



www.csiro.au

Southern Ocean mixed-layer response to atmospheric variability

Jean-Baptiste Sallée

K. Speer, S. Rintoul

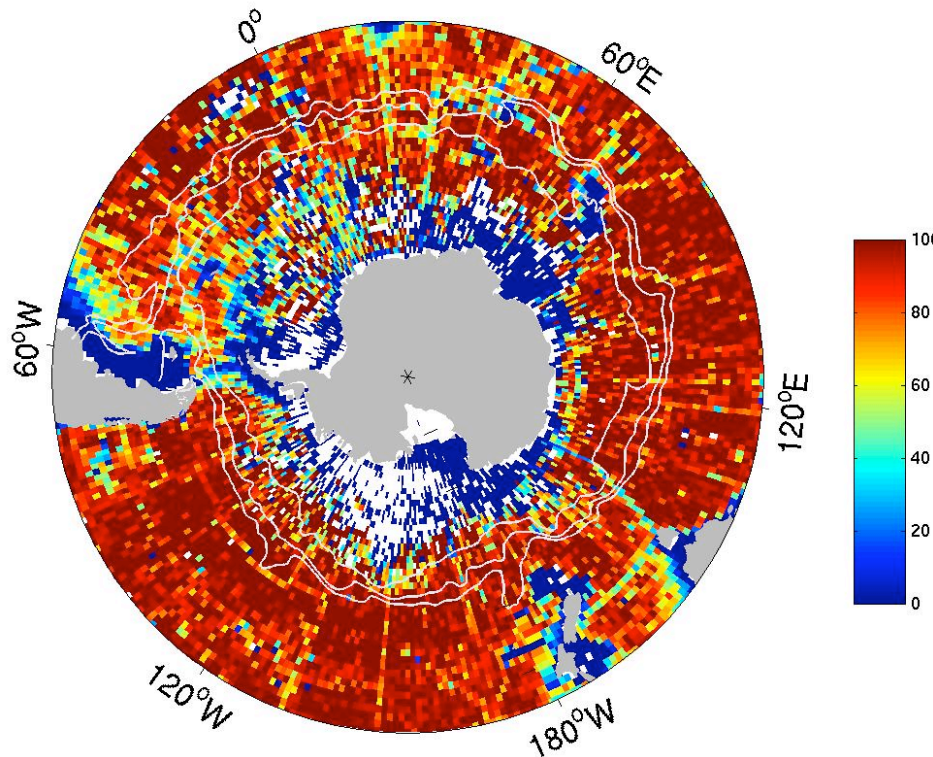
National Research
FLAGSHIPS
Wealth from Oceans



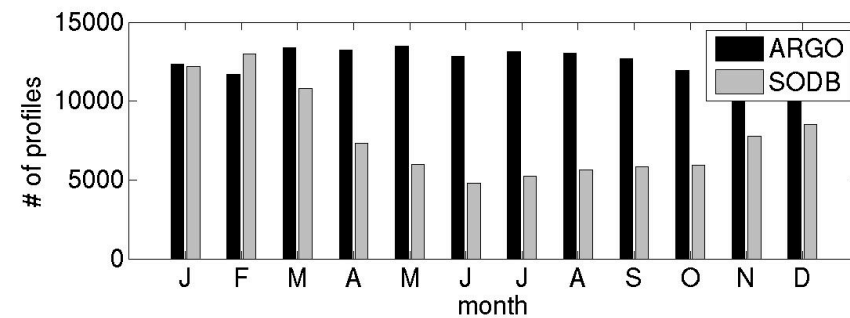
Argo

For the first time ever
Argo => seasonal cycle + good coverage

Argo compare to a classical ship-based database (SODB)



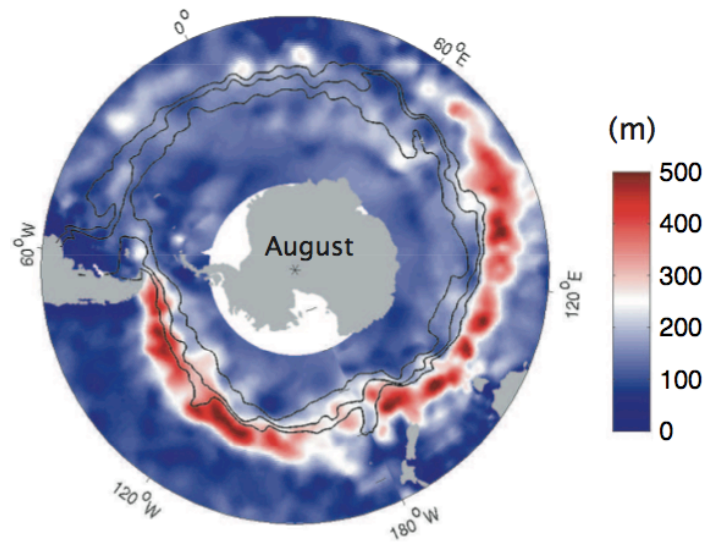
Percentage of Argo profiles in 1°bins
Red=100% Argo



