Low-Frequency Transport Variability in the Southern Ocean: The Importance of Regional Variations

Don Chambers, Michael Kosempa, & Jessica Makowski

College of Marine Science

University of South Florida

Computing Zonal Geostrophic Transport Variability

Satellite Gravimetry (GRACE) – integrating bottom pressure gradients over full depth

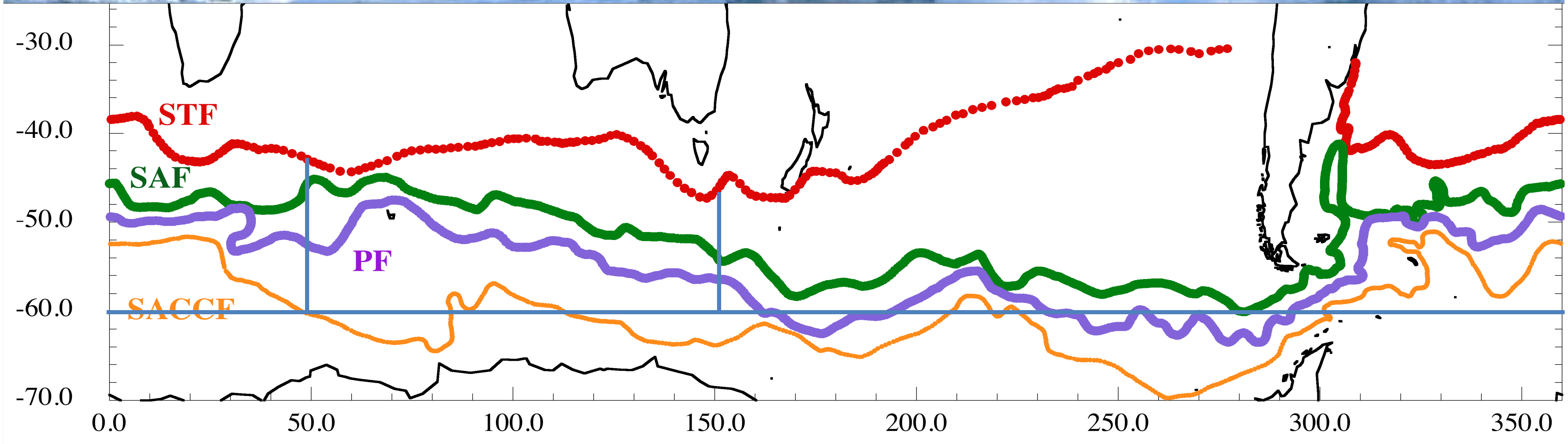
$$\Delta T(x) = \int_{y_s}^{y_n} \int_{-H}^{\eta} -\frac{1}{f\rho} \frac{\partial \Delta P}{\partial y} dz dy \approx \int_{y_s}^{y_n} \int_{-H}^{\eta} \Delta \bar{u}(x, y, t)\, dz dy$$

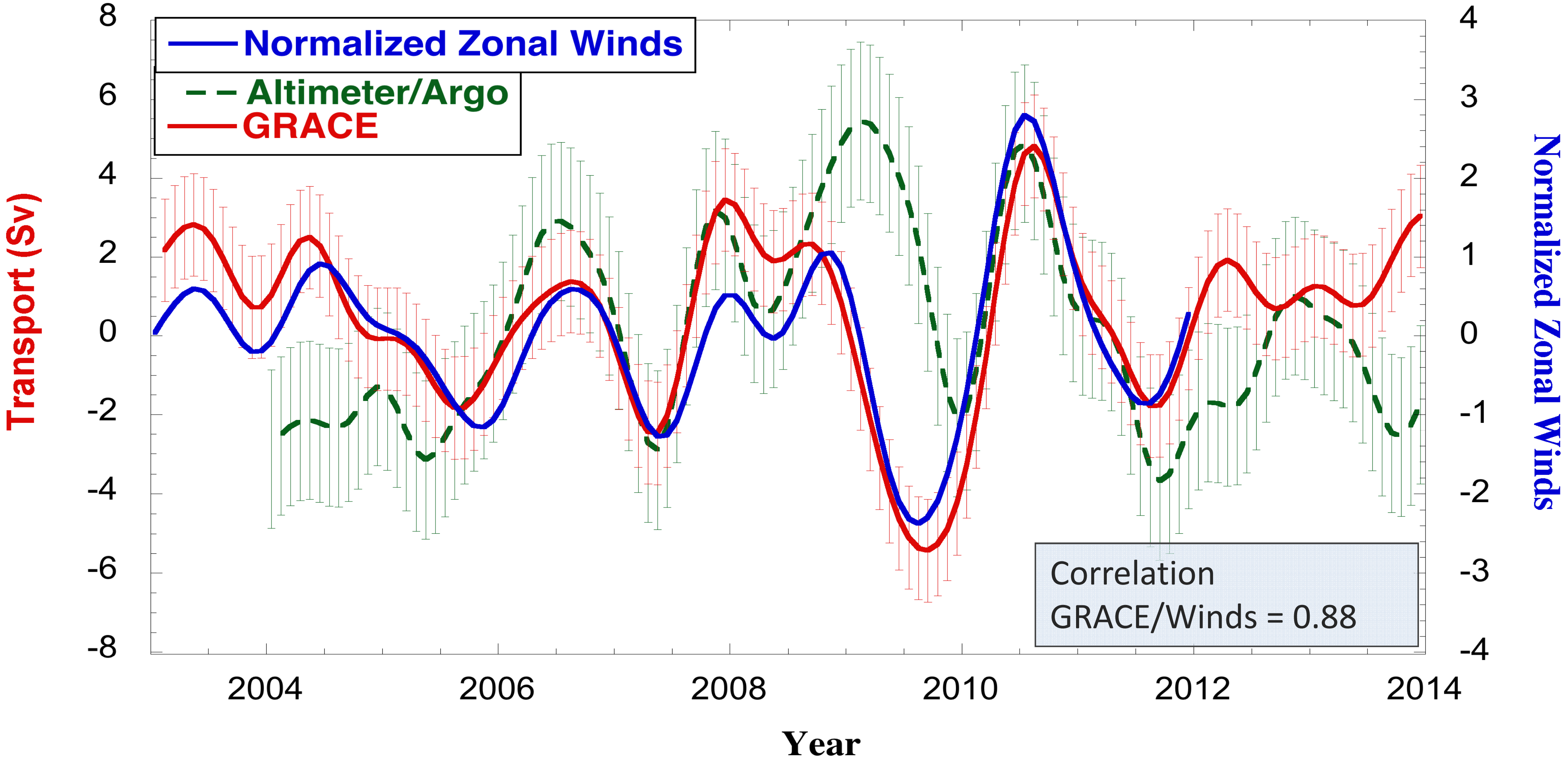
Makowski, J. K., D. P. Chambers, and J.A. Bonin (2015), Using Ocean Bottom Pressure from the Gravity Recovery and Climate Experiment (GRACE) to Estimate Transport Variability in the Southern Indian Ocean, *J. Geophys. Res. Oceans, 120*, doi: 10.1002/2014JC010575

Satellite altimetry and Argo – combine surface currents from altimetry, with relative currents from Argo-derived density, plus a reference current at depth derived from a combination of altimetry and Argo. Only to 1975 dbars

