Impact of Typhoons on the Western Pacific: Temporal and horizontal variability of SST cooling Annual Report, 2011

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Long-term Goals/Scientific Background

The long term goal is to understand how the spatial variation of ocean and hurricane parameters, e.g., upper ocean temperature gradient, initial mixed-layer depth, etc., contribute to hurricane-ocean interaction. With this understanding we should then be in position to make better forecasts of hurricane-ocean interaction, and especially of hurricane intensity (Emanuel et al., 2004).

The phenomenon of direct interest is the cooling of SST caused by hurricanes and typhoons, typically 2 to 5°C (Price et al., 1994; Sanford et al., 2007; Cornillon et al., 1987). This SST cooling is observed to vary temporally - disappearing in O(10) days (Price et al., 2008), and spatially. The most impressive spatial structure of most cool wakes is that SST cooling is significantly biased to the right side of the hurricane track (looking in the direction of the hurricane motion) for translation speeds greater than about 3 m sec^{-1}. Of particular interest here is that there is almost always a substantial, ± 0.5 °C, variation of SST cooling in the direction *parallel* to a hurricane track as well. Factors that could cause along-track variation of cooling include spatial variation in the pre-hurricane oceanic temperature (and salinity) stratification, and of course spatial variation of the hurricane intensity and translation speed (Lin et al., 2008; Jaimes and Shay, 2010).

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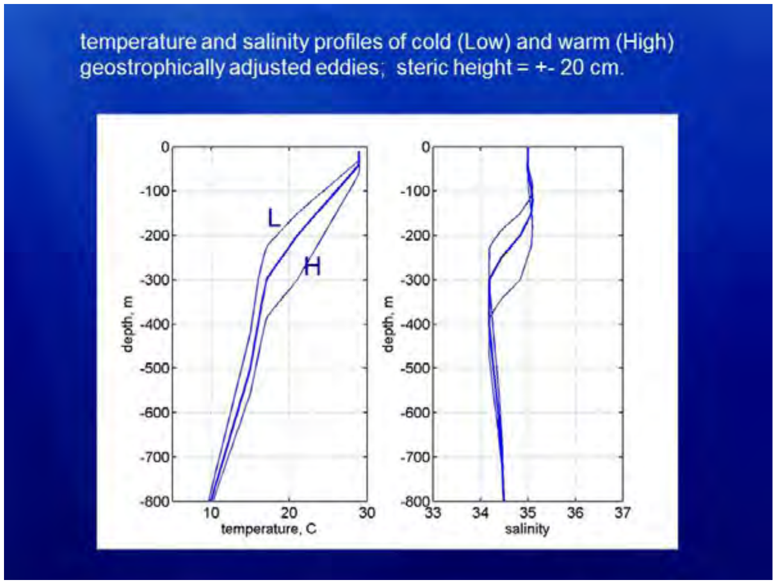

Figure 1: Temperature and salinity profiles (left and right) that represent a cold core, geostrophically balanced eddy (raised thermocline, low surface pressure and marked L), a warm core eddy (depressed thermocline, high surface pressure marked H) and the control (no eddy, the middle profile). These profiles are from the center of an eddy presumed to have a diameter of 200 km.

Objectives

The objective of this project is to make a quantitative estimate of the sensitivity of SST cooling to the hurricane and ocean variables that contribute to SST cooling. These include the ocean initial condition, e.g., if a mesoscale eddy is present, hurricane translation speed and hurricane intensity, among others. Emphasis here is upon ocean variability.

Approach

The main tool for assessing this sensitivity will be the 3DPWP ocean model (Price et al., 1994; Sanford et al., 2011), followed by a study of field observation, firstly CBLAST 2004, and now including ITOP/TCS10. ITOP provides several additional examples of cool wake evolution, and greater detail from *in situ* ocean data than has ever been available before.

Work Completed/Results

A set of three numerical experiments show the sensitivity of SST to a displaced (vertically) main thermocline (Fig. 1). A raised (lowered) thermocline results in greater (lesser) SST cooling underneath the storm during the forced stage response. The largest amplitude of cooling (about 50 km to the right of the track) shows a sensitivity of about ± -0.5 °C (Fig. 2) for realistic amplitudes of thermocline displacement,

