ITOP Cold Wake Cruise Report

October 18, 2010

1 Overview

The Cold Wake cruise took place from 17 September to 11 October 2010 on the R/V Roger Revelle. The cruise was one component of the large ITOP (Impact of Typhoons on the Ocean in the Pacific) project. The general objective of the cruise was to understand how the ocean responds and recovers after the passage of a strong typhoon, focusing in particular on the cold wake formed along the typhoon track.

During the cruise, we studied the cold wake formed by Typhoon Fanapi, a category 3 typhoon that formed on 14 September, made landfall in Taiwan on 19 Sept., and dissipated on 22 Sept. over mainland China.

We primarily studied two sites during the cruise (Figure 1). The cold wake at Site A was formed on 9/18 was storm was intense (>50 m/s winds) but moving fairly fast. The cold wake (> 2°C) was narrow and well-defined, and quickly got capped by strong surface heat fluxes associated with solar radiation. We arrived at the wake less than 4 days after the storm. The wake was also highly strained, presumably by the mesoscale circulation. After sampling for Site A for about one week, we moved to studying the south-west edge of the large cold pool formed when the storm was intensifying and moving slowly (Site B).

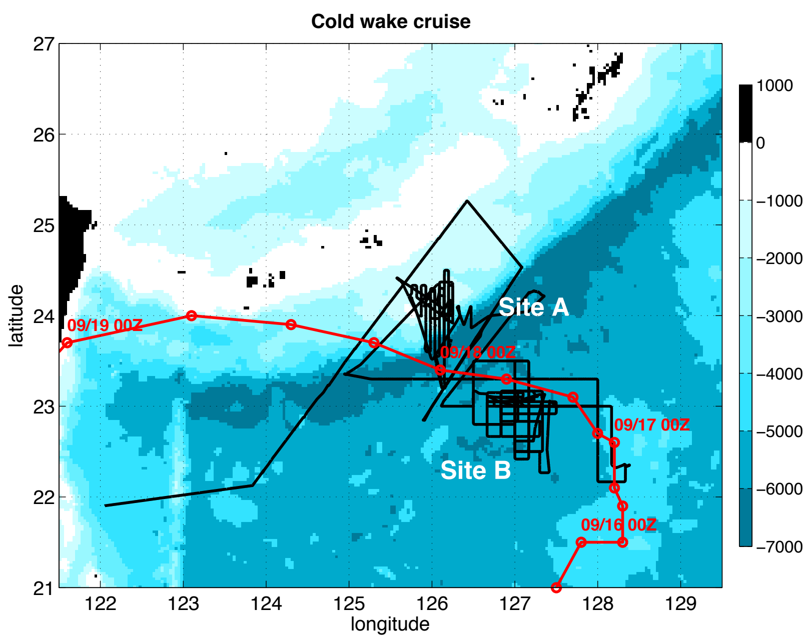

Figure 1: Cruise track of the Revelle (black) during the Cold Wake cruise. Typhoon track is indicated in red. We concentrated on 2 distinct sites: Site A near 24°N 126°E, and Site B near 23°N 127°E.

At both sites, we initially deployed gliders in key sites (in and outside the wake, and in the walls), and the sampling strategy for the ship was to conduct surveys on scales of 1 day and 50-75 km (to follow the mesoscale evolution of the wake), and revisit a particular site for several hours every day to capture small temporal and spatial scale, in particular the inertial variation of shear and strain in the 'walls' and at the bottom of the wake. Underway-CTD surveys, glider measurements, CTD and water sampling, and VMP profiles (both single casts and yo-yo surveys) were done to resolve all these scales as well as possible.

Summary of cruise accomplishments:

- 2917 underway-CTD profiles recorded.
- 10 gliders deployed, 4 glider recovered. 6 gliders are still operating.
- 172 VMP profiles.
- 21 CTD profiles with water samples (12 bottles per cast).
- 3 sediment trap deployed, 2 recovered (1 lost).
- 3 superdrifters recovered, 1 ADOS drifter recovered.
- Coordinated operations with the C-130 (AXBT calibration and observation of a float deployment)

2 Underway CTD

The main instrument used during the cruise was OceanScience's underway-CTD. This instrument was used to do 3162 casts: 82 casts to 400-m (18 min cycles at 10 kts), 8 casts to 850 m (20 min cycles, holding station during the AXBT calibration C-130 flight), with the balance being mostly profiles to 160 m at 10 kts (every 6 min). Because of instrument failures or operator errors, the data for a few profiles is missing: 2917 uwCTD profiles were recorded (92% success rate). We used 4 probes, lost 2. We operated the uwCTD almost continuously for 3 weeks – the winch seemed to be on its last leg in the last few days, but it lasted through the whole cruise. In general we are quite satisfied with the uwCTD system.

