

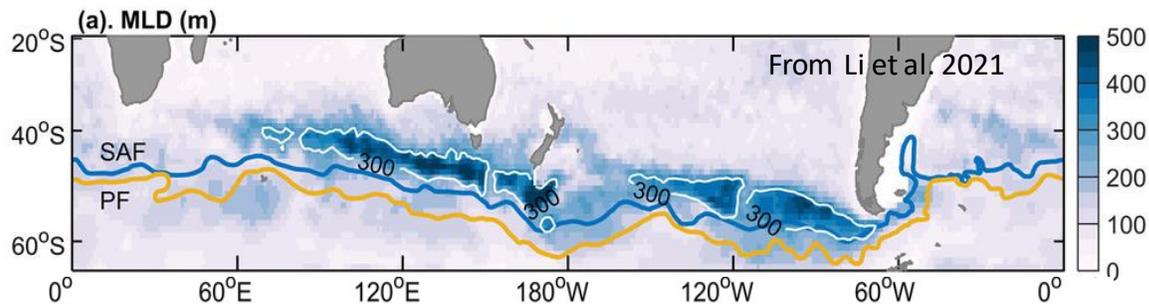
Lagrangian pathways for heat, nutrients and carbon subduction with sub-Antarctic Mode Waters

Bieito Fernández Castro*, Alberto C. Naveira Garabato, Ric Williams, Matthew Mazloff

*b.fernandez-castro@soton.ac.uk

@BieitoFC

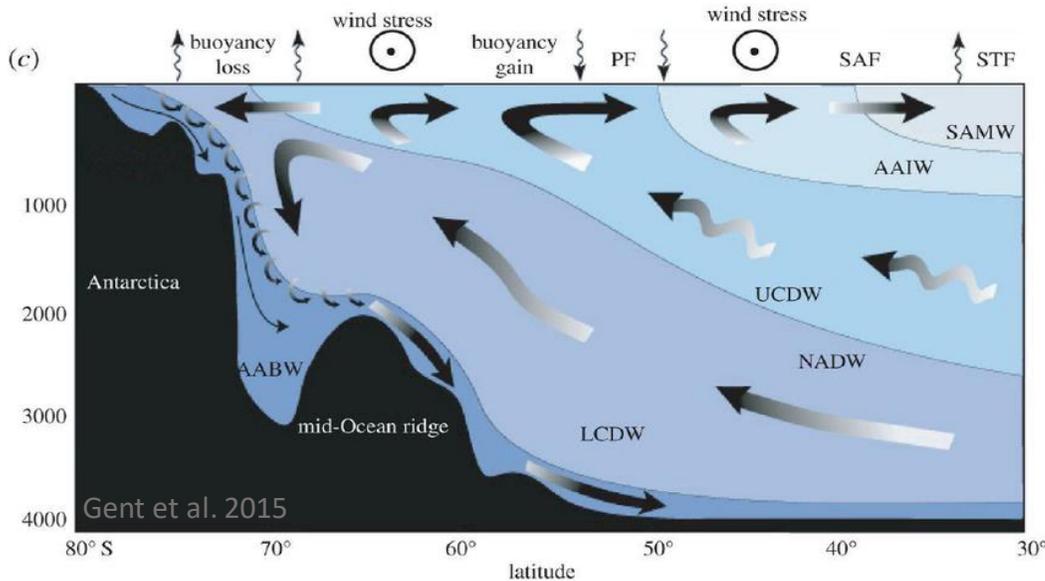
7th Argo Science Workshop
Brussels, 11-13 October 2022



