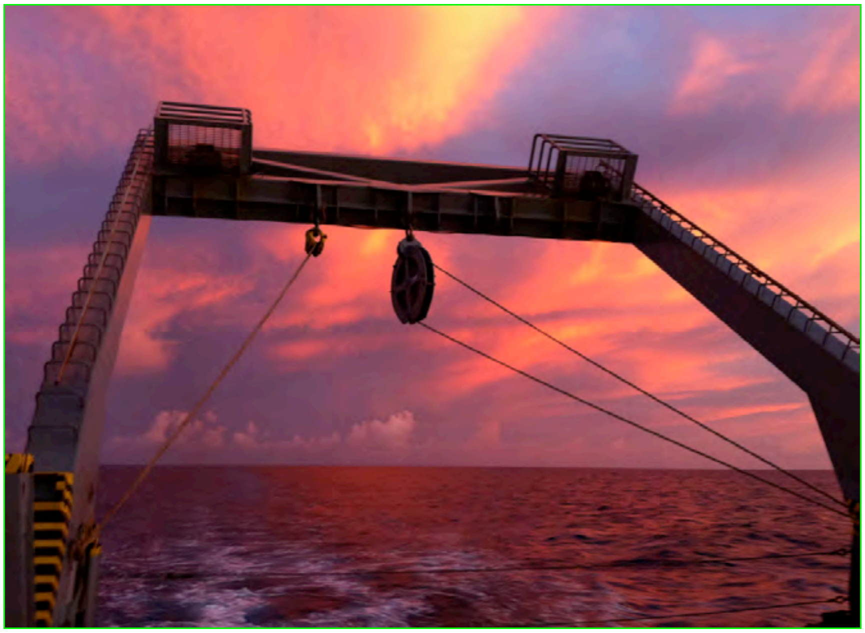
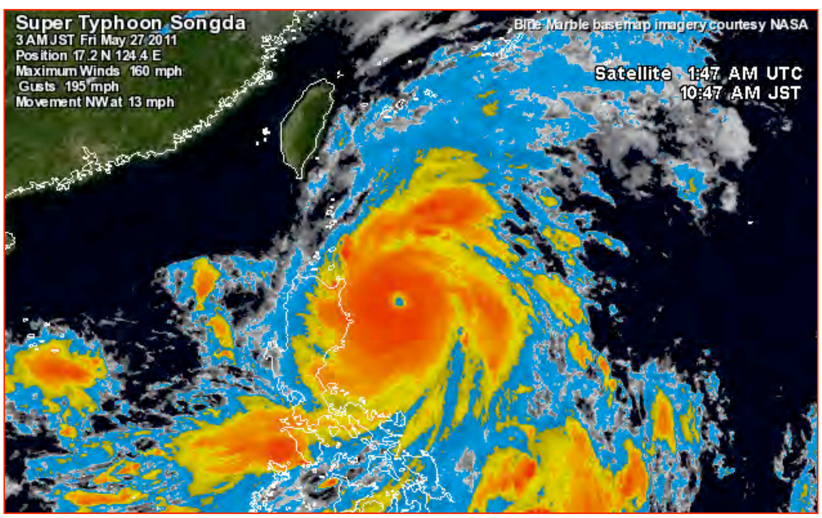
R/V Revelle, cruise 1107, Lamon Bay, Kaohsiung to Kaohsiung, 18 May - 6 June 2011,

Personnel exchange at Port Irene, Philippines on 19 May and 4 June

Arnold L. Gordon, Chief Scientist



23 May 2011 5:05 AM local: before the storm [Songda]
"Red sky in the morning sailor take warning"



Satellite image of Songda on 27 May at 9:47 AM local time. At 2:00 AM local Songda had winds of 160 mph, and was moving northward at 13 mph, Revelle was in the southeastern Lamon Bay.

Summary *of Lamon Bay Cruise #1 (2011) key science results [preliminary impression; see descriptive figures in section V of this report]*:

The circulation within Lamon Bay (defined here as west of 124°E, south of 18°N, north of 14°N) is vigorous, with surface layer currents often between 1 and 2 kts. The Kuroshio at 18.35°N (northeastern tip of Luzon) was nearly 3 kts at the sea surface, and extended to ~350 m. Within Lamon Bay are 2 energetic gyres or dipoles that bracket a northwestward stream into the Kuroshio. These features extend to only 150-200 m. The cyclonic dipole is within the southern tier of Lamon Bay; the much more energetic anticyclonic dipole is to the north of the Kuroshio feeder stream. This sets up a bifurcation along the western boundary of Lamon Bay, near 16°-17°N, which is likely more relevant to the Kuroshio than the bifurcation near 13°N. The first occurrence of (what I would call) the Kuroshio is at the 16.5°N western boundary. The vorticity transfer linking the nascent Kuroshio to the dipoles needs to be considered in understanding the origin of the Kuroshio.

The Lamon Bay dipole has a branch entering into Polillo Strait, and then exported from the shelf north of Calagua Island, introducing low salinity surface water into the Lamon Bay cyclonic dipole. Lamon Bay is a confluence of waters from different ocean regimes that then contribute to the Kuroshio. The Kuroshio off the northeastern point of Luzon is mainly drawn from North Pacific subtropical water (subtropical component of the North Equatorial Current) and western North Pacific Kuroshio recirculation. Input from the equatorial component of the North Equatorial Current, derived from the bifurcation near 13°N, is small. From continuity it is limited in the long-term to compensate for the loss of upper kilometer water form the North Pacific: Bering Strait export to the Arctic and export of North Pacific Intermediate water to the Mindanao Current; estimate: ~ 4 Sv.

The Lamon Bay project mooring will provide 1-year record of the dipoles and Kuroshio feeder stream behavior; Lamon Bay 2012 cruise will provide another snapshot to test the concepts drawn from the Lamon Bay 2011 cruise.

I Introduction:

The research objectives of the cruise is to quantity the spatial and temporal characteristics of the ocean processes governing the stratification & circulation within Lamon Bay and their relationship to marine productivity and ecosystems and to investigate possible linkage of Lamon Bay dynamics to the development of the Kuroshio.

The observational program consists of integrated physical and biological oceanography measurements, obtained from ship-based underway oceanographic and meteorological sensors, including the hull mounted ADCP; and by water column stations (CTD-O2 with a 24-bottle 10-liter water sample rosette). The sea floor sediment will be sampled with gravity cores.

The research cruise is carried out in the May/June 2011 (Lamon Bay 1) with a follow up cruise in the same time frame 2012 (Lamon Bay 2). The ship based surveys are tied together by mooring based time series observations of ocean currents and T/S stratification and by a land based high frequency radio array, as well as satellite coverage of SST, ocean color and altimetry, and larger scale ocean observations by global observational programs and by OKMC (Origin of the Kuroshio and Mindanao Current, a ONR program).

II Schedule and observational Approach.

The R/V Revelle departed Kaohsiung 1405 local time 18 May 2011, arriving at Port Irene 1500 local time 19 May 2011. The rest of the research group boarded the ship and at 1900 local time 19 may 2011 the science program began. *[local time is GMT +8 hours. departed Kaohsiung at 0605Z 18 May 2011, year day 138. Arrived Port Irene at 0700Z 19 May 2011]*

The cruise plan may be viewed as involving 3 phases, though detailed schedule and activities remain flexible so as to respond to the incoming data flow information that may be relevant to the continued data collection strategy, as well as the realities of equipment/weather/other aspects of working at sea.

The 3 phases are (Figure 1):
Phase 1 Regional Survey to resolve stratification and circulation conditions seaward of Lamon Bay Proper. The return to Port Irene at the end of the cruise provides additional opportunity to contribute to the Regional Survey
Phase 2 Mooring Deployment
Phase 3 physical and biological conditions within Lamon Bay southern tier (Lamon Bay Proper).

The research phases still form the approach of our data collection activity, but their timing are 'interwoven', e.g. do parts of phase 1, go to phase 2, continue phase 1 later, etc.

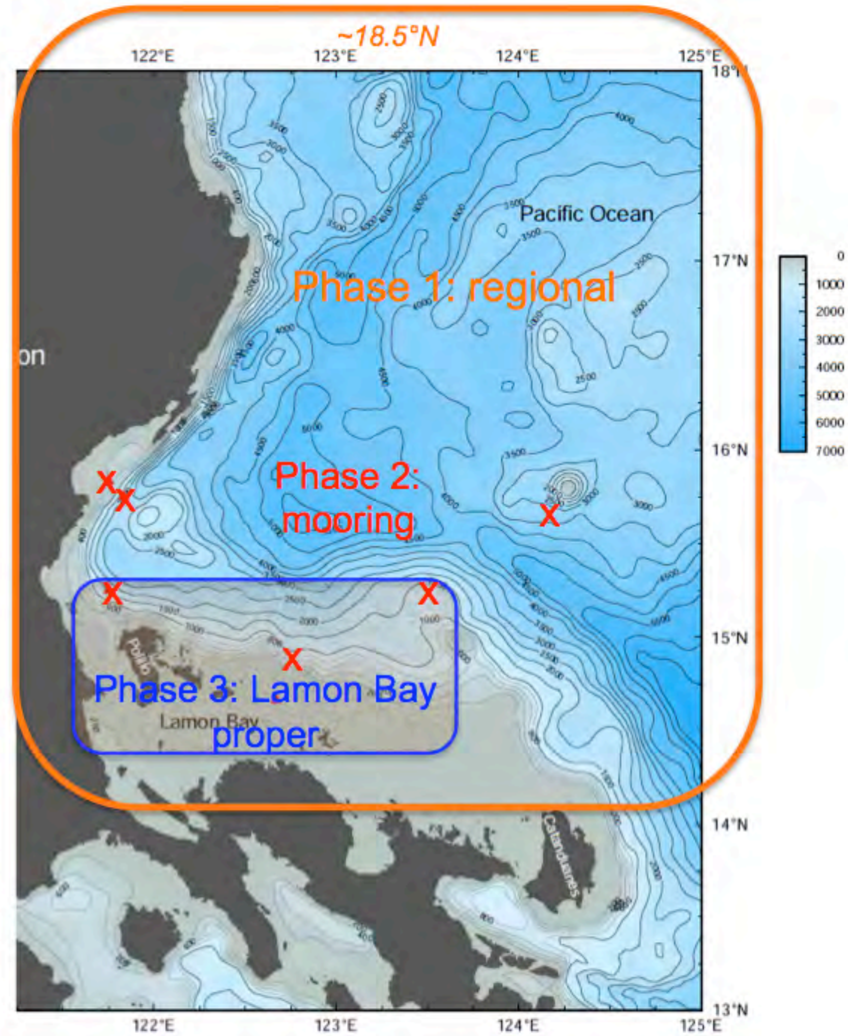


Figure 1: Schematic of the 3 Phases of Lamon Bay 1. The red X symbol marks the approximate sites of the year-long moorings for current and temperature/salinity time series measurements

• Lamon Bay time lost to Songda:

One of the weather realities was Typhoon Songda (Figure 2, and cover picture). This forced the ship to leave Lamon Bay and head south towards ~10°N off the east coast of the Philippines. While this allowed underway data collection within North Equatorial Current bifurcation feeding into the northward flowing Kuroshio and into the southward Mindanao Current, which has science value, it reduced the time we had to work within Lamon Bay. The 'time lost' is considered to be the interval from CTD 16 at 14.6694°N, 124.5504°E, 23 May 2011, 0621 GMT which has direct Lamon Bay relevance, to the return to that approximate position, 14.6922°N, 124.5511°E on 26 May 2011, 0221 GMT, before heading westward to the moorings sites in the western boundary of Lamon Bay. **The interval of time lost to addressing explicit Lamon Bay objectives due to Typhoon Songda was 3.83 days (3 days, 20 hours).**

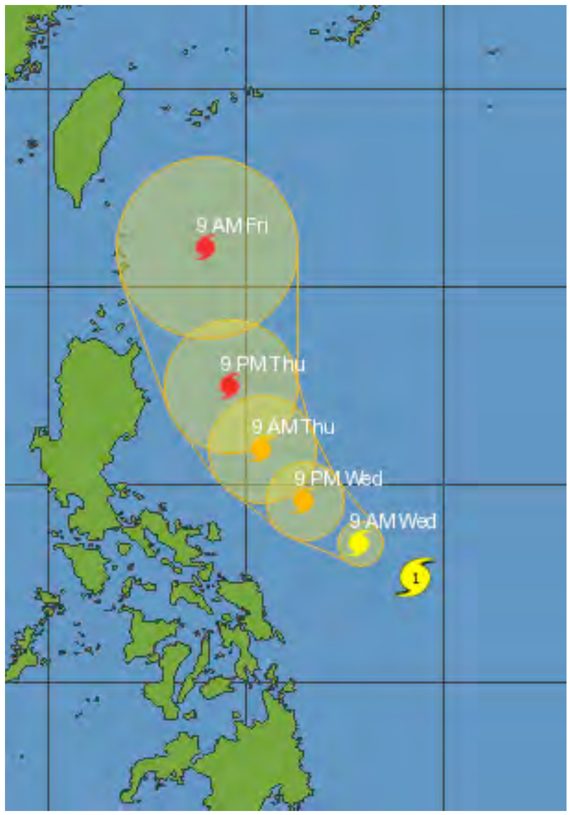


Figure 2: Songda [Philippine designated name: Chedeng]