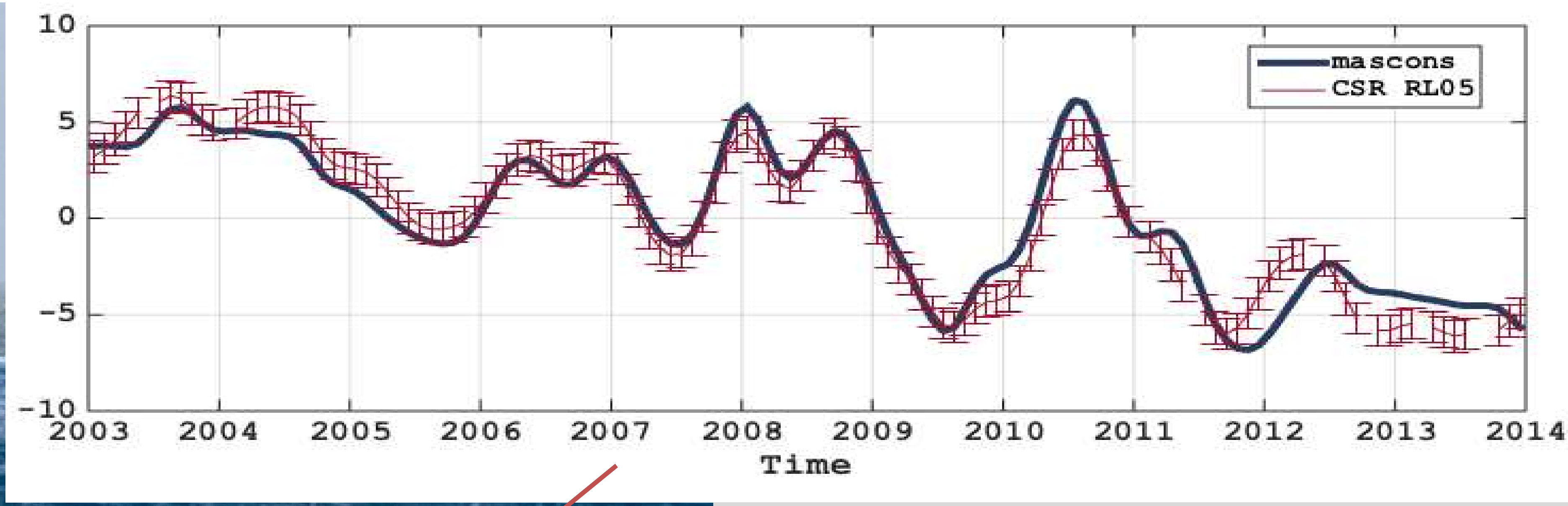
$$\Delta T(x) = \int_{y_s}^{y_n} \int_{-1975}^{\eta} \Delta u(x, y, z, t)\, dz dy$$

Kosempa, M., and D. P. Chambers, (2014) Southern Ocean Velocity and Geostrophic Transport Fields Estimated by Combining Jason Altimetry and Argo Data, *J. Geophys. Res. Oceans, 119*, doi:10.1002/2014JC00985.

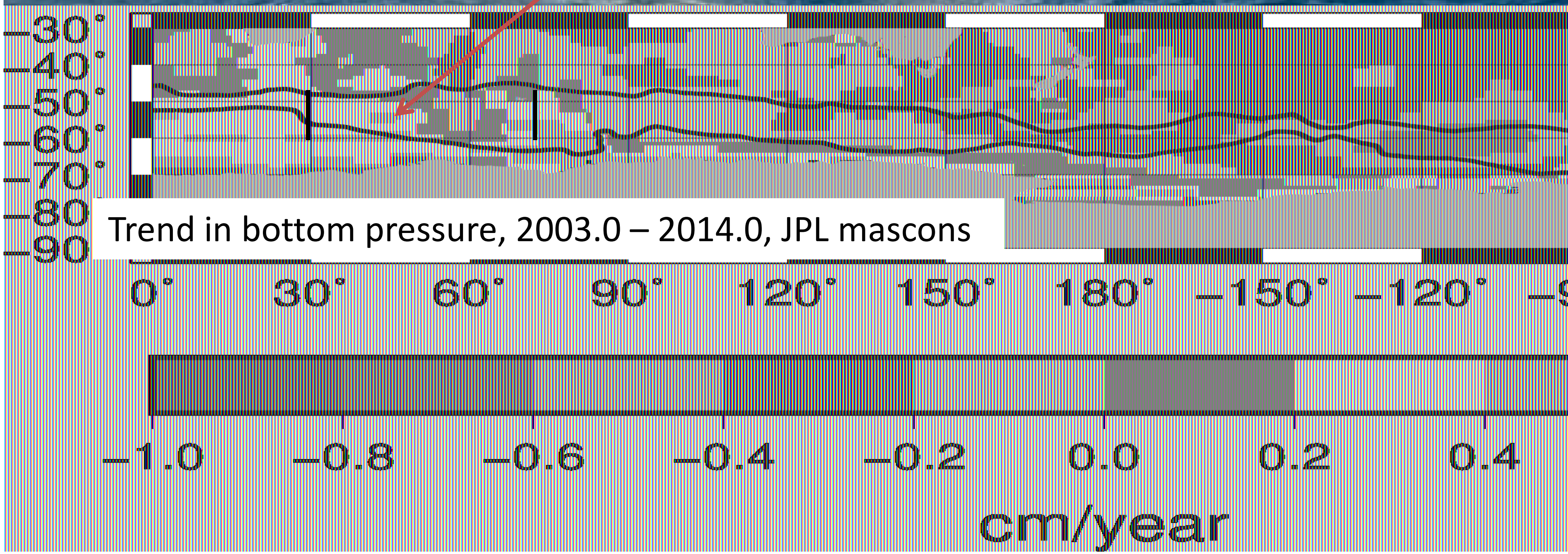

STF
SAF
PF
SACCF
-30.0
-40.0
-50.0
-60.0
-70.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0



