Remote influence of Interdecadal Pacific Oscillation on the South Atlantic Meridional Overturning Circulation variability

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Goal and Objectives

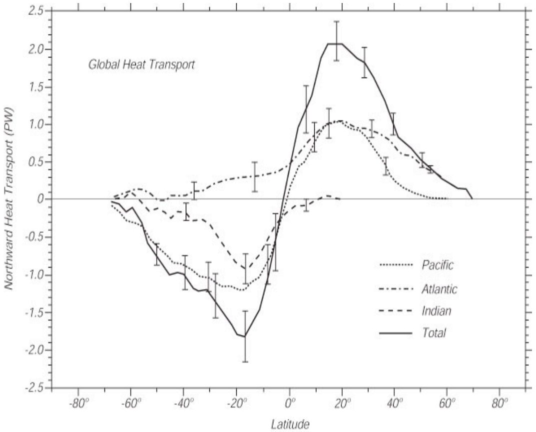
<u>Goal</u>: *Enhance our knowledge of the role of the ocean in climate and extreme weather events.*

<u>Objective</u>: *Investigate climate factors that influence decadal variability of the South Atlantic Meridional Overturning Circulation (SAMOC).*

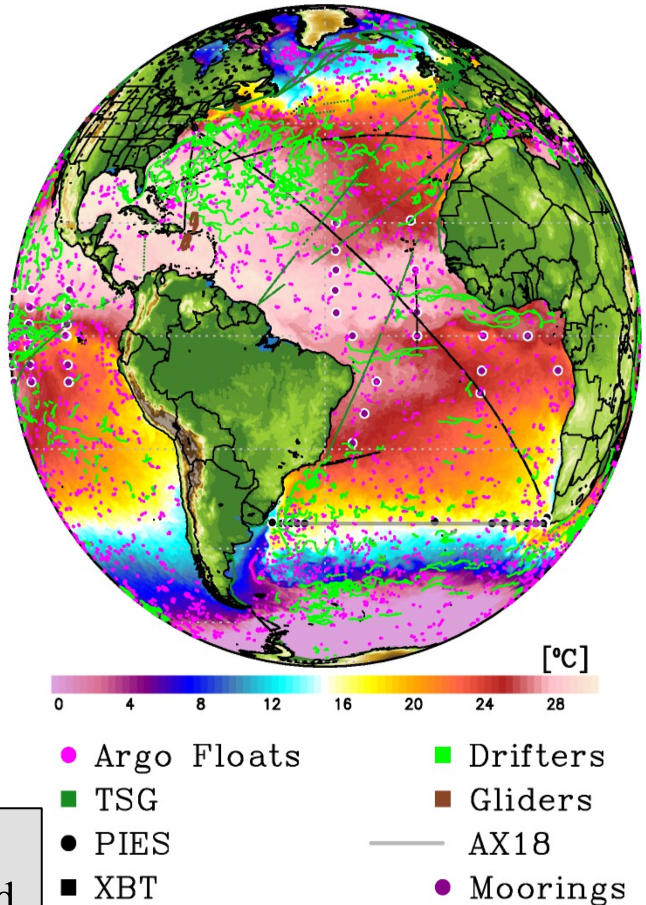
Results presented here were published in GRL [Lopez et al. 2016].

South Atlantic Meridional Overturning Circulation

- The global oceans distribute mass and heat through all basins in a large-scale circulation called the **Meridional Overturning Circulation (MOC)**.
- NOAA, and other partners, are placing big efforts to monitor and understand the AMOC and associated MHT.



- The MOC in the South Atlantic is unique in that its upper branch carries heat equatorward (Talley 2003; Lumpkin and Speer 2007).



- South Atlantic MOC and MHT are influenced by:
    1. The Agulhas leakage (Sloyan and Rintoul 2001; Garzoli and Matano 2011).
    2. Malvinas-Brazil Confluence (Garzoli and Garraffo 1989; Goni et al. 2011).
    3. Inter-ocean transport from the Indian Ocean (Lee et al. 2011).
    4. **?**

South Atlantic MOC and MHT are influenced by?

Hypothesis: "*Atmospheric teleconnections forced by diabatic heating from the Inter-decadal Pacific Oscillation (IPO) could influence the South Atlantic wind stress field and SAMOC.*"

Observations:

- SAMOC at 30S is derived from Dong et al. [2015]
- SSH from satellite altimetry for the period of 1993-2011 [Ducet et al. 2000]
- SST from the Extended Reconstructed Sea Surface Temperature version 4 (ERSST4) for the period of 1900-2015.
- Atmospheric variables:
  - ❖ NOAA-CIRES 20th Century Reanalysis [Compo et al. 2011] for the period of 1950-2012.
  - ❖ ERA-20 Century Reanalysis [Poli et al. 2016] for the period of 1900-2010.

