Electromagnetic Bias Estimation using satellite, model & Buoy data

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Summary:

For quantitative studies of the ocean circulation, altimetric measurements must be corrected for electromagnetic (EM) bias effects. In the present study we analyse the application of the operational EM Bias correction along with theoretical predictions of EM bias (Srokosz, 1986) and an empirical algorithm based on tower observations (Melville et al., 2002). The operational correction of TOPEX data has been derived using variance minimization techniques correlated with wind speed and wave height, whereas Melville's algorithm was determined from independent tower-based radar data and depends upon non-dimensional parameters such as wave slope and wave age.

We find a significant correlation between high frequency ocean signals and the operational EM bias correction, suggesting that barotropic ocean signal is leaking into the empirical em-bias correction through the variance minimization procedure. Using buoy wave data and WAM wave model output, we find good agreement between the theoretical correction and the empirical correction based on the wave slope and wave age over a significant range of parameters; however, further work is needed to extend comparisons to larger wave slopes. Because the EM bias depends on parameters that cannot be measured by the altimeter alone (e.g. wave slope), improved theoretical corrections appear to be preferable to altimetry-based empirical estimates. Nevertheless, operational theoretical corrections for EM bias will require input from wind-wave and coupled models, and perhaps other satellite sensors.

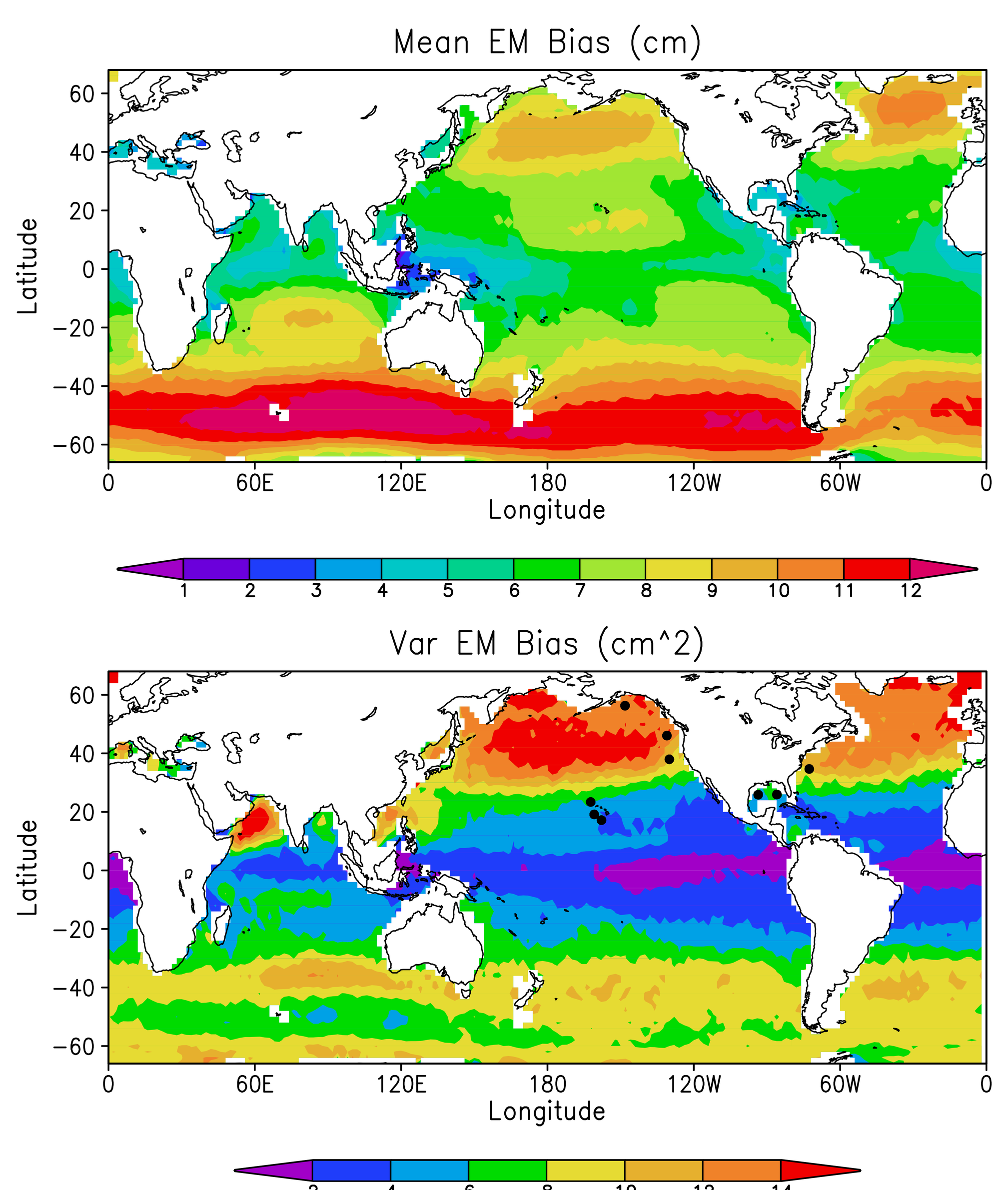

Figure 1: Mean and Variance of EM Bias computed using operational TOPEX algorithm for the period 1992-2000. Shows high values of variance in Bias at high latitudes. Maximum values of mean and variance are approx. of the same order.

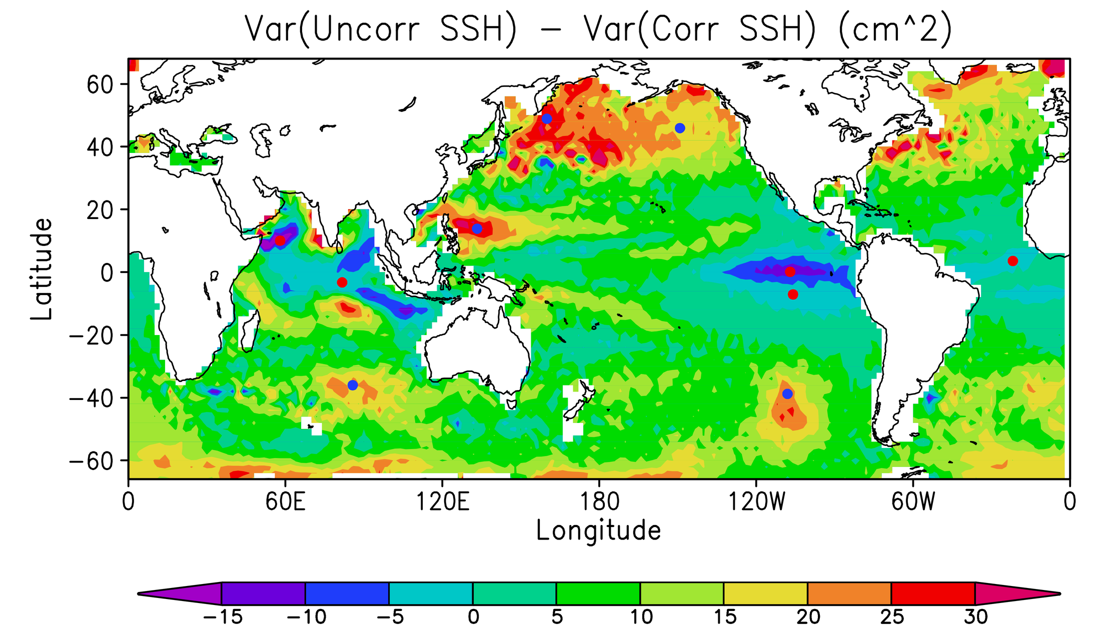

Figure 2: Reduction in the variance of Sea Surface Height (SSH) variability after applying operational algorithm for EM Bias correction. Positive values show reduction in variability. Globally variance reduced from 92 cm^2 to 83 cm^2. Reduction higher in higher latitudes. However, in several regions, variance increased, significantly in tropical Pacific and Indian Ocean. Pattern seems to reflect ocean current structures.

