Meridional overturning estimates using pilot array data at 34.5°S in the Atlantic

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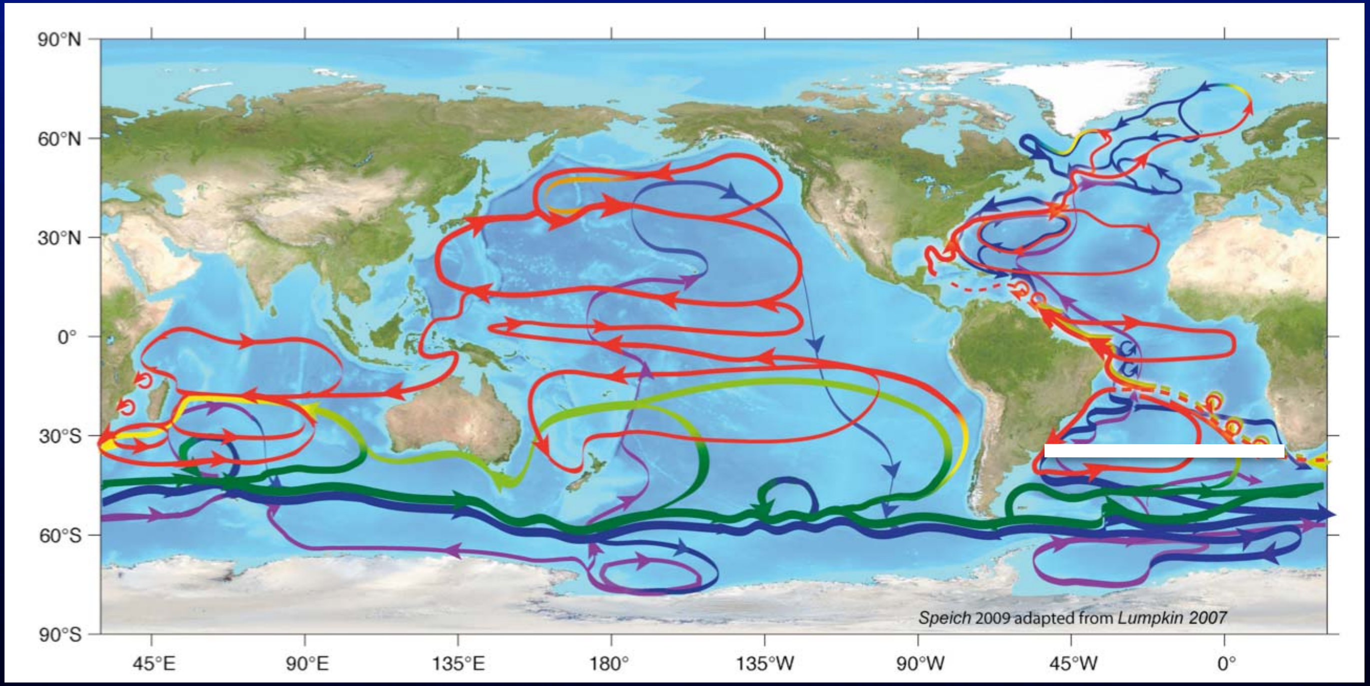
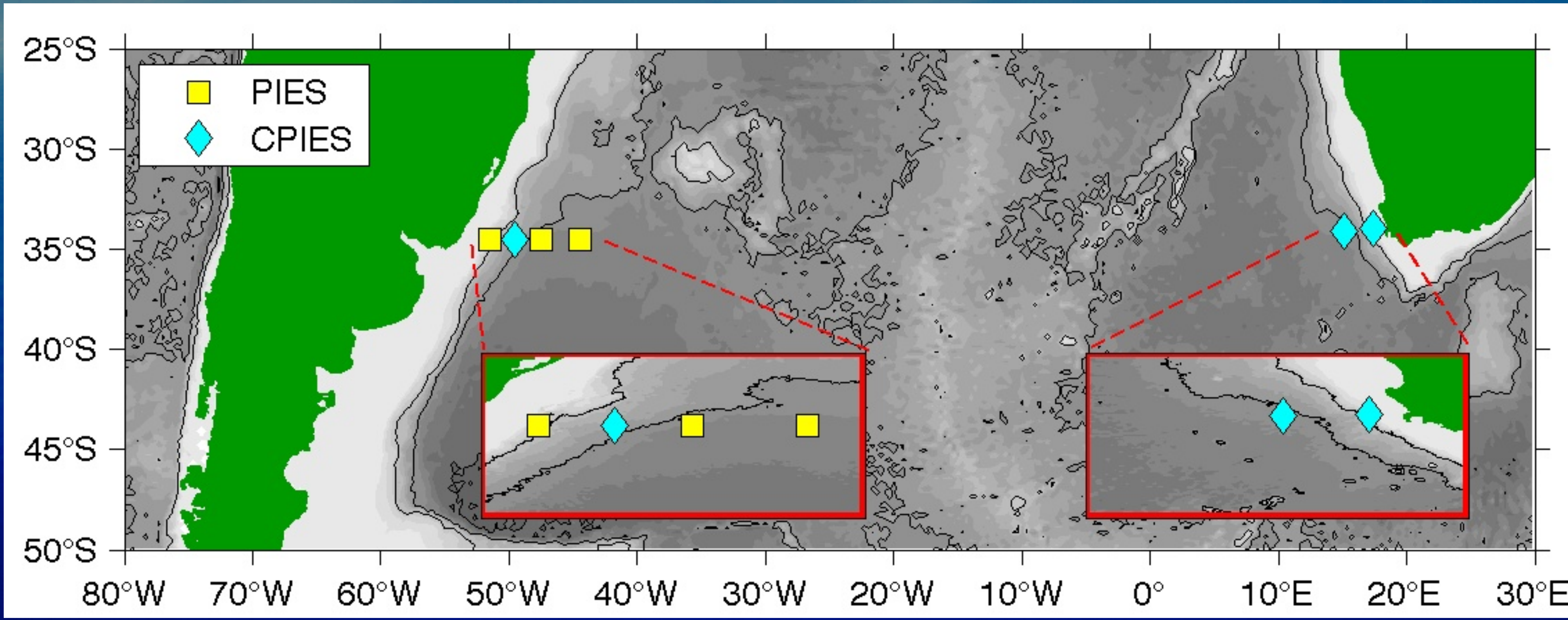




<u>Southwest Atlantic MOC ("SAM") project (US, Argentina & Brazil)</u>

Three PIES and one CPIES: March 2009 to July 2011

Four PIES: July 2011 to the present

<u>GoodHope project (France & South Africa, w/Russia & Germany)</u>

Two CPIES: February 2008 to December 2010

<u>Concurrent time period:</u>

March 20, 2009 through December 2, 2010 (623 days total)

<u>Also used:</u> 27-year run from the OFES model and a 6-year run of the NEMO model

So can we get a first look at the MOC time series at 34.5°S using these data?

