The Meridional Overturning Circulation in the South Atlantic from Observations and Numerical Models

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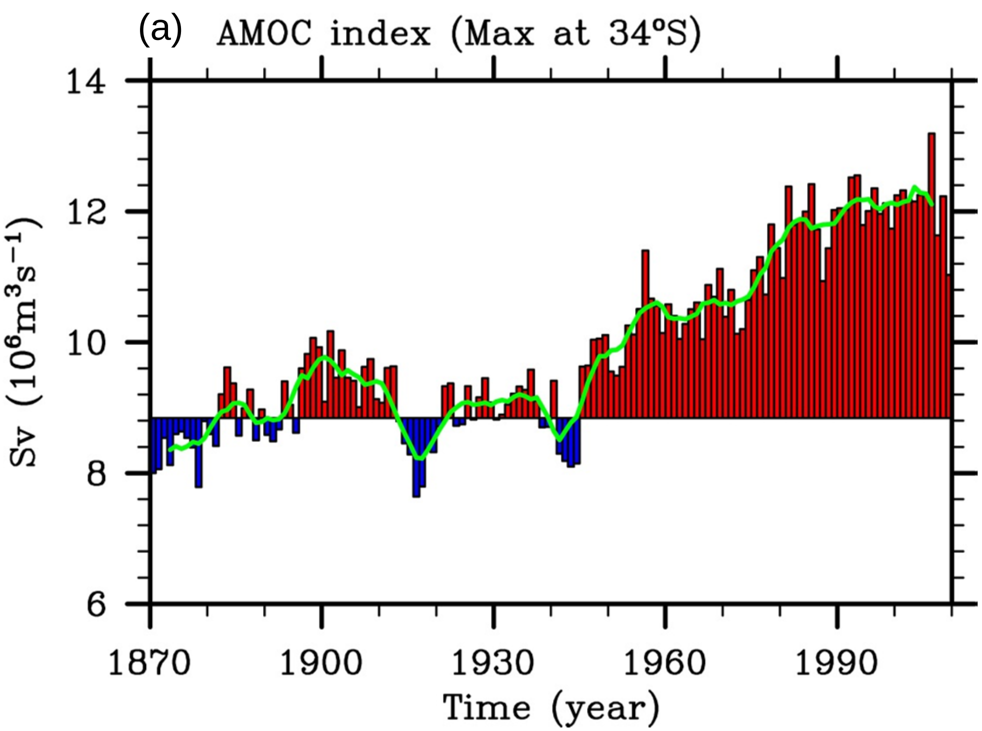
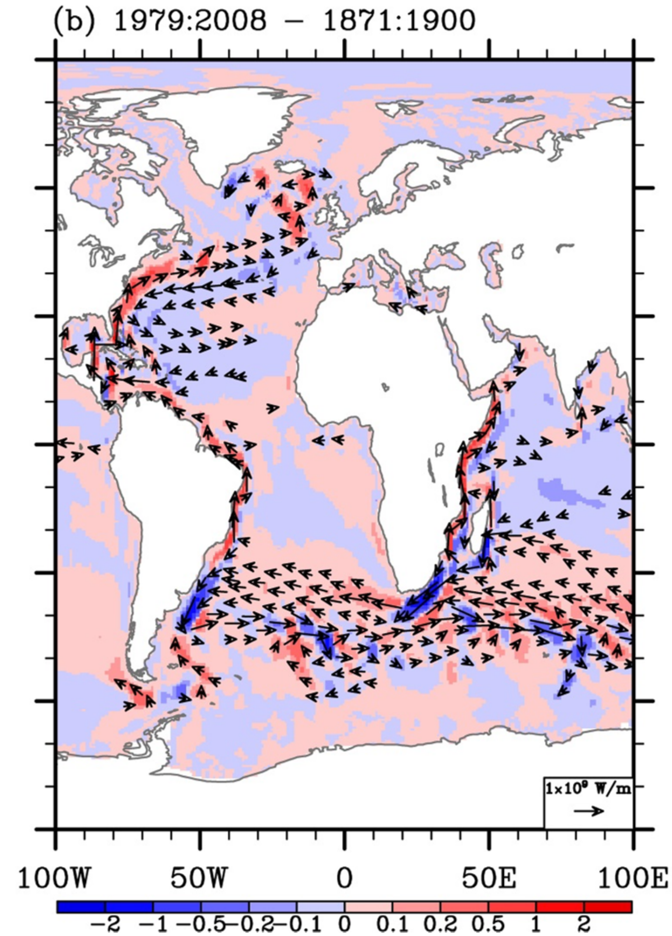
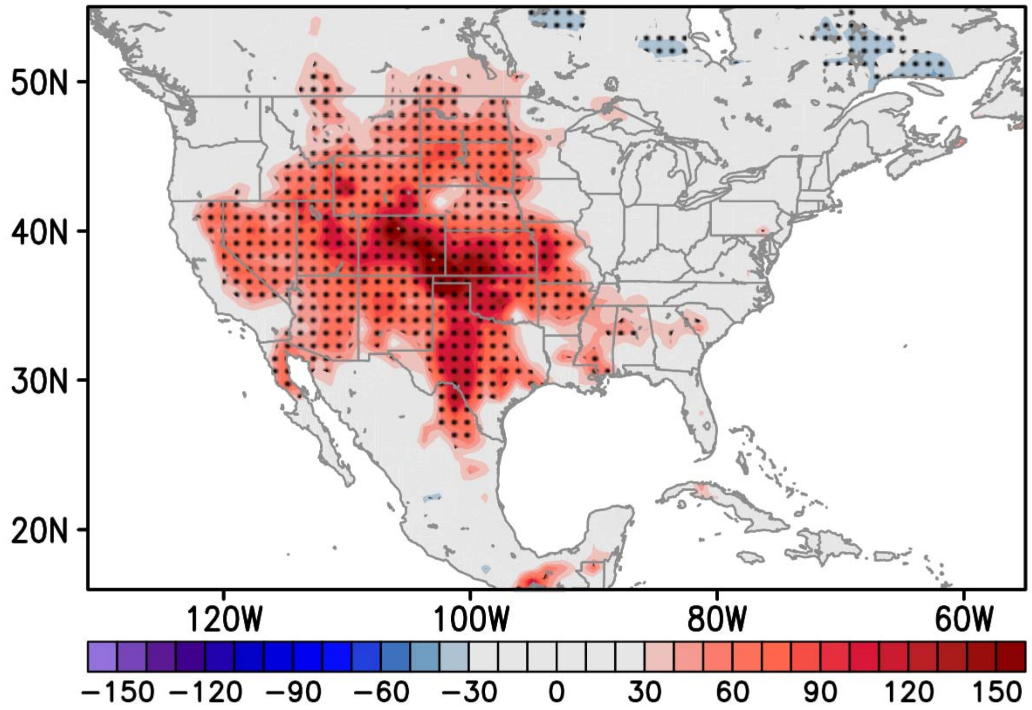
Motivation: Impact of SAMOC on Atlantic warming





- Lee et al. (2011): 20th century global ocean simulation shows an important role played by SAMOC on the rapid warming of the Atlantic Ocean since the 1950s.

