South Atlantic heat balance in a warming climate

Maurício Rocha[1] (he/him)

In collaboration with: Gustavo Marques[2], Frederic Castruccio[2] , Gokhan Danabasoglu[2], Olga Sato[1], Michael Levy[2], Frank Bryan[2],Anna-Lena Deppenmeier[2], Shenfu Dong[3], Cecile Hannay[2], and Keith Lindsay[2]

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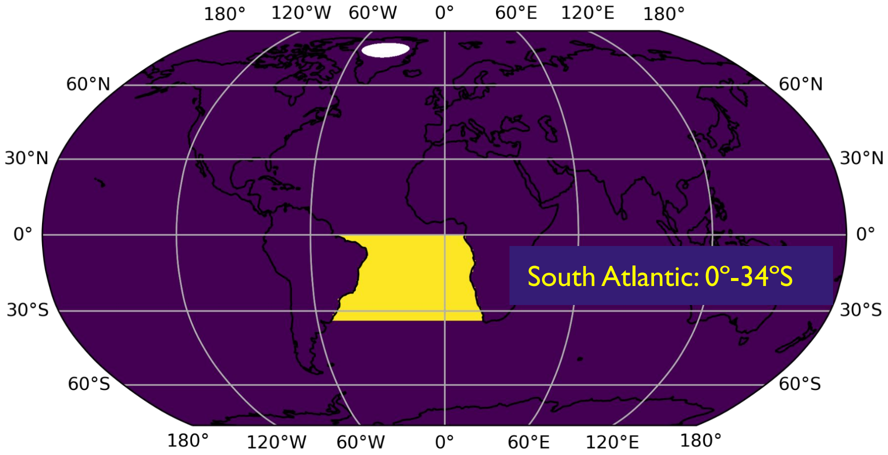
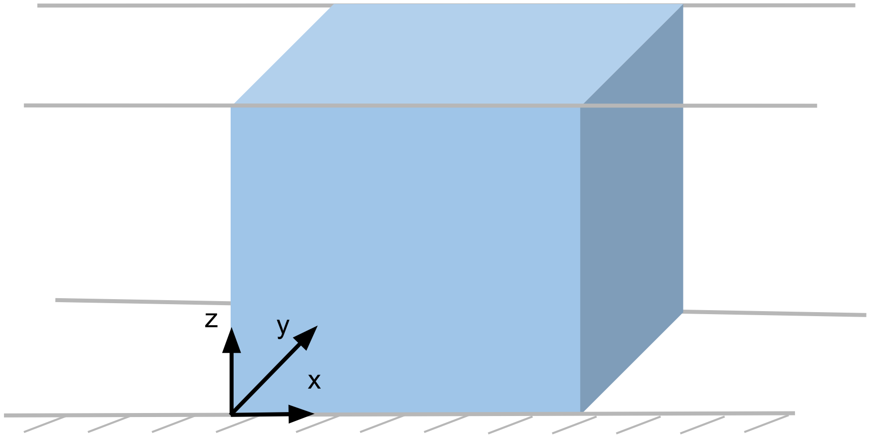
Heat balance

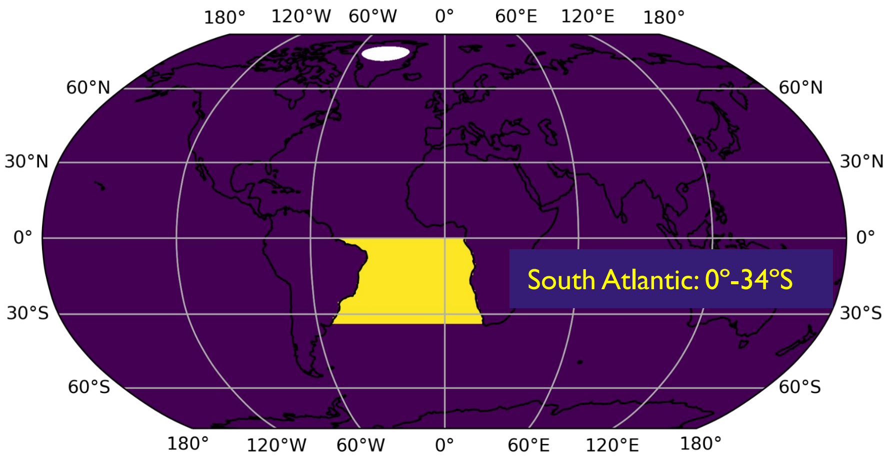


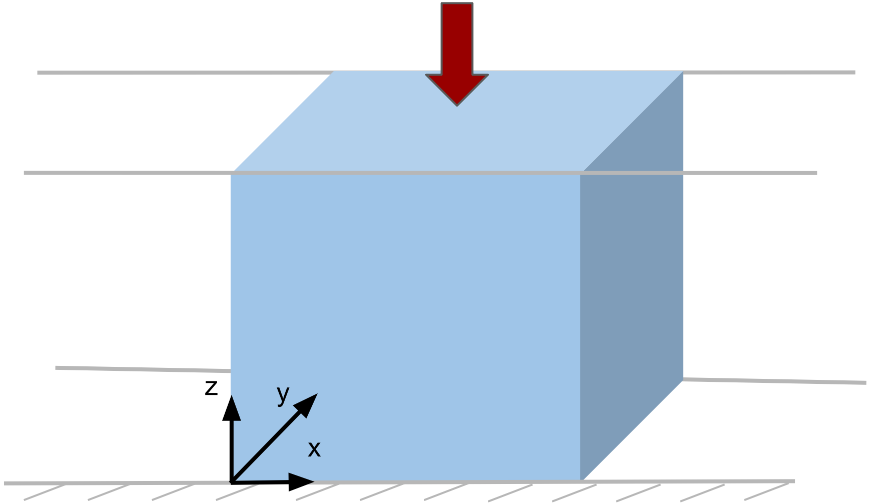


Heat balance

1°- Total surface heat flux (SHF):

- Latent heat flux + sensible heat flux + longwave heat flux + shortwave heat flux.





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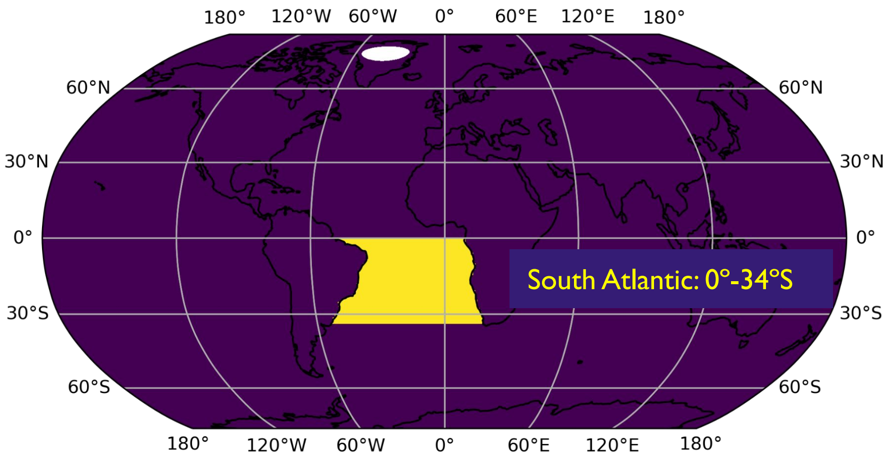
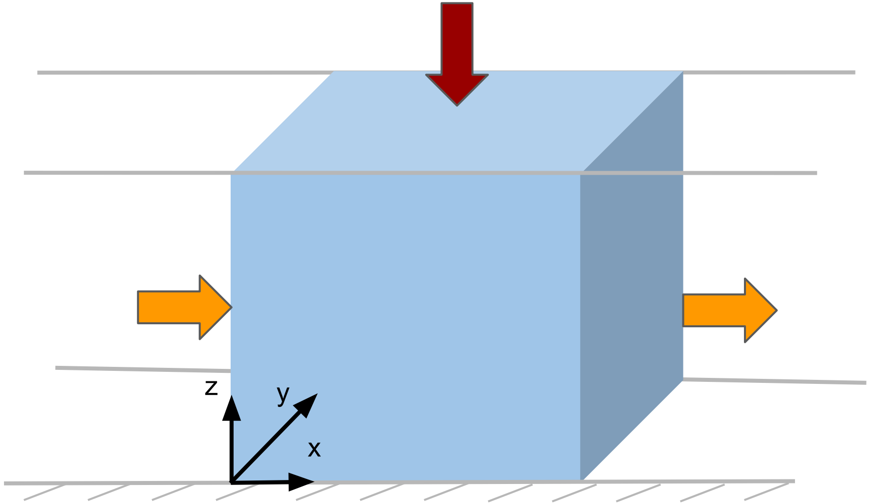
2°- Horizontal heat transport:

