SAMOC Variations during the Past 24 Years and their Role in Ocean Heat Content Changes

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Summary

Satellite and in situ measurements during 1993-2016 have been used to estimate the MOC and MHT at latitudes between 20°S and 35°S (*Fig.1*). The results demonstrate that the relative roles of the geostrophic and Ekman transports on the interannual variations in the MOC/MHT varies with time and latitude (*Fig.2*). More specifically, the Ekman component plays a larger role than the density-driven (i.e., geostrophic) component at 20°S. At 35°S, on the other hand, the geostrophic component dominates over most of study period, except during 2007-2012 when the Ekman component dominates.

The MHT estimates are further examined to better understand what caused the observed heat deficit in the South Atlantic during 2009-2012 (*Fig.5*). Our analysis indicates that this heat deficit is largely contributed by anomalous ocean heat divergence, largely due to the negative (i.e., southward) anomalies in Ekman transport across 35°S (*Figs.6 &7*). Both the Southern Annular Mode and the Pacific-South American mode 2 (PSA2) are contributing to the negative Ekman transport, with the PSA2, which is known to be linked to tropical heating anomalies in the central Pacific, playing a larger role for this particular event (*Fig.8*). This conclusion is consistent with Lopez et al. (2016), and further stresses that the South Atlantic ocean heat content is affected by the remote influence of the Interdecadal Pacific Oscillation (IPO) and the associated Ekman transport.

Main Conclusions are:

- Satellite altimetry provides an extended time series of MOC/MHT back to 1993 (Fig.1).
- The relative importance of the Geostrophic and Ekman components in the MOC and MHT varies with time and latitude (Fig.2).
- Before 2004, large differences are seen between the estimates of the South Atlantic heat content provided by different data sets/products, pointing to the need for a better heat content product for the South Atlantic (Fig.5).
- After 2004, all data sets show a consistent decrease in heat content from 2008 to 2011 and an increase afterwards, resulting in a large heat deficit during 2009-2012 (Fig.5).
- The negative (southward) Ekman transport across 35°S is the largest contributor for the 2009-2012 heat deficit.
- Both the positive phase in the Southern Annular Mode (SAM) and negative phase in the Pacific-South American mode 2 (PSA2) contribute to the negative anomalies in the Ekman transport.