Motivation: Impact of SAMHT on Extreme Weather

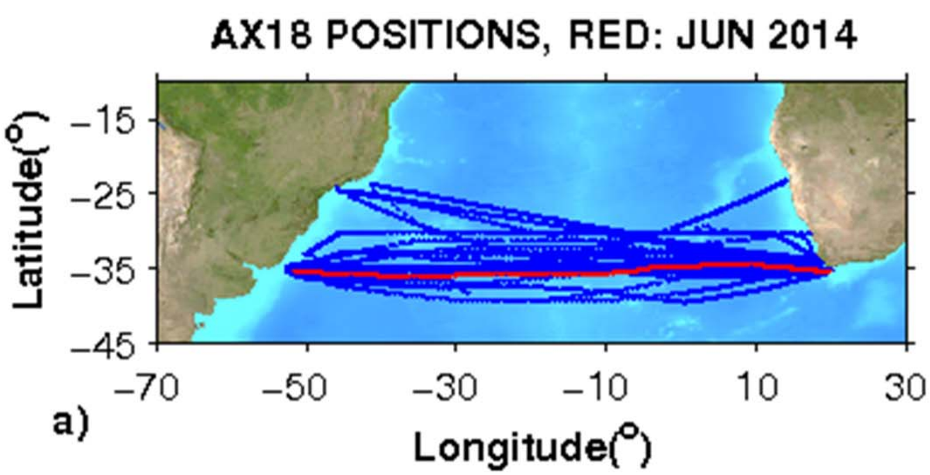


Composite difference of the number of heat wave days during weak minus strong SAMHT. Stipples indicate 95% confidence. The composite difference is normalized by the total number of heat waves days and multiplied by 100 to show as percentage change.

Most of the increased in heat wave occurs over the western half of the US. This argues that the AMOC is an important component of internal climate variability that modulates heat waves

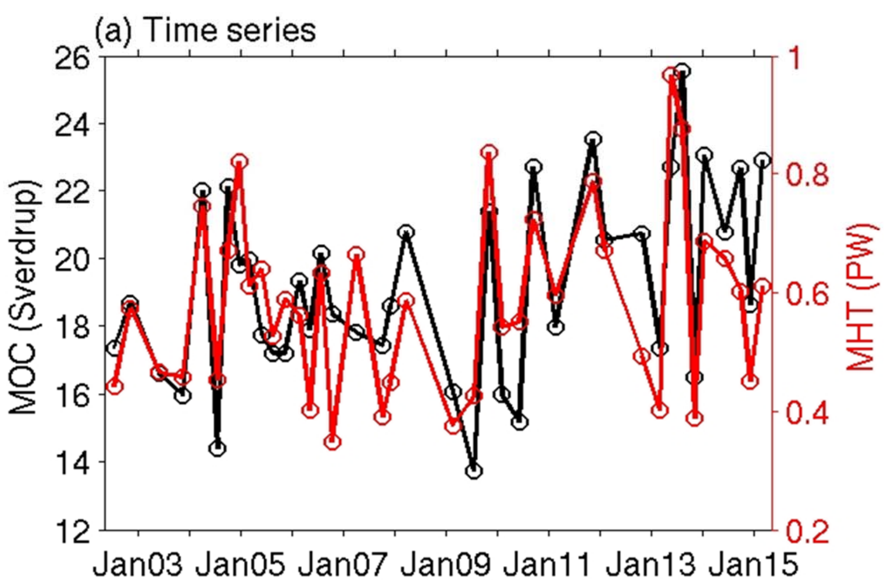
(*Provided by Hosmay Lopez*)

High-Density XBT Transect along 34.5°S

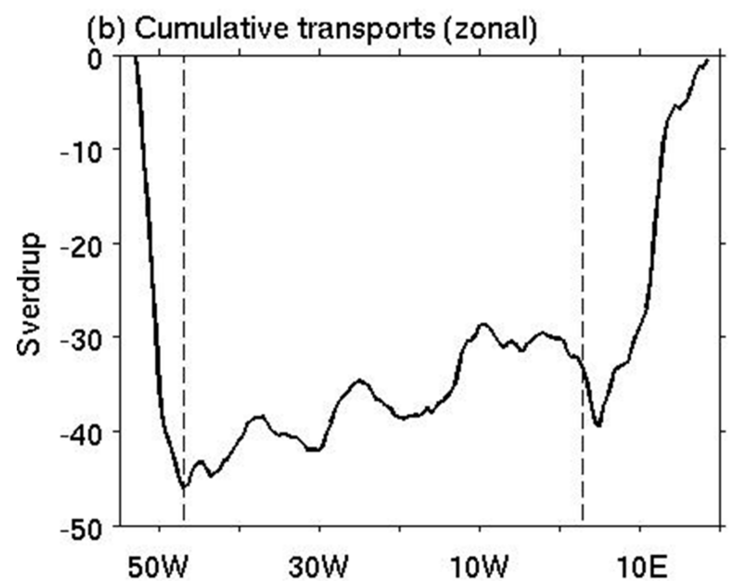


The overall objective of the AX18 (2002-present) is to monitor the upper limb of the MOC in the South Atlantic.

- 42 transects, provide the first MOC/MHT time series over 13 years in the S. Atlantic.
- Examine the MOC/MHT in the S. Atlantic.
- Evaluate performance of numerical models in simulating the S. Atlantic MOC/MHT.



Well correspondence between MOC and MHT across AX18.



Strong boundary current transports.

