An optimal XBT-based monitoring system for the South Atlantic Meridional Overturning Circulation at 34°S

Marlos Goes[1,2], Gustavo Goni[2], Shenfu Dong[1,2], Molly Baringer[2]

[1] Cooperative Institute for Marine and Atmospheric Studies

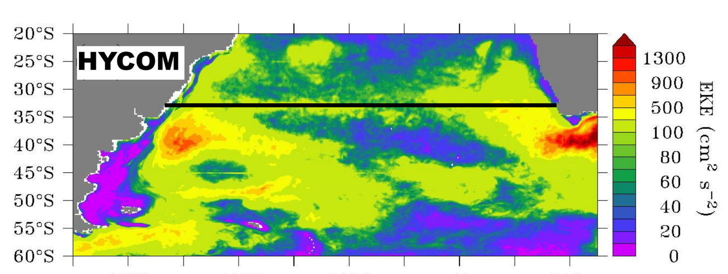
[2] National Oceanic and Atmospheric Administration

ABSTRACT

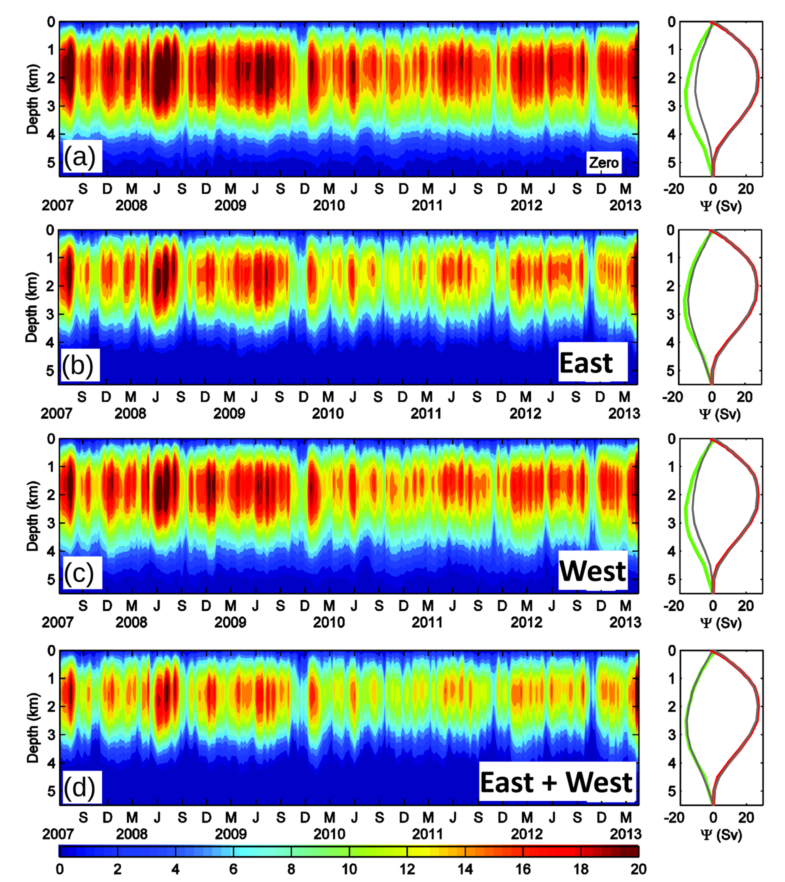
The South Atlantic is an important pathway for the inter-basin exchanges of heat and freshwater with strong influence on the global meridional overturning stability and variability. Along the 34°S parallel, a quarterly, high density expendable bathythermograph (XBT) transect (AX18) samples the temperature structure in the upper ocean. The AX18 transect has been shown to be a useful component of a meridional overturning monitoring system of the region. However, a feasible, cost-effective design for an XBT-based system has not yet been developed. Here we use a high-resolution ocean reanalysis to simulate an XBT-based observational system across the South Atlantic. The sensitivities of the meridional heat transport, meridional overturning circulation, and geostrophic velocities to key observational and methodological assumptions are studied. Key assumptions taken into account are the horizontal and temporal sampling of the transect and the level of reference for geostrophic velocities. In addition, the sensitivity of the meridional transports to XBT measurement errors, such as historical fall-rate equation biases and temperature accuracy, are estimated. With the current sampling strategy, the largest errors in the meridional overturning and heat transport are the estimation of the barotropic velocities, and the western boundary sampling. An approach for estimating barotropic velocities using altimetry data is presented.