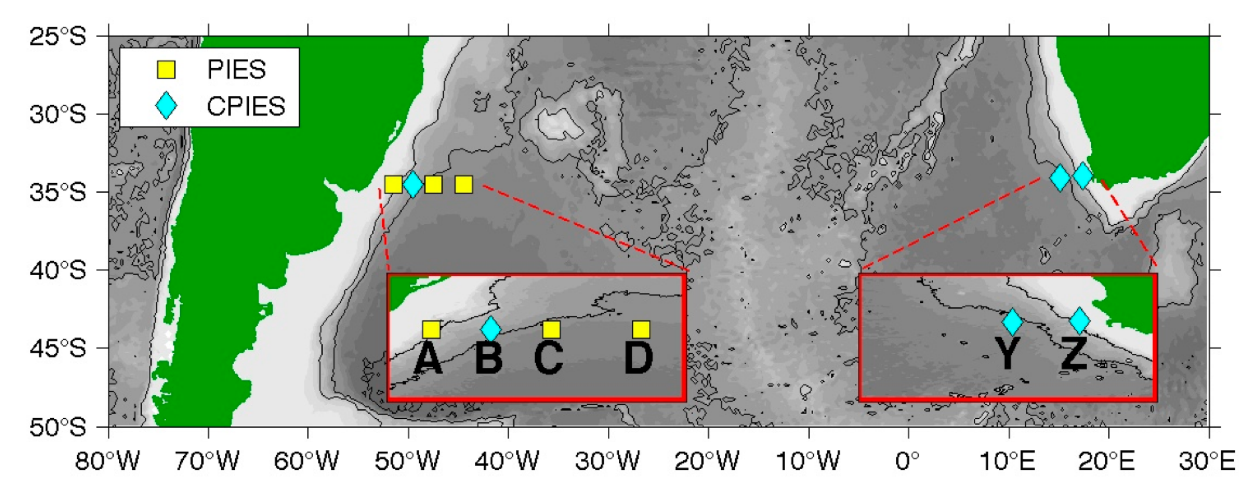
I'm going to argue that we can – but I'll also touch on the limitations as we progress.

For starters, we're going to estimate the basin-wide integrated meridional transports between Sites A and Z using the PIES & CPIES data at those two sites.

Analyzing PIES data

The PIES/CPIES measure:

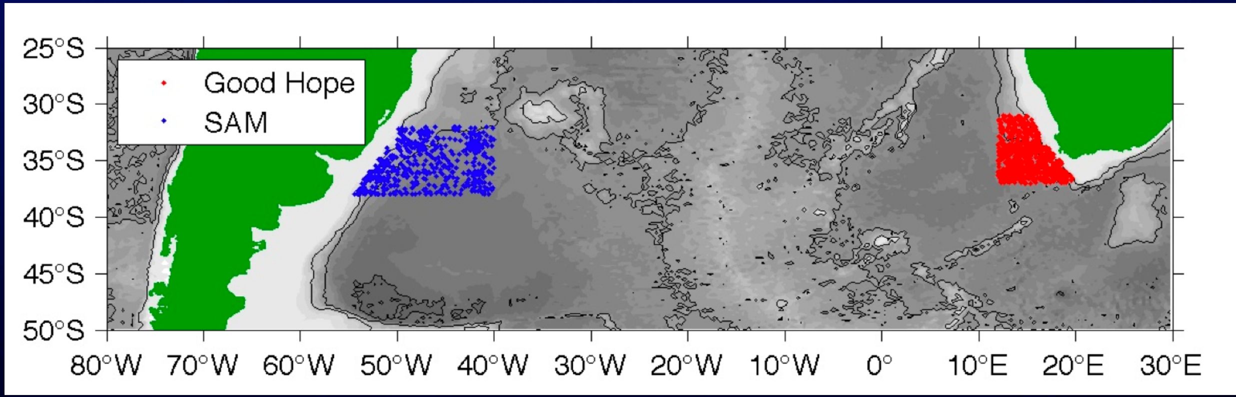
•Round trip acoustic travel time
•Bottom pressure
•Near-bottom current (CPIES only)



Travel time measurements are really only useful when combined with hydrographic data from the region. We had available:

SAM region: 565 casts
GoodHope region: 770 casts

Includes CTD & Argo

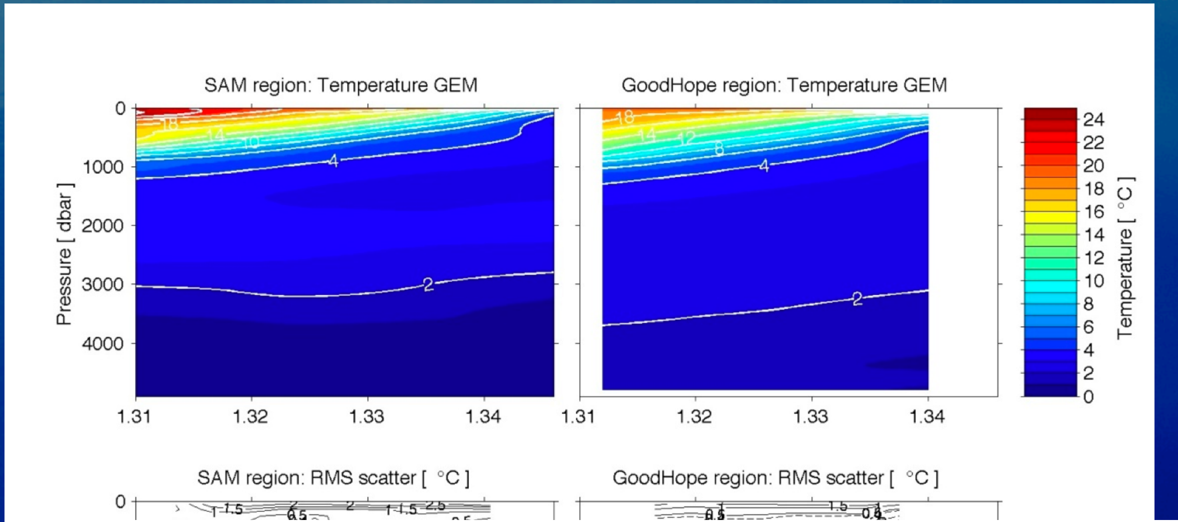


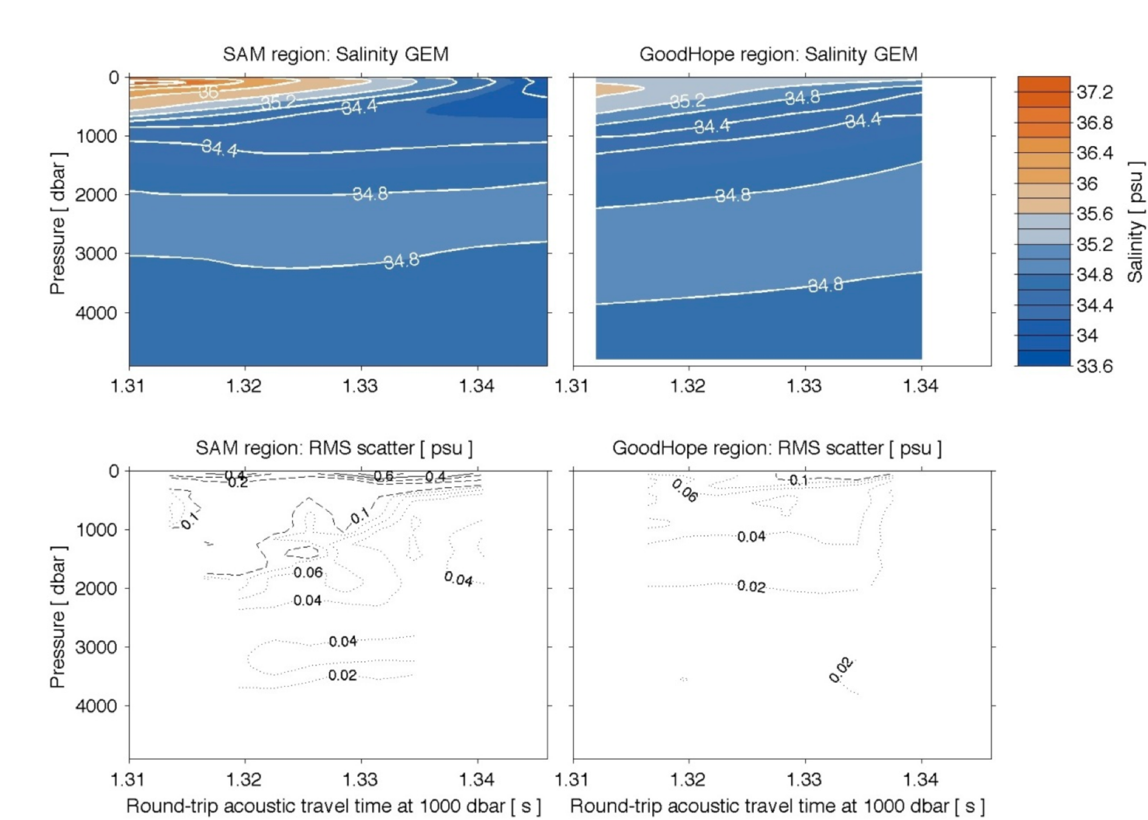
Analyzing PIES data, cont.