We started sampling at the A4 mooring, going towards the wake along a line parallel to the float deployment line. This section might help link the mooring time series with the signals propagating from the wake. We then came down along the float deployment line, deployed the sediment trap and gliders, and started the intense surveys.

3 VMP casts

Nearly 200 profiles were recorded using a Rockland Scientifics VMP-500 microstructure profiler. Most of these were done in long (5-6 hours) yo-yo station, going slowly forward at 2 kts. These sections were typically done in the cold wake and crossing its edge.

A least one VMP profile was done every time a glider was deployed. Profiles were also obtained during mesoscale surveys around the wake, and intense VMP surveys of the walls were conducted. The system worked quite well.

4 Seagliders

11 Seagliders were shipped and prepared for the ITOP cruise. In total, we did 10 glider deployments and 4 recoveries. 6 gliders remain on site and will still be sampling for the next several weeks. They will be recovered at a later time.

8 gliders were deployed at Site A, in and outside the wake. Two of these were recovered before we moved to Site B. 2 gliders (including one of the recovered ones from Site A) were deployed at Site B. At the end of the cruise, 2 gliders (with Tmicro) were recovered.

Three of the Seagliders deployed during ITOP are equipped with turbulence microstructure sensors (developed as part of the ITOP program). The Tmicro Seagliders are sending real-time (processed) microstructure profiles, as well as recording all the raw data on board. The preliminary results are very exciting.

All gliders sampled faster than in regular (long-lasting) mission. The Seagliders did 500-m dives every 2 hours or so. At the end of the Revelle cold wake cruise (Oct. 11), the ITOP gliders had collected 1521 profiles to 500 m, including 501 profiles with temperature microstructure. Nearly 70 profiles per day at key sites (doing sections across the remnant of the wake) are still being collected.

5 Biogeochemistry program

Three NTOU graduate students from Dr. Chin-Chang Hung (National Taiwan Ocean University) joined the cruise and collected water and made in-situ observations of various parameters, nutrients, oxygen, chlorophyl-a, pCO2, POC, etc.

Two sediment traps were deployed on the first days of the cruise: one in the middle of the cold wake at Site A (22 Sept.), and one outside the wake (23 Sept). We visited the cold wake trap on a daily basis, doing a CTD cast and collecting water. Both traps drifted quickly to the east. The cold wake trap was recovered on 27 September. The trap deployed south of the wake was recovered a day later (28 September).

The cold wake trap was redeployed at site B on 29 Sept. and again visited daily to collect a CTD profile and water samples. However, upon recovery (06 Oct.), it was found that the line broke and the trap was lost.

6 Coordinated operations with the C-130

On 07 October, we conducted joint operation with the C-130. Several different types of AXBT were dropped near the Revelle, while we were continuously doing CTD profiles. The comparison will allow to determine if there is any offset or delay in recording the AXBT data from the plane.

In addition, the C-130 launched one Lagrangian float from near the Revelle. We observed and recorded the float deployment - it was quite nice to witness! The float was recovered after being in the water for 2 hours.

7 Aerosol measurements

Jeff Reid at NRL in Monterey provided a hand-held Microtops II to collect some insolation measurements for studying atmospheric aerosols. Measurements were collected a couple of times a day when the atmospheric conditions allowed.

