

TROPICAL CYCLONE TURBULENT MIXING AS OBSERVED BY AUTONOMOUS OCEANIC PROFILERS WITH THE HIGH REPETITION RATE.

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Summary Changes in structure of the mixed layer in the ocean caused by passage of two tropical cyclones are presented. Profiles of temperature and salinity sampled by Argo float of high repetition cycle show that the typhoon passage cools the upper ocean. Results from numerical simulations show that the change in mixed layer effects from entrainment through thermocline due to turbulence induced by the high wind.

INTRODUCTION

Tropical cyclone (TC) impact on the upper ocean is manifested by decrease of the sea surface temperature known as the "cold wake" [1]. Enhanced surface wind stress forces turbulence and downward momentum transport, leading to increased shear at the bottom of the mixed layer. In turn, increased entrainment of cold water from the thermocline [2] and following turbulent mixing results in decrease of the mean temperature of the upper ocean.

Typically, the ocean response is stronger on the one side of the TC track [2] which is explained by coupling of the wind stress curl with inertial oscillations. On northern hemisphere this is possible on the right side of the TC track only. The extreme wind speeds in tropical cyclones prevent from direct manned measurements of the cold wakes. Arrays of mooring buoys, such as TOGA TAO array, are sparse and rarely capture the TC passage [3]. However, autonomous profiling buoys such as ARGO [4] enable direct measurements of the oceanic mixing underneath a tropical cyclone as well as analysis of the ocean mixed layer time dependence after the tropical cyclone passage.

METHODS AND DATA

Typical Argo profiler spends most of its time parked at arbitral depth - usually 1500m - and ascends every 10 days taking vertical profile of temperature and salinity. The number of floats operating in a cycle shorter than three days is very limited but such timescale is necessary because the transitional speed of tropical cyclone is typically 4 to 8m/s. In this analysis data from a non-standard autonomous float, operated with 1 day cycle instead of typical 10 days is used.

Finding suitable measurement data was possible comparing databases about cyclone tracks to the information on position of Argo profilers. In effect it was found that the ARGO float WMO ID 5901579 (18N, 127 E) coincided between September 9th and October 5th (Day of the year 253-279, 2008) with two typhoons - TY Hagupit and TY Jangmi. Hagupit passed 80km south west from the buoy leaving it on its right side; Jangmi passed 60km north east from the float leaving it on the left side of the track. Additionally we used satellite data from QuikScat scatterometer and Tropical Rainfall Measurement Mission (TRMM) radar in order to estimate wind speeds (Fig.1) and precipitation (Fig.2) at the location of the profiler.

The first peak of the wind speed (Fig.1) represents TY Hagupit, the second one corresponds to TY Jangmi. Maximum value of the wind speed was about 25m/s for each typhoon. Maxima in wind speed are associated with peaks in the precipitation (Fig. 2). An idealized, 3 dimensional, primitive equation, hydrostatic numerical ocean model (3D PWP) [5] was used to obtain further insight on the oceanic mixing processes. The model was initiated with the ocean state based on data from an ARGO profiler collected before passage of typhoons. Surface forcing was taken from the International Best Tracks Archive for Climate Stewardship (IBTrACS) and other telemetric data.

RESULTS

Temporal evolution of upper ocean temperature interpolated from consecutive profiles from Argo float is presented on Fig. 3. Arrows show intensive cooling during on days 263 and 269 (September 19th and 25th, respectively). These dates match the shortest distances of the float from typhoons Hagupit and Jangmi. Cooling is associated with deepening of the mixed layer, which indicates importance of entrainment from the thermocline.

Temperature drop after Hagupit was greater than after Jangmi. This can be explained by the fact, that measurements were taken on the right side of the first typhoon and on the left side of the other. Another factor was that the depth of the mixed layer and stability at the thermocline increased after the first TC. That resulted in less entrainment and redistribution of heat in the thicker column of water.