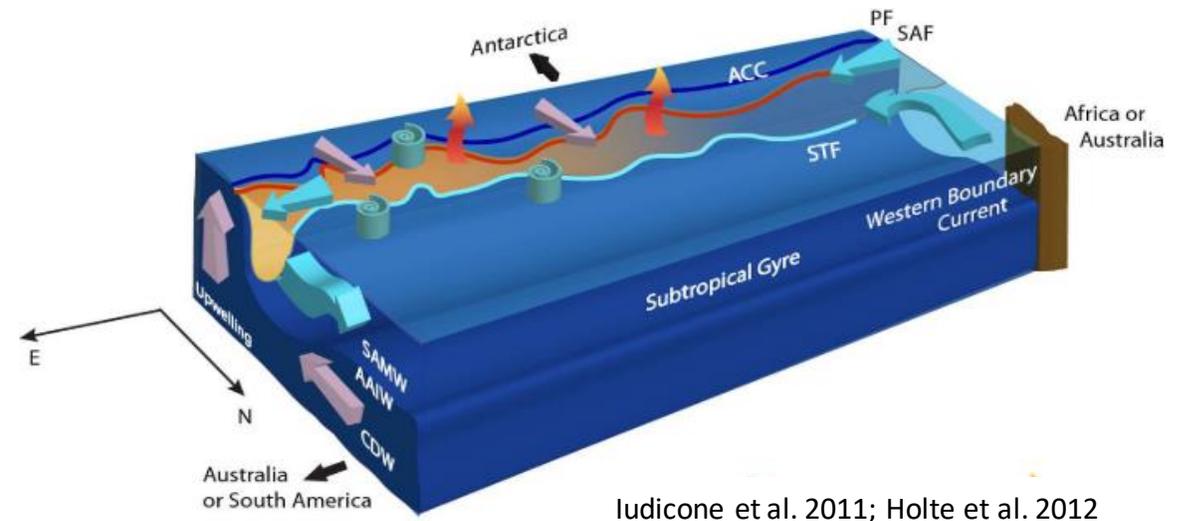
Motivation

SAMW form in deep mixed layers to the North of the ACC, contribute to the **Southern Ocean overturning circulation**, sequester vast amounts of anthropogenic **heat** and **carbon** and return **nutrients** from the Southern Ocean to low latitudes. The processes by which SAMW acquire their physical and biogeochemical properties are key for these roles, but there are **contrasting views on SAMW sources and formation**:

a) SAMW from lightening of Antarctic Waters



b) SAMW from densification of subtropical waters



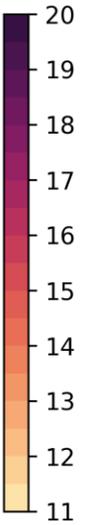
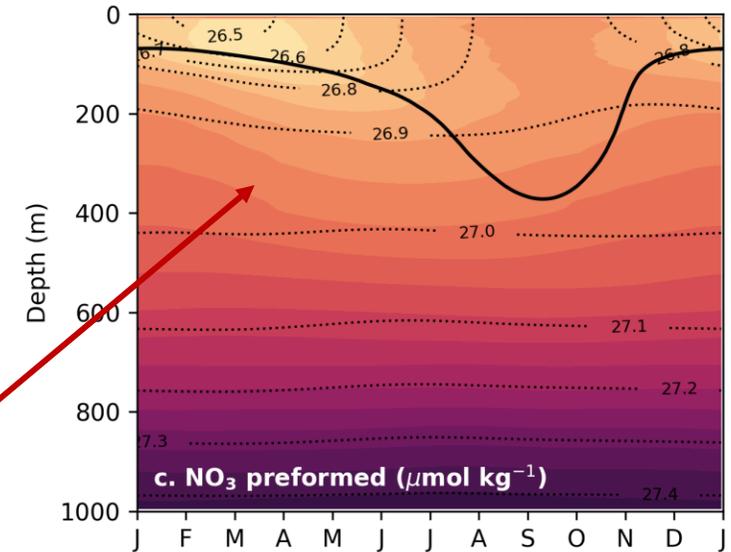
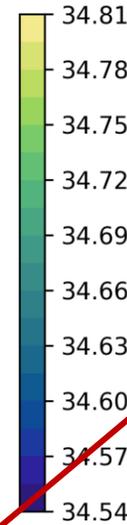
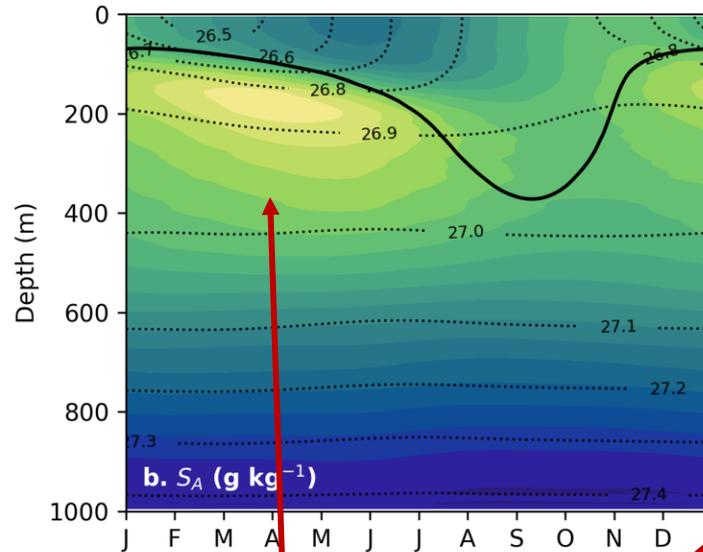
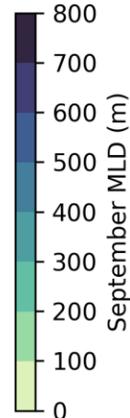
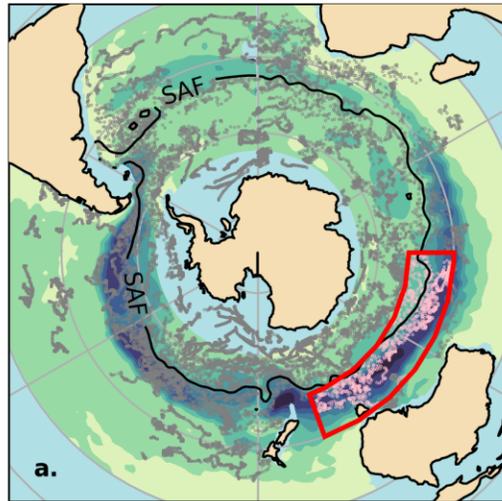
Iudicone et al. 2011; Holte et al. 2012

What is the role of subtropical source waters in SAMW formation?