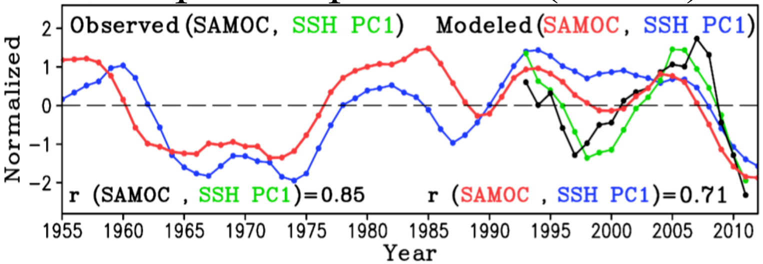
Model simulations:

- Surface-forced ocean model run (ocean-sea ice Parallel Ocean Program (POP2) model) integrated using:
  - ❖ NOAA-CIRES 20th Century Reanalysis
  - ❖ ERA-Interim reanalysis from ECMWF.
  - ❖ MERRA reanalysis from NASA
- Fully coupled model:
  - ❖ 1000-year pre-industrial Community Earth System Model (CESM1) Large Ensemble Simulation [Kay et al. 2014].
  - ❖ Atmospheric component has 30 vertical levels with horizontal resolution of 1.25˚ in the zonal and 0.94˚ in the meridional direction.
  - ❖ Ocean component has horizontal resolution of about 1˚, with 60 vertical levels.

The ocean and sea-ice models are identical for the surface-forced and fully coupled runs.

Leading mode of SSH variability in the South Atlantic

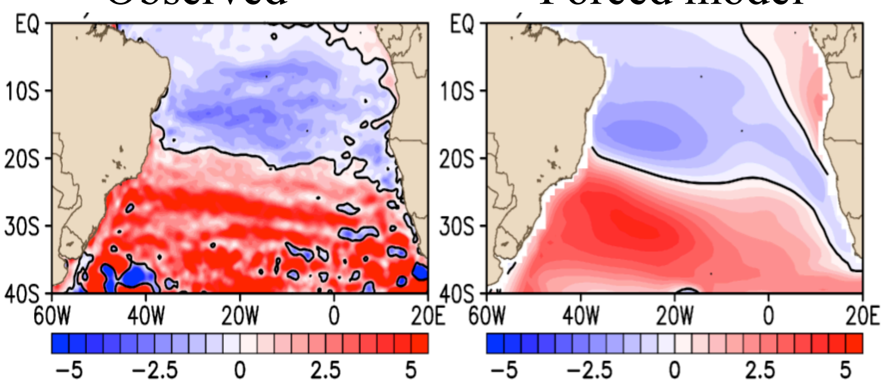
Principal component PC (annual)



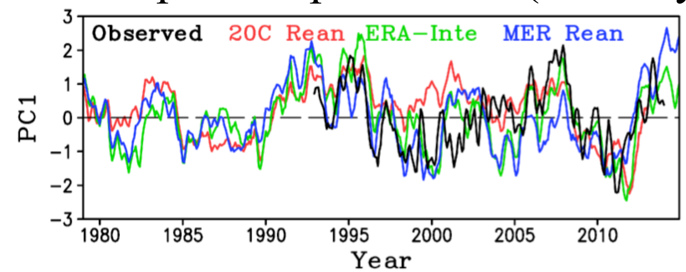
- AVISO altimetry dataset (green) and from the POP2 model (blue).
- SAMOC interannual anomaly estimate at 30S from altimeter (black) and from the forced POP2 ocean model (red).

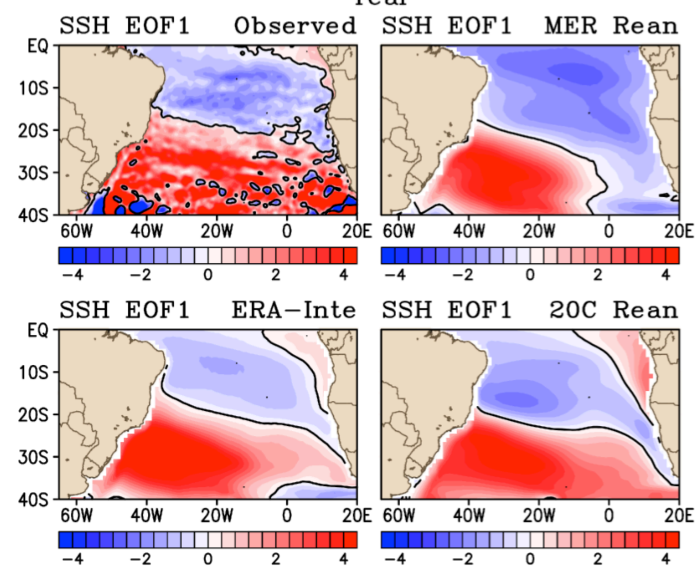
Leading pattern (annual)

