GEOPHYSICAL APPLICATIONS OF TOPEX/POSEIDON DATA

J. Wahr and E. Leuliette
(University of Colorado, USA)

In our TOPEX/POSEIDON work, we are using the altimeter data both for oceanographic studies and to better remove the effects of the oceans from certain types of geophysical measurements in order to study the solid earth. Here, we describe three on-going projects.

Coupled Pattern Analyses

Steric changes in sea level at global scales are dominated by thermal effects. At long wavelengths sea surface temperature (SST) is a reasonable proxy for the thermal content of the mixed layer. To try to better identify thermal effects on sea level, we are using a coupled pattern analysis (CPA) to compare three years of TOPEX/POSEIDON sea surface height (SSH) data with SST data from the National Meteorological Center's global analysis.

In CPA, the covariance of two spatially- and temporally-dependent gridded fields (eg. SSH and SST) is used to construct orthogonal "modes", rank ordered in terms of the size of their contribution to the covariance. Each mode has a SSH and a SST component, both of which consist of a spatial pattern multiplied by a function of time. A mode that has a large contribution to the covariance, and that also has significant correlations between its SSH and SST spatial patterns and between its SSH and SST temporal functions, is likely to represent causally-related SSH and SST signals.

As an example, Figure 1 shows the Pacific Ocean mode with the largest contribution (60%) to the SSH/SST covariance obtained after seasonal terms have been removed. The SSH and SST components have a spatial correlation that rises well above the 99% confidence interval and a temporal correlation in excess of 0.94, which all suggests that these SSH and SST components are likely to have a physical connection.