1. SAMOC estimates combining satellite and in situ observations

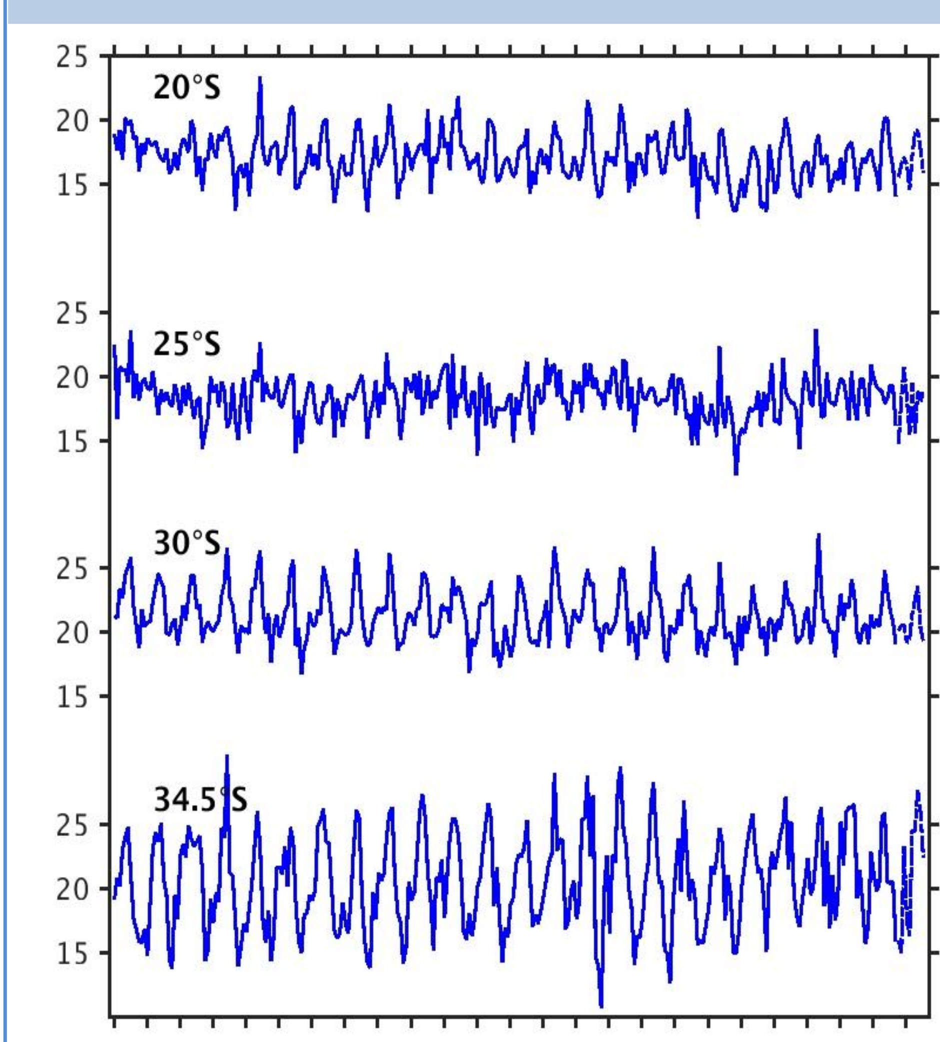

Figure 1. Time series of the South Atlantic MOC derived from a combination of satellite altimetry and in situ measurements (methodology described in Dong et al. 2015).

