STUDIES OF TROPICAL PACIFIC VARIABILITY

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For the TOPEX/POSEIDON (T/P) Extended Mission (TPEM) we proposed studies in two general areas. First, we are examining tropical Pacific mass and heat balances based on descriptions we are making of tropical geostrophic and Ekman current variations, which are coordinated with the analysis of in situ data and numerical model studies. Second, we are studying the interaction of the tropical Pacific Ocean with the subtropics. Specifically, we will:

- **examine the extended period of anomalous conditions in the Pacific during the 1990's,**
- **explore tropical processes that may lead to covariations between the subtropical gyres in the northern and southern hemispheres,**
- **study the interaction of mesoscale eddies with the North Equatorial Current (NEC).**

One focus of our TPEM proposal was understanding the connection of tropical Pacific mass and heat transports with interannual variability, work which was begun during the primary T/P mission. During the primary mission, we focused on the relationship of the Pacific to Indian Ocean throughflow (ITF) to the heat content of the western Pacific warm pool, and we showed [Lukas et al., 1995; Potemra et al., 1996] that throughflow monitoring by altimetric sea level is feasible. We realized during the primary T/P mission, however, that we would have to be careful in choosing a reference surface for the T/P data before attempting to analyze low frequency anomalies. During the TPEM we have used in situ sea level data to estimate the magnitude of these errors, and we are also attempting to determine a temporal subset of the entire T/P time series that could be used as an improved reference period [Mitchum et al., 1997]. Briefly, we used 17 sea level gauges in the western tropical Pacific that had time series at least 20 years in length. These sea level time series were referenced to the 20-year mean, and used to estimate the errors that would have occurred if only the last N years of data were available to make the average (Figure 1). We also found that using data only from the last two quarters of the calendar year, rather than the entire year, significantly reduced the errors. We are continuing this work with sea surface heights from numerical models to better study the spatial patterns of the errors.

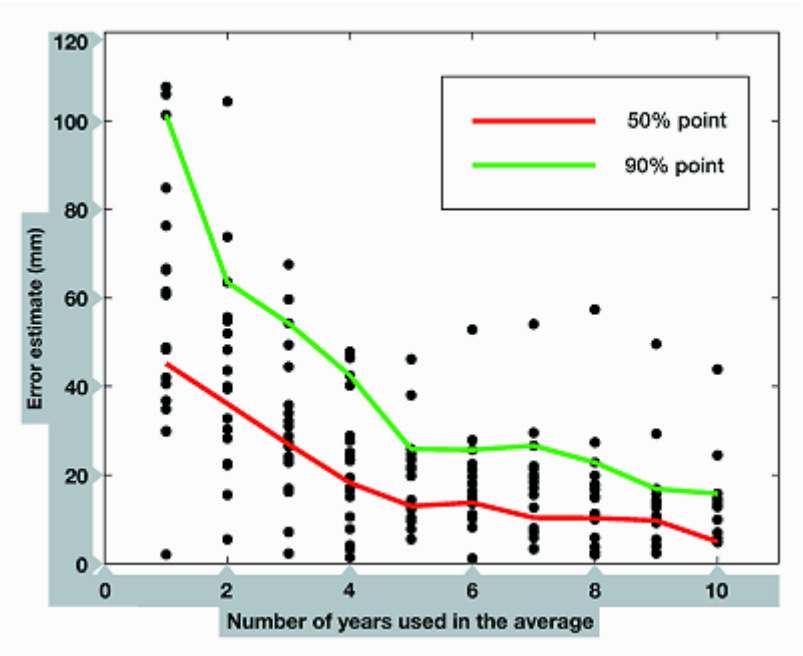


Figure 1
Estimates of errors due to having short time series available for computing the mean height field. The solid circles are the error estimates for each of the 17 sea level stations used in the analysis. The red and green lines connect the 50th and 90th percentiles, respectively.