The travel time data are analyzed via look-up tables that are developed using the hydrographic profiles for the region. The tables, called the ‘Gravest Empirical Mode’ or ‘GEM’ fields, are developed for temperature, salinity, and density.

From density we can derive dynamic height anomaly profiles at Sites A and Z.

Gradients between dynamic height profiles give us relative velocity profiles via the standard geostrophic method.





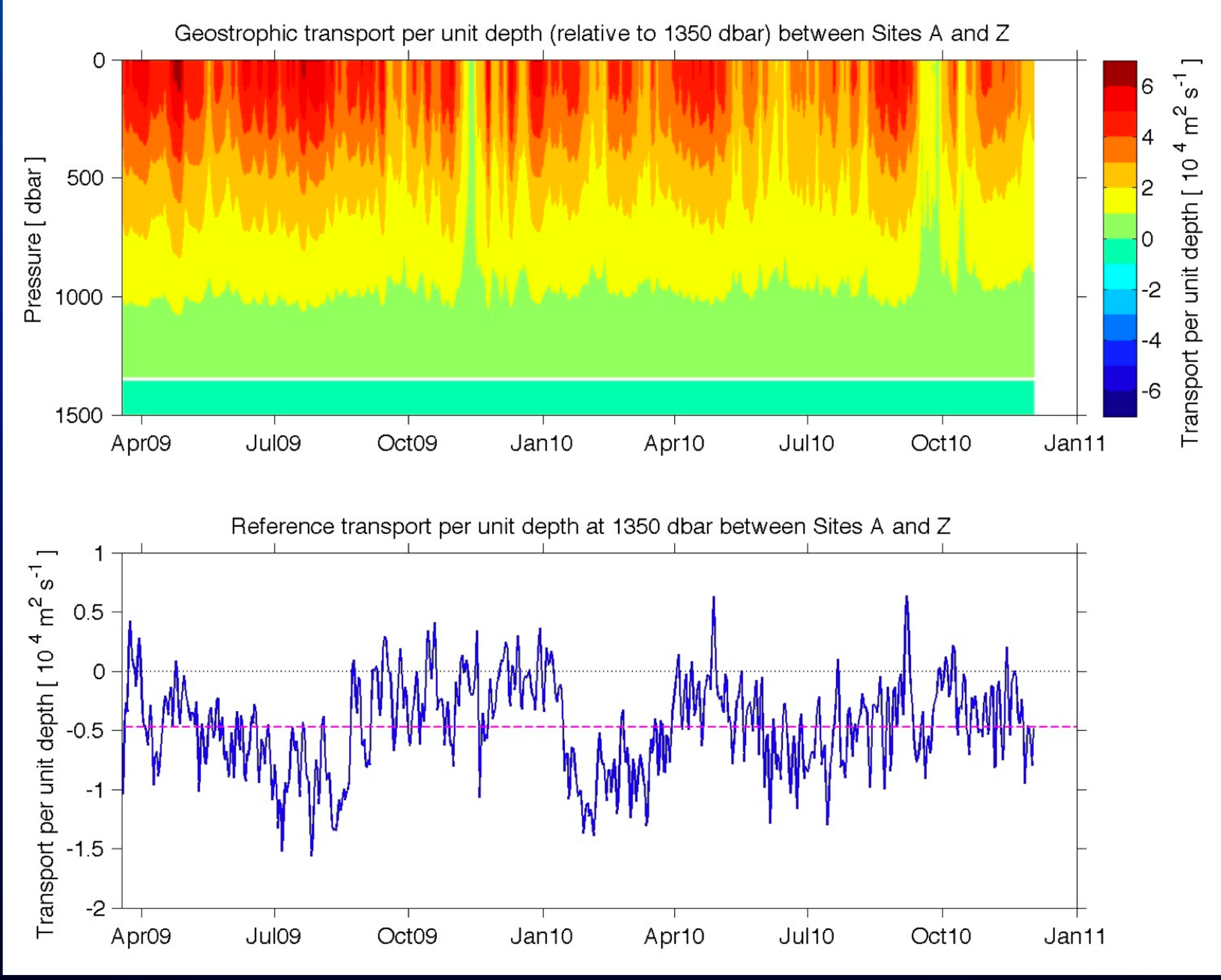
Analyzing PIES data, cont.

Multiplying the geostrophic relative velocities by the basin width between Sites A and Z yields profiles of the geostrophic transport per unit depth (relative to an assumed level of no motion at 1350 dbar).

The absolute reference velocity at 1350 dbar can be determined from the difference in the bottom pressure measurements a Sites A and Z.

The pressure difference gives the absolute velocity variability at that level, but not the time mean.

Here the mean from a 27-year run of the OFES model is used.

