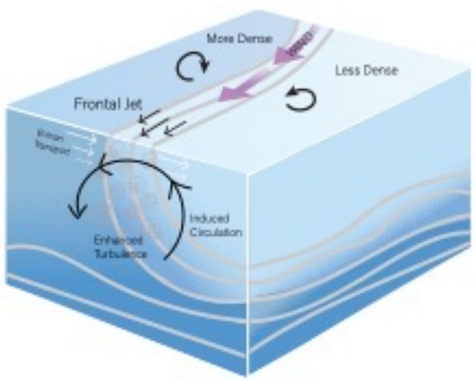
Mixing and stratification by wind-submesoscale interactions

Glider currents



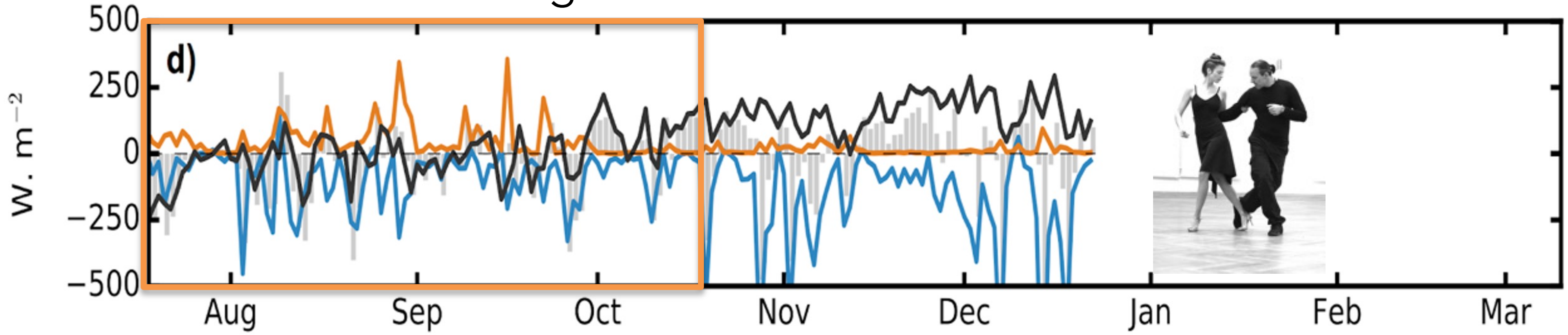
Wind stress