III Personnel blue font means boarded in Kaohsiung, Taiwan, the rest boarded in Port Irene, Philippines; the underlined disembark in Kaohsiung on 6 June, rest in Port Irene, 4 June

Last Name	First Name	Affiliation
GORDON	ARNOLD L.	Columbia University

BENJAMIN	LINDSEY	U HAWAII
BOLLOZOS	IRIS SALUD	UD Diliman
CABACABA	SHEEN ROSE	UD Diliman

CABRERA	OLIVIA CANTAVEROS	UD Diliman
CALDERWOOD	JOHN	SIO
CAMOYING	MARIANNE	UD Diliman
COLE	DREW	SIO
DELAHOYDE	FRANK	SIO
DOUSSET	BENEDICTE	U HAWAII
ESCOBAR	MARIA THERESA	UD Diliman
FERRERA	CHARISSA MARCAIDA	UD Diliman
FLAMENT	PIERRE	U HAWAII
HUBER *18/19 May only*	BRUCE	Columbia University
JACINTO	GIL SUICO	UD Diliman
LETHABY	PAUL	U HAWAII
LUMAYNO	SANNY DAVID	UD Diliman

MAGURA	BENJAMIN ZAMBRANO	
MARTIN	MARILOU	UD Diliman
MELE	PHILIP A.	Columbia University
NAPITU	ASMI MARINTAN	Columbia University
PALERMO	JOSEPH DOMINIC	UD Diliman
QUEVEDO	JAY MAR	UD Diliman
SABAN	RHODELYN	UD Diliman
SENAL	MARIA ISABEL	UD Diliman
SOLERA	LEILANI	UD Diliman
SOTTO	LARA PATRICIA	UD Diliman
TENTIA	MARY CHRIS	UD Diliman
VILLANOY	CESAR L.	UD Diliman
YINIGUEZ	ALETTA T.	UD Diliman

IV Events [see appendices; and station/track map, figure 3]:

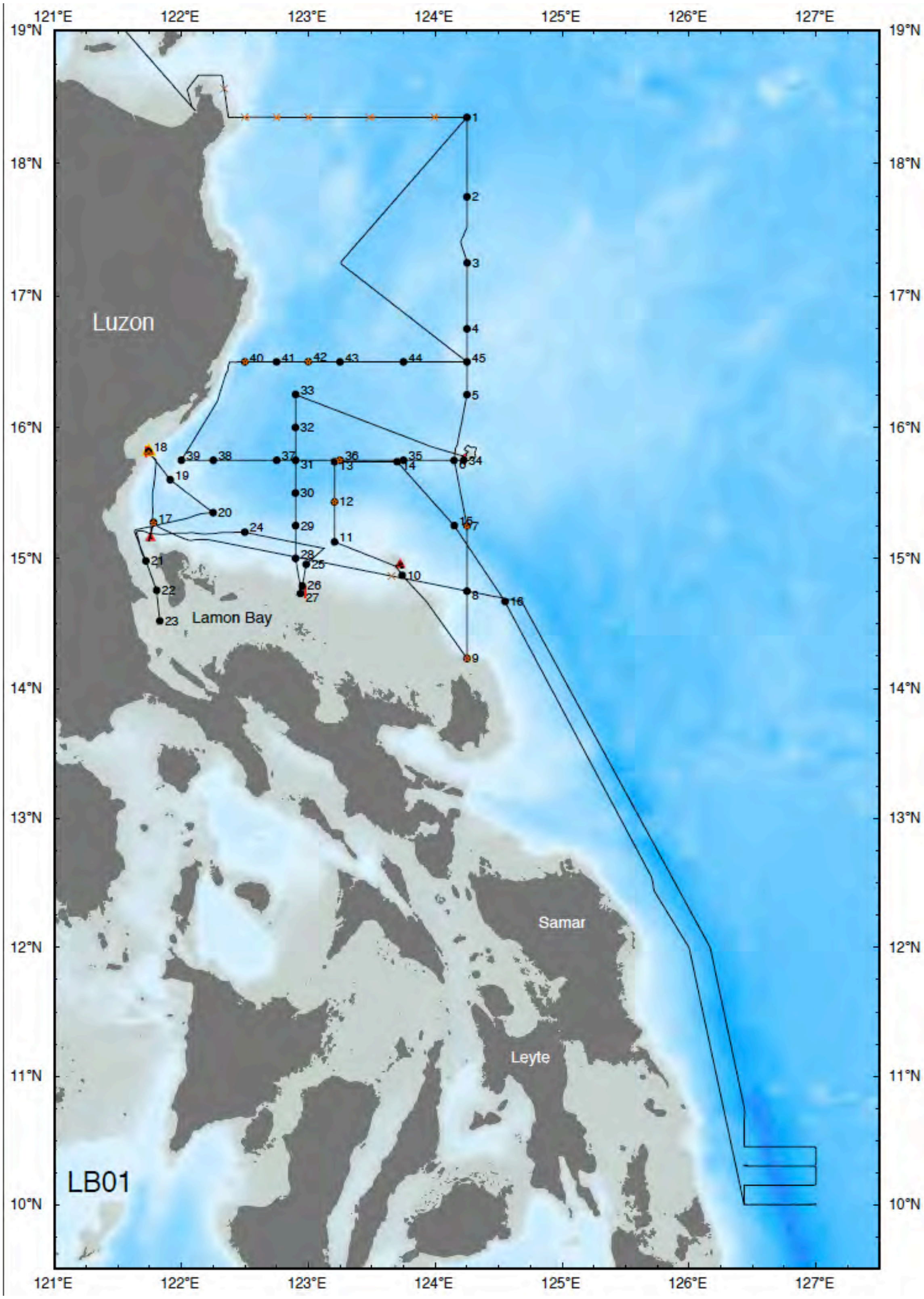


figure 3: Station/track map of Lamon Bay 1. Red dots show drifter deployments [13 in total]; red triangles are mooring deployment sites [6 in total]. There were 45 CTD stations most with water samples for chemistry.

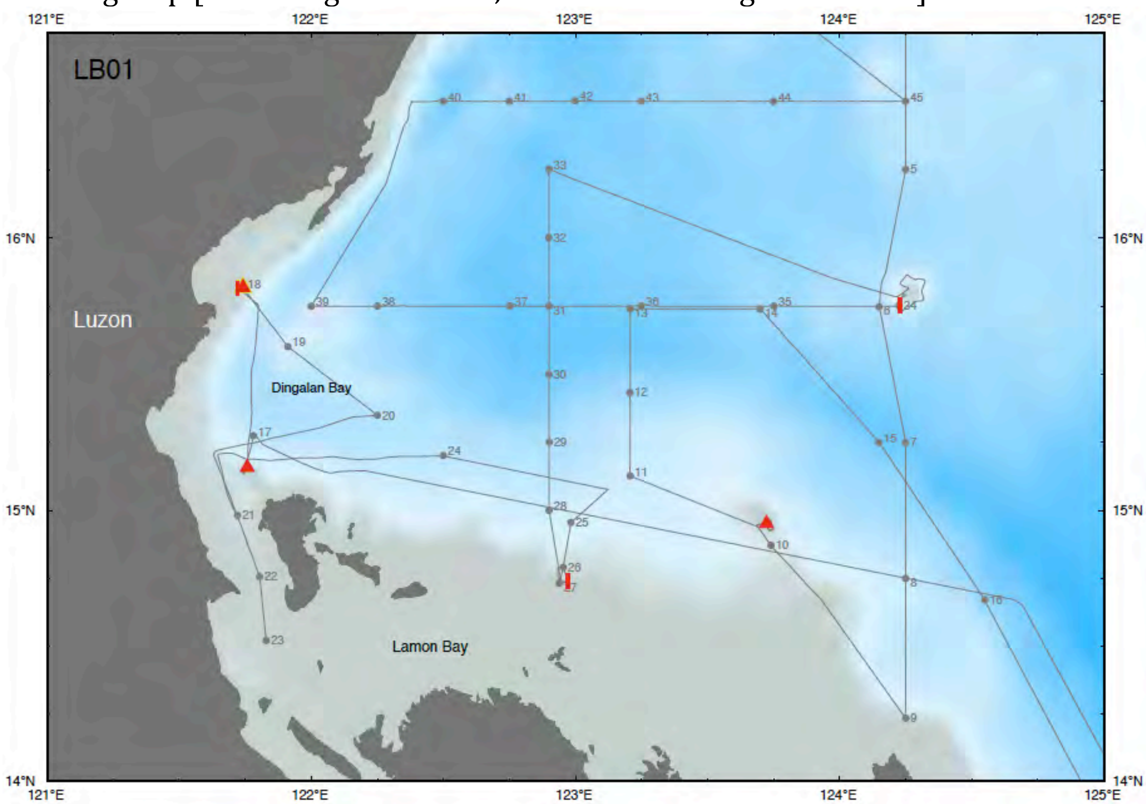
[A] CTD, XBT

CTD/water sampling stations extended to 1500 m. It was more important with the time available for Lamon Bay measurements to gain lat/long coverage, so as to resolve the upper kilometer, the major component of the dynamic relief, than to sample the deep and bottom stratum.

[B] Moorings deployed during Lamon Bay #1 [to be recovered in 2012]:

what	long°E	latitude°N	Day GMT	depth
TRBM1	123.7233	14.9517	22may2011	145
TRBM2	121.7572	15.1581	27may2011	192
TRBM3:	121.7415	15.8186	28may2011	180
T/S Bottom:	121.7201	15.8158	28may2011	86
Mooring [line] 1	122.9715	14.7405	30may2011	226
Mooring [line] 2	124.2274	15.7540	31may2011	757

Mooring map [red triangles = TRBM; red bars: moorings with cable]



[C] Drifters deployed during Lamon Bay 1, 2011

Drifter	Day GMT	Time GMT	Latitude N	Longitude E

1	82446	19-May	1545	18°20.926'	122°30.98'
2	43511	19-May	1711	18°21.013'	122°45.473'
3	82404	19-May	1831	18°21.006'	123°00.393'
4	82448	19-May	2106	18°20.962'	123°30.198'
5	82408	19-May	2345	18°21.010'	124°00.112'
6	82405	21-May	527	15°14.770'	124°14.960'
7	98887	21-May	1348	14°14.0116'	124°14.9813'
8	43660	22-May	1239	15°26.0352'	123°12.4106'
9	82380	27-May	2001	15°16.232'	121°46.771'
10	82412	28-May	908	15°49.008'	121°44.490'
11	82443	1-Jun	11	15°45.085'	123°14.844'
12	82411	1-Jun	2135	16°30.057'	122°30.171'
13	82406	2-Jun	316	16°30.069'	123°00.045'

[D] gravity cores

5/22/11	14	57.10N.	123	43.40E.
5/28/11	15	25.36N.	121	46.39E.
5/29/11	14	31.27N.	121	49.75E.
5/29/11	15	11.41N.	121	44.96E.
5/29/11	15	04.61N.	123	07.39E.
5/31/11	15	45.20N.	124	13.50E.
6/1/11	15	45.00N.	122	00.00E.
6/1/11	16	29.90N.	122	22.70E.

V Research findings, Narrative [few words, but descriptive figures, if anyone wants higher resolution figures, request from Arnold L. Gordon, Chief Scientist, agordon@ldeo.columbia.edu]:

[A] Kuroshio at 18.35°N (Figure 4):

A clear signal of the Kuroshio is observed at18.45°N. The strong northward flow extends to ~ 350 m, attaining 2-3 knots. The 18°C subtropical mode water observed by the XBT indicate that we transversed the SW corner of the Kuroshio recirculation gyre.