In order to do the mass and heat balance studies, we are determining the total surface circulation (Ekman + geostrophic) and its effect on the heat balances. We made progress in this area during the primary mission [Lagerloef et al., 1995], and have made significant improvements in the first year of the TPEM [Lagerloef et al., 1997]. These improvements result from more carefully representing the zonal flows near and on the equator by using a blending of solutions from the meridionally differentiated form of the meridional geostrophic balance on the equatorial beta plane and from the standard geostrophic balance. An example from this blended analysis is shown for February 1997 (Figure 2), and further details about this particular time period are given in the figure caption. Our plans for the mass and heat studies include an examination of Wyrtki's [1985] hypothesis that the processes that normally remove heat from the western Pacific warm pool region are not efficient enough, and that periodically the slow accumulation of heat is flushed during ENSO events. This analysis has been questioned [e.g., Miller and Cheney, 1990; Springer et al., 1990], and it is interesting to note a recent theory by Gu and Philander [1996], who find ENSO events to be characterized by zonal shifts in the mass distribution, but decadal scale events to be due to meridional mass exchanges with mid-latitudes. During the TPEM we will investigate whether an imbalance between surface heat advection and net surface forcing accounts for the slowly varying heat storage, and by what pathways the accumulated heat leaves the warm pool subsequent to ENSO.

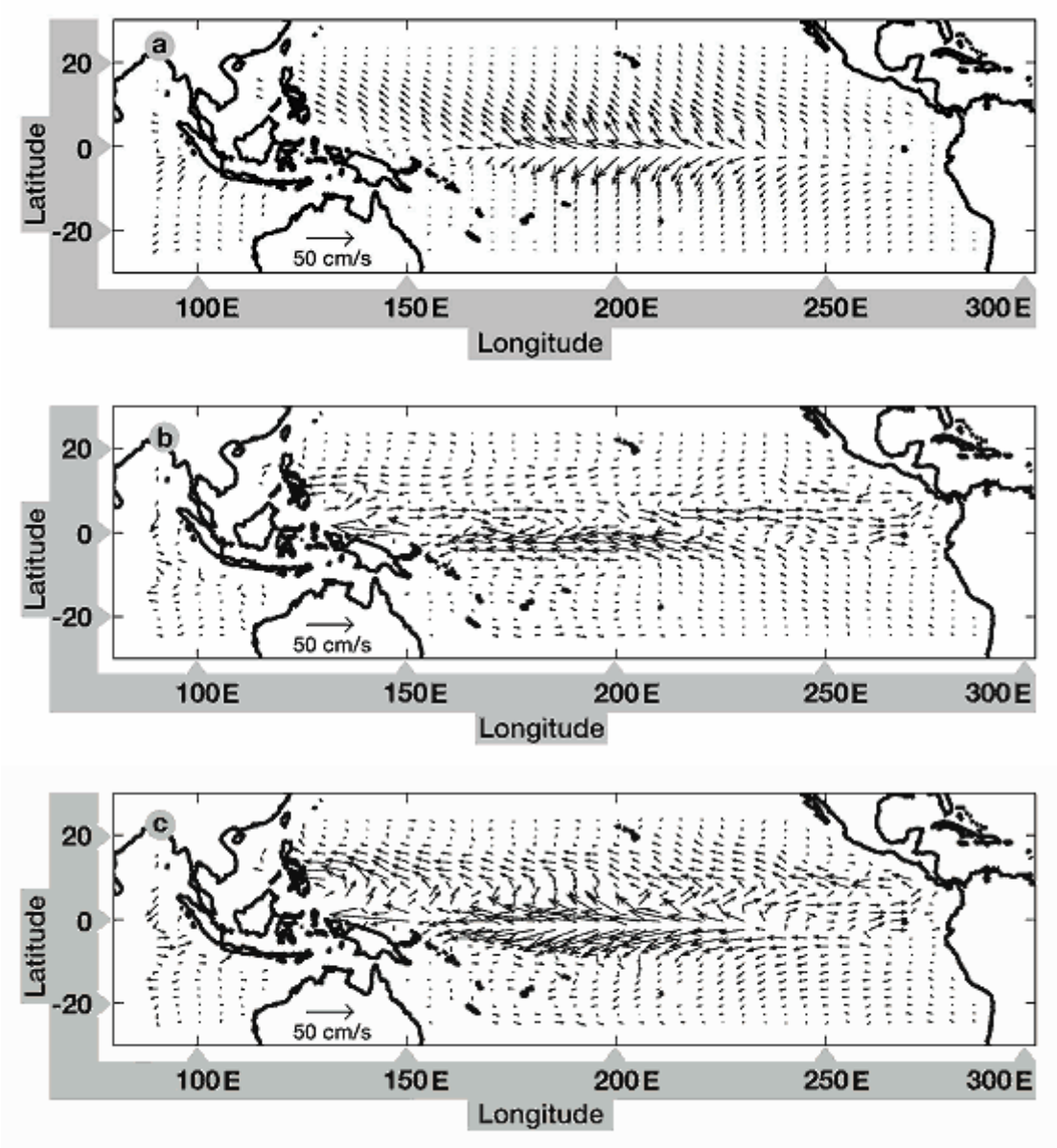
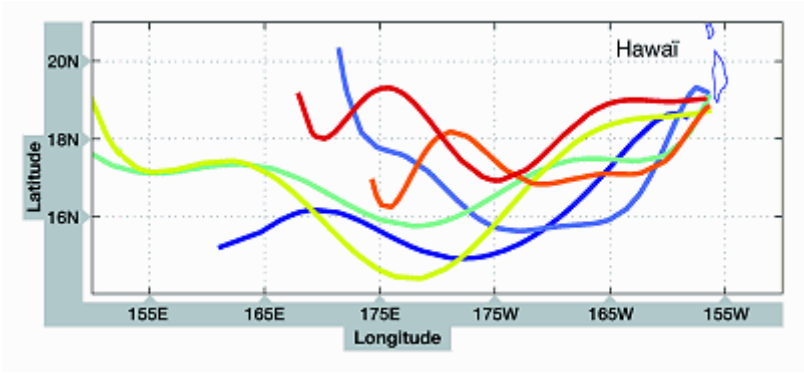