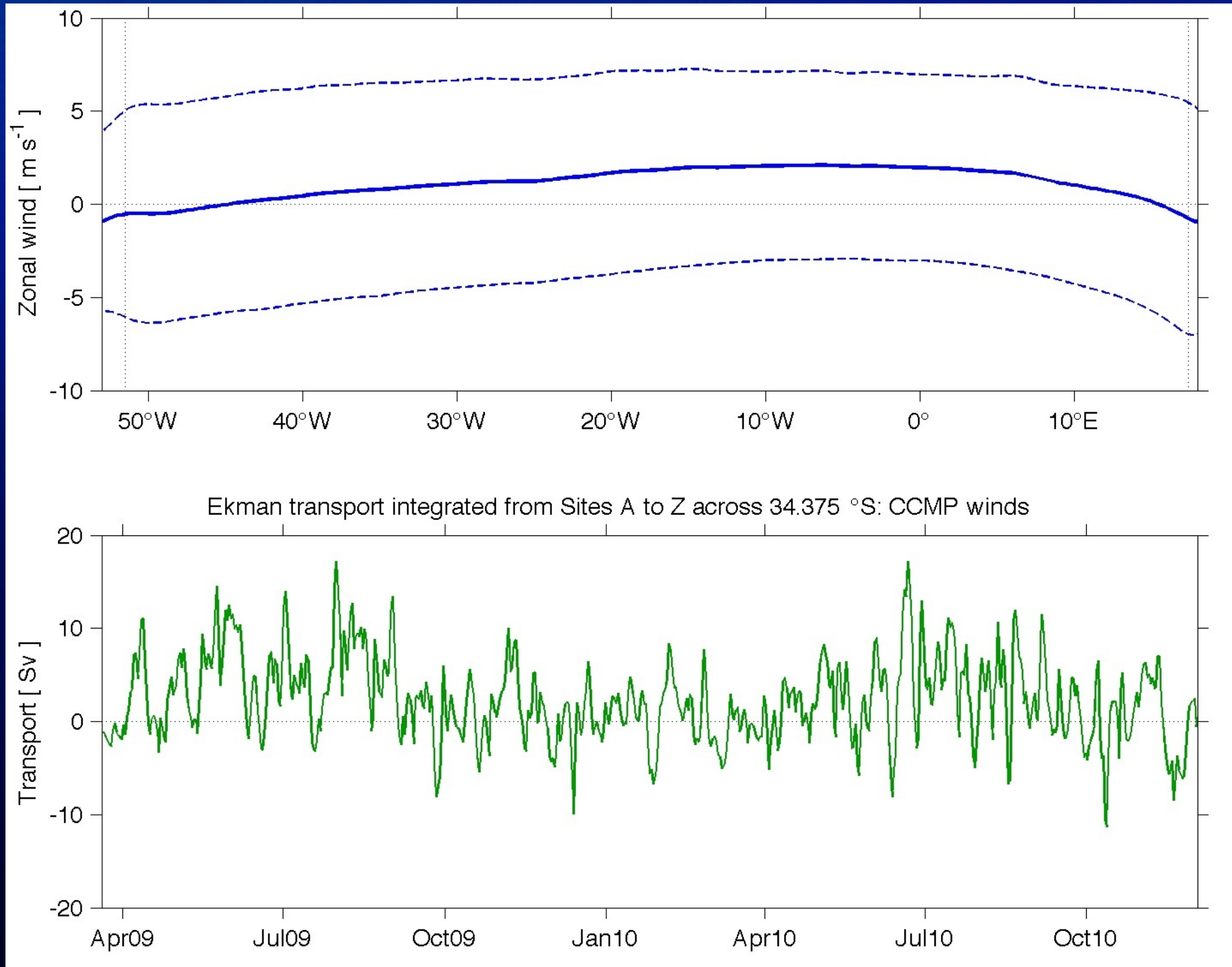


Ekman Transport

Winds from the CCMP 6-hour product (Atlas et al., 2011) are averaged to once per day. Data from the grid line nearest to 34.5°S were used (34.375°S).

The wind speeds in this region are not particularly strong, so they are converted into wind stress using a constant drag coefficient (1.43×10^{-3}) and air density ($1.225\ kg\ m^{-3}$) following Weisberg and Wang (1997)

Using this simple method, the Ekman transports integrated between Sites A and Z during the March 20, 2009 to December 2, 2010 time period have a time mean of 1.5 Sv and a standard deviation of 4.3 Sv.



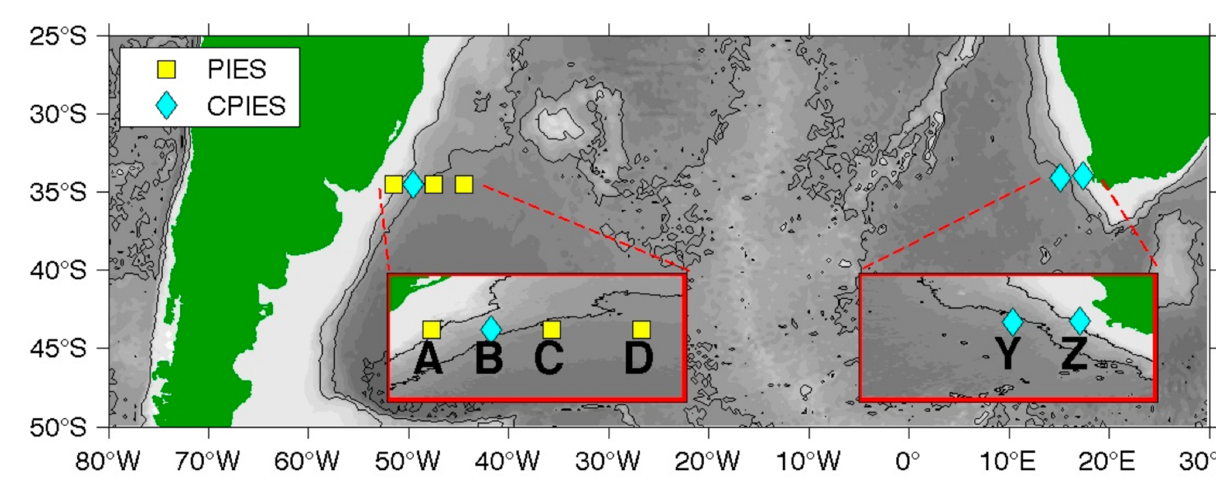
Shelves & upper slopes

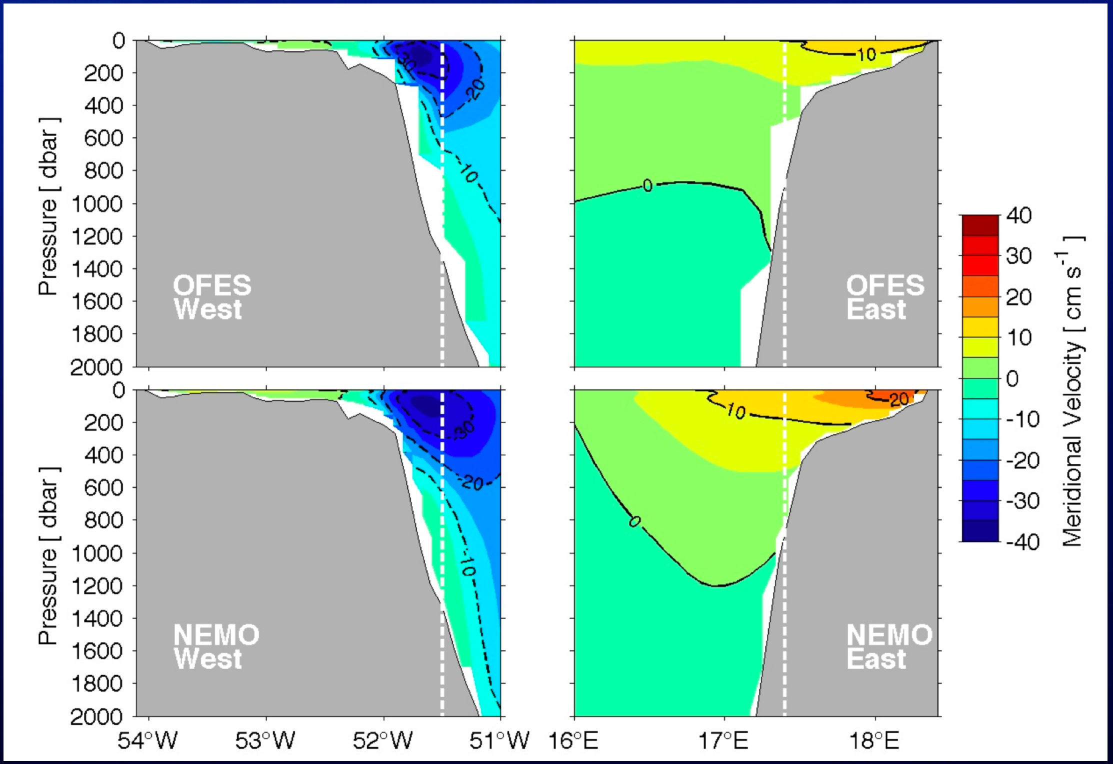
There is a small but non-trivial portion of the trans-basin section that is inshore of Sites A and Z.

The PIES/CPIES arrays do not help us in these regions.

For this first-look at the data, the transports of two models were investigated, as well as estimates from nearby XBT sections.

