Multiscale Study of Currents Affected by Topography

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LONG-TERM GOALS

Understanding the roles of topography on the ocean general circulation is challenging because of the multiscale nature of the flow interactions. Small-scale details of the topography, and the waves, drag, and turbulence generated at the boundary, from meter scale to mesoscale, interact in the boundary layers to influence the larger-scale flow. We are using modern modeling and state estimation methods at multiple scales for collaborative study of the interaction of significant currents with steep topography in the western Tropical Pacific.

OBJECTIVES

Our scientific goals are to understand the interactions of the topography with the large-scale flow. Success will be indicated by successful predictive models and comparisons with independent observations. We will provide contextual state estimates to synthesize the observations taken during the DRI and to provide skillful boundary conditions to contribute to studies of the small-scale circulation around islands.

Our technical goals are to achieve seamless nested assimilation in a region characterized by strong mean flows impinging on abrupt topography and to add value to the HYCOM/NCODA analysis and prediction infrastructure.

APPROACH

We will run a nested set of models for the region and use state estimation to synchronize them with observations to provide a reanalysis of the observations taken during the experiments. The nesting starts with the entire Tropical Pacific at $1/3^o$ resolution in order to resolve the large-scale circulation, primarily wind-driven flows. The boundary conditions from this outer model (as well as the HYCOM/NCODA global analysis) will be used to initialize a series of nested models from $1/6^o$ resolution to scales approaching 5 km ($1/24^o$ resolution). The inner state estimates will be evaluated for skill and will supply boundary conditions to even finer-scale models, such as Delft3d, applied to local regions.

We will explore and answer these questions through numerical model-based data analysis, including state estimation in nested domains. We will use assimilated global HYCOM/NCODA and the MIT general circulation model (MITgcm) in nested domains starting from basin scale, connected to high-resolution (sub km) inner domains modeled with Delft3D or ROMS within about a degree of the island which will be configured and run by other investigators. Our results will be used in collaboration with other investigators to plan the experiments and to help to understand the observations. We will use the ocean models to provide a dynamically-consistent re-analysis of the observations in the region, both from the experiment and from other sources (Argo, Altimetry, SST, TAO, etc.).

WORK COMPLETED

We have created prototype nested model grids and run adjoint sensitivity experiments for the region encompassing Guam, Yap, and Palau to trace back influences to the North Equatorial Counter Current (NECC) as well as to the eastern boundary of the model. An example snapshot is shown in Figure 1. The model boundary conditions have been adjusted to show no adjoint Kelvin wave propagation along the boundaries, which can negatively affect regional state estimation experiments.

RESULTS

The adjoint sensitivity (Figures 2 and 3) of SSH in the region outlined in Figure 1 to SSH at earlier times shows no propagation along the boundaries and advection by the NECC provides a potentially important path of influence, complementing the effects of local wind forcing and westward-propagating waves and eddies.