Figs 4 compared 3 successive profiles from the measurements and simulations with the numerical model. Modeled oceanic response compares reasonably with observations showing the mixing effect of typhoon passage on the upper ocean.

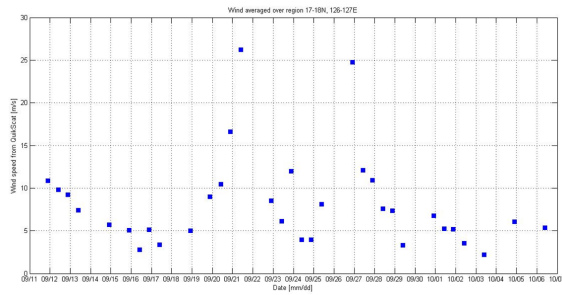


Figure 1. Wind speed in m/s from QuikScat.

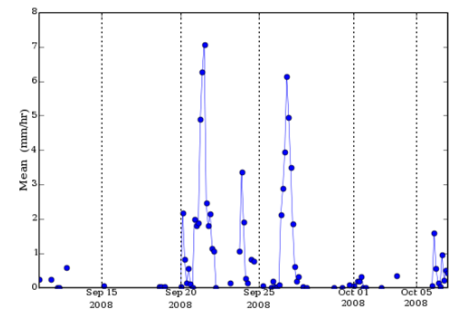


Figure 2. Precipitation rate from TRMM.

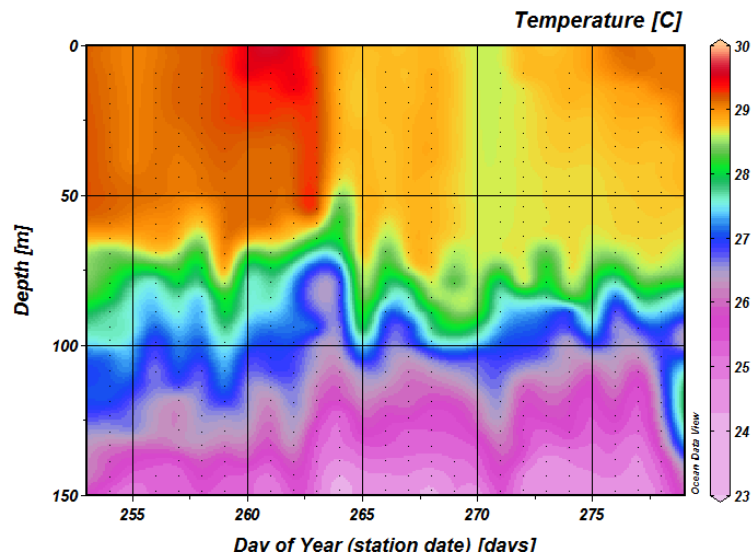


Figure 3. Temperature changes observed by Argo float. Time vs depth on the axis, temperature in Celcius degrees in colours.

References

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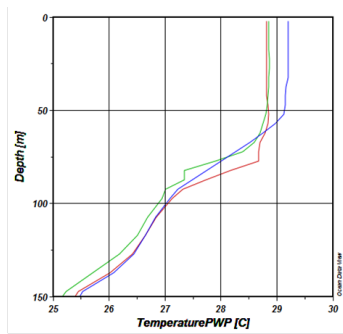


Figure 4. Temperature profiles from 3D PWP ocean model. Blue is first, green following and red is the latter.

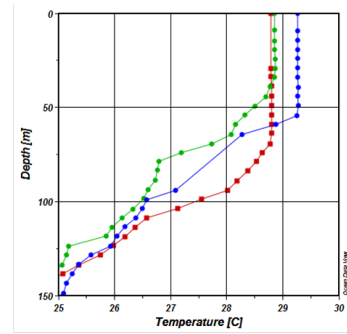


Figure 5. Temperature profiles from Argo measurements. Colours correspond with ones on Fig. 4.