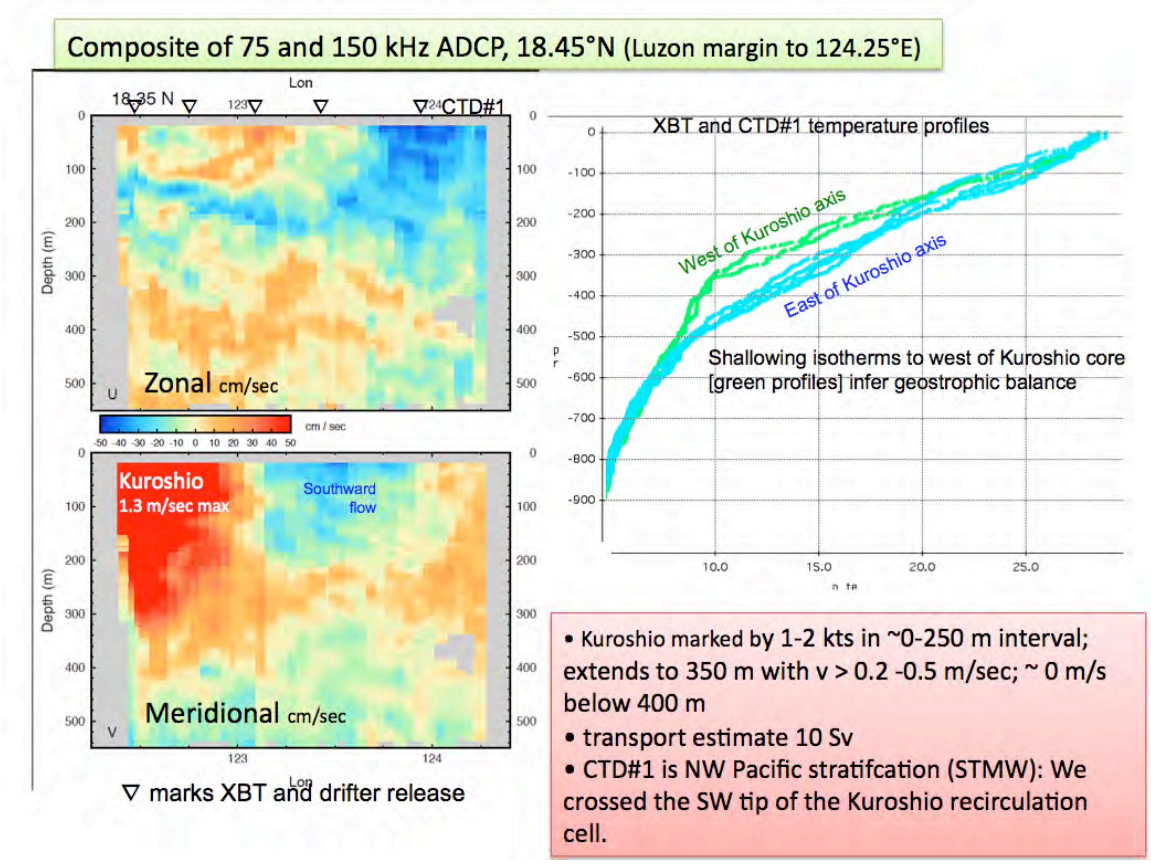


Figure 4: Kuroshio Crossing at 18.35°N

[B] Regional Circulation Pattern [the Kuroshio and its Dipoles]:

Within the Lamon Bay regional area the circulation displays energetic eddy like cells, arranged as dipoles around a stream feeding into the Kuroshio observed at 18.35°N. No doubt that this arrangement changes in time. The Lamon Bay mooring based time series and Lamon Bay 2 in 2012; satellite images of ocean color, sea level; and of regional in situ data e.g. drifters, and OKMC (ONR program Origin of the Kuroshio and Mindanao Current) will provide information about the evolving nature of the Lamon Bay circulation.

The vorticity transfer linking the nascent Kuroshio to the dipoles needs to be considered in understanding the origin of the Kuroshio. Is the more powerful anticyclonic dipole extracting negative vorticity from the stream that then develops into the western boundary current to the north? Is the cyclonic dipole related to the high productivity of the Lamon Bay proper? Can it impart some of the needed positive vorticity into the Kuroshio to propel it northward?

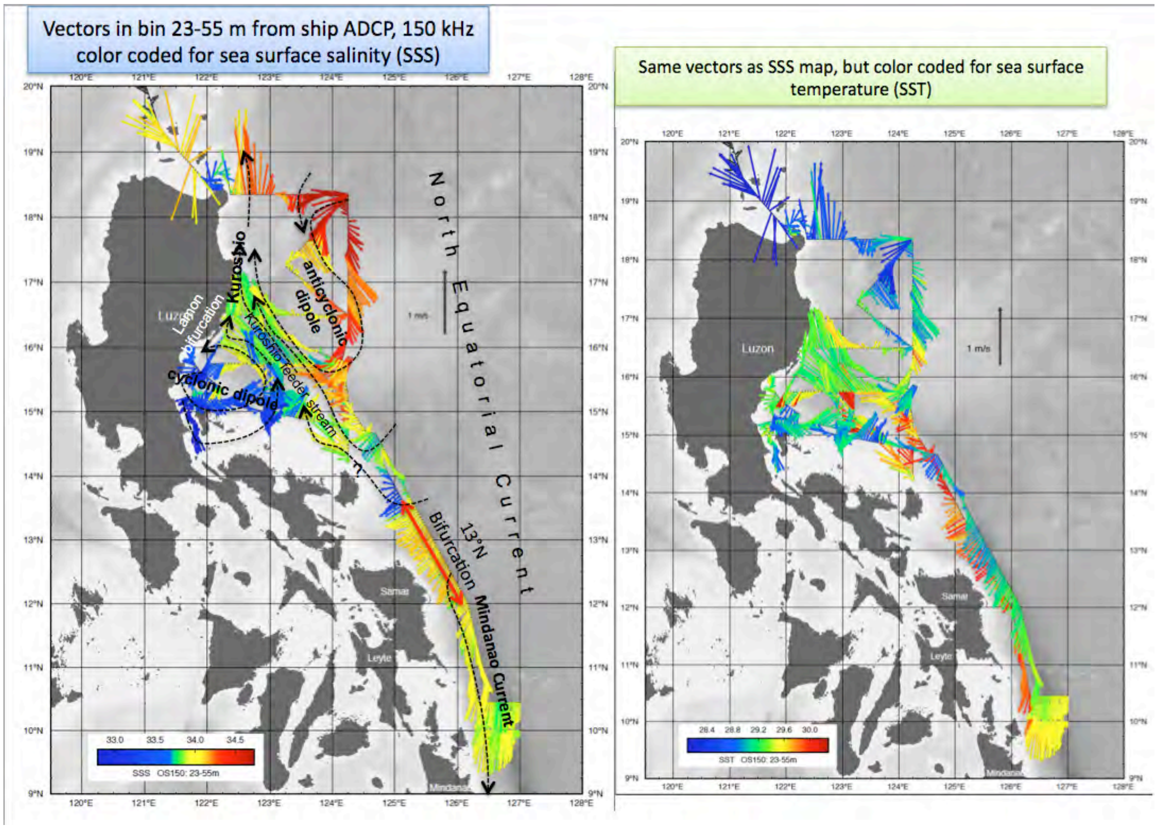


Figure 5: Regional Circulation 23-55 m interval, color coded vectors by sea surface salinity (SSS) and sea surface temperature (SST). See figures 7a and 8a for a blow up of the Bifurcation and Lamon Bay regions, respectively. The first clear sign of a northward flowing western boundary Kuroshio is at 16 to 17°N. Continuity of significant northward flow from the 13°N bifurcation into Lamon Bay is not clear, main activity appears to be associated with the cyclonic and anticyclonic dipoles with Lamon Bay

[C] Lamon Bay Eastern boundary, 124.25°E (Figure 6)

The eastern boundary crossing reveals strong zonal speeds associated with the anticyclonic 'dipole' (figure 5), and within the stratification there is evident of isopycnal stirring of water columns from the tropical and subtropical components of the North Pacific 's North Equatorial Current, and with waters from the higher latitude western North Pacific, likely introduced to the Lamon Bay region by the Kuroshio recirculation cell (figures 6b, 8c).

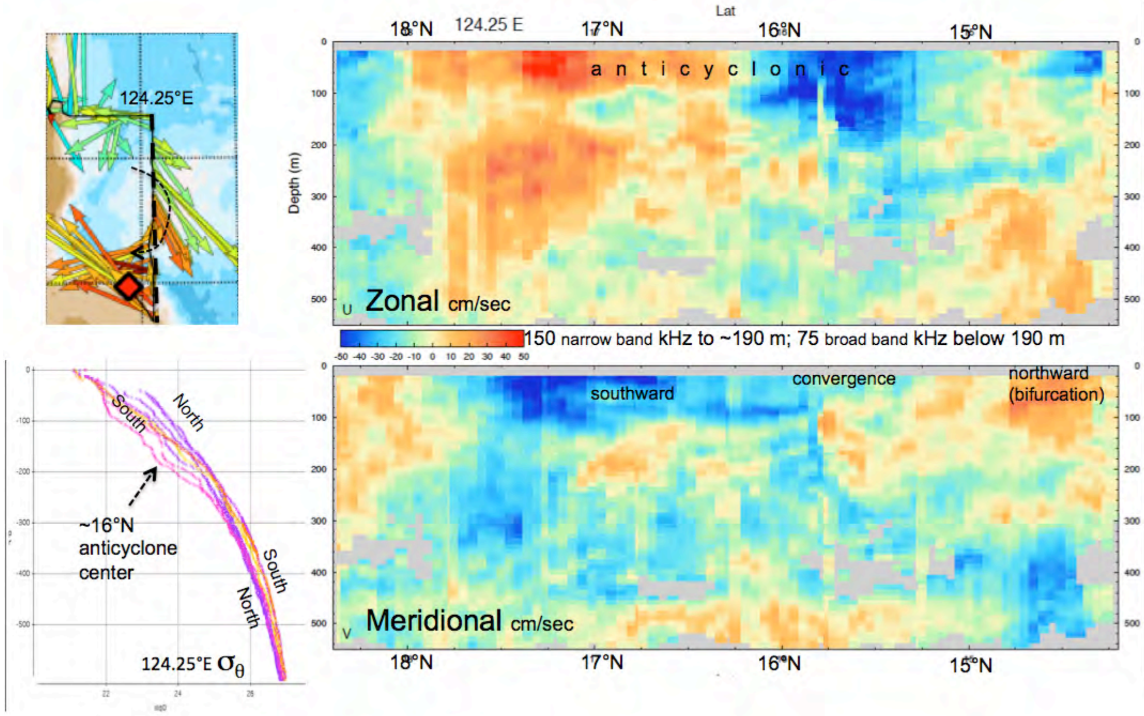


Figure 6a: Zonal and meridional speeds along the eastern boundary (124.25°E) of Lamon Bay

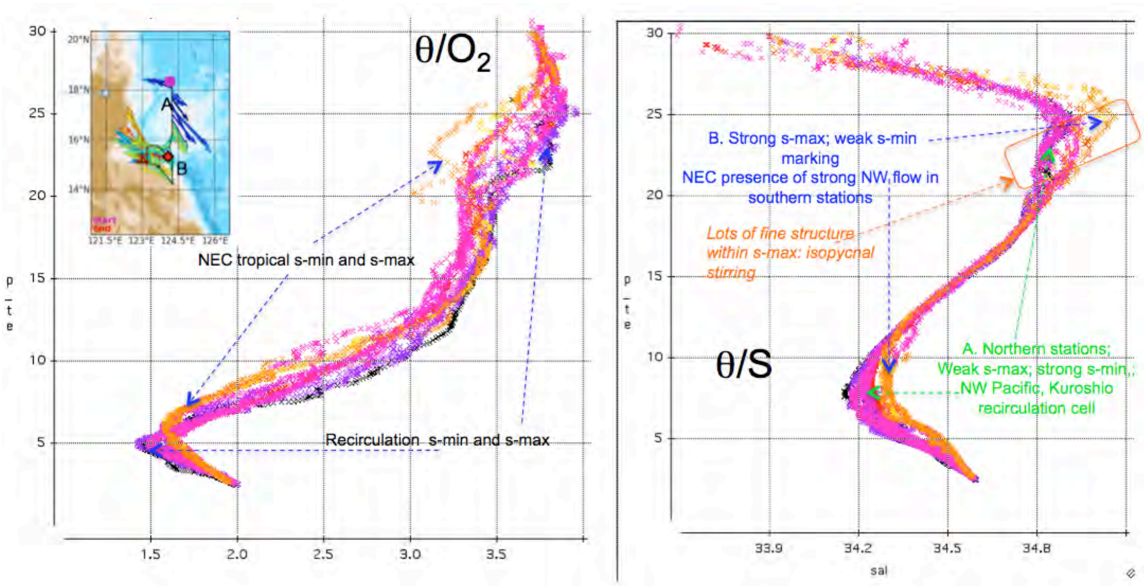


Figure 6b: θ/S and θ/O_2 from the CTD stations 1-16, before the Songda detour. The range of s-max and s-min T/S values, denoting northern or southern origin, is found throughout Lamon Bay, which allows for water type identification associated with the ADCP detected circulation pattern.

[D] Songda Detour, the 13°N Bifurcation:

The two bifurcation (figure 7) crossing made during the Songda Typhoon detour, while not directly addressing Lamon Bay objectives, does provide larger scale regional setting of Lamon Bay. Here are 4 images of the data, provided without descriptive text, but points are included within the figures.