Model

In the present study we use data from the global HYCOM/NCODA assimilative product (Chassignet et al., 2009) to simulate XBT measurements along 34°S. This model includes a Mercator grid with an average of 1/12° horizontal spacing and 32 vertical layers, forced by the 3-hourly and 0.5° output from the NOGAPS model. Assimilated data include satellite sea height anomaly, *in-situ* SST and vertical temperature/salinity profiles from XBTs, Argo floats, and moored buoys.

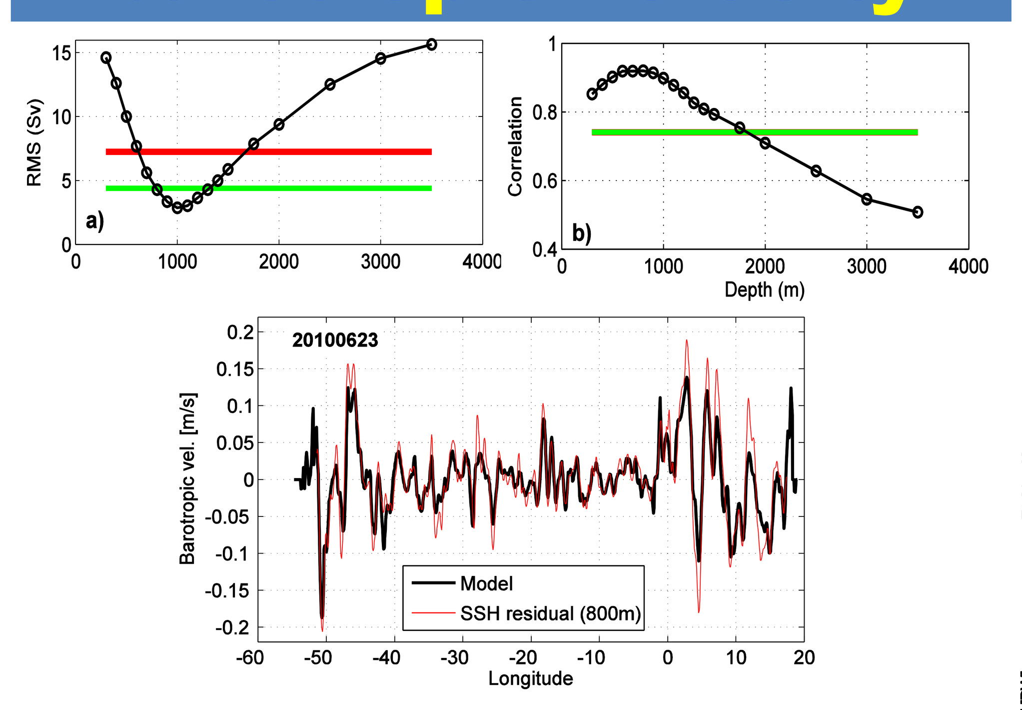


Reference velocity choice



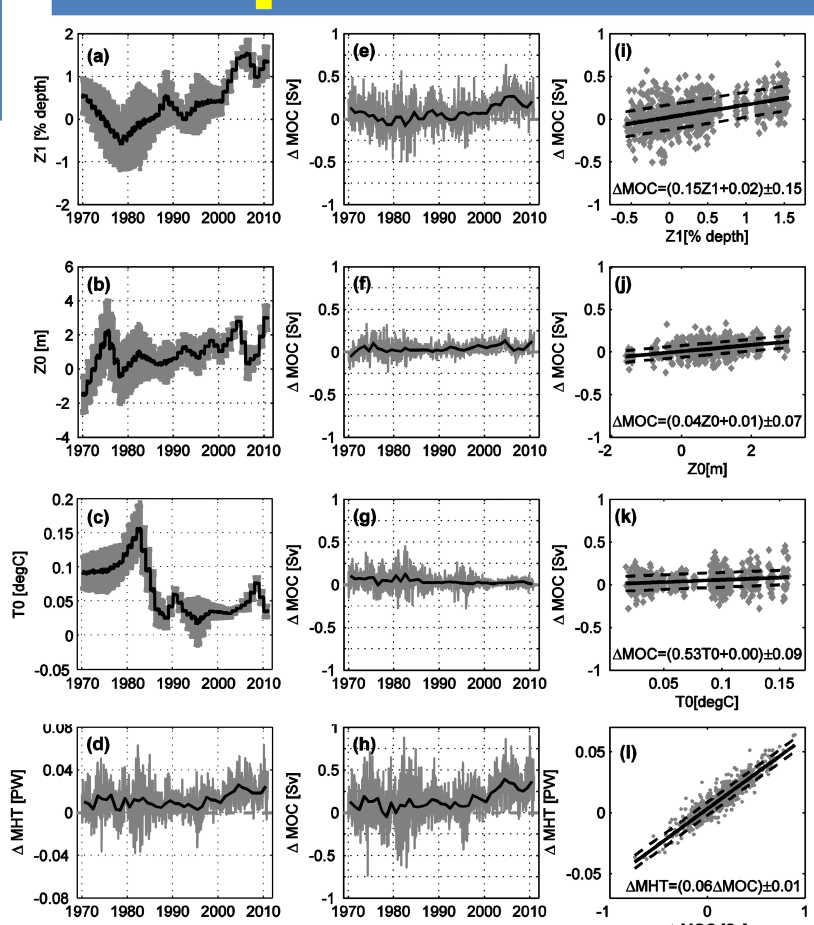
