Assessing the Impact of Satellite Altimeter Data On The NOAA/NCEP Operational Ocean Analysis

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Abstract

In order to improve the accuracy of NOAA's operational El Niño forecasting system, a series of model experiments was performed to assess the impact of assimilating different combinations of in-situ and satellite derived observations into the NCEP operational ocean analysis. In the first experiment, designated Model(t), only in-situ temperature was assimilated in addition to wind forcing. In the second, Model(t,s), synthetic salinity profiles derived from temperature and T/P sea level observations were also included. Finally, in the third experiment, Model(t,s,tp), temperature profile corrections also derived from T/P observations were added to the assimilation scheme.

In general, all three experiments show high correlations (r>0.8) between model sea level and T/P sea level in a +/-10° latitude band along the equator and much lower values poleward of 10°. Within the equatorial band, two types of salinity problems are identified, each producing discrepancies of 5 to 10 cm. The most serious is a drift in the M(t) run causing a fictitious 0.6 psu decline of the subsurface salinity maximum in the western Pacific between 1993 and 1996. Comparisons with independent CTD observations verify that both the M(t,s) and M(t,s,tp) runs correct this problem.

The second type of salinity error is associated with the zonal displacement of the Western Warm Pool during periods of westerly wind bursts and ENSO activity. The eastern boundary of the Warm Pool is marked by sharp gradients in both salinity and temperature. Because of the abundance of in-situ temperature data and absence of in-situ salinity data, all of the model runs correctly account for the temperature fluctuations associated with displacements of the eastern boundary, but none completely account for the salinity fluctuations.

1. Experiments

The ocean data assimilation system used in these experiments is based on the ocean general circulation model, MOM v.1, developed at GFDL. The model is confined to the Pacific basin and has a nominal horizontal resolution of 1° with increased resolution in the tropics and a vertical resolution of 28 levels. In all experiments the model was driven by monthly values of wind stress computed from 10 meter winds, surface heat flux, precipitation and evaporation from the NCEP/NCAR atmospheric reanalysis [1]. In addition, the surface temperature was relaxed to an analysis of the observed SST [2]. The assimilation system is a 3D variational scheme originally developed by Derber and Rosati [3] to assimilate temperature profile data and subsequently extended to assimilate other data types [4]. Three experiments are included in this study. The first, designated Model(t), assimilates only in-situ temperature profiles. The second, Model(t,s), in addition to temperature assimilates synthetic salinity profiles computed by the method of Maes and Behringer [5]. Finally, the third experiment, Model(t,s,tp), assimilates T/P observations as well. In this last experiment the T/P data are used to apply further correction to the temperature and salinity fields. The information on the sea surface height, contained in the T/P data, is distributed down into the water column through the specification of the first guess (or model) error covariance.