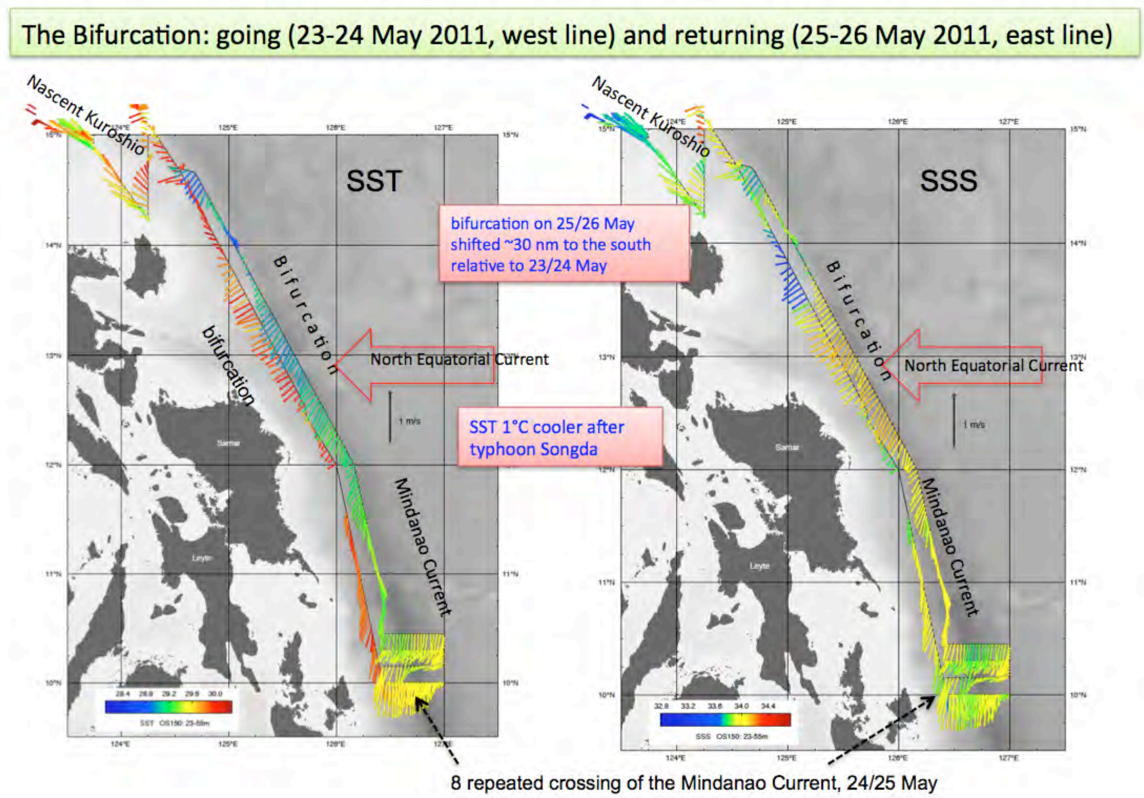


Figure 7a: Vectors 23-55 m interval from ship 150 kHz ADCP during southward transit to 'duck' Songda. Before and After Songda

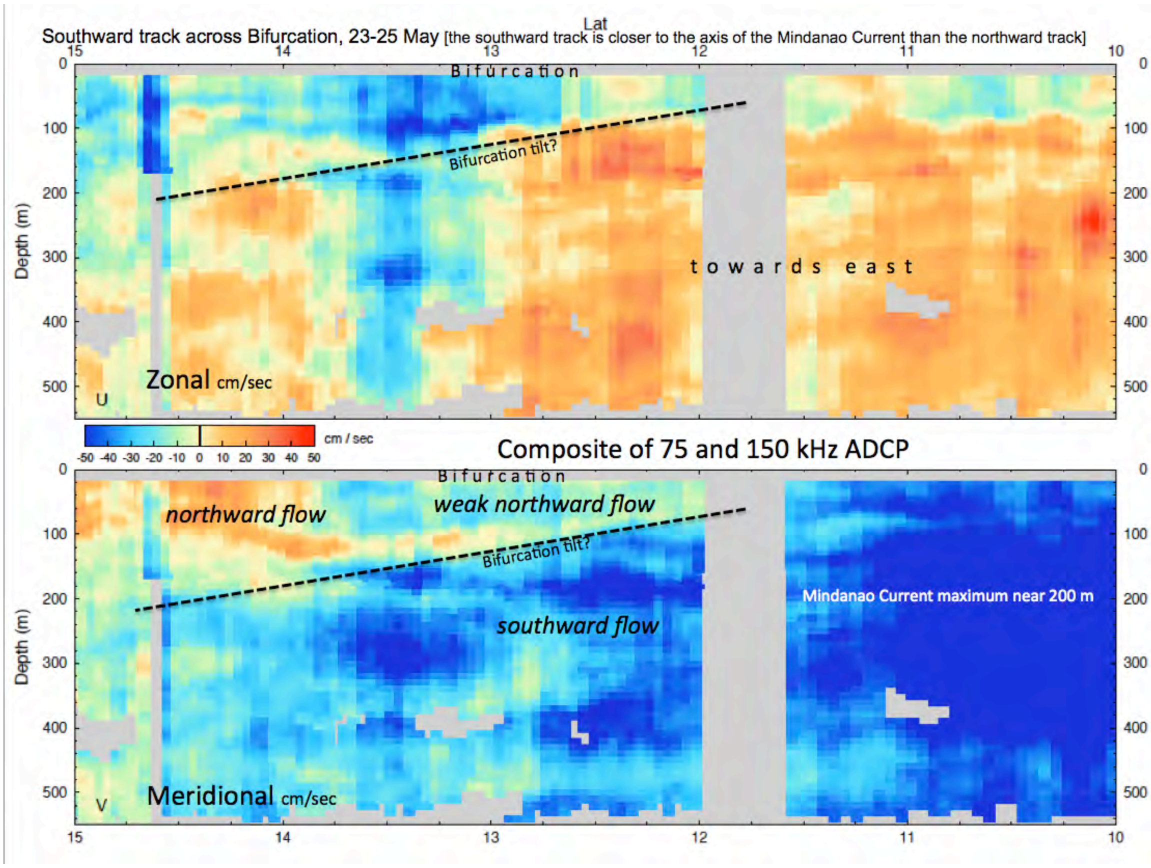


Figure 7b: zonal and meridional currents along the southward directed bifurcation crossing. The interface separating northward from southward flow is inclined, being more northward as depth increases. The Mindanao Current has increasing northward scope as depth increases; the northward arm of the bifurcation is limited to the upper 100 - 200 m.

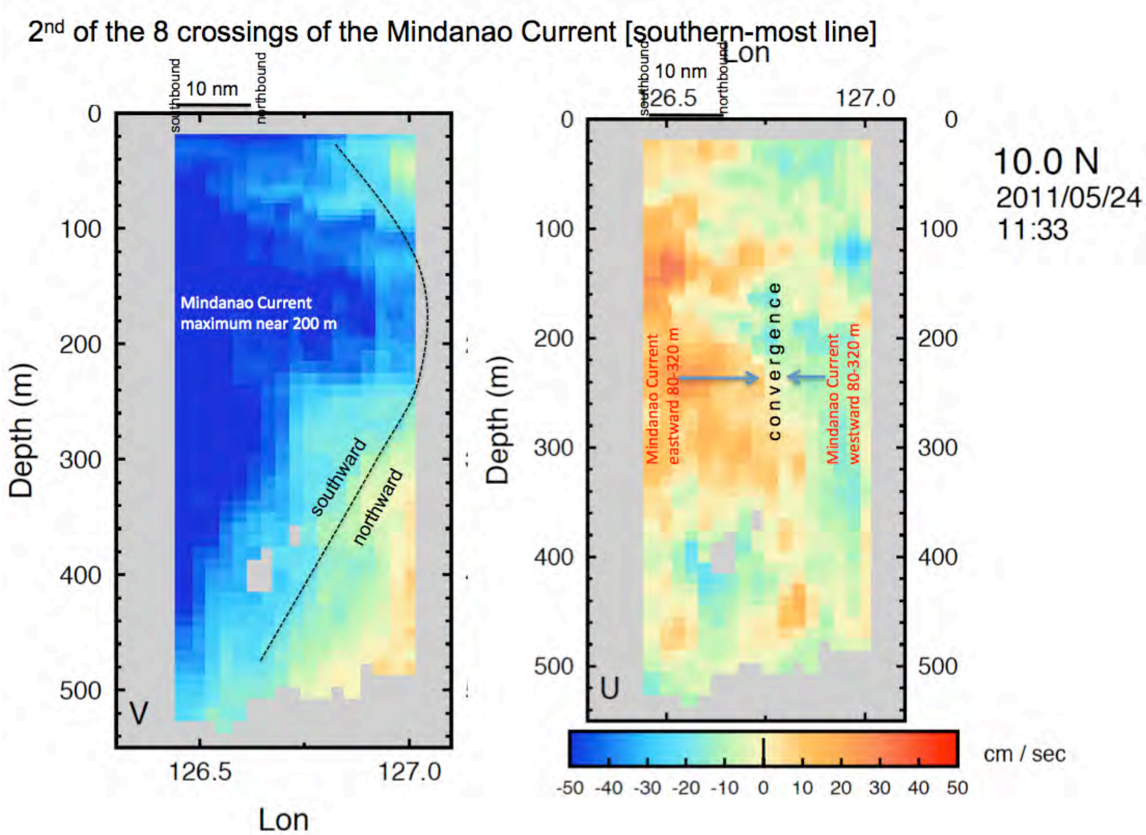


Figure 7c: Cross the Mindanao Current. A subsurface southward current maximum.

[E] Lamon Bay proper, southern tier

The southern reaches of Lamon Bay including the broad continental shelf, referred to as Lamon Bay Proper, is dominated by the cyclonic dipole discussed above (figure 5), the northern limb of which is the Kuroshio feeder stream. The circulation schematic is shown in figure 8.

North Equatorial Current [NEC] is a broad current, that in its northern reaches is composed of North Pacific subtropical gyre waters, but in its southern reaches it is more tropical in characteristics and includes waters from the southern hemisphere that cross the equator in the western Pacific and pass eastward within the North Equatorial Counter Current and eventually into the NEC.

The water from the broad NEC are injected into the Lamon Bay. While some come from the 13°N bifurcation, the bulk is derived directly from the subtropical (northern) part of the NEC, to flow between the anticyclonic dipole and the cyclonic dipole (figure 8). The anticyclonic dipole is open to the ocean north and east of Lamon Bay, and likely incorporates water not just from the broad NEC but also from the Kuroshio recirculation gyre. The cyclonic dipole is bounded by land and is exposed to the ocean only along the Kuroshio feeder stream. as it is 'spun-up' by the Kuroshio feeder stream, it lifts nutrient rich water into the euphotic layer, to support high biological productivity.

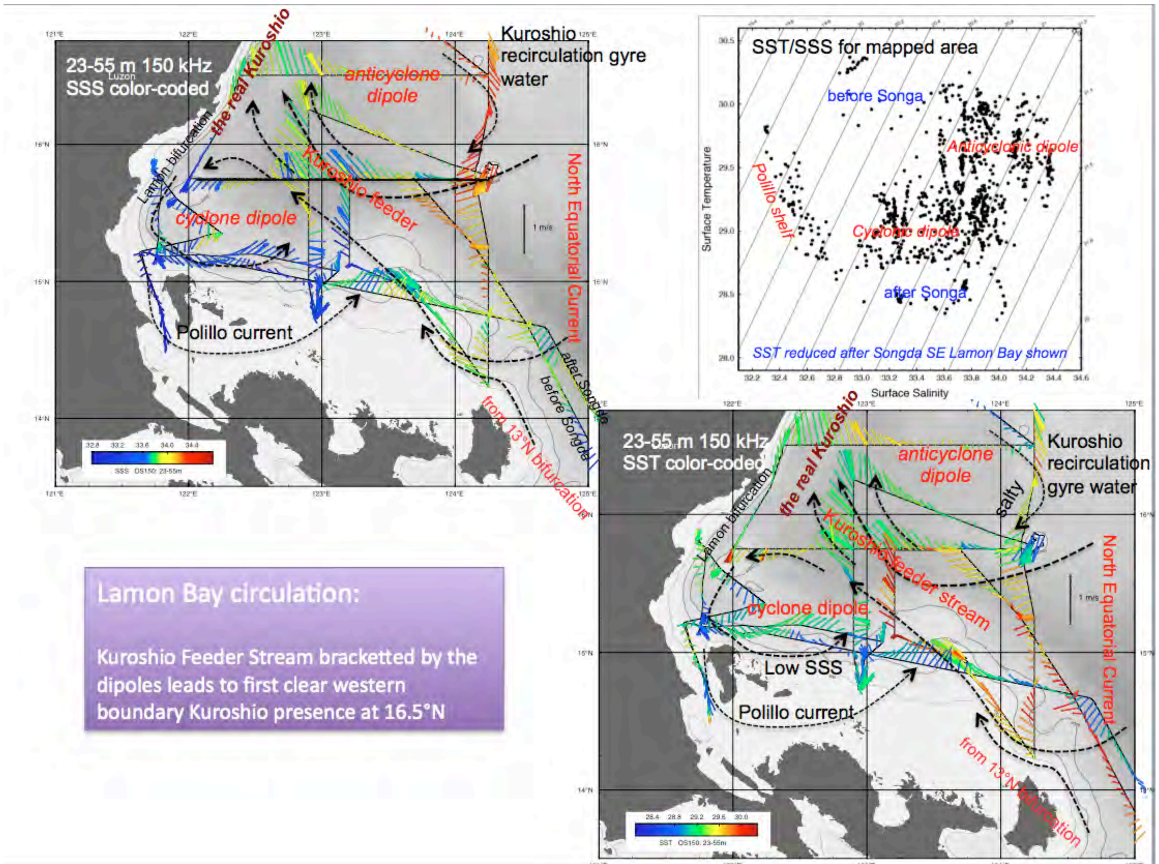


Figure 8a: Lamon Bay circulation, showing the anticyclonic and cyclonic dipoles, surface water T/S, and ADCP section along 15.75°N. The dipole and Kuroshio feeder stream between the dipoles extend to <200 m, the sea surface to the mid-pycnocline levels.

