A joint inversion of GRACE, GPS, modeled and in-situ ocean bottom pressure.

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1 Introduction

Ocean bottom pressure (OBP) is a key quantity in oceanic research because it defines a reference pressure field. In addition it quantifies the mass load on the bottom of the ocean. Investigating the time variability of the mass load is of high interest for climate change research and for modelers who use the global mean ocean mass variation to verify and to constrain their models. To this end Rietbroek et al. (2012) performed a joint inversion of GRACE, GPS and modeled ocean bottom pressure data. Their results show good agreement with in-situ OBP in some regions but not globally. The aim of the present work is to improve the inversion of Rietbroek et al. (2012) by including measured OBP anomalies from Bottom Pressure Recorder (BPR) as additional constraint in the joint inversion.

2.1 Methods: Data

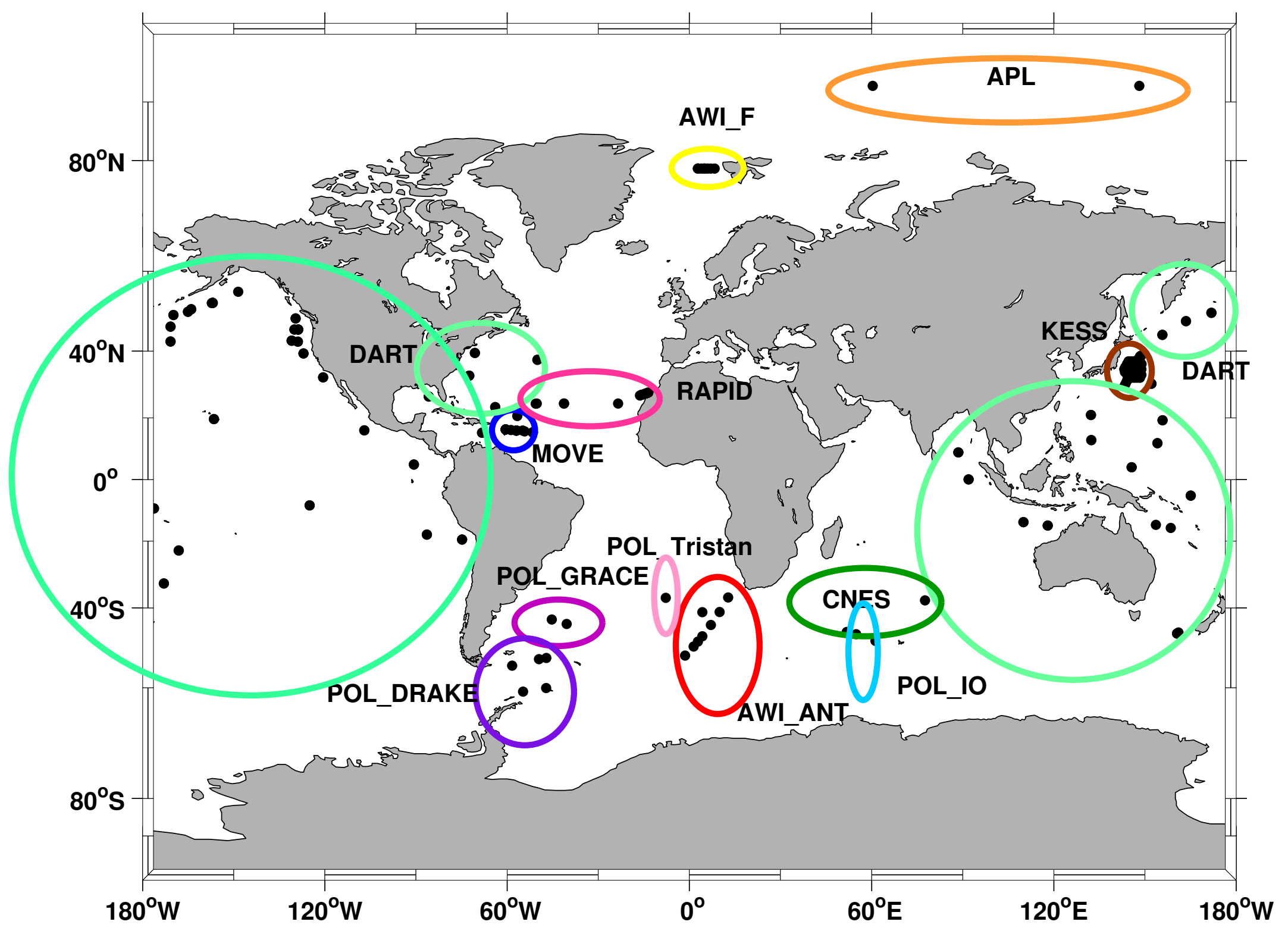

Figure 1: Spatial distribution of in-situ OBP data. The circles indicate the array/project the data belongs to.

The in-situ OBP data were obtained from the AWI OBP database (Macrander et al., 2010). Figure 1 shows the global distribution of the in-situ measurements and indicates the different arrays like the Meridional Overturning Variability Experiment (MOVE) or the Antarctic array (AWI_ANT) of the Alfred Wegener Institute (AWI).

2.2 Methods: Inversion