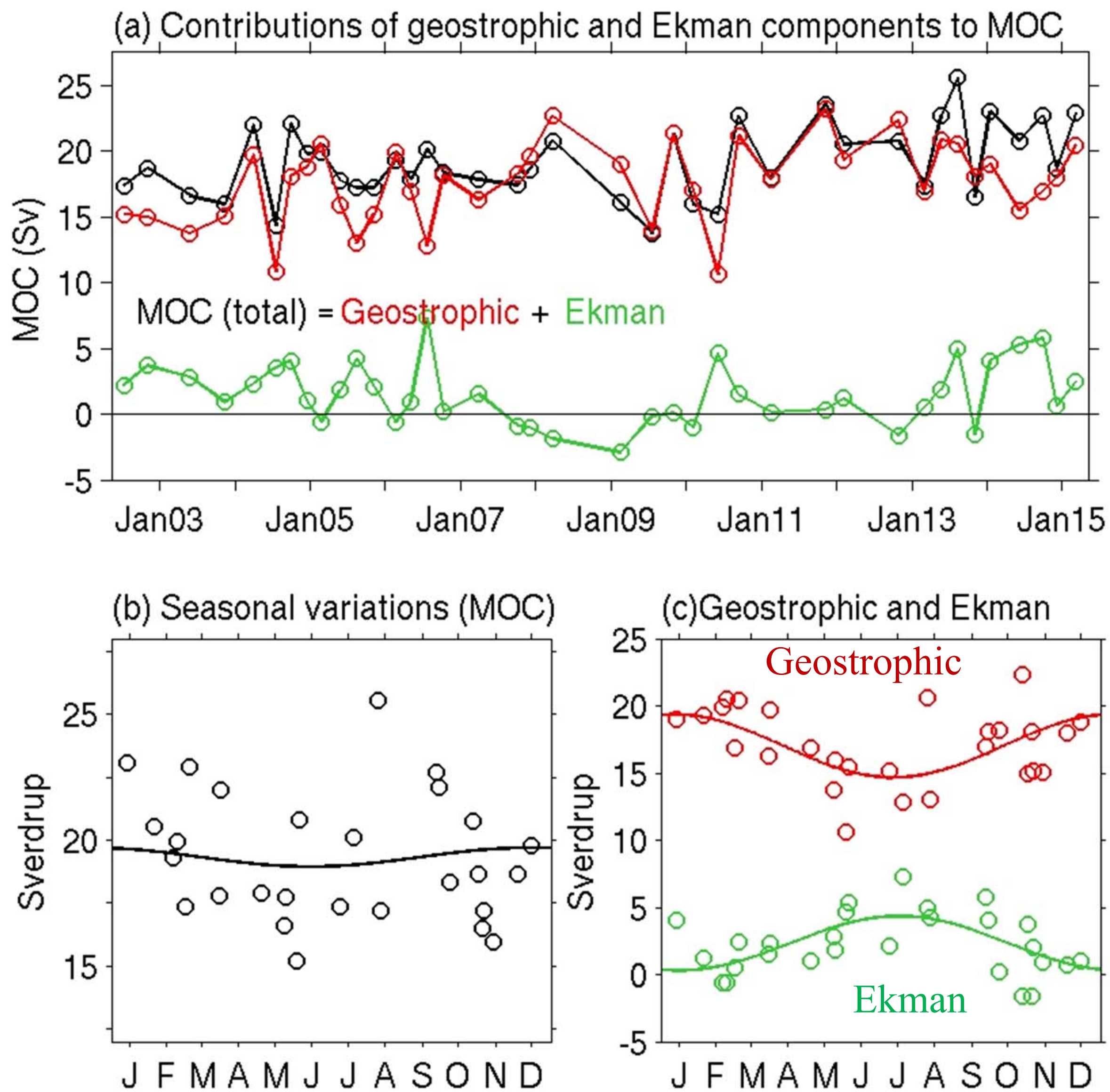
MOC and MHT from XBT Transect AX18

MOC: 19.16 ± 2.80 Sv

Geostr.: 17.63 ± 3.12 Sv

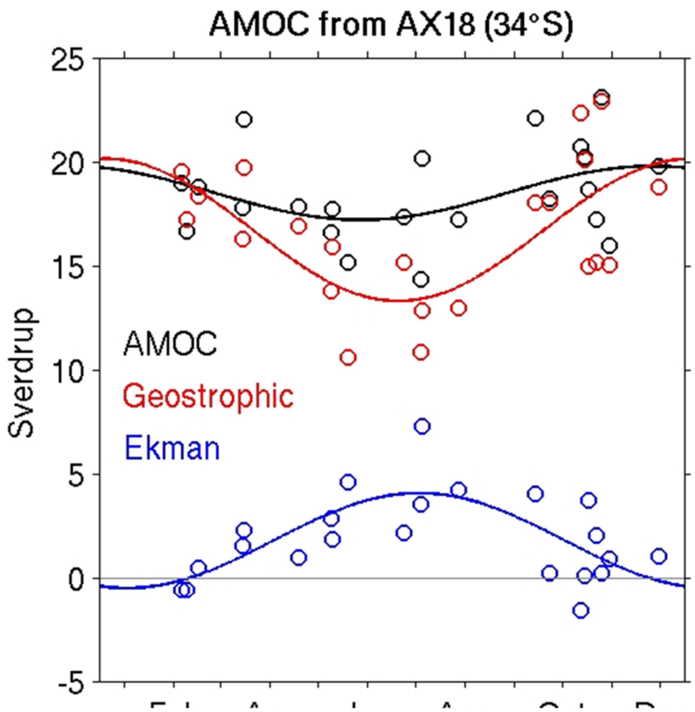
Ekman: 1.53 ± 2.36 Sv

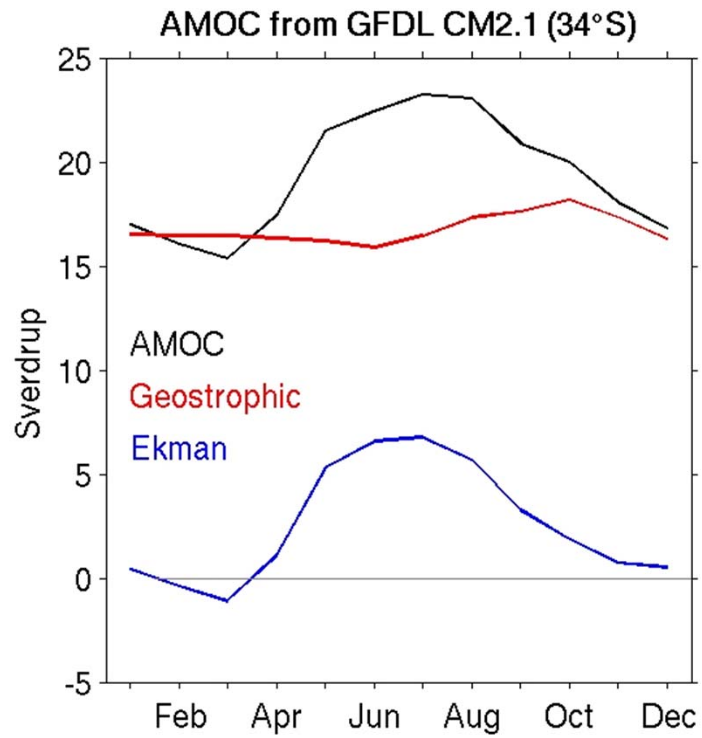
- Time-mean AMOC is dominated by geostrophic component.
- Both geostrophic and Ekman components are important in explaining the AMOC variability.
- Both geostrophic and Ekman contributions to the AMOC experience annual cycles, but they are out of phase.

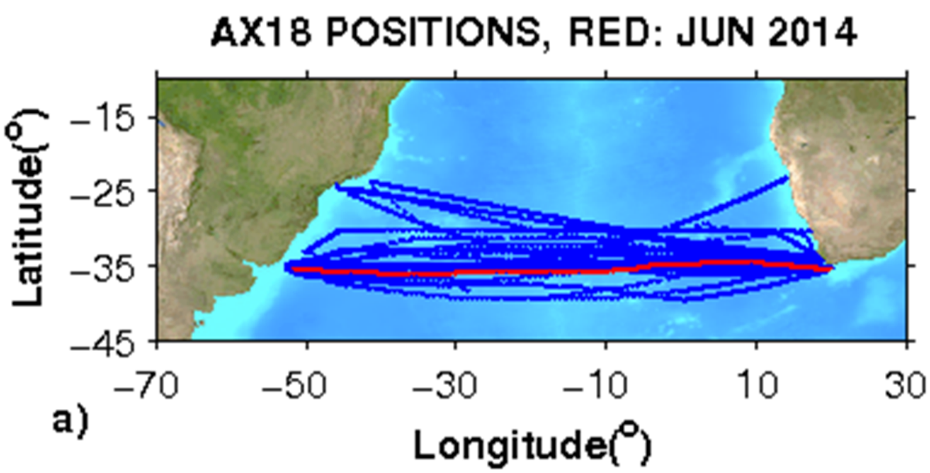


Dong et al., 2009

Seasonal Variations in the MOC







The Annual cycle in the MOC is dominated by Ekman component, and the geostrophic component shows little seasonal variations.

Model-data Comparison: Seasonal Variations

Goal:

To investigate what causes the differences in the MOC seasonal variations estimated from observations and numerical models.

Methodology

➢Monthly climatologies of T/S on a 1° longitude grid along 34°S are constructed both from observations (Argo/WOA13) and numerical models (last 50-year output) to estimate the geostrophic transport.

