Using satellite altimetry to improve operational El Niño forecasts

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In order to improve the accuracy of NOAA's operational El Niño forecasting system, we have devoted the past several years to developing methods for processing and assimilating near real time sea level observations from multiple satellite altimeter missions into an ocean general circulation model used to initialize forecast runs. The problem of designing an assimilation scheme is complicated by the fact that, although sea level variability in the equatorial Pacific is primarily controlled by temperature, salinity plays an important role, particularly on interannual time scales in the western half of the ocean.

We have developed techniques using TOPEX/POSEIDON (T/P) altimeter data and subsurface temperature data, primarily from the Tropical Atmosphere Ocean (TAO) array, to estimate the vertical structure of this salinity variability. Here we present a brief description of these techniques and the results from some experiments aimed at assessing the impact of salinity variability on equatorial sea level and, most importantly, on the accuracy of El Niño forecasting.

Background

Ji et al. [2000] noted that during 1996 in the western equatorial Pacific there were 5-10 cm errors in sea level in the National Centers for Environmental Prediction (NCEP) operational ocean analysis. This conclusion was based on comparisons with both tide gauge and TOPEX/POSEIDON (T/P) observations. Temperature in the model was known to be accurate owing to the abundance of in-situ thermal data already being assimilated. The model sea level error must therefore have been the result of salinity variability not accounted for in the analysis due to the absence of in-situ salinity observations. To help overcome the fact that direct salinity measurements will remain rare, at least until the Array for Real-time Geostrophic Oceanography (ARGO) is deployed, considerable thought has been given to the idea of inferring salinity variability from altimetric measurements of sea level.
The general idea is to use any discrepancy between sea level estimated by a model analysis and sea level measured by the altimeter to infer a correction to the vertical salinity profile in the analysis.

Since much of the salinity variability in the western Pacific occurs in the surface barrier layer and sea surface salinity (SSS) could be readily measured by ships-of-opportunity, Vossepoel et al. [1999] devised a method for correcting climatological T-S correlations with SSS and altimetric sea level observation. Maes and Behringer [2000] approached the problem somewhat differently. Instead of working with fixed T-S relationships, they generated synthetic salinity profiles from a set of statistically computed joint empirical orthogonal functions (EOFs) that tie salinity fluctuations to variations in temperature and sea surface height.

Experiments

To evaluate the impact of the Maes and Behringer technique on the NCEP ocean analysis used to initialize El Niño forecasts, several experiments were carried out.
In the first, designated as Model, only wind forcing was applied.
In the second, Model (T), only in-situ temperature observations were assimilated in addition to wind forcing. Finally, in the third experiment, Model (T, S), in-situ temperature and synthetic salinity profiles derived from temperature and TOPEX/POSEIDON sea level observations were assimilated in addition to wind forcing.

Figure 1 illustrates the effects of these different runs on the vertical salinity field along the equator in August 1996, at a time when the operational analysis, then similar to Model (T), indicated dynamic heights 5-10 cm higher than either tide gauge or T/P observations [Ji et al., 2000]. The Model and Model (T, S) salinities are similar to the monthly Levitus climatology, whereas the Model (T) field is weaker overall and has a different vertical structure in the western Pacific. These results suggest that the combined assimilation of temperature and synthetic salinity is successful in counteracting whatever negative impact the assimilation of temperature alone has on salinity. Indeed, sea surface height differences across the Pacific in the Model (T, S) run are lower by as much as 10 cm compared to the Model (T) run and corresponding changes in the strength of the equatorial undercurrent are as large as 25 cm/s.

Although we can demonstrate that the assimilation of temperature and synthetic salinity improves the accuracy of the ocean analysis, we have not yet shown significant improvement in the accuracy of the forecast model using this analysis scheme. We are continuing to refine the background salinity error covariance and expanding the assimilation system to handle temperature, synthetic salinity (derived in part from T/P data), and sea level from T/P data directly.
In the near future, this mix of observations, particularly salinity, will be greatly improved by the arrival of ARGO profile data.