The time-mean inshore flows cancel to within <1 Sv, but the time varying flows of around 3-4 Sv contribute to the overall MOC error bars.



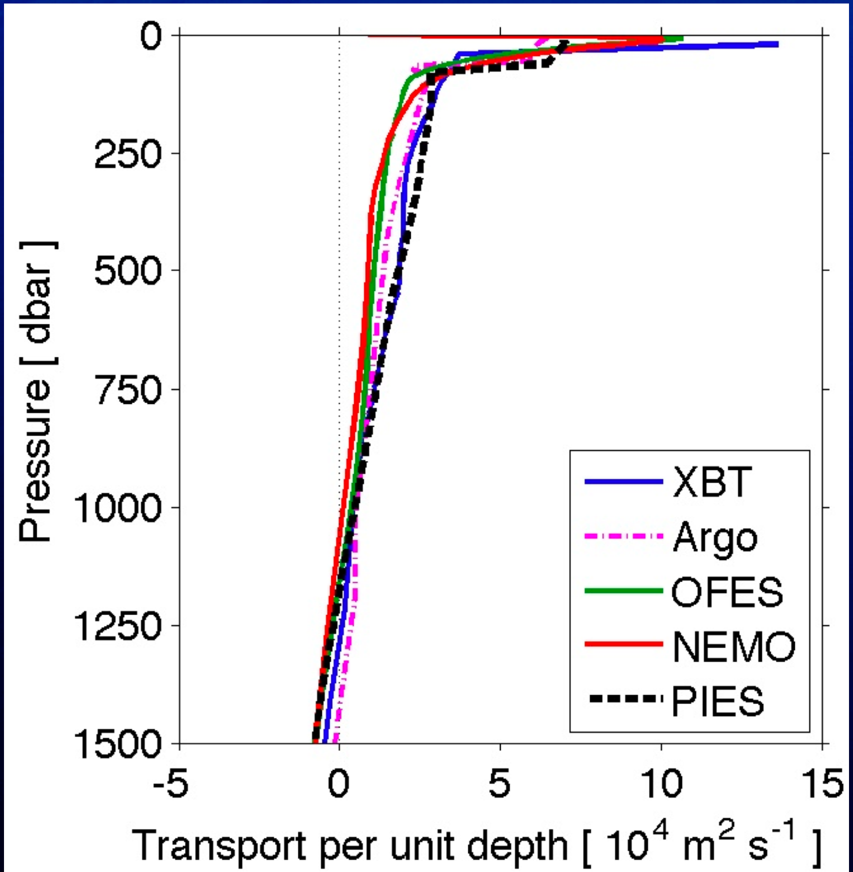


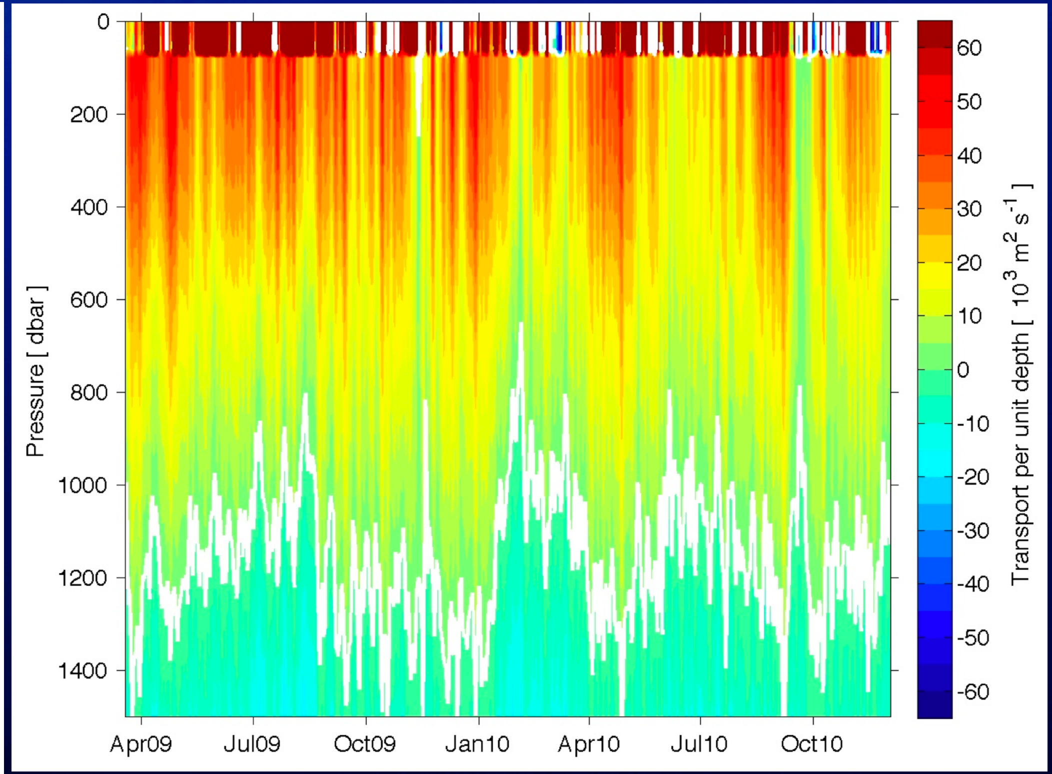
Total integrated absolute meridional transport per unit depth

Adding up the geostrophic (relative and reference), Ekman, and shelf/upper slope flows yields the total basin-wide ***absolute*** transport as a function of depth.

Mean transition from northward to southward flow: 1170 dbar ± 170 dbar (mean ± std)

Perhaps unsurprisingly – the time mean structure agrees with other observations. Also roughly agrees with the OFES and NEMO model means.



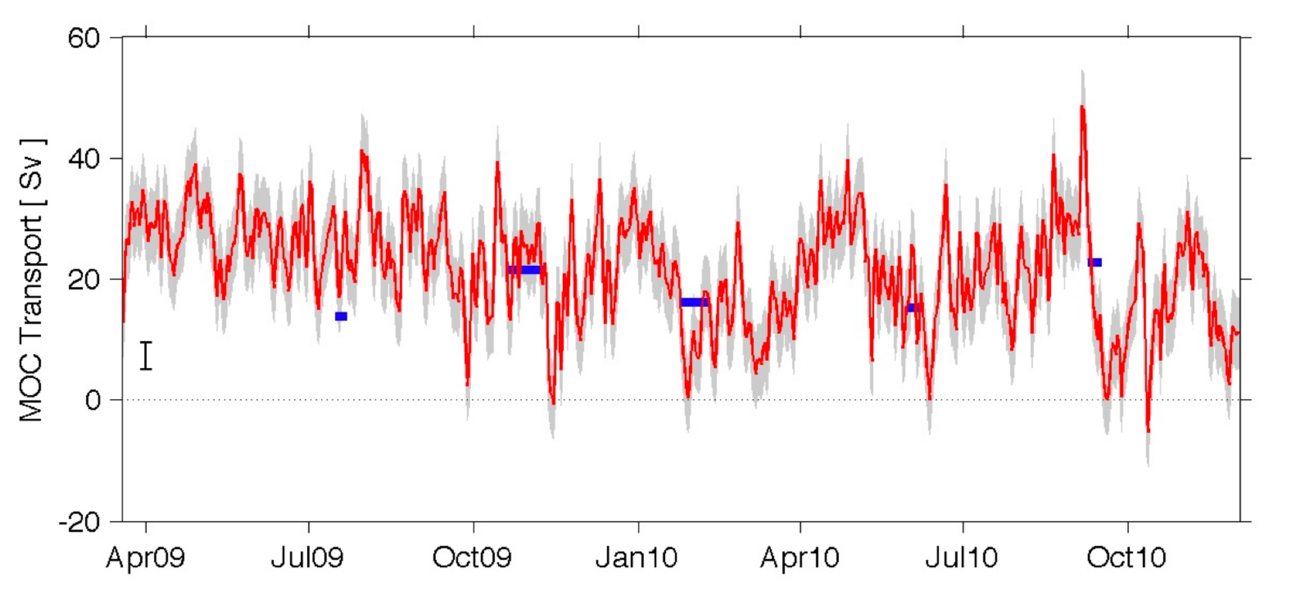


Total MOC transport

Integrating down to the reversal in flow sign yields the total volume transport of the MOC as a function of time.