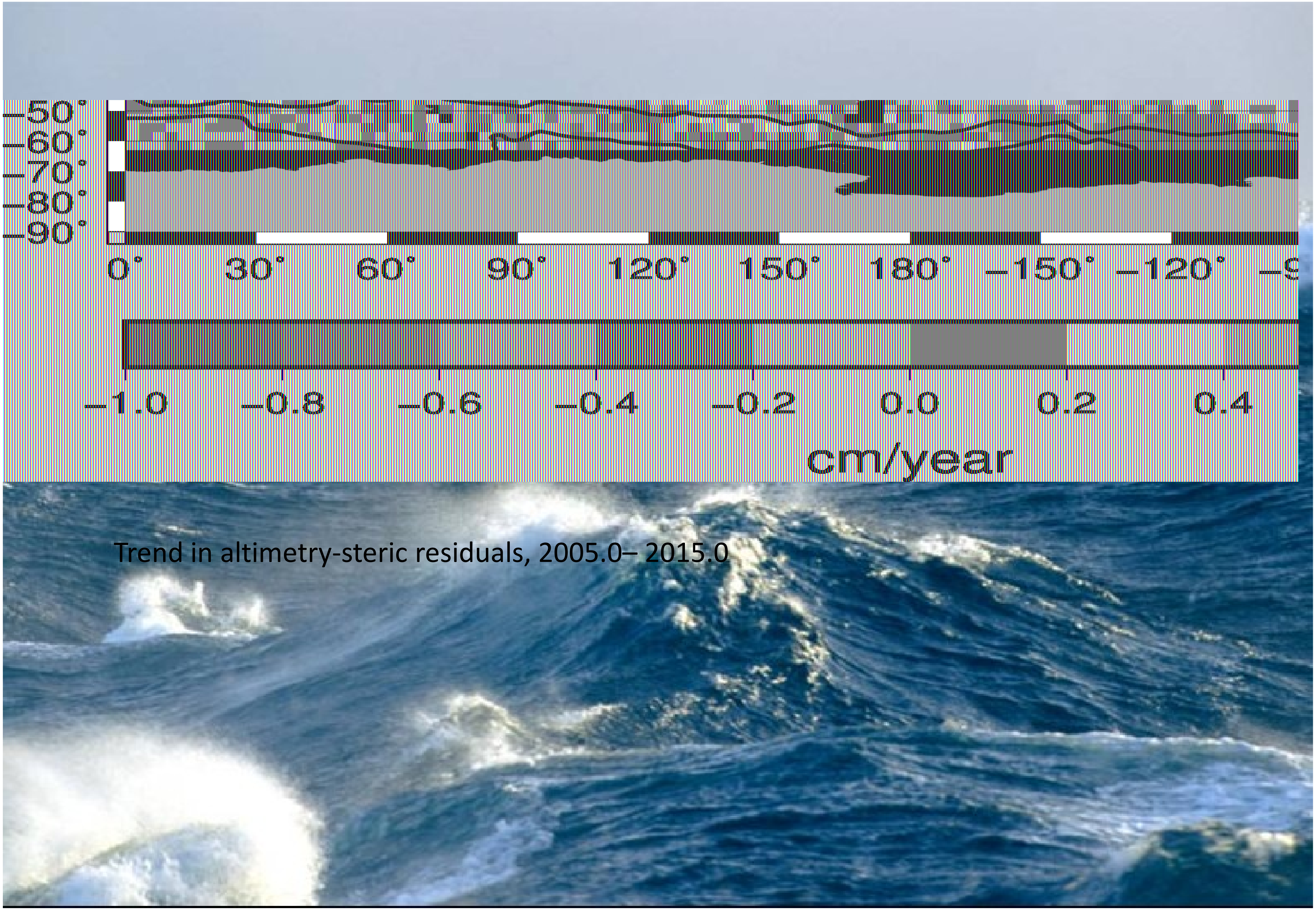
Average of CCMP zonal winds between 45°S-65°S, 0-360°E, normalized by standard deviation
Trend in GRACE transport removed
Low-pass filtered by removing annual sinusoid and using a 3-month Gaussian filter
Uncertainty 1 standard error