Sea Level Correlation - 1993 thru 1999

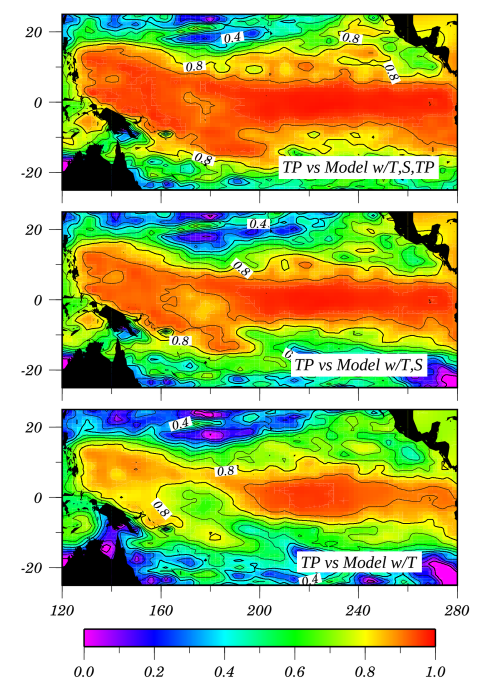

Fig. 1

Sea Level Correlation - 1993 thru 1995

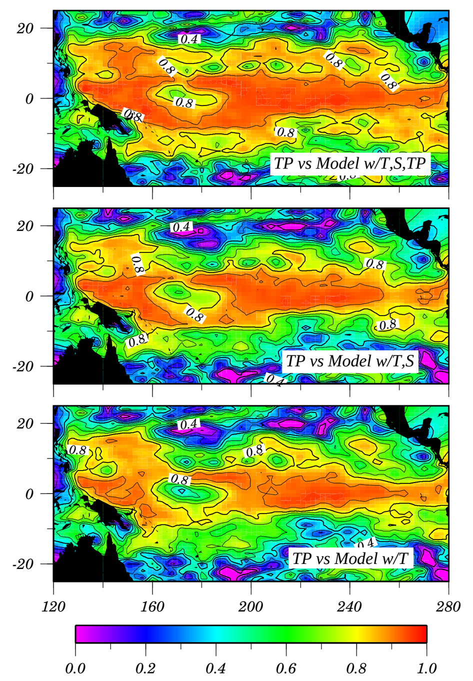

Fig. 2

Sea Level Correlation - 1996 thru 1999

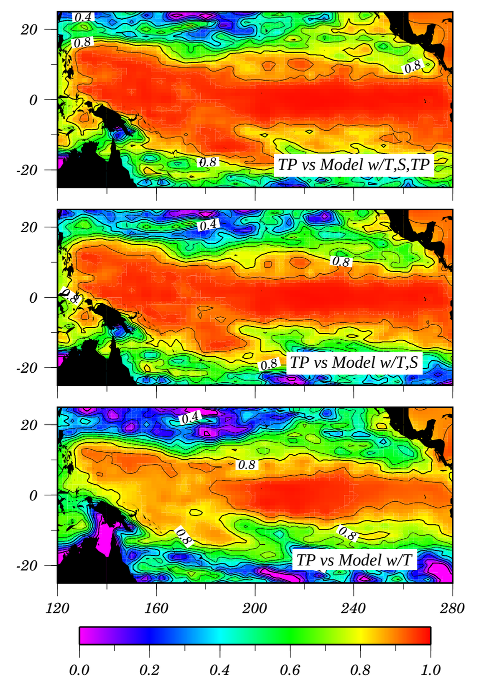

Fig. 3

2. Sea Level Correlations

To assess how well the different combinations of input data are able to accurately reproduce sea level, Fig. 1 presents a set of maps showing the correlation between T/P sea level and model sea level computed over the interval 1993-99. In general, all three experiments show high correlations (r>0.8) near the equator and medium to low values (r=0.2 to 0.4) at latitudes higher than 10°. However, there are significant differences, particularly in the western Pacific. The M(t) run is conspicuously weak between 160°E and 200°E along the equator and also south of the equator.

To determine if these differences relate to ENSO activity, sea level correlations were also computed for two time intervals, 1993-95, 1996-99, Figs. 2 and 3, respectively. The first corresponds to a period of relatively neutral Southern Oscillation Index, but some westerly wind burst activity. The second includes the strong El Niño/La Niña events of 1996-98. Both periods exhibit zonal correlation maximums along the equator in all three runs, as in Fig. 1., however the maximums are significantly weaker and more narrowly confined to the equator in the 1993-95 period compared to the 1996-99 period. Also in 1993-95, all three experiments show a low correlation bullseye on the equator near the dateline.

3. Subsurface Salinity Maximum Problem

A close examination of the model results in the western equatorial Pacific reveals two types of salinity problems contributing to weak sea level correlations. The most serious is a fictitious 0.6 psu decline in the magnitude of the subsurface salinity maximum in the M(t) run between 1993 and 1999. This is illustrated in maps of the salinity maximum at 136m depth, in January 1993 (Fig. 4) and January 1998 (Fig.5), and also in vertical profiles of salinity at 10°S 170°E (Fig. 6). The maps show a weakening of the salinity maximum in the M(t) run west of 140°W by January 1998, although the source region, near 20°S 120°W, appears unchanged. The M(t) profiles (lower plot, Fig 6), show vertical thinning and a decline in the core maximum occurring mostly between 1995 and 1997 at this location.

