"TOWARD OPERATIONAL OCEAN STATE ESTIMATION"

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ABSTRACT

An ocean data assimilation system is being developed so as to routinely estimate the time-evolving, global, three-dimensional state of ocean circulation by combining satellite measurements and in situ observations using numerical ocean circulation models.

ASSIMILATION

The Hierarchical "Cellular" Kalman Filter (HKF) has been devised that approximates the overall filter (K) by a hierarchy of smaller filters ($K = K_1 + K_2 + \ldots$), enabling practical estimation at high resolution. ➨ Figures 1, 2, 3.

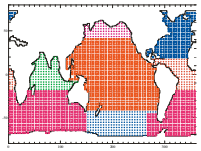

FIGURE 1: Cellular Grid for Assimilation
Overlapping cells resolve separate regional uncertainties.

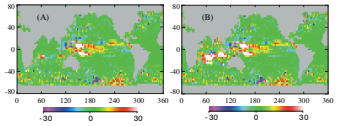

FIGURE 2: Explained Observed Sea Level Variance (cm^2)
The skill ('93 relative to simulation) of adding the Indian Ocean filter (B) is additive to that without this filter (A).

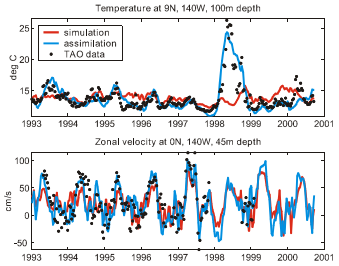

FIGURE 3: Validation of Assimilated Estimates
Assimilated estimates (blue) are in closer agreement with independent observations (dots) than the simulation (red) is.

STATE ESTIMATES

Sea level observations from TOPEX/POSEIDON are assimilated into a near-global, high-resolution, primitive equation model of the ocean. Estimates (Figures 4) reveal, among others, the evolution associated with the 1997~1998 El Niño, 1998~2000 La Niña, and the 1999~2000 emergence of the negative phase of the Pacific Decadal Oscillation (PDO). Differences among anomalies of sea level, sea surface temperature, and surface heat content (Figure 4) illustrate the magnitude and depth of the changes occurring within the water column; e.g., eastern equatorial Pacific (1998), central North Pacific (2000.5). Diagnostics of underlying processes (Figure 5) indicate ocean advection controlling many of the changes associated with the occurrences of interannual warming and cooling. Counter to traditional expectation of low-frequency variations, changes in heat content, except for those associated with El Niño/La Niña, are due to high-frequency episodic events (Figure 6).

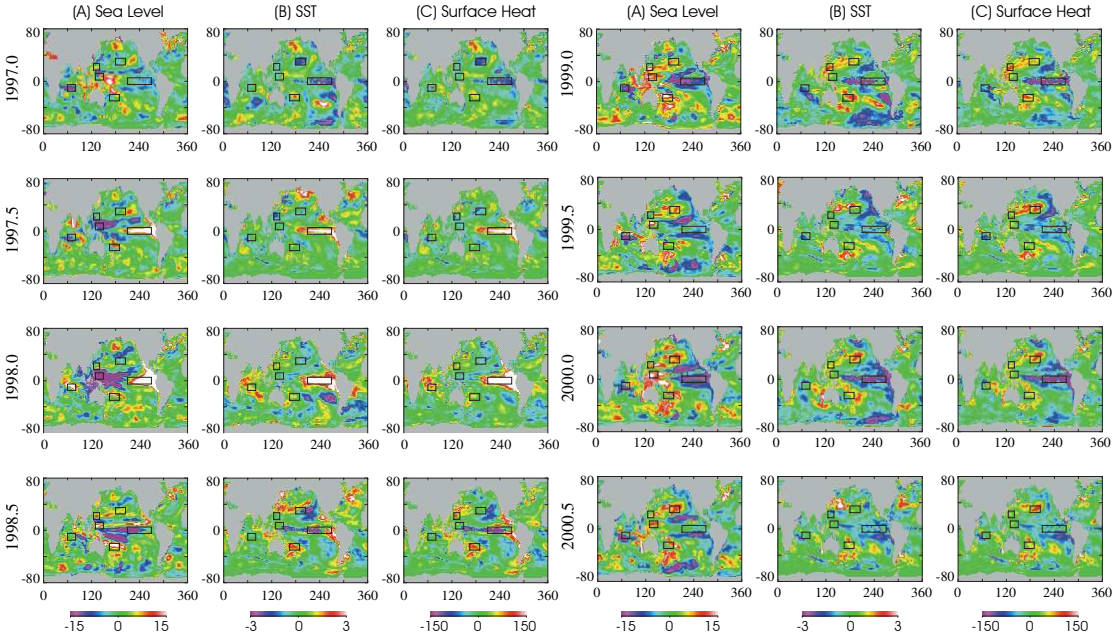

FIGURE 4: Estimates of Interannual Ocean State Anomalies from Assimilating TOPEX/POSEIDON Sea Level Data
(A) sea level (cm), (B) sea surface temperature (°C), (C) heat content of the top 50m (m·°C). Anomalies are defined with respect to the 4-year mean annual cycle of 1993~1996. Boxes denote areas of the diagnostics shown in Figures 5 & 6.

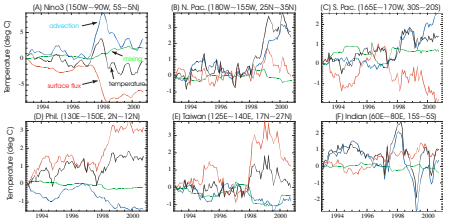

FIGURE 5: Diagnostics of Changing Surface Heat Content (°C)
Changes in interannual surface heat content anomalies (upper 50m, black) diagnosed from contributions from surface fluxes (red), advection (blue), and mixing (green). Each panel corresponds to averages over boxes indicated in Figure 4.

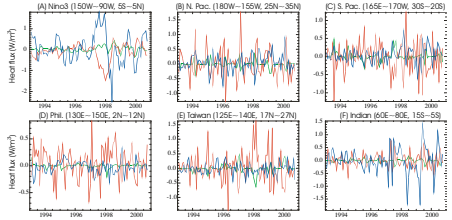

FIGURE 6: Heat Flux Convergence (W/m^2)
Same as Figure 5, except for convergence of heat flux.

CONCLUSION

An advanced data assimilation system is being established to monitor and diagnose processes underlying observed changes of the ocean, many of which are difficult to measure directly (e.g., sub-surface circulation and other data void instances in time and space). Preliminary analysis suggests episodic events controlling low frequency variations in mid-latitude near-surface heat content anomalies, which supports the need for continuous observations.

Present analyses are being extended in terms of spatial and temporal coverage, resolution, and the number of processes that are being resolved. Other data types will also be incorporated in the analysis to further constrain and optimize the solution. A data server is being prepared to disseminate the analysis products for wider utilization.