These measurements will be included in the AERONET dataset, a global network coordinating observations and archival of atmospheric aerosol measurements (http://aeronet.gsfc.nasa.gov/)

8 Cold wake cruise science party

Science party (16, including STS personnel):

Steven Jayne	WHOI	chief scientist
Luc Rainville	APL/UW	co-chief scientist
Elizabeth Douglass	WHOI	postdoctoral investigator
Adam Huxtable	APL/UW	technician – Seagliders
Stephanie Downey	APL/UW	technician
Pedro De La Torre	KAUST/WHOI	graduate student
Steve Lambert	FSU	technician – VMP
Jay Hopper	FSU	graduate student
Samantha Stevenson	UC Boulder	graduate student
Ke Hsien Fu	NSYSU	graduate student
Bo Feng Wu	NSYSU	graduate student
Jiun Wei Hsu	NSYSU	graduate student
I Hsiang Chen	NTOU	graduate student
Hsin-Lun Chiang	NTOU	graduate student
Szu Ying Chen	NTOU	graduate student
Drew Cole	SIO	Restech

9 Preliminary results

In the section, we present some example of the data we collected. This is by no means an exhaustive list. Maybe more than usual, the data from this cruise are both very exciting and somewhat puzzling. A full interpretation will require an integrated approach with all the remote sensing data, float and drifters measurements, gliders, ship, mooring, etc. Through a great collaboration between several groups, ITOP did provide all these measurements. Some of the important first results are:

- Fanapi created a intense ($< 2°$C) cold wake.
- Solar radiation quickly capped the cold wake, making it difficult to detect in satellite SST image, but in-situ observation revealed that the cold wake persisted for several weeks, and is still present in some form now – a month after the storm.
- Phenomena on several time and spatial scales are playing a role in the evolution of the cold wake - inertial, mesosale, propagating waves, ... We will need to synthesize the ship observations, glider measurements, float and drifter measurements and remote sensing to adequately describe the evolution of the wake.

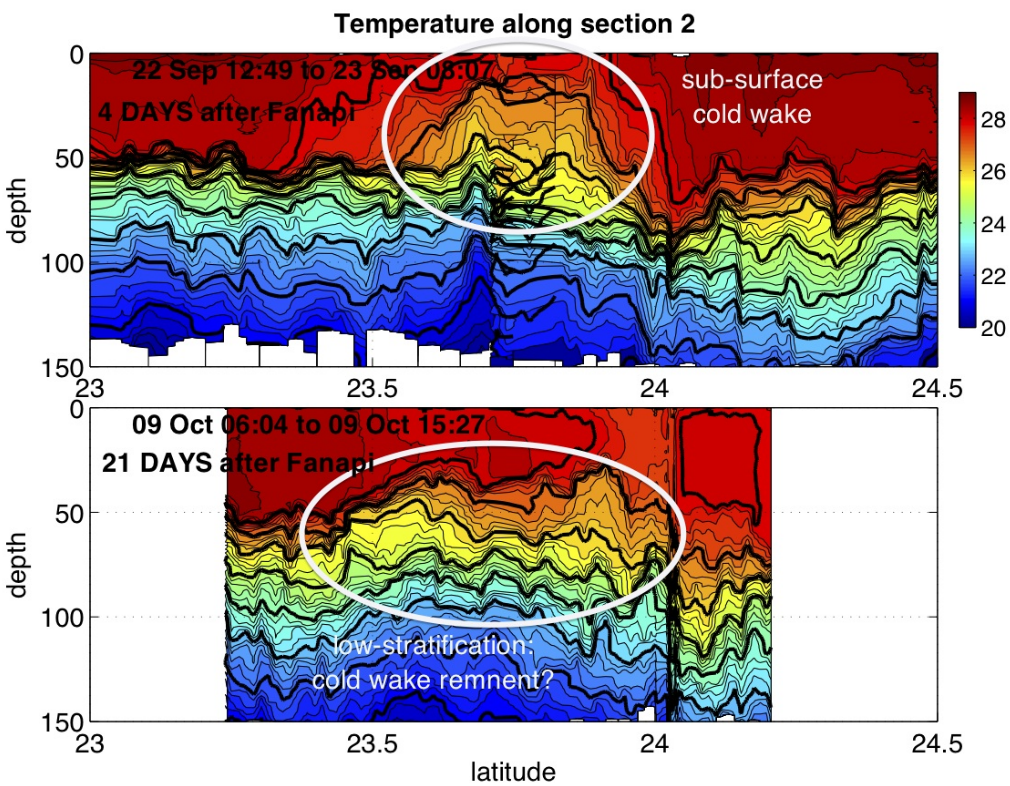

Figure 2: Temperature along the long diagonal section across the cold wake at Site A. Top panel: one of the first section we obtained of Fanapi's cold wake, 4 days after the storm. The cold wake is most obvious between 20 and 60 m near 23.75°N,, where the water is over 2°C colder than outside the wake. There is a small SST signature, but the cold wake is mostly capped by a layer of warm water near the surface, most likely due to the strong solar heat fluxes prevalent in the first week after the storm. Bottom panel: we repeated this section shortly before the end of the cruise. There is hardly a SST signal, but a layer of weak stratification between 50 and 100 m is still observed. From the glider time series, this weak stratification can be linked to the cold wake.