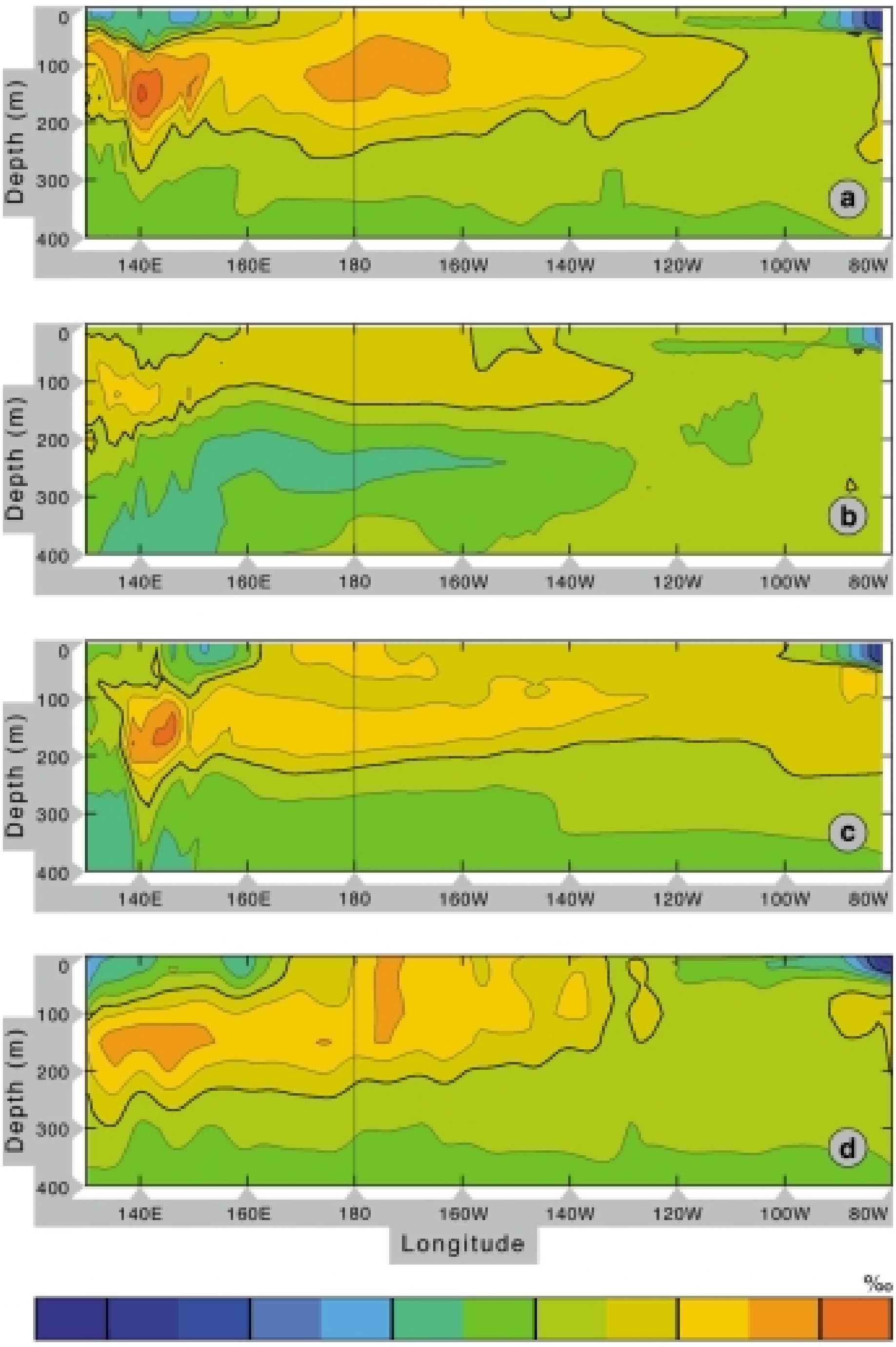

Figure 1: Effects of different runs on the vertical salinity field along the equator in August 1996, at a time when the operational analysis, then similar to Model (T) (b), indicated dynamic heights 5-10 cm higher than either tide gauge or T/P observations [Ji et al., 2000]. The Model (c) and Model (T, S) (a) salinities are similar to the monthly Levitus climatology (d), whereas the Model (T) field is weaker overall and has a different vertical structure in the western Pacific.

References

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