Causes for Model-Data Differences in Seasonal Variations of the South Atlantic MOC

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Objective:

- Examine possible causes for the different seasonal variations in the South Atlantic MOC found between observations and model simulations.

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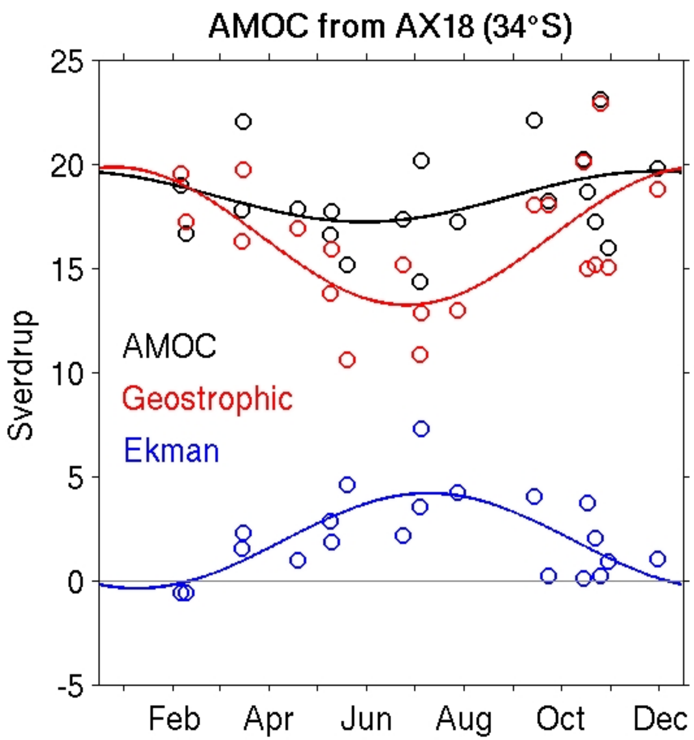
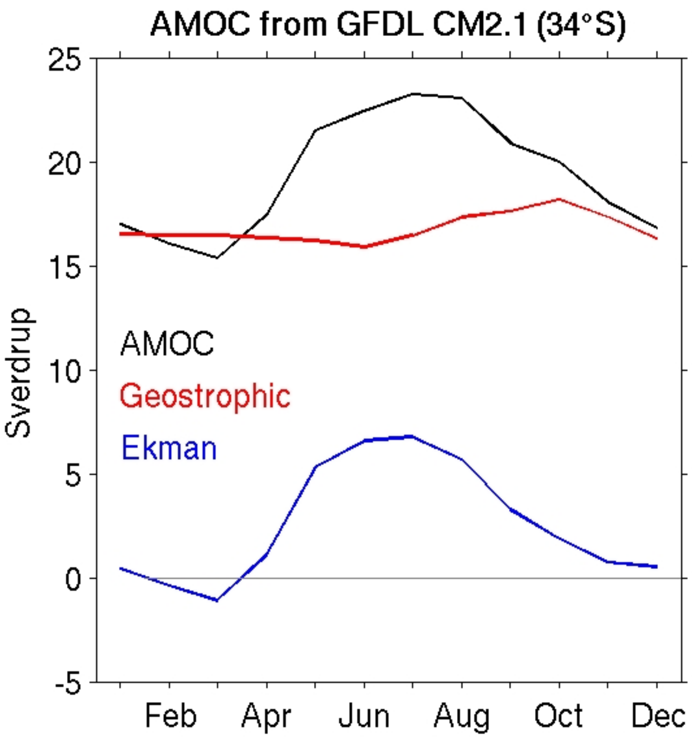
Seasonal Variations in the MOC at 34°S





Both geostrophic and Ekman contributions to the MOC experience annual cycles, but they are out of phase.

No significant seasonal cycle was found in the MOC.

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

Methodology

❖ **Determine MOC using monthly climatological T/S fields from observations and models.**

(1) Observations: Argo T/S fields in upper 2000 m (SIO, Roemmich and Gilson, 2009) and WOA climatology below 2000 m.

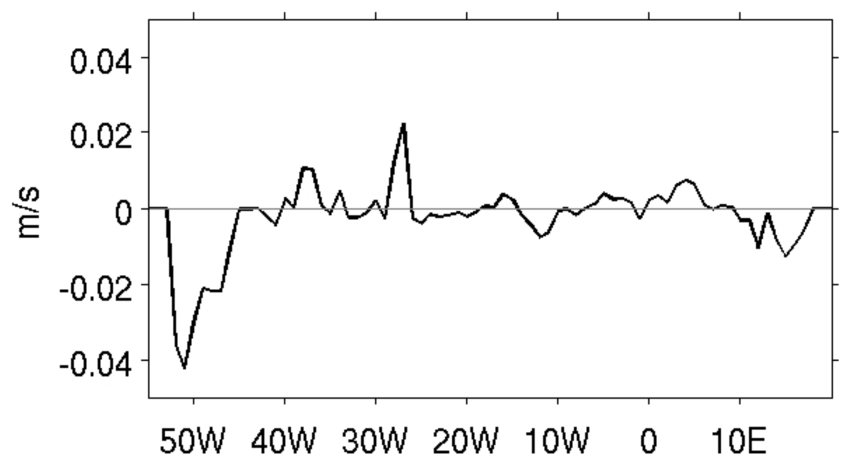
(2) Model: T/S monthly climatology constructed from GFDL CM2.1.