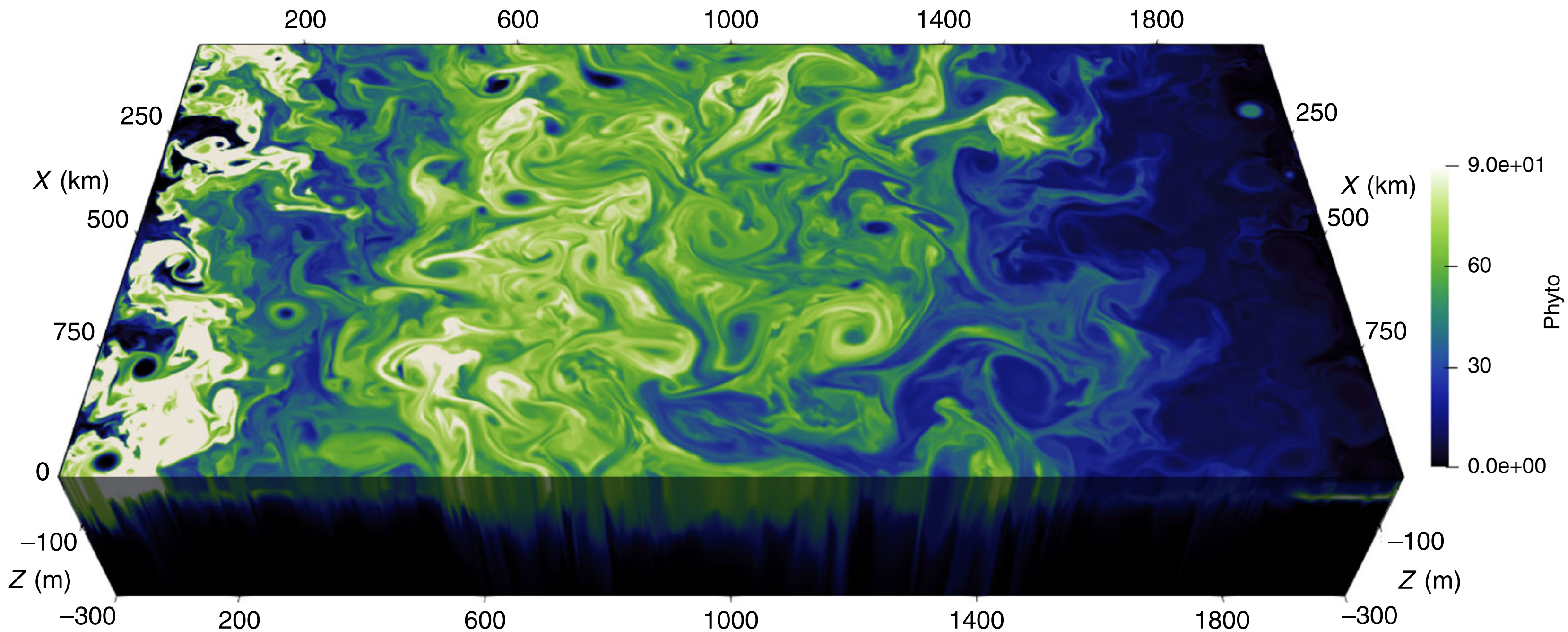
Adapted from D'Asaro et al., 2011

MLE – EBF Tango



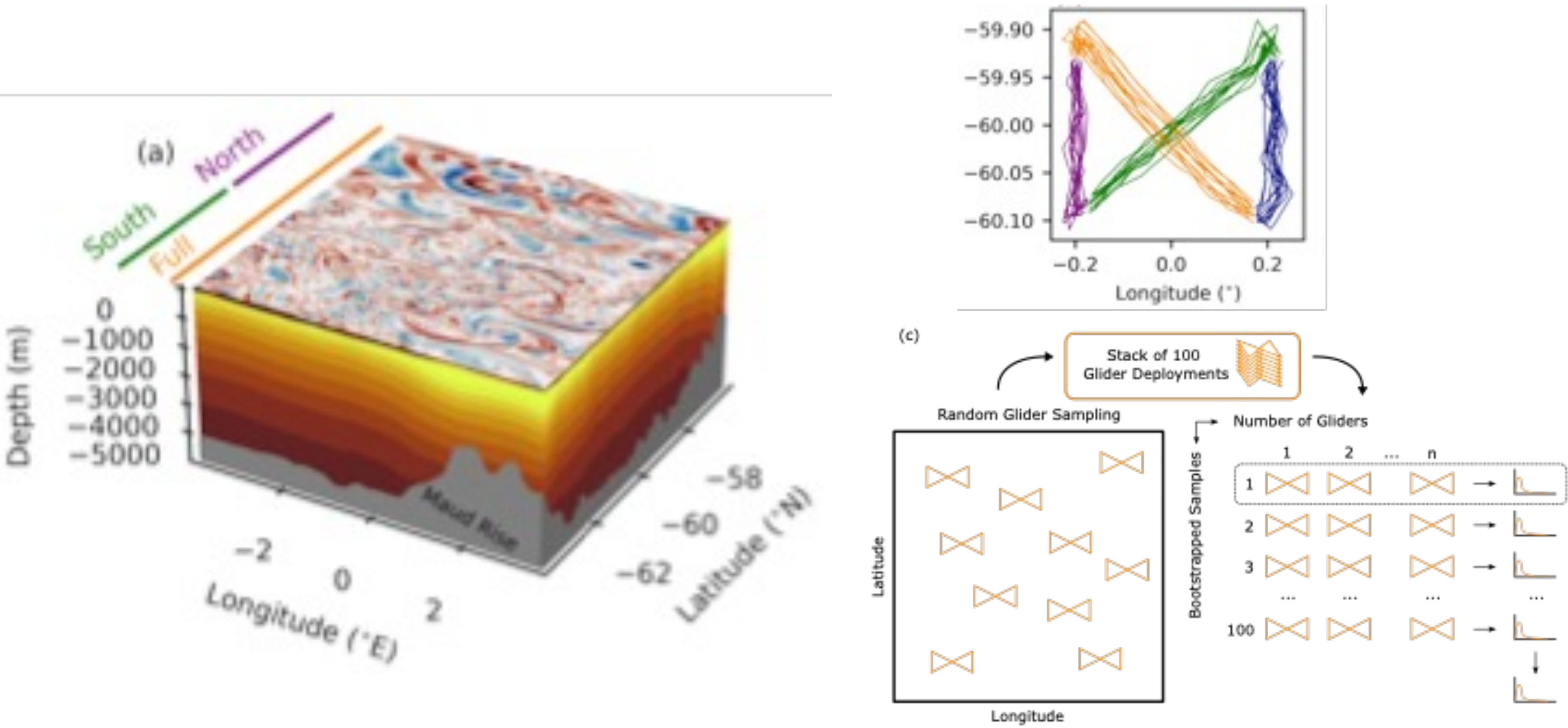
du Plessis et al., JGR, 2017 & JPO, 2019
Giddy et al., JGR, 2021