- Zonal component.





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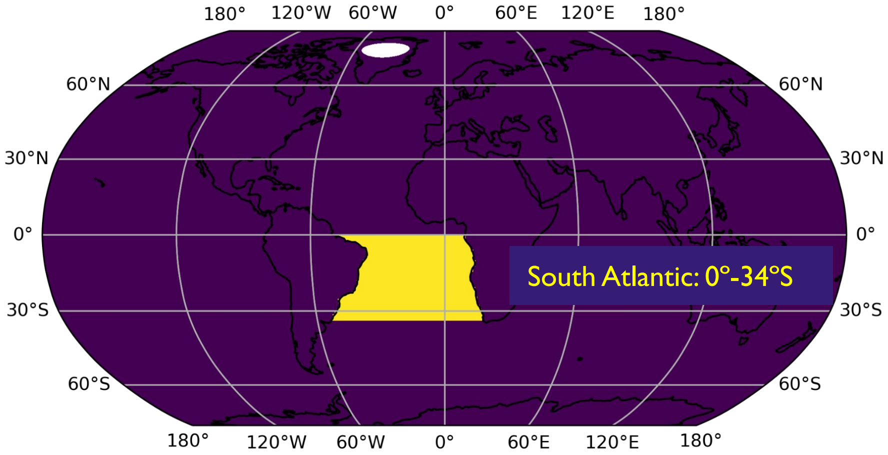

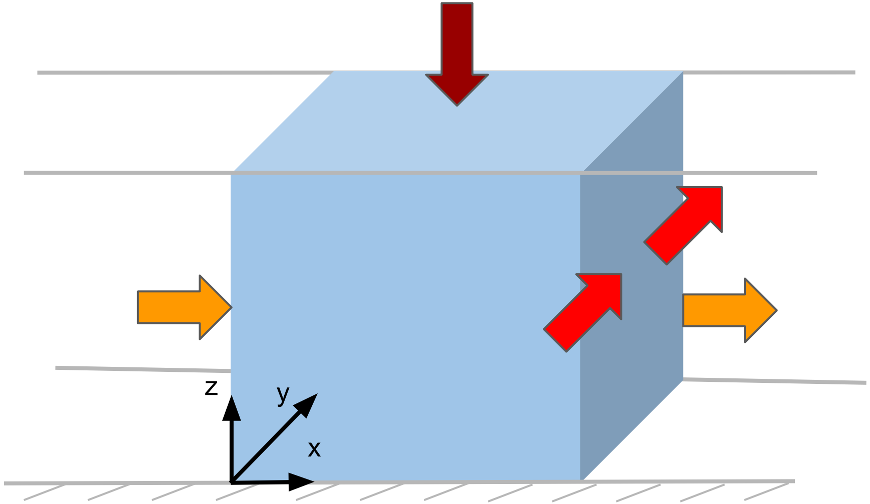

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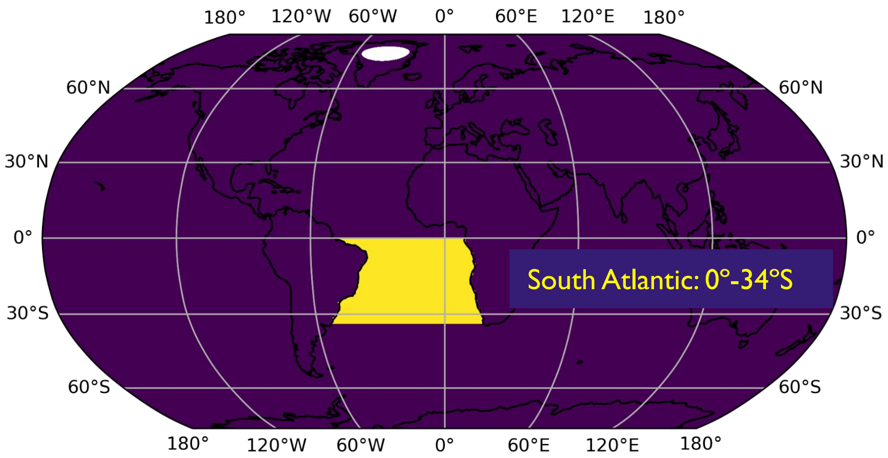
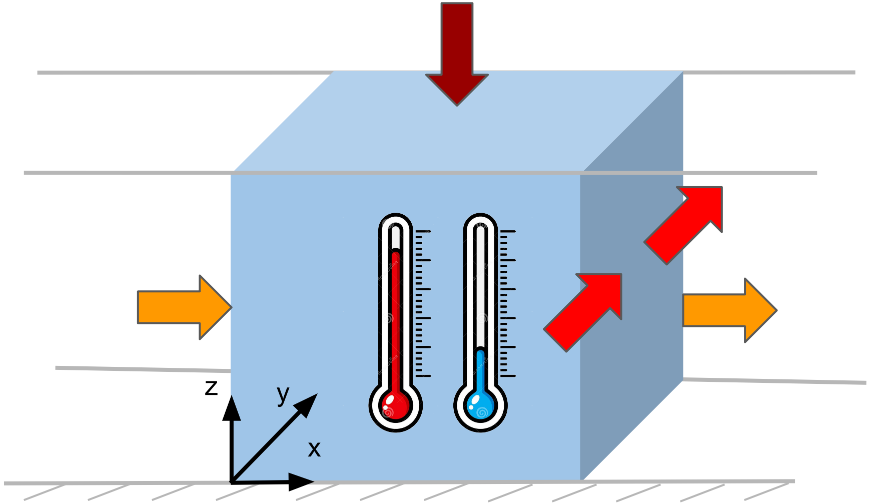
3°- Heat storage (HS):

- Mass integral of temperature from the surface to the bottom.



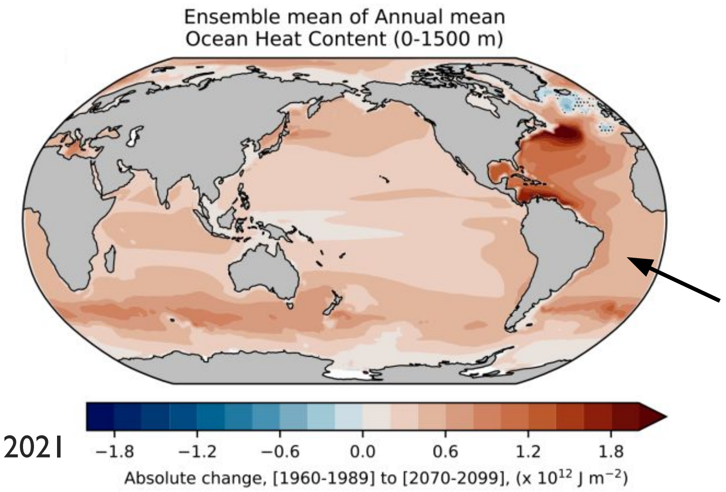


Motivation

- The South Atlantic has been warming significantly since the last century (Cheng et al. 2017, 2020).