Observed　　Forced model



Principal component PC (monthly)

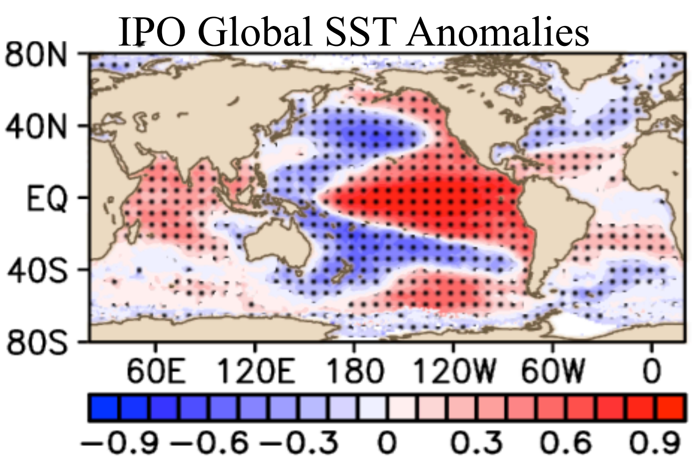


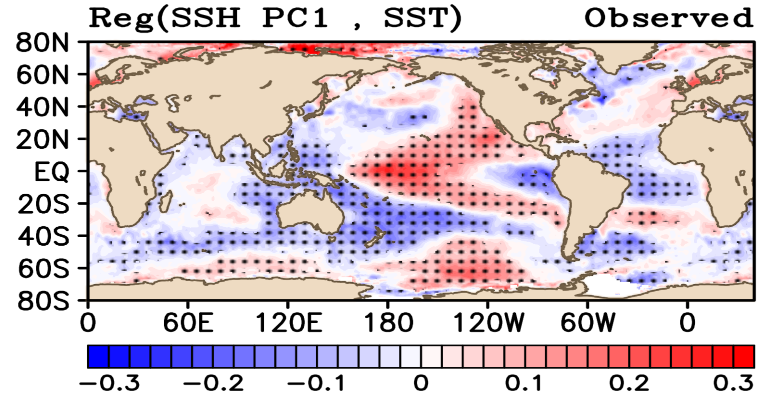


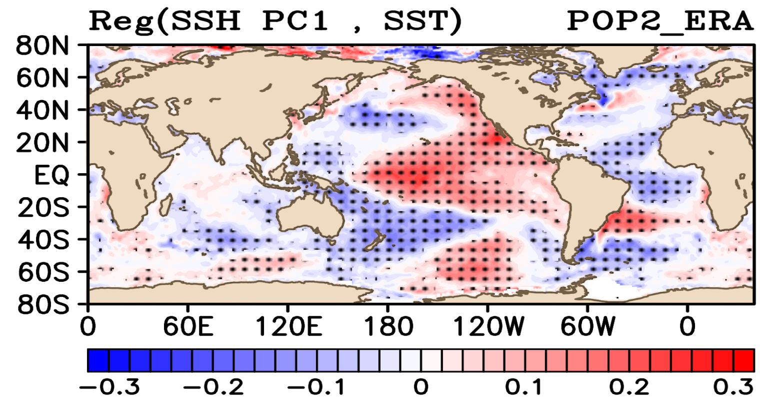
- Monthly SSH pattern is almost identical to the annual mean pattern.
- The surface-forced runs well reproduced the observed spatial and temporal evolution of the altimetry-derived SSH variability.

