DETERMINATION AND INTERPRETATION OF DYNAMIC TOPOGRAPHY FROM TOPEX/POSEIDON

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One of the goals of the TOPEX/POSEIDON (T/P) mission is to improve the measurement of the ocean circulation since the relative proportion of the oceanic heat budget carried by the oceanís currents is poorly known. Because of dramatic improvements in the orbit accuracy of T/P compared to previous satellites, the limiting factor in better ocean circulation determination has become the oceanic geoid. Over long wavelengths, the errors in geostrophic velocity caused by geoid errors are on the order of 5 to 10 cm/sec, about the same size as errors in hydrographic solutions [Ganachaud et al., 1997]. Consequently, with current geoid accuracy, satellite altimetry data are no better than in situ measurements in determining the absolute heat transport in many areas.

One method which has been proposed to improve the oceanic geoid is to combine altimetric measurements of the sea-surface height (accurate to 1 to 2 cm over long-wavelengths) with measurements of dynamic ocean topography from numerical general ocean circulation models (OGCM) to estimate a oceanic geoid consistent with the mean circulation implied by the model. The goal is an oceanic geoid which combines in an optimal way all available information: the satellite tracking and satellite altimetry that has been used in the current geopotential models, and a prior knowledge of the ocean circulation from numerical models or actual current measurements. In addition, the estimate of the geoid error from the solution covariance should more reasonably reflect the geographical distribution of the errors in our knowledge of the ocean circulation. The main problem with this strategy is that the numerical models do not provide any estimate of the error in their output. Any error in the OGCM dynamic topography measurement will be mapped into an error in the oceanic geoid, so it is critical that an estimate of the error is incorporated into the solution process.

One method for determining the errors of the OGCM output is a comparison against drifter buoy velocities (Figure 1). While the model shows significantly smaller differences than T/P compared to the buoys in terms of global rms (8.1 cm/sec vs. 11.7 cm/sec), this is due to large differences between ± 10° latitude. Outside of this region, the average rms values are virtually identical (6.2 cm/sec vs. 6.5 cm/sec). It would be incorrect to weight the OGCM data equally in all areas when estimating the geoid, as the model appears to be less accurate in some areas than in others. Finally, the very long wavelength portions of the oceanic geoid, determined from satellite tracking data, are believed to be fairly well known in modern geoid models, and it is critical that errors in the OGCM at these wavelengths do not corrupt the gravity model. At present, we are investigating methods of improving the oceanic geoid by using satellite tracking data, altimetry, surface gravity data, and output from a OGCM, *along with estimates of their errors*, in a joint solution of the oceanic dynamic topography and the Earthís gravity field.

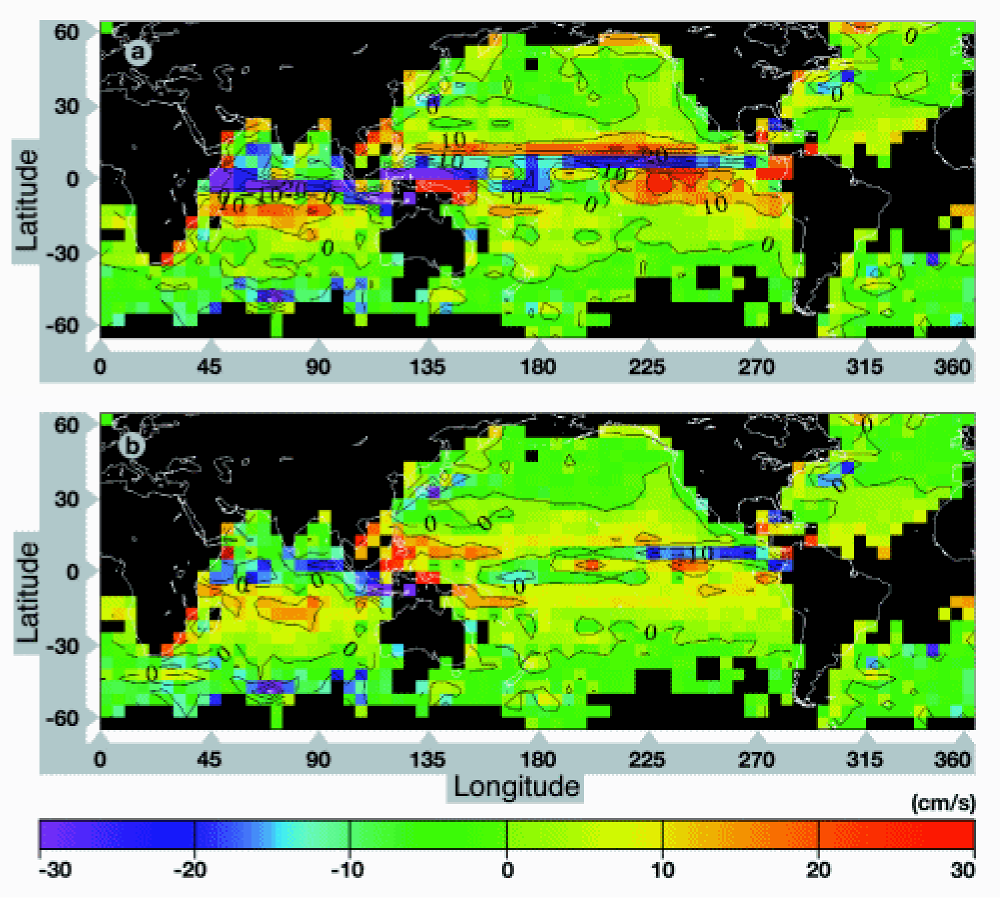

Figure 1

Differences in zonal currents from drifter buoys and geostrophic velocities from T/P (a) and Parallel Ocean Circulation Model (POCM) (b) dynamic topography. The drifter buoy data are from an averaged grid provided by the Drifting Buoy Data Assembly Center, Atlantic Oceanographic and Meteorological Laboratory, NOAA. Units are cm/sec.