Figure 2

Tropical Pacific surface current maps for the month of February 1997: (a) Ekman flow from NSCAT winds, (b) geostrophic flow from T/P and (c) the sum of the upper two fields. A strong pulse of easterly trade winds near the date line and weak trades in the eastern equatorial Pacific is evident in the Ekman field. The central and western parts of the basin show intense westward flow in the bottom two panels, while a reversal of surface flow in the eastern quarter of the basin is evident. This pattern preceded the appearance of SST anomalies off Ecuador in March, indicating that the early evolution of the warm event may have been initiated as warmer water was advected by this localized eastward flow, and the light trade winds suppressed local equatorial upwelling. (The height fields used to compute the middle panel were obtained from the U. Texas while we are in the process of computing our own analysis of the 1997 T/P data.)

The second major thrust of our TPEM proposal is in the area of tropical-subtropical interactions, an interest that also began during the T/P primary mission. We have shown that anticyclonic eddies generated at the Big Island of Hawaii initially drift southward as well as westward, in accord with theories of wave drag [Flierl, 1984], but subsequently turn back northward, possibly due to an interaction with the NEC. To date we have tracked 6 eddies (Figure 3), and we are working on improved descriptions of the eddies and their movement. We are also making progress with modelling studies [Holland and Mitchum, 1997]. But the main emphasis of our work on tropical-subtropical interactions concerns decadal variations in the Pacific. Gu and Philander [1996] explicitly cite large scale meridional transfers between the tropics and subtropics as the cause of decadal anomalies in the tropical Pacific. Lu and McCreary [1995] argue instead that the ITCZ forms a barrier to flow moving directly from the subtropics to the tropics, and that the subtropical water first moves to the western boundary, and then southward around the ITCZ barrier. In contrast to these theories of tropical Pacific decadal variations, Latif and Barnett [1994] conclude that a decadal variation in the North Pacific is due to an air-sea interaction that is essentially confined to the mid-latitudes. We are considering these problems together, as we believe that it is difficult to separate the subtropical gyre flow from the tropical circulation at these time scales.

Figure 3
Positions of anticyclonic eddies tracked from the Big Island over with T/P data. The solid lines are smooth interpolates to position estimates that are made for each individual 10-day cycle.



We have proposed an approach to these problems that relies heavily on sigma and isopycnal modelling [e.g., Murtugudde et al., 1995; Seager et al., 1997] and long in situ time series, with the T/P data used to examine specific questions about spatial patterns. The first step will be to examine the model outputs to determine the sea level signatures associated with the decadal events. Then, analysis of long in situ series and T/P altimetry data will be used to evaluate and suggest improvements in the model simulations, and the process will then be iterated. Although this part of the work proposed to the TPEM was described as exploratory, we see this approach as one that attempts to make optimal use of several very different tools; namely, the length of the in situ time series, the strengths of the new model formulations, and the excellent spatial coverage of the T/P altimeter.

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