Upper-ocean circulation of the Southern Ocean from in situ Argo float measurements and altimeter data

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1. Introduction

The aim of this work is to estimate the mean upper ocean circulation and density field of the Southern Ocean by combining in situ Argo float measurements and altimeter data. Identifying and understanding changes in the mean properties of the Antarctic Circumpolar Current (ACC) during the last decade would contribute to the understanding of the Southern Ocean's role in global warming. Eddy variability in the density (ρ), temperature (T) and salinity (S) fields is estimated using sea surface height (SSH) anomaly maps and linear regression coefficients (α) of SSH as a function of position and depth. Due to the equivalent barotropic nature of the ACC, high correlation values between the altimeter signal and the Argo profiles are obtained for pressure levels down to 2000 db.

2. Data and methods

Since the inception of the Argo program in the year 2000, a steady increase in the number of T and S profiles has allowed a better description of the mean properties of the Southern Ocean. As of today, the Argo float array is large enough (Figure 1) to accurately map the mean and eddy fields during the last decade. Previous studies have shown that SSH is correlated with the upper ocean density anomalies (Gilson et al., 1998; Willis et al., 2004; Willis and Fu, 2008). In this work, the same technique is applied to the ρ, T and S anomalies of the Southern Ocean. To remove the eddy variability in the ρ, T and S fields using the SSH anomaly signal, the spatially varying mean over the period of interest (January 2001 through December 2010) is first removed from each variable. Anomalies for each Argo profile are estimated by removing the local mean defined by averaging all observations within a 200 km radius of each profile. Regression coefficients α(x, y, z) of SSH anomalies onto ρ, T and S were then computed in 4° longitude by 2° latitude bins for each vertical level from the surface to 2000 db (Figure 2). The estimate of the time-average fields is then computed as:

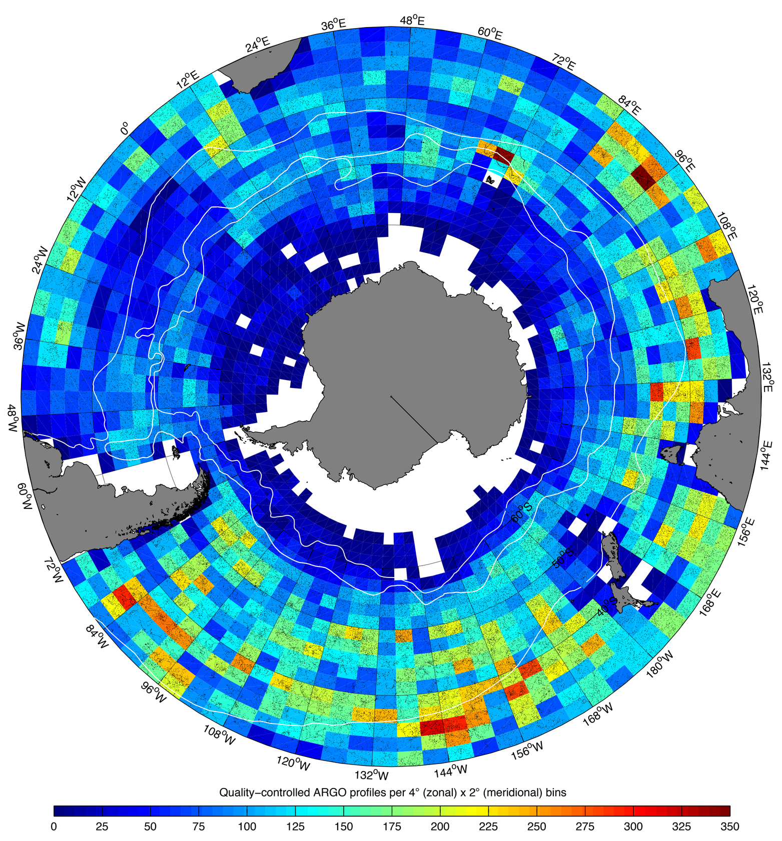

Figure 1: Argo profiles per 4° x 2° bins.

$$f_{estimate} = \{f_{profile} - \alpha\, x\, SSH'\} + \overline{\alpha\, x\, SSH'}$$

Where curly brackets represent objective mapping (Bretherton et al., 1976) and the over bar represents the time average over the study period. Subtraction of the altimeter signal significantly reduces the variance of ρ, T and S anomalies (Figure 3).