- The weather was fairly calm for the first 2 weeks of the cruise. Winds started to increase during the last week and we observed a deepening if the surface mixed layer.
- Particularly at Site B, it seems that we observed large propagating waves (coming from Luzon Strait?). We will need to carefully look at ship and glider data to sort this out.

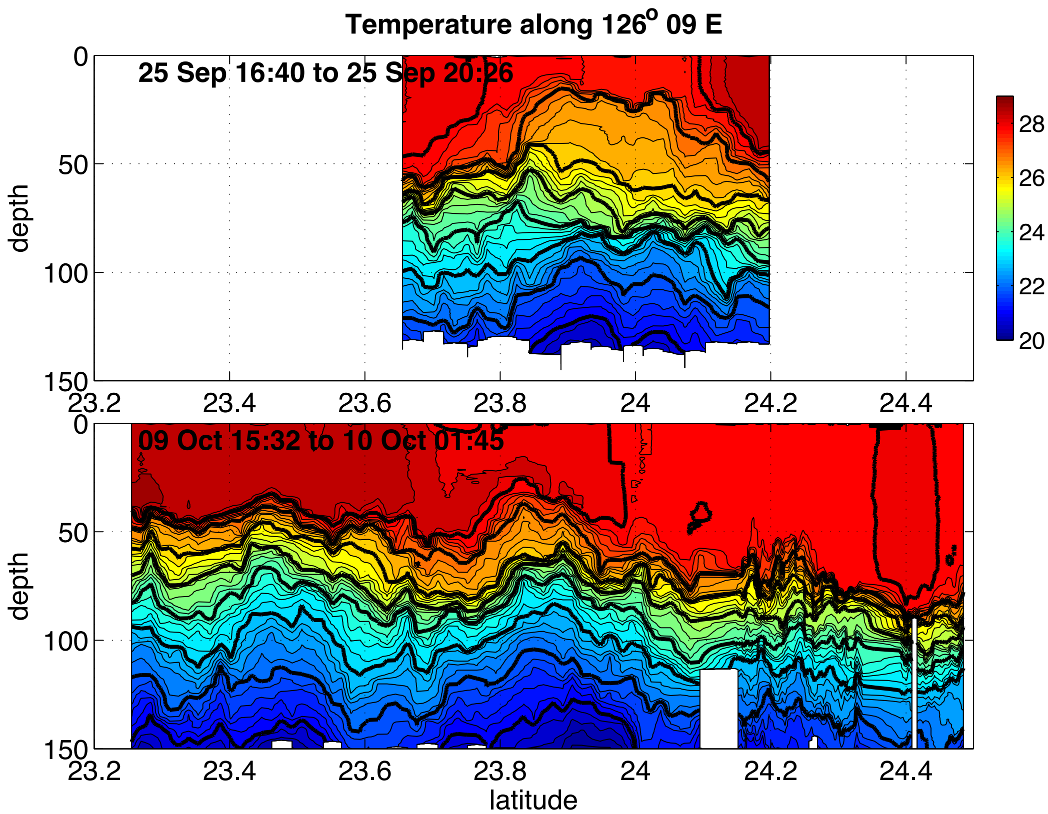

Figure 3: Same as Fig. 2, but for a section along 126°09'E at Site A. The cold wake in the Oct. 09 section is not clearly apparent - maybe due to internal wave activity (straining of the upper thermocline?). The deep mixed layers in the north end of the section ($> 24°$N) are probably due to the winds ramping up.