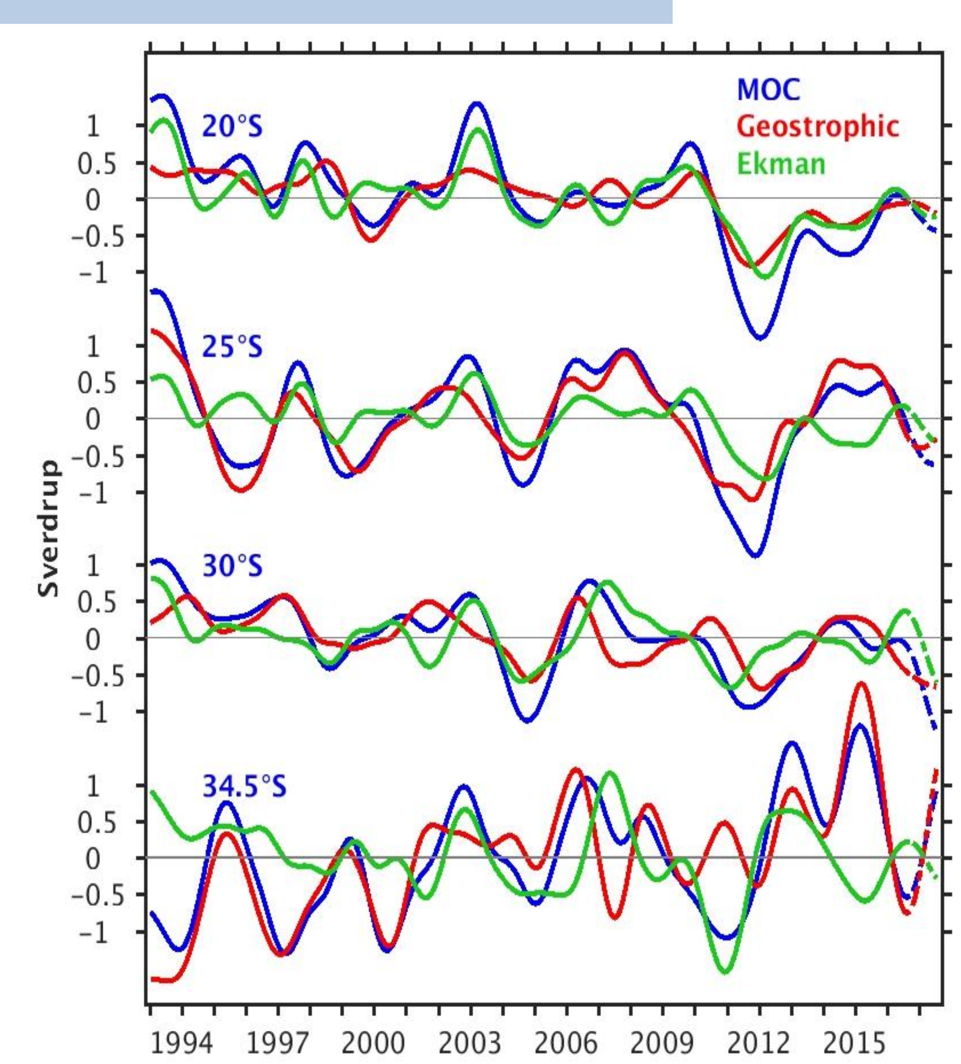

Figure 2. Interannual variations of the MOC (black) and contributions from the geostrophic (red) and Ekman (green) components. A low-pass filter was applied to remove signals with periods less than a year.

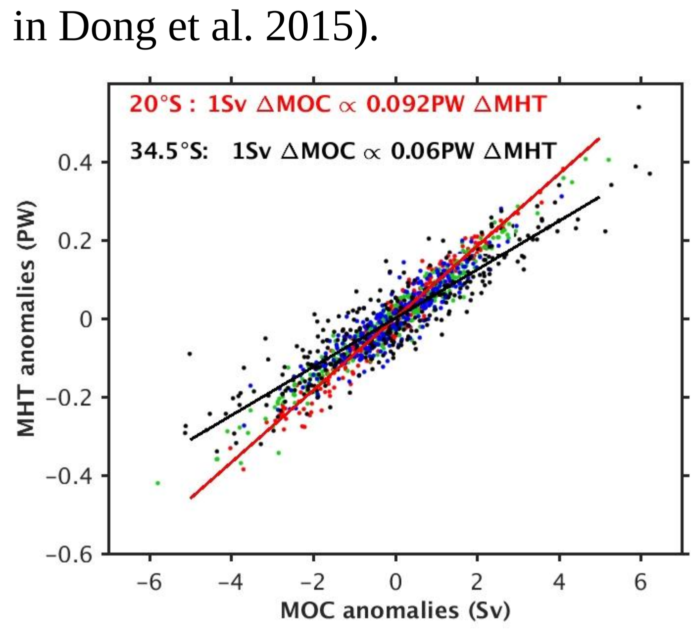

Figure 3. Scatterplot of MHT against MOC.

- Statistically significant correlations of the MOC interannual variations are found from 20°S-30°S (correlation varies between 0.62 to 0.82), but not with 34.5°S.
- Maximum variability at 34.5°S, twice as large as that at 20°S.
- Strong seasonal variations at 34.5°S and 30°S.
- Linear relationship between MOC and MHT, response of MHT to MOC strengthens northward (Fig.3).