Mean* = 21.3 Sv
(*depends on OFES!)

STD = 8.7 Sv



MOC accuracy

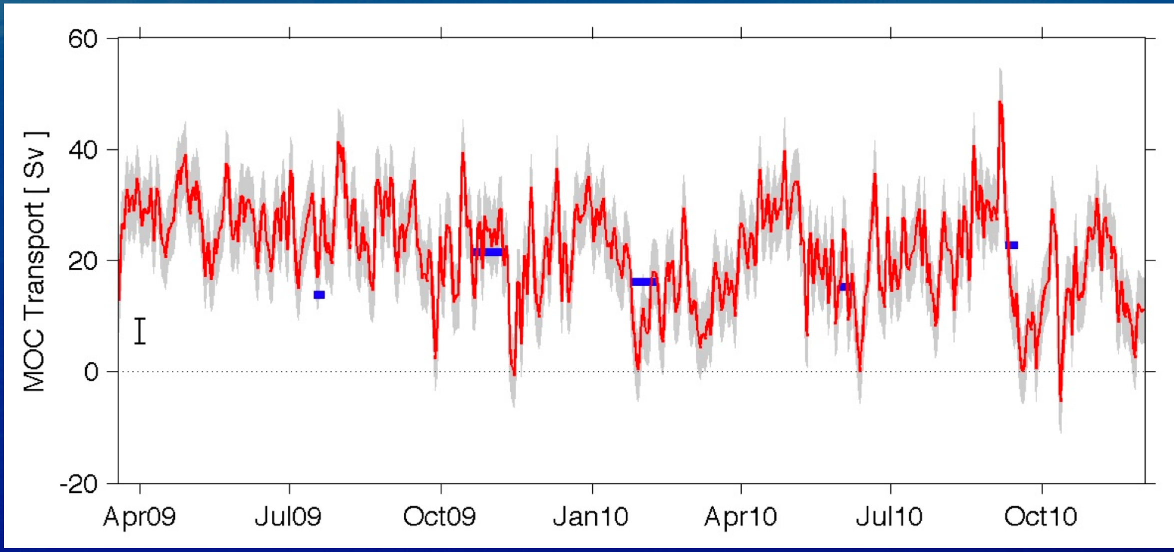
One advantage of this method is that it does not use a residual calculation – so the error bars can be determined explicitly.

Based on a careful analysis of the various contributions to the accuracy, we determine that the mean is accurate to within ± 4.4 Sv and the daily values are accurate to within a random accuracy of ± 5.9 Sv.

	Accuracy estimate
RANDOM SOURCES	
GEM look-up table accuracy	3.1 Sv
Scatter in τ_{PIES} vs. τ_{1000} relationship	0.5 Sv
Measured τ accuracy	1.2 Sv
Baroclinic shear 1000 to 1500 dbar	2.3 Sv
Measured pressure accuracy	1.9 Sv
Ekman accuracy	1.4 Sv
West shelf missed variability	2.5 Sv
East shelf missed variability	2.5 Sv
Total Random	**5.9 Sv**
BIAS SOURCES	
Calibration of τ_{PIES} with concurrent CTDs	4.2 Sv
Accuracy of reference velocity time-mean	1.4 Sv
Ekman time-mean accuracy	0.02 Sv
Combined shelf missed time-mean	0.2 Sv
Total Bias	**4.4 Sv**

Comparison to XBT estimates

The only concurrent measurements of the MOC at 34.5°S are from repeat XBT sections collected along the "AX18" line.



There were five AX18 sections collected during the ~20 months of the PIES/CPIES array overlap (blue bars at right).

The sections all agree within the estimated error bars for the PIES/CPIES data.

The PIES/CPIES data also shows large variability during the transit time for each section. This highlights the asynoptic problem of the sections…

Dates of XBT cruise	XBT MOC estimate	Mean PIES MOC estimate during cruise	STD PIES MOC estimate during cruise	Peak-to-peak range of MOC estimates during cruise
Jul. 16-22, 2009	13.7 Sv	23.4 Sv	5.3 Sv	17.0 –31.3 Sv
Oct. 20-Nov. 10, 2009	21.4 Sv	22.8 Sv	4.4 Sv	13.2 – 29.3 Sv
Jan. 25-Feb. 10, 2010	16.0 Sv	9.6 Sv	5.6 Sv	0.4 – 18.0 Sv
May 31-Jun. 9, 2010	**15.2 Sv**	**16.3 Sv**	**5.5 Sv**	**9.3 – 25.6 Sv**
Sep. 9-16, 2010	22.7 Sv	15.1 Sv	6.8 Sv	6.0 – 27.2 Sv

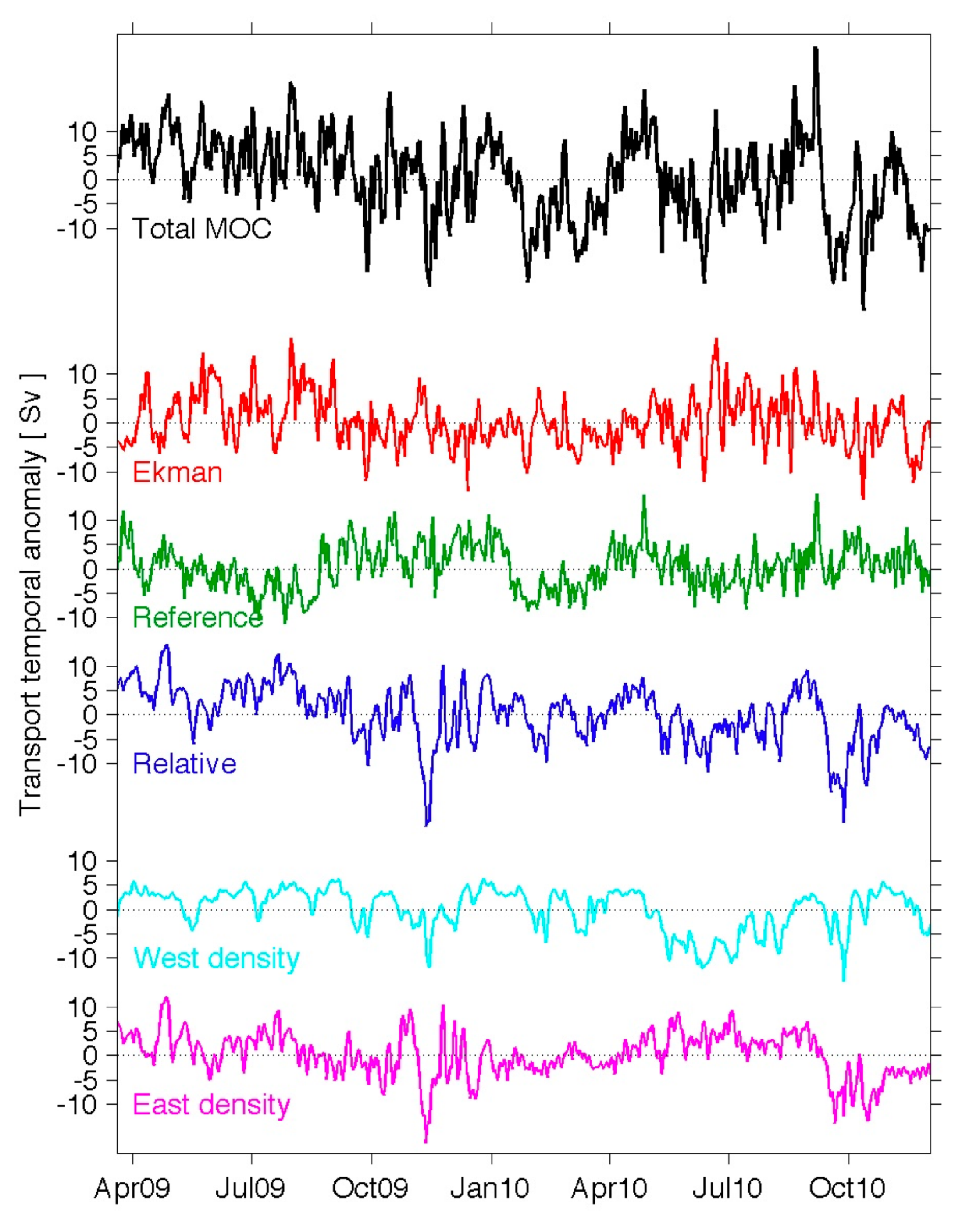
What causes the variability?

