Autonomous Measurements of Ocean Response to Typhoons and Lagrangian Floats for Typhoon and Mixing Studies (DURIP)

Eric A. D'Asaro
APL/UW 1013 NE 40th St.
Seattle, WA 98105
phone: (206) 685-2982 fax: (206) 543-6785 email: dasaro@apl.washington.edu

Grant Numbers: N00014-08-1-0577, N00014-09-1-0816
http://opd.apl.washington.edu/~dasaro/HOME/

LONG-TERM GOALS

I seek to understand the interactions between the ocean and tropical cyclones, including typhoons and hurricanes.

OBJECTIVES

These grants support efforts in the TC10/ITOP (Tropical Cyclone 2010 / Impacts of Typhoons on the Ocean in the Pacific) program. This program, joint between ONR and Taiwanese investigators, aims to study the ocean response to typhoons in the western Pacific Ocean. Experimental planning has focused the experiment on the following scientific questions:

What are the air-sea fluxes for winds greater than 30 m/s?

Tropical cyclones draw their energy from the underlying warm ocean. Their intensity depends on the exchanges with the ocean with a greater flux of heat and moisture to the storm leading to a stronger storm, but a larger drag on the ocean leading to a weaker storm. These exchanges are poorly parameterized in existing typhoon forecast models leading to errors in the ability of these models to predict typhoon intensity. The first reliable estimates of the exchange coefficients at these high wind speeds, made during the last decade, have shown a dramatic decrease in drag coefficient relative to previous parameterizations. ITOP seeks to make more such measurements, at higher wind speeds and under a larger variety of conditions.

What is the surface wave field under typhoons?

The air-sea exchange depends critically on the state of the ocean surface, most importantly characterized by the surface waves. The wave fields beneath typhoons are complex, with multiple dominant wave directions varying and interacting across the different storm quadrants. Modern coupled air-sea models of tropical cyclones include explicit models of the wave fields from which the air-sea exchange rates are computed. More practically, the enormous surface waves produced by

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE **Autonomous Measurements of Ocean Response to Typhoons and Lagrangian Floats for Typhoon and Mixing Studies (DURIP)**	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) **University of Washington,Applied Physics Laboratory,Seattle,WA,98105**	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
Approved for public release; distribution unlimited

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 **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

typhoons are of great interest in themselves. ITOP seeks to measure the surface wave field underneath typhoons, compare these measurements with models and assess their impact on air-sea exchange.

What is the three-dimensional response of the ocean to typhoons?

Typhoons produce a complex three-dimensional response of the underlying ocean including strong surface currents, upwelling of the thermocline and intense mixing across the thermocline. This results in the radiation of internal waves and the formation of a cold wake. ITOP seeks to measure this response in detail and compare these measurements with the results with models.

How do ocean eddies affect this response?

The ocean response is expected to be strongly affected by the mesoscale eddy field, both through its modulation of the thermocline depth and through advection by currents. ITOP seeks to make the first comprehensive measurements of these effects.

How does the ocean response affect typhoon intensity?

Cooling of the ocean by a typhoon reduces the typhoon intensity by reducing the amount of moisture and heat exchange from the ocean. This process is modulated by the mesoscale eddy field so that ocean eddies affect typhoon intensity. ITOP seeks to study these interactions in detail.

How does the cold wake of a typhoon disappear?

The intense upper ocean mixing caused by typhoons creates a wake of cold, deep mixed layers. Although the surface signature of this wake usually disappears within days to a week, a deep signature may persist much longer. A competition between the vertically stratifying effects of solar radiation, the mixing effects of wind and waves, the lateral effects of baroclinic instability and stirring by mesoscale eddies will likely control the evolution of the wake. ITOP seeks to make the first measurements of these processes and balances.

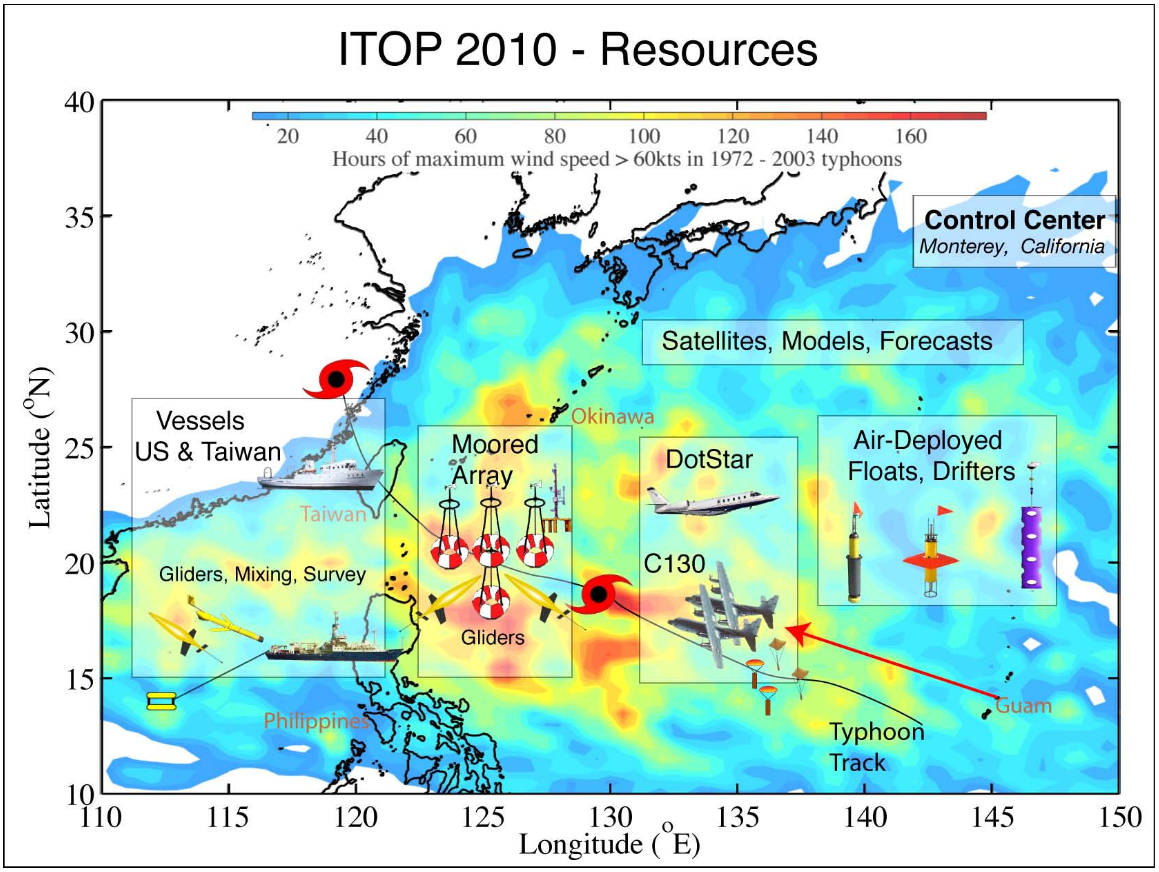
What is the biological response to typhoons?