Insights from Argo observations (see Fernández Castro et al. GRL, 2022)



East Indian SAMW



- **BGC Argo floats** reveal a marked seasonal cycle in salinity and nutrients in the seasonal thermocline of SAMW formation regions
- The summer **increase in salinity** and **decrease in nutrients** is due to the **advection of subtropical waters** along the ACC
- Subtropical sources increase salinity and decrease nutrient concentration in SAMW

Emerging questions

- 1 - What proportion of the SAMW source waters come from subtropical vs. Antarctic origins?
- 2 - Are subtropical pathways connected to the western boundary currents? In which time scale?

- 3 - What processes influence water-mass physical and biogeochemical properties along their pathways?
- (4 - Are these pathways and processes different across formation regions?)

Approach: A Lagrangian investigation

Backward particle tracking experiment in BSOSE
(Biogeochemical Southern Ocean State Estimate)

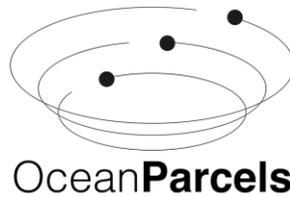
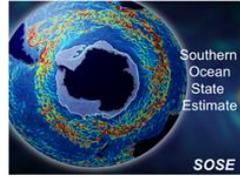
BSOSE: mitGCM+BLING, 1/6°

Jan 2013 – Dec 2019, 5-daily output

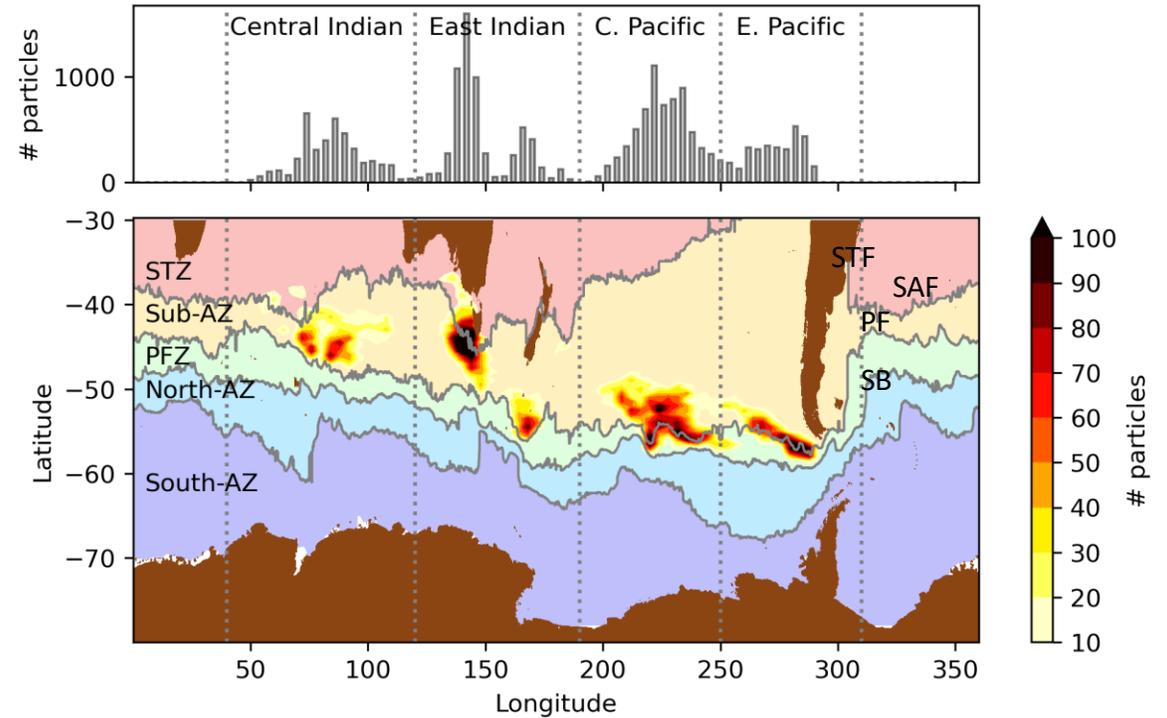
20k particles released randomly in deep mixed layers (>300 m) between 2013 and 2019

Particles tracked with OceanParcels for **7 years**
(model output looped twice)