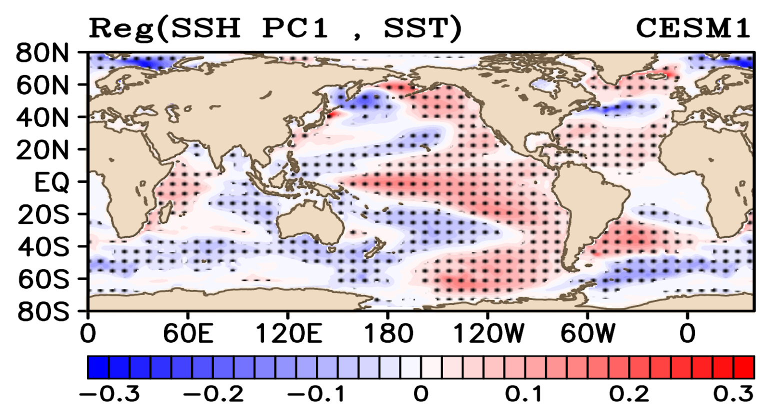
Global SST and leading mode of SSH variability in the South Atlantic

- Meridional pattern in the South Atlantic from 60°S to the equator, similar to the spatial pattern of the leading SSH PC.
- Regressed global SST pattern is consistent between observation and models.
- Structure in the Pacific closely resembles that of the IPO [Folland et al. 1999].







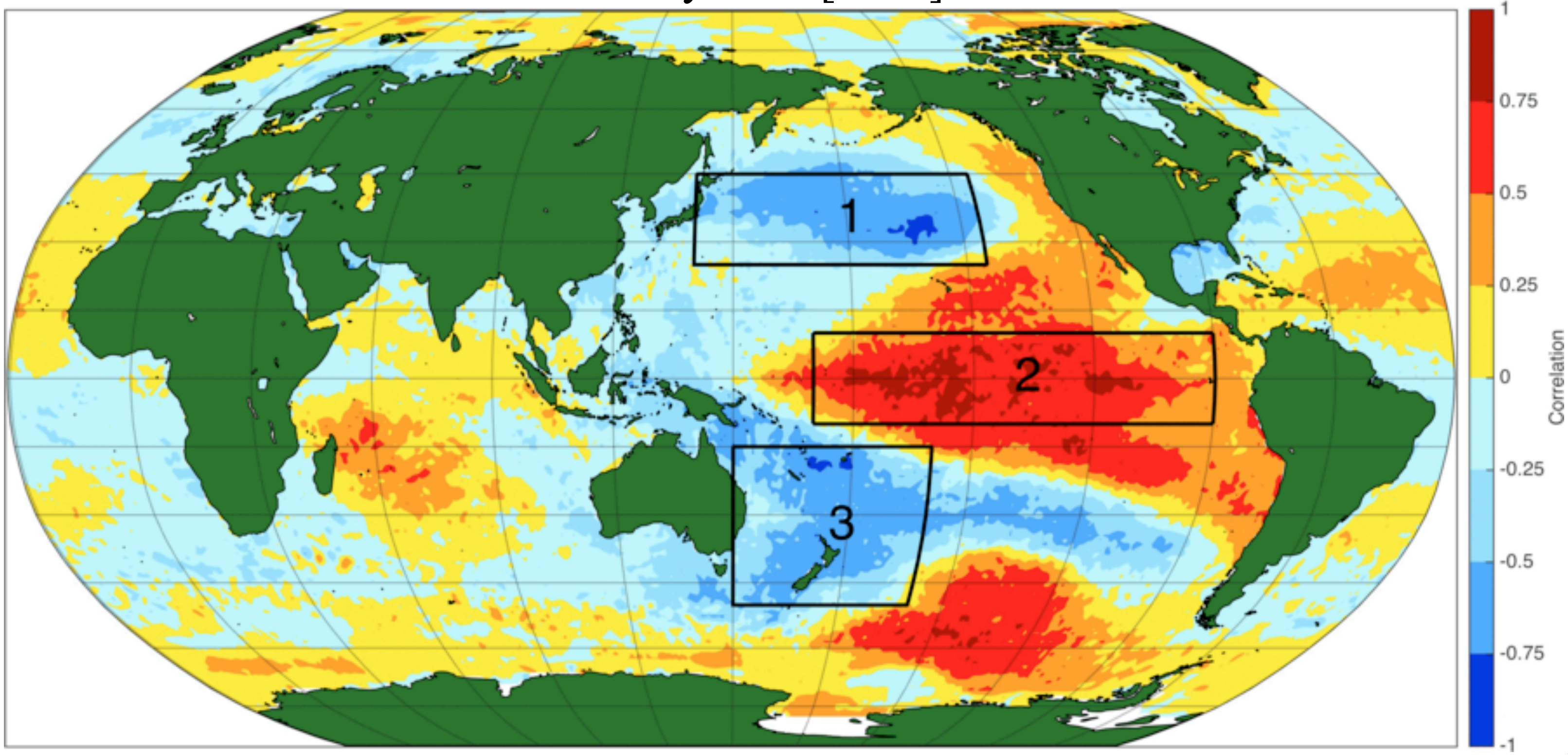


Stipples indicate statistical significance to a 95% confidence level from a student-T test.