- Climate change projections suggest an increase in the heat storage for the South Atlantic (Rodgers et al. 2021).

- Ocean heat storage is directly related to important climate processes.



Rodgers et al. 2021

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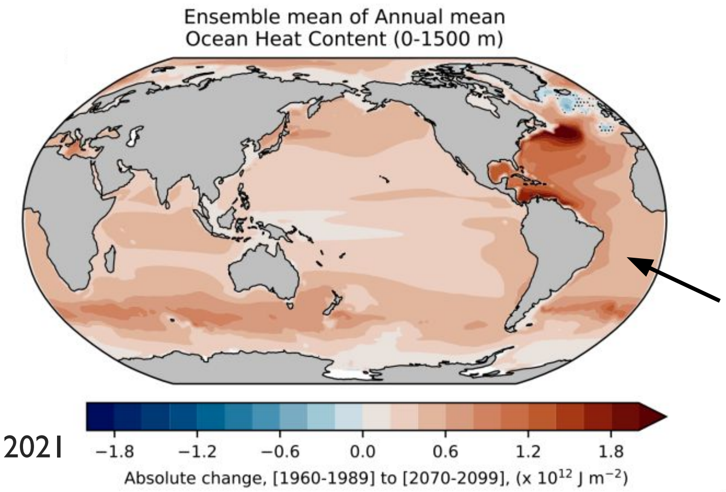
- Ocean heat storage is directly related to important climate processes.
- Particular attention to climate change injustice.



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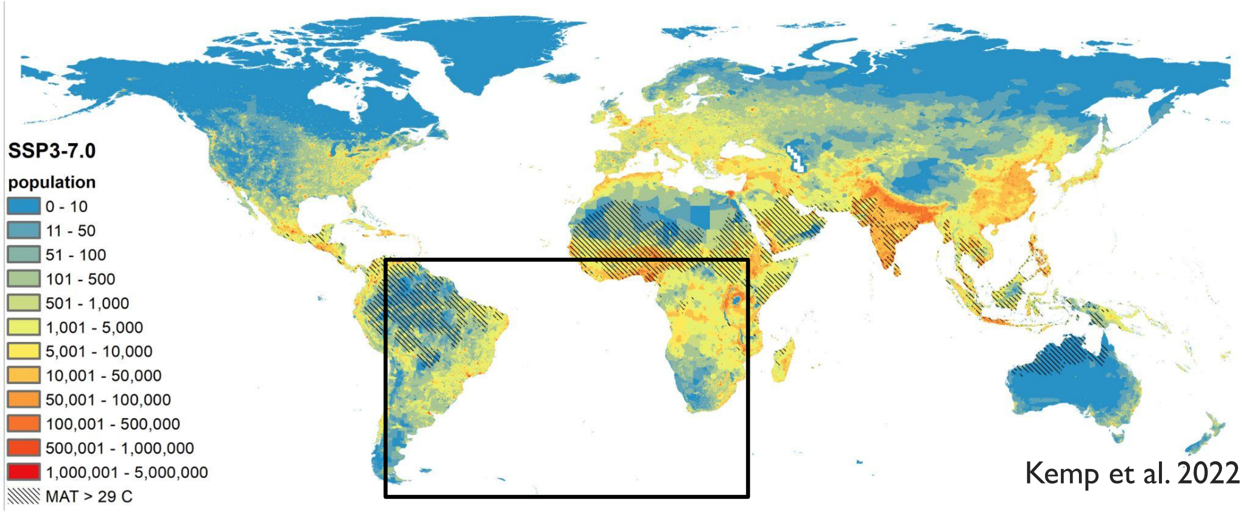


Kemp et al. 2022

Data

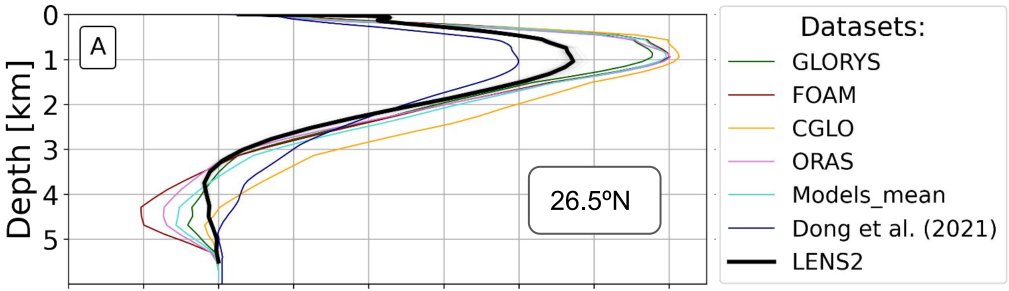
1- Community Earth System Model version 2 Large ENSemble Community Project (LENS2) (Rodgers et al. 2021):

- Fully coupled simulations; ocean model has ~1° for spatial resolution.
- CMIP6 scenario: 165-year simulations (1850 to 2014 - historical) plus 86-year simulations (2015 to 2100 - forcing - SSP370).
- 100 members (micro and macro perturbations).
- These simulations were designed to study different phases of the Atlantic Meridional Overturning Circulation (AMOC).

LENS2 AMOC validation

- Mean AMOC from 1993 to 2020 for different latitudes of the Atlantic Ocean.

- AMOC is well represented when compared to available reanalysis products.