50 vertical layers, 1° longitude resolution, 1° latitude resolution from pole to 30° with zonal grid increases from 1° to 1/3° from 30° to equator

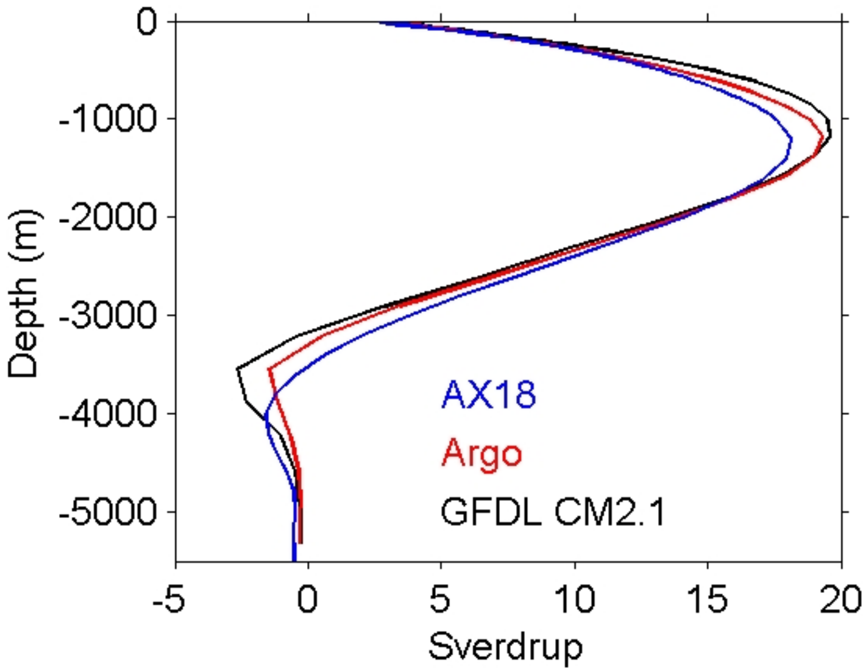
➢ Geostrophic type calculation with CM2.1 bottom velocity as reference velocity.

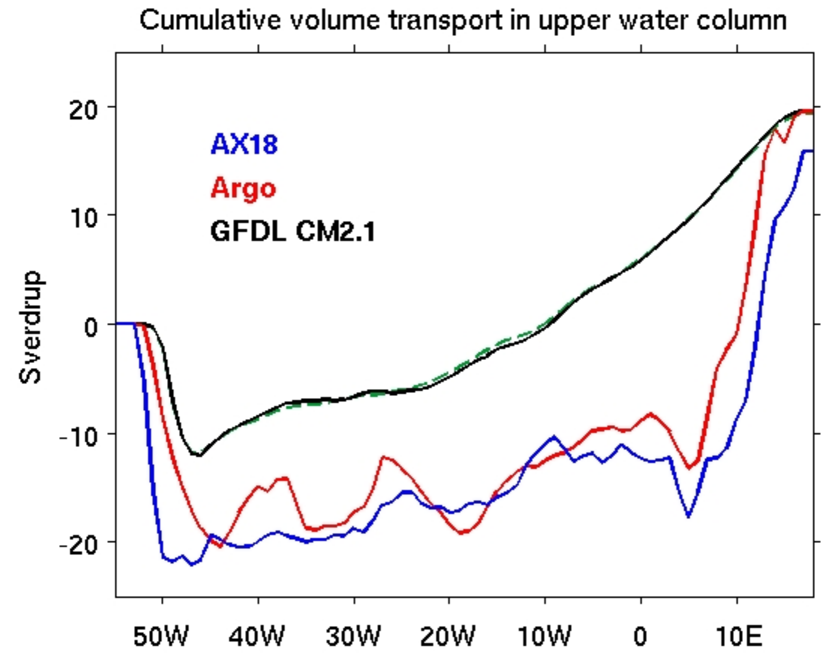
Net volume transport (geostrophic + Ekman) across the trans-basin section is set to be zero by adding a uniform velocity correction across the section.

Mean bottom velocity



Time-mean Cumulative Volume Transport

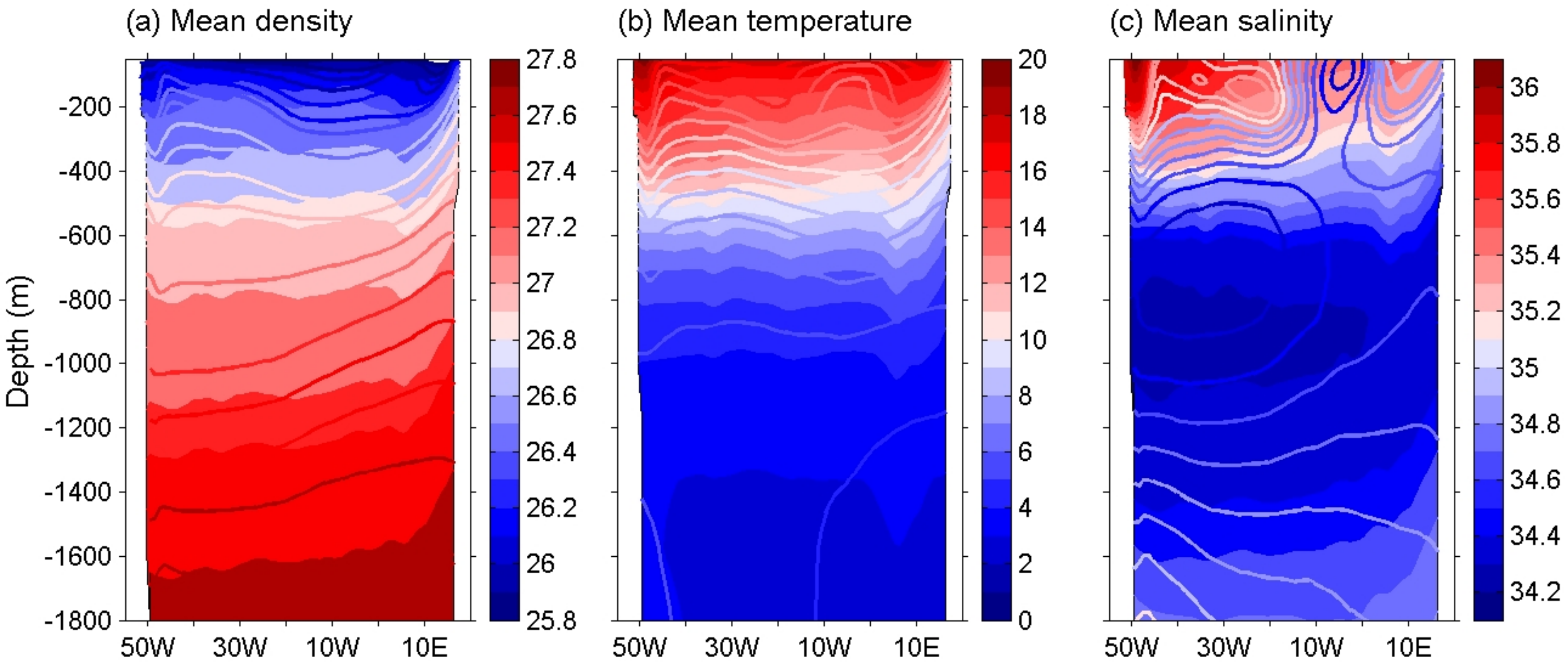




Compared to Argo estimates, estimates from model T/S fields show:

- weak transports in the eastern and western boundaries.
- strong northward transport in the interior region, particularly, east of 20°W.