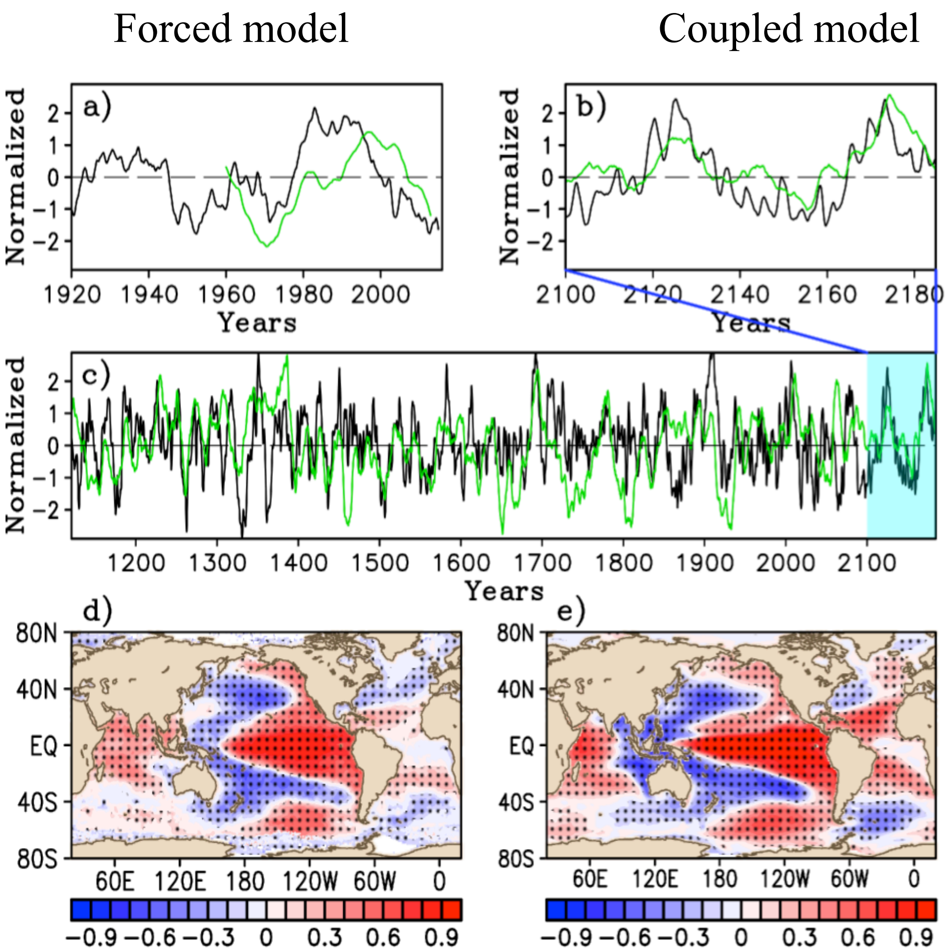
What is the IPO?

- The IPO is a multidecadal SST mode of variability similar to ENSO.
- It shows a symmetric structure about the equator.

IPO Index from Henley et al. [2015]



Leading mode of SSH variability in the South Atlantic and IPO



IPO (black) and SSH PC (green)

r(IPO,SSH PC) = 0.43 forced model

r(IPO,SSH PC) = 0.67 coupled model

Regression of IPO index onto SST.

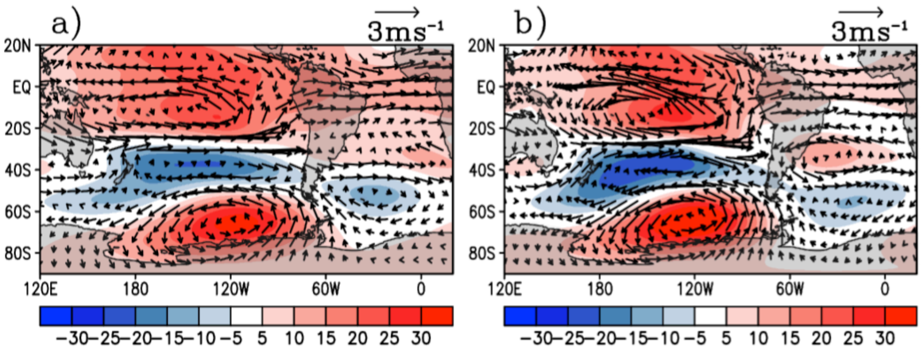
- The SST over the South Atlantic show a meridional dipole with warm (cold) anomalies north (south) of 40°S.
- SST anomalies associated with the IPO and those associated with the South Atlantic SSH PC are consistent in both the observation and the CESM1 model runs.