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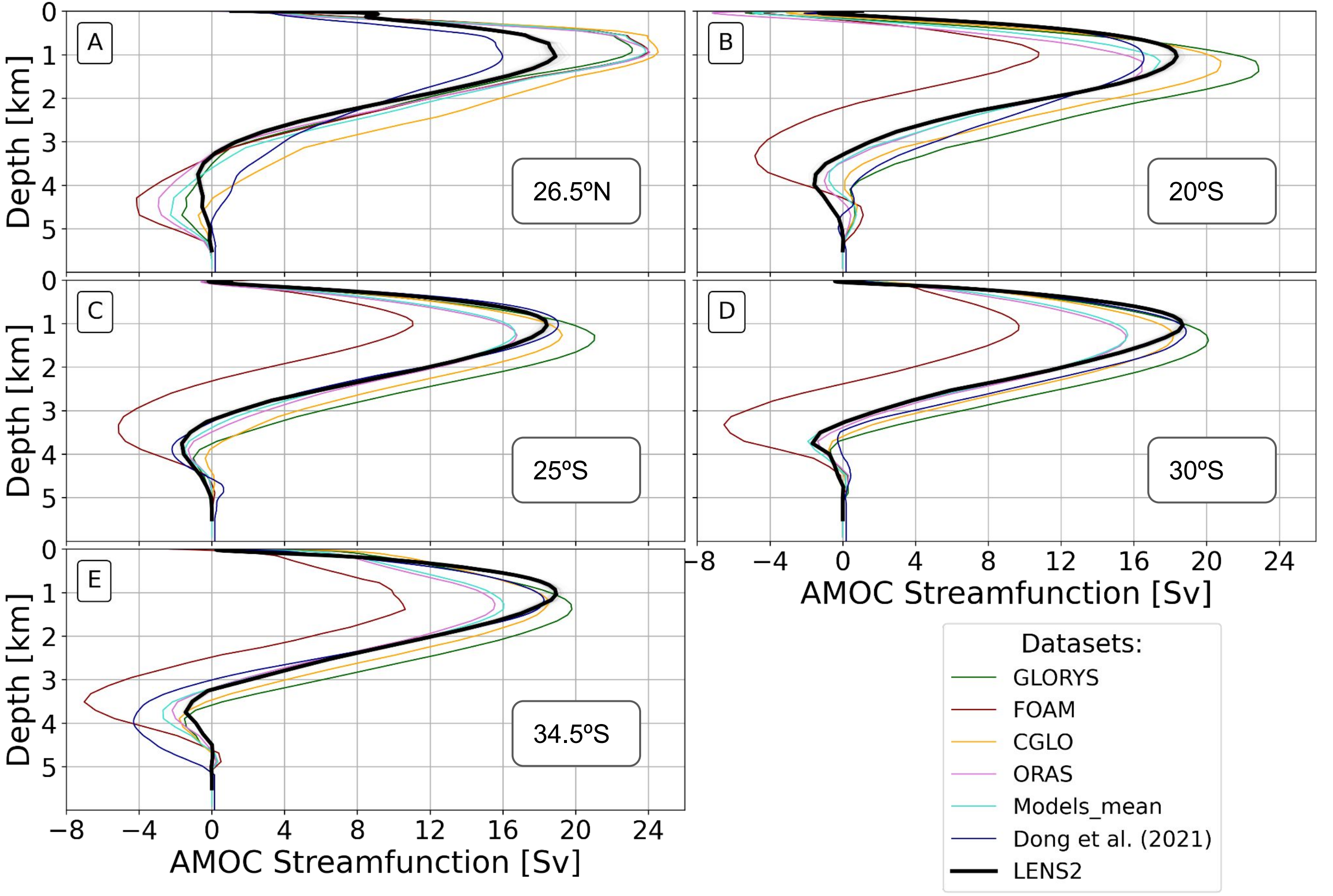
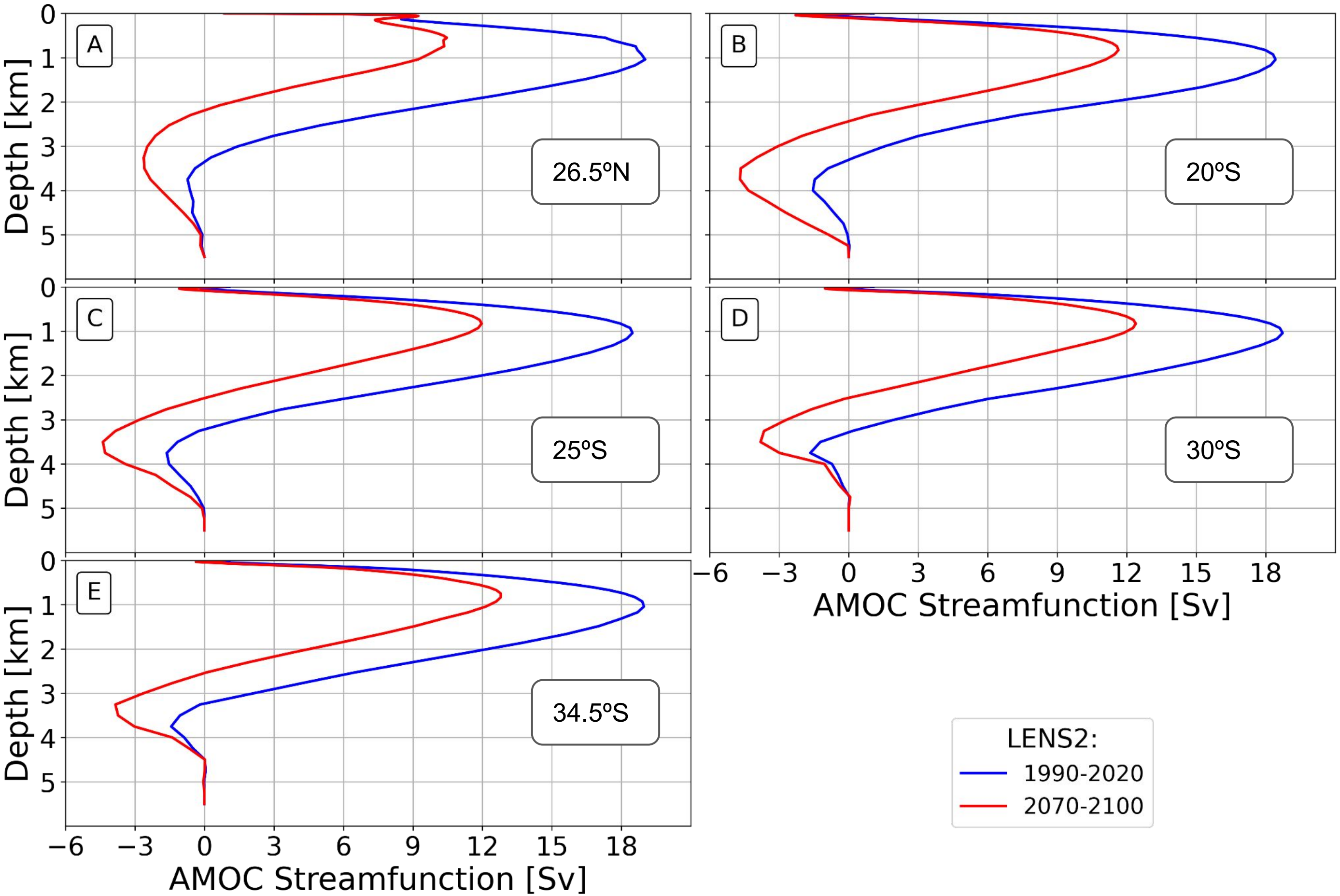