Trend Mascons: -0.72 ± 0.4 Sv/year

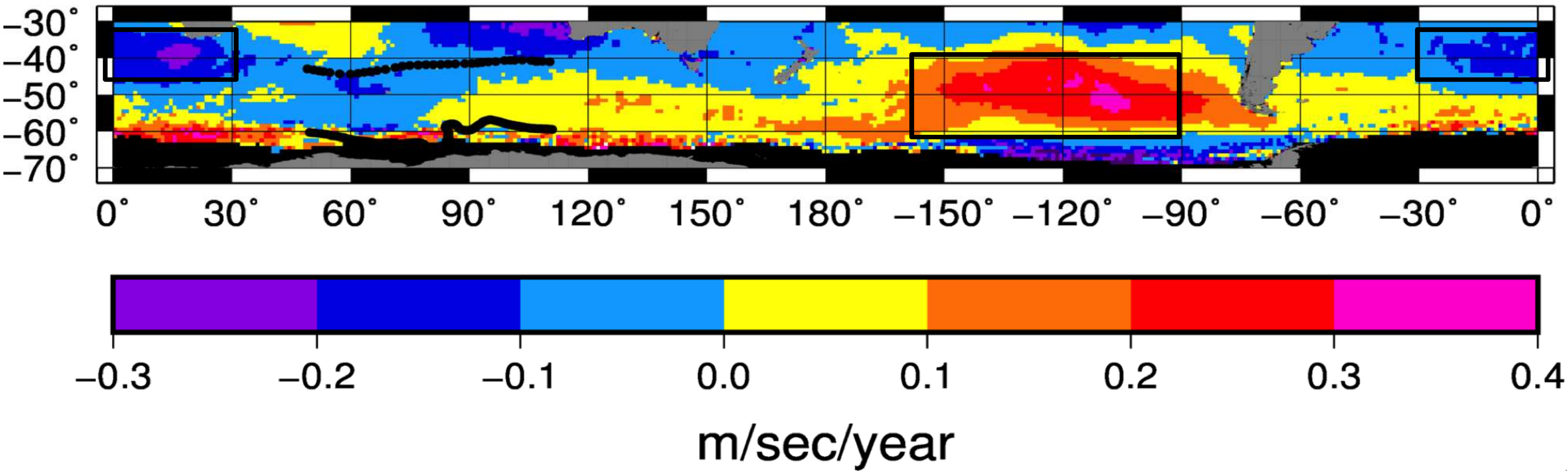


Trend in bottom pressure, 2003.0 – 2014.0, JPL mascons

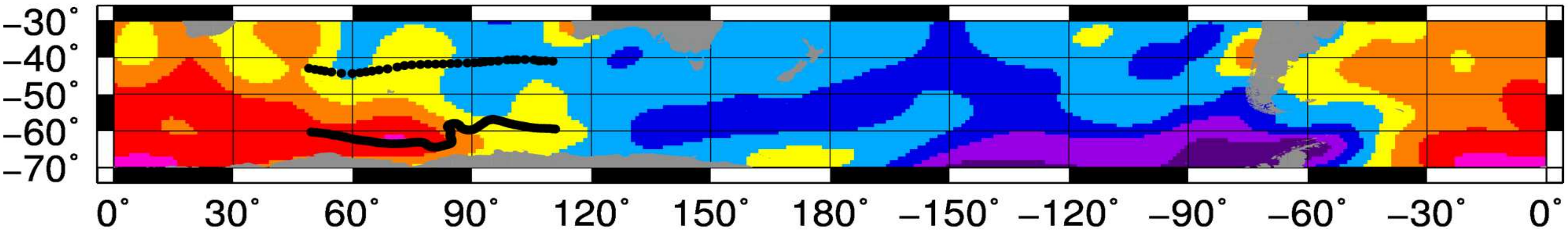


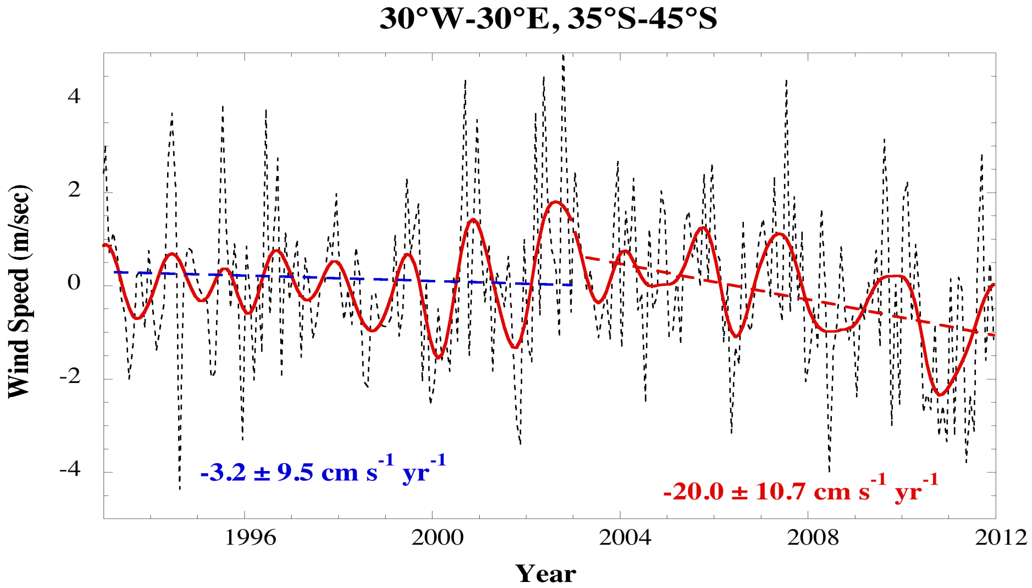
Trend in altimetry-steric residuals, 2005.0– 2015.0

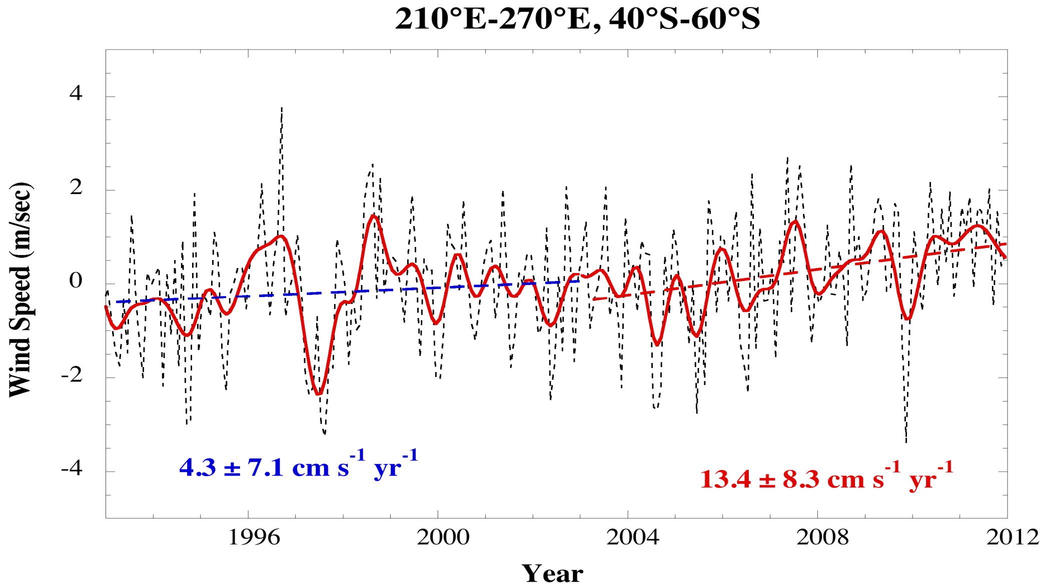
a) Trends in Zonal Wind Speed (CCMP)



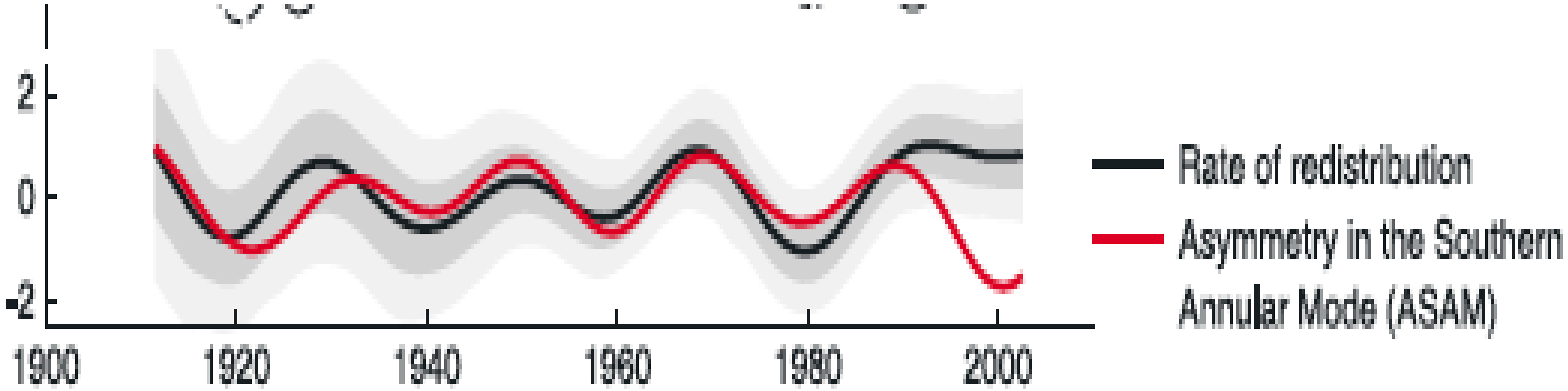
b) Trends in OBP (GRACE)