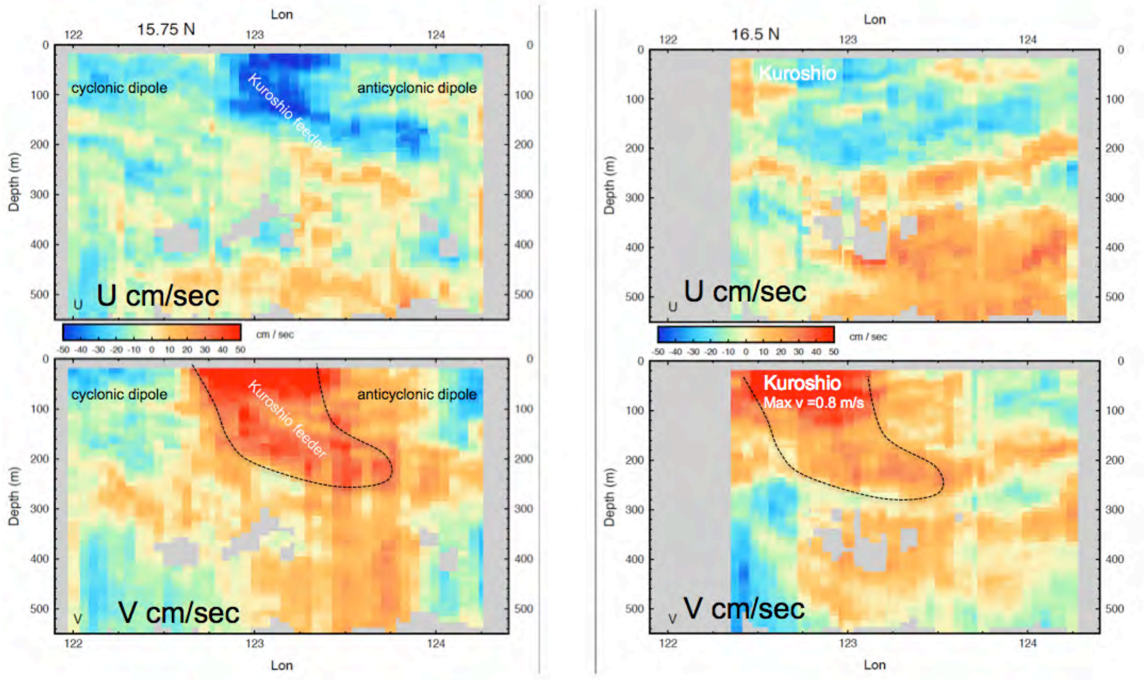


Figure 8b: Composite of 75 and 150 kHz ADCP, at 15.75 and 16.50°N. The northward flowing western boundary current at 16.5°N may be considered the southern-most, clearest expression of the Kuroshio. The Kuroshio 'takes shape' within Lamon Bay, between the dipoles. Estimated transport of Kuroshio at 16.5°N is 11 Sv (using u and v; the same as observed earlier in the cruise at 18.35°N). The Kuroshio extends to around 300 m; its axis shifts eastward with increasing depth. This is also observed within the Kuroshio feeder stream at 15.75°N

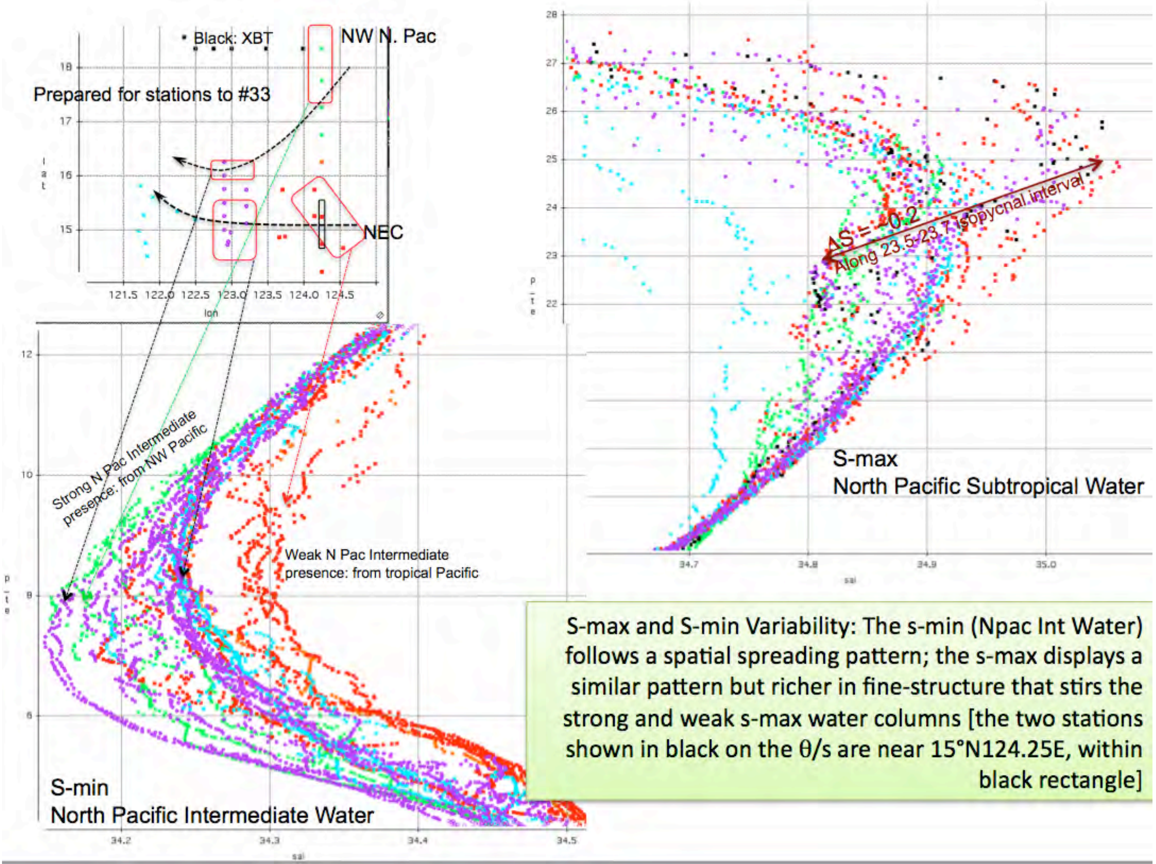


Figure 8c: The θ/S scatter in Lamon Bay Proper reveals varied sources and isopycnal stirring within the S-max (North Pacific subtropical water) and S-min (North Pacific Intermediate Water).

The cyclonic dipole branches onto the shelf with south flow in Polillo Strait [west of Polillo Island]. It exits the shelf north of Calagua Island. This shelf branch introduces low salinity surface water into the open Lamon Bay.

A distinct Oxygen minimum appears in 150-200 m layer of Polillo Strait (figure 8d). Only way out is to the north (too shallow to exit in the Calagua Island path). Once it spreads into Lamon Bay it is advected eastward by the southern limb of the Lamon Bay cyclonic dipole. It mixes into a homogeneous oxygen layer. Might it be low oxygen coming from the deep isolated basin in the SW corner of the Polillo Strait, 150 m sill [Cesar Villanoy, pc]? It appears at stat 16. Is this happening in other deep inlets?

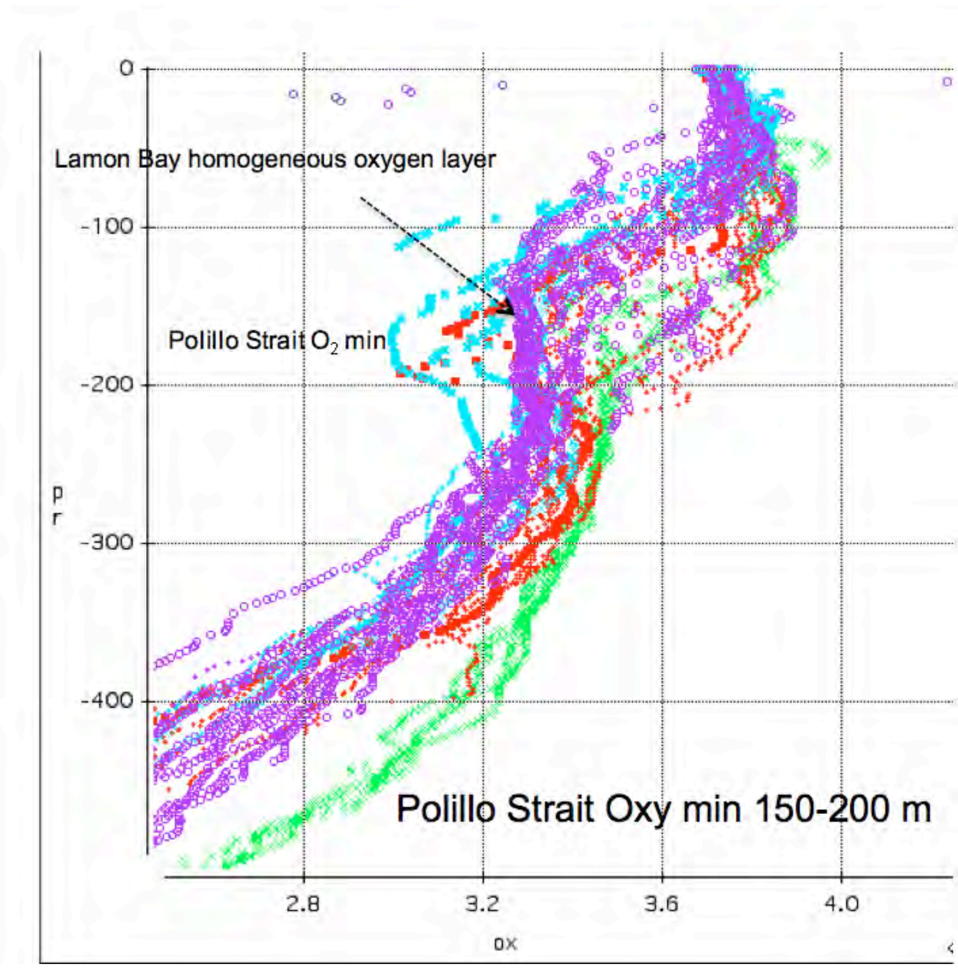


figure 8d Polillo Strait oxygen minimum and the "oxygen-stad" within the Lamon Bay thermocline. Are they related? *[also see figures 10 and 11]*

The ratio of the three components composing the Kuroshio feeder stream is not yet determined. We see evidence in the T/S stratification of isopycnal stirring between NW Pacific water and NEC water within the Kuroshio feeder stream (figure 8c).

[F] Consideration of Lamon Bay Place at the Ocean Scale

The Lamon Bay data suggests that Lamon Bay is situated in the confluence of waters of very different ocean regimes (figure 9). Lamon Bay may play a pivotal role in the initial development of the Kuroshio. Repeat of figure 9 caption for text completeness: The Kuroshio off the northeastern point of Luzon is mainly drawn from North Pacific subtropical water and western North Pacific Kuroshio recirculation. Input of from the equatorial waters is limited to balance the loss of upper kilometer water form the North Pacific: Bering Strait export to the Arctic and export of North Pacific

Intermediate water to the Mindanao Current. The latter contributes to the Indonesian Throughflow. Blue arrow total Estimate: ~ 4 Sv.

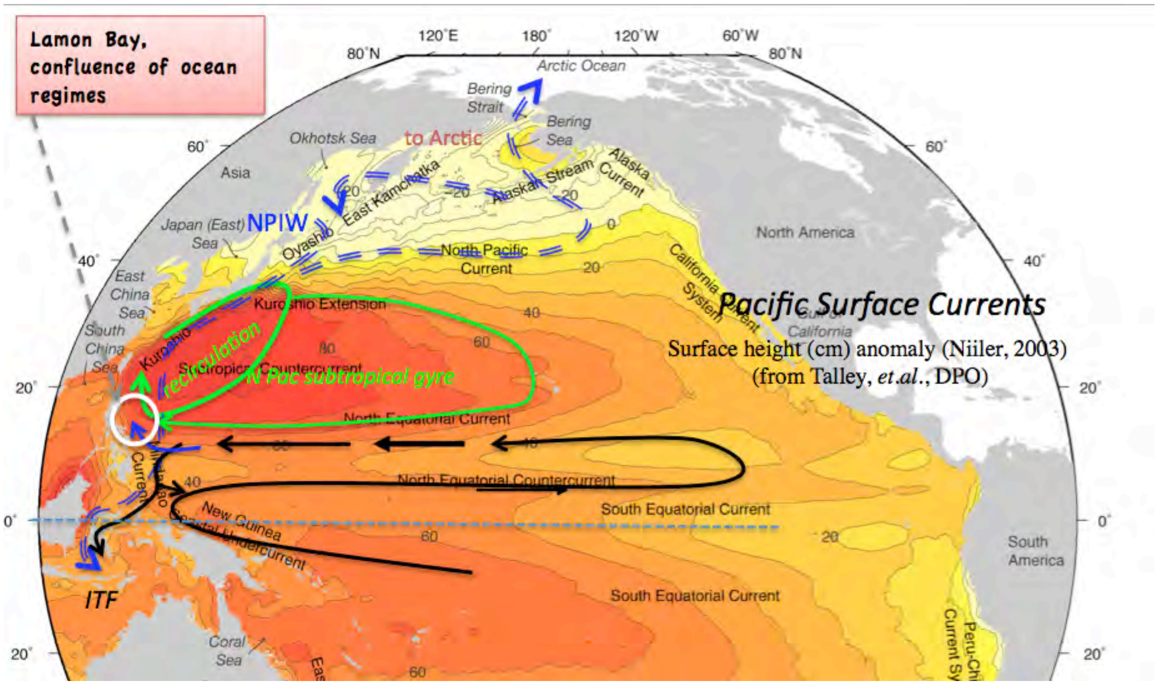


Figure 9: The Kuroshio off the northeastern point of Luzon is mainly drawn from North Pacific subtropical water and western North Pacific Kuroshio recirculation (green arrows). Input of from the equatorial waters is limited to balance the export of upper kilometer water form the North Pacific: Bering Strait export to the Arctic and export of North Pacific Intermediate water to the Mindanao Current (blue arrows). The latter contributes to the Indonesian Throughflow. Blue arrow total Estimate: ~ 4 Sv.