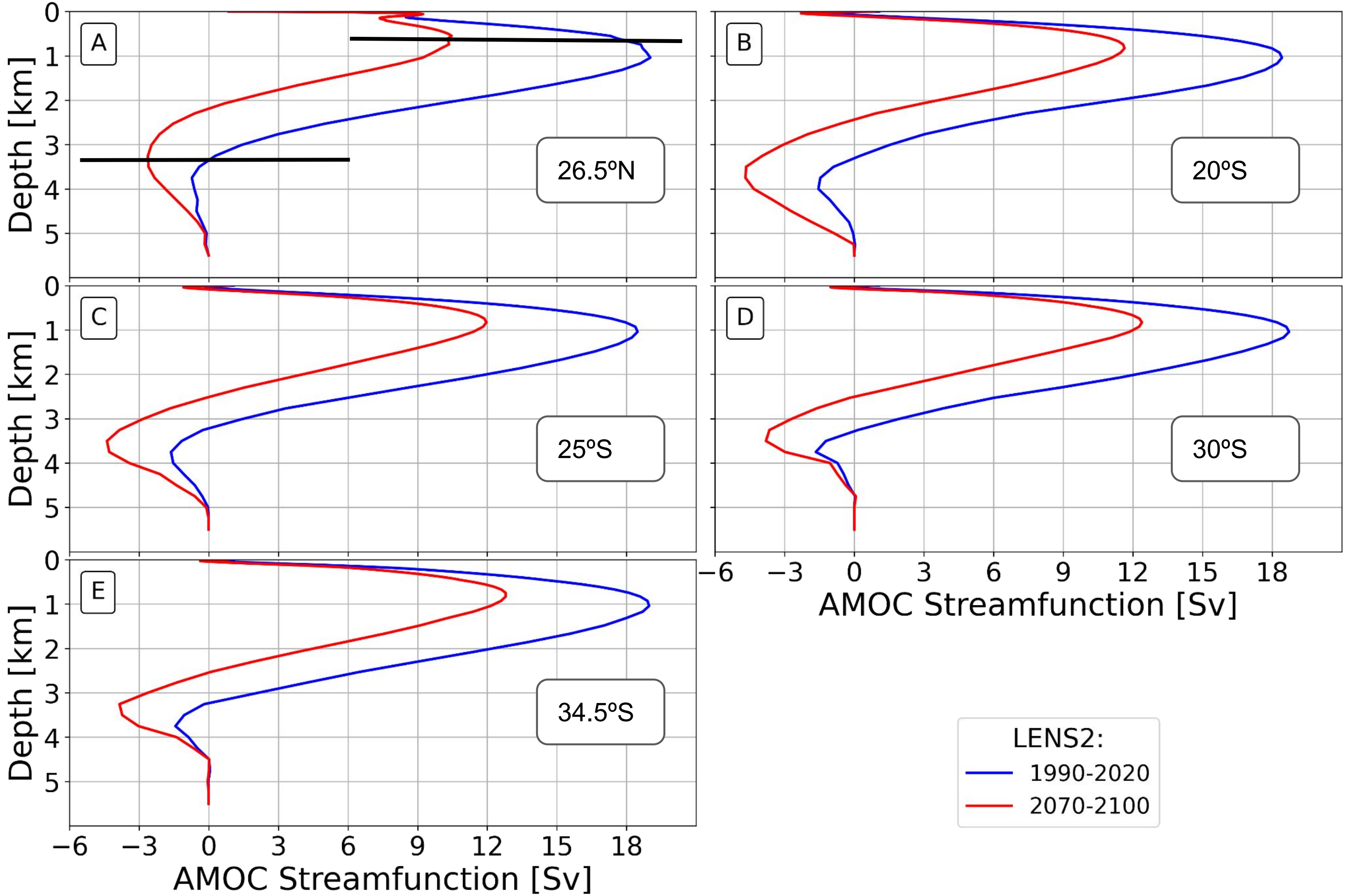
AMOC comparison: present versus future

- Weakening of AMOC.



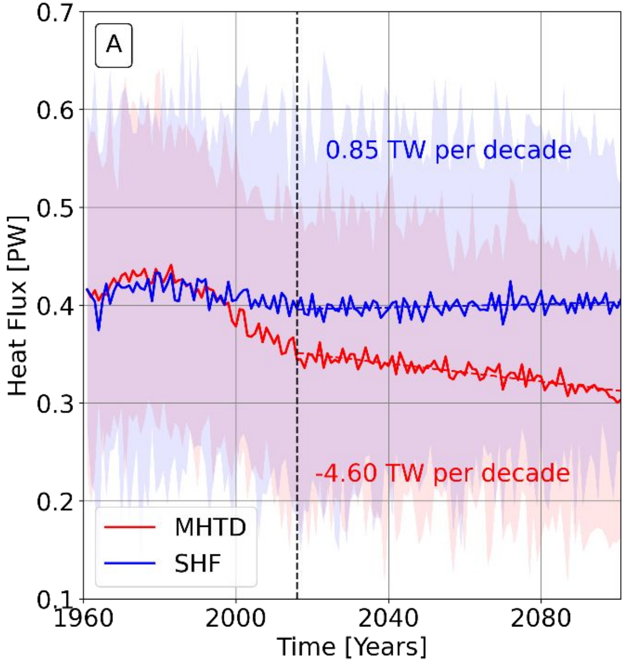
AMOC comparison: present versus future

- Inflection points have become shallower in the future scenario.
- Antarctic Bottom Water is expanding because **a)** it is getting less dense; **b)** the North Atlantic Deep Water is contracting; or **c)** both **a)** and **b)**.



Heat balance

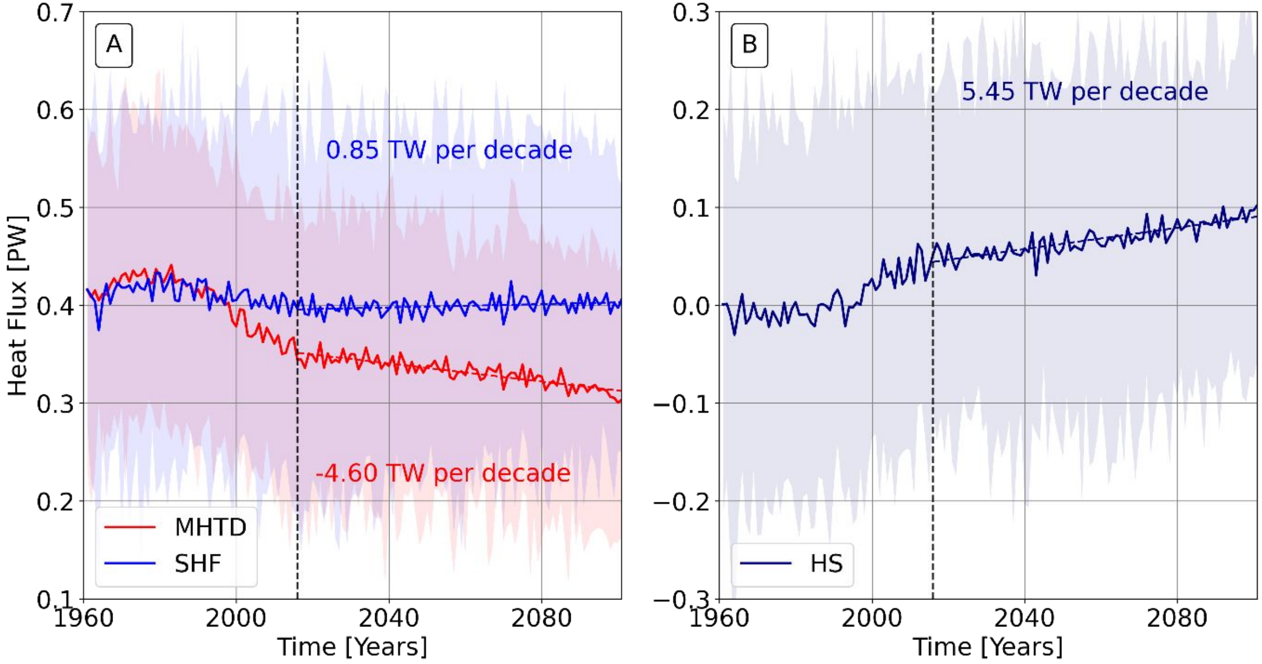
Meridional heat transport difference (North minus South) (MHTD) and total surface heat flux (to the ocean) (SHF).



Heat balance

Meridional heat transport difference (North minus South) (MHTD), total surface heat flux (to the ocean) (SHF), and heat storage (HS).

- 84% of the HS trend is because of MHTD, and 16% is because of SHF.