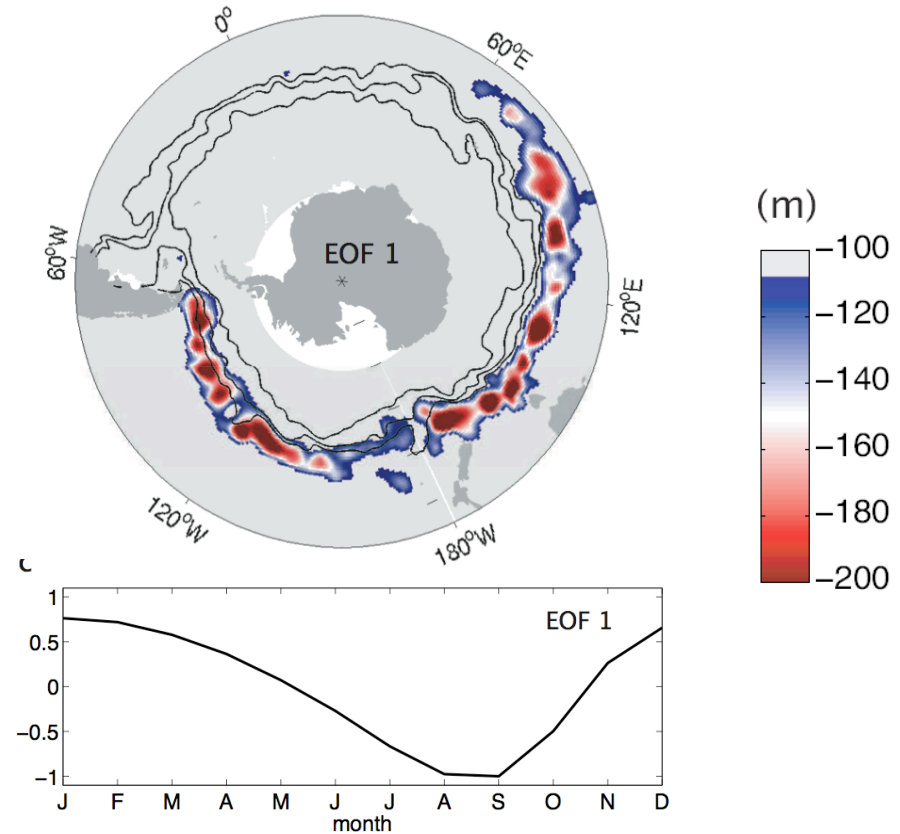
Mixed-layer depth

For the first time ever
Argo => seasonal cycle + good coverage

1) Winter mean

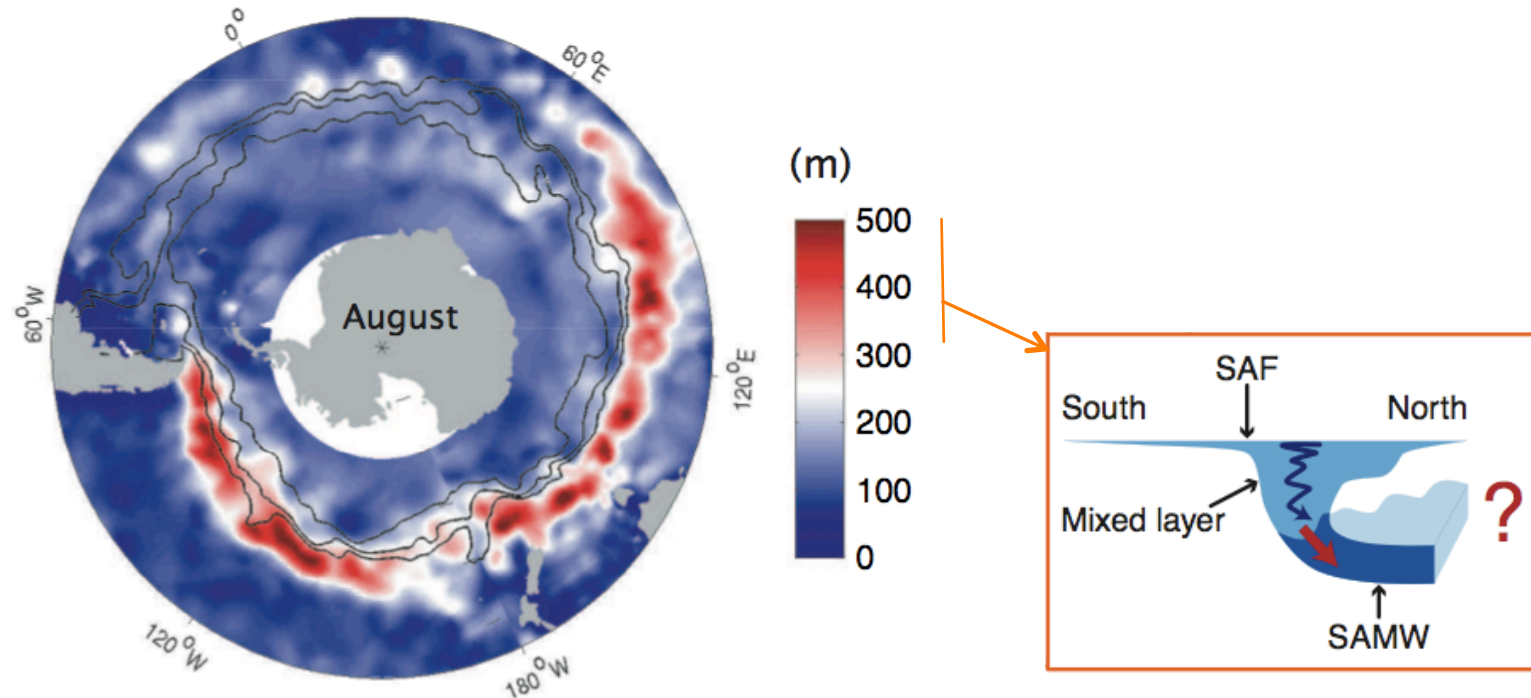


2) Mode 1 (90%): seasonal cycle