2. Heat content in the South Atlantic (20°S-35°S)

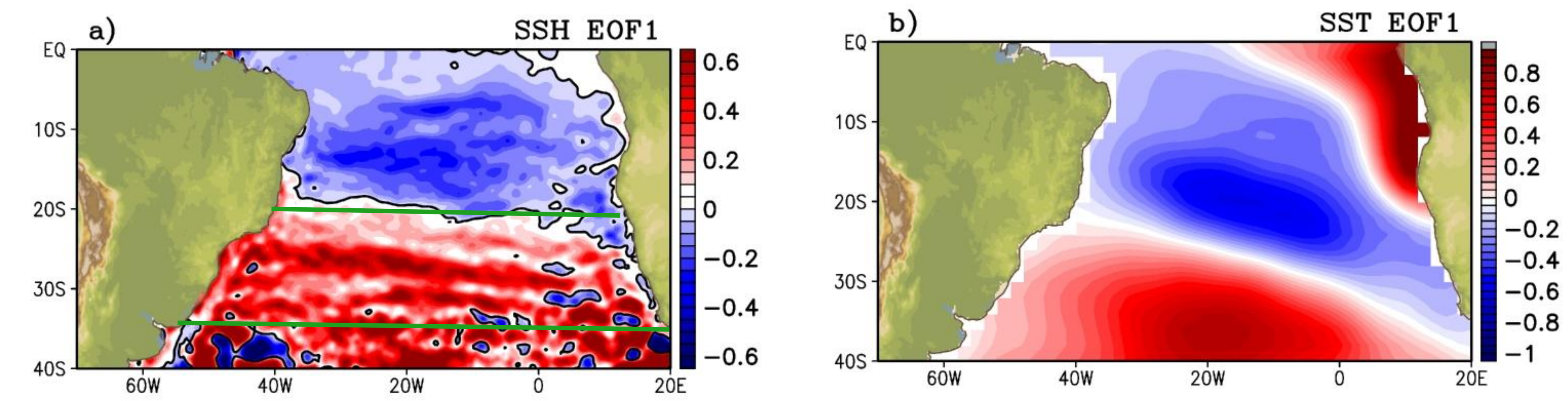

Figure 4. The first EOF mode in SSH and SST in the South Atlantic shows the South Atlantic Subtropical Dipole (SASD), the dominant mode of coupled ocean-atmosphere variability, plays an important role for South America Monsoon and South Atlantic convergence zone.

SAMOC and SASD are highly correlated (Lopez et al., 2017).

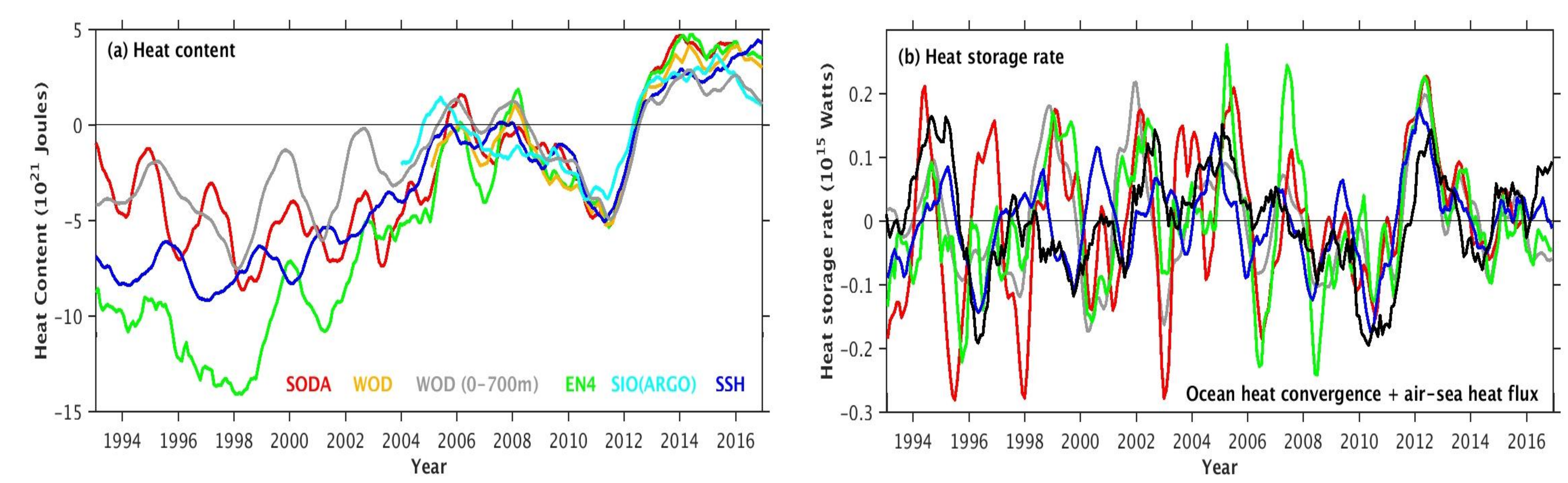

Figure 5. Interannual variations in (a) ocean heat content and (b) heat storage rate in the region 20°S-35°S.

- Good agreement among various products during Argo period since 2004, but large differences are seen during pre-Argo period.
- Large heat deficit during 2009-2012.