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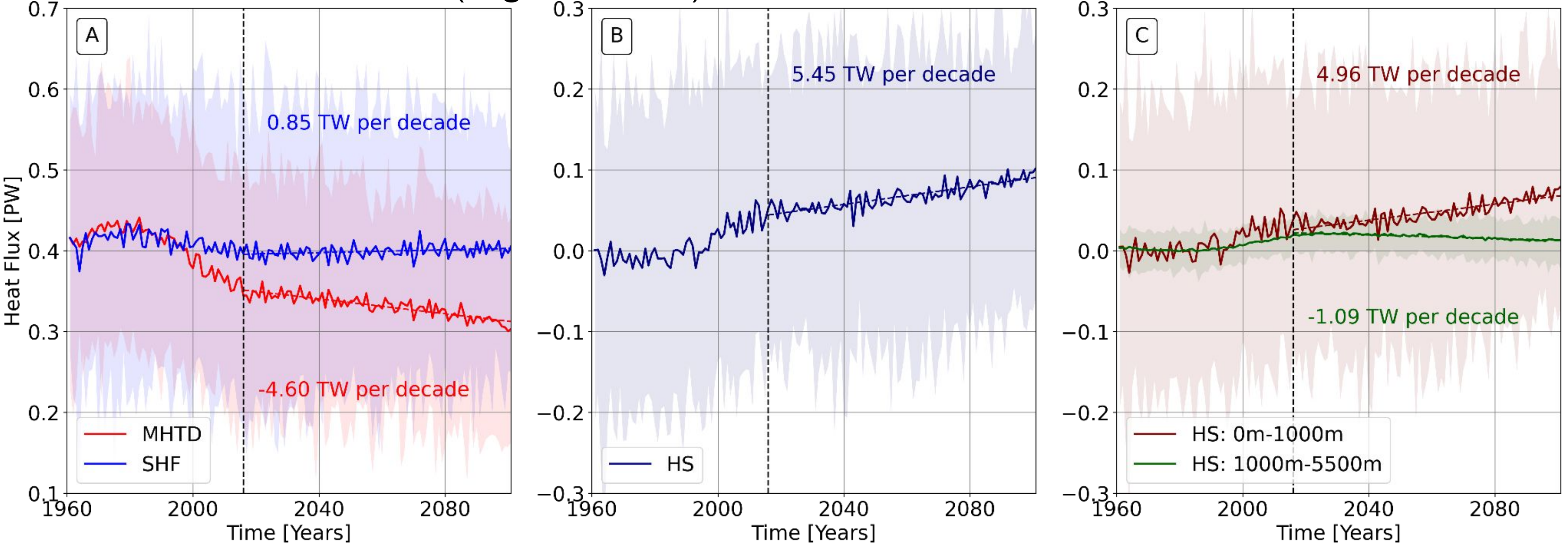
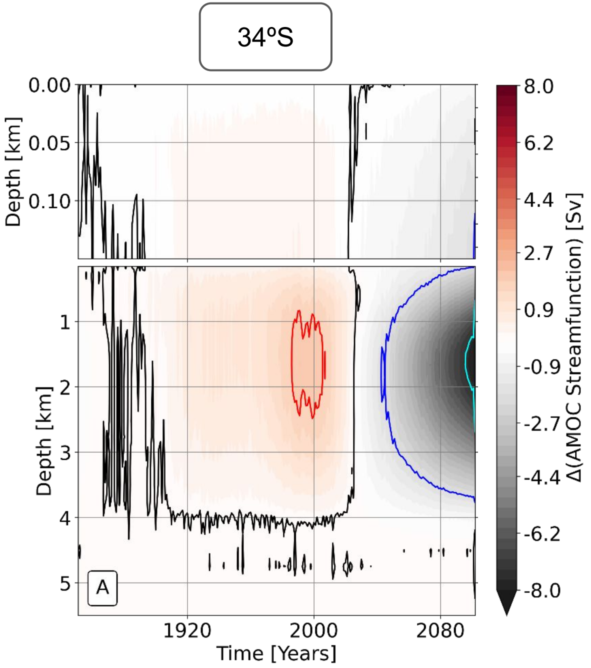
- 82% of the HS trend occurs in the first 1000 meters (positive trend), and 18% occurs below 1000 meters (negative trend).



Weakening of AMOC in the SSP370 scenario



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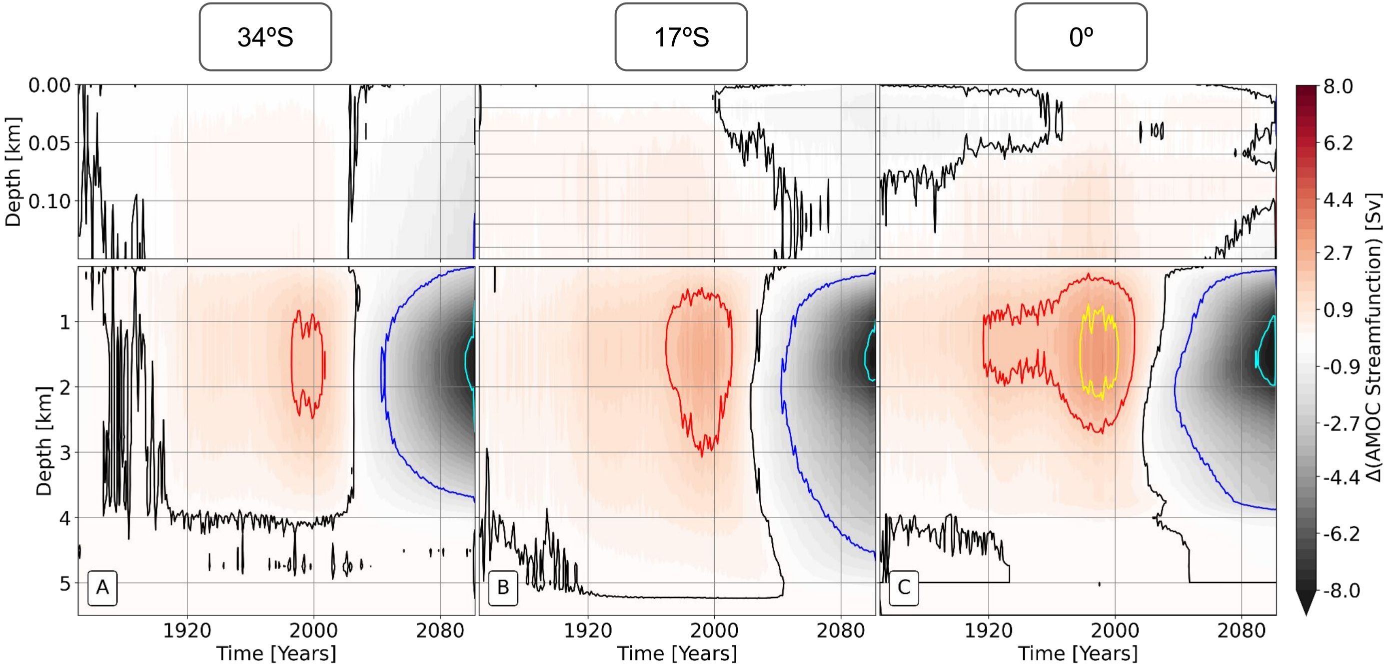
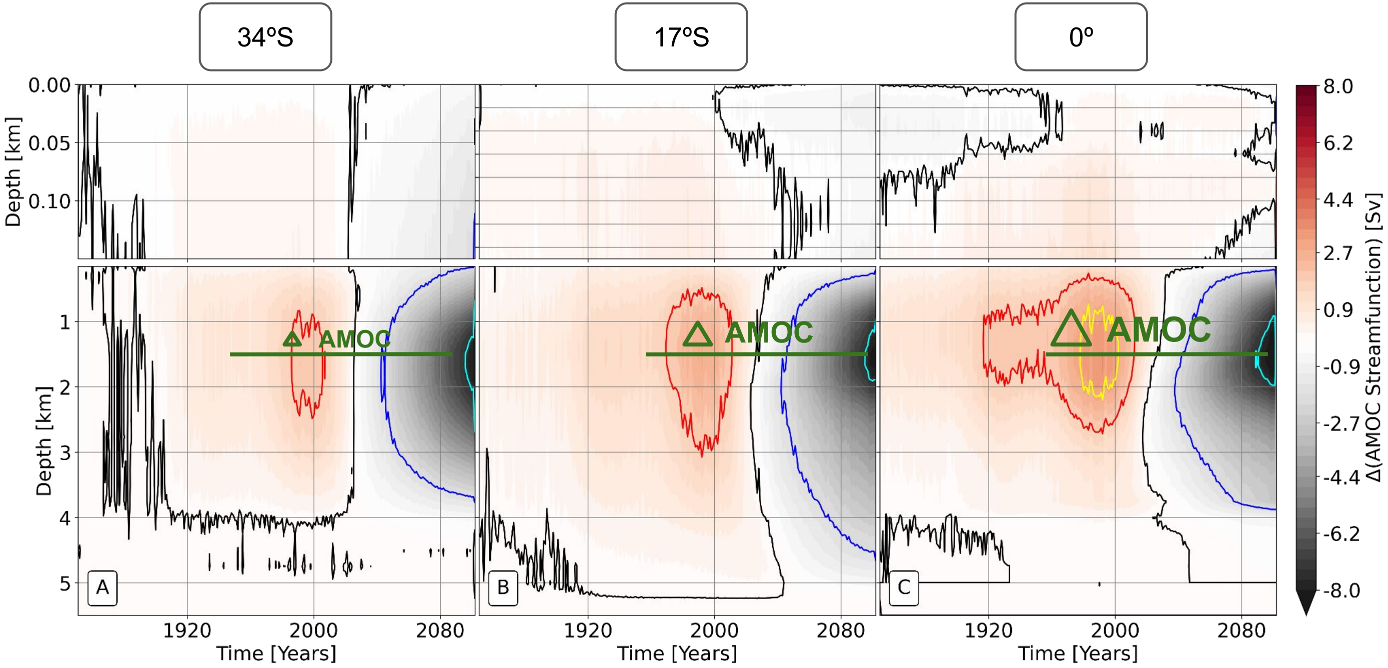