Stratification by submesoscale processes

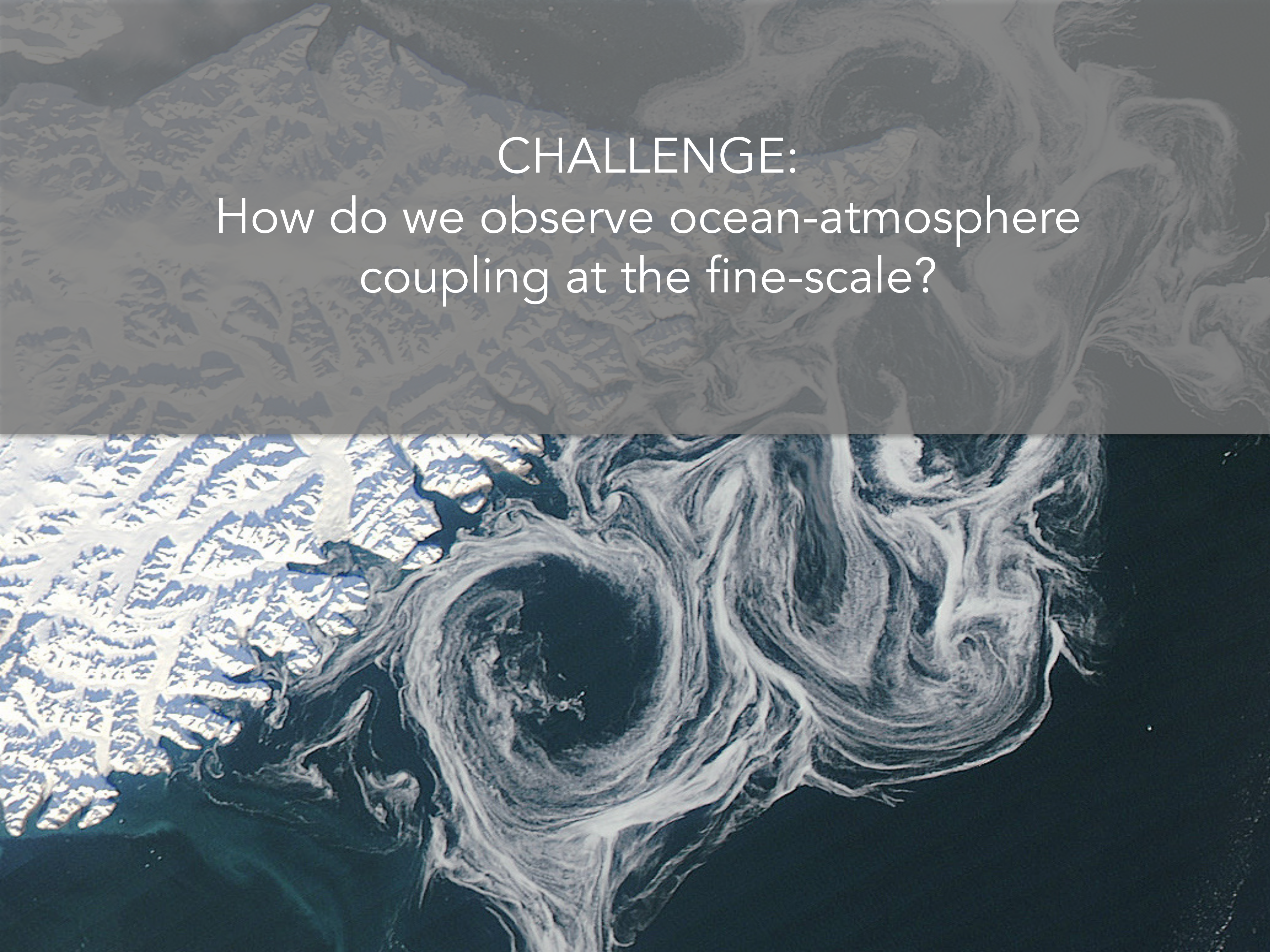


Uchida et al., 2020
Nicholson et al., 2019

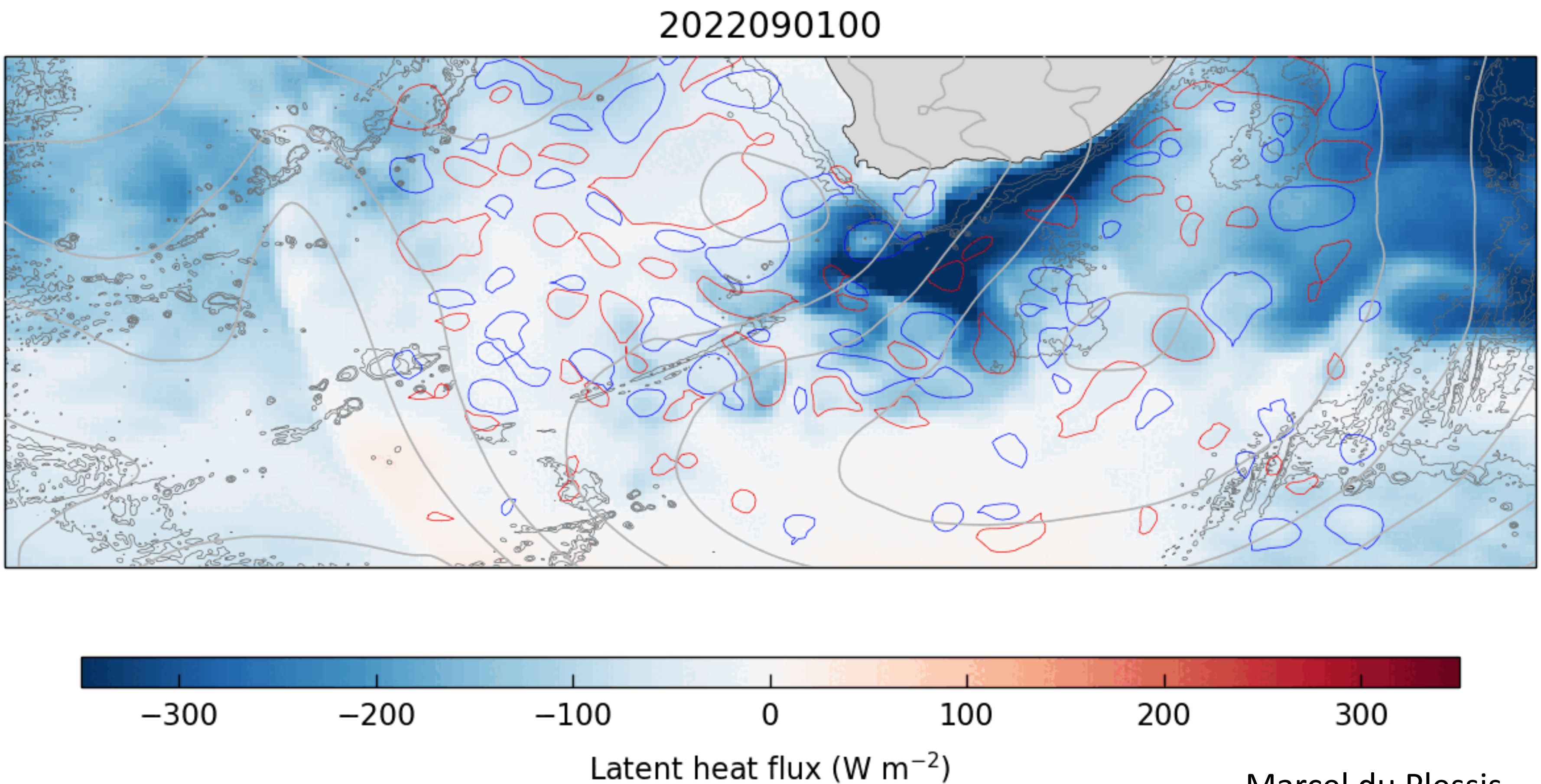
How to sample with gliders?



Patmore et al., JTECH, 2024

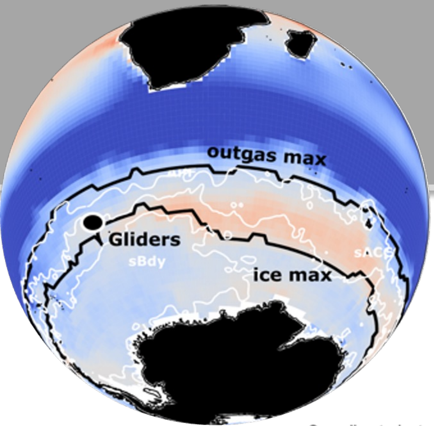

CHALLENGE:
How do we observe ocean-atmosphere coupling at the fine-scale?

