ITOP Cold Wake Cruise Plan.

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1 Overview

This document describes the operations that will take place during the ITOP (Impact of Typhoons on the Ocean in the Pacific) Cold wake cruise. The general objective of the cruise is to understand how the ocean evolves and recovers after the passage of a strong typhoon, in particular the cold wake that is formed along the typhoon track. This cruise is part of a large field program that involves aircrafts, floats and drifters, and other research vessels from Taiwan. By nature, we can not predict when a strong storm will happen, therefore the exact dates of this cruise are yet unkown.

The current ship schedule includes a 92-day block for ITOP running from July, 24 2010 through October 23, 2010. During this time period, a two-leg expedition spanning approximately 6 weeks will be undertaken

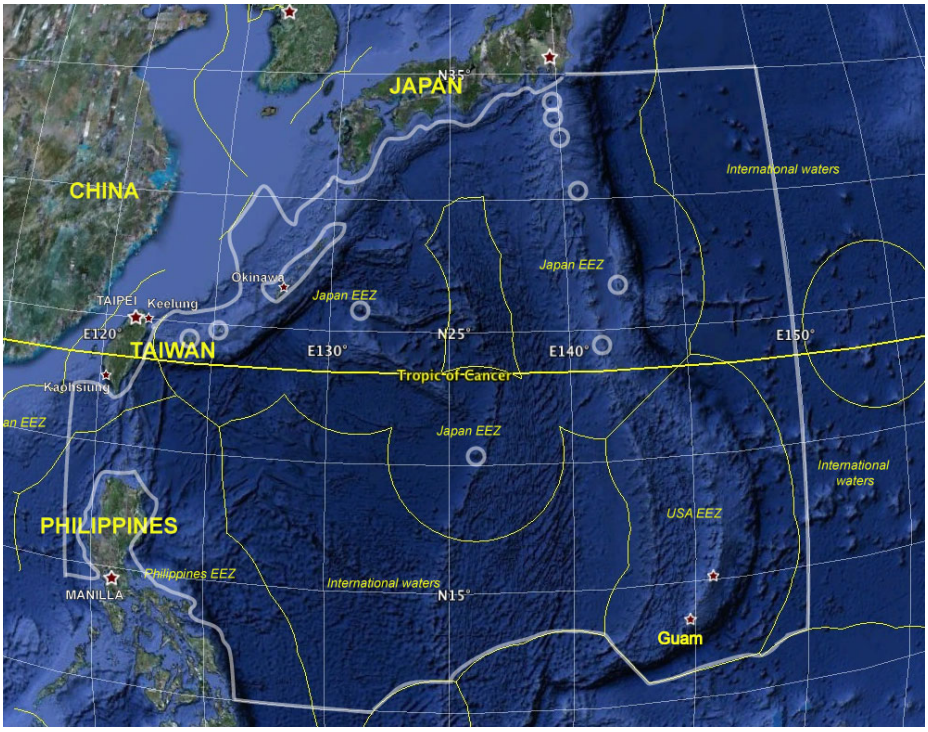

Figure 1: Map of the Western Pacific, showing the area in which ITOP operations will take place. Because we cannot predict where and when typhoons will occur, ITOP float deployments and cold-wake surveys might take place in the region between 10°–35°N and 120°–150°E (excluding contested EEZs and territorial waters), indicated by the white box.

to deploy assets into, survey, and recover assets from a cold-wake following the passage of a typhoon. The first leg will be an approximately 3-week cruise to survey the recovery of the cold wake in the initial two-weeks after the passage of the typhoon. Steven Jayne (WHOI) will serve as chief scientist for this survey, with Luc Rainville as co-chief scientist, with a science team consisting of personnel from WHOI, UW/APL, National Taiwan Ocean University (NTOU), National Sun Yet-sen University (NSYSU), and other partner institutions. The approximate dates of this cruise would be from August 20, 2010 through October 23, 2010. However, the exact dates of this cruise will be dependent on typhoon activity and decision of the science team to intensively study a particular storm, but the period from September 12 – October 23 is regarded as the most likely for the survey leg.

Starting mid-August, ITOP will have a **control center in Monterey, CA**, constantly monitoring satellite images, products from various meteorological agencies, and running prediction models. Once a typhoon has formed in the study region, and the decision has been made that a particular typhoon is to be targeted, the ship will be recalled to nearest safe harbor, and the science party will meet the ship and immediately get underway. Kaohsiung, Taiwan, will be planned as the default staging area.