The joint inversion is performed in the spectral domain. The normal equation is built using a design matrix A which consists of spherical harmonics ($\bar{Y}_{nm}$) evaluated at the positions of the in-situ OBP data for degree and order up to 30.

$$A \cdot \vec{x} = \sum_{n=0}^{30} \sum_{m=-n}^{n} x_{nm} \bar{Y}_{nm}(Lat, Lon) = \vec{b} \qquad (1)$$

The covariance matrix C is designed as diagonal matrix of the variances at each position plus 1 mm. Furthermore a scaling factor α for the covariance matrix has to be determined to assure a proper weight of the in-situ OBP. This results in the following normal equation:

$$\underbrace{A^T \cdot \alpha C^{-1} \cdot A}_{N_{in-situ}} \cdot \vec{x} = \underbrace{A^T \cdot \alpha C^{-1} \vec{b}}_{\vec{d}_{in-situ}} \qquad (2)$$

The GRACE+GPS+OBP normal equation N from Rietbroek et al. (2012) is augmented with the normal equation from equation 2 and solved for $\vec{x}$ by using a least square inversion.

$$(N + N_{in-situ}) \cdot \vec{x} = \vec{d} + \vec{d}_{in-situ} \qquad (3)$$

The inversion is performed for each available GPS week between week 1200 and week 1510. The amount of available in-situ data varies over time.

3.1 Results: Scaling Factor α and change in spherical harmonic coordinates

Testing Scenario:

Randomly, half of the time series (63 out of 127) were chosen and the inversion was performed for scaling factors between 1 and 100. The remaining 64 time series were used for validation. This experiment was performed for 100 different random data sets and the scaling factor α with the highest mean correlation with the validation set was determined. Figure 2 shows the distribution of these scaling factors.