The total MOC can be broken down into constituent parts to identify which terms are causing the various MOC changes.

Not surprisingly, Ekman drives much of the highest frequency (<10 day) variability.

The relative (or baroclinic) term is the strongest contributor (53% of total variance), while the Ekman and reference terms are smaller contributors (31% & 11%, respectively).

The relative term is driven roughly equally by density changes on the west and east sides of the basin.



Conclusions

•A first estimate of the MOC at 34.5°S using PIES/CPIES (in concert with the CCMP winds and time-mean shelf estimates and reference velocity from OFES) finds a time varying MOC of comparable magnitude to that observed with the more complete array at 26.5°N (i.e. STD (range) of 10-day low-pass filtered records of 7 Sv (37 Sv) at 34.5°S and 5 Sv (36 Sv) at 26.5°N).

•There is some agreement between the PIES/CPIES based estimates and concurrent XBT based estimates, although the asynopticity inherent in the 1-2+ week completion time for the XBT sections makes the comparison difficult.

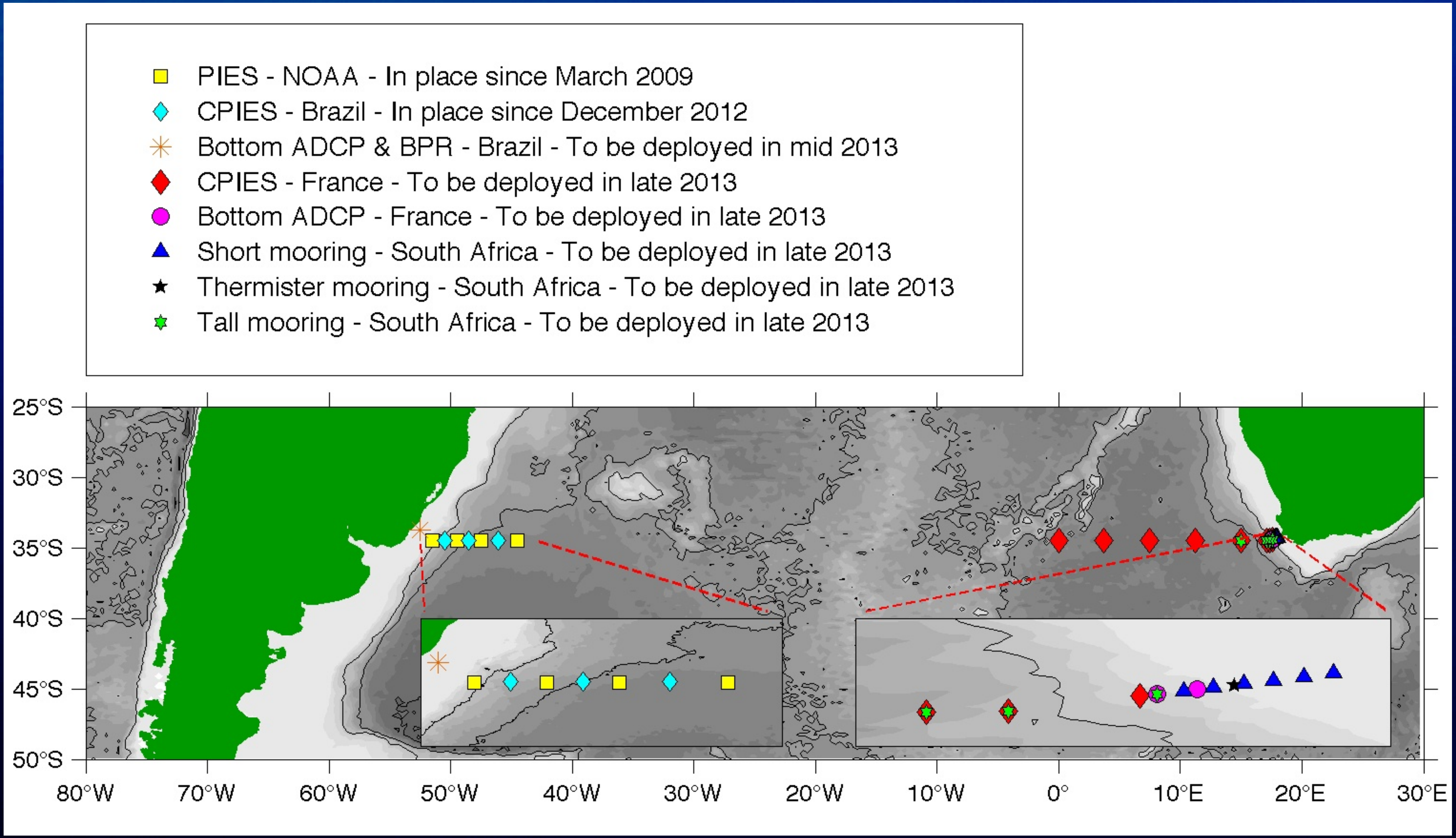
•The PIES/CPIES results suggest that the high frequency (< 10 day) variability in the MOC at 34.5°S is dominated by Ekman flows, but at longer periods the geostrophic contributions (baroclinic and barotropic) become at least as important.

•The geostrophic contributions to the MOC are driven nearly equally by variations in density on the western and eastern boundary of the basin. Future observations at 34.5°S will require monitoring at both boundaries.

•Future observations will require time series observations (PIES, moorings, etc.), but snapshot sections are still valuable.

