

## **Analysis of the Impact of Typhoons on the Pacific**

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Award Number: N00014-11-1-0394  
<http://www.whoi.edu/science/PO/people/ipun/>

### **LONG-TERM GOALS**

The long-term goal of this work was to observe, understand, quantify and parameterize upper-ocean mixing in the cold wake of a typhoon. A second goal is to create an improved ocean heat content estimates are critical for forecasts of tropical cyclone formation, intensity, and structure.

### **OBJECTIVES**

The objective of our research program during the ITOP field campaign was to observe the temporal and spatial evolution of typhoon cold wakes, in particular we directly observed the mixing associated with turbulence generated by the strong air-sea interaction in a typhoon (D'Asaro et al. 2011; Pun et al. 2011; Mrvaljevic et al. 2013). These observations will be used to make quantifiable assessments of mixed layer models under the extreme conditions of a typhoon. We observed the restratification of the cold wake from air-sea fluxes to understand the subsequent evolution of the cold wake after the typhoon had passed. We have now moved on to analysis of the observations.

Although there is a high demand for upper ocean thermal structure in tropical cyclone intensity research and forecasting, it is extremely difficult to operationally obtain good estimates of it with *in situ* means alone, especially in a vast ocean basin like the North Atlantic Ocean. *In situ* observations of the vertical structure of ocean temperature are simply too sparse in time and space to compared to the scales that impact tropical cyclone forecasts. Therefore we seek to improve estimates of ocean heat content using both *in situ* data and satellite observed ocean variables (Pun et al. 2013).

### **APPROACH**

Our approach is to synthesize the observations from the ITOP field program with numerical modelling of the formation of the cold wake and the subsequent restratification afterwards to understand the physical processes important for each. In addition to the *in situ* data, we are working with satellite-observed sea surface height and sea surface temperature, as well as 1-dimensional and 3-dimensional mixed layer models.

An upper ocean thermal structure product, based on the physical correlation between the sea surface height anomaly and upper ocean heat content, we developed a linear regression method specifically for

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Form Approved  
OMB No. 0704-0188

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1. REPORT DATE <b>30 SEP 2014</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2014 to 00-00-2014</b>	
4. TITLE AND SUBTITLE <b>Analysis of the Impact of Typhoons on the Pacific</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Woods Hole Oceanographic Institution, 266 Woods Hole Rd, Woods Hole, MA, 02543</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

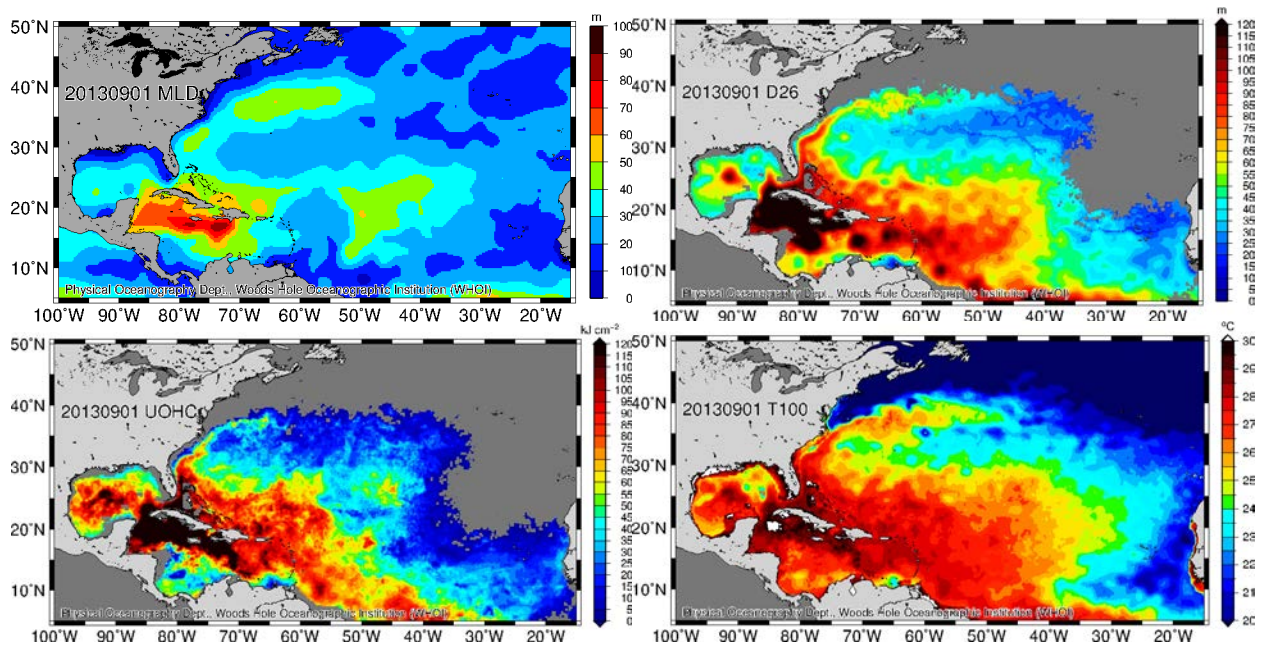
the North Atlantic Ocean. Using the observed sea surface height anomalies altimetry, satellite sea surface temperature, and more than 180,000 shipboard CTD, XBT and Argo temperature profiles from 2000–2010 during the months of June through November. In addition to the observational data, a simple mixed layer model (1-dimensional Price-Weller-Pinkel) is used to predict the mixed layer depth.