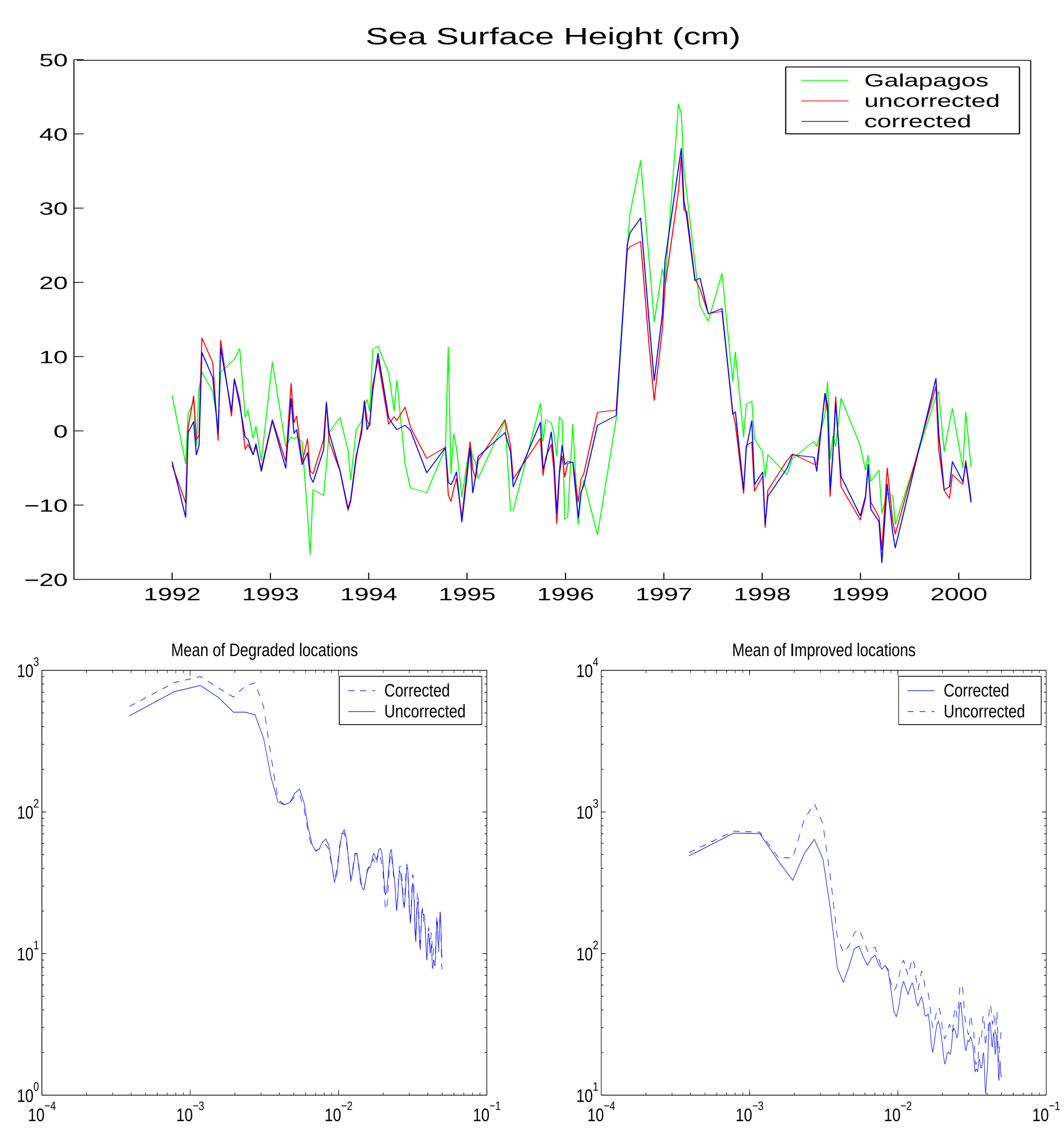

Figure 3: Sea Surface Height comparison using Tide Gauge data at Galapagos Island with uncorrected and Bias corrected data. Corrected data is closer to tide gauge data. (b) Shows the mean of 5 locations where variance increased in Fig. 2. Shows no impact of correction for periods shorter than a year, however clear difference in power for periods more than a year. (c)Shows the mean of locations where variance decreased after correction. It shows that power decreases for almost all periods shorter than a year. It means that global minimisation may not be appropriate, frequency dependent minimisation may improve the correction.

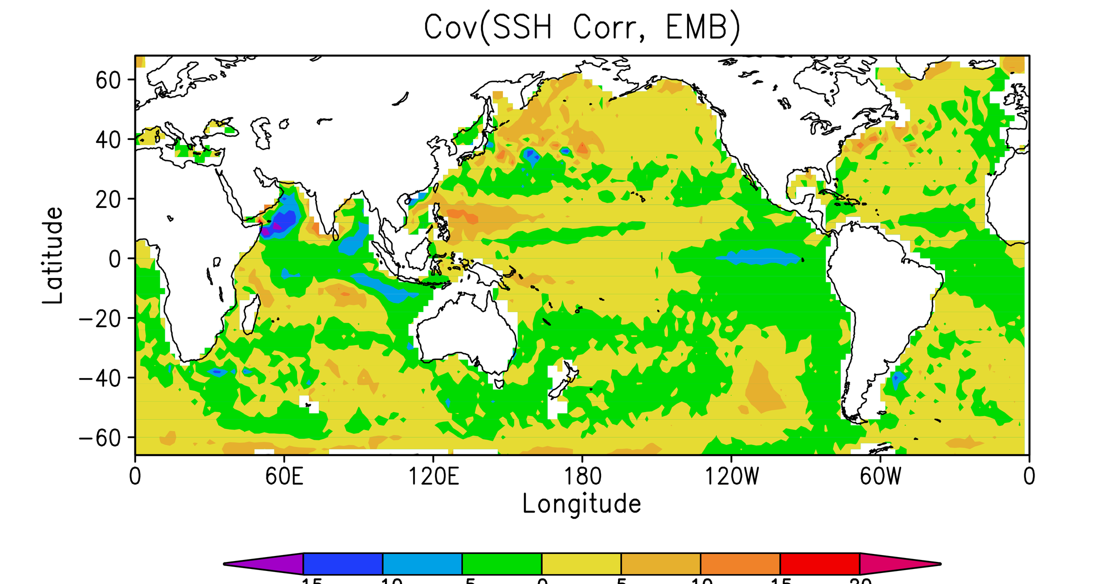

Figure 4: Covariance of corrected SSH and EM Bias, In variance minimisation technique for EM bias correction, this term is supposed to be zero, however figure shows that it is of the same order of magnitude as of EM Bias term (Fig 1). suggesting that operational EM Bias correction also removes high frequency ocean signal.

Slope Based Algorithm Many authors [1,2] have shown that non dimensional parameters, such as slope and wave age are better parameters for the computation of EM Bias. Based on tower measurements, [1] has derived empirical relationship between slope, age and bias. We have computed bias at a few locations using above relationship and buoy data in the Pacific ocean. For this purpose, slope spectrum was computed from the buoy spectrum. Since algorithm was developed for frequencies upto 1.0 Hz and buoy data is available upto 0.4 Hz, the buoy spectrum has been extended using f^{-5} tail.