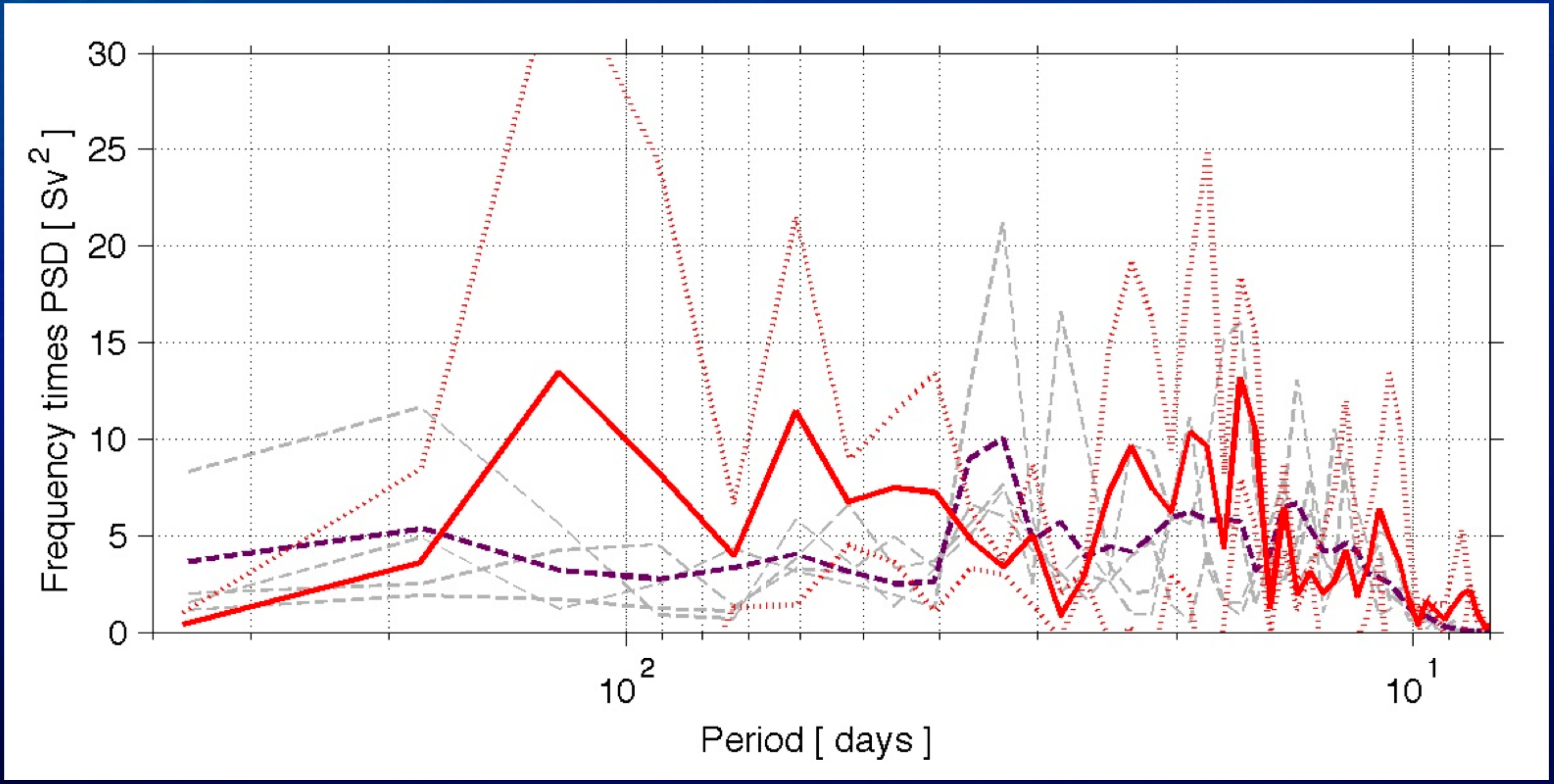
Future plans

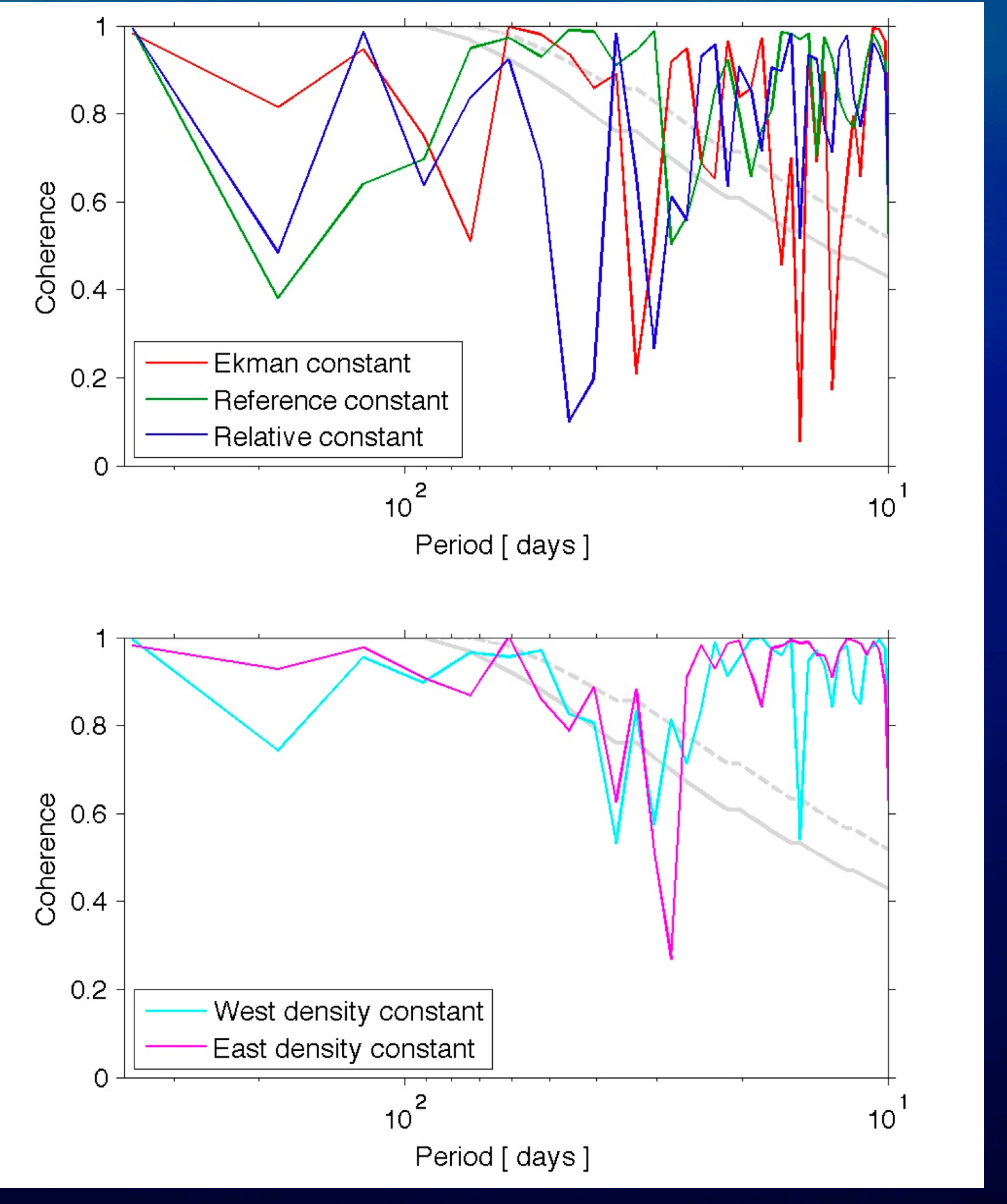
The accuracy/quality of the MOC estimates at 34.5°S will be greatly improved by several forthcoming enhancements to the initial pilot arrays:



Thank you for your attention!

Questions?


30
25
20
15
10
5
0
Frequency times PSD [Sv^2]
10^2
10^1
Period [days]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0.8
0.6
0.4
0.2
0
Coherence
10^2
10^1
Period [days]
Ekman constant
Reference constant
Relative constant
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0.8
0.6
0.4
0.2
0
Coherence
10^2
10^1
Period [days]
West density constant
East density constant