Operations can take place over a very large region in the Western North Pacific in the Philippine Sea in the region of 120°E – 145°E and 12°N – 27°N (Fig. 1), but most likely it will be within a 2–3 day transit from Taiwan (west of 135°E). This region encompasses the territorial waters of Taiwan, Japan, the Philippines, and the United States, as well as international waters.

Before and during the cruise, we will have a daily web/phone meeting at 2300 UTC (0700 local time) with the control center in Monterey to discuss current weather, synoptic situations and outlook, coordination with planes and other resources, and science objective status.

Airplanes

The C-130 airplanes will be deployed in Guam from **August 20, 2010 through October 20, 2010**. The planes will survey typhoons as they form and intensify. They will also drop floats and drifters in front of and immediately after the storm to monitor the oceanic response. The ship will steam to that same patch of ocean a few days after the passage of the typhoon to conduct an intense survey of the storm's cold wake.

Many of the floats and drifters deployed by the aircraft will need to be recovered. Some of these recoveries may take place during the cold-wake survey cruise if they are in the immediate vicinity of the survey area. However, a float-recovery cruise will immediately follow the cold wake cruise to recover the majority of the assets.

IWISE

The IWISE cruise (chief scientist: Matthew Alford) is planning on leaving Kaohsiung at 1600 on August 14, 2010 (local time). If a good storm occurs before the end of their 29-day cruise, they will return to Taiwan and the cold wake cruise will start. If they are not interrupted, they will return at 0800 on September 11, 2010.

The IWISE operations are in Luzon strait. Given the advance notice that we anticipate to be able to give them (2–3 days while we watch the storm develop), it will not be a problem for them to return to Kaohsiung in time for the Cold wake cruise to depart as soon as possible after the passage of the storm (or after it veered away from Taiwan).

If we do interrupt IWISE, ITOP would take over R/V Revelle for 6 consecutive weeks. The IWISE PIs might want to return after the two ITOP cruises and use the remaining ship time (and recover moorings left behind, for example).

ITOP Schedule

We hope to reach the cold wake of the typhoon as soon as possible (probably $\sim$ 3 days after the storm). Ideally, we would sample the wake for **3 weeks**, and the Cold wake cruise would be followed by a **3-week float recovery cruise**.

The schedule is flexible, within the few important dates listed here:

- 20 AUG: First possible date we would sail on.
- 12 SEP: 6 weeks left of ship time. IWISE over.
- 26 SEP: 4 weeks left of ship time.
- 23 OCT: end of ITOP/IWISE ship time. R/V Revelle has to be back in Taiwan.

We can think of 3 basic scenarios:

1. Typhoon between 20 AUG and 11 SEP: We interrupt IWISE. Cold wake science party gets to Taiwan as soon as possible. 3-week cold wake cruise followed by a 3-week recovery cruise.
2. Typhoon between 12 SEP and 26 SEP: Cold wake science party gets to Taiwan as soon as possible. Hopefully we can keep the science cruise to 3 weeks, followed by a float recovery cruise. However, after a while we would have to evaluate how to maximize the science we can do and balance it how much time we need for the recovery of floats (less than 3 weeks, but no shorter than 1 week).
3. If we haven't picked a storm before on 26 SEP (4 weeks left), we sail and do science of opportunity. In this scenario, there is no separate float recovery cruise. Whenever a typhoon comes, we will be already there and can probably get to the wake much faster. We can then do science in the cold wake for as long as we deem possible, again weighing the recovery of floats... We would stay out for 4 weeks if needed.

General Cold wake cruise timeline

Days -7 – -5	A typhoon is targeted for intensive study, PIs for the wake survey are notified to make travel arrangements. A port of call for the vessel is identified, and the ship is notified to transit to the dock.
Days -1 – -4	PIs for the wake survey travel to Kaohsiung, Taiwan, or other identified port of call. The ship transits to this location.
Day 0	PIs for the cold wake survey arrive at the dock, ready to board. PIs from the previous leg with disembark from the ship.
Days 1 – 3	The vessel gets underway and steams to north or south of the wake.
Days 4 – 18	Arrive at cold wake, deploy gliders, and conduct survey using ship-deployed underway CTD and microstructure profiling. Recovery of air-deployed instruments is done on an opportunistic basis. The Slocum glider will be recovered at the end of this period. Recovery of some or all Seagliders will be done according to guidance from APL/UW.
Days 19 – 21	Return to port.
Day 22	Offload personnel and some equipment. Personnel for the Float recovery cruise will board the ship and depart soon after.