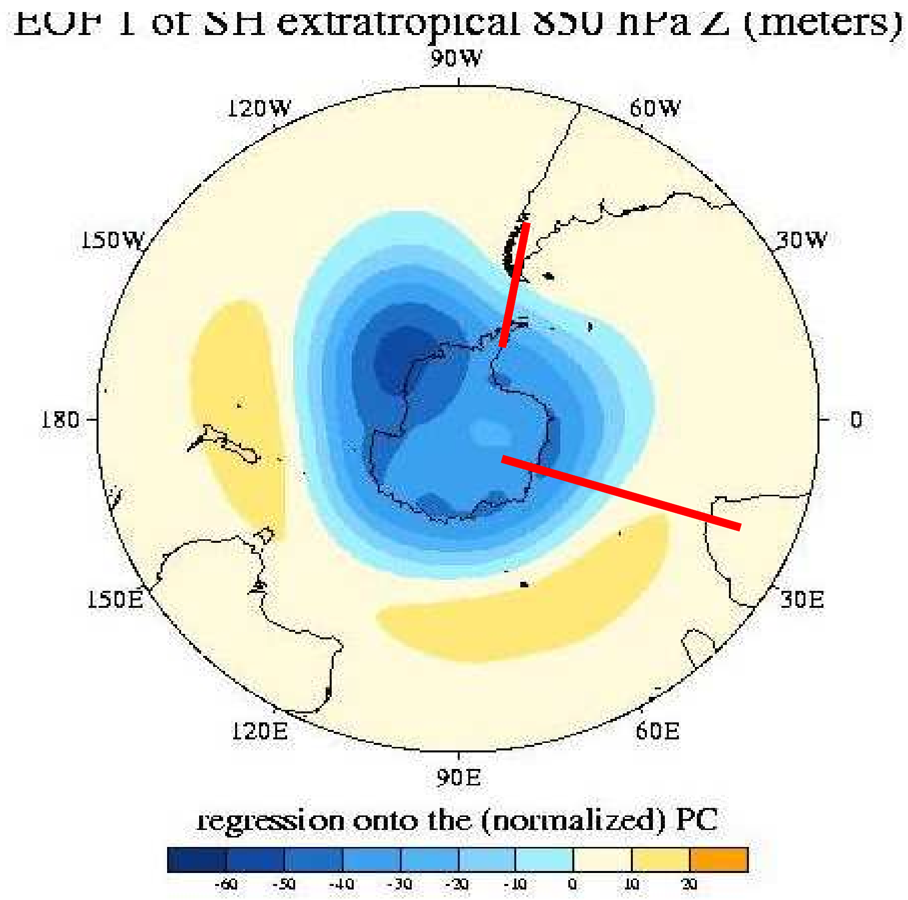


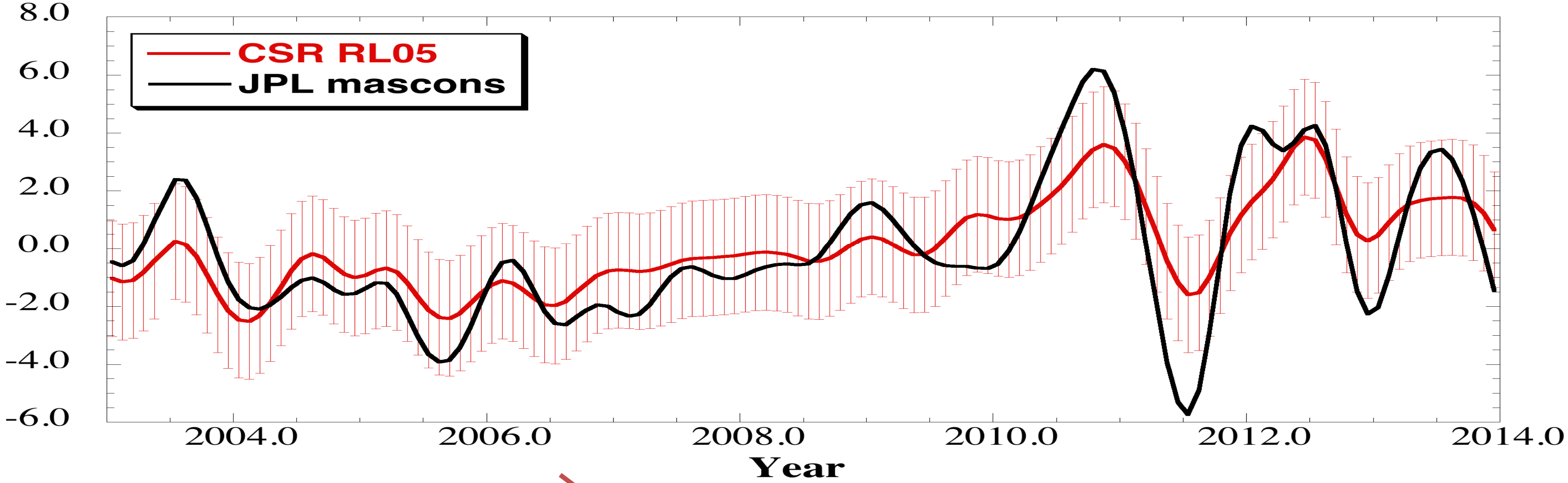


- Winds averaged over box, then 0-360° average and seasonal climatology removed (black dotted)
- Red curve is low-pass filtered (4-month Gaussian)
- Trend uncertainty 95% confidence computed using covariance of unfiltered residuals to compute AR(1) colored noise model and 1000-member Monte Carlo simulation

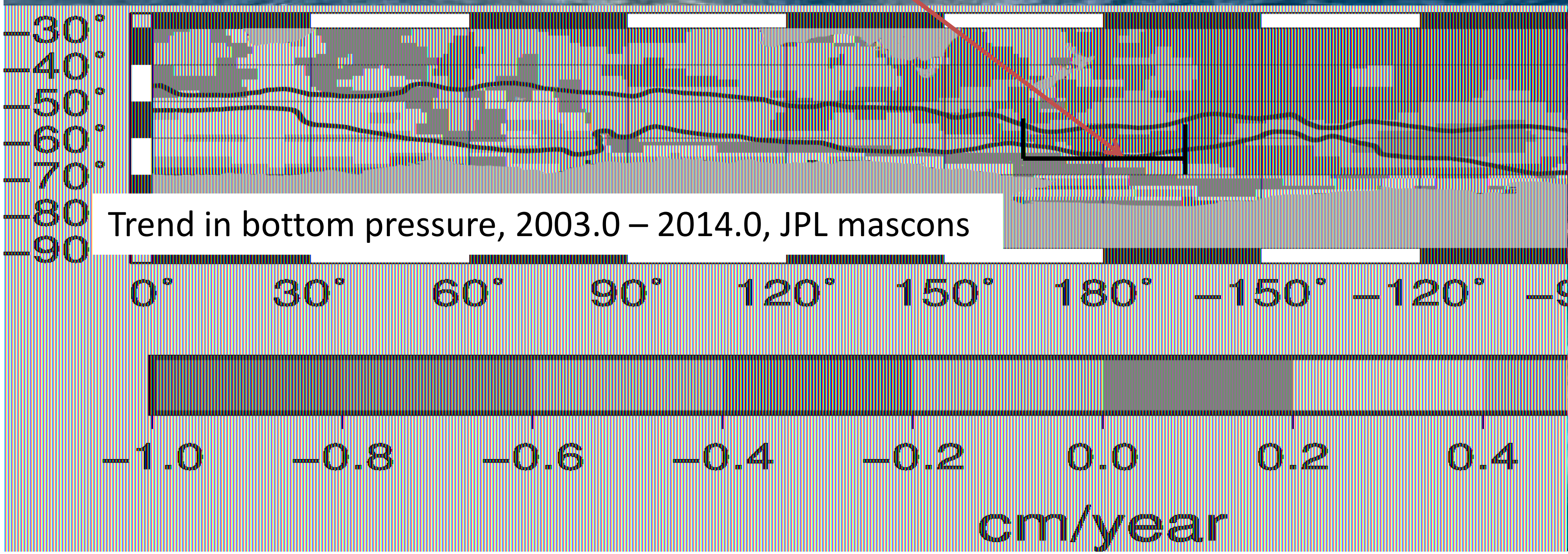


Thompson and Merrifield (JGR, 2014) recently demonstrated there is an asymmetry in the zonal winds in the Southern Ocean, with a period near 20-years.