G. some standard figures:

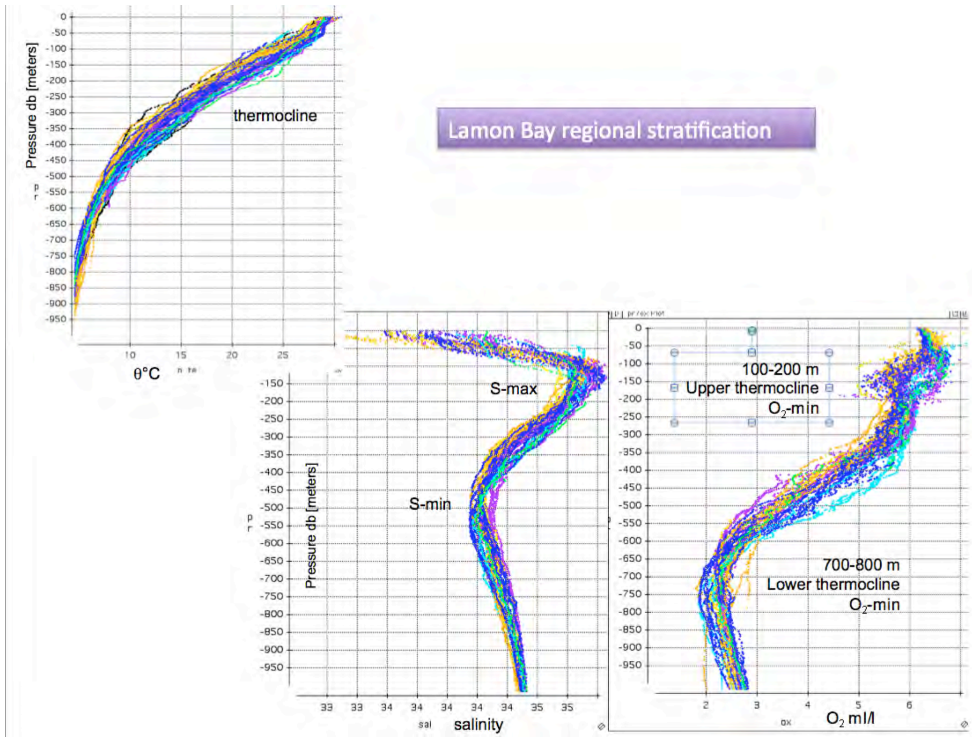


Figure 10 Potential, salinity, oxygen stratification

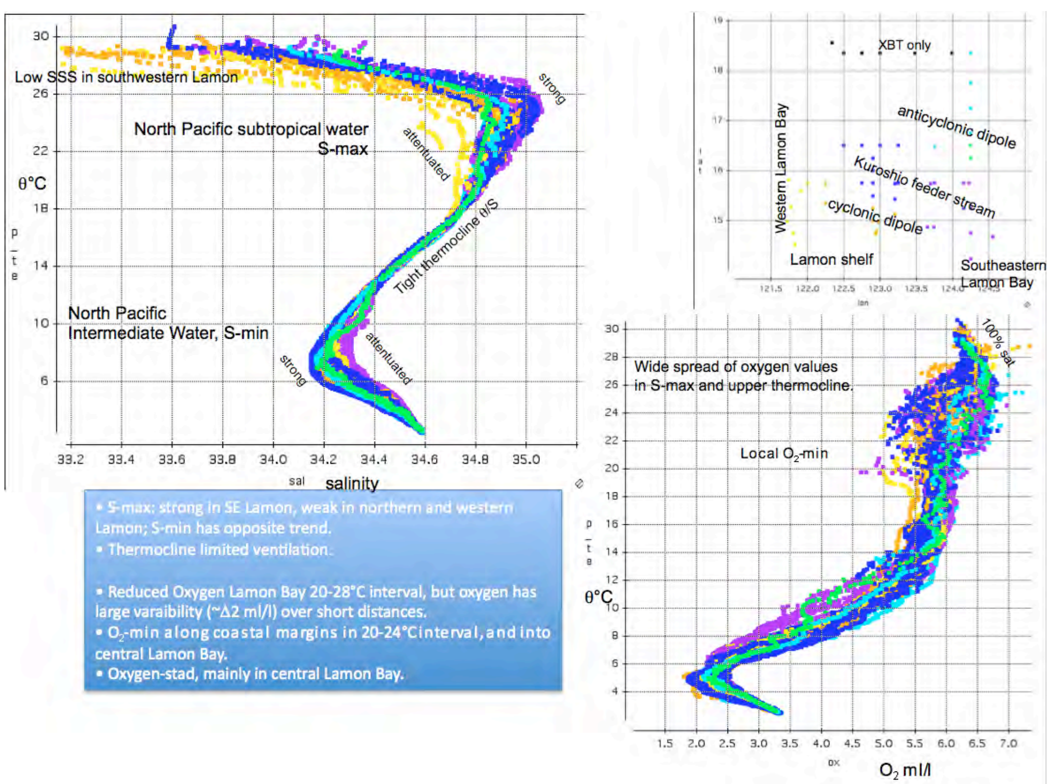


Figure 11: θ/S and θ/O_2

Acknowledgements:

Though we lost time to Typhoon Songda we accomplished a lot during Lamon Bay cruise #1. This was made possible by the wonderful efforts of the science and ship teams. The science team was effective, highly responsible. The Philippine group is a delight to work with. I thank Cesar Villanoy for arranging and coordinating their contribution. Special thanks is extended to my loyal, dedicated, research assistant of the last ~30 years, Phil Mele. Scripps ResTech were, as usual, capable and very willing to help meet the cruise objectives, allowing the science team to interface with the ship facilities seamlessly. It was so nice to sail again with Frank Delahoyde and Drew Cole, and to meet John Calderwood. Ship food just great, thanks to Marc and Mark. Ship Captain, T.J. Desjardins, ship officers and crew friendly and helpful in what was a challenging cruise because of the typhoon forced loss of time and uncertainties of ocean depths once over the southern tier of Lamon Bay.

4 June 2011
Arnold L. Gordon, Chief Scientist

Appendices

Shipboard Data Collection

Frank Delahoyde

Shipboard Data Collection

The R/V Roger Revelle has a variety of installed sensors, data collection systems and support instrumentation. Most of these were in use during Lamon Bay 2011, and consisted of:

Navigation Equipment

- Furuno GP150 GPS receivers (normally the primary source of GPS position);
- Leica MX421 GPS receiver;
- Ashtech ADU5 differential GPS receiver;
- Ixsea Hydrins inertial navigation and MRU;
- Ixsea Phins inertial navigation and MRU.

The survey locations for this equipment is included in the data distribution.

Acoustic Equipment

- Knudsen single beam echosounders with 3.5kHz and 12kHz transducers using a 320B amplifier deck unit;
- Kongsberg EM122 multibeam echosounder (full ocean range, center frequency 12kHz);
- RDI OS-75 75kHz ADCP;
- RDI NB-150 150kHz ADCP;
- SIO HDSS 50kHz and 140kHz ADCPs.

The survey locations for this equipment is included in the data distribution.

Underway System

- Met data collection system integrates flow-through (sea surface) and meteorological measurements, presents the data through a web interface and provides time series data sets.
- Two flow-through systems, the first located in the bow-thruster room provides accurate sea surface temperature and salinity. The second is located in the hydro lab, approximately 30 meters aft of the intake and provides for a variety of near sea surface measurements including:
    - Temperature and salinity;
    - Dissolved oxygen;
    - Chlorophyll-A (fluorometer);
    - Transmissivity (transmissometer).

  Additionally, science-supplied instrumentation can be incorporated into this system given advanced notice.

CTD and Rosette Systems

- SBE 911 CTDs with redundant temperature and conductivity, dissolved oxygen, fluorometer, transmissometer, PAR and altimeter sensors;
- 24-place 10L rosette with SBE 32 carousel;
- Dedicated acquisition systems in the computer lab.

Miscellaneous Instrumentation

- Gravimeter (Bell Aero BGM-3);
- WAMOS X-band RADAR and wave height detection system;
- XBT acquisition system (Turo and Sippican).

The Revelle has computer networks (1000/100 Mbit, wifi) connecting these instruments to servers and to computers throughout the ship, including lab spaces and cabins. Two satellite communications systems (HighSeasNet and

Fleet Broadband) provide 24/7 internet connectivity. Additionally, a 3G modem provides internet connectivity in ports where satellite communication is limited or not feasible.

Operational notes for Lamon Bay 2011/RR1107

There were very few operational problems with shipboard instrumentation during Lamon Bay 2011.The Leica MX421 GPS receiver was repaired shortly before leaving Kao-hsiung, Taiwan after the antenna cable had inadvertently been pulled out of the antenna. It operated without further incident. The primary satellite communications system (HighSeasNet) was not operational for most of the cruise, but was repaired during the last week. The CTD acquisition systems occasionally would not communicate with the SBE 11 deck unit, a problem that was traced to a bad interaction between printing and the specific version of the SBE Seasave software. The HDSS systems stopped acquiring data several times during periods of bad weather and required restarting.

The Kongsberg EM122 multibeam data were acquired with SIS-3.8 software from Kongsberg, and reprocessed and gridded with mbsystem-5.2.0-0.1880 for the data distribution. Sound speed profiles derived from CTD casts and 7 XBT drops were applied at regular intervals, but were not applied to the mbsystem-reprocessed data. These data have not been ping-edited or otherwise cleaned up and are provided as-is. The Knudsen 3.5kHz single beam echosounder was run at the same time as the EM122 for much of the cruise. The pings were synchronized between the two echosounders using external synchronization.

CTD data were acquired on a dedicated system running SBE Seasave-7.21a. The raw data and bottle trip location information were reprocessed into 2 db down cast pressure series files with sioodf-5.1.6-1 software from the SIO STS Oceanographic Data Facility, software used for WOCE and CLIVAR CTD processing. Both the SBE-processed CTD data and the SIO-processed CTD data are provided in the data distribution, in data/CTD and data/ctd-sio respectively.

Cruise event logs were maintained by the bridge and by the SIO CTD system and consist of times and positions of deployments and recoveries. The bridge event log is data/event.log and the SIO CTD event logs are data/ctd-sio/lb01-casttimes* in the data distribution.

Survey locations of GPS antennas, MRUs and SONAR transducers are provided in the data distribution in data/doc/vessel_reference_system.

CTD/XBT/Drifter Report

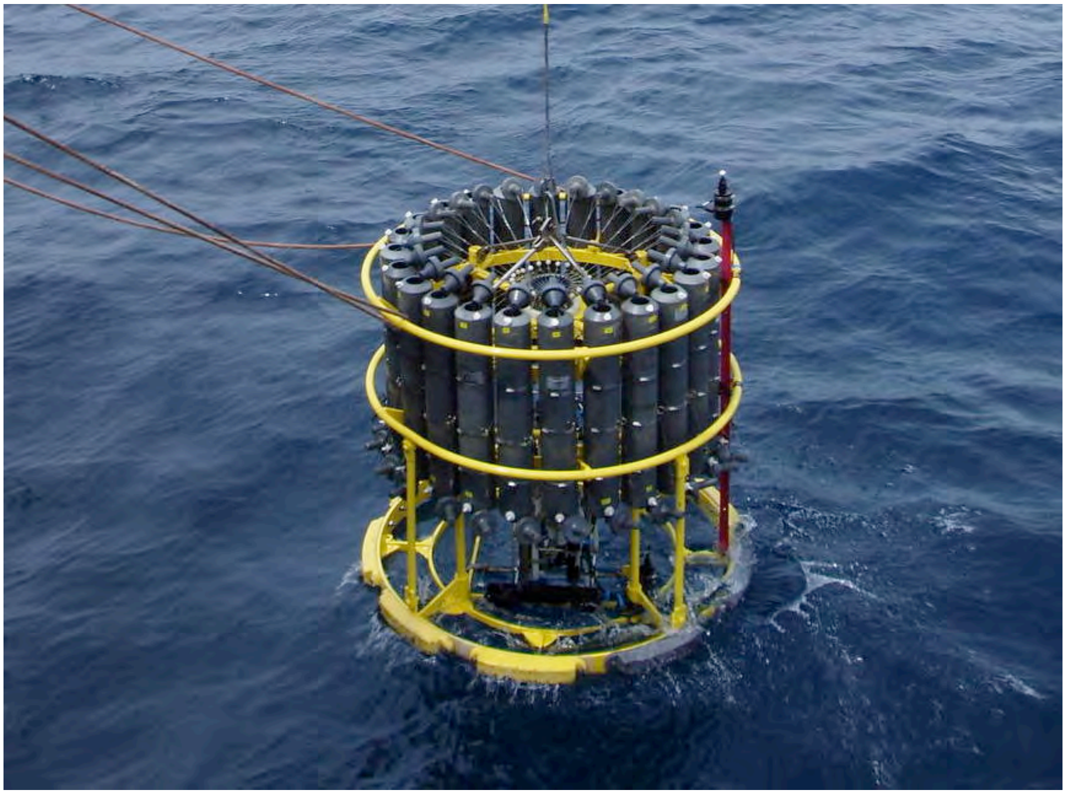
Phil Mele

CTD:

45 profiles of temperature, salinity and dissolved oxygen were obtained using equipment provided by ODF/SIO. The basic package consisted of a SeaBird Electronics SBE911+ CTD system fitted with two sets of ducted conductivity and temperature sensors, dual pumps, and a single SBE43 dissolved oxygen sensor. The sensor suite was mounted vertically. One second GP90 GPS data were merged with the CTD data stream and recorded at every CTD scan. Data were acquired using a Windows PC and SeaBird Seasave software. Data was processed by a suite of ODF programs. The CTD package remained on deck during the cruise.