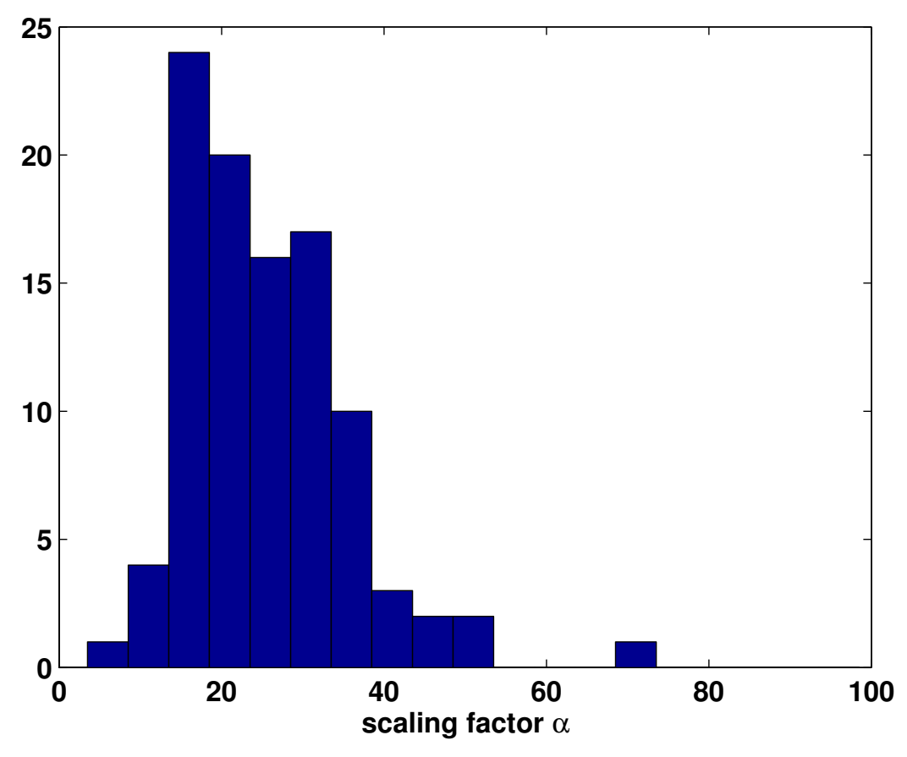

Figure 2: Histogram of the maximum differences with regard to the scaling factor α.

The median scaling factor is used for the inversion:

$$\alpha = 24$$

The chosen α suggests an error of $1/\sqrt{24} = 0.2mm$ for the in situ records.

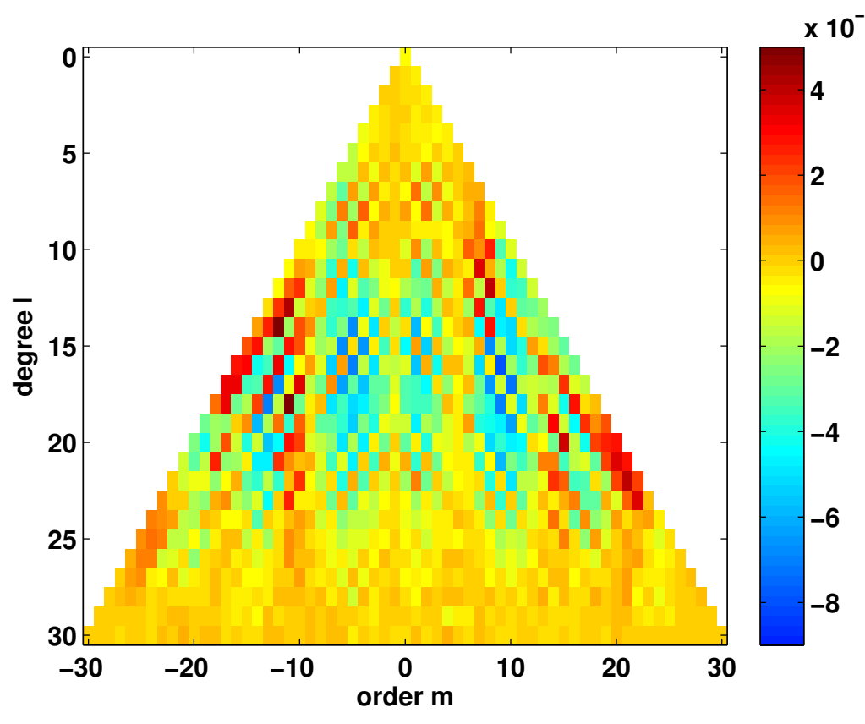

Figure 3: Change in the standard deviation of the spherical harmonic coefficients.

The main changes in the time variable spherical harmonic coefficients occur between degree 5 and 25 over all orders. In the spatial domain this means local and smooth changes in the vicinity of the recorders when including the in-situ data.