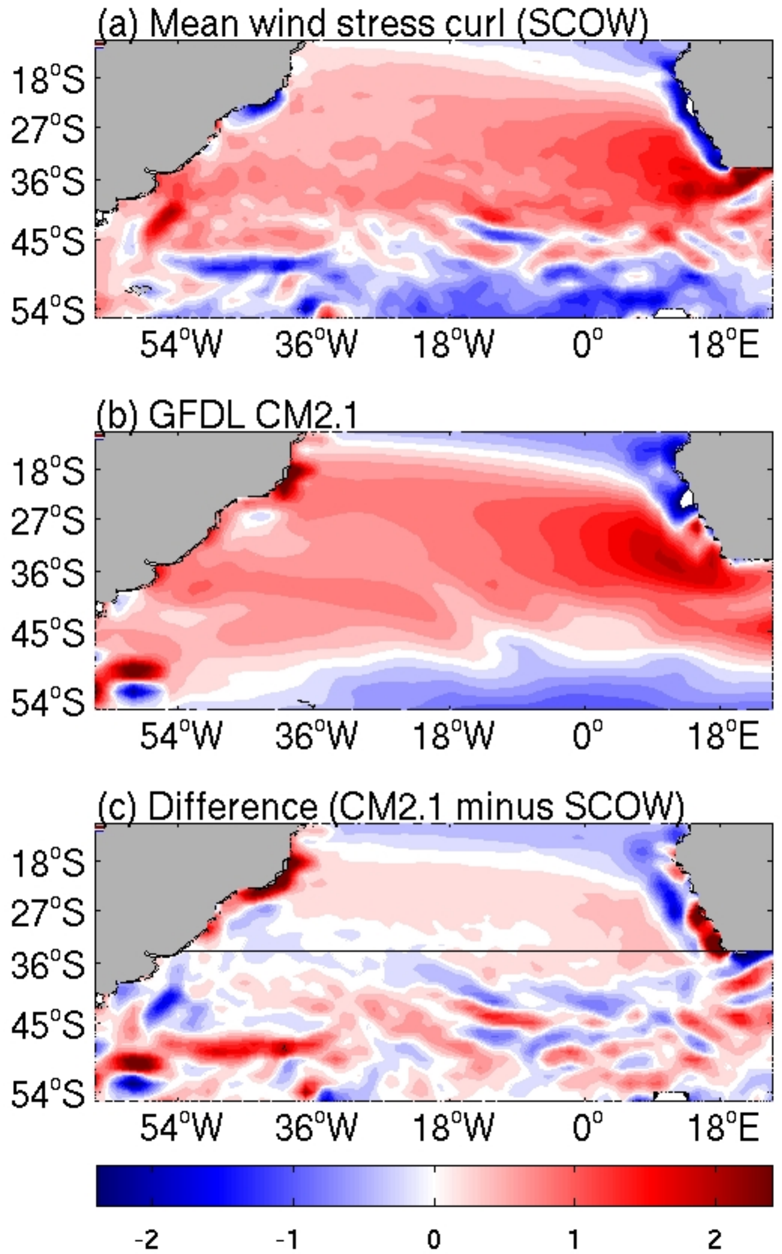
Mean Density, Temperature, and Salinity along 34°S



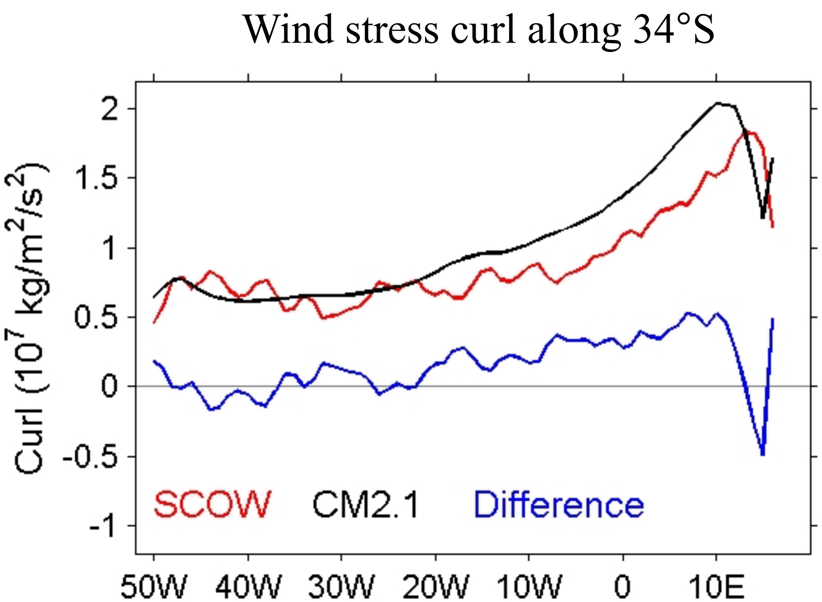
Color shading: Argo
Contour: GFDL CM2.1

- Strong upward slope between 20°W and 5°E, but weak upward slope east of 5°E.
- For Argo, T and S compensate each other in upper 1000 m with T dominates density structure. S dominates below that.
- For CM2.1, T dominates in upper 500 m and S dominates below.