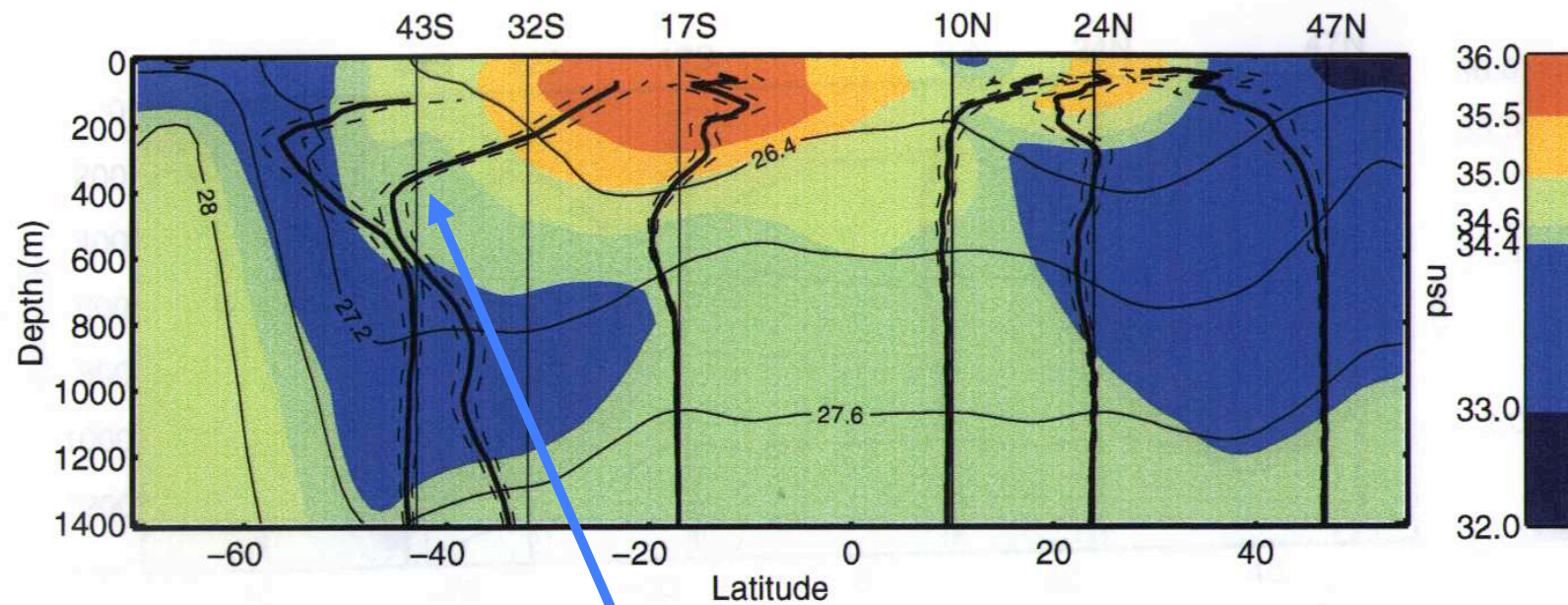
Why Mixed-layer depth ?

i – Associated with formation of mode and intermediate water



Why Mixed-layer depth ?

i – Associated with formation of mode and intermediate water: **relevant to climate !**