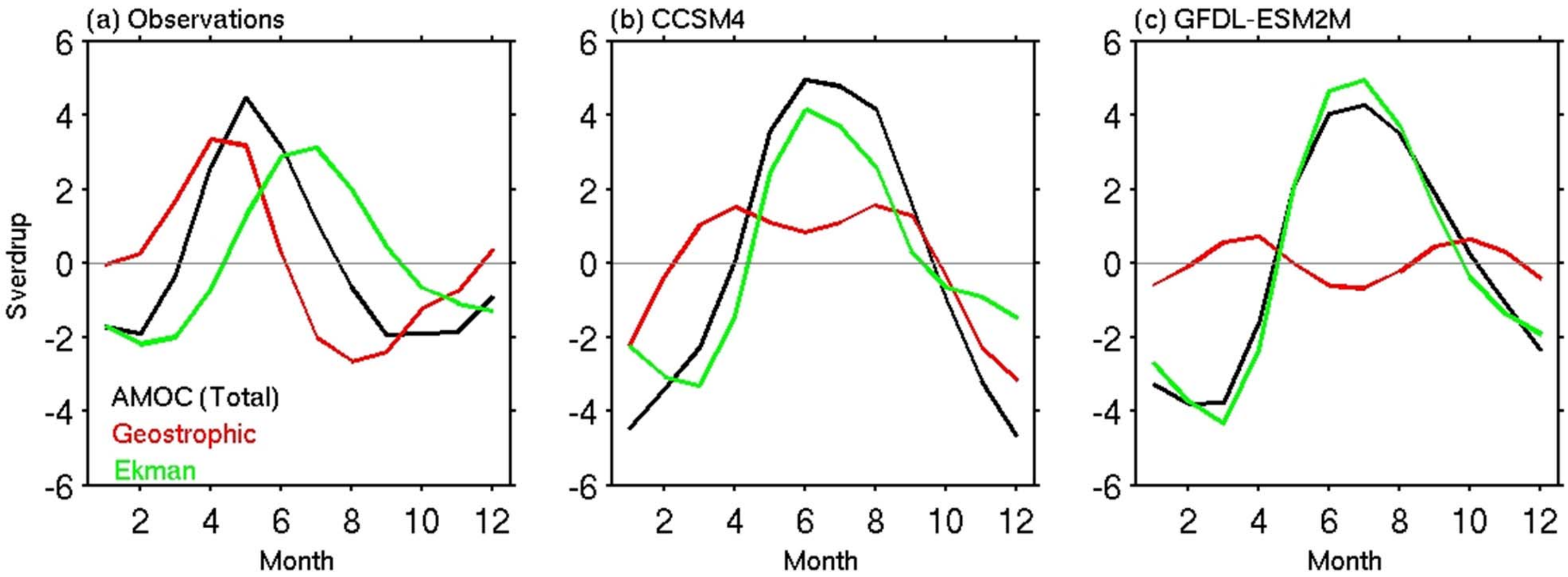
Two CMIP5 models are used: NCAR CCSM4 and GFDL ESM2M

➢Argo drifting velocity at 1000 m as reference velocity for the observations study. The mean velocity at 1000 m from corresponding models are used in model studies.

➢The Scatterometer Climatology of Ocean Winds (SCOW) is used to compute the Ekman transport in the observational study, and the Ekman transport for each model is derived from the zonal wind stress output of the corresponding model.

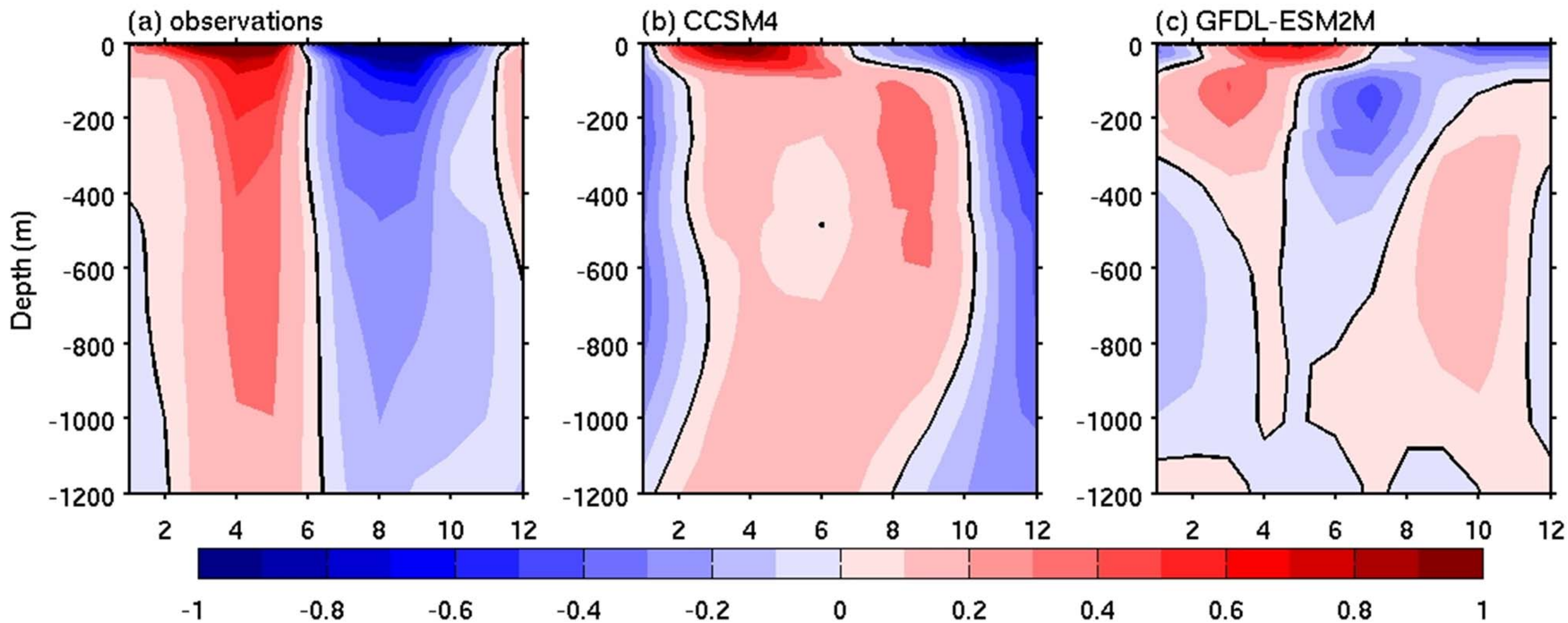
Dong et al., 2014

Seasonal Variations in the MOC at 34°S



- Observational estimates suggest that geostrophic and Ekman transports contribute equally to the seasonal variations in the MOC. But in the models, Ekman transport dominates.
- The modeled Ekman transport show stronger seasonality than observations.

Model-data Comparison: zonally-averaged meridional velocity



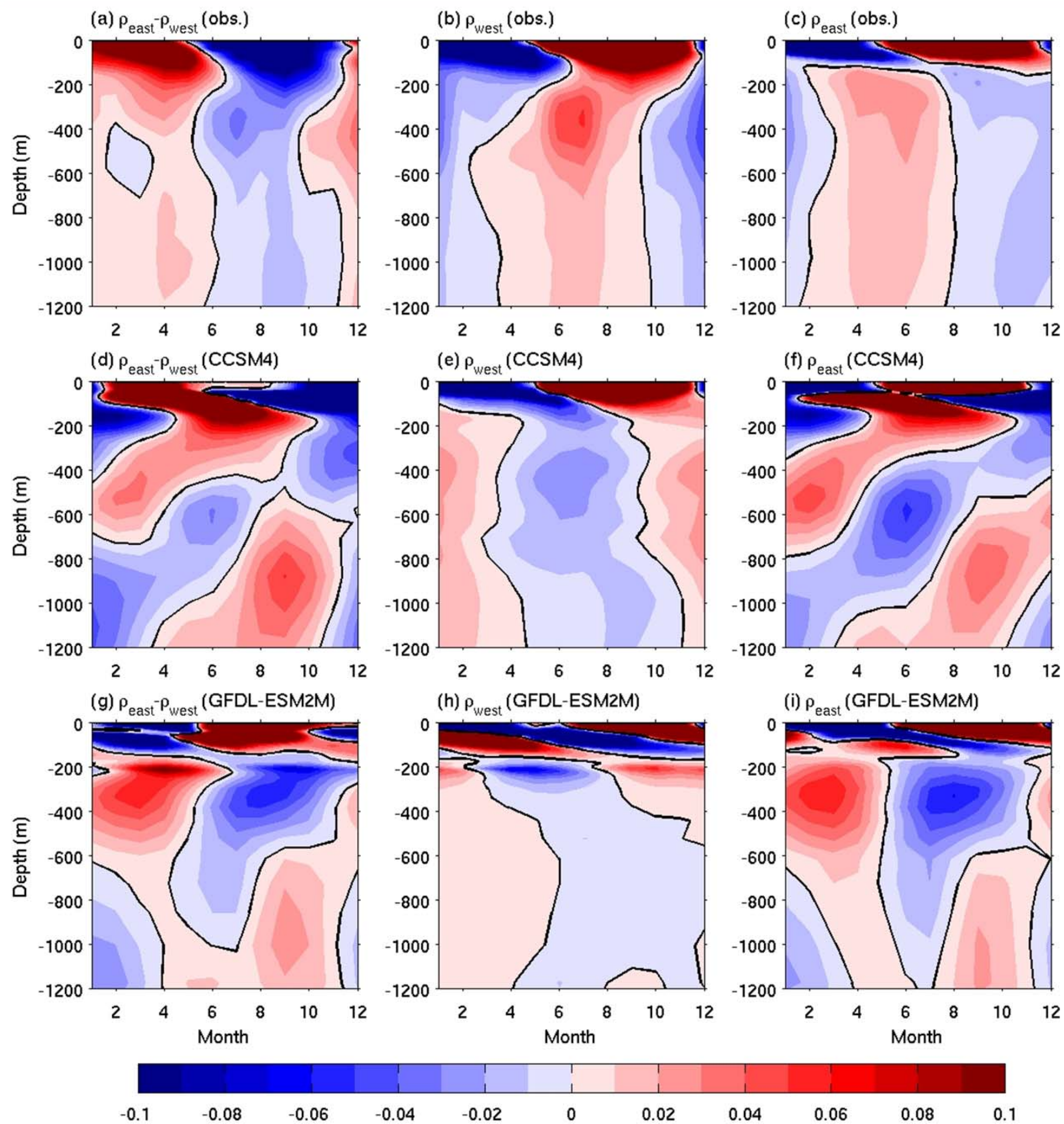
- ❖ Geostrophic velocity from observations shows vertically coherent seasonal variations, resulting strong seasonal variations in the upper-ocean geostrophic transport.
- ❖ Geostrophic velocity from the model T/S climatologies do not exhibit this type of vertically coherent seasonal cycle.