Time-mean Wind Stress Curl

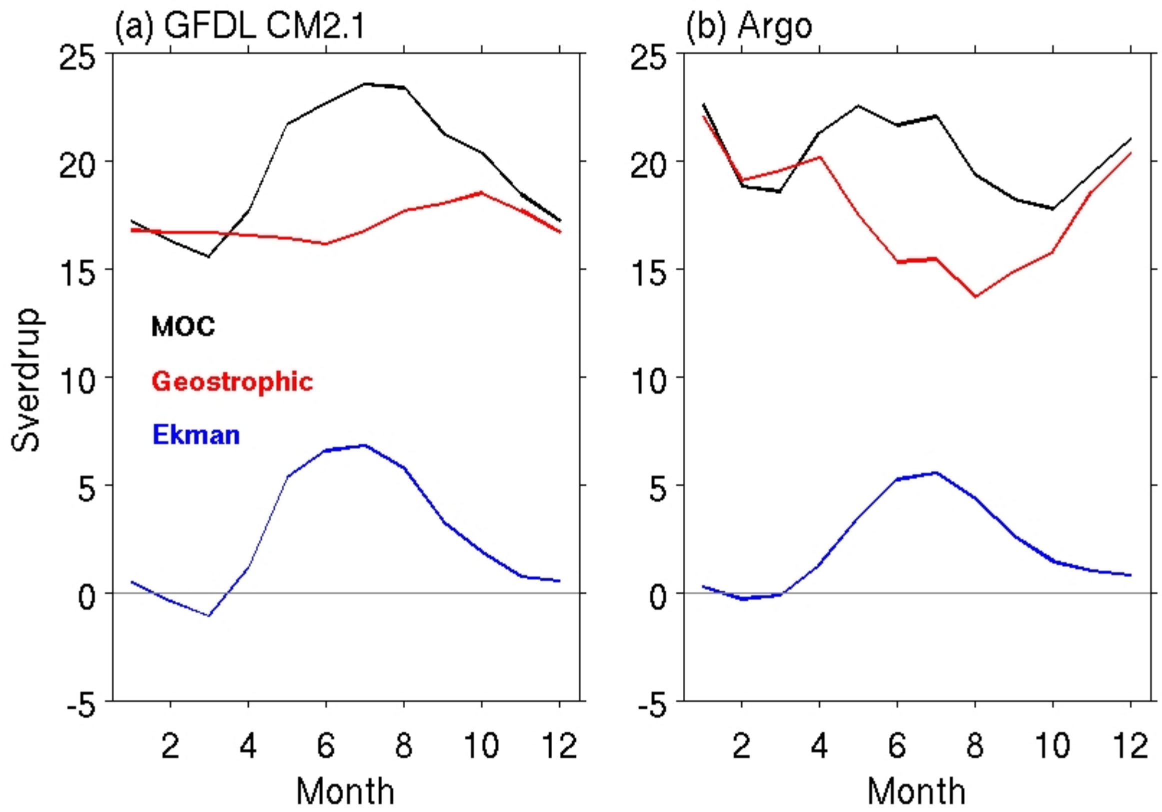


SCOW: Scatterometer Climatology of Ocean Winds (OSU, Risien and Chelton, 2008).



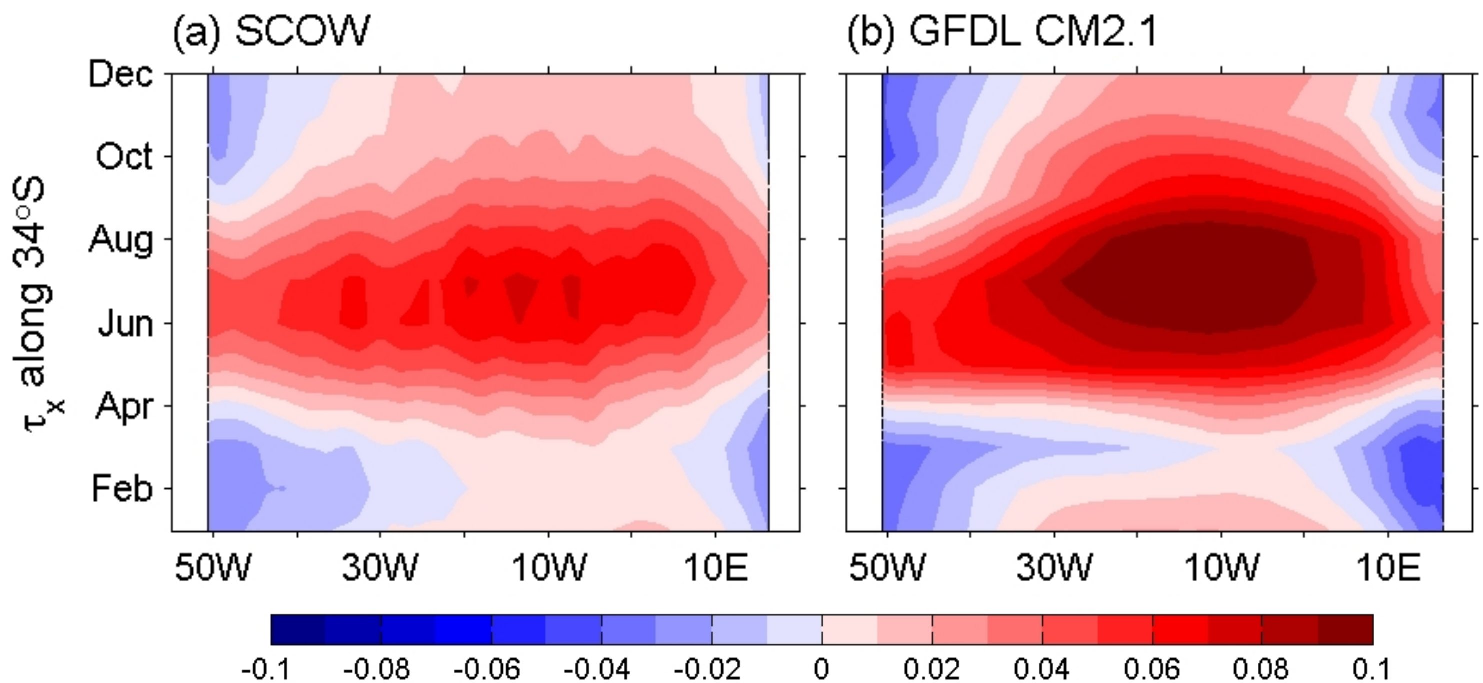
Positive wind stress curl biases east of 20°W.