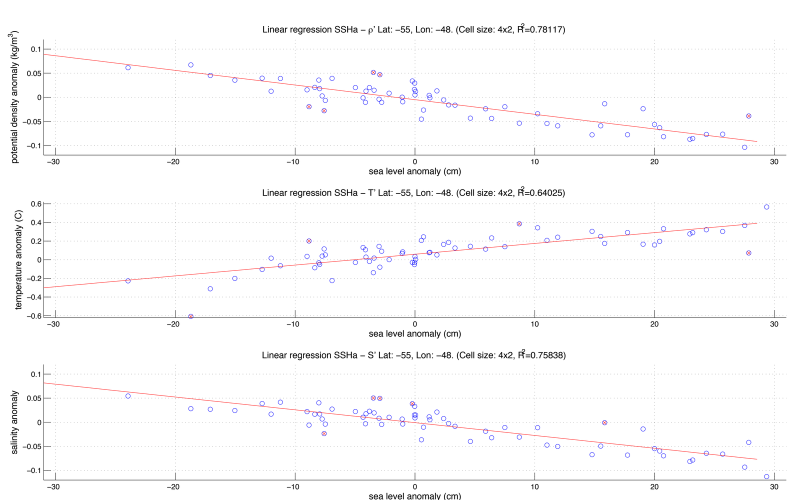

Figure 2: Example of linear regression between SSH anomalies and ρ (top), T (middle) and S (bottom).

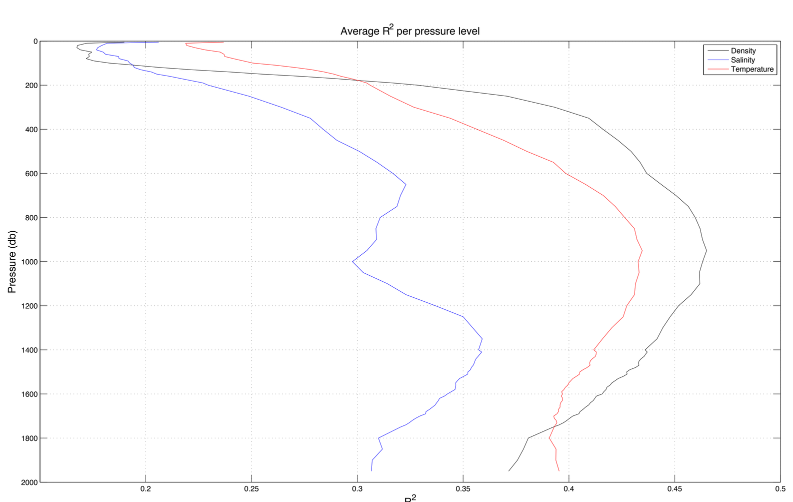

Figure 3: Domain-averaged R^2 between the altimeter signal and the Argo profiles per pressure level for ρ (black), T (red) and S (blue).

3. Combining altimeter and float data

The potential density (σ_θ) variance explained by the altimeter at 1150 db (pressure of maximum correlation, figure 3) is shown in figure 4. The average R^2 on the ACC is 0.6. Maximum correlations are generally found on the Atlantic and Indian side of the Southern Ocean and north of the Subantartic front (white solid line). Figures 5, 6 and 7 show the regression coefficient between SSH anomalies and S, T and σ_θ anomalies respectively. Different response behaviors can be seen south and north of the Polar front, specially for SSH and S anomalies where the slope of regression reverses sign. The mean density field at 1150db after removing the altimeter signal is shown in Figure 8.