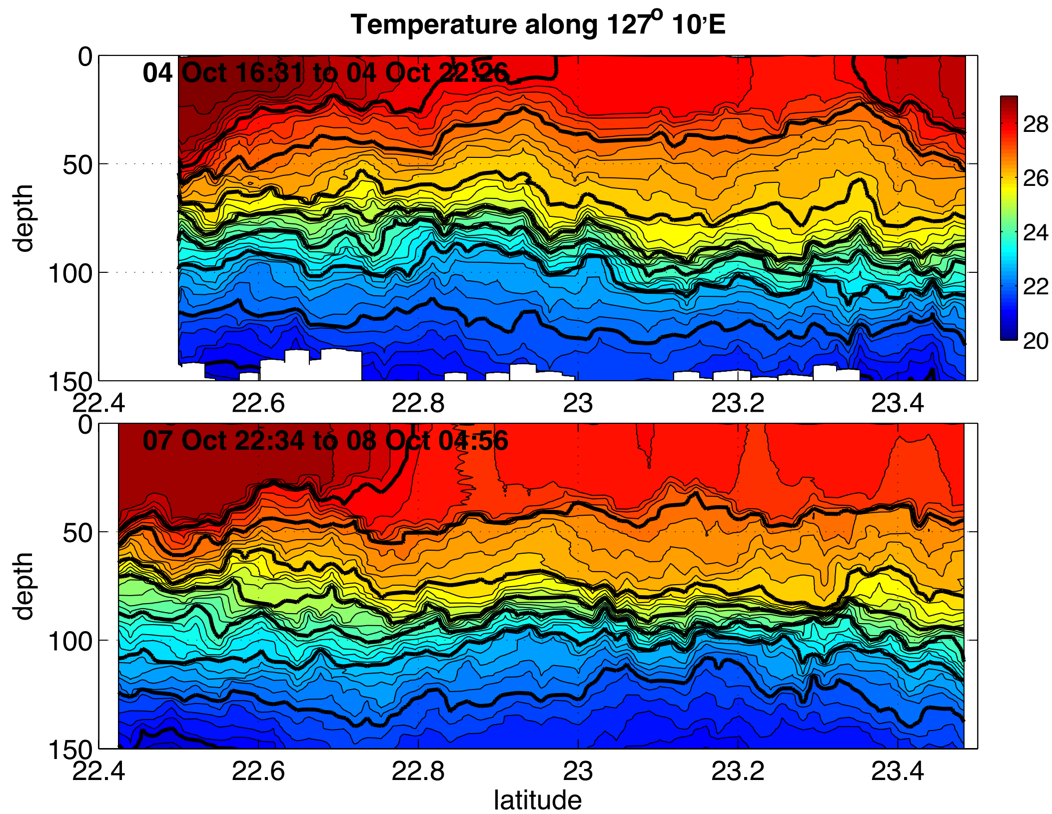

Figure 4: Temperature sections along 127°10'E at Site B. We completely crossed the cold patch during the Oct. 04 section (top). The northern edge seemed to have moved away 3 days later. At Site B, we concentrated on the south-west corner of the cold patch.

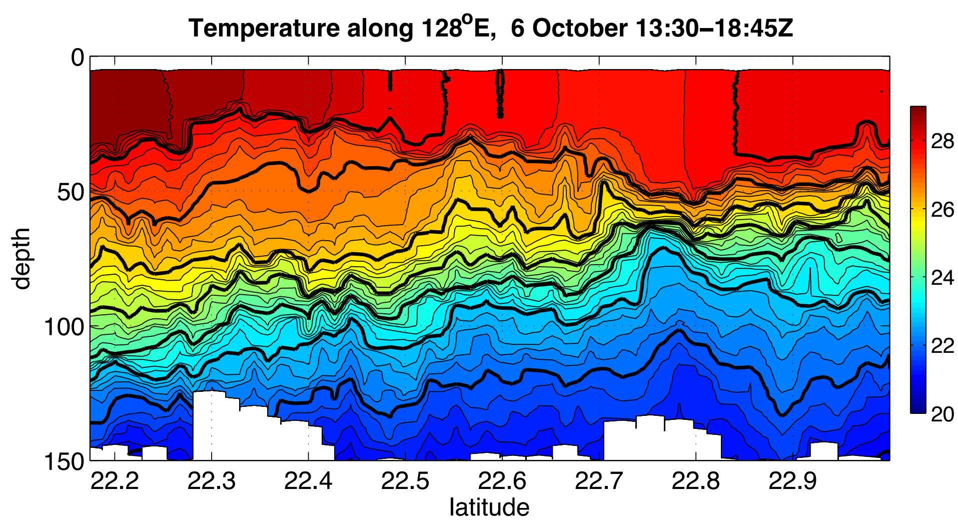

Figure 5: Temperature section along 128°E at Site B. Note that the sub-surface low-stratification between 50 and 100 m (centered near 22.4°N) is not aligned with the slightly cooler SST near 22.7°N.