Vertical shear component is insensitive to the choice of reference velocity. The barotropic component, on the other hand, needs at least climatological velocity values at eastern and western boundaries to represent its strength. A weaker barotropic mode produces a stronger MOC reconstruction.

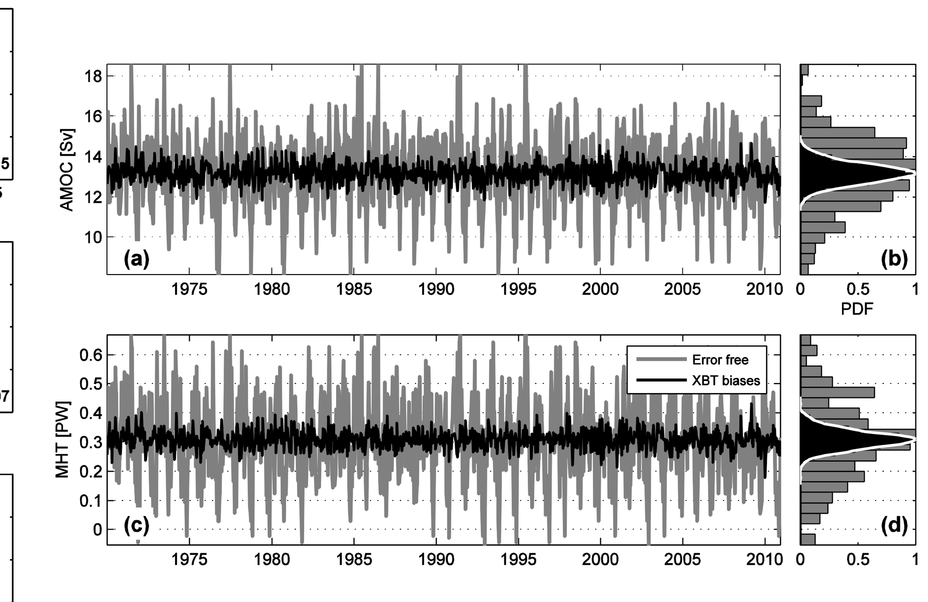
Altimetry to estimate barotropic velocity



A possible way to improve the estimation of the barotropic velocities is using altimetry and hydrography together. The residual between SSH and dynamic height referenced to a certain level gives the non-steric component: the barotropic SSH. Optimal reference values are around 800 to 1000m.