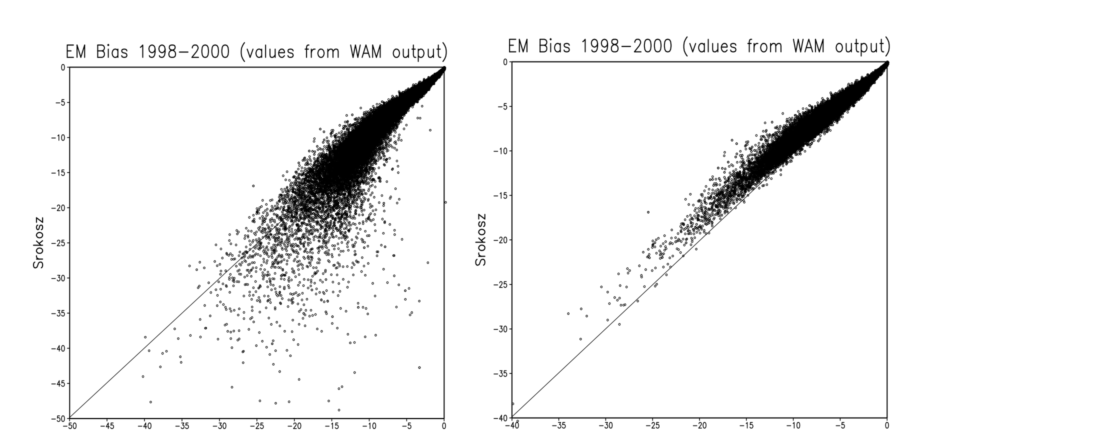

Figure 5: Comparison of EM Bias computed using theoretical Srokosz algorithm and Meliville's algorithm. The period is 1998-2000. (a) shows quite good agreement, in particular for less than -10 cm. A closer look of Melville algorithm showed that slopes used in measurements were less than 016. (b) Shows the comparison by discarding slopes larger than 0.12, results in much better agreement. Correlation increased form 0.93 to 0.98 cm and RMS difference decreased from 1.88 cm to 0.93 cm.