Physical and biogeochemical properties and fluxes recorded along pathways

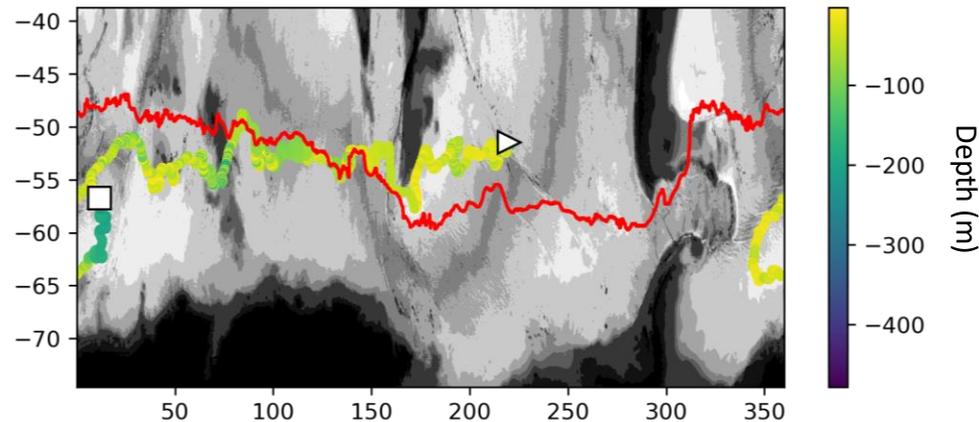


Particle release positions

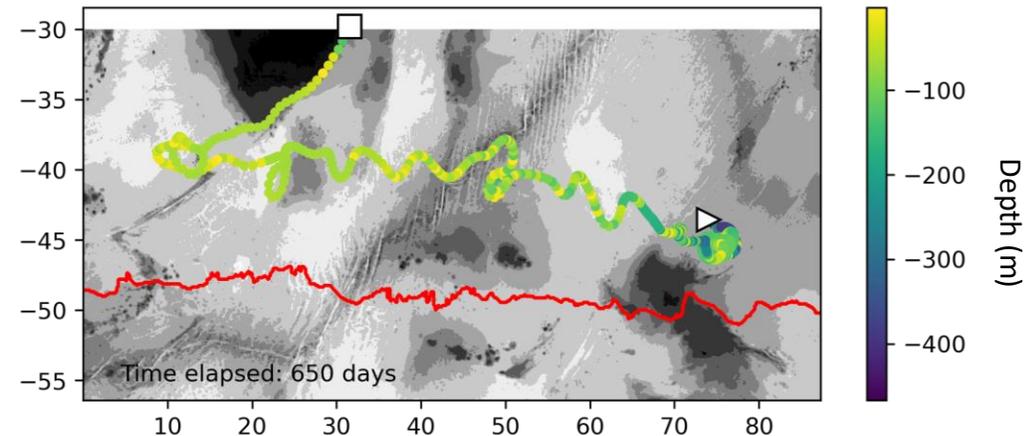


Example pathways

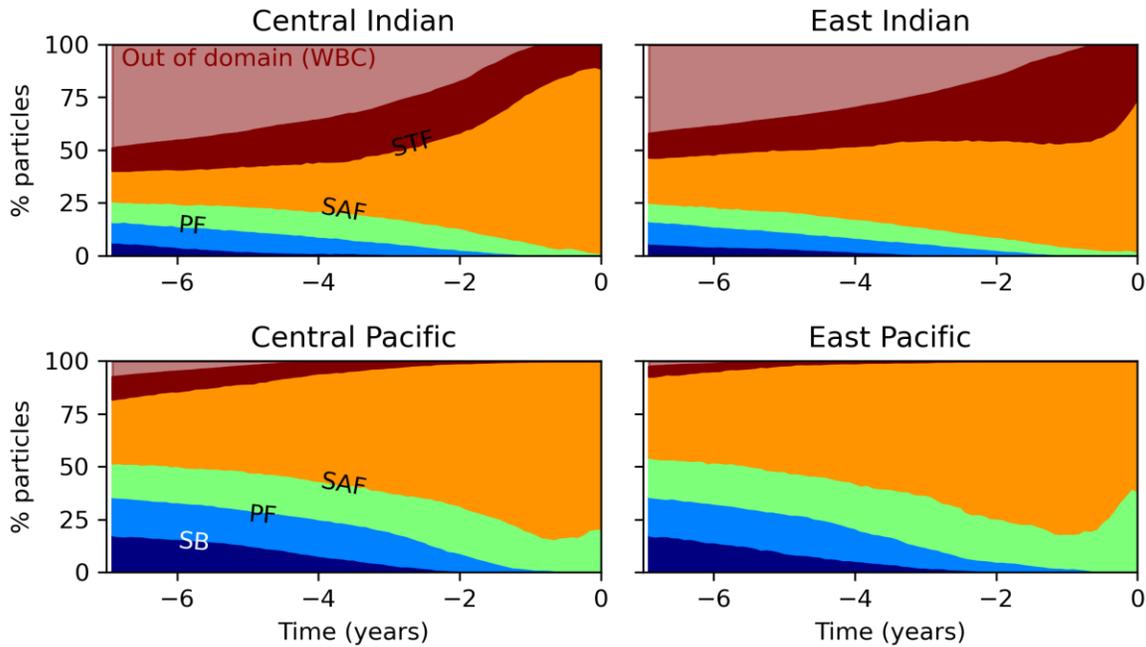
a) Antarctic (southern) pathway



b) Subtropical pathway (Agulhas western boundary current)