3.2 Results: Correlation of the inversion with the in-situ data

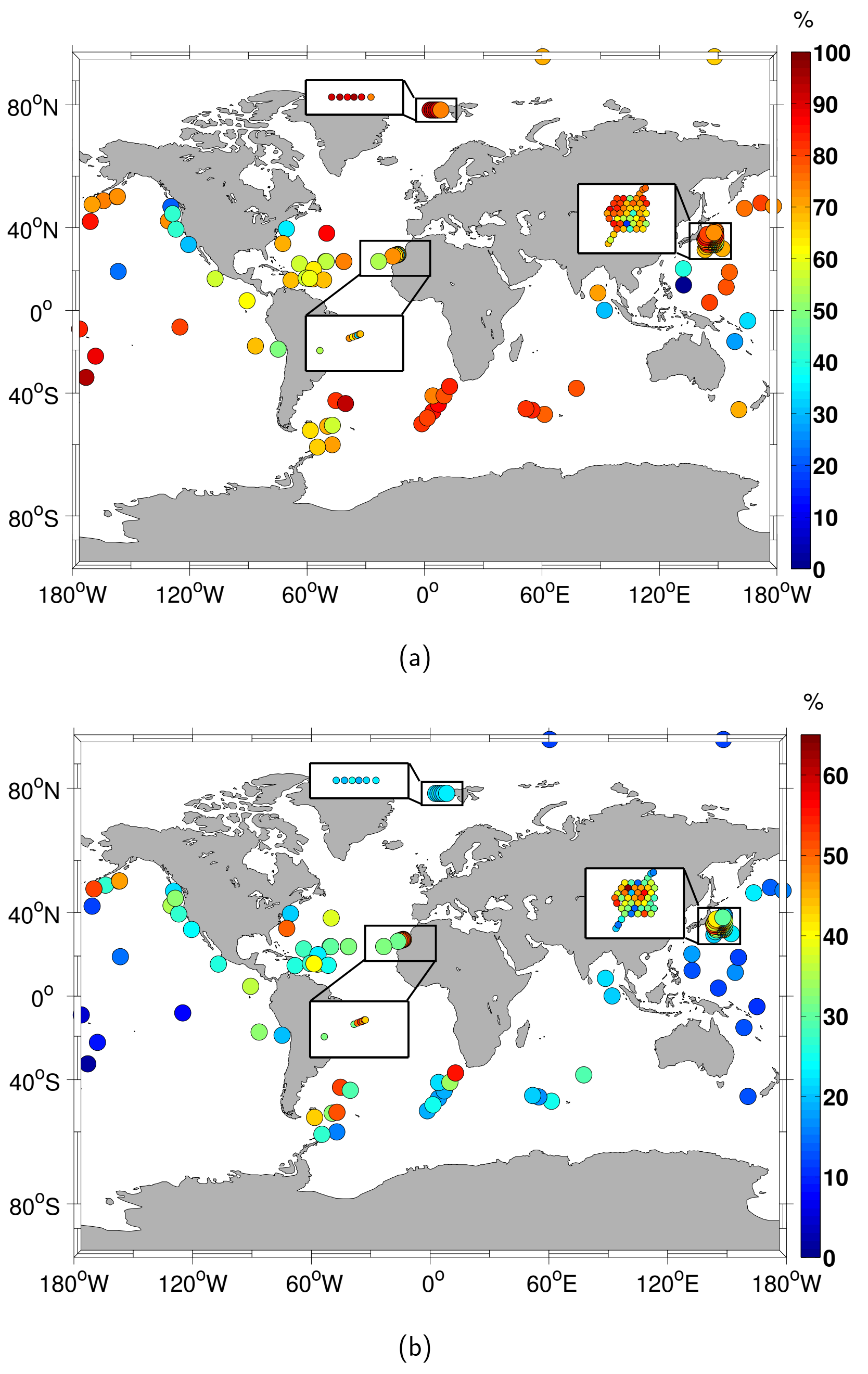

Figure 4: (a) Correlation between the Inversion with in-situ data included and the in-situ data. (b) Change in correlation compared to the inversion of Rietbroek et al. (2012).

The inversion with in-situ data shows a significant improvement of the correlation with the included recorders in most regions. On average the improvement is 30% and up to 63% localy.