Seasonal Variations in the MOC



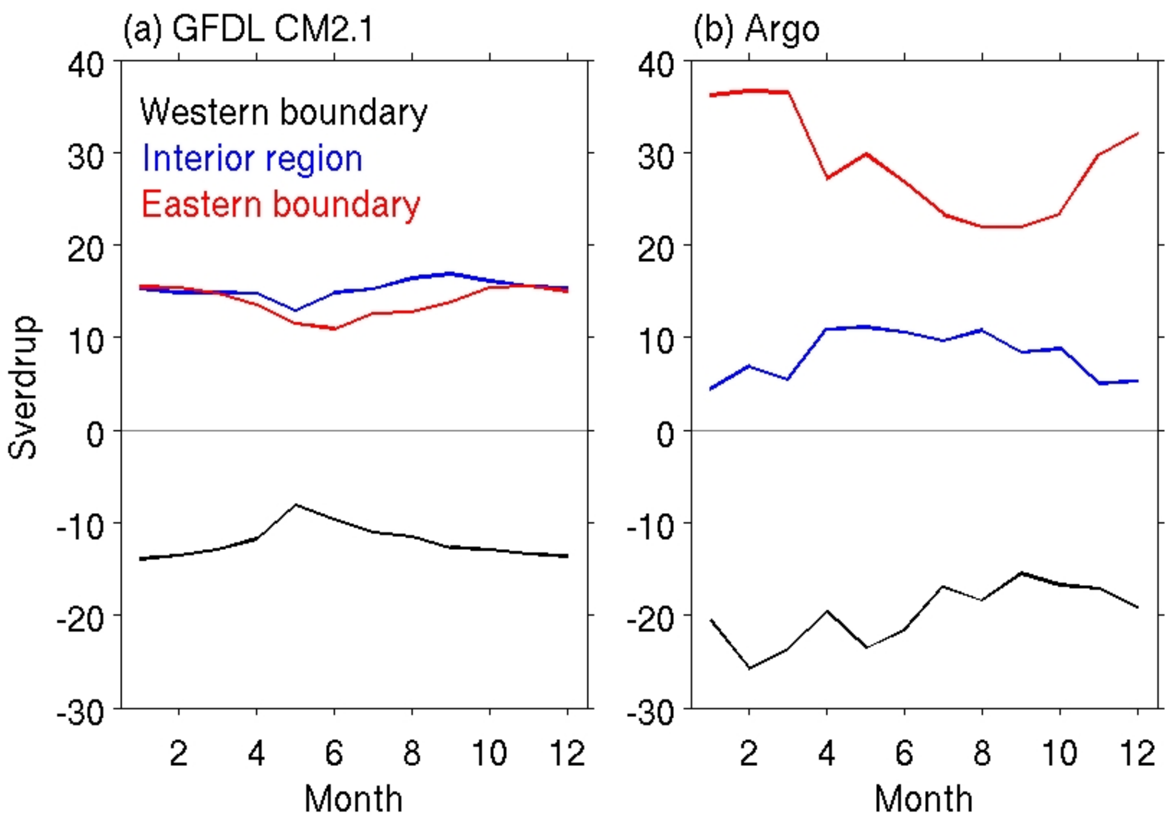
- Transport estimates from Argo show opposite seasonal variations in geostrophic and Ekman contributions to the MOC.
- Ekman transport based on model wind experiences a stronger seasonal variation.

Zonal Wind Stress along 34°S



The strong Ekman transport in the model is due to strong wind stress.

Regional Contributions to the MOC

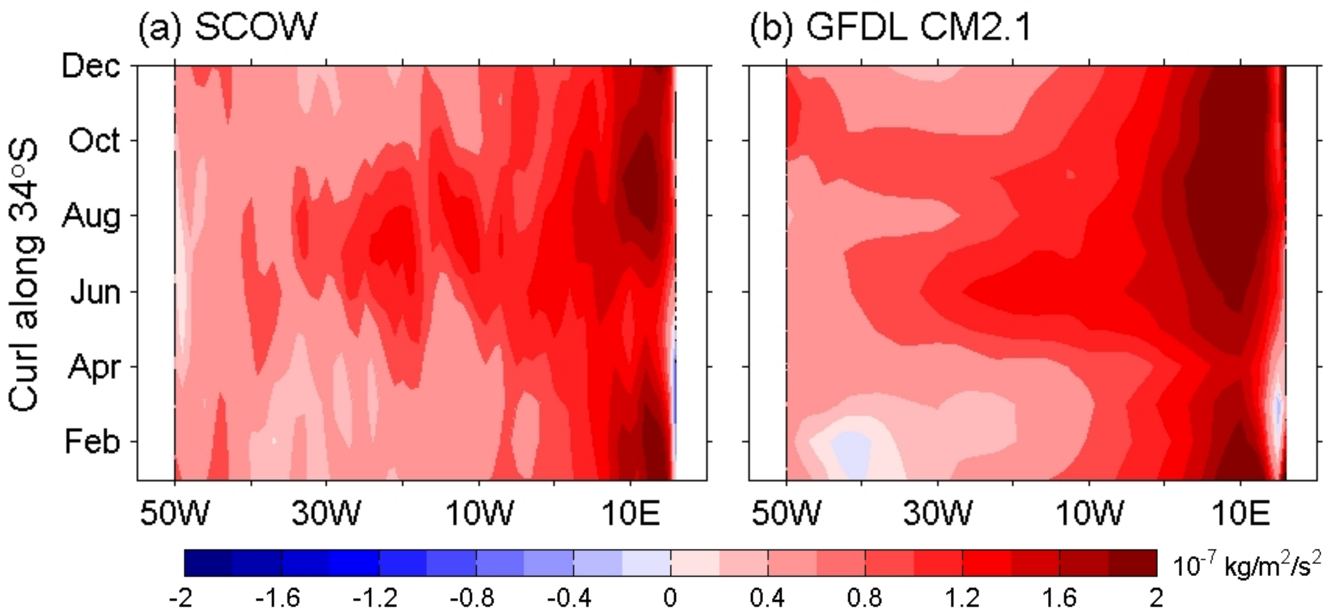


Western boundary: west of where current changes from southward to northward, ~45°W.

Eastern boundary: east of the western edge of the Walvis Ridge, ~3°E.

