SEA LEVEL AND ATMOSPHERIC PRESSURE: FROM AN INVERTED BAROMETER TO A DYNAMIC RESPONSE

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Atmospheric surface pressure drives significant variability in sea level. Until recently, this variability could only be studied at a few locations with tide gauge measurements. The situation drastically changed with the launching, five years ago, of the TOPEX/POSEIDON (T/P) altimeter, essentially a global tide gauge of remarkable precision. Analyses of T/P data and ocean model results are beginning to reveal in detail the nature of pressure-driven sea level signals over the global ocean, and how they relate to other sea level variability.

The sea level response to fluctuations in atmospheric pressure is usually taken to follow a simple inverted barometer (IB) model, for which an increase in pressure by 1 mbar is accompanied by a decrease of approximately 1 cm in sea level. In reality, the IB model is not expected to apply universally, and can become a poor approximation at periods of a few days and large spatial scales [e.g., Ponte 1997]. The high quality T/P dataset has provided the opportunity to test the validity of the IB approximation, and the general relation between sea level and atmospheric pressure, over the global oceans, providing the main theme for our investigation.

One simple way of assessing the IB model is to regress observed sea level on atmospheric pressure and compare the regression coefficients obtained with the expected value of 1 cm/mbar under a pure IB response. Crossover differences are particularly useful for this purpose, as they highlight high frequency signals due to the relatively short time between satellite overpasses (between 3 and 4 days on average), and thus are likely to reveal any departures from IB behavior at short periods. The results of such regression analysis performed for T/P cycles 11-121 yield coefficients with significant departures from the constant IB value in most regions, from the tropics to high latitudes (Figure 1).

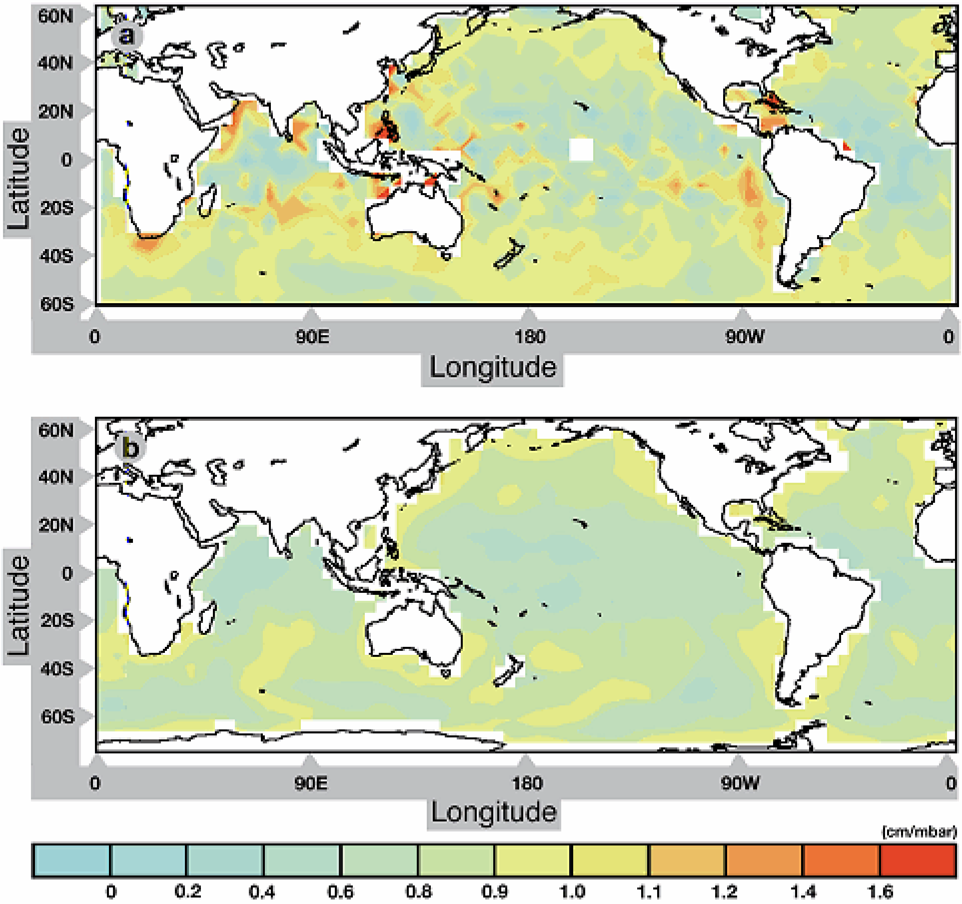

Figure 1

Regression coefficient between T/P sea level crossover differences and respective atmospheric pressure crossover differences for cycles 11 through 121 (a). Units are cm/mbar and a value near 1 cm/mbar is expected under a pure IB response. Regressions were computed over 5x5 degree boxes, after applying standard corrections to the T/P data. Corresponding model regression coefficients, based on sea level and pressure differences taken at 3-day intervals, are shown in the bottom panel (b).

The observed deviations from IB value can be caused by incidental correlations between measured atmospheric pressure and data errors or correlations between atmospheric pressure and dynamic sea level (i.e., sea level adjusted for an IB signal). Analysis for zonally-averaged regression results performed by Gaspar and Ponte [1997], based on only the first 60 T/P cycles, suggest that data errors cannot explain most of the observed IB deviations. Thus, the T/P results in Figure 1, which yield values mostly smaller than the IB value, indicate (positive) correlation of adjusted sea level with atmospheric pressure. As in Gaspar and Ponte [1997], an ocean model can be used to test and interpret this finding.

Results in Figure 1 are from an integration of the barotropic, near global model described by Gaspar and Ponte, for the 3-year period starting in January 1993 and concurrent with the T/P data. For this particular run, forcing by both wind stress and pressure fields (6-hour values from NCEP/NCAR reanalysis) was used. Although details are different, the spatial pattern of model deviations from IB value matches fairly well with the T/P results in general, both in sign and amplitude. Other preliminary analysis (not shown) of runs with only pressure forcing, different time smoothing, etc., point to some interesting findings. In particular, deviations from IB value in mid and high latitudes, although small, seem significant and mainly caused by relatively low frequency, wind-driven sea level signals that are correlated with atmospheric pressure [Ponte 1994]. Larger deviations over the Southern Ocean seem to occur over regions of closed f/H contours, and reflect the different dynamics of these regions, with local driving more important, and thus possibly stronger correlations of adjusted sea level with local wind forcing. Finally, the clear tendency for larger deviations from IB value in the tropics may be more essentially related to high frequency, dynamic response to pressure than at mid and high latitudes.

Some of the T/P results in Figure 1, particularly in the tropics, are noisy over short spatial scales. Yet, the convergence between model and data results goes much further than what was previously obtained with other altimeter datasets [vanDam and Wahr 1993] and highlights the quality of the T/P product. As more T/P data accumulates, the signal-to-noise ratios will improve and more signals will be left for explanation. Our objectives are to continue to pursue the interpretation of the observed IB departures and their spatial patterns in terms of the spatial characteristics of the forcing, the differences in regional dynamics and oceanic response to forcing, the effects of wind-driven signals, etc. In particular, the influence of high frequency signals, aliased by the altimeter sampling, needs to be fully assessed. Our approach will not involve only pure model and data comparisons, but also model runs with data assimilation, which will hopefully lead in the future to a full dynamical estimation of the pressure-driven sea level component.

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