Upper Ocean Response to the Super Tropical Cyclone Phailin (2013) over the Freshwater Region of the Bay of Bengal

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Abstract

This study investigates the impact of salinity stratification on the upper-ocean response to a category-5 TC, Phailin, that crossed the northern Bay of Bengal (BOB) from October 08-13, 2013. A drastic increase of up to 5.0 PSU in sea surface salinity (SSS) was observed after Phailin’s passage, whereas a weak drop of below 0.5°C was observed in sea surface temperature (SST). Rightward biases were apparent in surface current and SSS but not evident in SST. Phailin-induced SST variations can be divided into the warming and cooling stages, corresponding to the existence of the thick barrier layer (BL) and temperature inversion before and after Phailin’s passage, respectively. During the warming stage, SST increased due to strong entrainment of warmer water from the BL, which overcame the cooling induced by surface heat fluxes and horizontal advection. During the cooling stage, the entrainment and upwelling dominated the SST decrease. The pre-existing role of the BL, which reduced entrainment cooling by ~1.0°C, significantly weakened the overall Phailin-induced SST cooling. The HYbrid Coordinate Ocean Model (HYCOM) experiments confirm the crucial roles of entrainment and upwelling in the Phailin-induced dramatic SST increase and weak SST decrease. Analyses of upper-ocean stratification associated with 16 super TCs that occurred in the BOB during 1980-2015 show that intensifications of 13 TCs were associated with a thick isothermal layer, and 5 out of the 13 were associated with a thick BL. The calculation of TC intensity with and without considering subsurface temperature demonstrates the importance of large upper-ocean heat storage in TC growth.

Introduction

In the BOB, previous studies noted that in regions of weaker upper-ocean stratification, TC-induced SST cooling is around 2–6 °C, while over the northern Bay with stronger upper-ocean stratification due to low surface salinity, the SST decrease is below 1.5 °C. Using OGCM simulations, it has been suggested that in the BOB during the post-monsoon season, the salinity stratification accounts for 40% of the cooling reduction (Neetu et al. 2012). However, due to the lack of observations, an observational depiction of the effect of the BL, particularly with a pre-existing temperature inversion between the BL and ML, on TC induced SST cooling, is still lacking and the associated processes require in-depth investigation over the BOB.

Data and methods

- DATA. Time-series observations from the RAMA buoy located at 15° N, 90° E, together with TS profiles from the three Argo float groups are used to examine the evolution of atmospheric conditions and ocean response during Phailin. To provide a basin-scale view of the upper ocean response, we also analyze the gridded products of ocean surface currents, sea surface height (SSH), SST, SSS, ocean surface wind, surface heat flux, and precipitation. The 5-day resolved NCEP/NCAR reanalysis dataset is used to examine the barrier layer thickness (BLT), isothermal layer depth (ILD), and SST near the tracks of 16 super TCs for the period of 1980-2015.

- Methods. The effects of the BL, with a pre-existing temperature inversion between the ML and BL, on Phailin-induced surface cooling are quantitatively assessed, using field observations and a diagnostic ML temperature equation together with a hierarchy of experiments using the HYbrid Coordinate Ocean Model (HYCOM).

Result

- Figs. 1-4. Positions of TC Phailin (red) and sea surface salinity (SSS) distribution for October 2013. (a) The positions of Argo floats. (b) Time evolution of maximum wind speed and intensity of Phailin. (c) Barrier layer thickness (BLT); (d) Mixed layer depth (MLD). (e) SST observed from HYCOM and HYCOM experiment. (f) SST observed from HYCOM experiment and HYCOM experiment with the effect of freshwater. (g) SST observed from HYCOM experiment and HYCOM experiment with freshwater and river discharge.

- Figs. 5-8. SSS differences (psu) between HYCOM (red line) and HYCOM experiment (black line) for October 8-13, 2013. Panels (a,b): SSS difference from HYCOM vs. HYCOM experiment. (c) SSS difference from HYCOM experiment vs. HYCOM experiment with freshwater and river discharge. (d) SSS difference from HYCOM experiment vs. HYCOM experiment with freshwater and river discharge. (e) SSS difference from HYCOM experiment vs. HYCOM experiment with freshwater and river discharge. (f) SSS difference from HYCOM experiment vs. HYCOM experiment with freshwater and river discharge.

- Figs. 9-12. Surface currents (vector) from SODA and OOI Current Observing System 2 (OOICOS) and Argo profiles. (a) Current from SODA (blue line) and Argo profiles (red line). (b) Current from OOI Current Observing System (blue line) and Argo profiles (red line).

- Figs. 13-16. Upper-ocean temperature and salinity averaged from the Argo float profiles during the inversion stage (a) and the warming stage (b) for October 8-13, 2013. (c) Temperature and salinity averaged from the Argo float profiles during the inversion stage. (d) Temperature and salinity averaged from the Argo float profiles during the warming stage.

- Figs. 17-20. Time series distribution of sea surface temperature (SST) and sea surface salinity (SSS) for October 8-13, 2013. Panels (a) and (b) are the same as (a) and (b), respectively, but for the SST anomalies (SSTA).