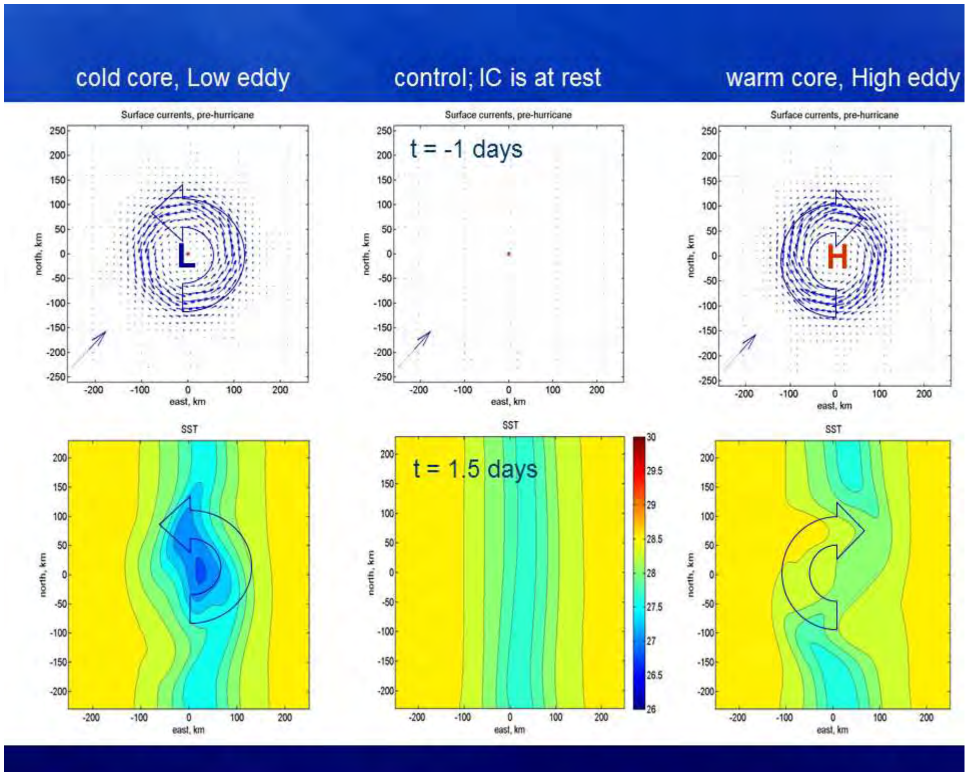

Figure 2: The upper row of panels show the initial condition of the surface layer currents for three numerical experiments that were initialized with, from left to right, a cold core eddy (low surface pressure cyclone), no eddy and hence no currents (the control case), and a warm core eddy (high pressure anticyclone). The lower row of panels are the SST anomaly (always cooling) at 1.5 days after the hurricane passage. The eddies cause significant anomalies of SST cooling compared with the control case. The eddy effect on the cooling is very obvious, but notice that there is also a significant (and confounding) advection by the eddy velocity field even after only a day and a half.

$\pm$ 50 m (Fig. 1). An eddy also leads to anomalous horizontal advection of the wake, and at longer times this will dominate the SST anomaly.

The challenge of this problem is that the eddy variability is of course two dimensional, as is the wake process itself. Thus an eddy may be directly on a track, assumed in the three experiments shown here, or to the left and right of a track. This adds one more to the rather long list of relevant external variables which suggests that we had better look for a simplified, efficient description of the eddy/cool wake interaction.

One possible description of this follows from a solution for SST cooling which indicates that the log derivative of SST cooling with respect to initial mixed layer depth and thermocline temperature gradient is -2; a raised thermocline causes reduced initial mixed layer thickness and an enhanced temperature gradient, both of which cause greater cooling for a given storm. This is the kind of amplitude-independent result that we are seeking, but we have to know how general this really is, e.g., does it hold for any eddy position and amplitude? Preliminary evidence is that '-2' obtains if there is an appreciable anomaly of thermocline height along the track, and if the estimate of cooling is made soon after a hurricane passage. Otherwise the observed cooling is sensitive to other processes, e.g., horizontal advection, which clearly have a very significant impact upon the cool wake (Fig. 2). We also seek to learn to the extent to which this result may be used with observed, pre-hurricane sea surface height anomaly to estimate cooling anomalies (ongoing).

Impact/Applications

None directly from the work of the past year. It is worth noting, however, that this kind of investigation lead to the metric T_{100} (Price, 2009) which was found to be useful during the ITOP field campaign as a simple, physically understandable metric of ocean stratification effects on cool wake amplitude. The ongoing research may yield something similar but tied to sea surface height.

Collaborations

The PI has collaborations ongoing with Dr. Tom Sanford, APL/UW (Sanford et al., 2010), Prof. Shuyi Chen of RSMAS Univeristry of Miami and Prof. I-I Lin of National Taiwan University. This past year the 3DPWP model was distributed to a number of other ITOP investigators who are using the model as a guide to the geostrophic currents generated by ITOP typhoons (R-C Lien of APL/UW) and the restratification process (Steve Jayne, WHOI), among others.

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