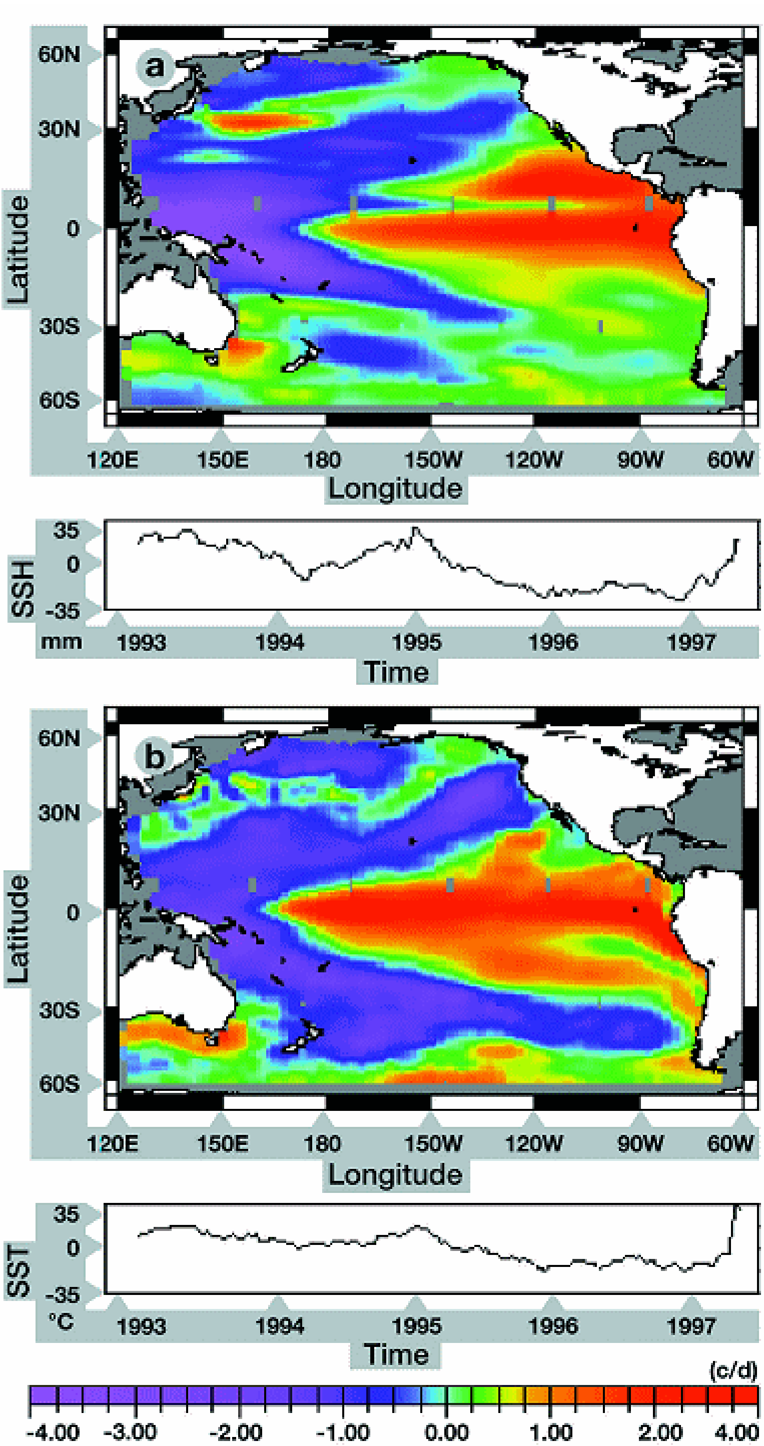

Figure 1

The principal non-seasonal CPA mode in the Pacific. Shown are the spatial patterns and the functions of time for both the SSH (a) and SST (b) components of the mode.

By constructing similar maps for each ocean basin, both before and after removing seasonal terms, we find that:

1. the dominant modes in the Atlantic and the Pacific are in-phase with the seasonal solar cycle, account for nearly all the covariance between the fields (97-98%), and have highly significant
2. SST/SSH spatial and temporal correlations; and
3. the principal modes obtained after first removing the seasonal terms, are interannual modes which capture 37%-60% of the non-seasonal covariance, and have significant spatial and temporal correlations in the Pacific and the Indian Oceans.

For each mode we apply a linear regression between its SST and SSH components. The results correspond to a thickness of the mixed-depth layer of about 40-50 m at an annual period, and about 2-3 times that at interannual periods. We are extending these results to consider all ocean basins simultaneously. We are also constructing a CPA between the SSH data and atmospheric pressure data, to better understand the response of the ocean to changes in pressure.

Tide Gauge Estimates of Crustal Motion

Although tide gauges are invariably installed for oceanographic applications, tide gauge records are often used to infer the vertical motion of the crust underlying the instrument. The most common application is the determination of crustal displacements caused by an earthquake. The main limitation is the difficulty of separating the effects of crustal motion from the oceanographic signal. Most studies look for similarities in recordings from all gauges in a region, remove the common signal, and interpret the remainder as the solid earth contribution. This procedure does not always work well, and can not be applied to data from geographically-isolated gauges. Better solutions could be obtained using independent information about SSH fluctuations, such as provided by an altimeter.

In this study, we are using a combination of TOPEX/POSEIDON SSH data, tide gauge sea level data, and geophysical models, to detect crustal deformation. We are using the SSH data to remove oceanographic signals from tide gauge data, so that the residuals can be better interpreted in terms of crustal motion. Our goal is partly to improve our understanding of specific earthquakes. But, our broader objective is to determine how effective the TOPEX/POSEIDON data could be in helping geophysicists address these problems, and how best to process the data.

Barotropic Modes

We are using TOPEX/POSEIDON tide models and output from meteorologically-forced barotropic ocean model [Ponte, 1993], to estimate the global-scale barotropic modes in the ocean at frequencies near 1 cycle/day (c/d). Besides their oceanographic significance, these modes have possible implications for the earth's rotation. The use of earth nutation measurements to learn about the coupling between the earth's mantle and fluid core, requires knowledge of the ocean's response to surface and tidal forcing across the diurnal band, including at tidal periods where the tidal amplitudes are too small to allow for direct TOPEX/POSEIDON solutions. That response will be largely determined by the characteristics of the ocean's barotropic modes at nearby frequencies.

Our initial strategy for determining these modes, is to look for frequency-dependent effects in the tidal admittances inferred from the TOPEX/POSEIDON tide models, that would be caused by modes near the tidal frequency band [see Cartwright and Ray, 1991]. Once we have estimated these modes, we will compare them with the frequencies and spatial patterns of the modes predicted by the model.

References:

- Cartwright, D.E. and R.D. Ray, 1991: Energetics of global ocean tides from Geosat altimetry. *J. Geophys. Res.*, *96*, 16897-16912.
- Ponte, R.M., 1993: Variability on a homogeneous global ocean forced by barometric pressure. *Dyn. Atmos. Oceans*, *18*, 209-234.