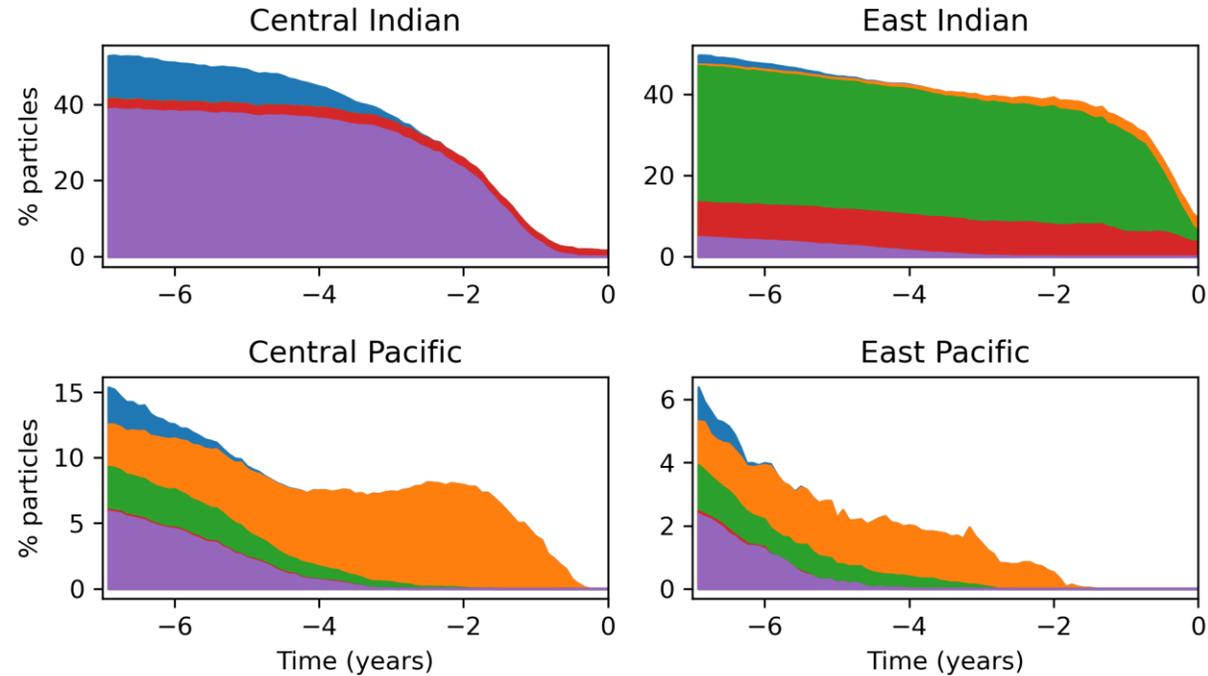


What proportion of the SAMW source waters come from subtropical vs. Antarctic origins?