Weakening of AMOC in the SSP370 scenario

More significant weakening at the northern boundary compared to the southern border.



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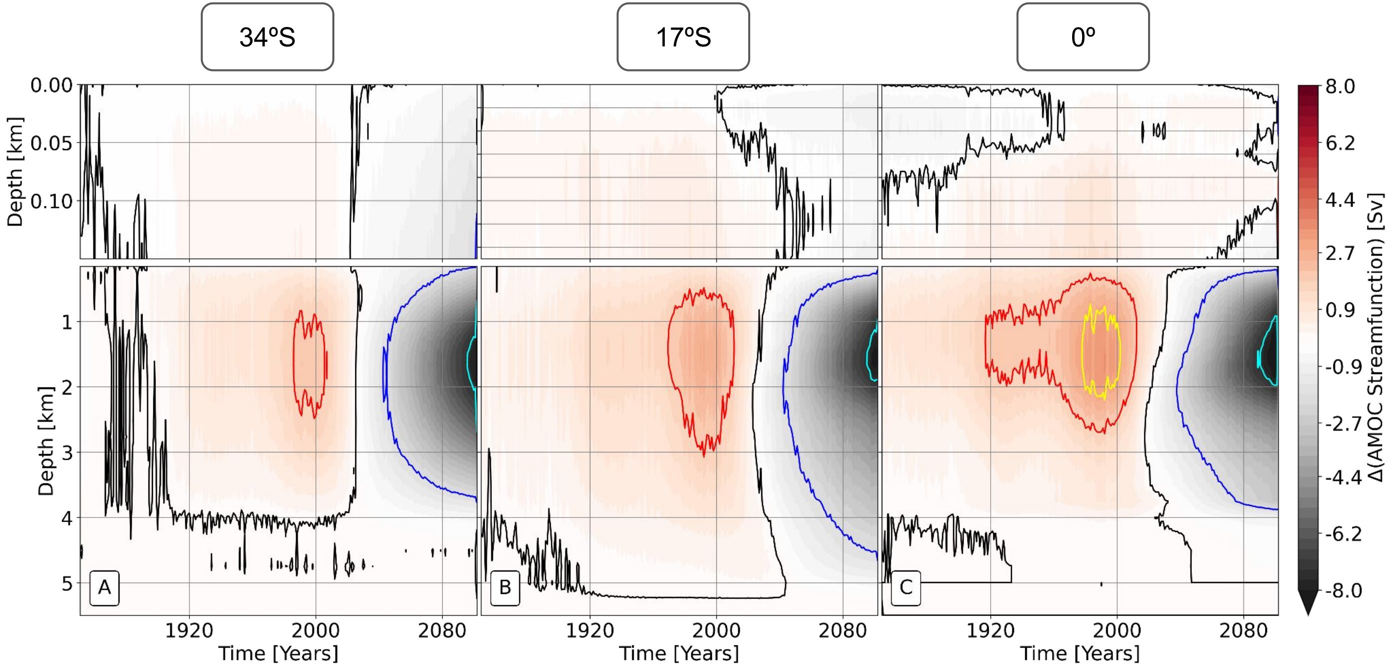

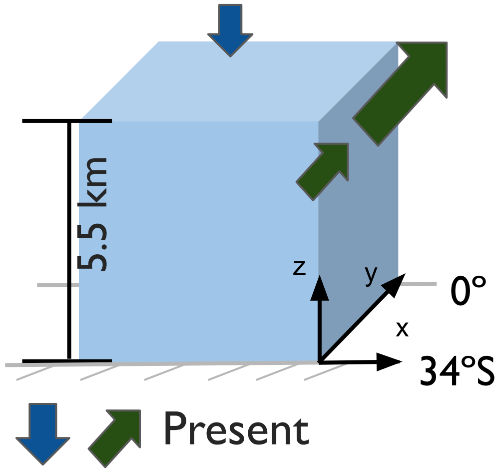

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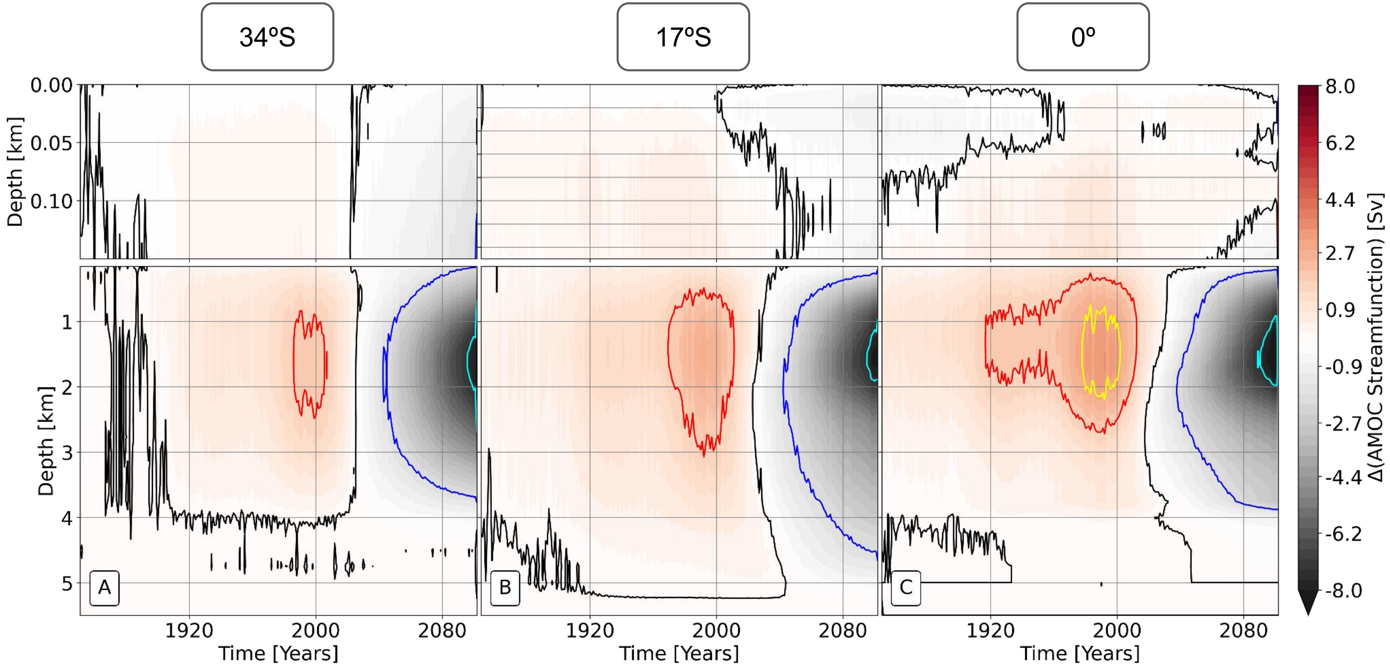
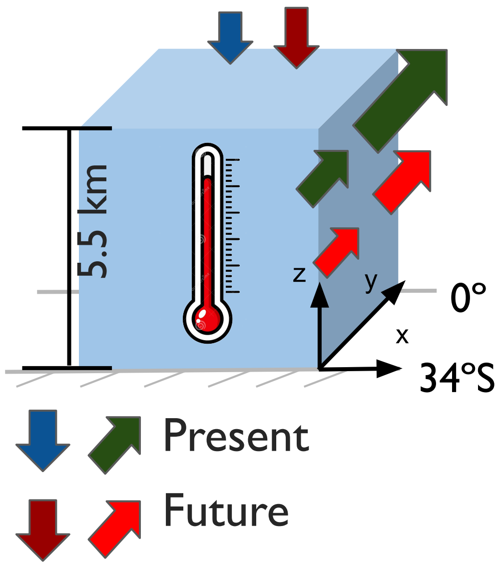