Strongest climate signal in the mode and intermediate waters

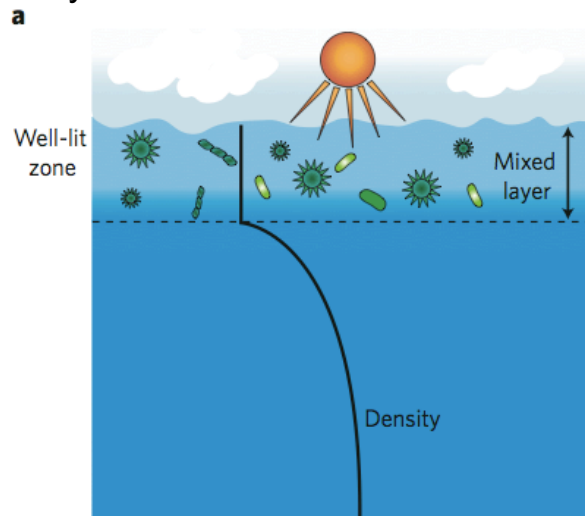
-0.1 psu 0 +0.1 psu

Wong et al., 1999

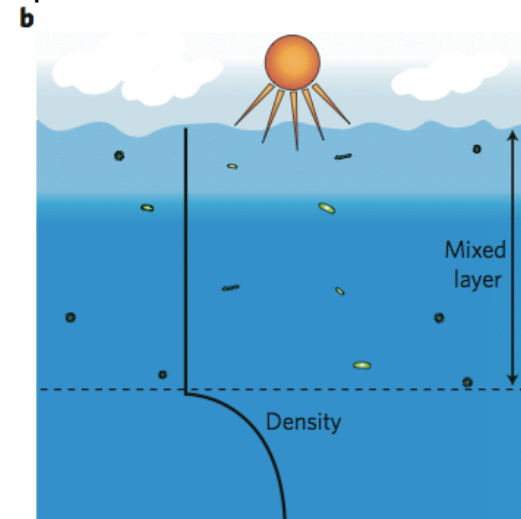
Why Mixed-layer depth ?

- i – Associated with formation of mode and intermediate water
- ii – Important for primary productivity**
- iii – Gas uptake: O₂ and CO₂ (Verdy et al, 2007)**

Shallow mixed-layer: phytoplankton stays in the well-lit zone



Deep mixed-layer: phytoplankton is spread out the well-lit zone



Introduction

Motivations:

- i – Associated with formation of mode and intermediate water
- ii – Important for primary productivity
- iii – Gas uptake: O₂ and CO₂ (Verdy et al, 200

Questions:

- What is the intraseasonal and interannual variability ?
- Does it respond to atmosphere variability ?

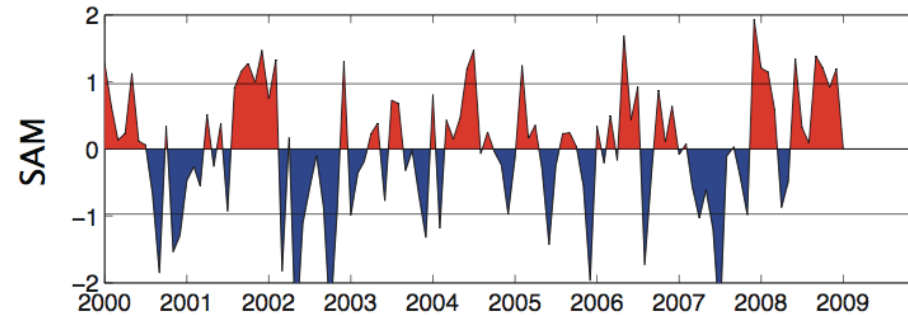
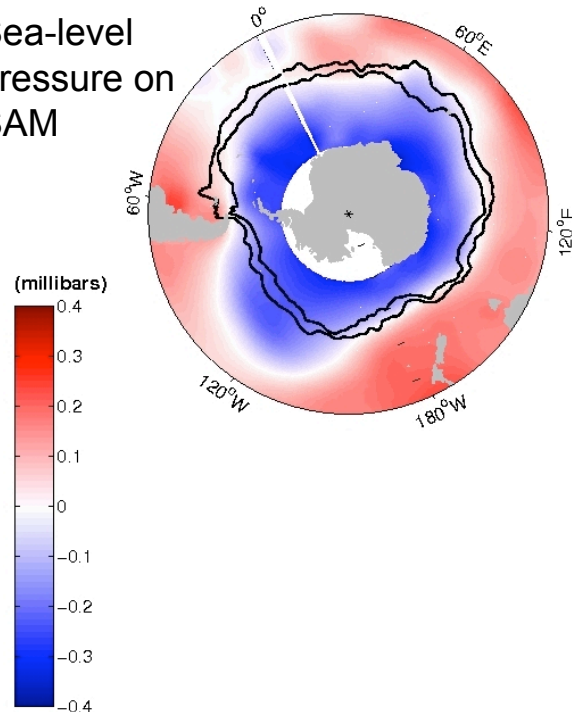
Limitation:

We don't have enough profiles to analyze time series yet

Mixed-layer variability: *atmospheric index*

Two main modes of atmospheric variability in the Southern Ocean: SAM and ENSO

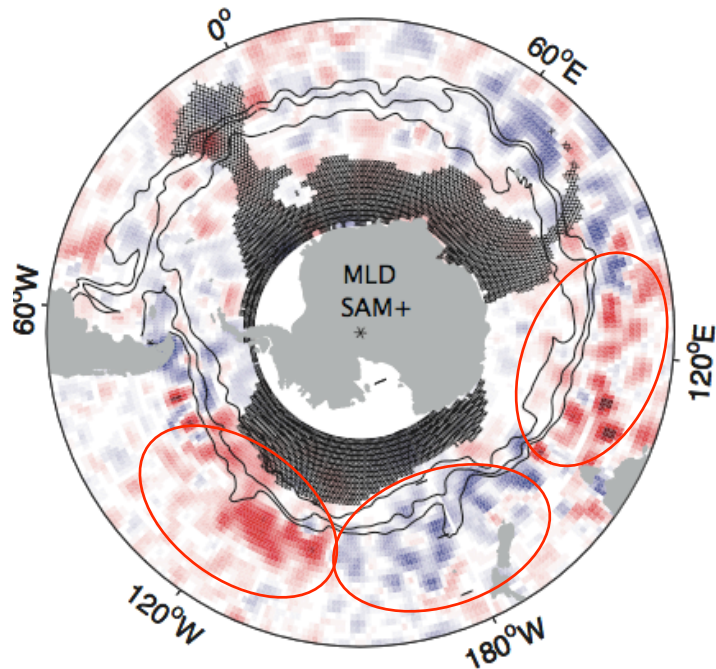
Sea-level pressure on SAM



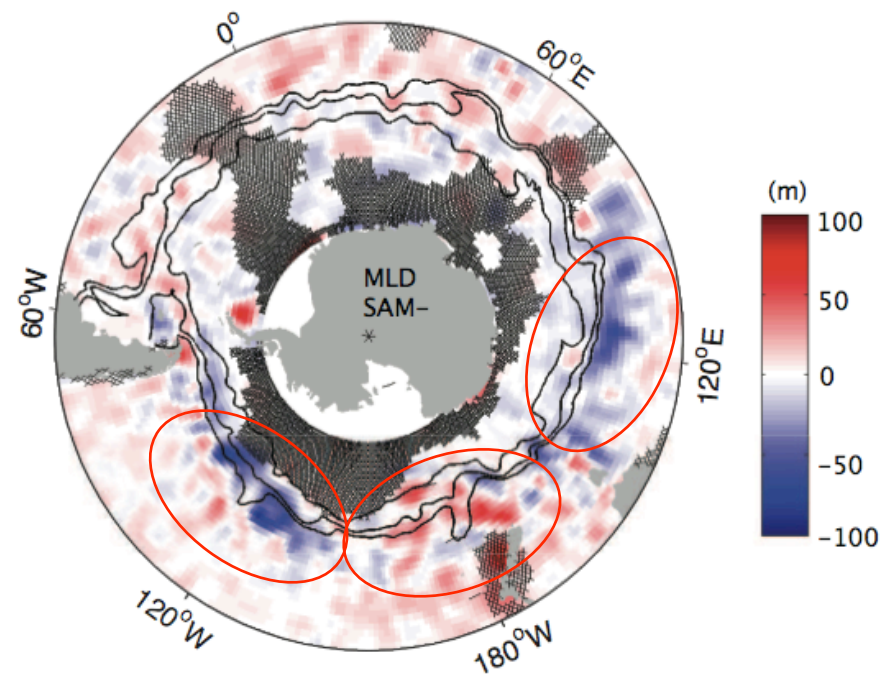
Mixed-layer variability: *response to SAM*