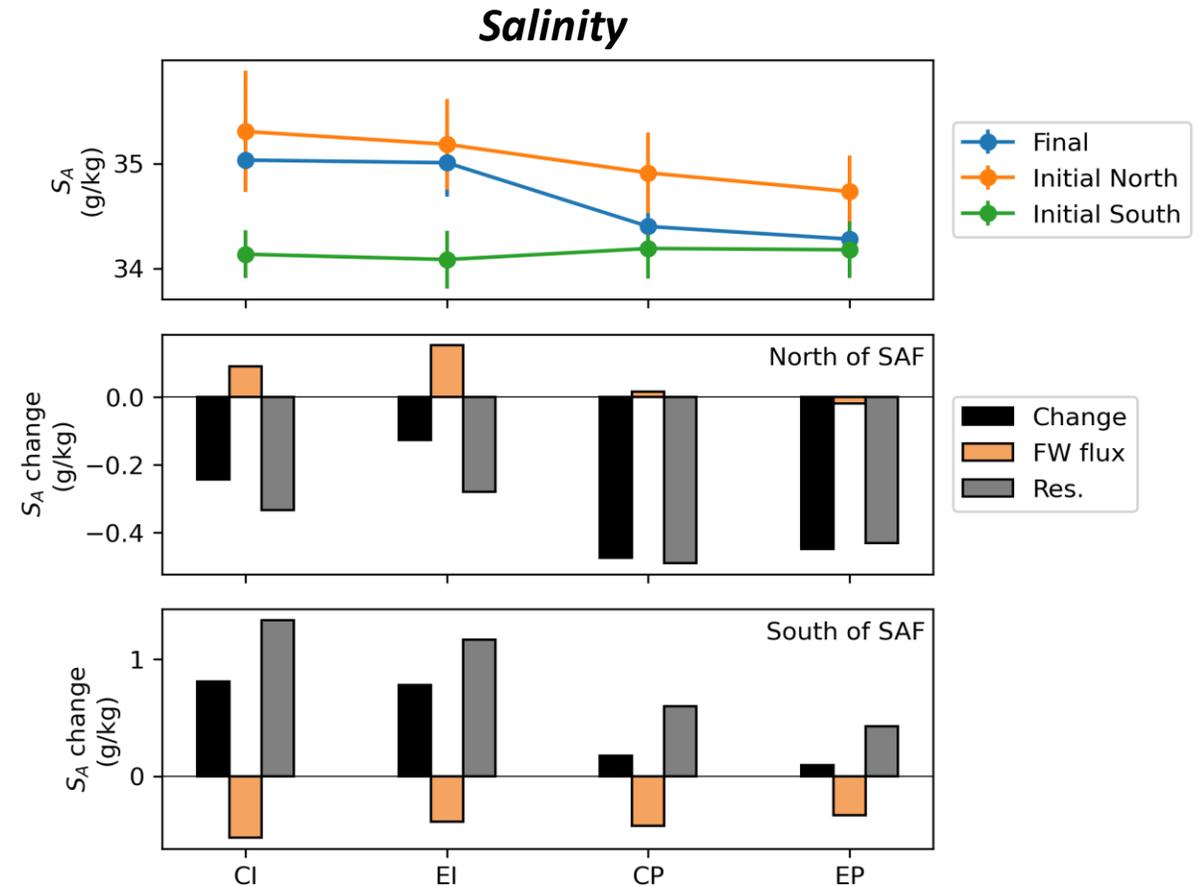
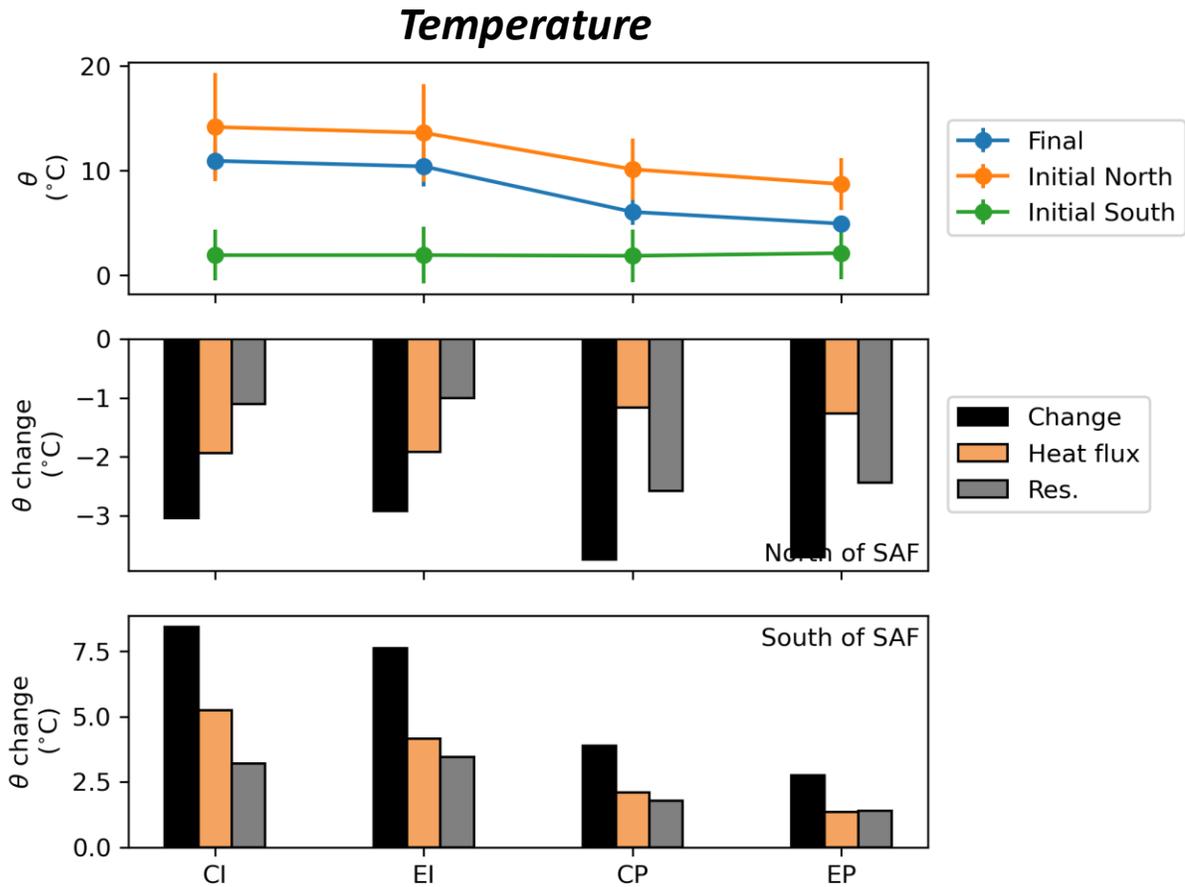
Subtropical sources make up to 50% of SAMW sources in the Indian Ocean and less so in the Pacific, with higher Antarctic contribution (~40%)