Trend Mascons: +0.32 ± 0.3 Sv/yr
Trend CSR05 SH: + 0.35 ± 0.3 Sv/yr

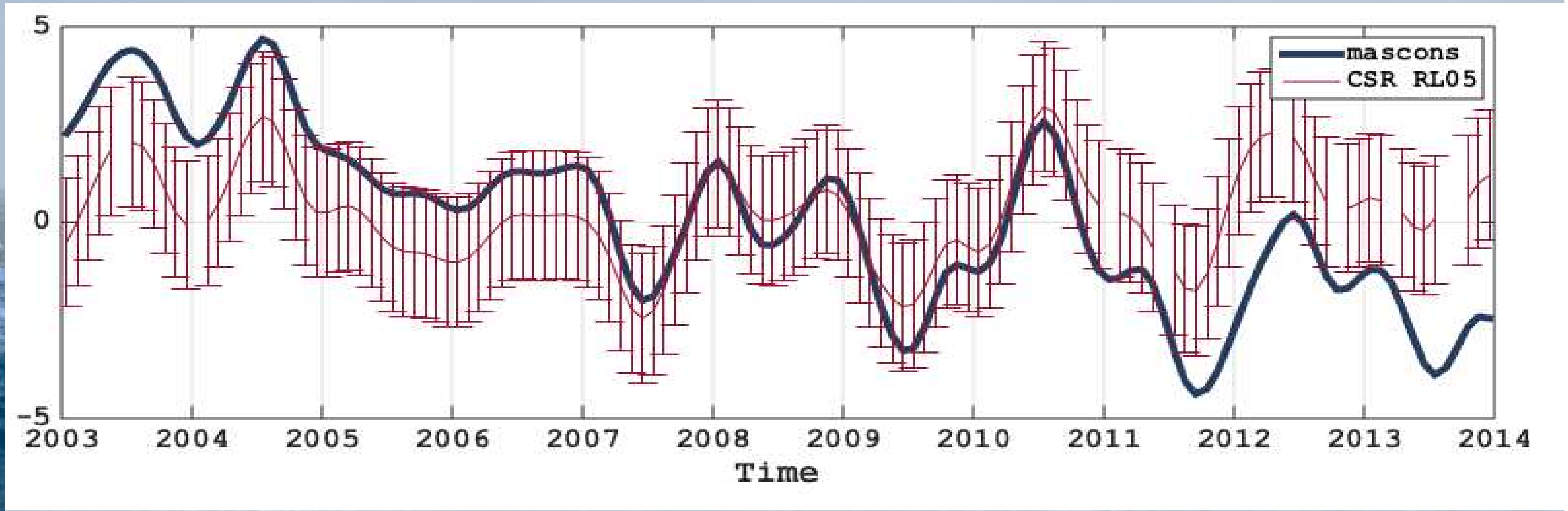


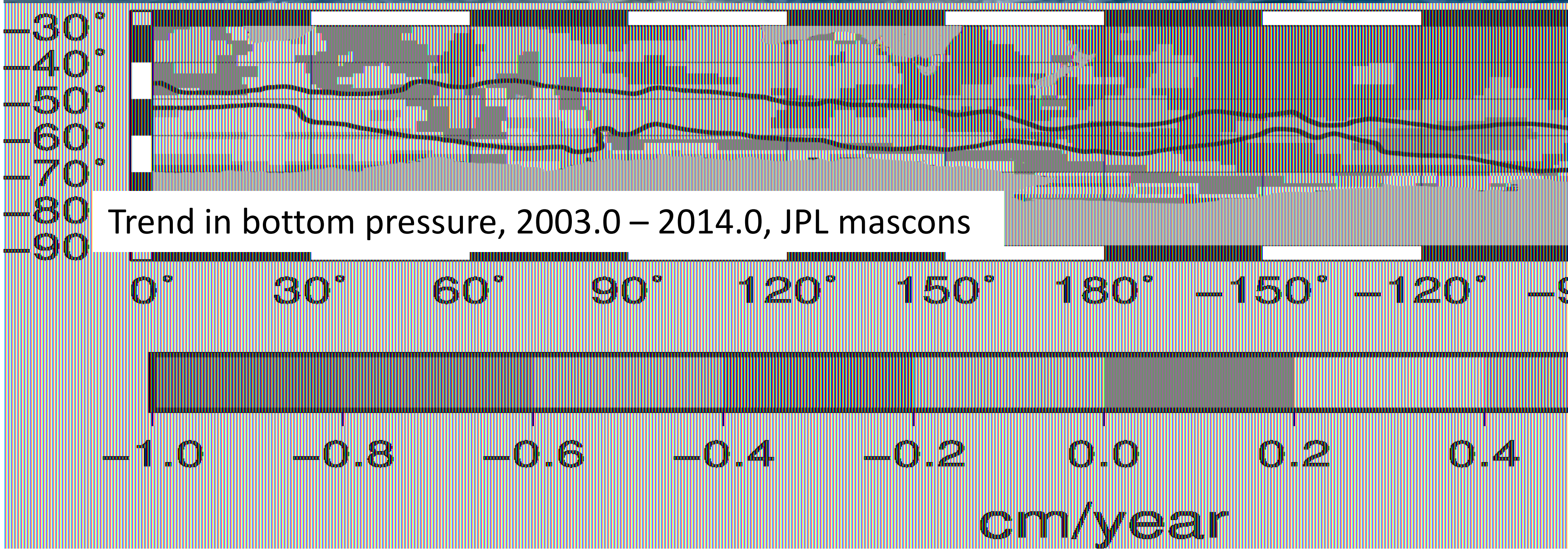
Trend in bottom pressure, 2003.0 – 2014.0, JPL mascons

Conclusions

- Significant decadal-scale variability in Southern Ocean
- Different sign of trend in Indian Ocean, South Pacific
- Can we really measure climate-related transport change in in the ACC using only repeat hydrography transects across the Drake Passage?

Integrated between PF and SAF, averaged over 0-360°E





Trend in bottom pressure, 2003.0 – 2014.0, JPL mascons


Questions?