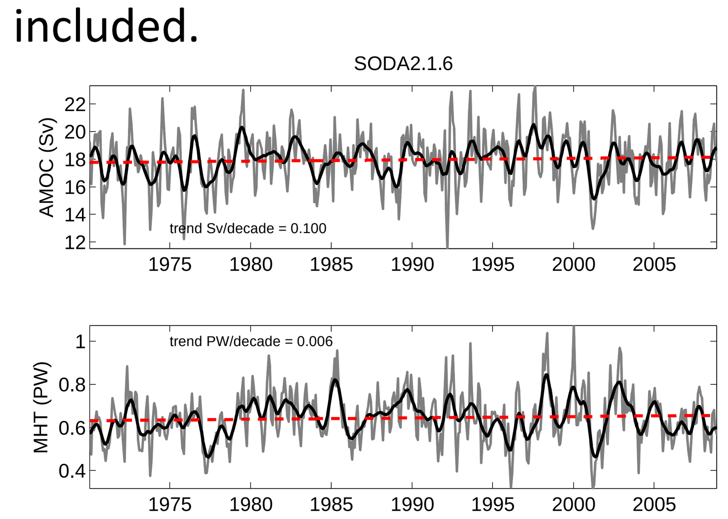
Impact of historical XBT biases

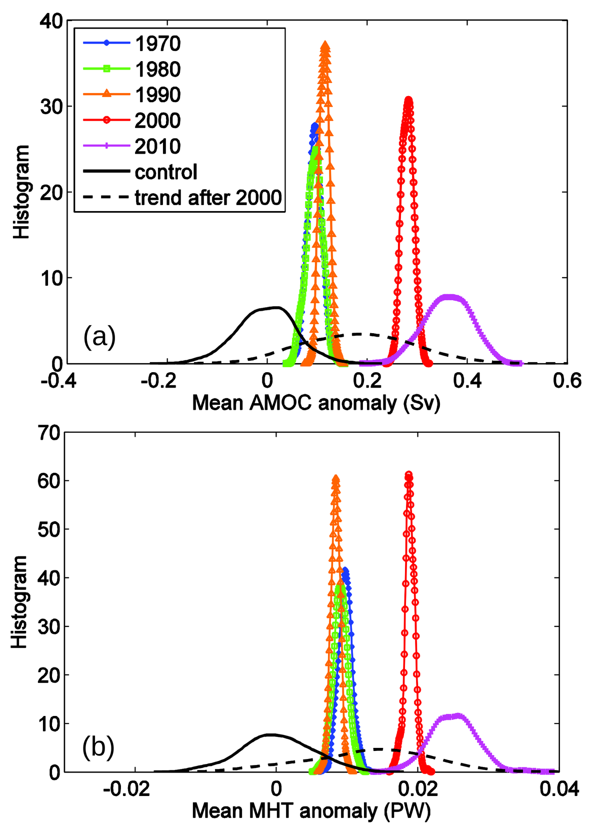




We use XBT biases since 1970 (Cowley et al., 2013) to estimate associated errors in MOC and MHT. All XBT errors are positively correlated to MOC. Fall rate equation errors are dominant. A positive bias is observed when all errors are included.