Are subtropical pathways connected to the western boundary currents? In which time scale?



~50% of Indian SAMW source waters are connected with the WBC's within a 2-3 years, smaller contribution (<15%) in the Pacific, with longer time-scales

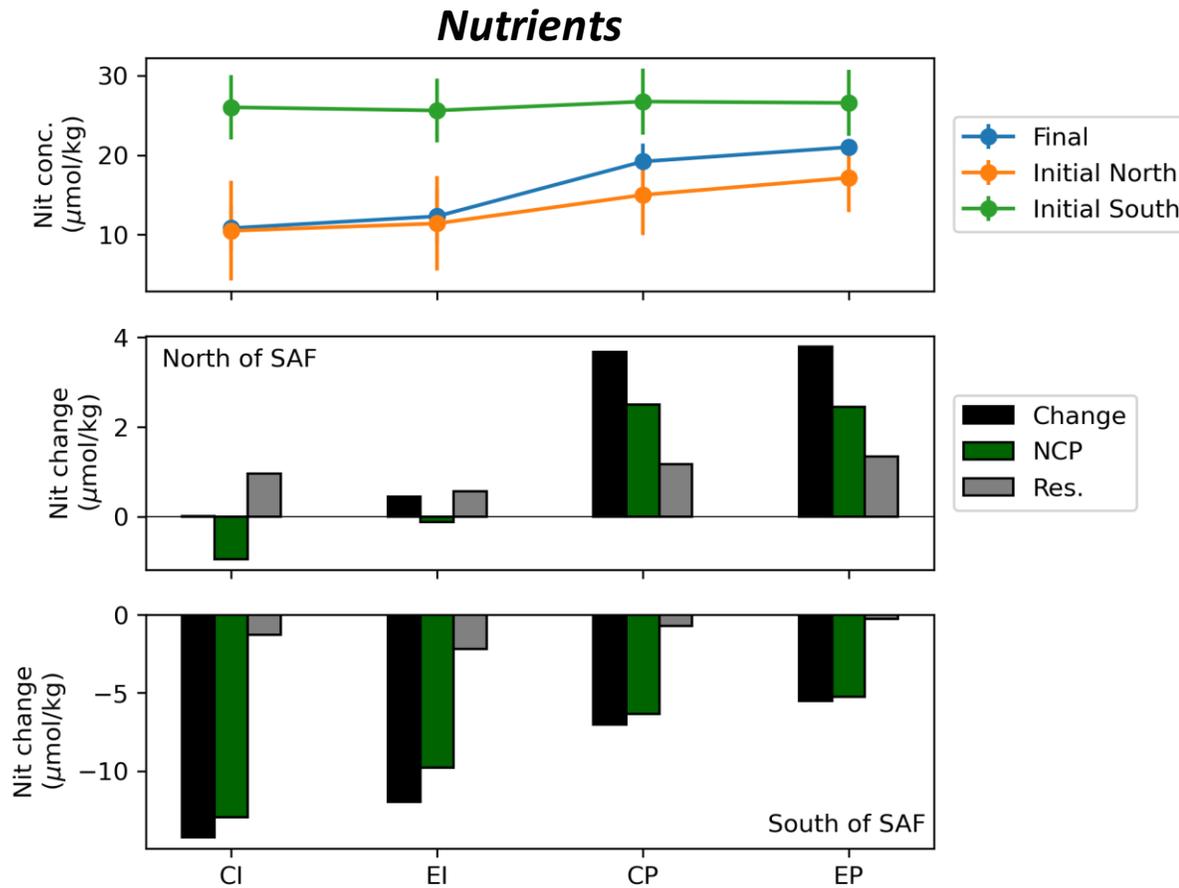
What processes influence water-mass *physical* properties along their pathways?



Subtropical (**north**) waters are cooled and subpolar (**south**) waters are warmed to become SAMW
 Air-sea fluxes and ocean mixing (Res.) contribute similarly to temperature changes.