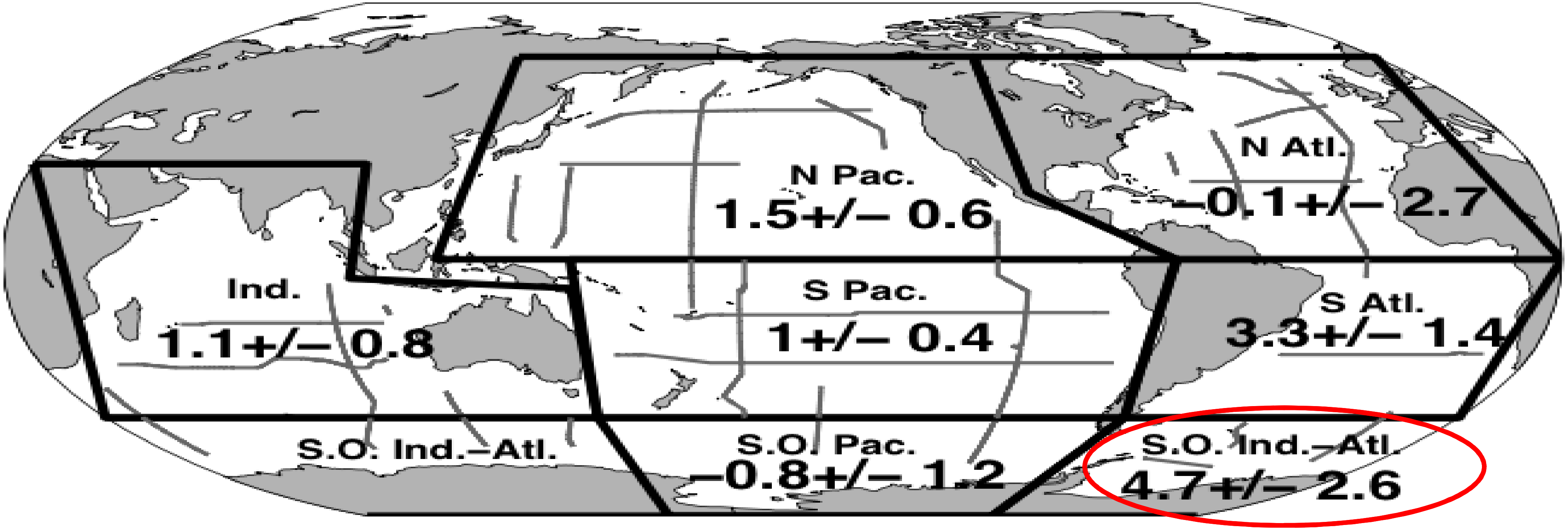
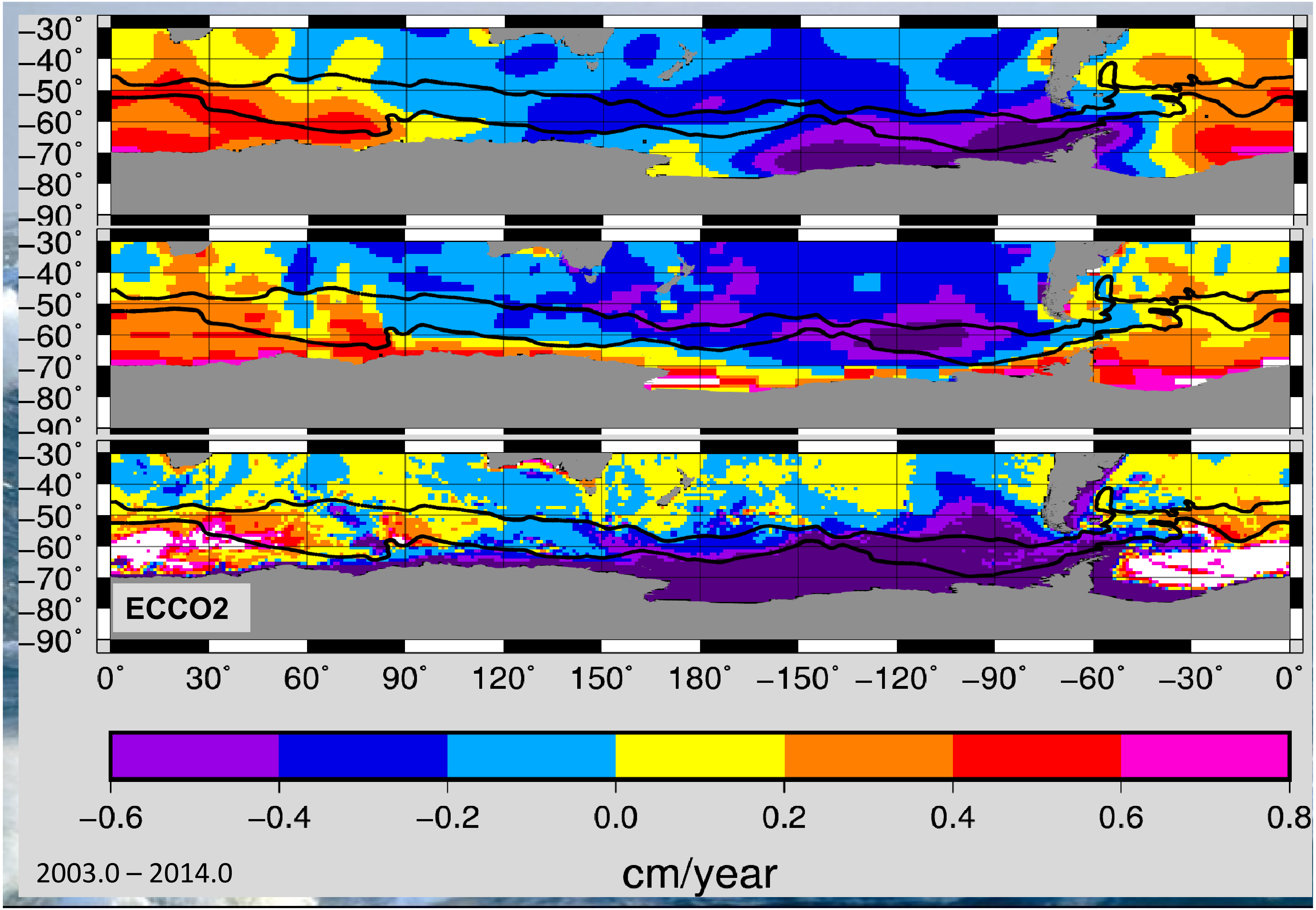
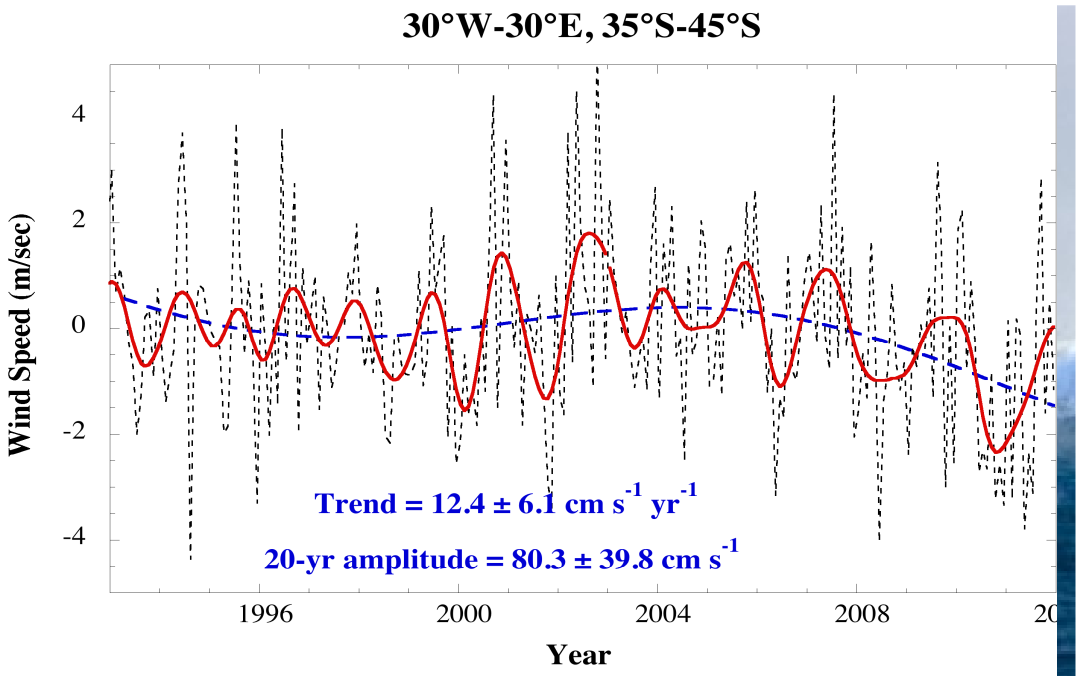
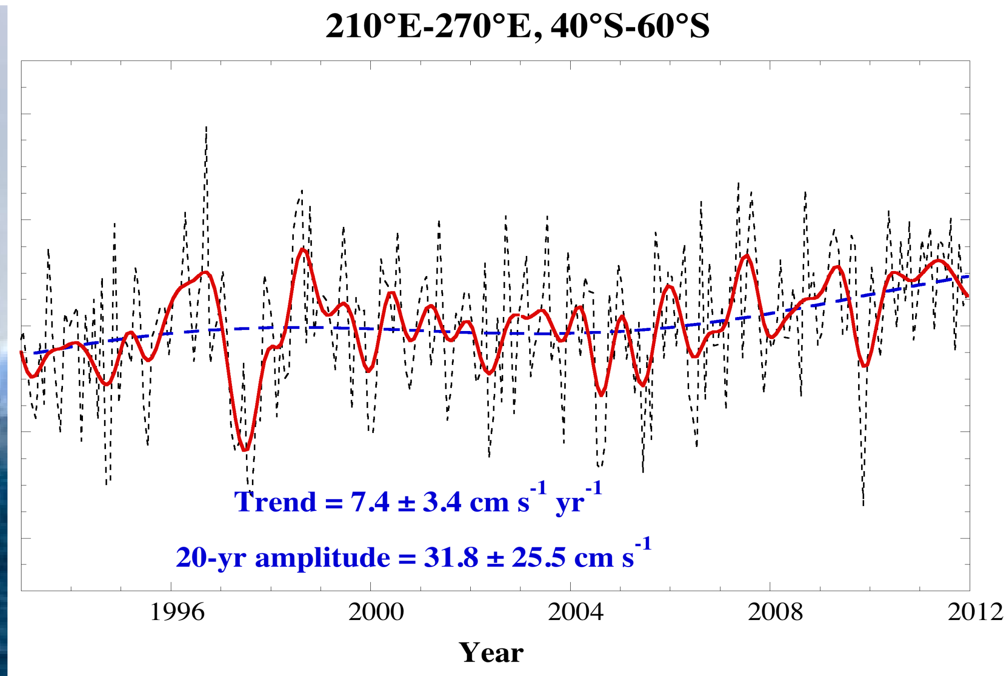