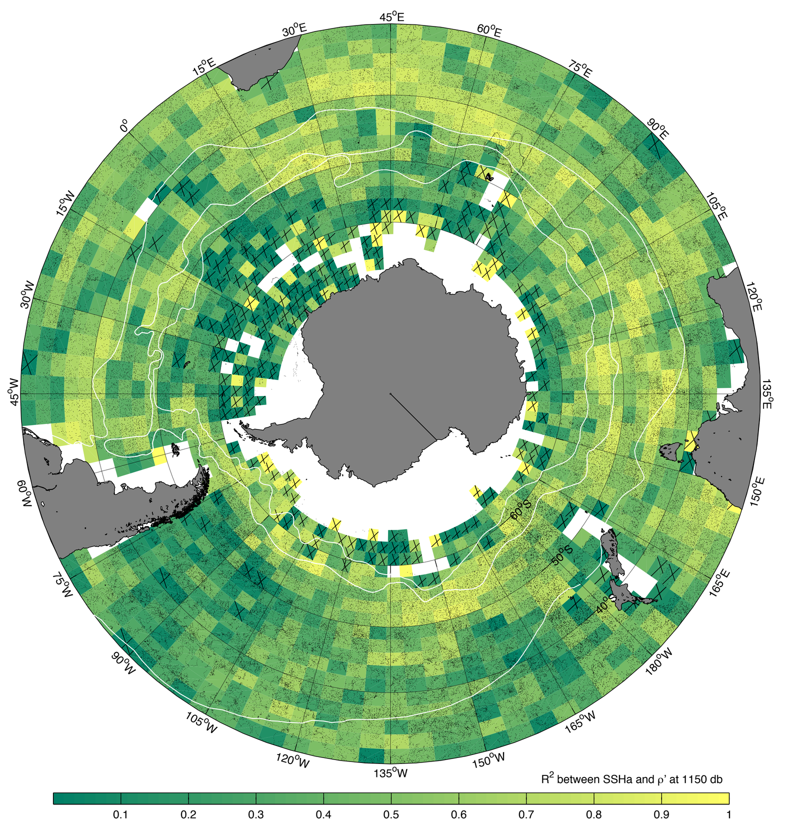

Figure 4: R^2 between SSH and σ_θ anomalies at 1150db.

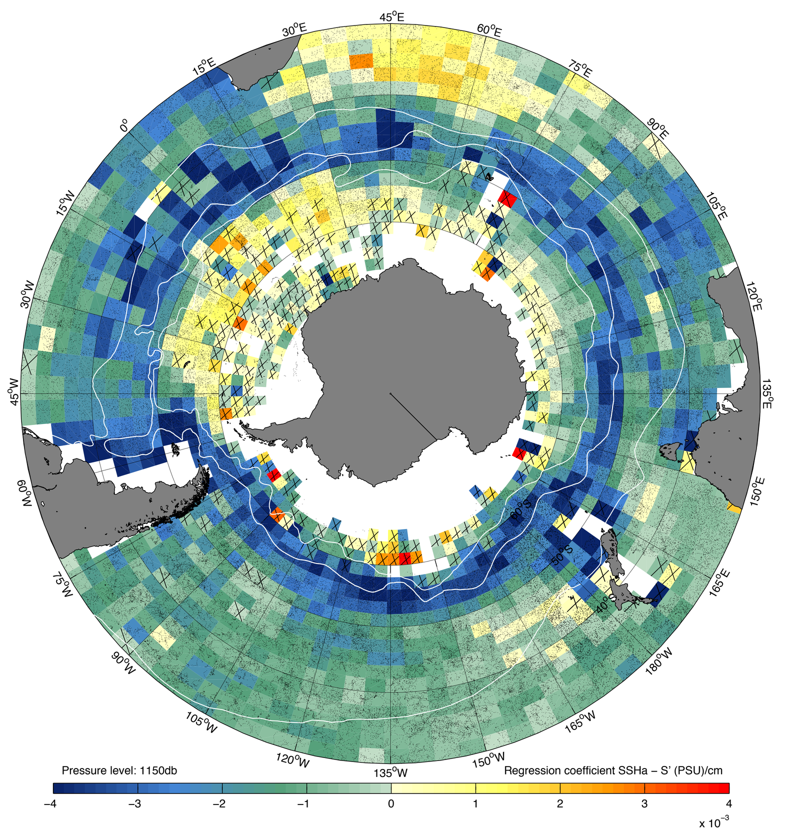

Figure 5: Regression coefficient between SSH and S anomalies at 1150db.