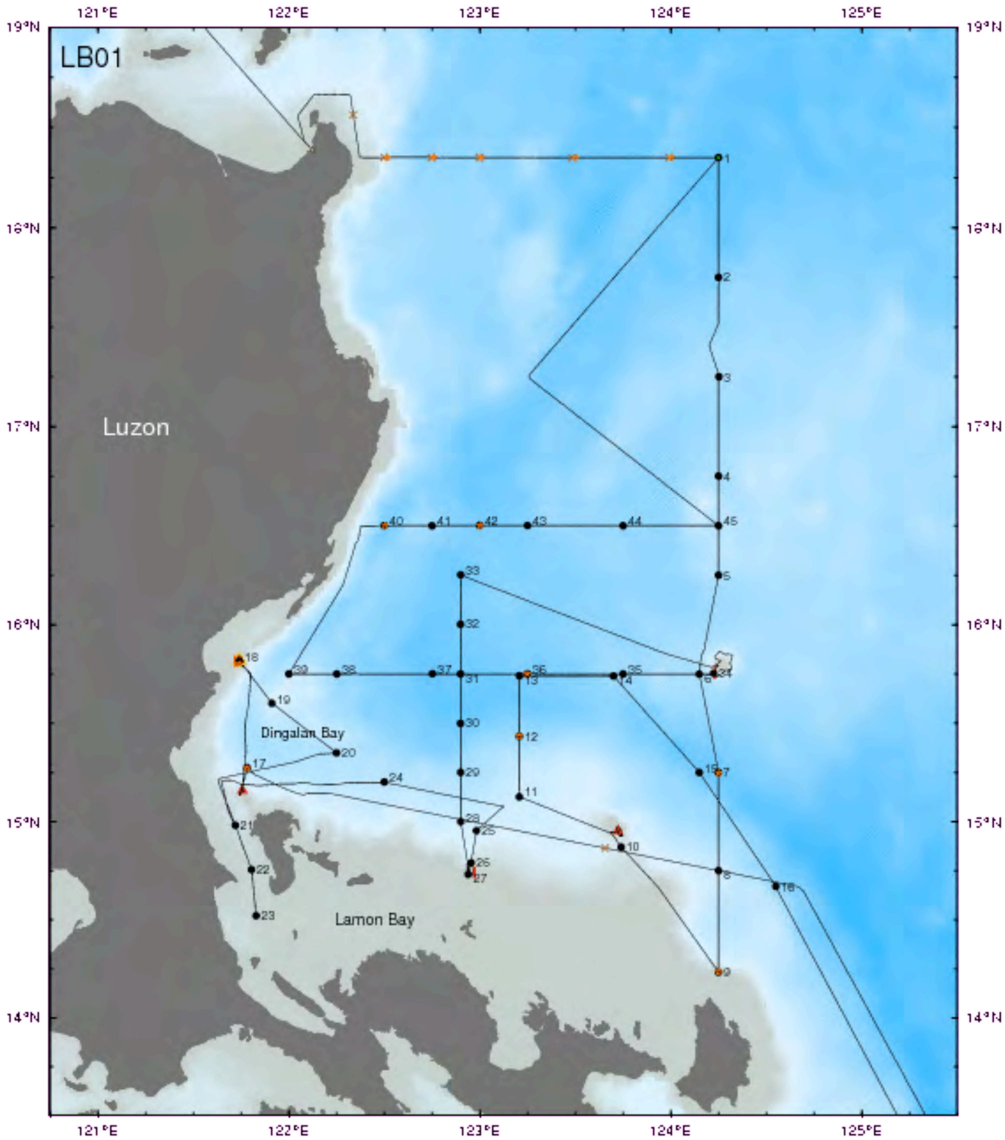
Most profiles were ended at 1550 m, or to within 10 m of the bottom where the bottom was shallower. Approach to the bottom was guided by a Benthos altimeter mounted on the frame.

Water samples were collected using a 24-position carousel fitted with 24 10 liter water sample bottles. Water samples were collected for on board analysis of dissolved oxygen for standardizing the CTD data. Water sample dissolved oxygen was determined by modified Winkler method for a spectrophotometer.



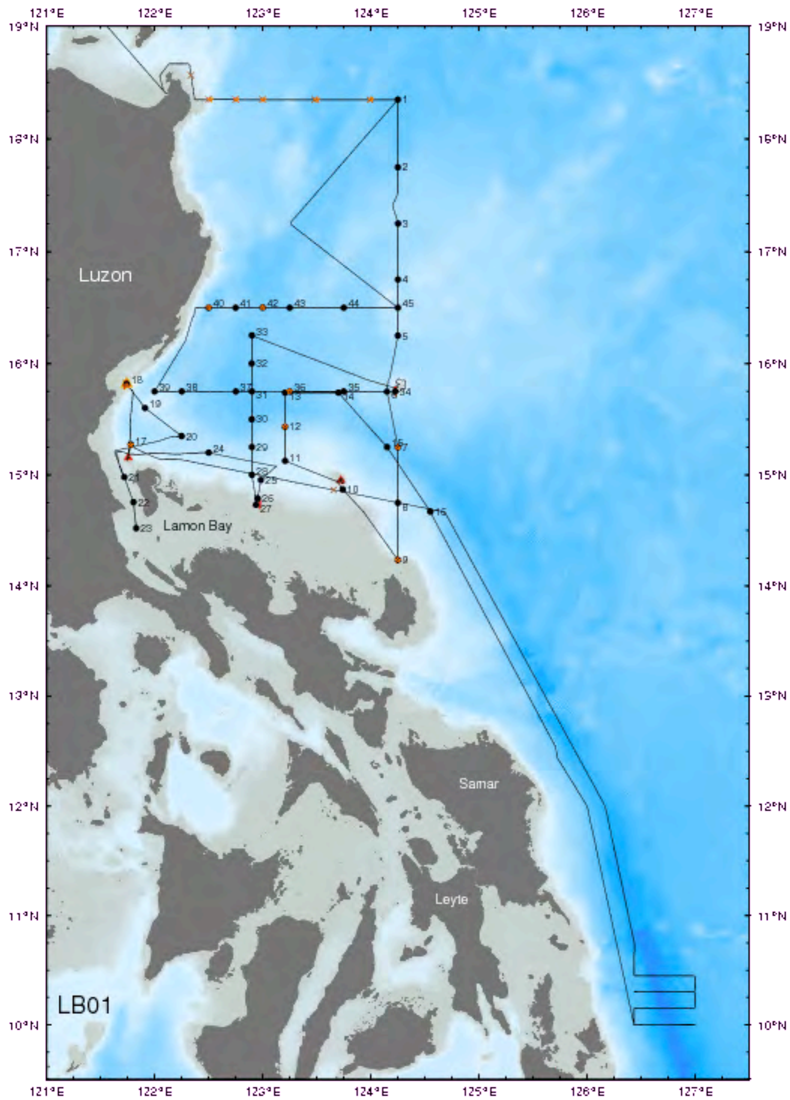
CTD Summary Table:
depth: seafloor depths are from MultiBeam data.

sta	lat (N)	lon (E)	yyyy/mm/dd	hh:mm	depth
1	18 21.00	124 14.99	2011/05/20	02:05	5785
2	17 45.00	124 14.99	2011/05/20	06:28	4691
3	17 15.04	124 15.14	2011/05/20	10:42	3195
4	16 45.01	124 15.01	2011/05/20	15:01	2818
5	16 15.01	124 15.01	2011/05/20	19:22	2934
6	15 44.92	124 8.94	2011/05/20	23:38	2504
7	15 15.00	124 14.96	2011/05/21	03:52	5733
8	14 44.99	124 14.99	2011/05/21	08:06	1937
9	14 14.00	124 15.01	2011/05/21	12:59	341
10	14 52.28	123 44.39	2011/05/21	17:57	603
11	15 7.60	123 12.40	2011/05/22	08:32	1368
12	15 25.99	123 12.38	2011/05/22	11:08	3484
13	15 44.40	123 12.40	2011/05/22	14:26	5068
14	15 44.39	123 41.97	2011/05/22	18:57	3630
15	15 15.04	124 8.95	2011/05/23	00:22	5242
16	14 40.23	124 32.99	2011/05/23	05:15	3672
17	15 16.49	121 46.85	2011/05/27	18:20	2693
18	15 49.01	121 44.49	2011/05/28	08:38	179
19	15 36.11	121 54.69	2011/05/28	12:25	1443



sta	lat (N)	lon (E)	yyyy/mm/dd	hh:mm	depth
20	15 20.99	122 14.99	2011/05/28	17:53	2797
21	14 58.89	121 43.21	2011/05/28	23:57	413
22	14 45.34	121 48.28	2011/05/29	02:18	251
23	14 31.27	121 49.76	2011/05/29	04:14	121
24	15 12.11	122 29.97	2011/05/29	14:32	2338
25	14 57.30	122 58.96	2011/05/29	22:01	1116
26	14 47.42	122 57.23	2011/05/30	02:01	792
27	14 43.91	122 56.33	2011/05/30	07:07	81
28	15 0.00	122 53.99	2011/05/30	09:00	1467
29	15 15.04	122 54.03	2011/05/30	11:28	2913
30	15 29.99	122 53.93	2011/05/30	14:30	5041
31	15 45.02	122 53.95	2011/05/30	16:59	5563
32	16 0.09	122 53.93	2011/05/30	19:48	5002
33	16 15.11	122 54.02	2011/05/30	22:15	5290
34	15 45.18	124 13.49	2011/05/31	09:48	638
35	15 45.03	123 45.03	2011/05/31	18:34	3333
36	15 45.05	123 14.96	2011/05/31	22:50	4829
37	15 45.08	122 45.14	2011/06/01	02:41	5640
38	15 45.02	122 15.07	2011/06/01	06:48	3153
39	15 45.00	122 0.02	2011/06/01	09:52	1669