The timeline proposed here is tentative. Steaming time to and from the cold wake is dependent on the actual distance from the originating port, and on weather and sea-state conditions during the transit. There will likely be a need to stop survey activities to avoid other typhoons influencing the survey area subsequent to targeted typhoon of interest. These conditions may both subtract from the survey time, and delay the return of the ship to port.

2 Cold wake cruise operations

2.1 Loadout

All the equipment needed for the cruise should be already loaded on the ship before IWISE leaves. Craig Lee and Luc Rainville will be in Taiwan on 13-14 August for loadout and discuss ship operations with the Master and crew.

Very little gear will be will need to be transferred during the port stops between the IWISE and the Cold wake cruises. Only personnel will be transferred between the Cold wake and Float recovery cruises.

2.2 Sampling plan

A schematic of possible ship operations during the cold wake cruise is shown in Fig. 2, based on a typhoon that occurred last year. The transit from Taiwan would take about 3 days. Once we are on site, we would establish the 3-D structure of the wake (guided by float and drifter observations, satellite products, and models). The scale of such survey is about 200 km (11 hour at 10 kts). Gliders would be deployed in and just outside the wake as early as possible. Sediment trap would be deployed in the wake. CTD profiles (with water samples) and turbulence profiles would be collected in the wake.

Another type of survey is a 'submesoscale' survey, where small patch of ocean, probably one of the edges of the wake, is sampled intensely for a couple of days. This is shown here as the surveys for days 3-4.

Following such a survey, we would monitor the 'mesoscale' evolution of the wake with another larger scale survey. Microstructure profiles and CTD / water sample profiles would be taken periodically.

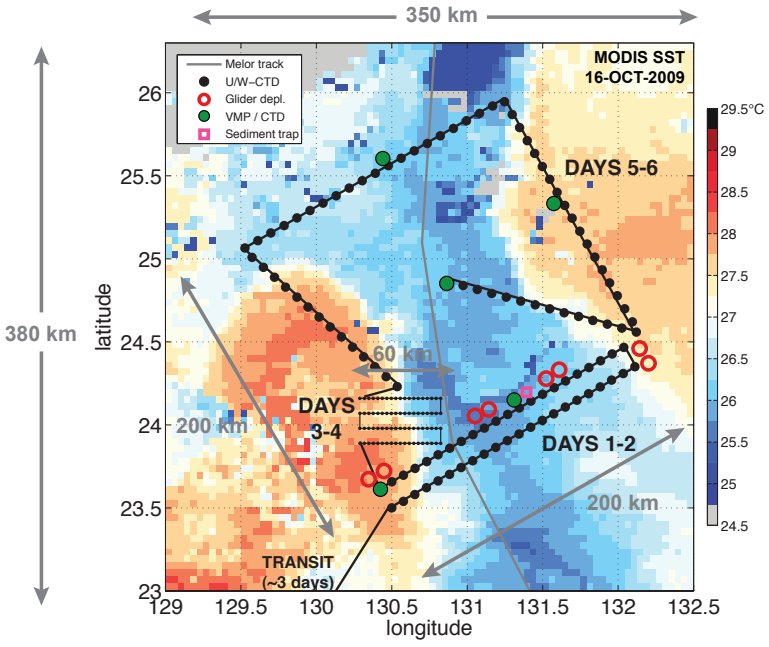

Figure 2: Example of the sequence of operations to be conducted during the cold wake cruise. Colors show the sea-surface temperature measured by satellite, showing the cold wake along the track of the typhoon Melor (October 2009). **Note:** Because there are too many aspects we cannot predict (location, transit time, etc.), this is only a schematic of ship operations. We will have to constantly adapt to changing conditions.

2.3 Underway-CTD

The OceanScience Underway CTD system is designed to be deployed behind the ship while steaming at up to 20 knots (Fig. 3). It consists of a very small winch and a self-recording tethered probe. It is the primary instrument to be used during the Cold wake cruise, operated around the clock from the starboard aft quarter.

Figure 3: Winch of the underway CTD.