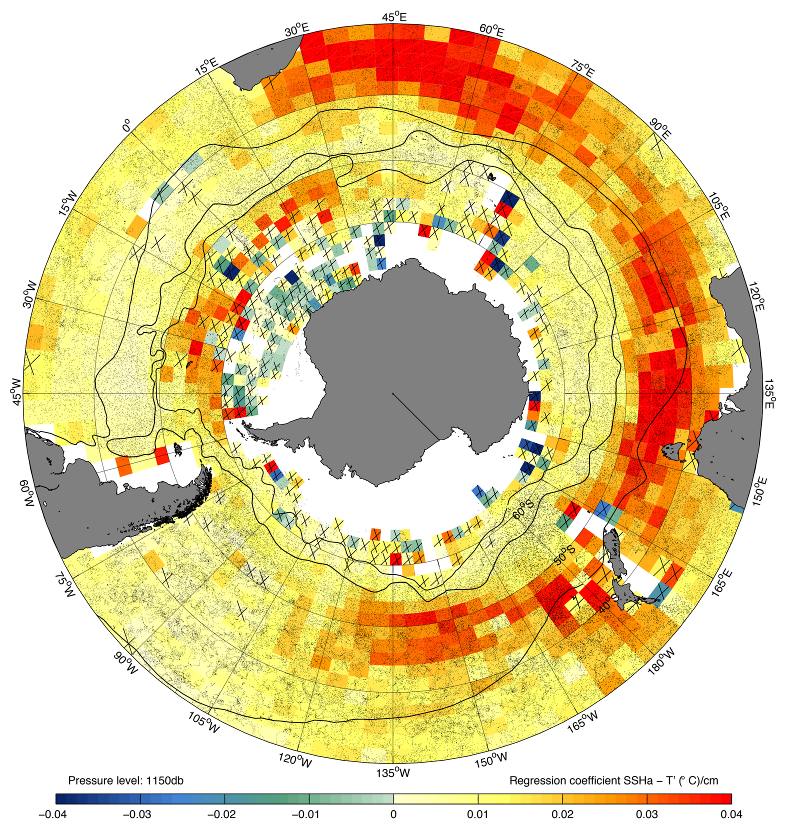

Figure 6: Regression coefficient between SSH and T anomalies at 1150db.