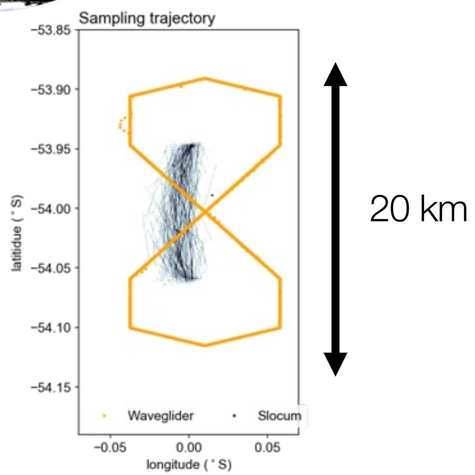
The ocean's imprint on air-sea fluxes

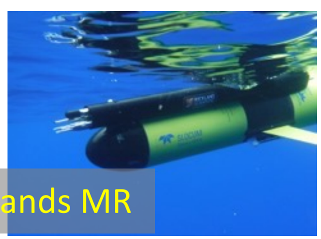


Marcel du Plessis

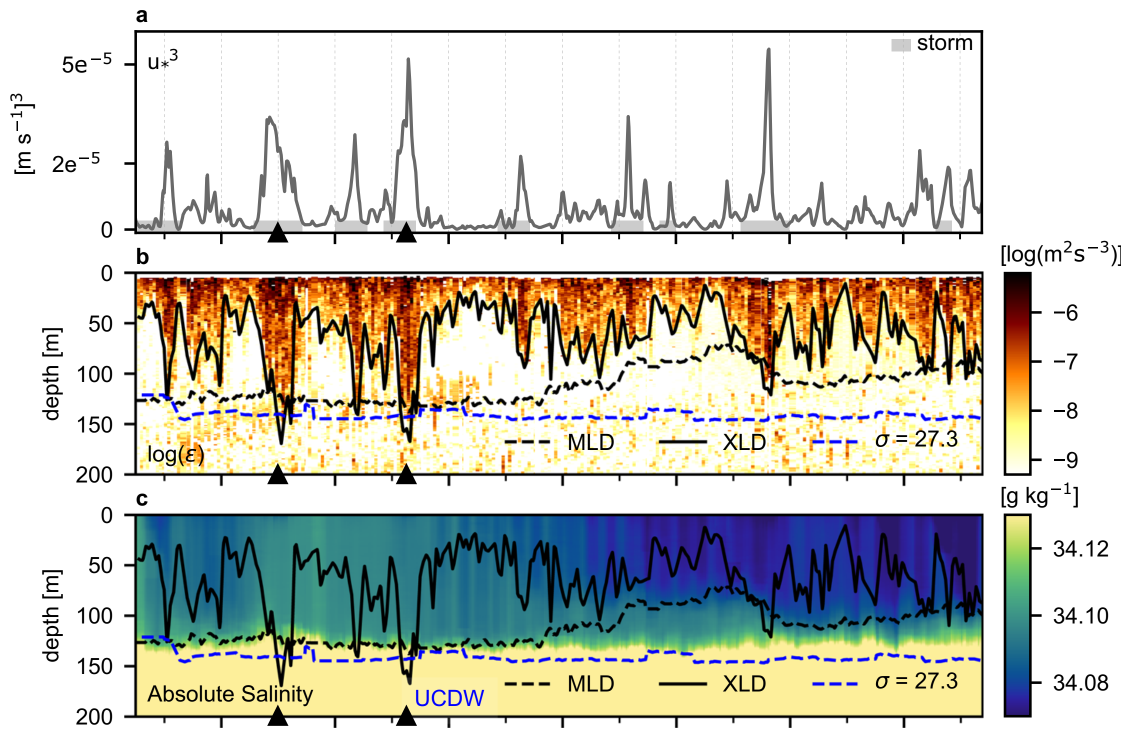
Ocean – atmosphere coupling at the fine-scale







With Rocklands MR



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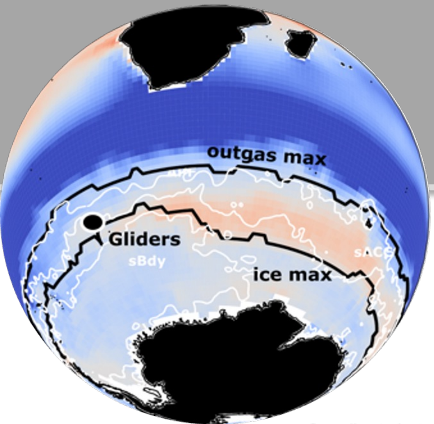
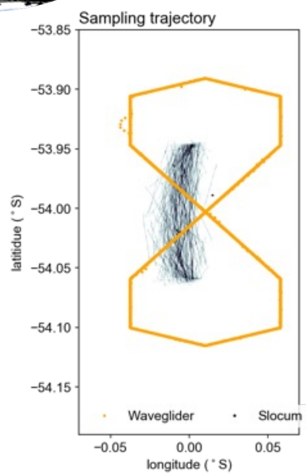
Storms drive outgassing of CO_2 in the subpolar Southern Ocean

Sarah-Anne Nicholson[1✉], Daniel B. Whitt[2,3], Ilker Fer[4], Marcel D. du Plessis[1,5,6], Alice D. Lebéhot[1,6,7], Sebastiaan Swart[5,6], Adrienne J. Sutton[8] & Pedro M. S. Monteiro[1,6]