Figure 1: Boundaries (black lines) of study regions termed North Pacific (N. Pac.), North Atlantic (N. Alt.), Indian (Ind.), South Pacific (S. Pac.), South Atlantic (S. Atl.), Indian–Atlantic sector of the Southern Ocean (S.O. Ind.-Atl.) and the Pacific Sector of the Southern Ocean (S.O. Pac.) with mean ocean mass sea level rise (mm yr^{-1}) calculated from the residual between total and steric sea level changes along sections (gray lines). Uncertainties given are two-tailed 90% confidence limits.

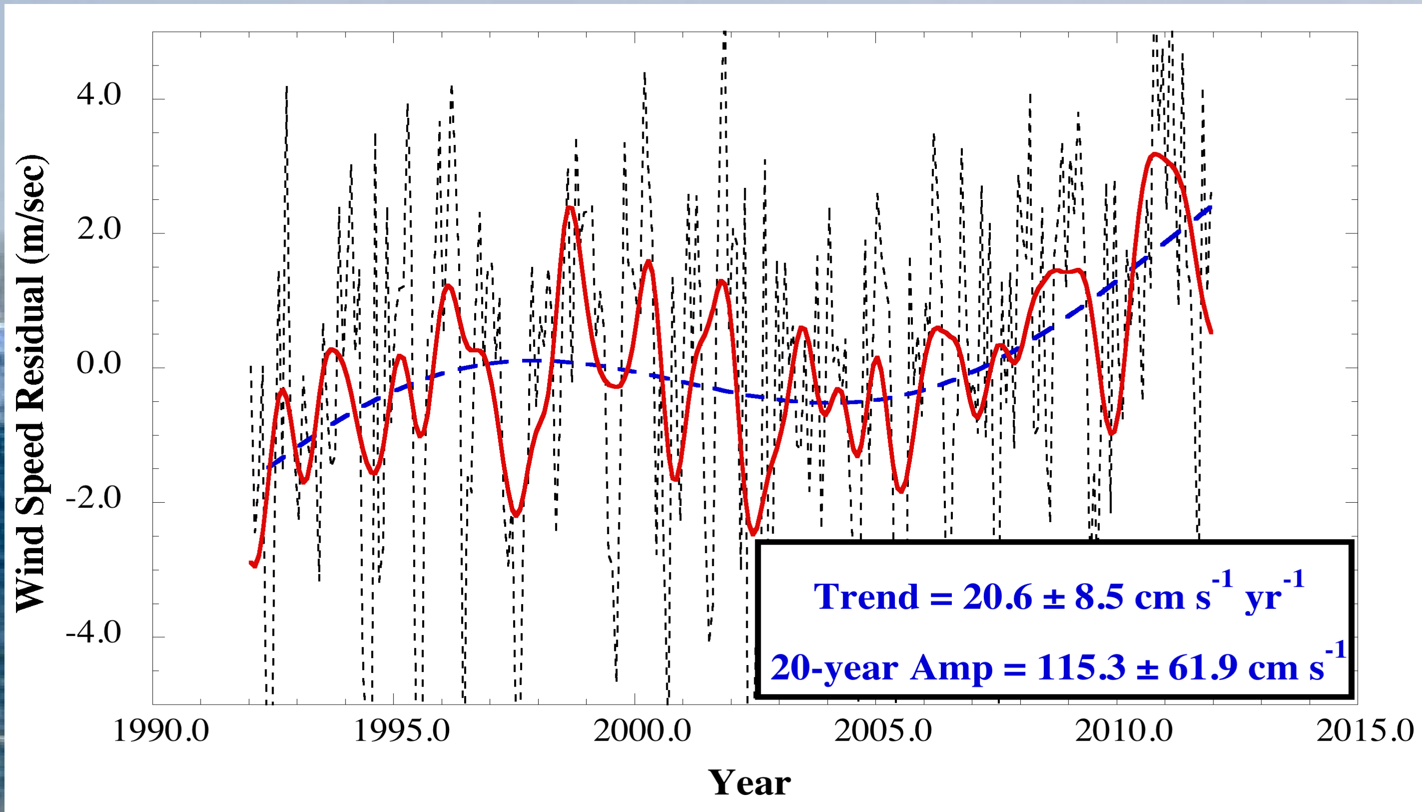
Purkey, S. G., G. C. Johnson, and D. P. Chambers (2014), Relative contributions of ocean mass and deep steric changes to sea level rise between 1993 and 2013, *J. Geophys. Res. Oceans, 119*, doi:10.1002/2014JC010180.


ECCO2
−30°
−40°
−50°
−60°
−70°
−80°
−90°
0°
30°
60°
90°
120°
150°
180°
−150°
−120°
−90°
−60°
−30°
0°
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
cm/year
2003.0 – 2014.0





- Correlation of low-pass curves is -0.45 ($p < 0.01$)
- Uncertainty 95% confidence computed using covariance of unfiltered residuals to compute AR(1) colored noise model and 1000-member Monte Carlo simulation



- Pacific winds minus Indo-Atlantic winds
- 20-year oscillation + trend explains 42% of low-frequency variance.