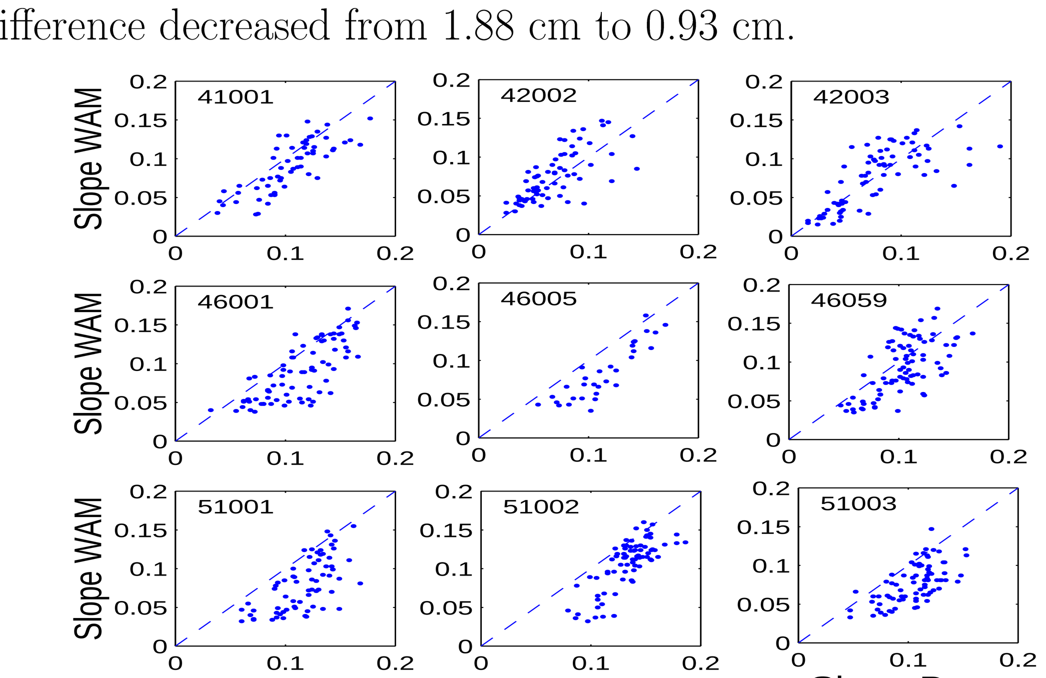

Figure 6: Comparison of wind speed, wave height and wave slope from all buoy locations. Buoy wave height and wind speed high correlations with WAM estimates, suggesting that in the absence of buoy data, WAM output should be appropriate for the purpose of EM Bias computations., The slope correlation is not so good ,which may be due to the difference in wind sea energy between buoy and WAM at a few locations resulting in difference in slopes.

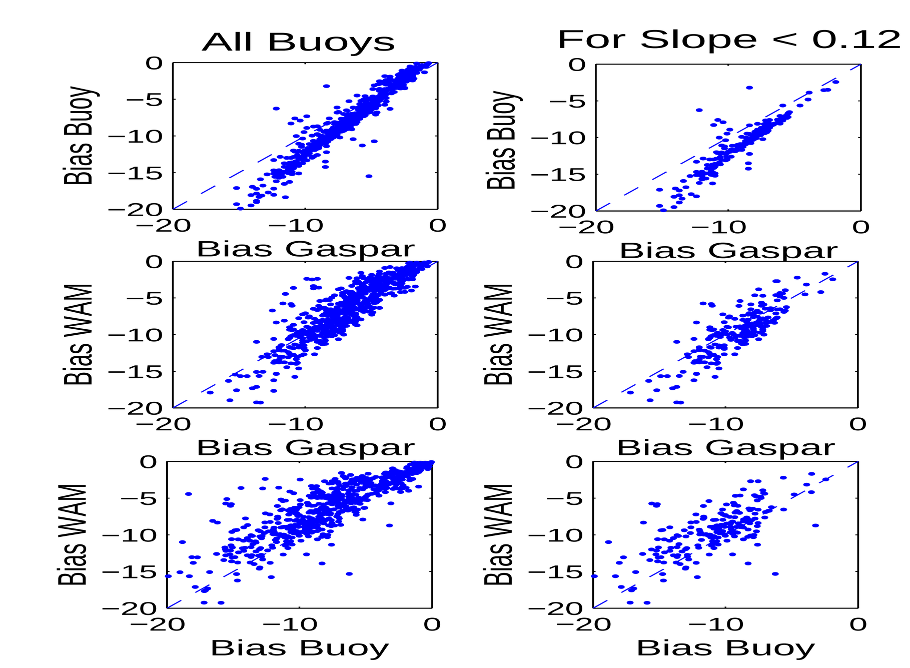

Figure 7: Comparison of the bias corrections from WAM output and buoy data at buoy locations using Melville's algorithm and operational algorithm for slopes less than 0.12. Bias computed using operational algorithm agree with Melville algorithm for low amplitudes, however it is biased low for higher values. Similar tendency exits between WAM and operational algorithm. Buoy and WAM corrections agree well but show more scatter.

Discussions (1) Empirical corrections based on variance minimisation assumes covariance between SSH and EM bias is negligible, however it is of same magnitude of EM bias variance. (2) To avoid this, emipirically tested theoretical approaches need to be developed. (3) WAM model output will be much useful for EM Bias corrections using theoretical and empirical algorithms. However, in the high frequency part of the spectrum, it needs more testing with buoy data. (4) Difference in EM bias estimates using different algorithms are small for global variance in SSH, however regional differences may be important and improved understanding of EM bias and its correlation with other oceanographic variables is required for accurate estimates.

References

References

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