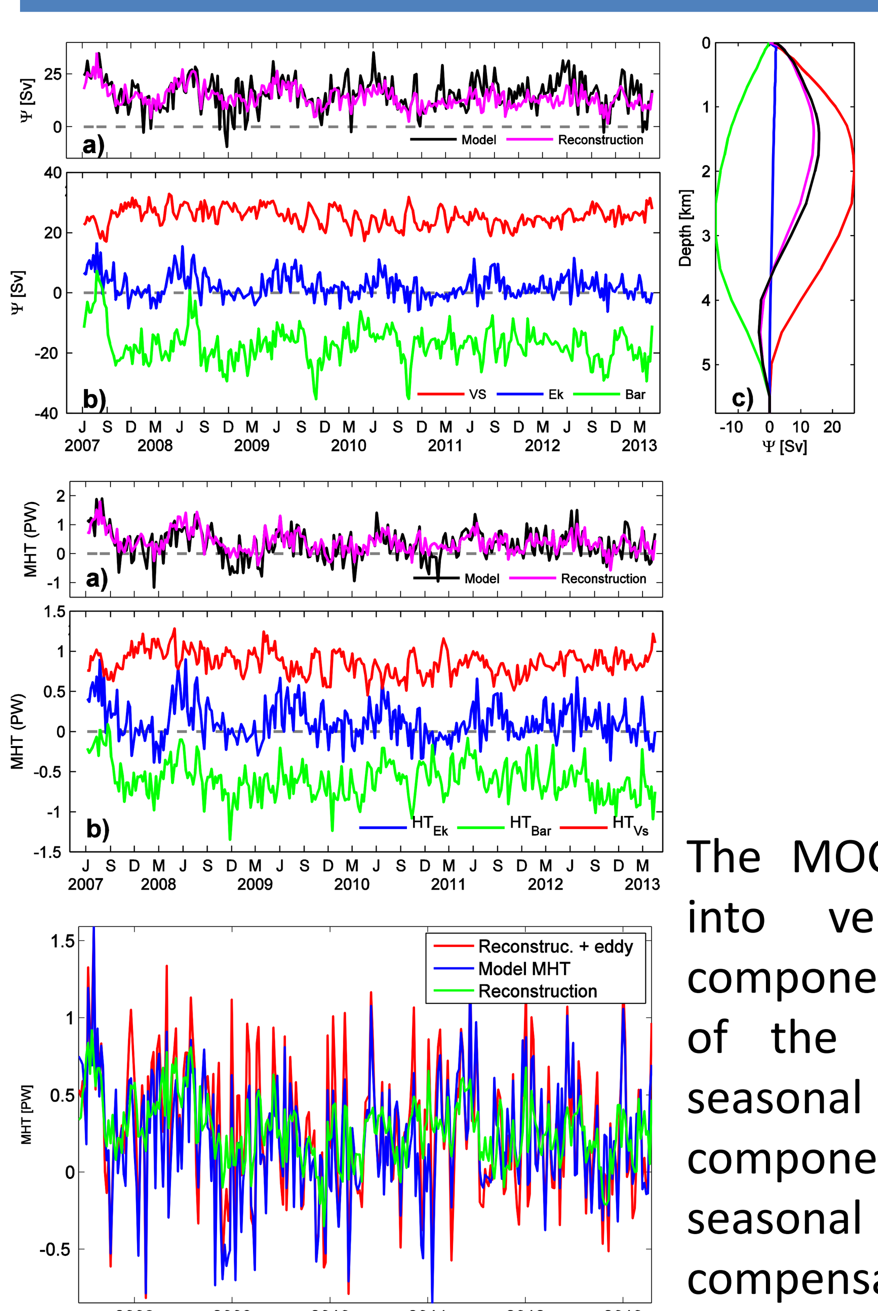
The XBT biases represent between 3-6% of the CONTROL (randomly resampled 2008 to 2013) geostrophic MOC/MHT variability assuming the manufacturer's accuracy distributions.

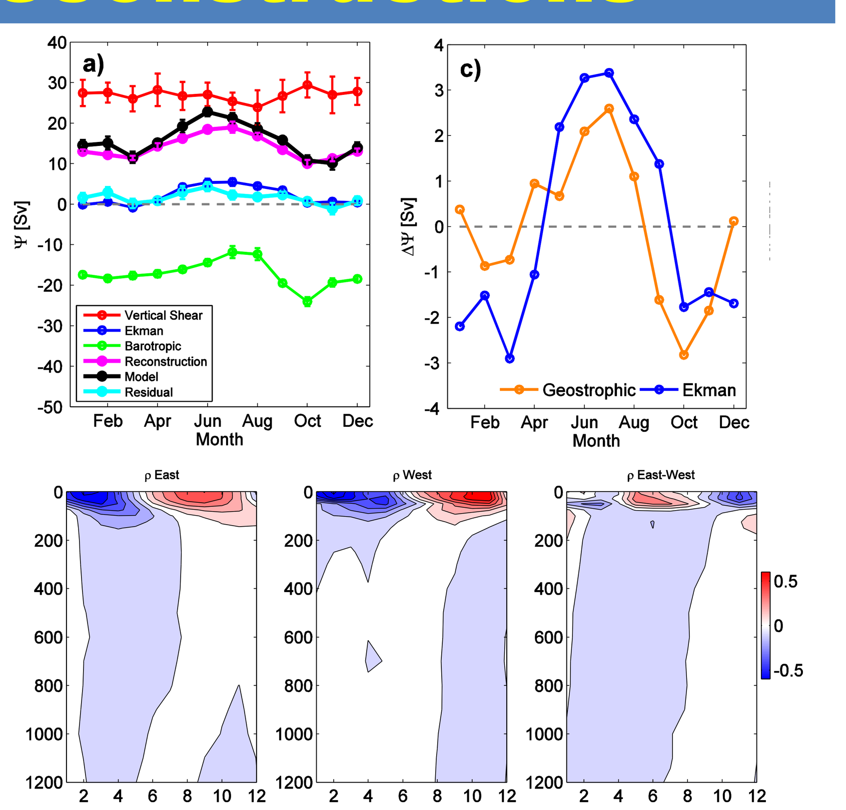




Left: MOC and MHT timeseries at 34°S from SODA 2.1.6 (gray). The linear trend is overlaid in red. Right: Histograms of bootstrapped distributions of the decadal mean of the (a) MOC and (b) MHT anomalies with respect to the control run. The colors are the anomalies caused by XBT measurement errors for each decade from 1970 to 2010. The CONTROL run distribution (black solid) and anomalies after 2000 of the CONTROL plus SODA trend (black dashed) are also displayed. XBT biases produce statistically significant trends after 2000.