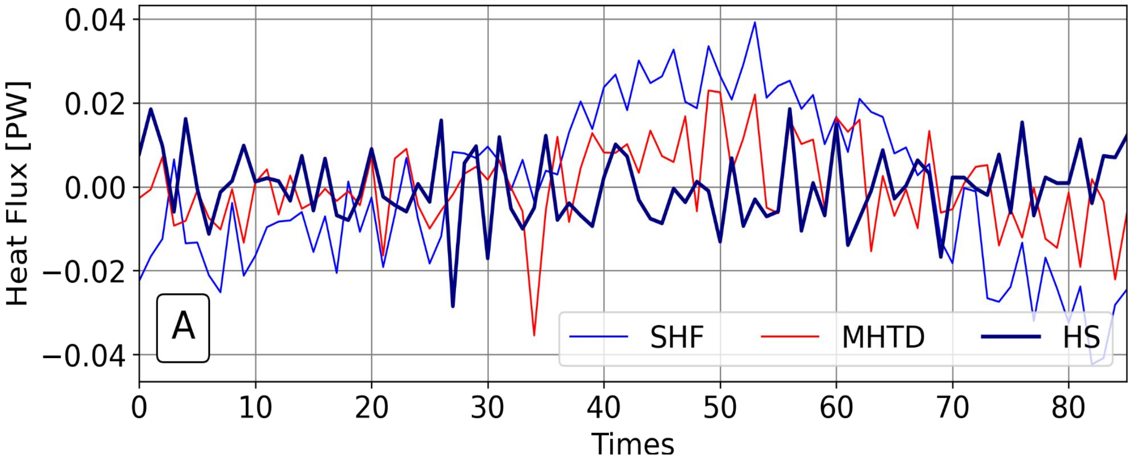


Correlation for lag zero with no linear trend

A: 1929-2014 (Historical):

- SHF and MHTD: 0.57
- SHF and HS: -0.84
- MHTD and HS: -0.04

Low influence of MHTD on HS variability.



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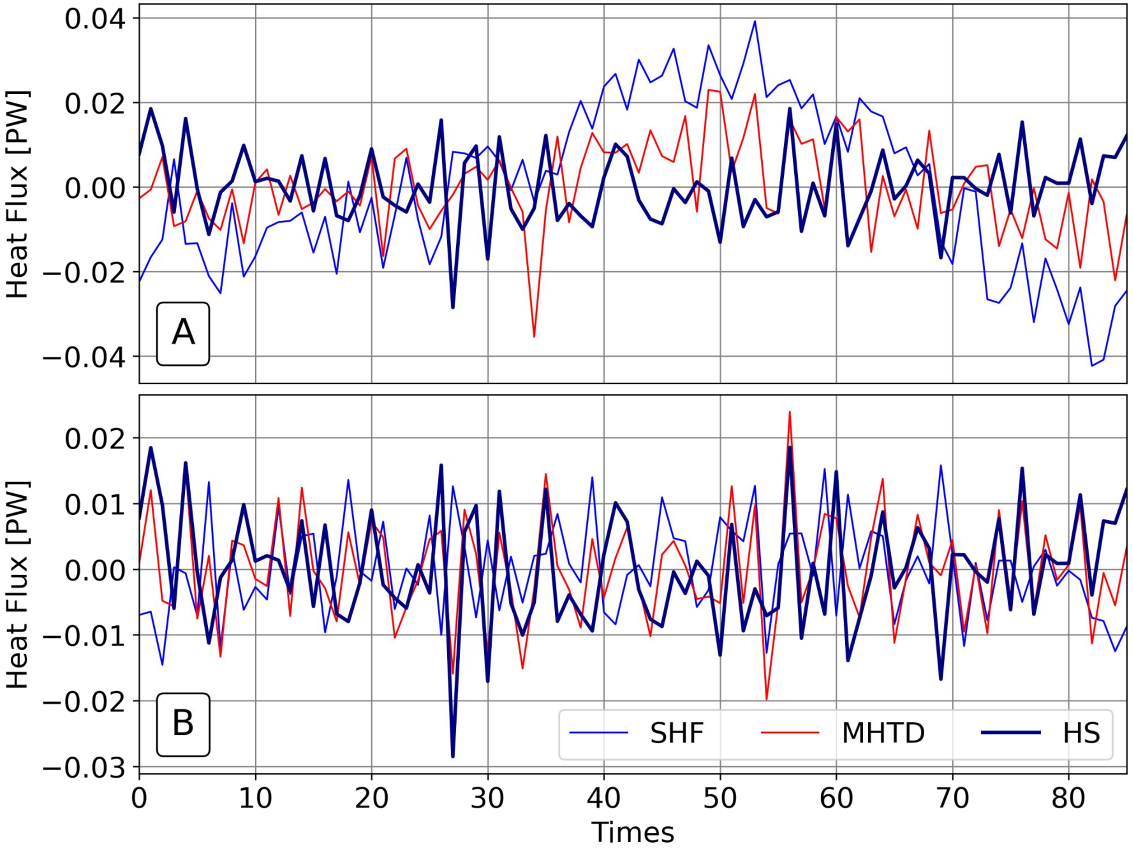
B: 2015-2100 (SSP370):

- SHF and MHTD: 0.34
- SHF and HS: -0.50
- MHTD and HS: 0.64

High influence of MHTD on HS variability.



Concluding remarks

- LENS2 suggests that the South Atlantic will warm mainly due to the weakening of northward heat transport at the northern boundary of the basin.
- This warming occurs in the upper ocean; however, the lower ocean is cooling.
- Northward heat transport is the main driver for the variability of heat storage, whereas, before 2015, this variability was driven by the total surface heat flux.

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Next step

- Calculate each component of the northward heat transport to determine which term is responsible for the increase in heat storage.

Thank you for your attention!

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maurocha

https://github.com/NCAR/south_atlantic_heat_balance.git