3.3 Results: Variance Reduction

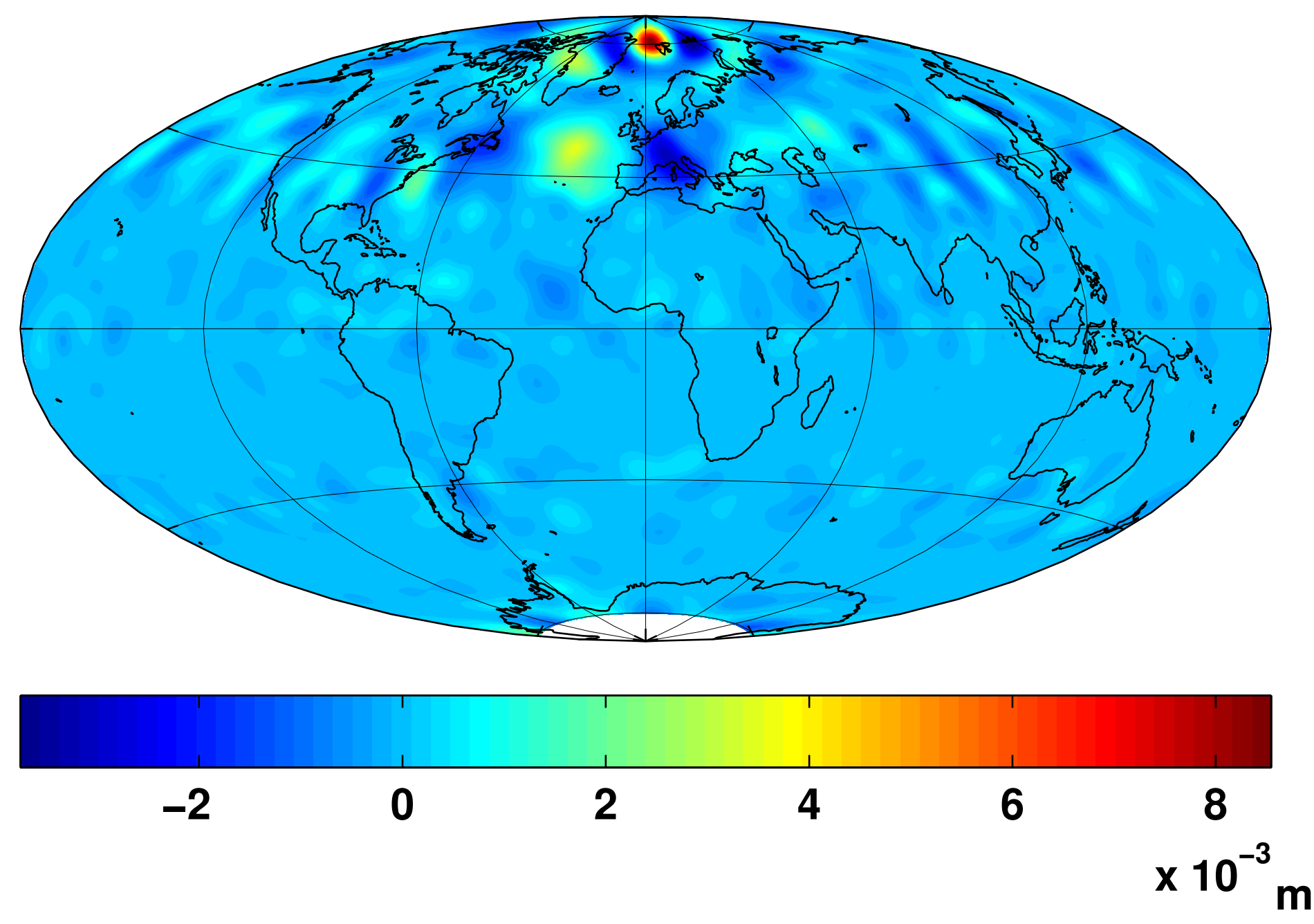

Figure 5: Variance reduction of ocean bottom pressure anomaly.