2–3 people will be on watch during operations.

We will use the instrument primarily in one of the following 3 modes:

- Ship at 10kts, profiles to 500 m: ∼30 min per profile (∼10-km spacing). Recover probe and rewind the tail between deployments.
- Ship at 10 kts, profiles to 150 m: ∼4.5 min per profile (∼1.5-km spacing). Recover probe periodically for checking line and download data.
- Ship at 6 kts, profiles to 150 m: ∼3 min per profile (∼0.5-km spacing). Recover probe periodically for checking line and download data.

2.4 Turbulence profiling (VMP-500)

A VMP-500 microstructure profiler will be operated from the back deck. The instrument is small and deployable by hand (Fig. 4). It is tethered to the ship by a custom line, which and puller system (Fig. 5) requiring a setup on the aft workdeck. Operation of the VMP require 3 personnel from the science party, a winch operator, a computer operation, and a person tending the line-puller and block arrangement who monitors the tether payout into the sea. Ken Decoteau (WHOI) will be the primary technician for the VMP system.

The VMP weighs about 70 pounds in air, and can be hand deployed and recovered. However, it is preferable to have the tether in the block for recoveries back to the deck, as the winch is the best way to lift the profiler out of the water. VMP profiling will be done continuously for runs ranging from 1 to 12 hour periods (as other cruise operations permit). Each cast will be done to depths ranging from 200 to 500 m. Successive casts will be done by reeling the profiler back to the surface without recovering, and then spooling again to depth. Deck recoveries are done only when a profiling session is complete or the instrument requires servicing.

Figure 4: The 500-m rated Rockland Scientific Vertical Microstructure Profiler (VMP-500). The sensors are located at the nose, protected by a guard ring. Drag whiskers are deployed at the tail. The tether terminates through a strain relieve component.

Figure 5: VMP winch system setup, with the spool unit (left) about 20 ft forward of the line-puller unit (right), which is directly on the stern under the A-frame. A Sherman-Riley block is suspended just fore of the line puller (this arrangement can be done by tilting the A-frame forward).

2.5 Seagliders

We will deploy 8 Seagliders early in the cruise – during first couple of days. Two of the Seagliders are equipped with temperature microstructure sensors (Fig. 7a) and will be deployed near the edge of the wake (in the area chosen for a submesoscale ship survey). Seagliders will be piloted remotely from APL in Seattle.

We anticipate that 2–3 gliders will be deployed simultaneously. For each group, the pre-deployment procedure will take ∼2 hours. The ship then will need to hold station for about 2 hours while the gliders are deployed and do their first dive. Realistically, we would need about 6 hours between the deployment of groups.

CTD and or microstructure operation would not interfere glider operations during while the ship hold station. In fact, CTD rosette, water samples (oxygen) would be beneficial for calibration of the glider sensors. Getting turbulence profiles when deploying the T-micro gliders would be ideal.

Seagliders will stay in water after the cruise. They will be recovered later (October or November) on separate cruises. Note that gliders might need to be repositioned during or at the end of the cruise. The T-micro gliders might also be recovered at the end of the cruise. Since downloading microstructure data would take a long time, we may choose not redeploy them (and possibly will want to deploy the spare T-micro Seaglider we're bringing).

Example of surveys that can be conducted by the gliders are shown in Fig. 7. Gliders can travel about 20 km/day and make 3–4 1000-m dives per day. During the cold wake cruise, we might reduce the maximum depth of the dives to 500 m, therefore increasing the sampling frequency (∼7 per day). A combination of all these survey patterns will likely be used during ITOP.