Composite of MLD anomaly (anomaly from seasonal cycle) on

Positive SAM events



Negative SAM events

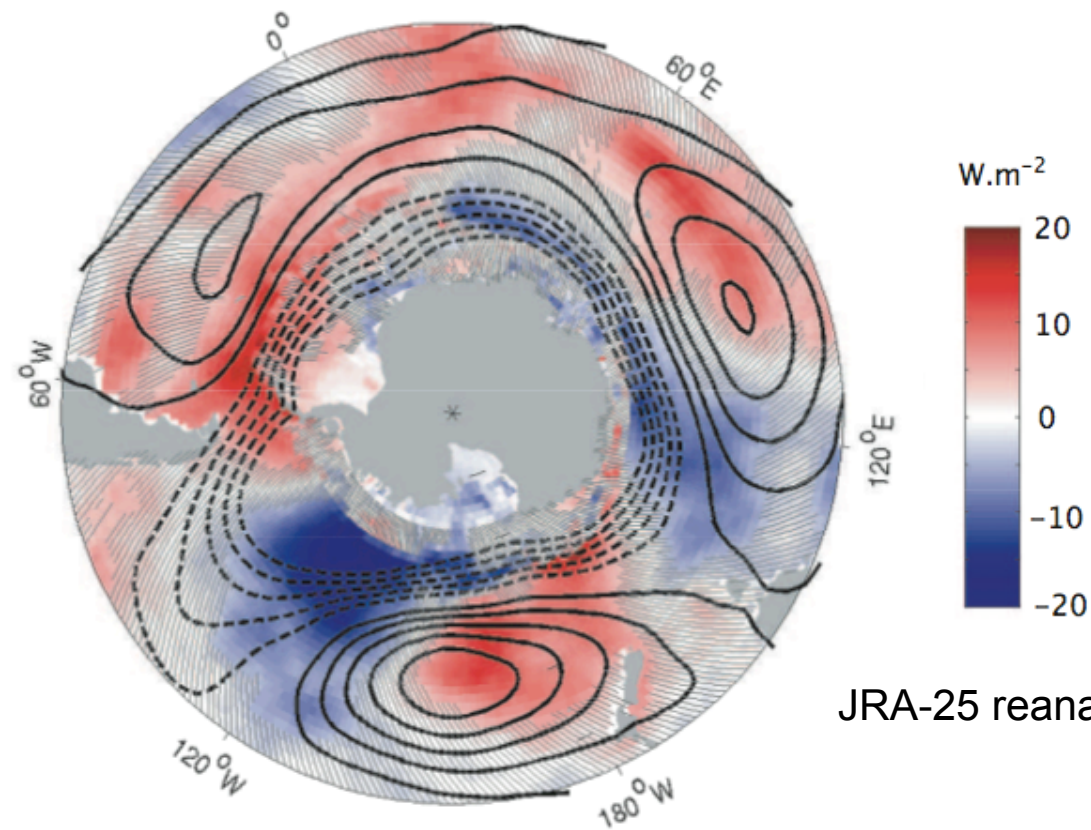


Zonally asymmetric response : counter-intuitive!

Mixed-layer variability: *forcing*

What is going on ?

Regression of heat flux (color) and sea level pressure onto SAM [during the Argo years 2000-2008]



JRA-25 reanalysis

Mixed-layer variability: *forcing*

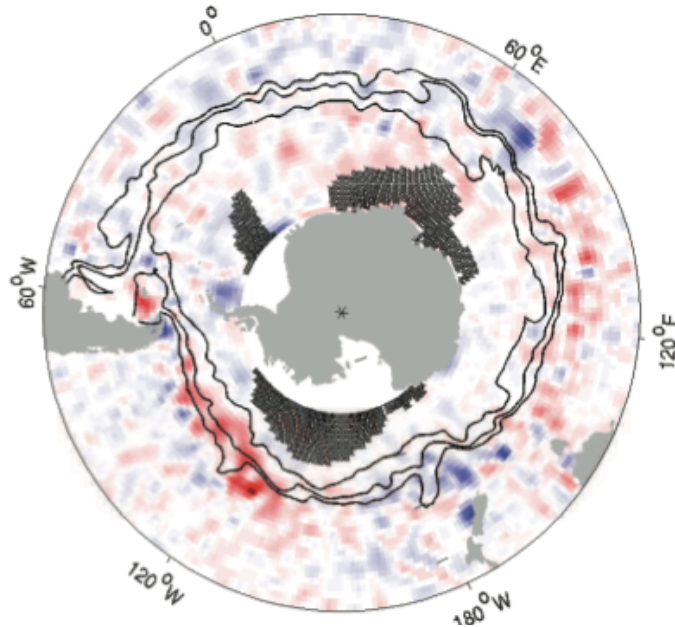
Enough to explained the observed anomaly ?

Simple heat budget based on:

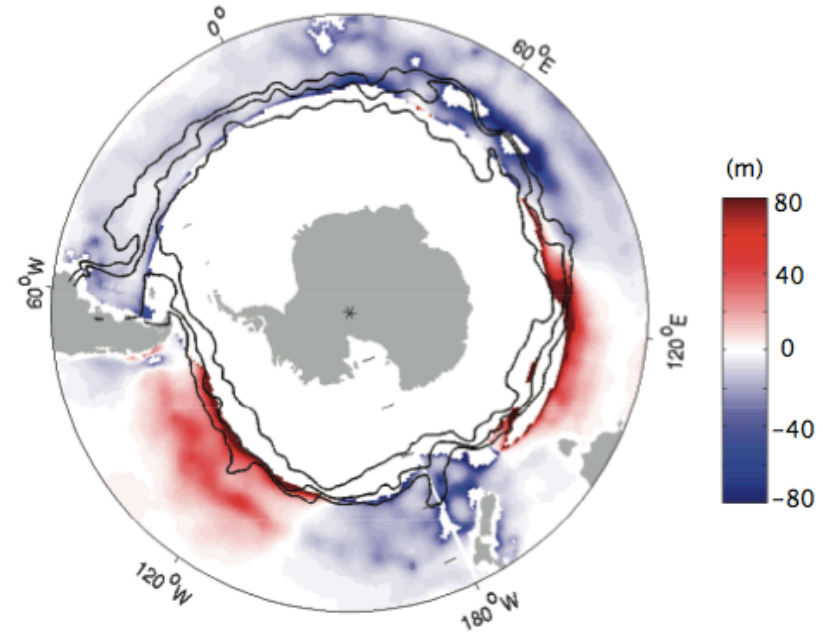
- regressed heat fluxes
- climatological stratification at the base of the mixed layer (Argo)