3. What causes the heat deficit during 2009-2012?

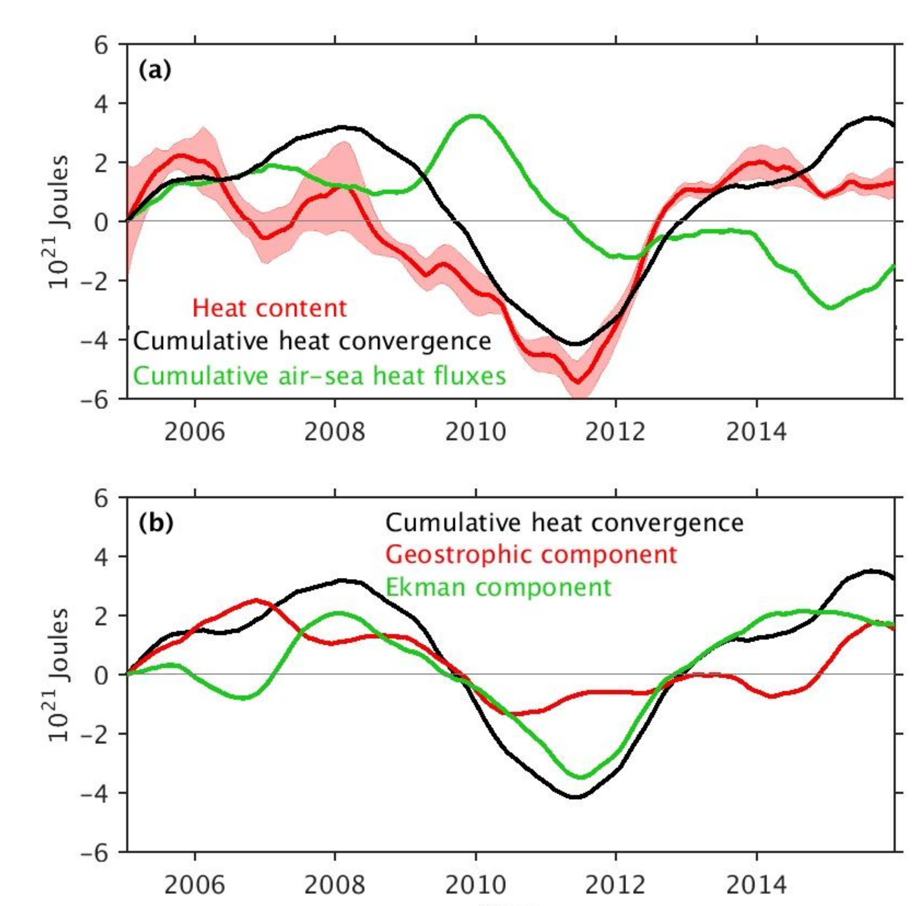

Figure 6. (a) Changes in ocean heat content (20S-35S, red) and contributions from ocean heat convergence (black) and surface air-sea heat flux (green). (b) Cumulative ocean heat convergence (black) and its geostrophic (red) and Ekman (green) components.