Stipples indicate statistical significance to a 95% confidence level based on a student-T test.

IPO influence on SAMOC through atmospheric teleconnection

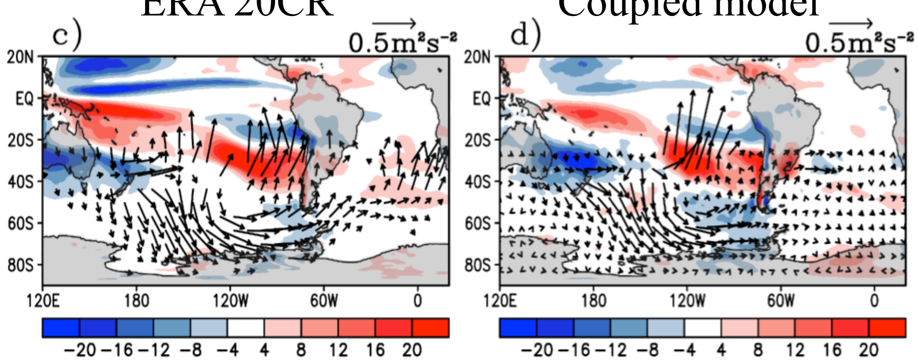
IPO regression on 200mb height and wind

ERA 20CR | Coupled model



IPO regression on Rossby wave flux and source

ERA 20CR | Coupled model



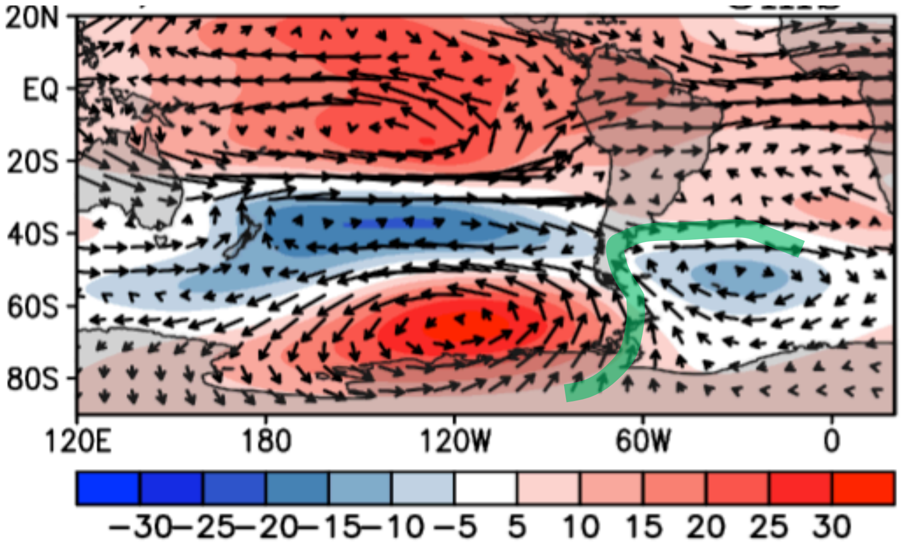
- Stationary Rossby wave with positive height anomalies over the central tropical Pacific and cyclonic circulation south of the equator, producing easterly flow along 45°S.
- Negative (positive) Z200 anomaly south (north) of 40°S over the South Atlantic, which leads to westerly anomaly centered at about 40°S and easterly anomaly at 60°S.
- The Rossby wave response to IPO forcing has a considerable meridional component, which makes possible the incursion of Rossby wave activity towards the South Atlantic.

$$Flux\ \vec{F} = P\begin{pmatrix} \frac{1}{2a^2 cos\emptyset}\left(\left(\frac{\partial\psi}{\partial\lambda}\right)^2 - \psi\frac{\partial^2\psi}{\partial\lambda^2}\right) \\ \frac{1}{2a^2}\left(\frac{\partial\psi}{\partial\lambda}\frac{\partial\psi}{\partial\emptyset} - \psi\frac{\partial^2\psi}{\partial\lambda\partial\emptyset}\right) \end{pmatrix}$$

$$RW\ Source = -\vec{V}_\chi \cdot \nabla(\zeta + f) - (\zeta + f)\nabla \cdot \vec{V}_\chi$$