IMPACT/APPLICATIONS

The sensitivity can be a guide to dynamical influences as well as informing sampling plans. The regional circulation can be estimated to produce a nested state estimate for comparison with HYCOM/NCODA. The state estimate should also provide improved analysis of the observations taken during the DRI.
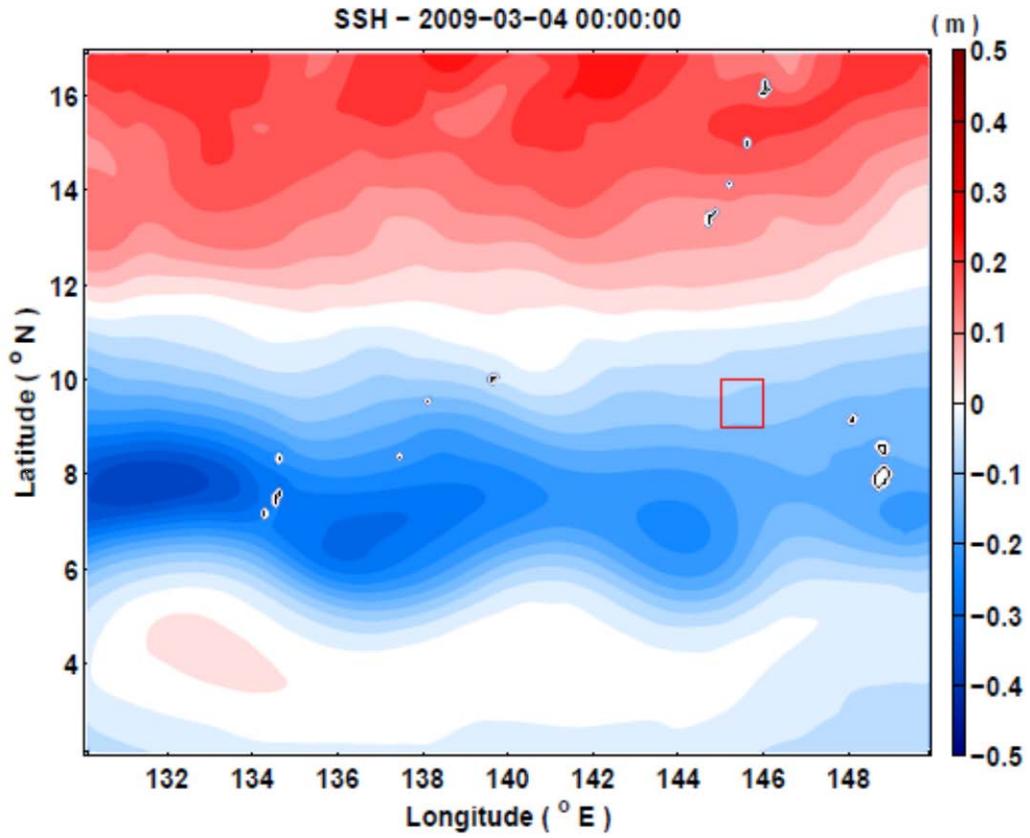
Figure 1: Snapshot of model SSH (m) on March 4 2009, the target time for an adjoint sensitivity calculation for the SSH averaged within the box with respect to model state at earlier times.
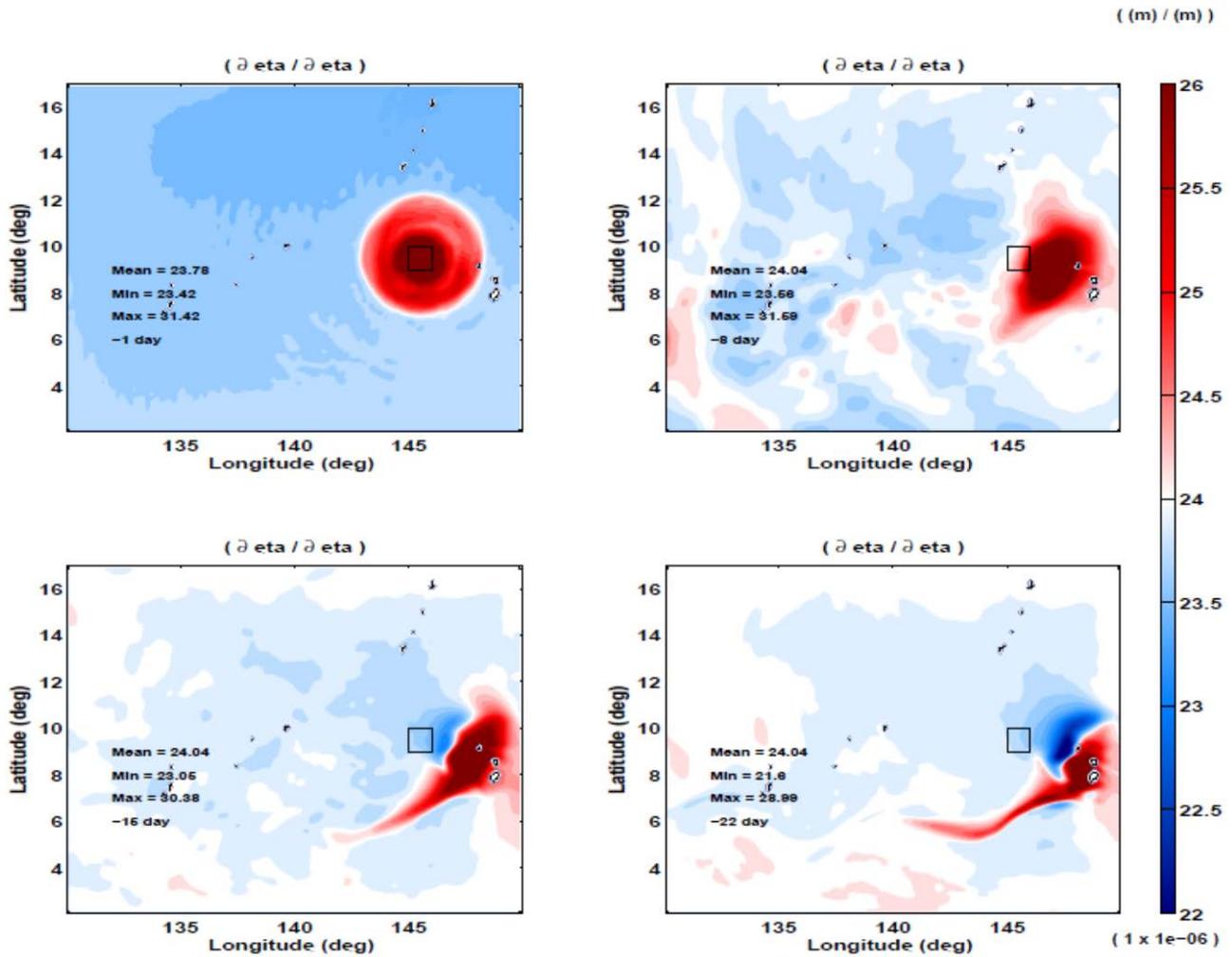