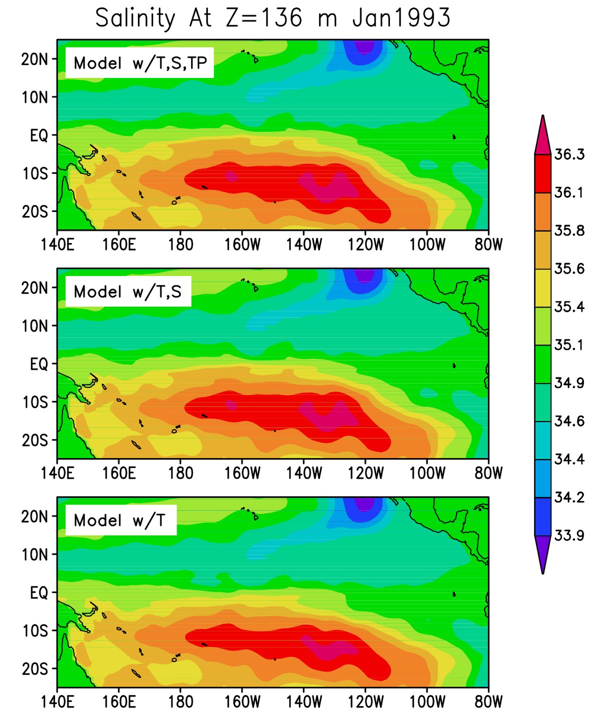

Fig. 4

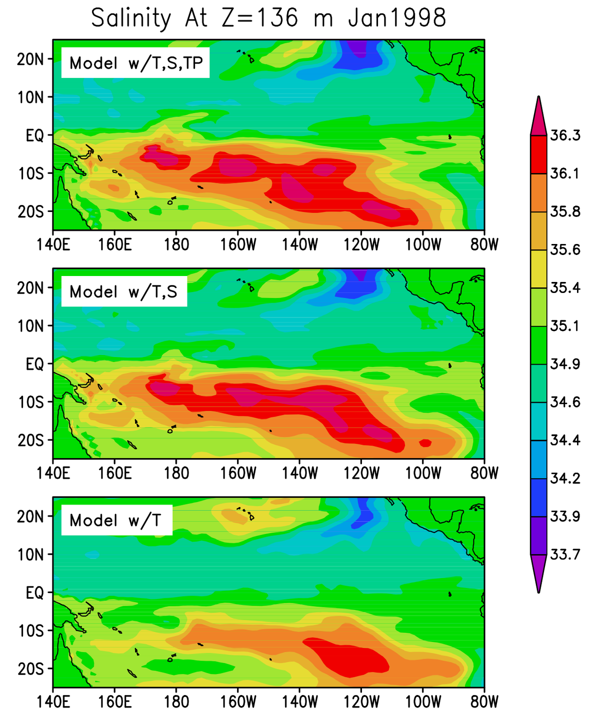

Fig. 5

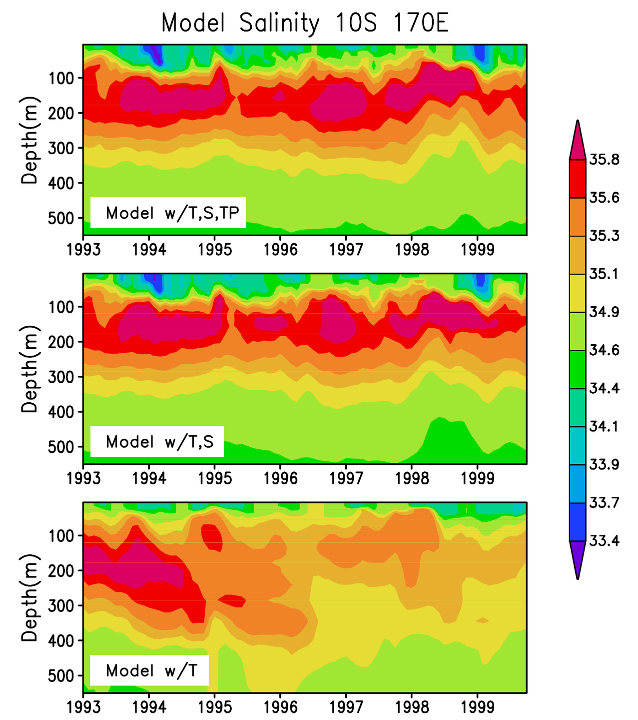

Fig. 6

A comparison of model salinities with CTD observations taken near 10°S 165°E (Fig. 7) demonstrates that the M(t) run is at fault. One indication of why the M(t) run drifts off can be seen in Fig.8, a plot of area averaged model salinities in the western Pacific, in and below the salinity maximum. The M(t) run shows a steady decline in the maximum, at 136m, and