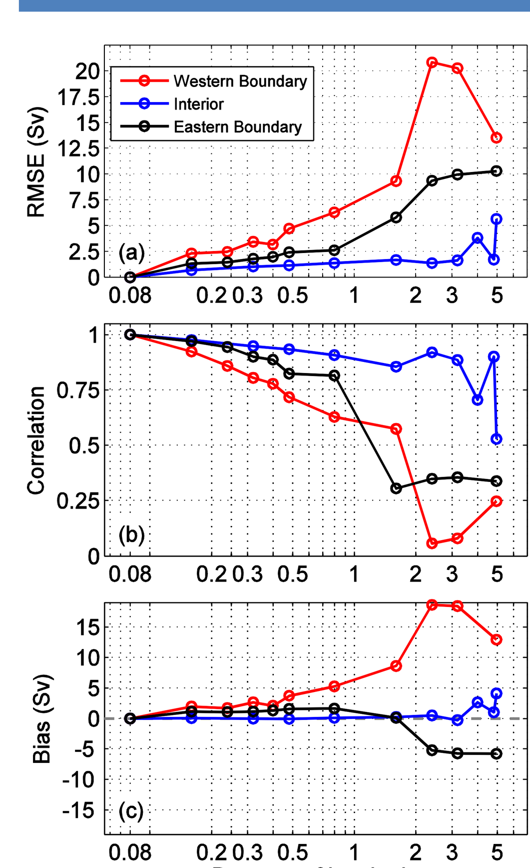
AMOC and MHT reconstructions



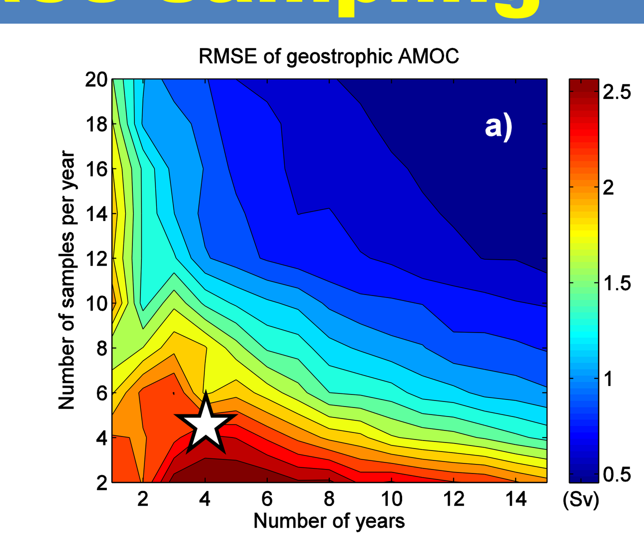


The MOC/MHT reconstructions are decomposed into vertical shear, barotropic and Ekman components. The eddy variability account for most of the residual (reconstruction - model). The seasonal cycle shows Ekman and geostrophic components in phase. Vertical shear has weak seasonal cycle because of strong zonal density compensation.

Time/Space sampling



Spatial sampling: The western boundary is the most sensitive to spacing, and the interior the least. Current sampling (25km boundary/50 km interior) is close to optimal.



Temporal sampling: The precision to represent the seasonal cycle in the AX18 transect depends on the number of samples/year and the number of years sampled. Thus far, the AX18 transect is in the region close to the most uncertain values in the parameter space (star).

References:

Goes, M., G. Goni, S. Dong, 2014: An optimal XBT-based monitoring system for the South Atlantic Meridional Overturning Circulation at 34S, submitted to J. Geophys. Res.

Goes, M., M. Baringer, G. Goni, 2014: The impact of historical biases on the XBT-derived meridional overturning circulation estimates at 34°S, submitted to Geophys. Res. Lett.