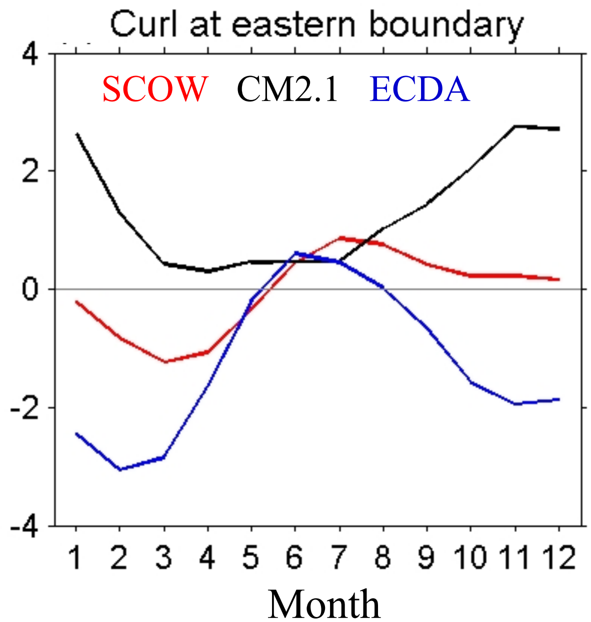
Interior region: 45°W – 3°E.

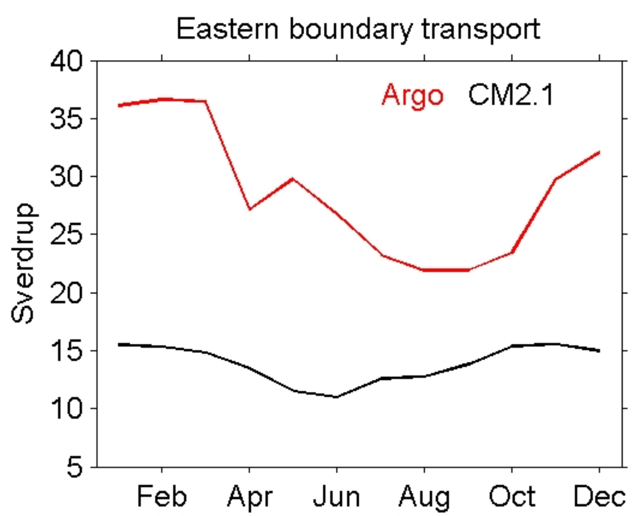
Wind Stress Curl along 34°S



Strong wind stress curl and seasonal cycle near the western boundary

Wind Stress Curl at the Eastern Boundary





At the eastern boundary

positive curl

⇓

pycnocline downward movement

⇓

negative density anomaly

⇓

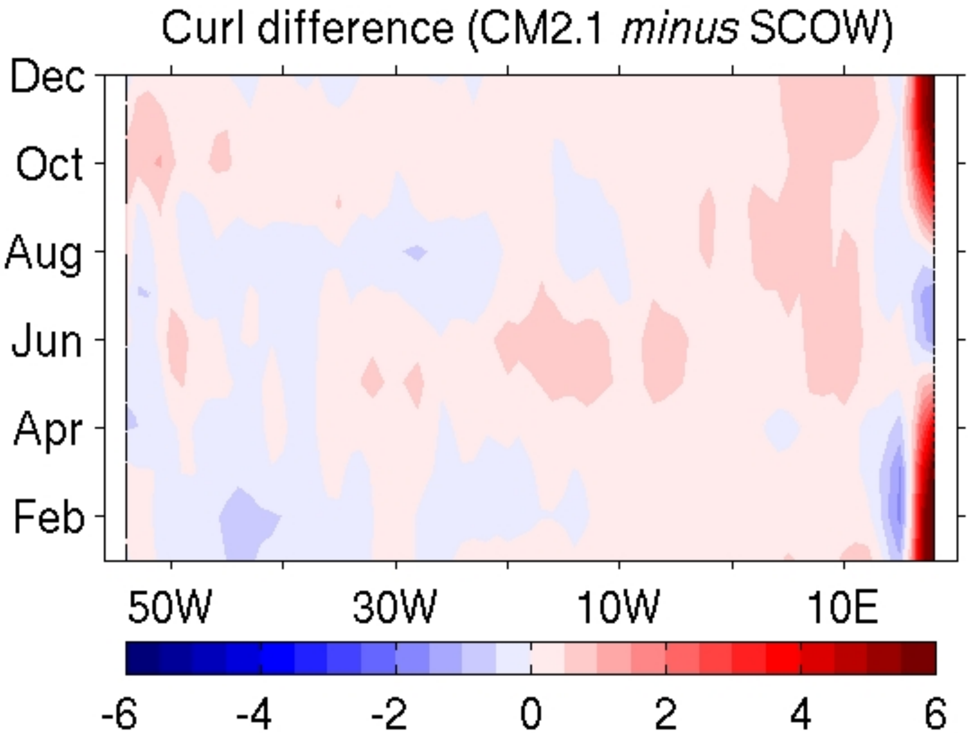
southward transport anomaly

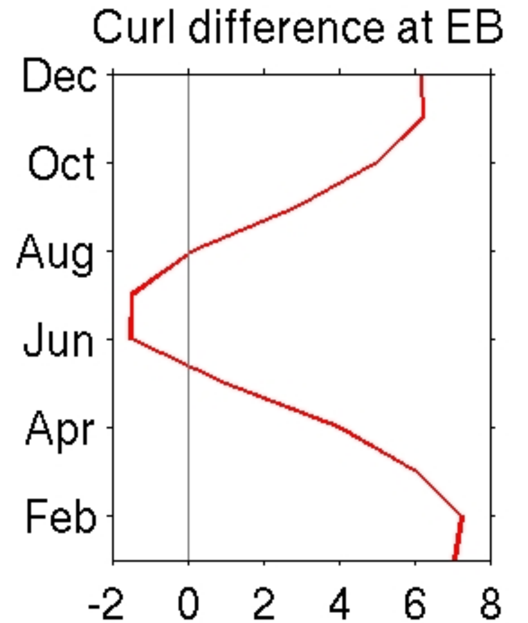
⇓

weak MOC

(*Kanzow et al., 2010*)