Figure 2: Derivative of the SSH within the box with respect to the SSH 1, 8, 15, and 22 days earlier. Note both the lack of propagation along the boundary and the tongue of sensitivity that follows the NECC upstream. The units are non-dimensional but represent the amount of SSH change in the box for a unit change in SSH at each grid point at the earlier time. There is a spatial mean component that represents the SSH anomaly spread by fast surface gravity waves. The red and blue colors are relative to that mean, which is shown as white on the figure.
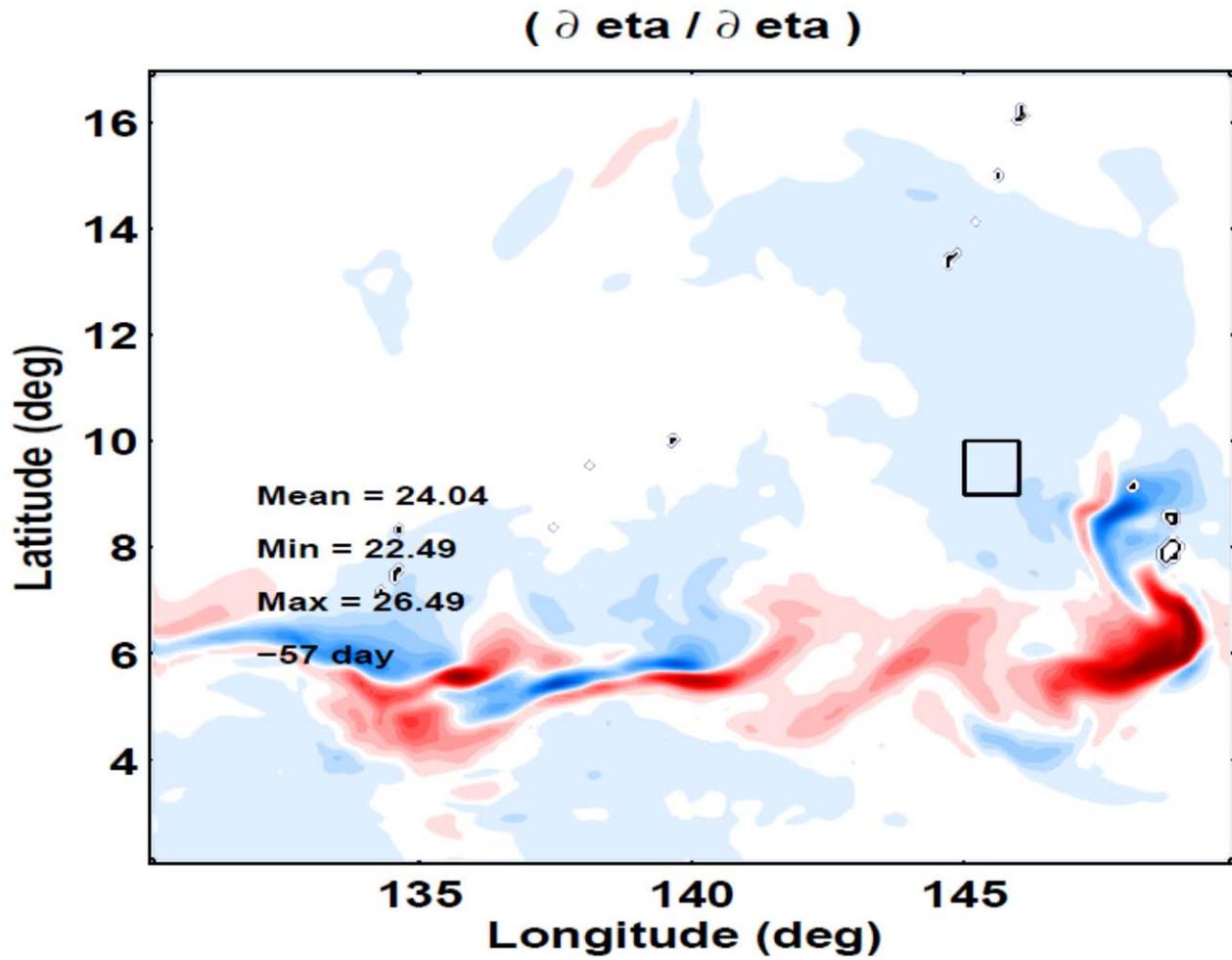
Figure 3: Same as Figure 2, but for 57 days earlier. The scale is the same as the earlier figure. The sensitivity pathway that follows the NECC upstream has reached the western edge of the domain.