Mixing may also bring nutrients into the euphotic zone of the ocean with a resulting increase in productivity in the typhoon wake. The magnitude of this effect will depend on the pre-storm distribution of nutrients with depth, on the mixing and on the conditions in the wake. ITOP seeks to understand these relationships.

APPROACH

ITOP will focus on typhoons in the Western Pacific Ocean. The experimental domain is approximately the region shown in Figure 1 below, but east of the Philippines, Taiwan and the Ryukyu (Okinawa) island chain and the Kuroshio current, west of Guam and between 10N and 32N. This is climatologically the region of highest tropical cyclone occurrence in the world. The ITOP will use a variety of experimental approaches to measure typhoons and the ocean’s response to them. The experimental measurements began in 2008, with enhanced measurements through the Spring, Summer and Fall of 2010 and an intensive operations period in September – October of 2010.

As shown in Fig. 1, a **moored array**, located in the region of maximum typhoon frequency near 20N 125E was deployed starting in 2008. During ITOP, it will be enhanced to include 4 moorings and perhaps a glider array, deployed and recovered by US and Taiwanese **research vessels**. During the intensive measurement period, two **C130**s of the 53rd Air Force Reserve Hurricane Hunter Squadron will be based in Guam. These aircraft will measure the properties of typhoons using onboard sensors and will deploy dropsondes. These efforts will complement those of the existing **DotStar** typhoon



surveillance program based in Taiwan. The C130s will also deploy arrays of **floats** and **drifters** in front of typhoons to measure the ocean response. After the passage of the typhoon, additional floats and drifters will be deployed into the wake. A **US research vessel** will be rapidly deployed into the typhoon's wake, **survey** the wake using a **towed vehicle**, deploy additional **gliders** and drifters and recover the air-deployed floats and drifters. The measurements will be guided by **satellite measurements**, of the storm location, evolution and structure and the ocean surface properties and numerical **models** of the atmosphere and of the coupled atmosphere-ocean evolution of the typhoons. During the intensive operations period, operations will be directed and coordinated from a **control center** located at the Naval Postgraduate School in Monterey, California.

My role within ITOP, and the part supported by these grants, is to act as Chief Scientist working with a small executive committee, to work at the control center coordinating the ship and aircraft operations during the intensive operations period, and to prepare and deploy 10 Lagrangian floats from the C130 aircraft to measure ocean waves and boundary layer turbulence.

WORK COMPLETED

During the last year, I have played a major role in five ITOP planning meetings, worked with the executive committee to produce a draft experiment plan and coordinated a joint purchase of 500 airdropsondes for use with the C130 aircraft. As I write, I am participating in a 'Dry Run' exercise at the Monterey control center. So far, we have planned aircraft and ship operations in real time in Typhoon Melor and learned many lessons how to do such deployments successfully next year.

The DURIP funding will pay for the construction of 5 additional Lagrangian floats for ITOP. Four of these are currently under construction. One float, upgraded to include ocean shear and dissipation measurements, was completed in July 2008 and was configured to be deployed during the 2009 Hurricane season in the Atlantic. Unfortunately, there were no deployments (so far) due to the very small number of storms, and this float will likely be returned and retrofitted for deployment in ITOP.

RESULTS

No scientific results yet. However, our dry run exercises in Typhoon Melor confirmed that with some luck and our newly honed skills it should be possible to make excellent combined aircraft and ship based measurements addressing the ITOP experiment goals.

IMPACT/APPLICATIONS

The execution of ITOP will promote a close cooperation between ocean experimentalists and operational Navy typhoon and ocean prediction products including those related to the NLOM and COAMPS models. This is likely to result in improvements in our understanding of the model accuracy and limitations.

RELATED PROJECTS

The Lagrangian floats used in this project and constructed using DURIP funds will be used in N0014-09-1-0172 as part of the Lateral Mixing DRI. Our understanding of these instruments and their measurement capabilities continue to grow with each usage.