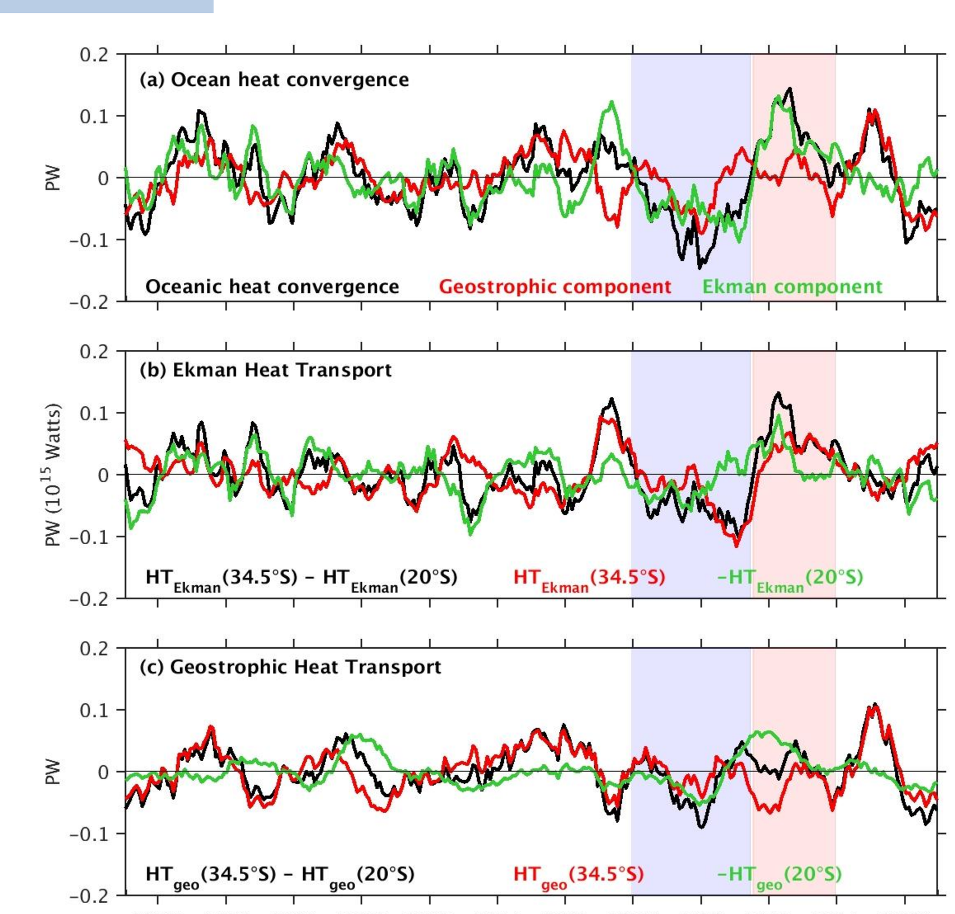

Figure 7. Interannual variations in (a) ocean heat convergence (MHT_{35S}-MTH_{20S}, black) and contributions from the geostrophic (red) and Ekman (green) components. (b) Ekman heat transport convergence (black) and Ekman heat transport across 20°S (green) and 35°S (red). (c) Similar as (b) but for the geostrophic heat transport.

Ekman transport through 35°S is the largest contributor to the 2009-2012 heat deficit.

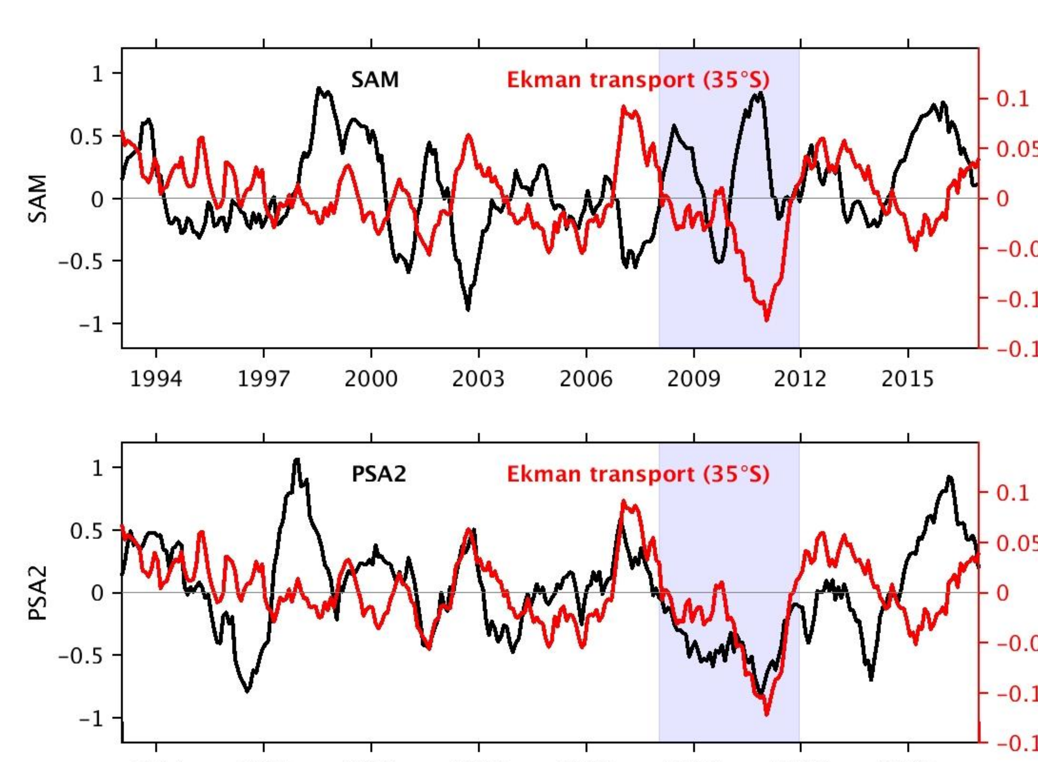

Figure 8. Time series of (a) the Southern Annular Mode (SAM) and (b) the Pacific-South American mode 2 (PSA2), and Ekman heat transport across 35°S (red).

Both the positive phase in SAM and negative phase in PSA2 contribute to the negative anomalies in the Ekman transport across 35°S.

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