Wind stirring is negligible for the $O(100\text{ m})$ Southern Ocean mixed layer

Observed anomaly onto SAM



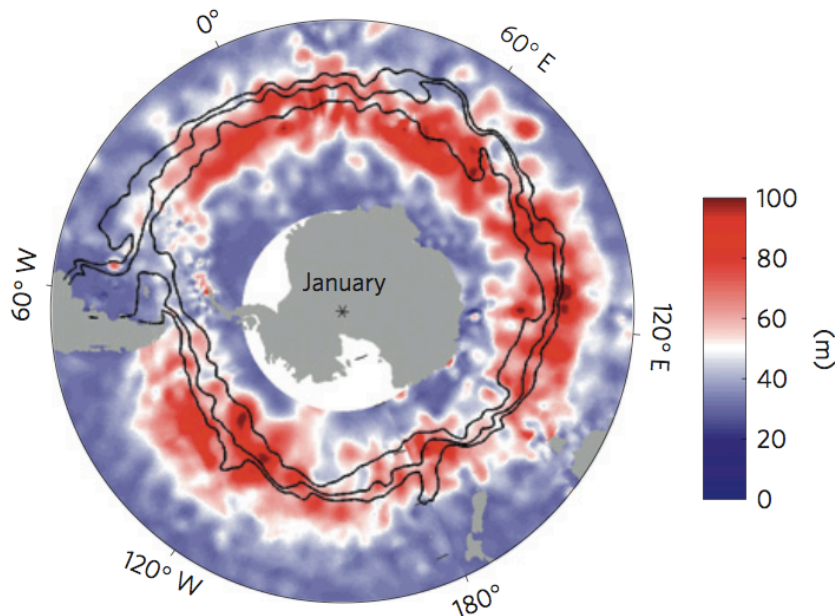
Explained by SAM-induced air-sea flux anomaly



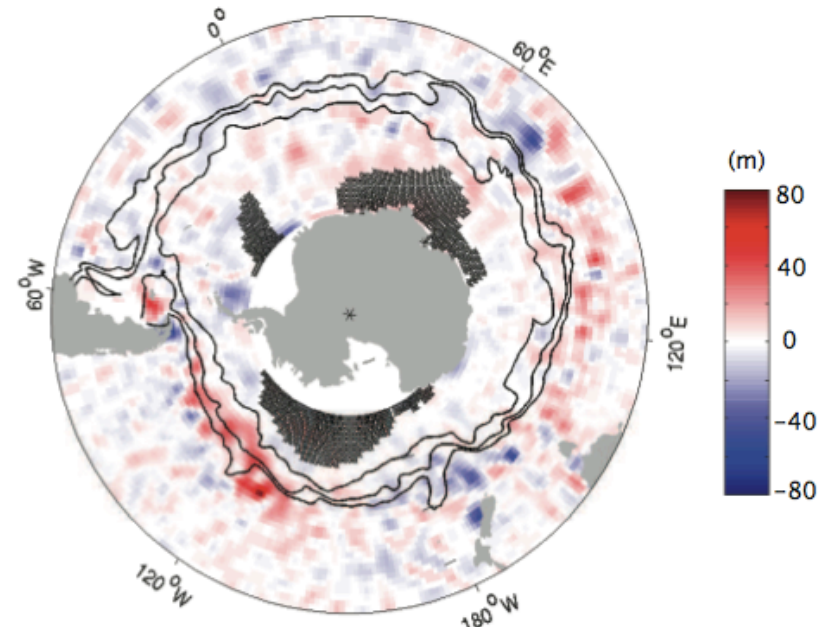
Mixed-layer variability: *forcing*

How these changes would impact on biological activity?