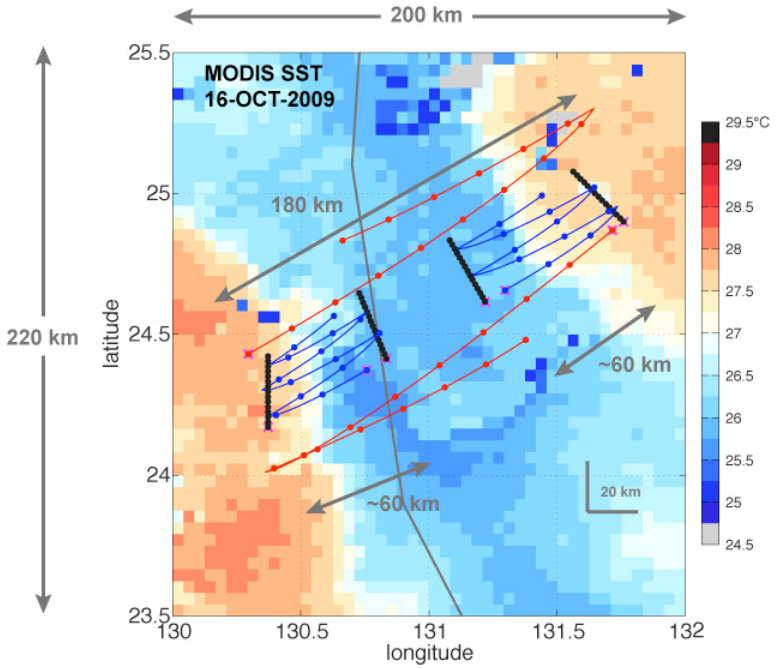

Figure 6: Example of surveys that can be conducted by the gliders (overlaid on the typhoon Melor SST). Tracks for 14 days are plotted. Gliders might be used in a 'virtual mooring' mode (black), more or less holding position and recording time series, or in a 'mesoscale survey' mode (red), traveling across the entire wake in a little over one week, or in a 'submesoscale' mode (blue), only sampling one edge of the wake.

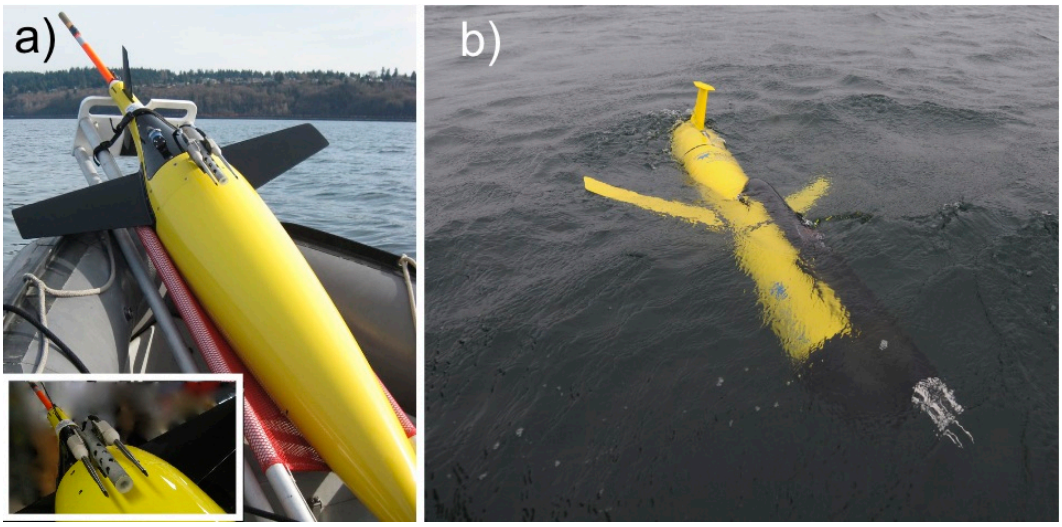

Figure 7: a) A Seaglider equipped with microstructure temperature sensors, ready for deployment in Puget Sound, WA. The inset shows a close-up of the two fast thermistors on either side of the CTD sensors. (b) The SLOCUM turbulence glider platform. The turbulence sensor assembly is carried above and forward of the glider body.

2.6 Turbulence Glider (t-slocum)

A 1000-m rated SLOCUM G2 electric glider will be deployed during the cold wake study. This system will be deployed for an autonomous mission in the cold wake, of nominal length of roughly 14 days. This system is equipped with full turbulence sensor array (Fig. 7b).

During the mission, communication with the glider will be done through Freewave (within 10 miles line-of-sight) and by Iridium. To maintain satellite communication, HighSea Net or Fleet Broad Band service must be available to allow for a terminal connect from ship to shore. The server for the t-slocum is at WHOI.

Ken Decoteau (WHOI) is the primary technician and pilot for this instrument. We will need considerable assistance during deployment and recovery. During deployment and recovery, considerable care must be taken to avoid damaging the fragile turbulence sensors.

During the mission, the health of the t-slocum will me monitored. If signs of distress are detected, we would like to divert the ship to recover the instrument. If such a mid-mission recovery occurs, we would plan to redeploy the glider once the problem is resolved.