Dong et al., 2014

Density at the Eastern and Western Boundaries and Their Differences

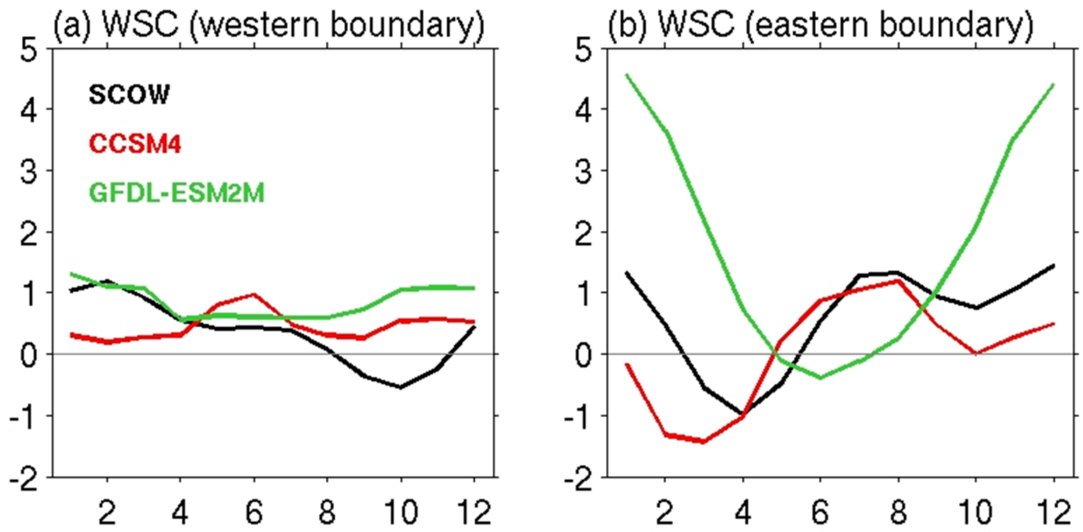
The observed east-west density difference is largely controlled by the western boundary, whereas in the coupled models, the eastern boundary dominates.

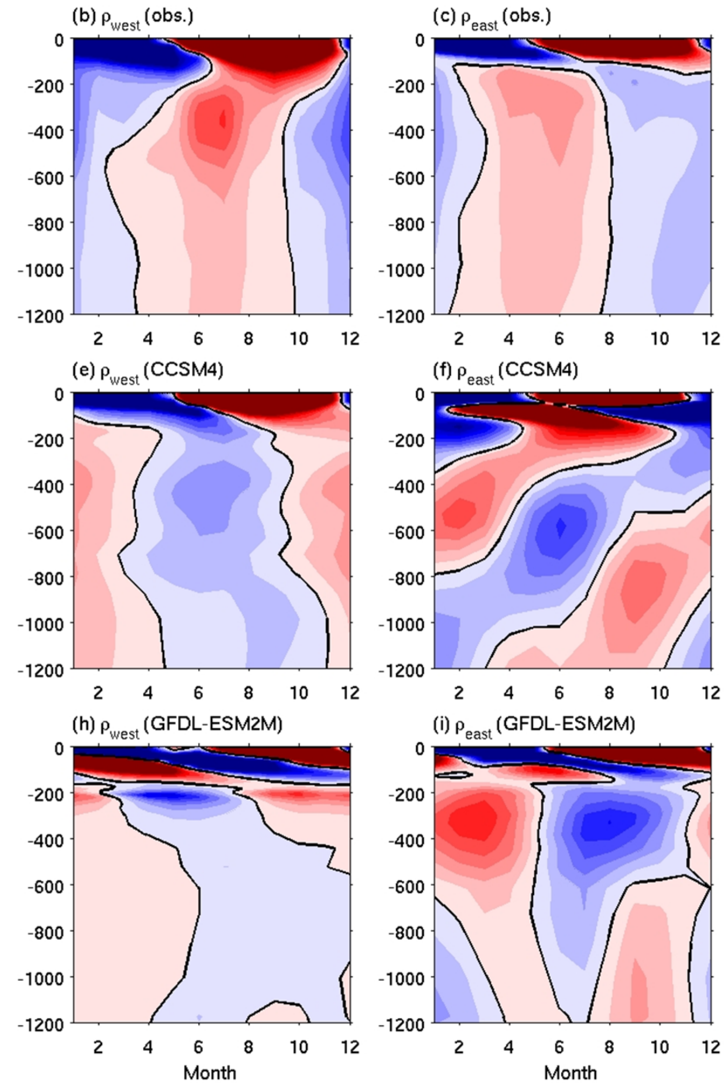
The strong baroclinicity at the base of the mixed layer in the model fields results in out-of-phase variations above and below this shear layer, which contributes to the weaker seasonality in the modeled geostrophic transport.