Summer depth average



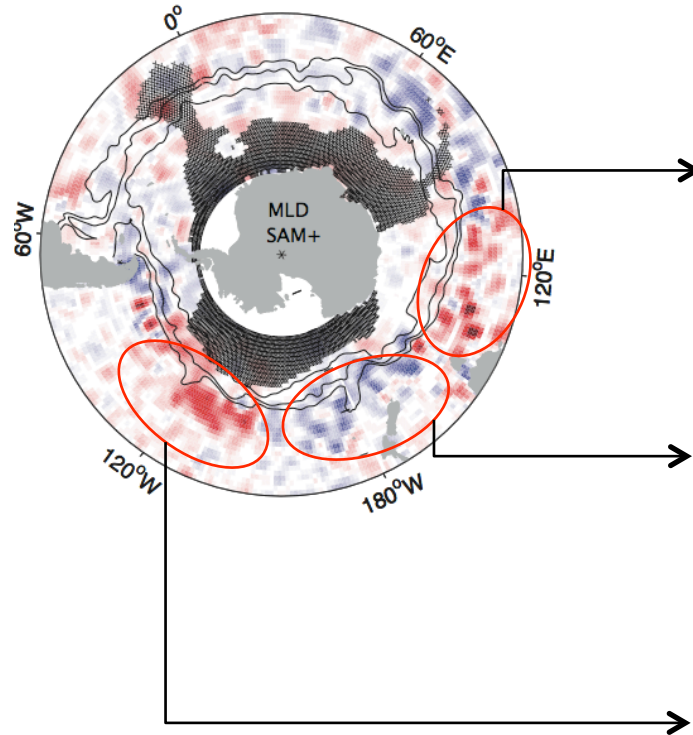
Observed anomaly onto SAM



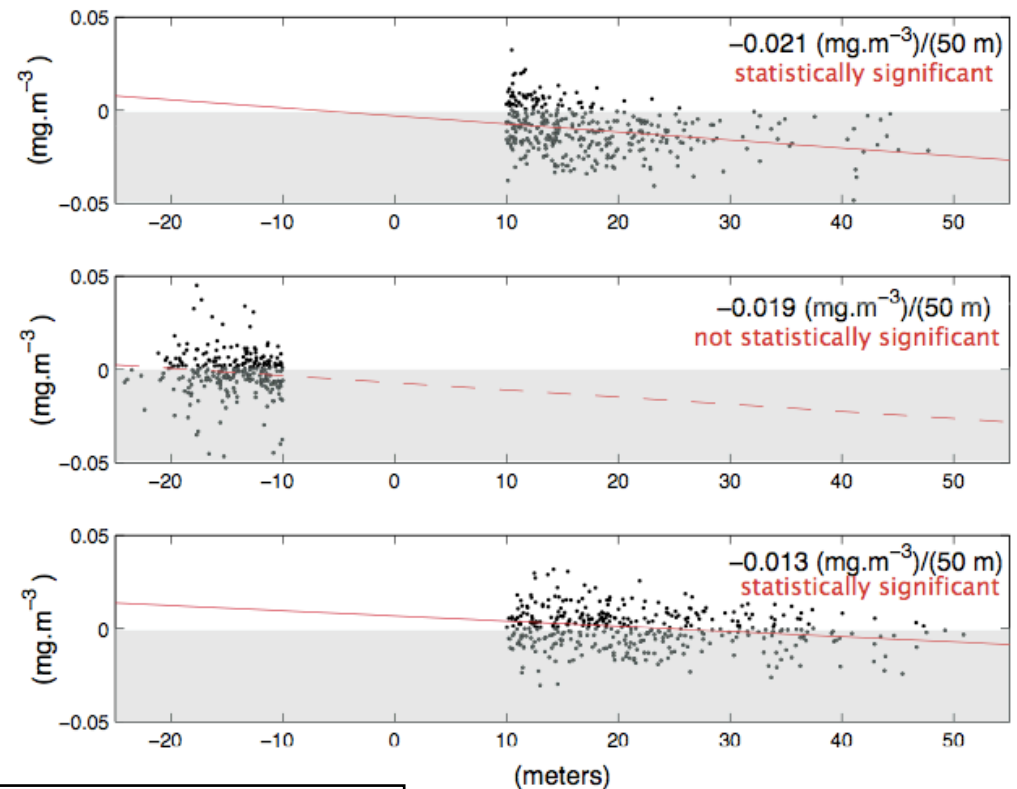
In summer: MLD \approx well-lit layer (~ 100 m)
So deepening would influence phytoplankton activity

Mixed-layer variability: *impact on Chl*

Impact on biological activity



Chl concentration anomaly versus mixed layer anomaly during a SAM event:



Reduction of Chlorophyll activity when mixed layer deepens: consistent with light limitation

Conclusion

1- Argo has revolutionised our view of the Southern Ocean

- Seasonal coverage
- Spatial coverage (middle of gyre)

2- Mixed layer respond to the main mode of Southern Hemisphere atmospheric variability

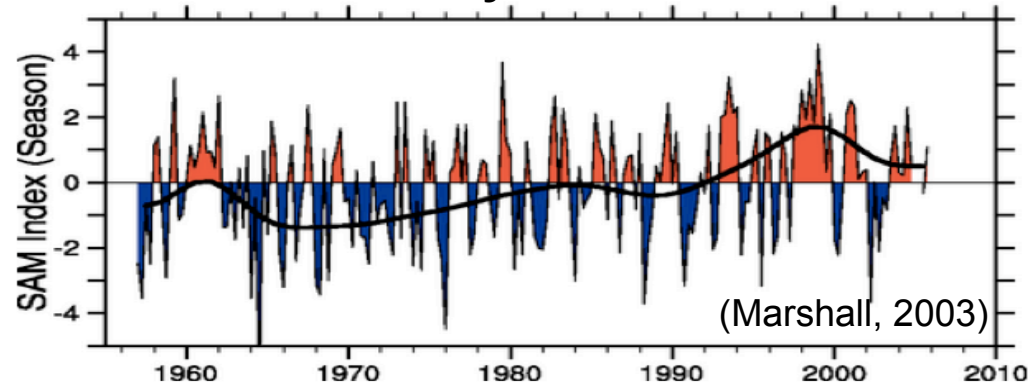
- The response is counter-intuitive (zonally asymmetric)
- The response is well explained by heat flux variability due to small meridional deviation of the mode

3- Biological activity is affected by the mixed-layer depth response ; consistent with light limitation

Ref: Sallée et al. 2010 – Nature Geoscience

Conclusion

- **SAM over the last 50 years: increase of 1-2 unit**



- **So the pattern and intensity of the MLD change expected over the last 50 years:**

- **Increase of SAM expected to continue in the next 100 years**

Ref: Sallée et al. 2010 – Nature Geoscience