- It might be useful to think of the cold wake as a 'mode water', although associated with faster time scales that these traditional water masses - water with homogeneous properties formed by strong mixing event associated with deep mixed layers, but rapidly capped by solar radiation. In this spirit, the thickness of the 26-27°C layer (located between 50 and 100 m) - as a marker for the cold wake location - is shown in the next figure. A narrow cold wake is observed at Site A, and the large pool of thick (and cold) water is observed at Site B.

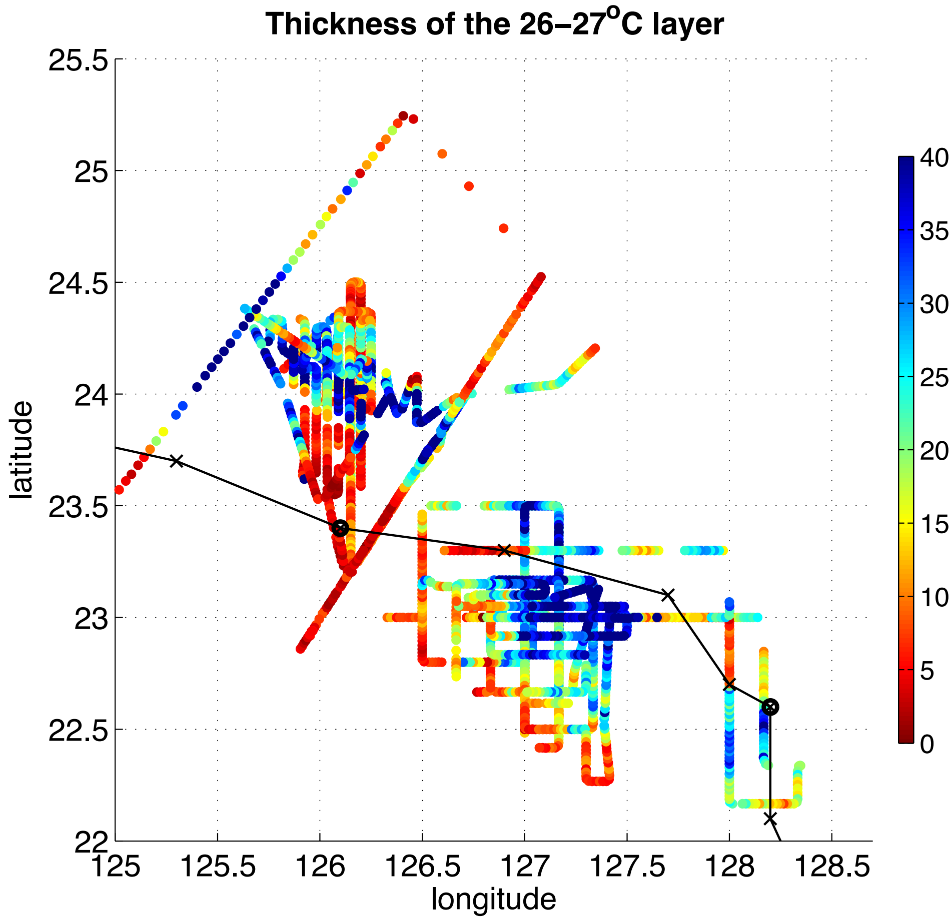

Figure 6: Thickness of the 26-27°C layer. The cold wake, with weak stratification in the upper 100 m, is associated with thicker 26-27°C layer. Note that the color scale is inverted from the typical matlab convention, to show the thick layer as blue (cold). Estimates from all 2917 uwCTD profiles are plotted (including many overlapping sections). Black line indicates the track of typhoon Fanapi (as in Fig. 1), with marks every 6 hours (circles at 00Z).