2.7 Radiometery

Jeff Reid at NRL in Monterey would like to to collect some hand-held insolation measurements for studying aerosols. Measurements will be collected a couple of times a day.

2.8 Biogeochemistry program

To get a comprehensive understanding what is the effect of typhoons on ocean properties (including marine organisms), we need to make in situ observations of various parameters, nutrients, oxygen, chlorophyl-a, pCO2, POC, etc.

Dr. Chin-Chang Hung (National Taiwan Ocean University) is leading this effort but won't be coming on the cruise. Three NTOU graduate students will join the ITOP Cold wake cruise.

2.8.1 Sediment trap deployments

A drifting sediment trap array, which consisted of twelve cylindrical plastic core tubes (6.8 cm diameter) with honeycomb baffles covering the trap mouths will be deployed for at least 8 hours (up to 1 or 2 days) at a depth of 120, 150, 200 m. The array will be attached to an electric surface buoy with a global positioning system (GPS) antenna (TGB-500, TAIYO, Japan). The trap position can be monitored by the GPS receiver (to be set on the R/V). The battery of GPS locater can sustain 1–2 weeks, while the effective distance of the GPS antenna should be around 120 miles. Alternatively, an Argos transmitter will be attach to the sediment trap array (no distance limitation).

Details of the operational procedure will be provided in a future version of this document.

2.8.2 Water samples

The biogeochemistry group from NTOU is bringing enough sample bottles (for nitrate, nitrate, phosphate, silicte), filters (chl-a, POC etc) and DO-reagents for about 120 sets (24 profiles with 5 depths each). The maximum depth will be 250 m for the CTD casts.

They hope to collect CTD data and seawater samples at several locations adjacent the cold wake (e.g a transect across the cold wake area).

Note: Eric D'Asaro will have 2 air-dropped biogeochemical floats. The objective is to deploy one inside and one outside of the cold wake. Chlorophyll, oxygen, and nutrient measurements near these floats would help us relate the float measurements to the water samples and sediment trap measurements.

3 Personnel for the Cold wake cruise

Science party (14, including STS personnel):

Steven Jayne	WHOI	chief scientist
Luc Rainville	APL/UW	co-chief scientist
Elizabeth Douglass	WHOI	postdoctoral investigator
Kenneth Decoteau	WHOI	technician – Slocum glider
Pedro De La Torre	KAUST/WHOI	graduate student
Jay Hopper	FSU	technician – VMP
Adam Huxtable	APL/UW	technician – Seagliders
Stephanie Downey	APL/UW	technician
Samantha Stevenson	UC Boulder	graduate student
Bo Feng Wu	NSYSU	graduate student
I Hsiang Chen	NTOU	graduate student
Hsin-Lun Chiang	NTOU	graduate student
Po-Kai Hu	NTOU	graduate student
Josh Manger (?)	SIO	Restech

Possible other participants:

Hayley Dosser	APL/UW	graduate student (depending on timing: classes)
Andy Pickering	APL/UW	graduate student (on the IWISE cruise, stays if we interrupt them early)

4 Personnel for the float recovery cruise

Possible participants to the float recovery cruise (to be determined):

Mike Ohmart	APL/UW
Avery Snyder	APL/UW
1 or 2 TBA	SIO

5 Taiwanese vessel schedule

OR1:	11 Aug – 17 Aug	01 Sep – 06 Sep	20 Oct – 26 Oct	
OR2:	24 Oct – 28 Oct	30 Oct – 03 Nov	05 Nov – 09 Nov	
OR3:	11 Sep – 16 Sep	18 Sep – 21 Sep	01 Oct – 04 Oct	06 Oct – 09 Oct

6 Climatology from the last 20 years...

This diagram shows when the cold wake and float recovery cruises would happen if ITOP had taken place in one of the last 20 years. Storms that we could potentially sample are indicated by star. Black stars indicate large storms (>40 m/s). Open stars are tropical storms that we might end up sampling (if we were desperate). Before the aircraft period (red box), the storms located near Taiwan that might be a problem for IWISE are indicated by gray stars. In each case, the first cruise (blue) is the science cold wake cruise, followed by a float recovery cruise (gray).

The two other cruises mentioned in this document (ASIS/EASI mooring deployment and IWISE pilot) are indicated at the bottom.