Figure 6 shows the global variance of the ocean bottom pressure anomaly from the inversion of Rietbroek et al. (2012) minus the inversion with in-situ data. The major changes occur in Fram Strait and in the North Atlantic. Due to the different amplitudes of variance the difference is calculated in percent of the variance of Rietbroek et al. (2012). This depiction shows clear changes at all BPR positions.

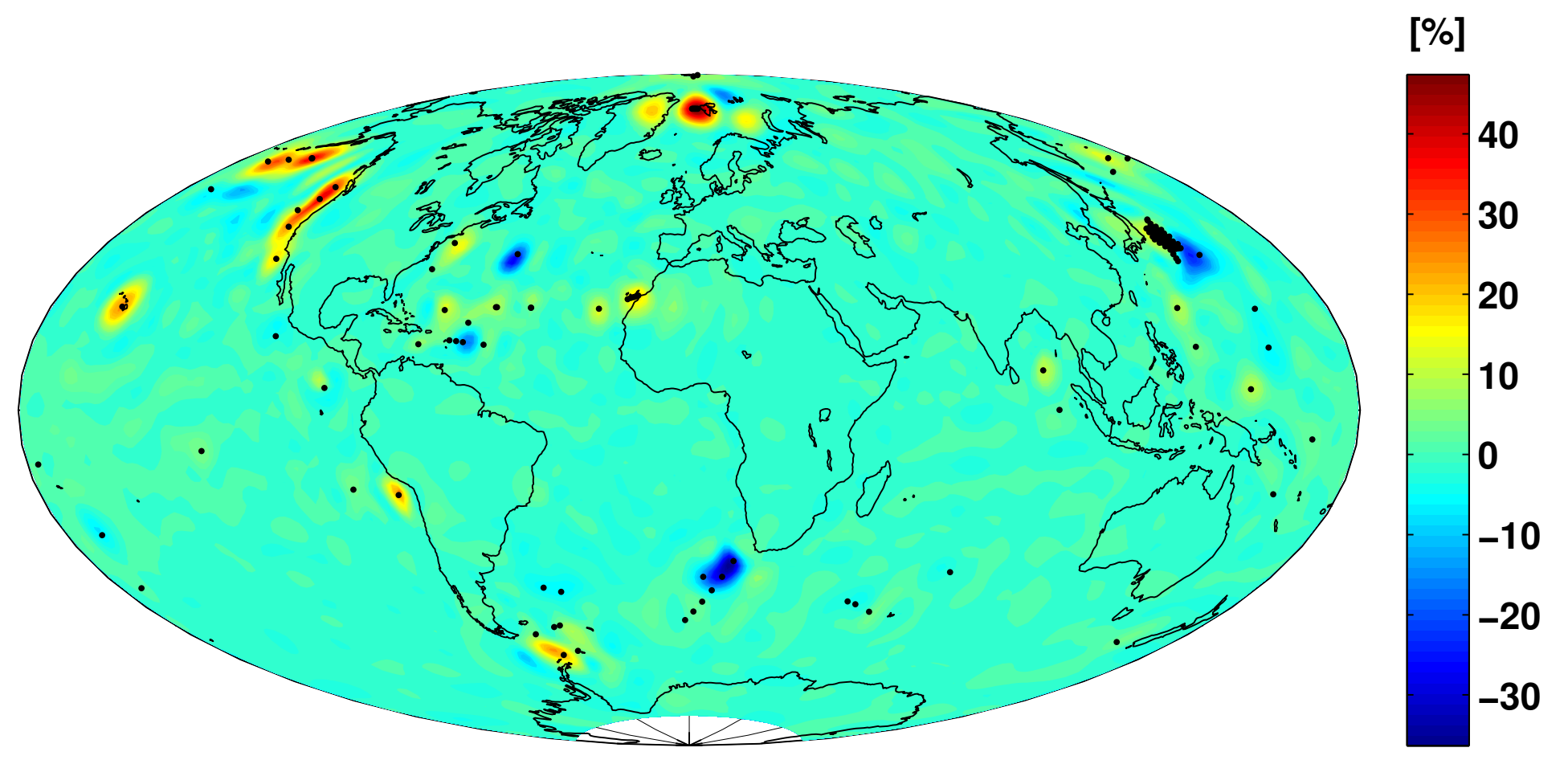

Figure 6: Variance reduction of ocean bottom pressure anomaly in percent of the variance from Rietbroek et al. (2012).