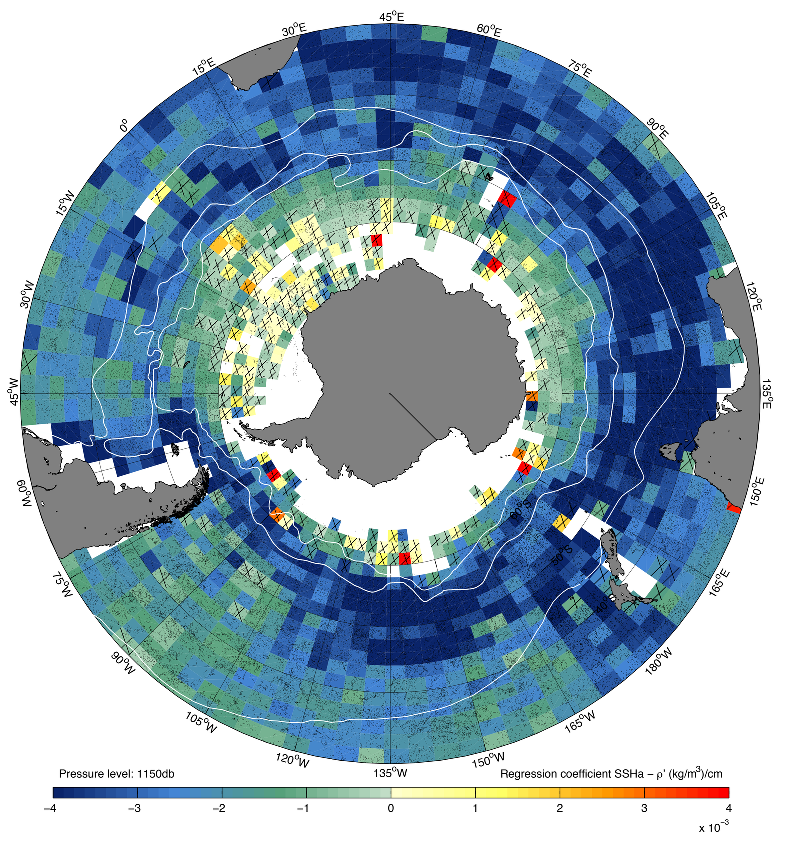

Figure 7: Regression coefficient between SSH and σ_θ anomalies at 1150db.

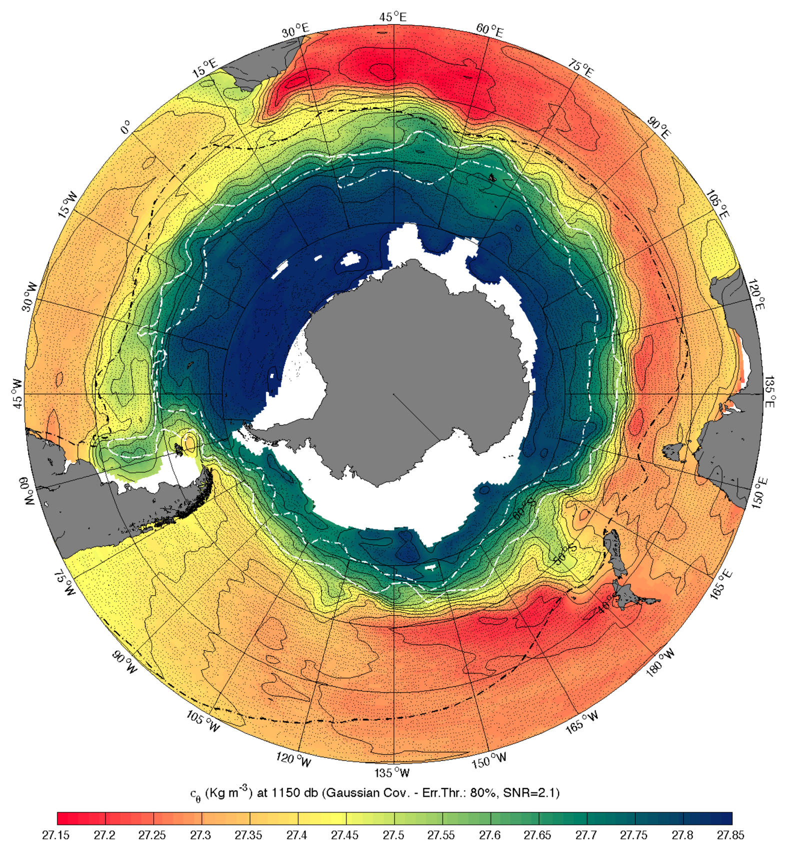

Figure 8: Mean density field at 1150db after removing the altimeter signal.

4. Future work

Further work will be directed towards the estimation of the relative contributions of the mean and eddy poleward heat transport at the Southern Ocean using the mean and eddy density and temperature fields estimated in this work.

Bretherton, F. P., R. E. Davis, and C. B. Fandry (1976), A technique for objective analysis and design of oceanographic experiments applied to MODE-73, Deep Sea Res., 23, 559–582.

Gilson, J., D. Roemmich, B. Cornuelle, and L.-L. Fu (1998), Relationship of TOPEX/Poseidon altimetric height to steric height and circulation of the North Pacific, J. Geophys. Res., 103, 27,947–27,965.

Willis, J. K., D. Roemmich, and B. Cornuelle (2004), Interannual variability in upper ocean heat content, temperature, and thermosteric expansion on global scales, J. Geophys. Res., 109, C12036, doi:10.1029/ 2003JC002260.

Willis, J.K., and L.-L. Fu, 2008: Combining altimeter and subsurface float data to estimate the time averaged circulation in the upper ocean, Journal of Geophysical Research., 113, C12017, doi:10.1029/2007JC004690.