Dong et al., 2014

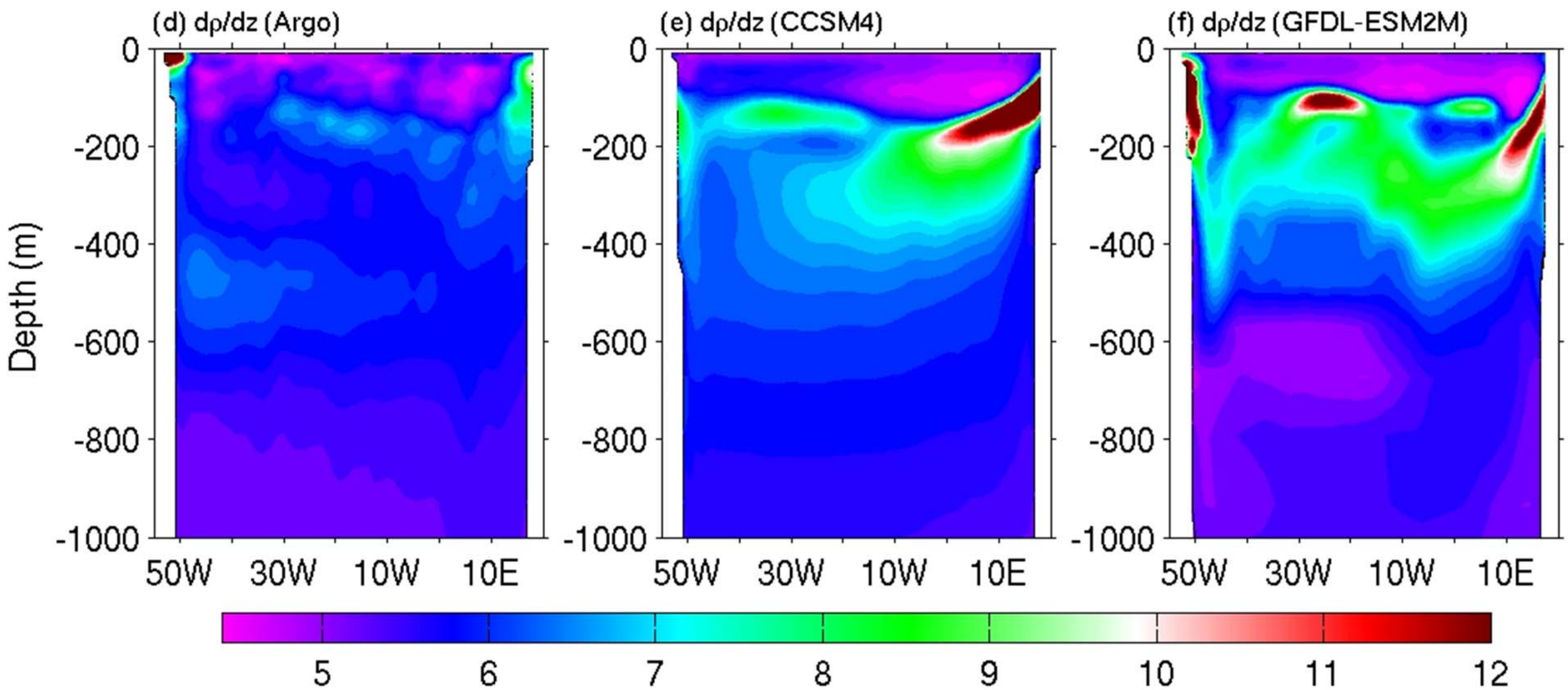
Wind Stress Curl at Boundaries





- Seasonal variations in the WSC at the western boundary is very weak.
- WSC at the eastern boundary may play a role in the seasonal variations of the observed subsurface density.
- WSC at the eastern boundary from GFDL model show strong seasonal variations. However, it can not explain changes in density.

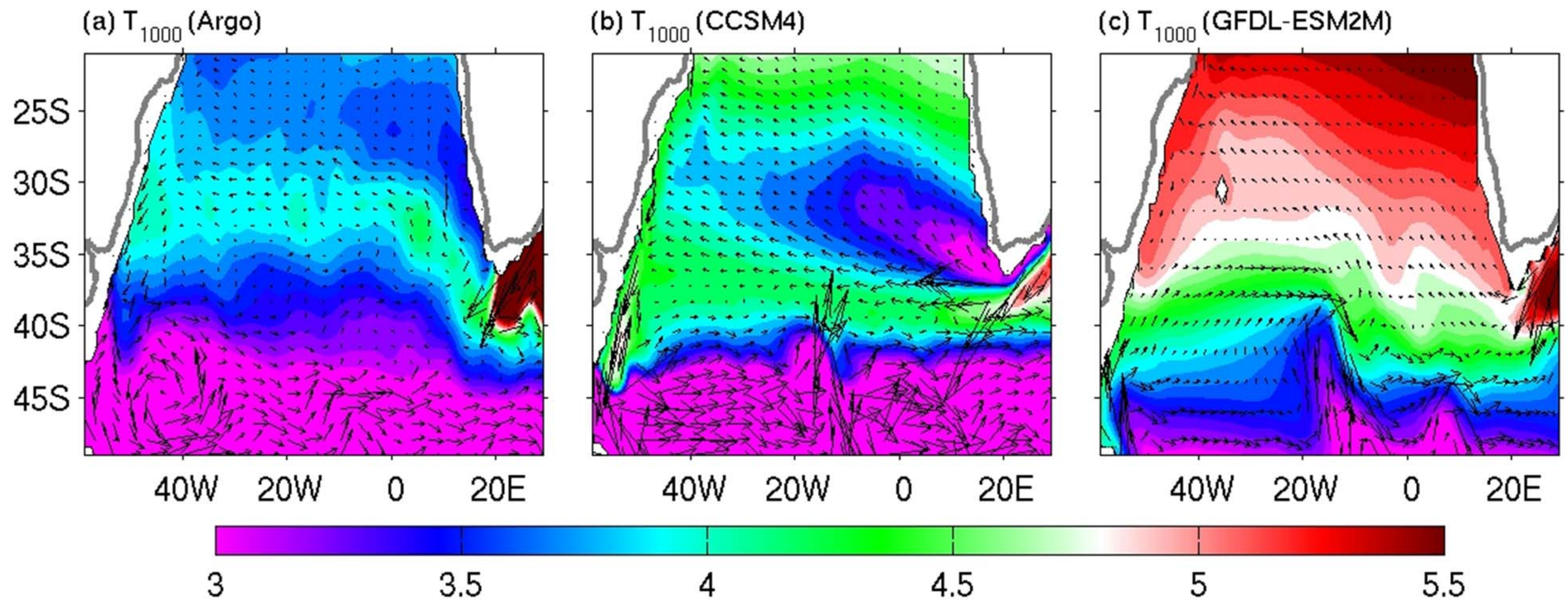
Model-data Comparison: vertical density gradient



The enhanced baroclinicity in the models is possibly due to the strong stratification in the modeled T/S fields. Vertical density gradient shows large model biases in the vertical stratification from 100 m to 500 m depth, particularly toward the eastern boundary.