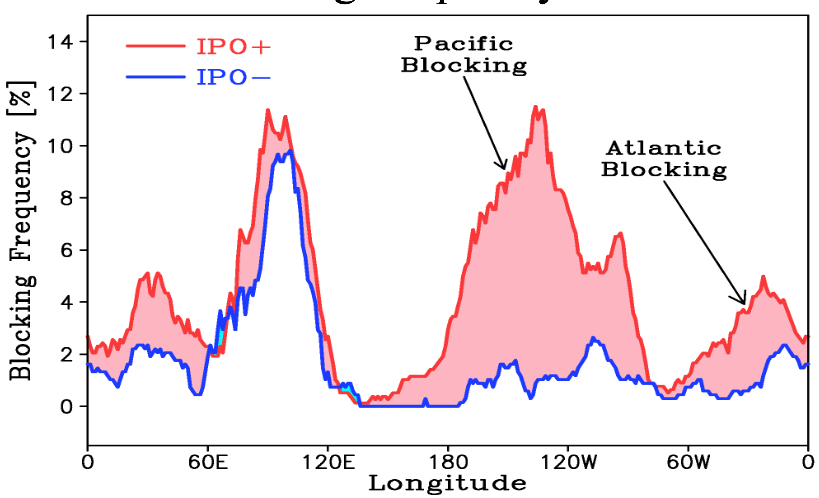
IPO influence on SAMOC through atmospheric teleconnection

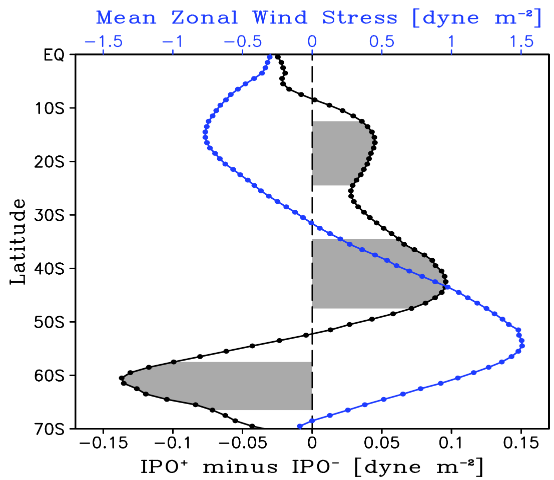
+IPO circulation



- Anticyclone serves as a “blocking” pattern.
- Blocking events are significantly more common over the South Pacific and South Atlantic during the positive IPO phase.
- The blocking events during a positive IPO occurs around 55°S, causing a significant equatorial shift of the zonal winds over the South Atlantic Ocean with anomalous positive zonal wind maxima around 40°S and negative anomalies around 60°S.

Blocking frequency

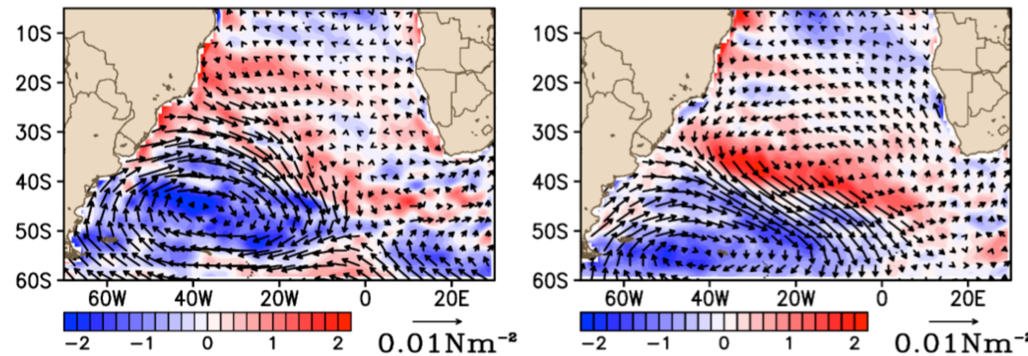


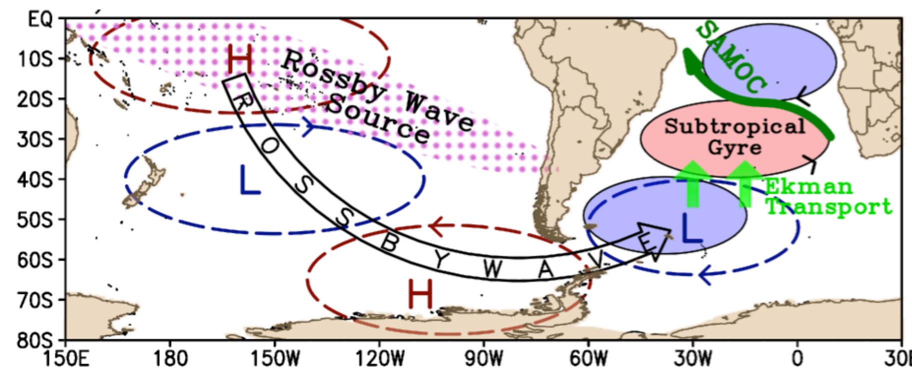


Atmospheric blocking events lead to significant meridional shifts of the jet stream and storm track