Wind Stress Curl Differences between Model and Observations





positive curl anomaly

⇓

thermocline downward movement

⇓

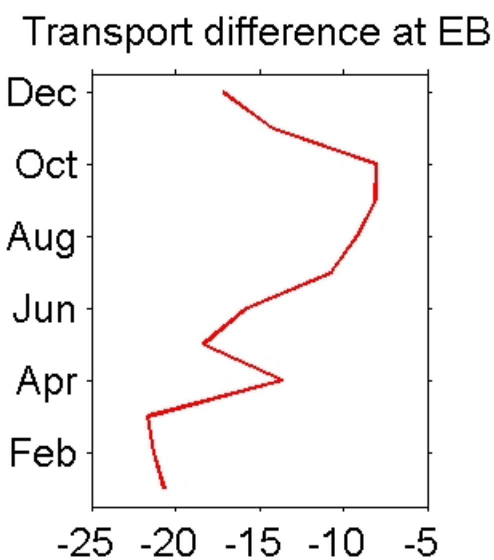
negative density anomaly

⇓

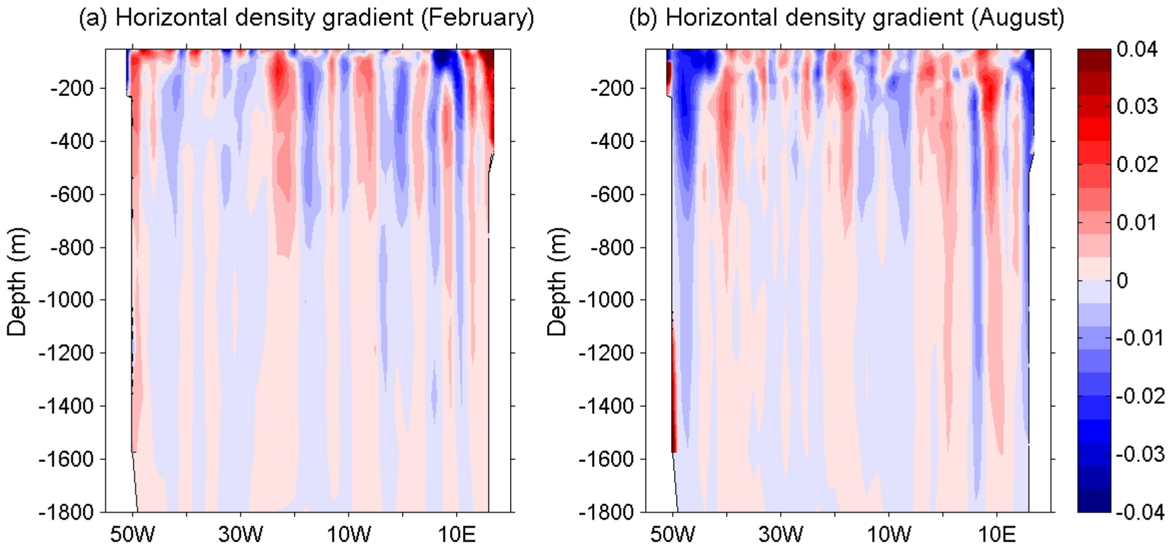
southward transport anomaly

⇓

weak MOC

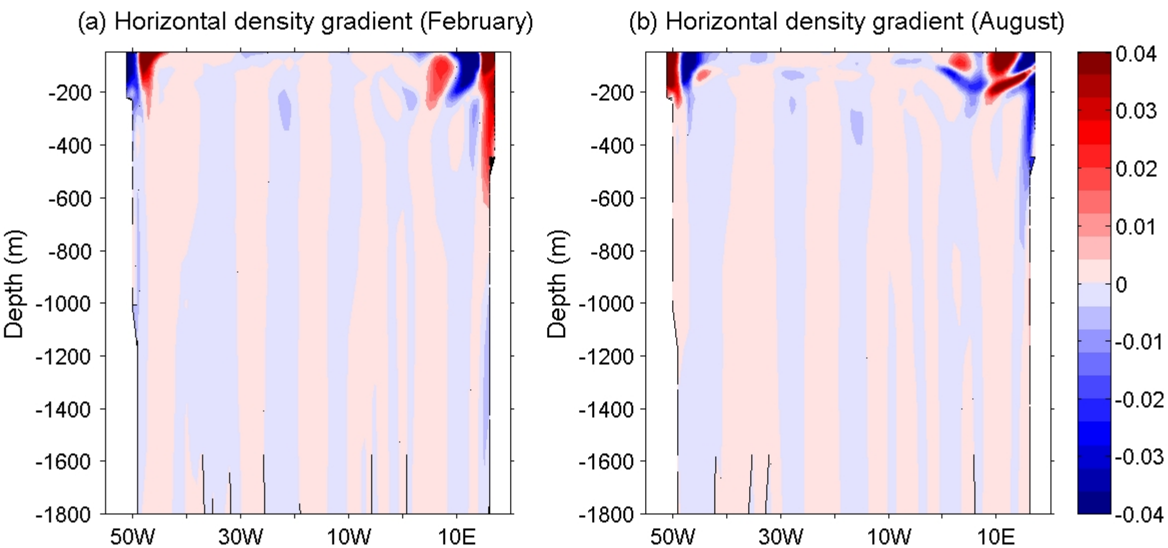


Zonal Density Gradient



Zonal density gradient from Argo show consistent vertical structure and reaches below 1000 m depth