While the absolute oceanic circulation and heat transport cannot be determined accurately from T/P, variations in these quantities can be. One of the most interesting examples of the oceanic heat budget related to climate change is the long-term secular rate in global mean sea-level caused by warming of the ocean. While secular rates are straightforward to compute from single altimeter missions, these records are still fairly short and could be dominated by decadal signals. Although a combination of the Geosat data with the T/P data would lead to a 10-year rate, this calculation has proven difficult because of an unknown relative bias between the two data sets. However, by using tide gauge measurements to link the two missions, a relative bias of 11.6 ± 2 cm has been determined [Guman, 1997]. Using this value for the relative bias, the global mean sea-level variations from Geosat, ERS-1 and T/P can be linked, giving an average rate from 1986 to 1996 of 1 ± 2 mm/year (Figure 2).

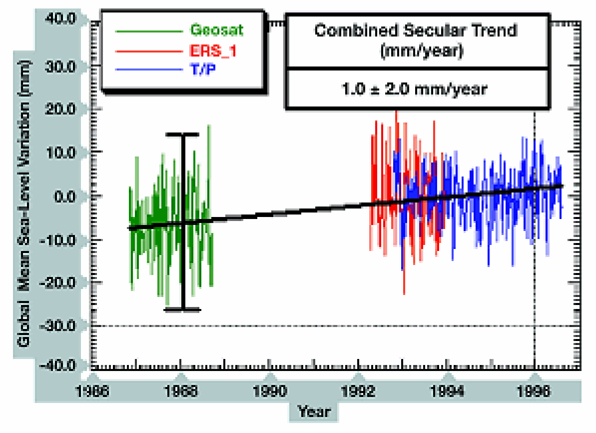

Figure 2
Combined Geosat, ERS-1, and TOPEX/POSEIDON global mean sea-level variations. The estimate of the decadal trend is shown (from Guman [1997]).

Local changes in oceanic heat-storage can also be determined from T/P sea-level variations, using a regression based on climatological data. A map of these local heat-storage rates (Figure 3) shows the aftereffects of the 1991-1993 El Niño, as the warm pool in the western Pacific has gained heat over the course of the T/P mission, while the eastern Pacific has lost heat. Although the tropical Pacific has the largest heating changes, the North Atlantic on average gained more heat per unit area than the North Pacific from November 1992 to November 1995: 1.5 W/m^2 compared to 0.2 W/m^2 [Chambers et al., 1997a].

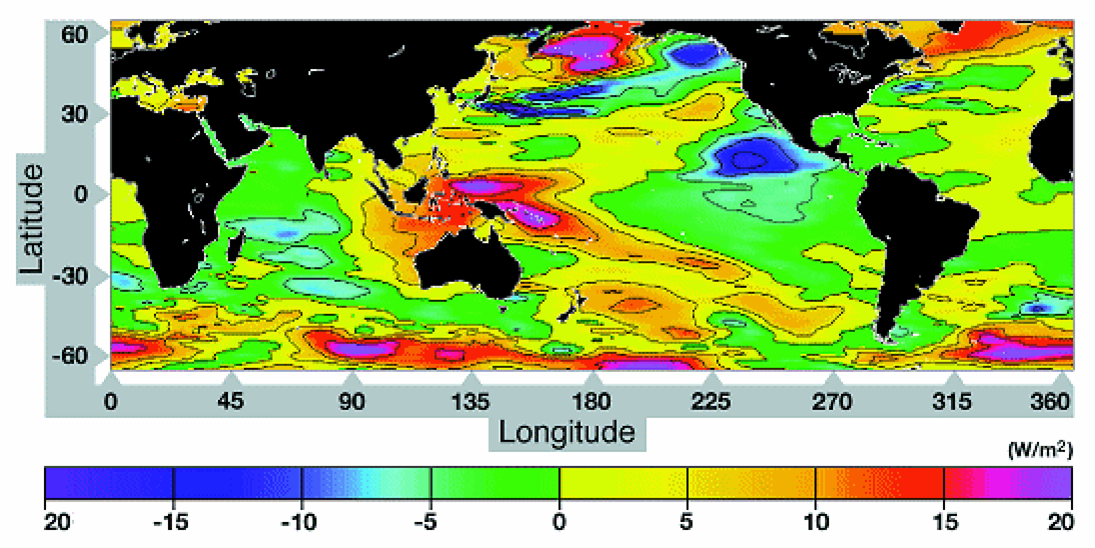

Figure 3
Average heat-storage rate inferred from TOPEX/POSEIDON sea-levels from December 1992 to June 1997. Units are W/m^2.

However, comparisons with moored buoys indicate that not all the heat changes are confined to the upper layer [Chambers et al., 1997b]. For instance, the long-term heat-storage rate inferred from T/P is about 30% smaller than the heating rate measured by moored buoys in the upper 300 m of the western Pacific. This suggests a substantial change in the heat transport below 300 m, most likely due to changes in the deeper currents. Thus, T/P can not only provide information about the surface heat transport, but by combining the data with near-surface measurements, it can be used to gain some insight into changes in deeper layers as well.

References :

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