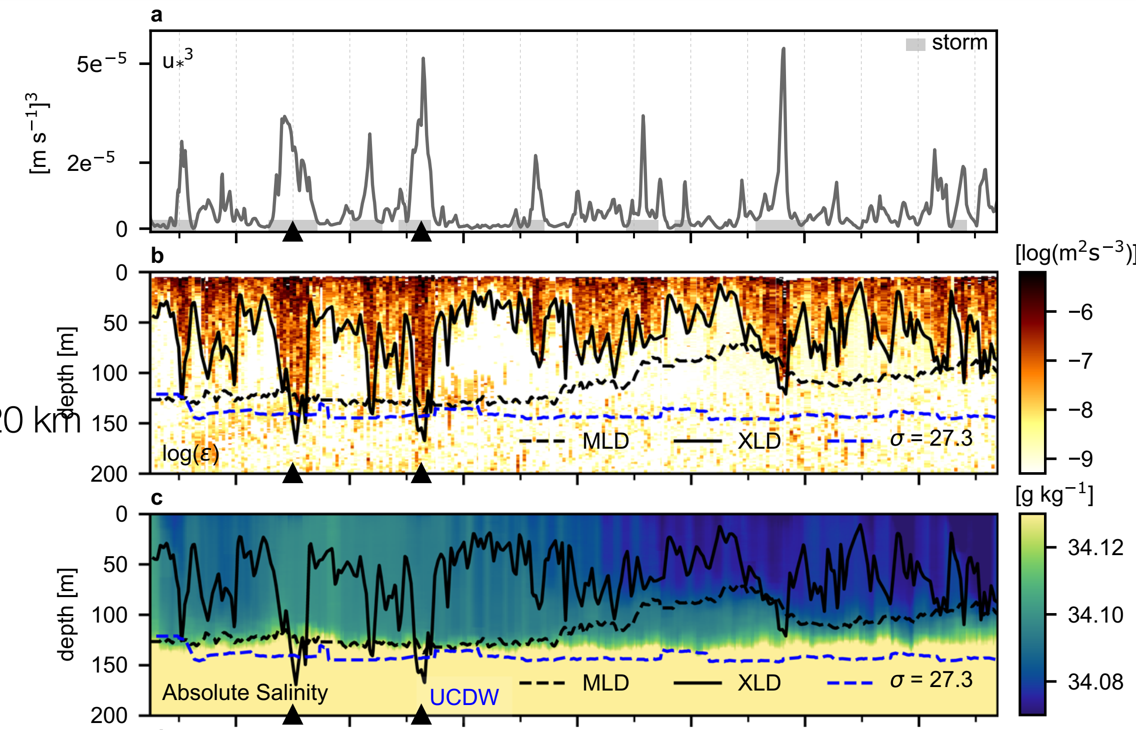
Ocean – atmosphere coupling at the fine-scale



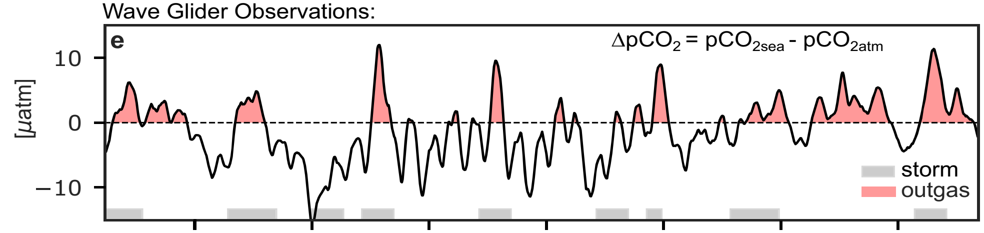


20 km

With Rocklands MR



Wave Glider Observations:



CO2 flux

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More tomorrow on heat fluxes by Marcel du Plessis

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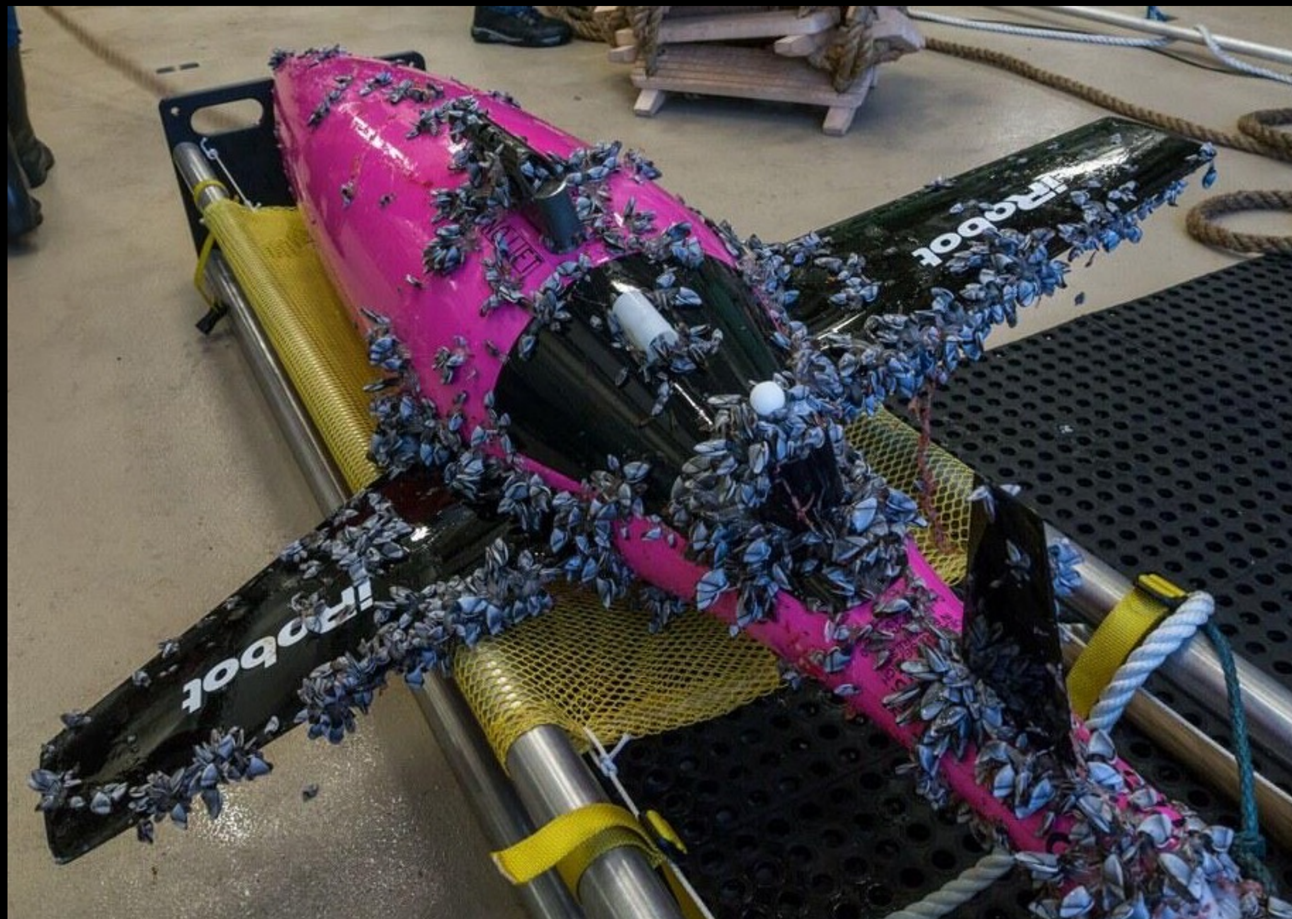
Many thanks for listening!