3.4 Results: Change of the global mean ocean mass anomaly

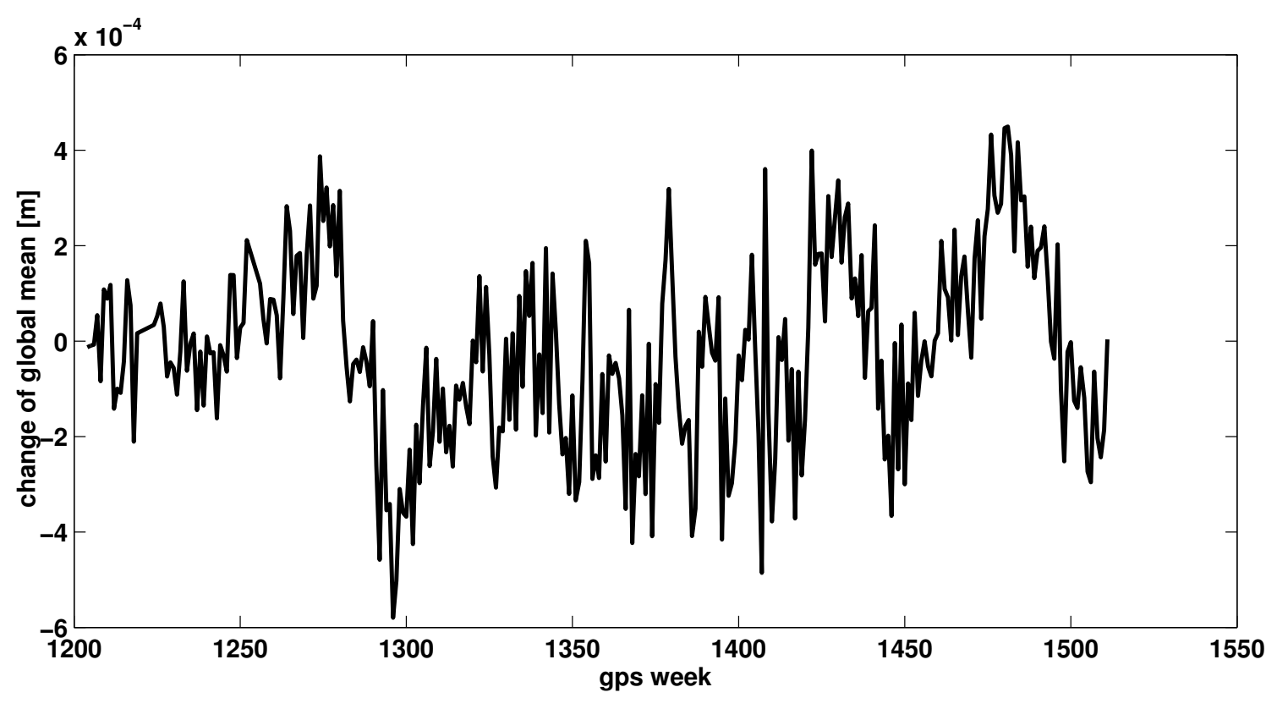

Figure 7: Change in global mean ocean mass anomalies.

Figure 7 shows the change of the global mean ocean mass anomaly which is two magnitudes smaller than the global mean ocean mass anomaly.

4 Conclusion

Including in-situ data into the inversion improves the correlation with the in-situ data by 30% on average (up to 63% locally). The influence on the variance is mostly localized at the positions of the in-situ data and largest in Fram Strait. The global mean ocean mass is only slightly changed.

References

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