Dong et al., 2014

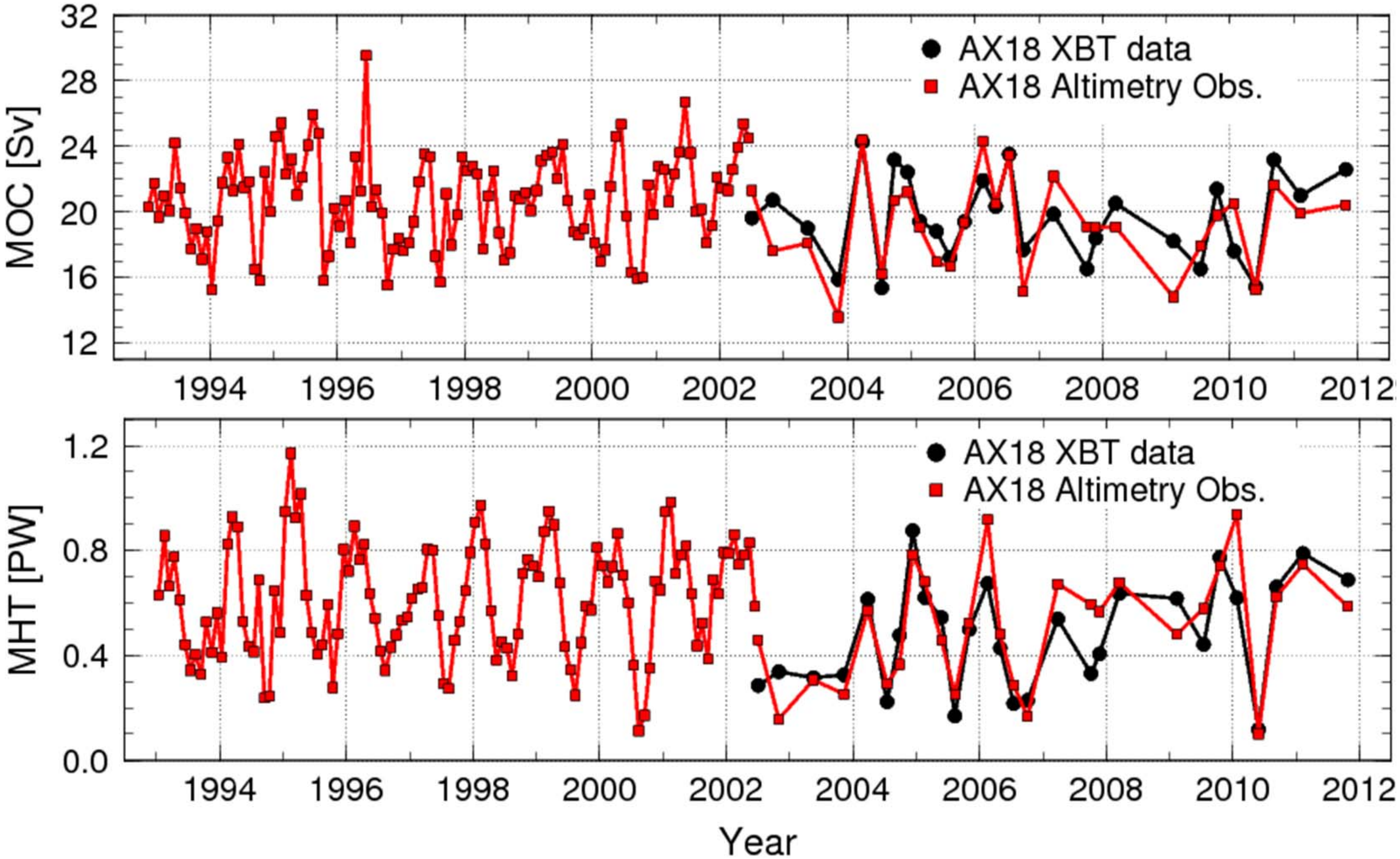
Model-data Comparison: temperature at 1000 m depth



The isotherms near the coast experience a stronger northward displacement during austral winter, when the northward flowing Malvinas Current is stronger and the southward flowing Brazil Current is weaker, and weaker displacement during austral summer, when the Malvinas Current is weaker and the Brazil Current is stronger. This seasonality of the currents is induced by the seasonal variations of the wind-driven gyre circulation. This is consistent with the observed positive density anomalies at the western boundary along 34° S during austral winter and negative anomalies during austral summer.

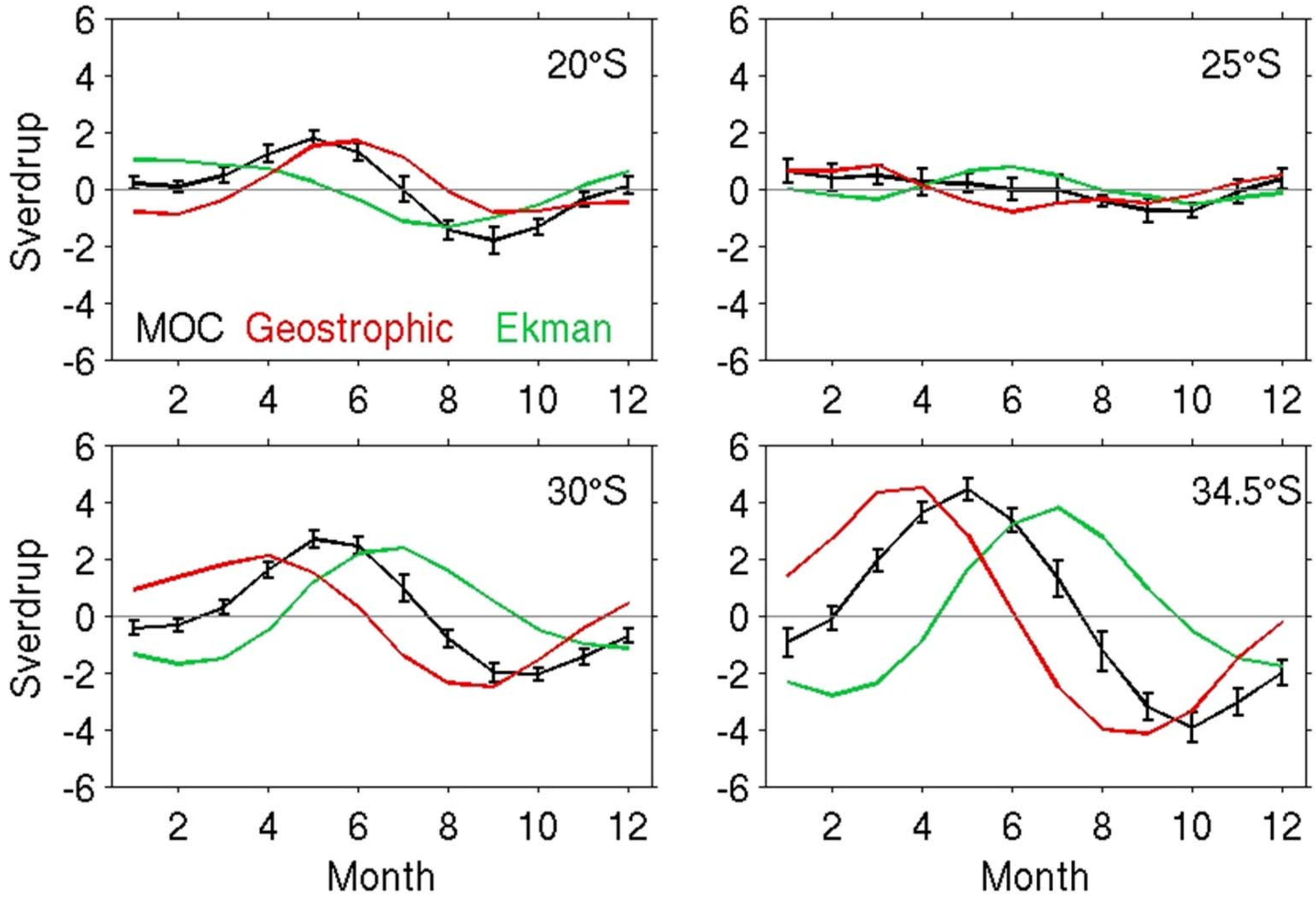
Altimetry-derived MOC/MHT at 34.5°S
Altimetry-XBT comparison

- **T(z) derived from satellite altimetry.**
- **S(z) derived from T(z)-S(z) look up tables built using profiles from all available CTD and Argo observations.**



