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Modeled Oceanic Response and Sea Surface Cooling to Typhoon Kai-Tak

Yu-Heng Tseng[1,*], Sen Jan[2], David E. Dietrich[3], I-I Lin[1], Ya-Ting Chang[4], and Tswen-Yung Tang[4]

[1] Department of Atmospheric Sciences, National Taiwan University, Taipei 10617, Taiwan, ROC
[2] Institute of Hydrological and Oceanic Sciences, National Central University, Jhongli 32001, Taiwan, ROC
[3] AcuSea Inc., 8450-101 Via Sonoma, La Jolla, CA92037, USA
[4] Institute of Oceanography, National Taiwan University, Taipei 10617, Taiwan, ROC

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ABSTRACT

An ocean response to typhoon Kai-Tak is simulated using an accurate fourth-order, basin-scale ocean model. The surface winds of typhoon Kai-Tak were obtained from QuikSCAT satellite images blended with the ECMWF wind fields. An intense nonlinear mesoscale eddy is generated in the northeast South China Sea (SCS) with a Rossby number of O(1) and on a 50 - 100 km horizontal scale. Inertial oscillation is clearly observed. Advection dominates as a strong wind shear drives the mixed layer flows outward, away from the typhoon center, thus forcing upwelling from deep levels with a high upwelling velocity (> 30 m day^{-1}). A drop in sea surface temperature (SST) of more than 9°C is found in both observation and simulation. We attribute this significant SST drop to the influence of the slow moving typhoon, initial stratification and bathymetry-induced upwelling in the northeast of the SCS where the typhoon hovered.

Key words: Air-sea interaction, Typhoon, Upwelling

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1. INTRODUCTION

It is well known that tropical cyclones (TCs), also known as typhoons (in the Pacific) and hurricanes (in the Atlantic), draw their energy from warm ocean waters (Emanuel et al. 1986). Through air-sea interaction, the ocean supplies energy for a typhoon's intensification (Emanuel et al. 1986; Moon et al. 2007, 2008; Lin et al. 2009a). Pre-existing ocean mesoscale features and subsurface structures may be far more important than sea surface temperature (SST) alone in the heat and moisture fluxes feeding the storm. Shay et al. (2000) noted an abrupt change in the intensity of hurricane Opal (9/28 - 10/5, 1995) when it passed over a large warm core eddy (WCE). Hurricane Katrina in August 2005 also showed a very similar intensification while passing over the Loop Current and WCE regions. Lin et al. (2005, 2008) noted the critical role of warm ocean eddies in the western North Pacific category-5 typhoons in observing that 30% of these super typhoons are fuelled by warm ocean features. Wu et al. (2007) used a simple coupled typhoon-ocean model to study the role of warm and cold eddies in a typhoon's intensification. Typhoons also cause significant SST cooling which provides negative feedback to the overlying storm by reducing the latent and sensible heat sources to the eye wall region. For example, satellite images showed that SST dropped more than 9 and 11°C in response to the passage of typhoons Kai-Tak (Lin et al. 2003) and Ling-Ling (Shang et al. 2008), respectively. Wu et al. (2008) studied the air-sea interaction between typhoon Nari and the Kuroshio current using satellite observations and an ocean model. The intensity of typhoon Nari varied a few times when it crossed over the Kuroshio current. These examples demonstrated the role of warm (and cold) oceanic features in providing a positive (as well as negative) feedback to the overlying storms by causing an intensification (or weakening) of the storms.

In general, the primary mechanisms accounting for sea surface cooling caused by TCs include mixed layer depth (vertical mixing/entrainment) and thermocline depth, an exchange of air-sea heat fluxes, and the storm's intensity

* *Corresponding author*
E-mail: yhtseng@as.ntu.edu.tw