Polar gliders



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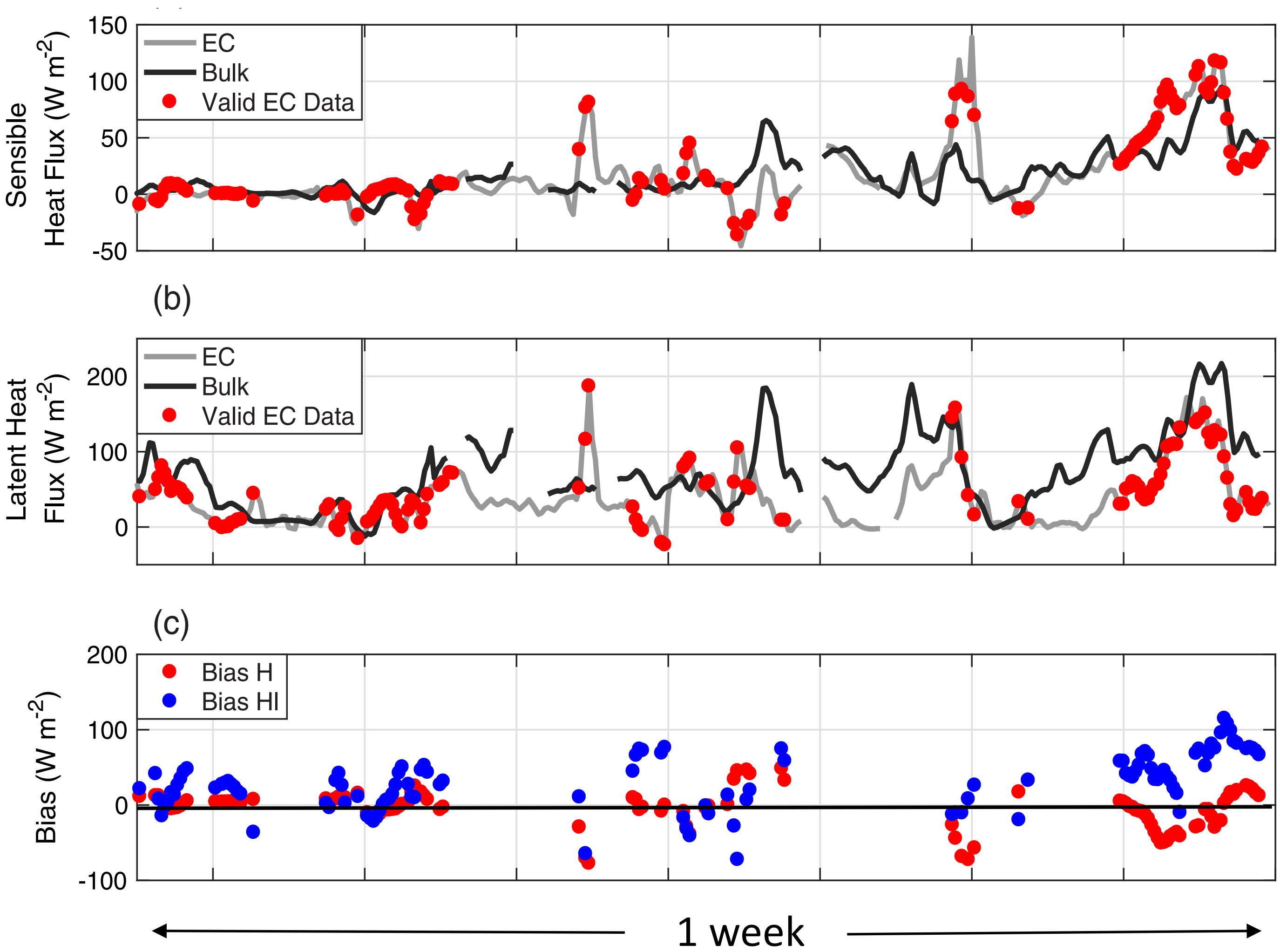
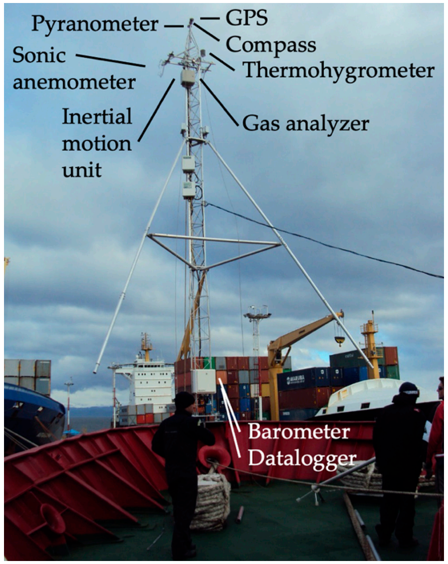
Ocean – atmosphere coupling at the fine scale