increasing salinity below the maximum, at 430m. This behavior suggests that the model is too diffusive, causing too much salt to be lost to the deep ocean. Both the M(t,s) and M(t,s,tp) runs largely correct this problem by assimilating additional salt into the maximum, however a better approach might involve improving the model vertical eddy diffusivity.

CTD vs. Model Salinity At 10S 165E 155m

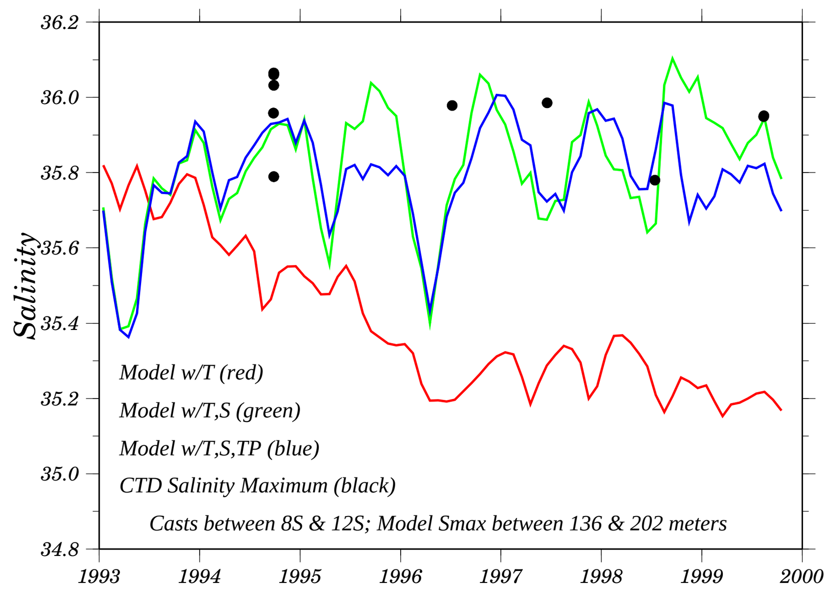

Fig. 7

Area Avg Salinity in Western Pacific (140Eto220E,30Sto0N)