Conclusions

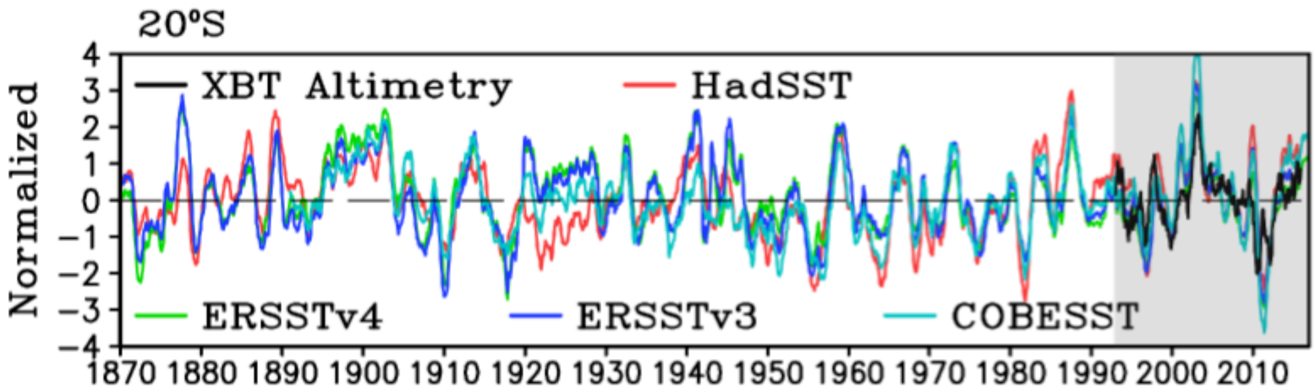
- The +IPO forces cyclonic and anti-cyclonic atmospheric Rossby waves extending from the tropical Pacific towards the South Atlantic.
- These Rossby waves have source regions that extend from the central Pacific southeastward towards the South American coast.
- Causing enhanced atmospheric blocking frequency west and east of the Drake Passage consequently shifting the westerlies equatorward towards the South Atlantic.

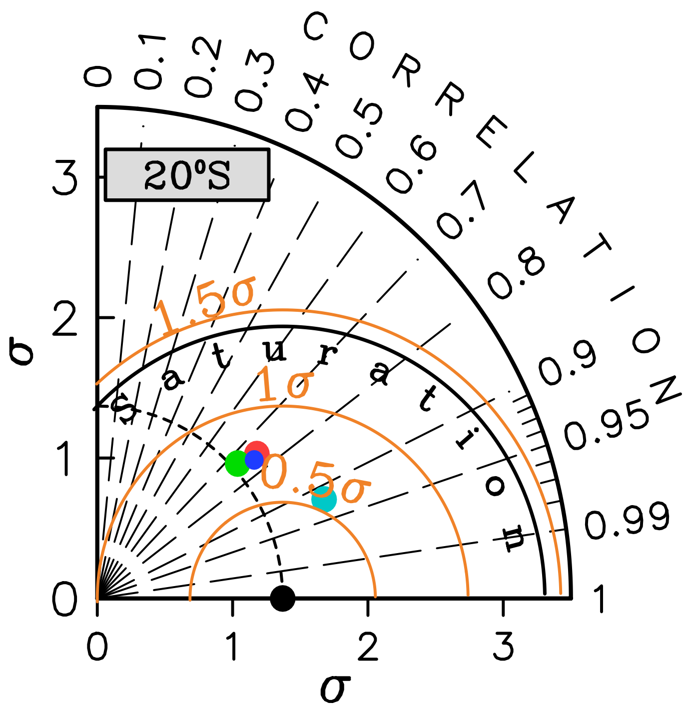




- This in turn produces a northward Ekman transport, positive (negative) wind stress curl north (south) of 40°S, thus modulating the strength of the subtropical gyre in the South Atlantic as well as SAMOC.
- This mechanism is verified by analyzing altimetry data as well as an ocean general circulation model forced with different atmospheric reanalysis data and a fully coupled model.

IPO-SAMOC relationship motivated the reconstruction of a century-long SAMOC timeseries.





Thank you!

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