

## **Impact of Typhoons on the Western Pacific: Temporal and horizontal variability of SST cooling**

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### Long-term Goals/Scientific Background

The long-term goal of this project (now in the first half of the second year of the ITOP program) 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, by defining a comparatively simple metric of the ocean's state (stratification, mainly) .

The impetus of this research is the observation that hurricanes cool the sea surface temperature (SST) by up to 2 to 5°C (Price et al., 1994; Sanford et al., 2007). This SST cooling is observed to vary temporally - disappearing in O(10) days, the subject of the previous (CBLAST) research by this PI (Price et al., 2008) - and spatially. The most impressive spatial variation of the cool wake seen behind moving hurricanes 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 less than 4 m/sec. There is almost always observed to be a substantial variation of SST cooling in the direction *parallel* to a hurricane track as well. Factors that could cause this sort of 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. This along-track variation has been a focus of this project.

# Report Documentation Page

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## Objectives

The objective of this project is a physically-based diagnostic (or 'metric') of the ocean's role in hurricane-ocean interaction. A form was suggested during the present year, viz, a depth-averaged temperature,  $T_{100}$ , in which averaging is over the upper 100 m of the water column, along with a more complex version that need not be discussed here.

## Approach

The main tool for deriving a new diagnostic has been guidance from the 3DPWP numerical model (Price et al., 1994). This model gives what appear to be realistic numerical solutions for a range of conditions, though the only objective, quantitative tests are for the Frances (2004) CBLAST case; Sanford et al. 2007. ITOP should provide several additional examples and even greater detail of the ocean response.

## Work Completed/Results

During the past year, 2009, the possibility of an improved ocean metric was described in detail in Price (2009). This paper argued that a depth-averaged temperature, e.g.,  $T_{100}$ , should be preferable to a depth-integrated temperature, the present hurricane-ocean metric usually called Upper Ocean Heat Content, or OHC (Goni and Trinanes, 2003; Lin et al., 2008). What Price (2009) did not do was show that  $T_{100}$  was in practice superior to OHC as a forecast tool. There are three ways to test whether  $T_{100}$  is a useful metric of hurricane-ocean interaction.

1) Comparison with comprehensive 3-d ocean models.  $T_{100}$  is, in essence, a simplified solution for SST cooling due to vertical mixing. As such it can be compared with solutions from a comprehensive 3-d ocean model. This was done in Price (2009) (in the supplementary material) and generally looked good.

2) The essential aspect of  $T_{100}$  in so far as the ocean goes is the dependence of cooling upon the ocean stratification. We can expect that ocean observations from ITOP this coming summer of 2010 will provide case studies that will help define the cooling dependence upon stratification. We can also encourage other modellers to share the corresponding results from other 3-d numerical ocean models.

3) The rigorous and direct test will be to find out whether  $T_{100}$  will in practice give better guidance for hurricane forecasters than does OHC. This is made complicated by the fact that no ocean metric can be expected to explain more than a fraction of the variance of hurricane intensity (Emanuel, 2004). Nevertheless, we will push this forward during ITOP and where any other opportunities that arise.

## Impact/Applications

The new metric,  $T_{100}$  has been taken up for operational testing alongside OHC in the East Asian Sea Forecasting System of NRL and Dr. Dong-Shan Ko. In shallow, continental shelf regions, e.g., the South China Sea, the

values of OHC are greatly decreased compared to the deep ocean, implying that coastal waters should be *unfavorable* for the intensification of a hurricane. In contrast,  $T_{100}$  may be high over a warm shelf region, simply because cool water will not be present in the water column and hence vertical mixing will be ineffective insofar as cooling SST is concerned (see observations of Cornillon et al., 1987). This qualitative difference between  $T_{100}$  and OHC stems from the qualitatively different physical premises behind these two metrics. An important goal for my work in ITOP will be to see which of these two metrics is more reliable in conditions of shallow water and cool water, especially.

## Collaborations

During the present year I have hosted a visit by Iam-Fei Pun from Taiwan National University, who is a Ph-D student of Prof. I-I Lin. He is quite experienced with the analysis of hurricane-ocean data sets, and plans to participate in the ITOP project in part by testing the  $T_{100}$  idea.

## References

- Cornillon, P., L. Stramma and J. F. Price, 'Satellite observations of sea surface cooling during hurricane Gloria', *Nature*, **326**, 373-375, 1987.
- Emanuel, K. A., C. DesAutels, C. Holloway and R. Korty, 'Environmental controls on tropical cyclone intensity', *J. Atmos. Sci.*, **61**, 843-858, 2004.
- Goni, G. J. and J. A. Trinane, 'Ocean thermal structure monitoring could aid in the intensity forecast of tropical cyclones', *Eos. Trans. Amer. Geophys. Union*, **84**, 573-580, 2003.
- Lin, I-I., C-C. Wu, I-F. Pun and D-S. Ko, 'Upper ocean thermal structure and the western North Pacific category 5 typhoons, Part I: Ocean features and the category 5 typhoon's intensification', *Mon. Wea. Rev.*, **136**, 3288-3306, 2008.
- Price, J. F., J. Morzel and P. P. Niiler, 'Warming of SST in the cool wake of a moving hurricane', *J. Geophys. Res.*, **113**, C07010, 2008. doi:10.1029/2007JC004393.
- Price, J. F., 'Metrics of hurricane-ocean interaction: depth-integrated or depth-averaged ocean temperature?' *Ocean Sci.*, **5**, 351-368, 2009. Available online at <http://www.ocean-sci.net/5/351/2009/os-5-351-2009.html>
- Sanford, T. B., J. F. Price, J. B. Girton and D. C. Webb, 'Highly resolved ocean response to a hurricane', *Geophys. Res. Lett.*, **34**, L13604, doi:10.1029/2007GL029679, 2007.