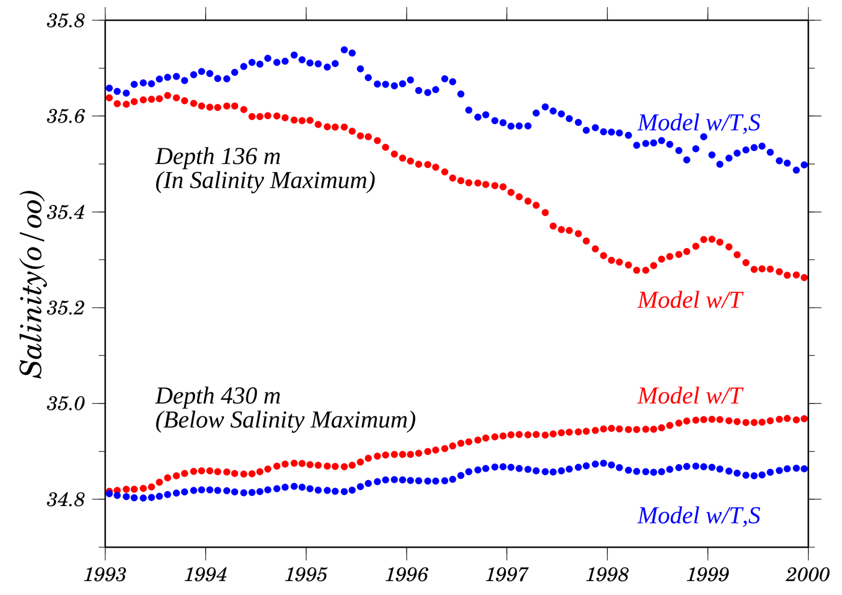

Fig. 8

4. Surface Salinity Problem

The second type of error is associated with zonal displacements of the Western Warm Pool during periods of westerly wind bursts and ENSO activity. The eastern boundary of the Warm Pool is marked by high gradients in both surface salinity and temperature. As this boundary moves zonally, back and forth, over a fixed location, sea level may vary by 5 to 10 cm. Evidence of this type of signal can be seen by comparing a plot of surface salinity along the equator (Fig. 9) with a plot of model and TP sea level at 0°N 170°E (Fig. 10). (Note that all of the sea level series have been referenced to zero mean between 1996 and 1999). Episodes of large eastward displacement of the 34.8 o/oo contour correspond to times of large sea level discrepancies. To highlight this relationship, Fig. 11 shows for 0°N 170°E the M(t,s) sea level error superimposed on the sea surface salinity and the surface geostrophic U component estimated by the method of Lagerloef et. al, 1999 [6]. Neither the M(t,s) run nor the M(t,s,tp) run is able to properly account for the surface salinity fluctuations at this location.