$$\partial v/\partial z \propto \partial \rho/\partial x$$

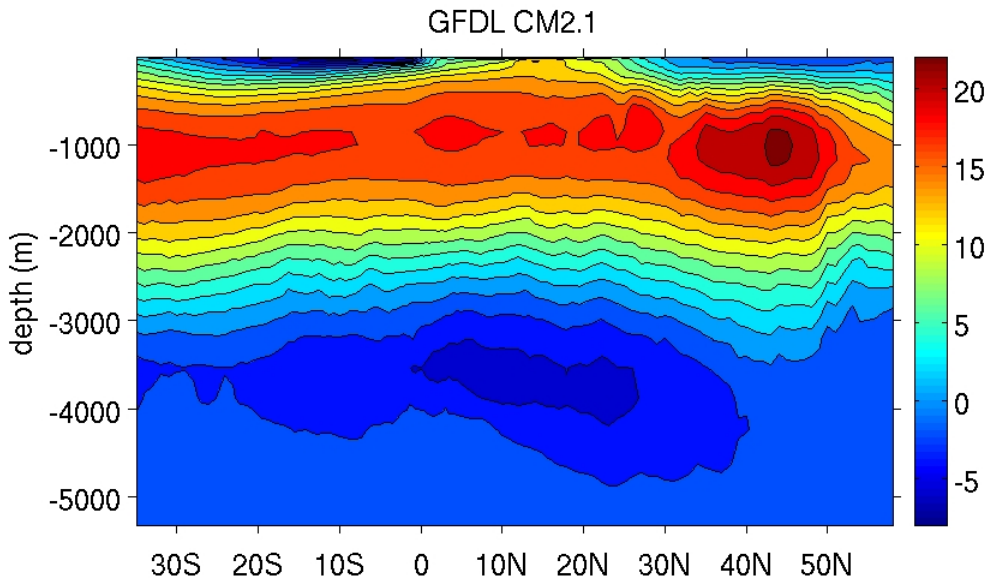


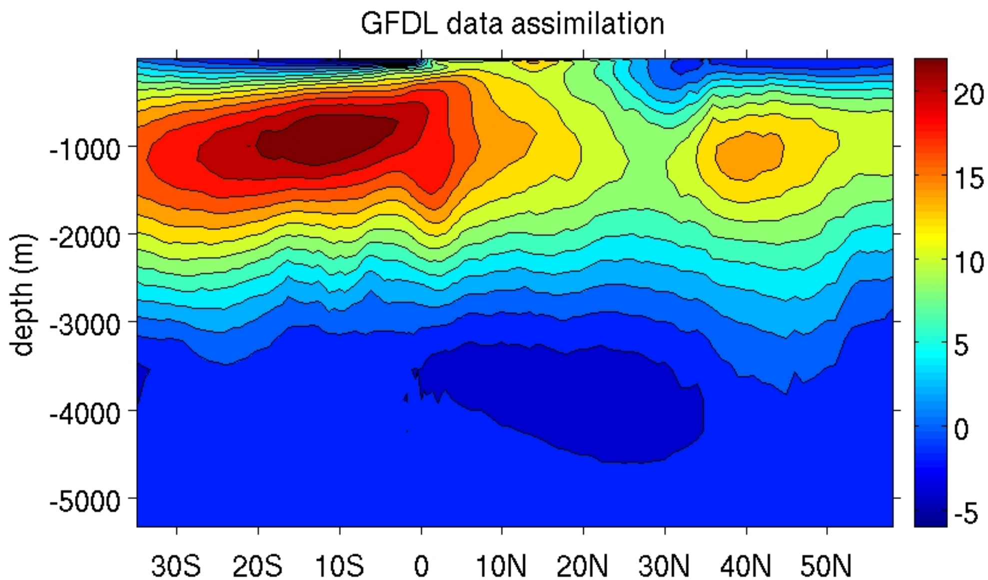
Zonal density gradient from CM2.1 is constrained in the top 200 m water column.

Conclusions

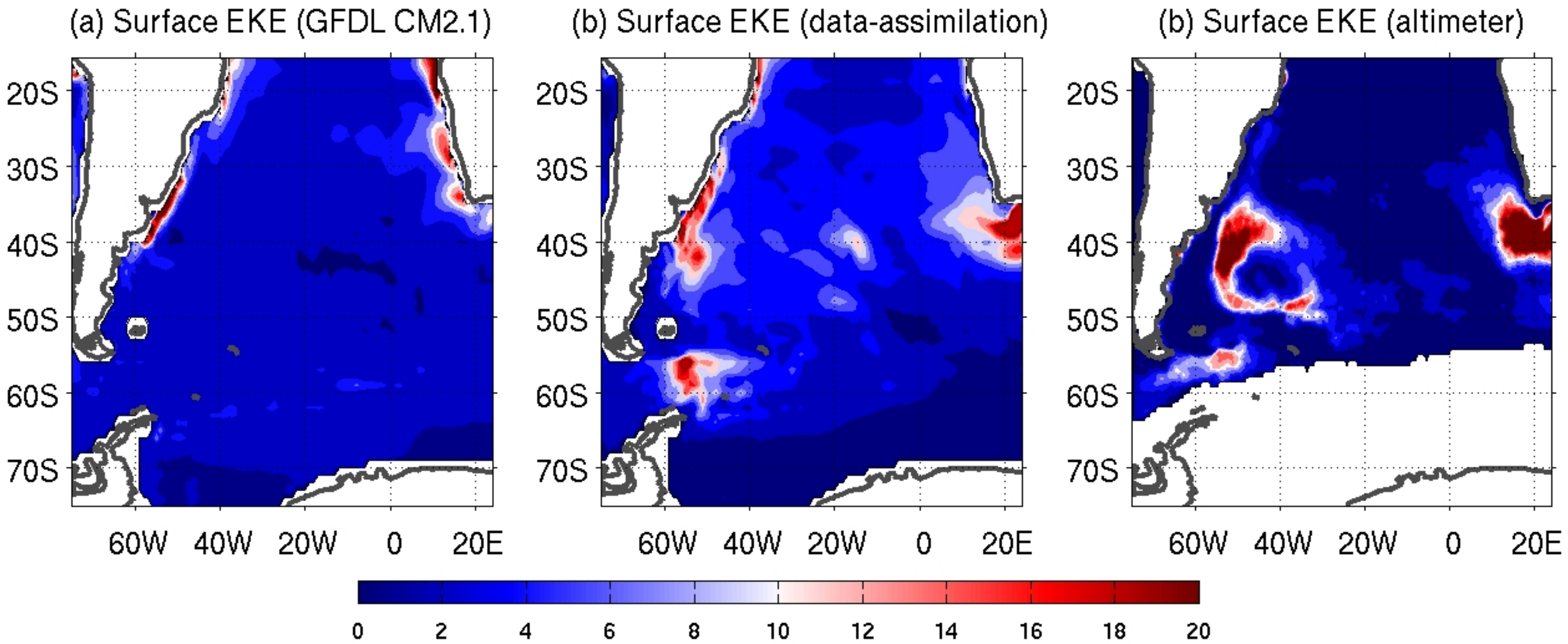
- Strong interior Geostrophic transport in GFDL CM2.1 may be related to the strong wind stress curl in the model.
- The wind stress curl biases in the model at the eastern boundary can explain the difference in the seasonal variations of the eastern boundary transport, based on the mechanism suggested by Kanzow et al. (2010).
- Weak seasonal variations in the geostrophic transport in CM2.1 could be due to the weak variations below 200 m.

Mean Streamfunction from Models





Comparison of Eddy Kinetic Energy



$$EKE = (u'^2 + v'^2)/2$$