## WORK COMPLETED

During the past year we hosted a postdoc, Iam-Fei Pun, who received his degree from I I Lin’s research group at National Taiwan University. His research project was to develop a real-time ocean thermal structure data product utilizing the data from satellite and in situ observations.

## RESULTS

A near-realtime daily estimate of the upper ocean thermal structure that is based upon the satellite sea surface height anomaly and sea surface temperature observations, as well as the mixed layer depth from the 1-dimensional Price-Weller-Pinkel (PWP) mixed layer model was developed and is available on the web. It provides basin-wide fields including D26 (depth of the 26°C isotherm), D20 (depth of the 20°C isotherm), T100 (averaged temperature of the upper 100 m), tropical cyclone heat potential, and mixed layer depth. The estimated upper ocean thermal is compared to an independent set of Argo float profiles from 2011–2012 that were withheld from the estimation process. It is found that the newly developed methodology is robust and compares favorably to, if not better than similar estimates from the HYCOM data-assimilative dynamical model.



**Figure 1: Maps of estimated mixed layer depth (MLD) (upper left), D26 (depth of the 26°C isotherm) (upper right), estimated tropical cyclone heat potential (lower left), and T100 (averaged temperature over the upper 100 meters) (lower right) all for September 1, 2013.**

A webpage has been constructed on WHOI web for providing near-realtime daily estimates of subsurface thermal structure: <http://www.whoi.edu/science/PO/people/ipun/>

## IMPACT/APPLICATIONS

The novel observations taken during the ITOP field campaign are being used to improve mixed layer models during the very different phases of the strong forcing by the extreme air-sea fluxes of a tropical cyclone to stable forcing regime after its passage.

The realtime ocean thermal structure will be useful for tropical cyclone prediction.

## RELATED PROJECTS

Related to this project is my work in understanding and parameterizing mixing in global ocean models, such as the Community Earth System Model (<http://www.cesm.ucar.edu/>), and an NSF funded Climate Process Team on the same subject (<http://www-pord.ucsd.edu/~jen/cpt/>).

## REFERENCES

- D'Asaro, E., P. Black, L. Centurioni, P. Harr, S. R. Jayne, I-I Lin, C. Lee, J. Morzel, R. Mrvaljevic, P. P. Niiler, L. Rainville, T. Sanford, and T. Y. Tang, 2011: Typhoons and the ocean in the western North Pacific: Part 1. *Oceanography*, **24**, 24–31.
- Mrvaljevic, R. K., P. G. Black, L. R. Centurioni, Y.-T. Chang, E. A. D'Asaro, S. R. Jayne, C. M. Lee, R.-C. Lien, I-I Lin, J. Morzel, P. P. Niiler, L. Rainville, and T. B. Sanford, 2013: Observations of the cold wake of Typhoon Fanapi (2010). *Geophysical Research Letters*, **40**, 316–321.
- Pun, I.-F., Y.-T. Chang, I-I Lin, T. Y. Tang, and R.-C. Lien, 2011: Typhoon-ocean interaction in the Western North Pacific: Part 2, *Oceanography*, **24**, 32–41.
- Pun, I. F., I. I. Lin, and D. S. Ko, 2014: New generation of satellite-derived ocean thermal structure for the western North Pacific typhoon intensity forecasting. *Progress in Oceanography*, 121, 109–124.

## PUBLICATIONS

- D'Asaro, E., P. Black, L. Centurioni, P. Harr, S. R. Jayne, I-I Lin, C. Lee, J. Morzel, R. Mrvaljevic, P. P. Niiler, L. Rainville, T. Sanford, and T. Y. Tang, 2011: Typhoons and the ocean in the western North Pacific: Part 1. *Oceanography*, **24**, 24–31. [published, refereed]
- Mrvaljevic, R. K., P. G. Black, L. R. Centurioni, Y.-T. Chang, E. A. D'Asaro, S. R. Jayne, C. M. Lee, R.-C. Lien, I. I. Lin, J. Morzel, P. P. Niiler, L. Rainville, and T. B. Sanford, 2013: Observations of the cold wake of Typhoon Fanapi (2010). *Geophysical Research Letters*, **40**, 316–321. [published, refereed]