Subtropical (**north**) waters are freshened and subpolar (**south**) waters get saltier to become SAMW
 The transformation is driven by (unresolved) mixing processes, opposing surface fluxes

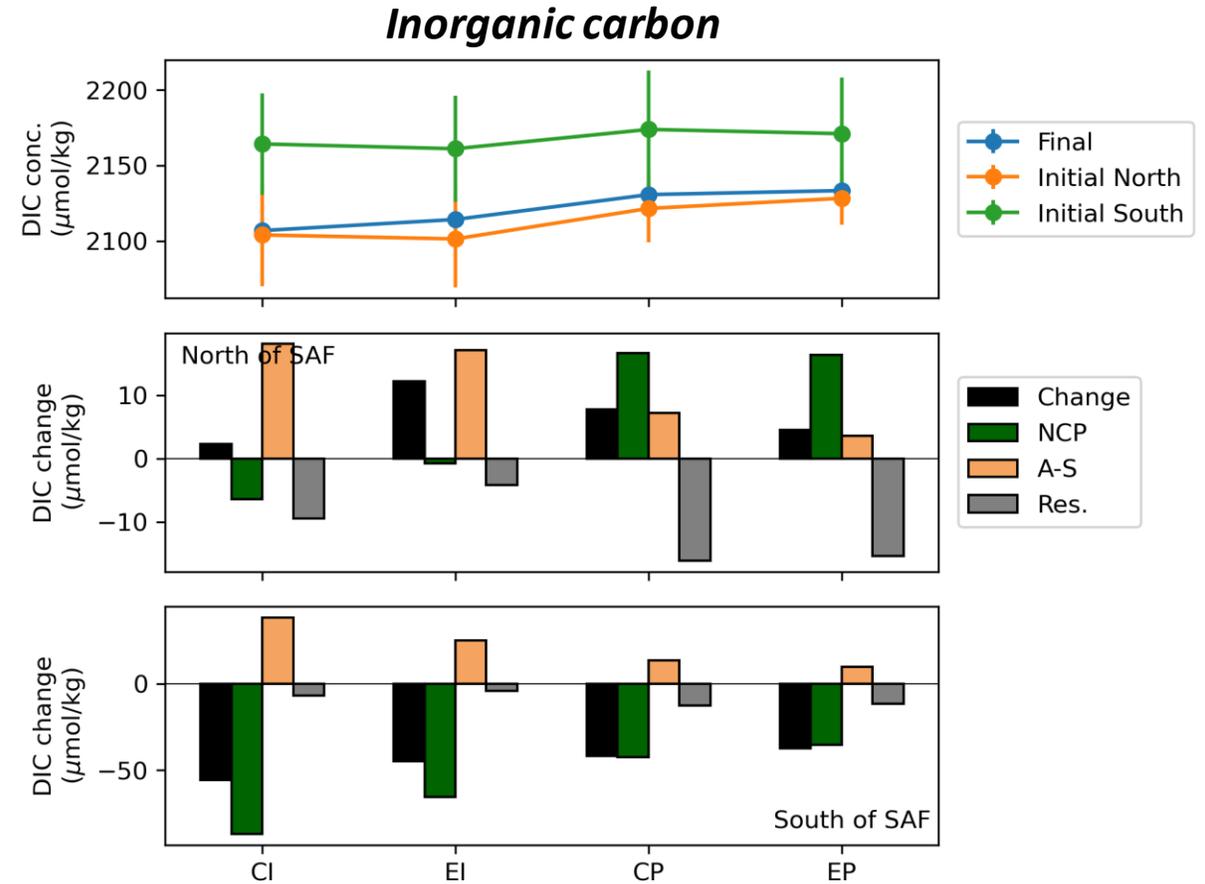
What processes influence water-mass biogeochemical properties along their pathways?



Net community production increases nutrient concentrations in subtropical waters (due to remineralisation) and increases it in Antarctic waters

Smaller contributions from mixing: **biology dominates**

SAMW nutrients in Indian Ocean very close to subtropical source



Net community production strongly depletes Antarctic waters from their carbon, despite **CO₂ uptake from the atmosphere** (which is actually driven by biology)

Weaker transformations in subtropical waters (carbon content close to SAMW)

Conclusions

- Subtropical sources make up to 50% of SAMW sources in the Indian Ocean and less so in the Pacific, with higher Antarctic contribution from south of the Polar Front (>30%)
- ~50% of Indian SAMW source waters are connected with the WBC's within a 2-3 years, weaker and slower connections in the Pacific
- SAMW biogeochemical properties strongly resemble northern source waters, more so in the Indian Ocean
- Changes in different properties driven by different processes:
 - Temperature changes driven by heat fluxes (+ mixing)
 - Mixing (+freshwater fluxes) dominates salinity changes
 - The biological pump plays a key role in nutrient and carbon changes for Antarctic waters to become SAMW

But, keep in mind: source waters are highly diverse in their origins, pathways and properties