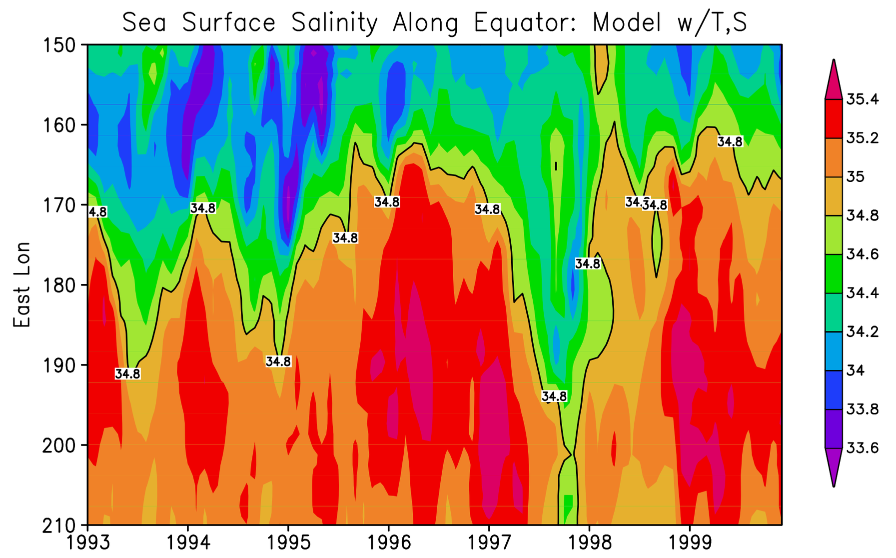

Fig. 9

Sea Level (ref wrt 1996-99) at 0N 170E

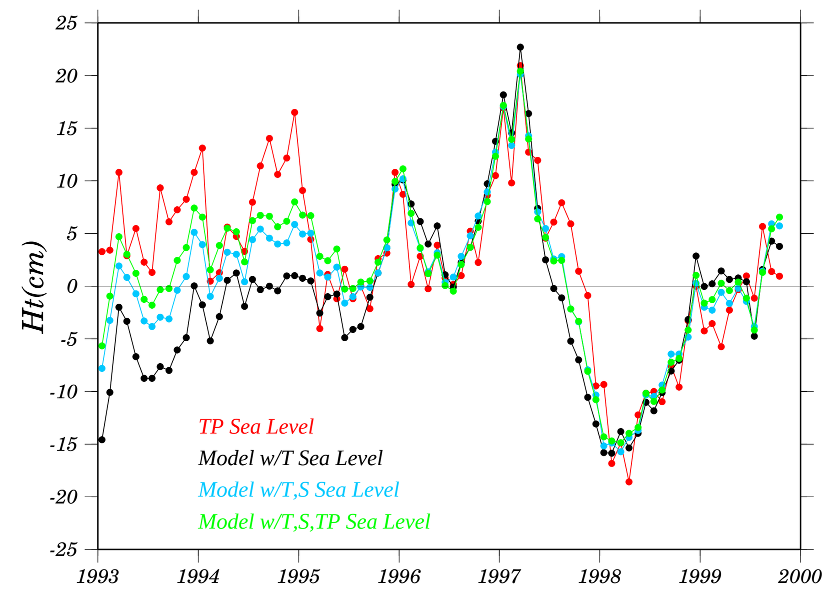

Fig. 10

Model SL Error / SSS / Geo Sfc Uvel at 0N 170E

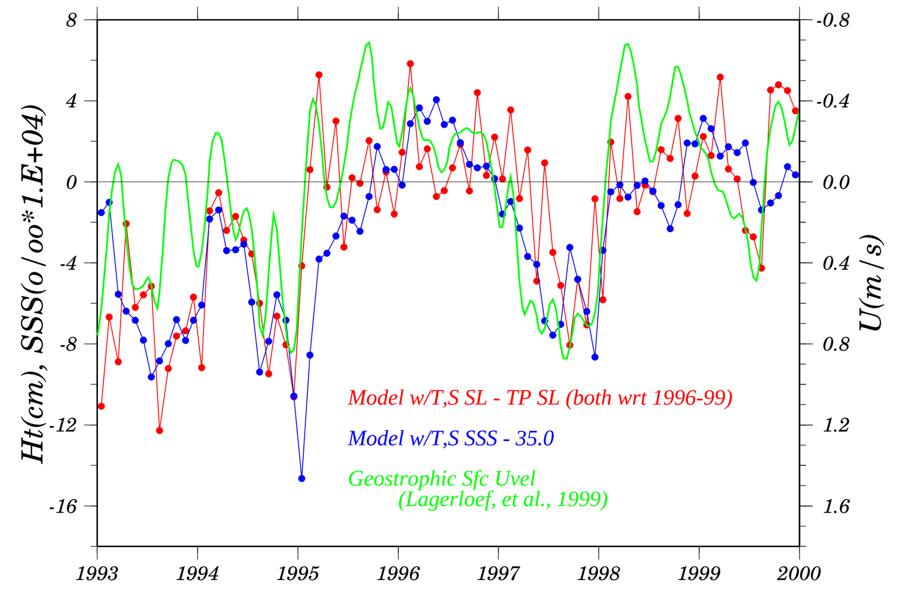

Fig. 11

5. Summary

All three model runs show high sea level correlations within +/-10° of the equator.

Two types of salinity errors affect the results:

(1). The most serious is a drift in the M(t) run caused by excessive vertical diffusion. This is corrected by assimilating a synthetic salinity signal.

(2). Zonal displacements of the Western Warm Pool cause salinity fluctuations in the surface mixed layer which none of the model runs completely account for.

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