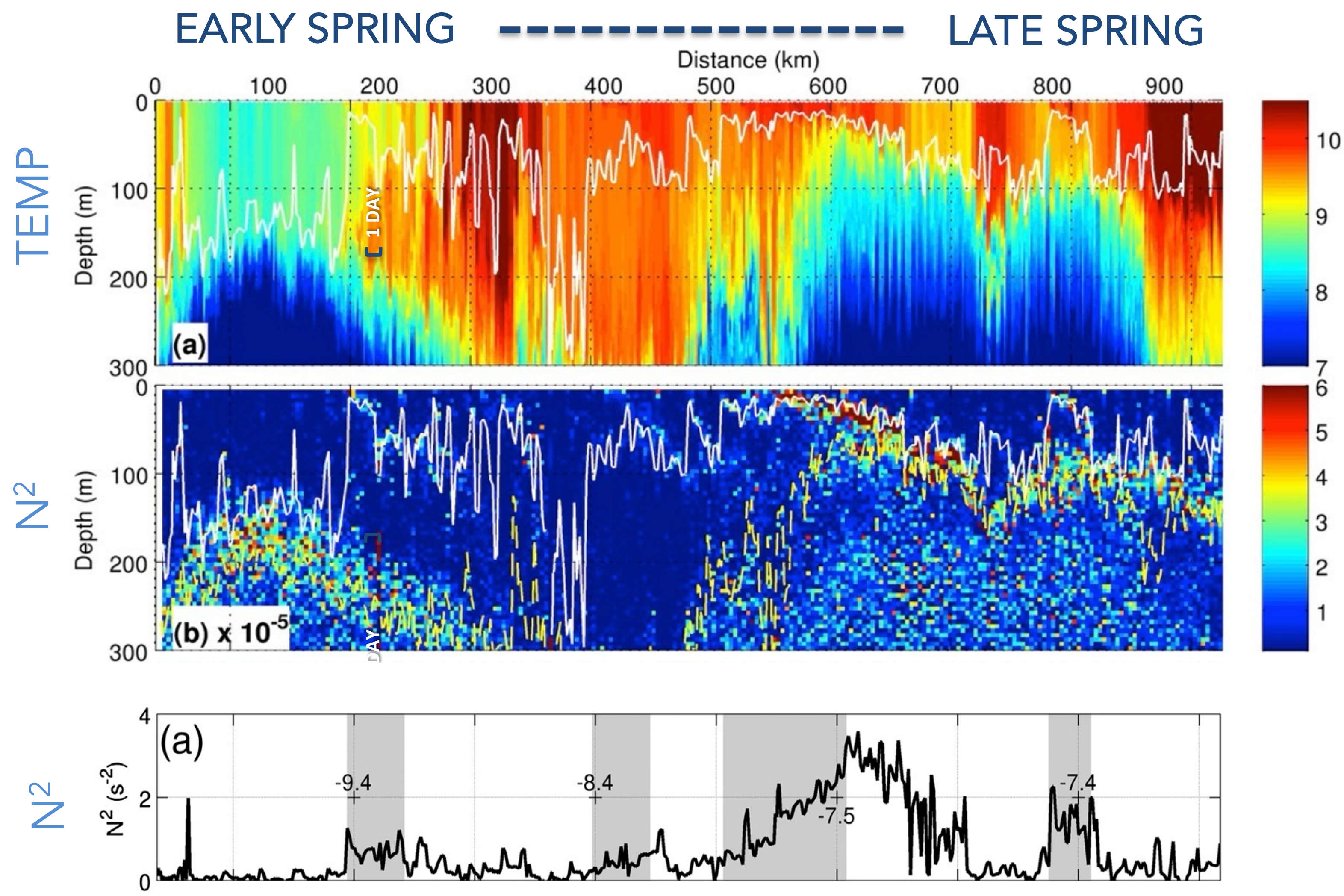


Brazilian icebreaker
Almirante - EC tower

Santini et al., 2020
De Souza et al., 2021

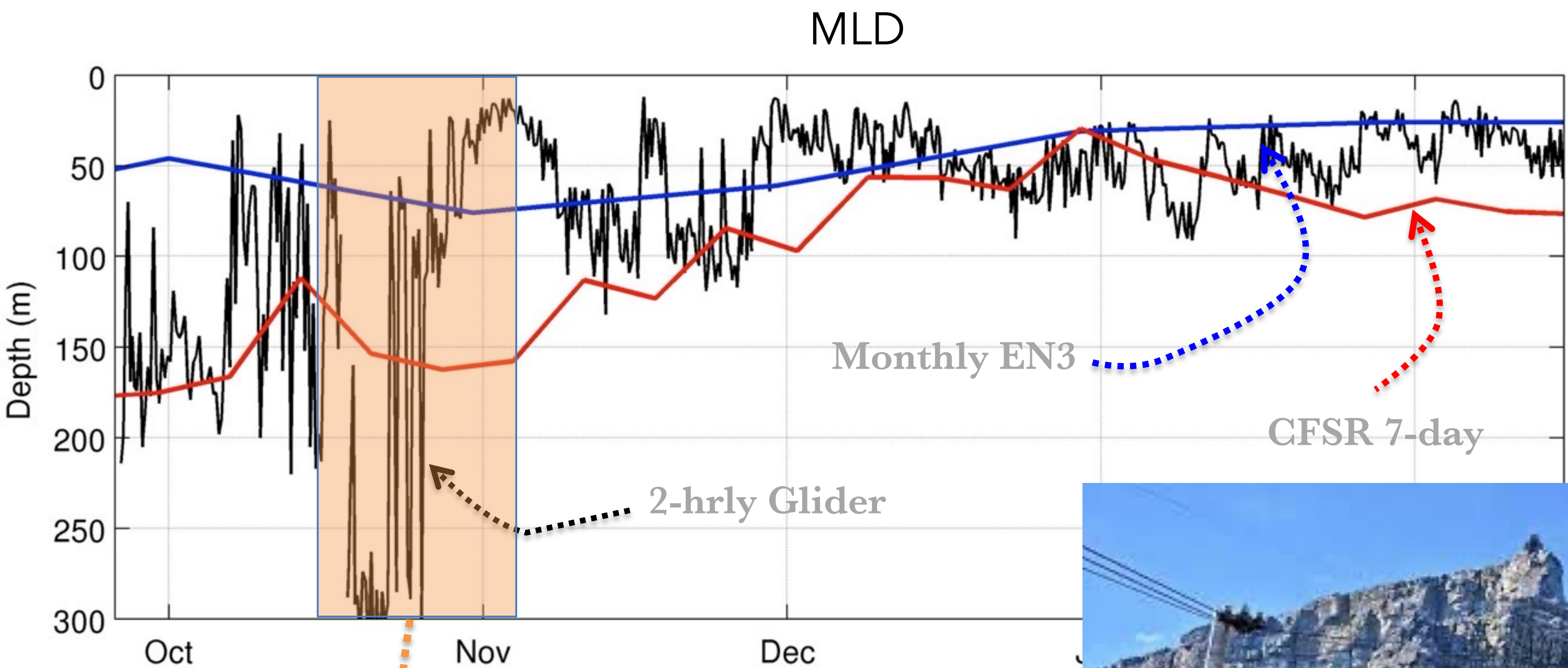

High resolution, multi-month (seasonal scale) observations are needed to understand the full system and its variability (incl. long term trends)
… in many systems we need this observed at multi-spheres, simultaneously

SOSCEx: >10 year ago already!



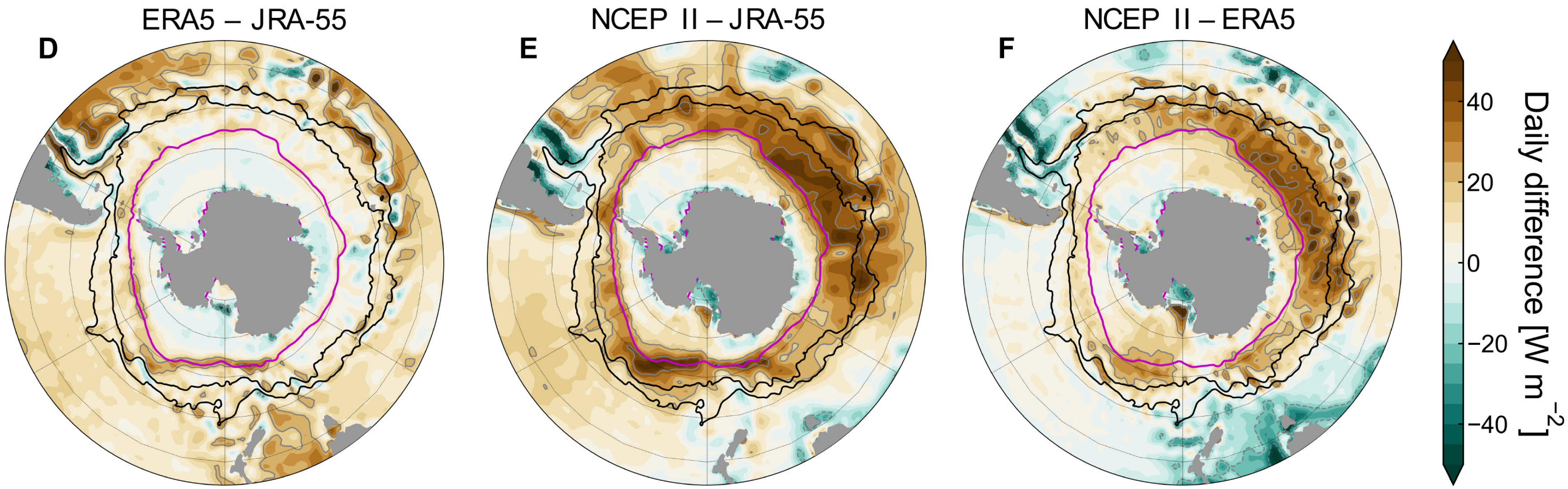
Swart et al., 2015

Spring – Summer MLD progression… a reminder of scales

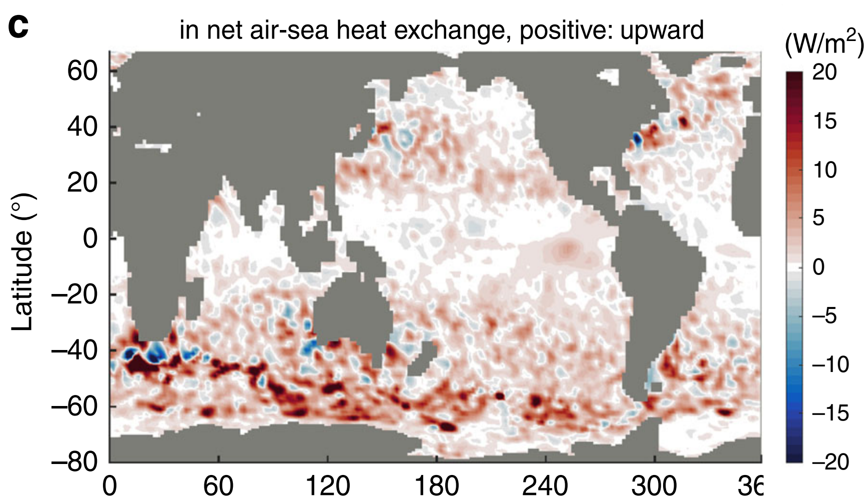


What are we missing?!

Satellite-reanalysis Q flux uncertainty



Swart et al. 2019



24^{th} to 48^{th} deg model Q difference

Su et al., 2018

But resolving at 10-50 km

Challenges

- Upper ocean and atm are very variable – but process studies are spotty!
  - Challenge: to get a better fine-scale view over circumpolar extent and the atm-ocean coupling… to know its impacts on fluxes and ventilation + <u>dissipation</u> (with models!)
- Autumn - winter - spring gaps and transitions
  - Challenge: field access and endurance to get a better fine-scale view of the temporal and regional atm-ocean coupled system to know its impacts on fluxes and ventilation
- The MIZ and under sea ice: very poorly observed/known
  - Challenge: Technological + field access and coverage