Dong et al., 2015

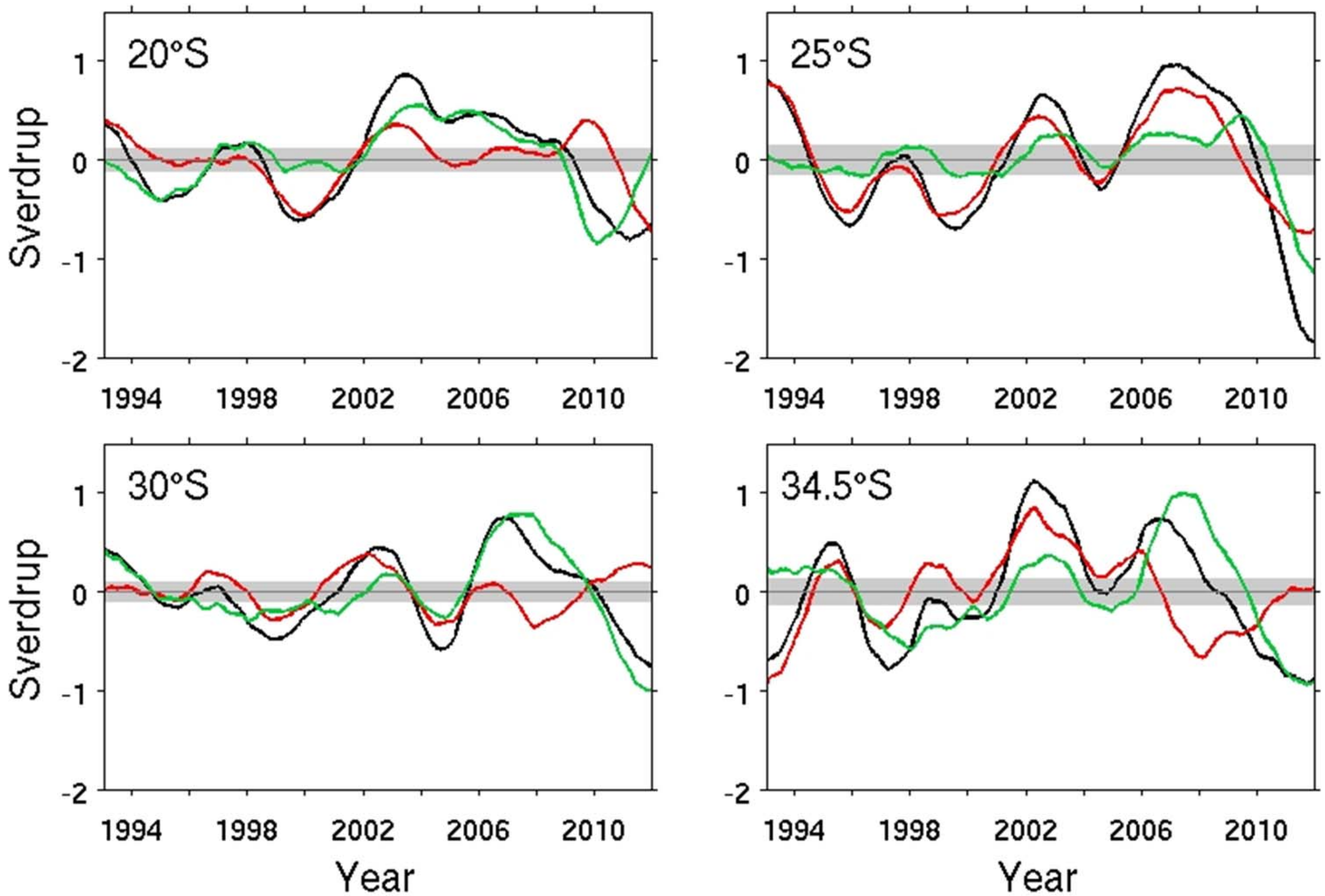
Altimetry-derived MOC: Seasonal Variability



- Both the Ekman and Geostrophic components experience seasonal variations.
- The amplitude of seasonal variations decreases towards equator.

Dong et al., 2015

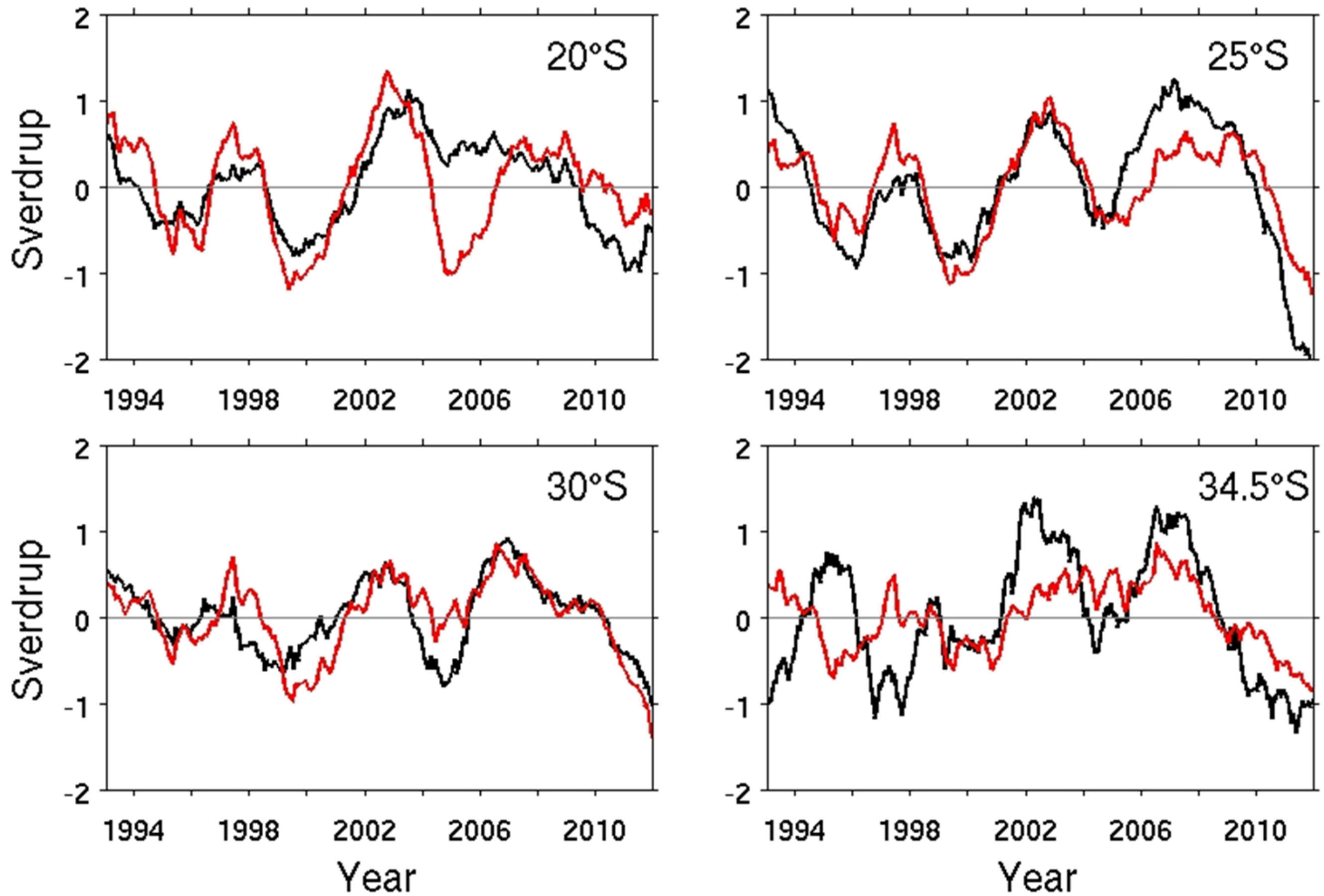
Altimetry-derived MOC: Interannual Variability



Geostrophic component dominates the MOC variations before 2006.
Ekman component dominates after 2006 (except 25°S).

Dong et al., 2015

Comparison with An Ocean Model Results



R = 0.59

R = 0.79

R = 0.80

R = 0.19

Good comparison between estimates from Altimeter and Model results at 20°S, 25°S, and 30°S, but not at 34.5°S.

Model: Global ocean-sea ice coupled model of the NCAR CESM1 forced with the 20th century Reanalysis surface forcing (S. Lee).

Conclusions

- Observational estimates suggest that the geostrophic transport plays an equal role to the Ekman transport in the MOC seasonal variations at 34.5° S, whereas in the models, the Ekman transport controls the MOC seasonality.

- The seasonality of the geostrophic transport from observations is largely controlled by the seasonal density variations at the western boundary, but in the models, the eastern boundary dominates.

- The observed density seasonality at the western boundary is linked to the intensity of the Malvinas Current, which is poorly reproduced in the models.

- The seasonality of the geostrophic velocity from observations show strong vertical coherence in upper 1200 m. The models lack this vertical coherence.

- Geostrophic component dominates the MOC variations before 2006, and Ekman component dominates after 2006.

References

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