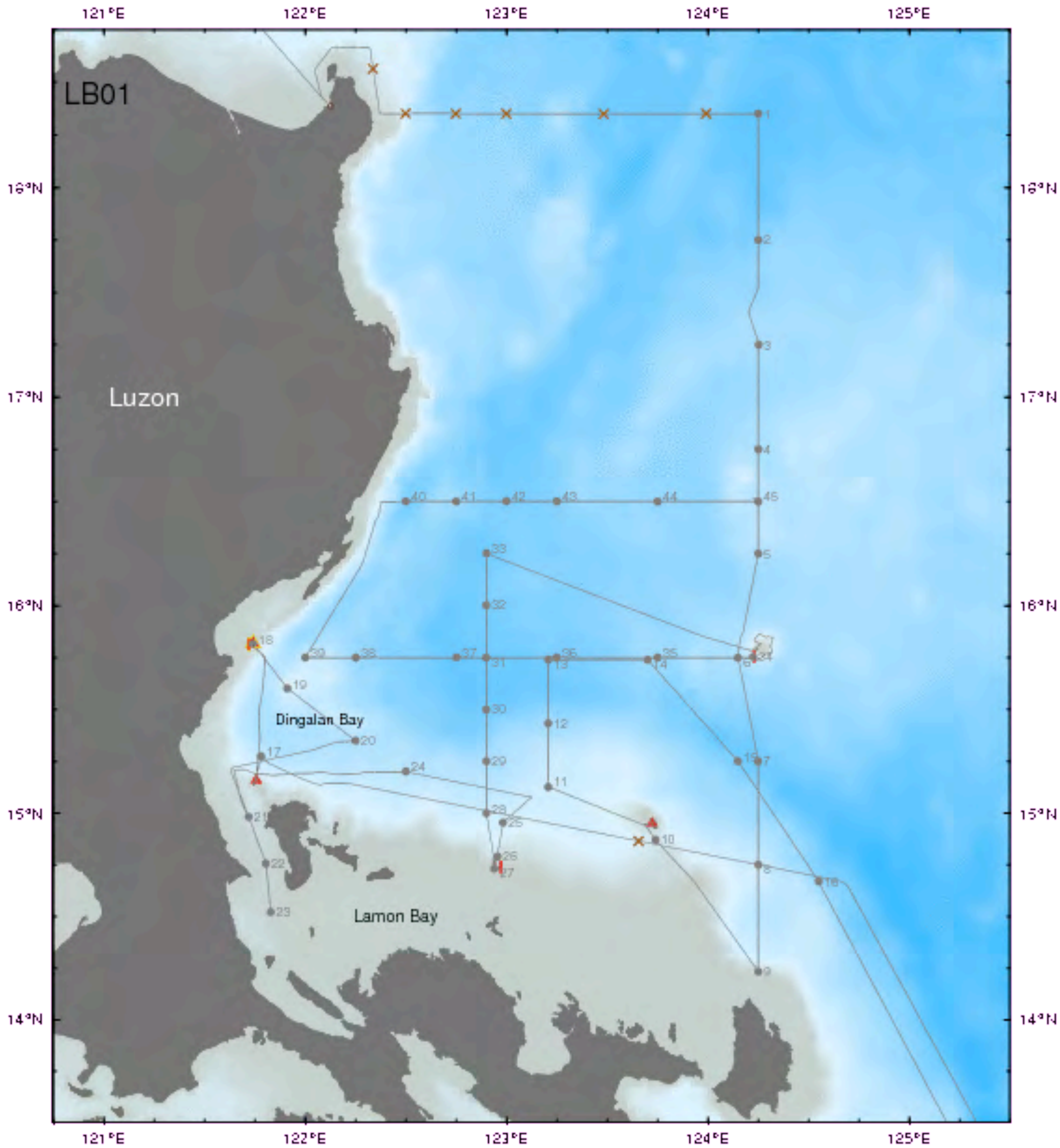
40	16 30.04	122 29.99	2011/06/01	19:46	4679
41	16 30.01	122 44.99	2011/06/01	23:05	3784
42	16 30.10	122 59.96	2011/06/02	01:49	5234
43	16 30.03	123 14.97	2011/06/02	04:44	4687
44	16 29.99	123 44.99	2011/06/02	08:34	3958
45	16 30.01	124 14.98	2011/06/02	12:22	2409



XBT

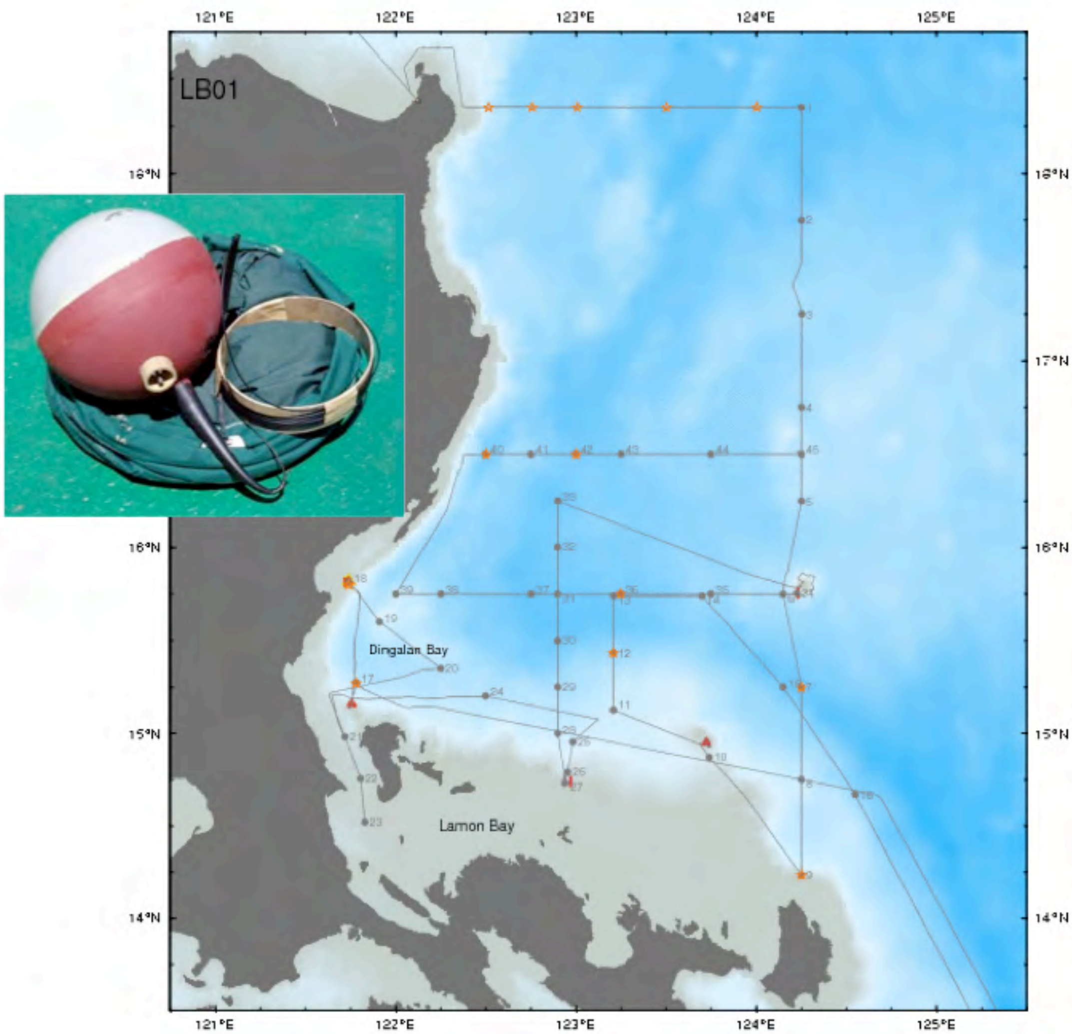
7 XBTs were launched during the cruise.

num	lat (N)	lon (E)	yyyy/mm/dd	hh:mm
1	18 33.82	122 20.22	2011/05/19	13:48
2	18 21.06	122 29.91	2011/05/19	15:32
3	18 21.05	122 44.90	2011/05/19	17:01
4	18 21.01	122 59.94	2011/05/19	18:24
5	18 20.97	123 28.92	2011/05/19	20:51
6	18 21.01	123 59.45	2011/05/19	23:35
7	14 51.92	123 39.31	2011/05/27	06:56


LB01
Luzon
Dingalan Bay
Lamon Bay
121°E
122°E
123°E
124°E
125°E
18°N
17°N
16°N
15°N
14°N

SVP Drifters

13 Surface Velocity Program (SVP) drifters were deployed in cooperation with Luca Centurioni (SIO).



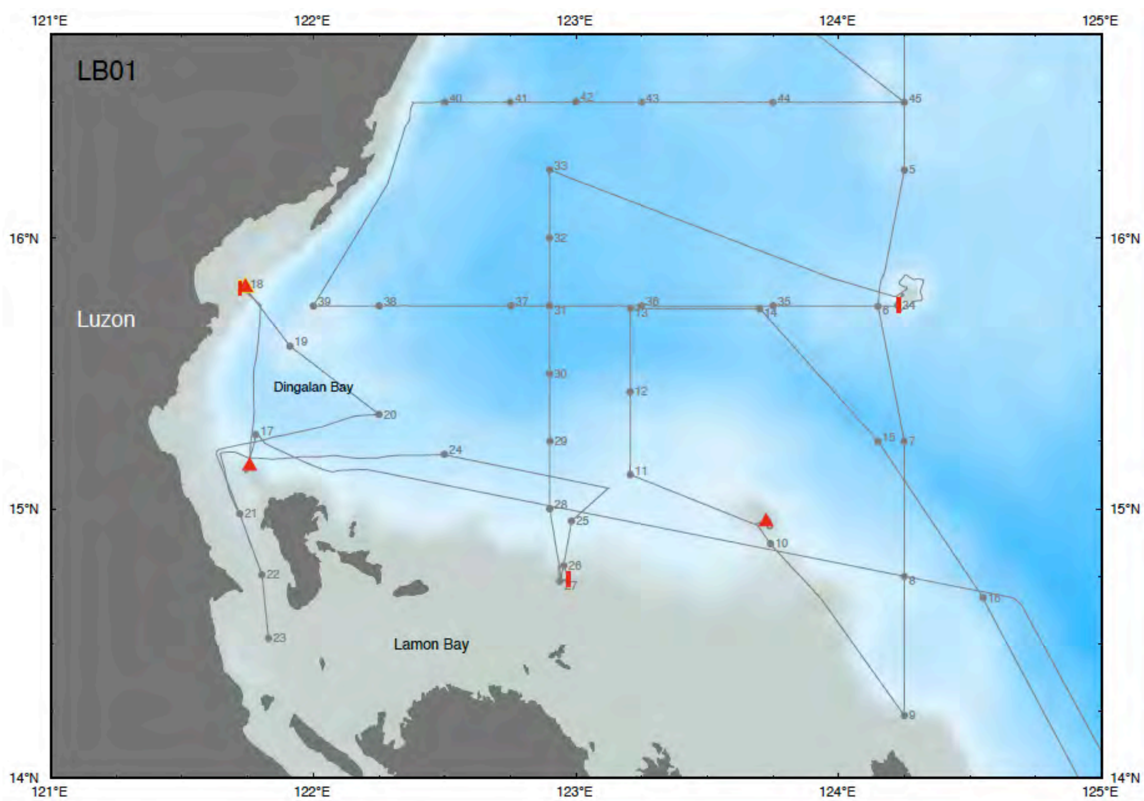
ID	date	gmt	lat	lon	notes
82446	19may2011	15:45	18 20.926	122 30.98	
43511	19may2011	17:11	18 21.013	122 45.473	magnet loose
82404	19may2011	18:31	18 21.006	123 00.393	
82448	19may2011	21:06	18 20.962	123 30.198	
82408	19may2011	23:45	18 21.010	124 00.112	
82405	21may2011	05:28	15 14.883	124 14.986	
98887	21may2011	13:48	14 14.012	124 14.981	
43660	22may2011	12:39	15 26.035	123 12.411	
82380	27may2011	20:01	15 16.232	121 46.771	
82412	28may2011	09:07	15 48.008	121 44.490	
82443	01jun2011	00:11	15 45.085	123 14.844	
82411	01jun2011	21:35	16 30.057	122 30.171	
82406	02jun2011	03:16	16 30.069	123 00.045	

Mooring Program

[B] Moorings deployed during Lamon Bay #1 [to be recovered in 2012]:

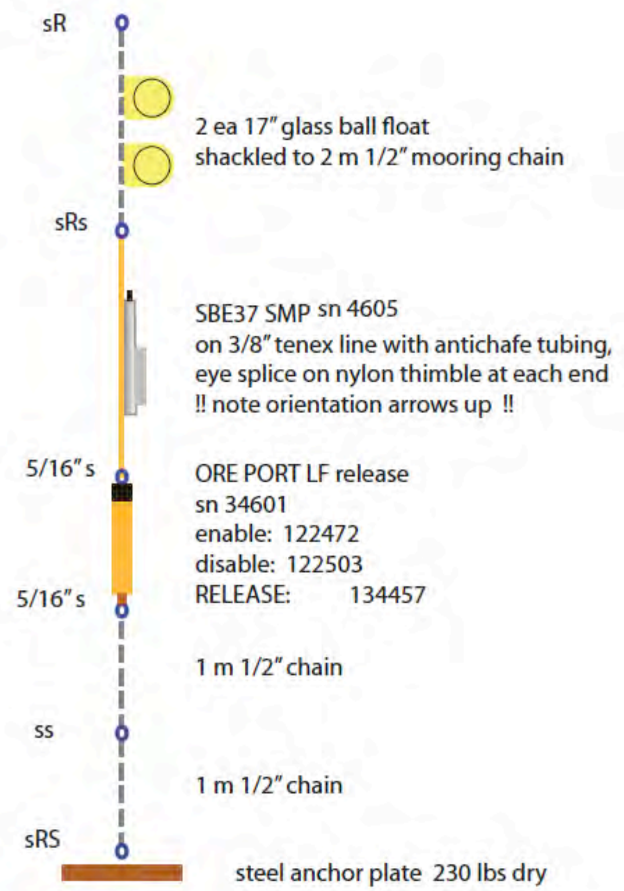
what	long°E	latitude°N	Day GMT	depth
TRBM1	123.7233	14.9517	22may2011	145
TRBM2	121.7572	15.1581	27may2011	192
TRBM3:	121.7415	15.8186	28may2011	180
T/S Bottom:	121.7201	15.8158	28may2011	86
Mooring [line] 1	122.9715	14.7405	30may2011	226
Mooring [line] 2	124.2274	15.7540	31may2011	757

Mooring map [red triangles = TRBM; red bars: moorings with cable]



There are a total of six (6) mooring, three on bottom mounts, and three on wire mounts.

1. Approximate Site: 15°50'N; 121°45'E; water depth ~ 50 m. Sea-Bird Electronics SBE37 temperature-salinity recorder; ORE CART acoustic release; anchor, glass-ball flotation.



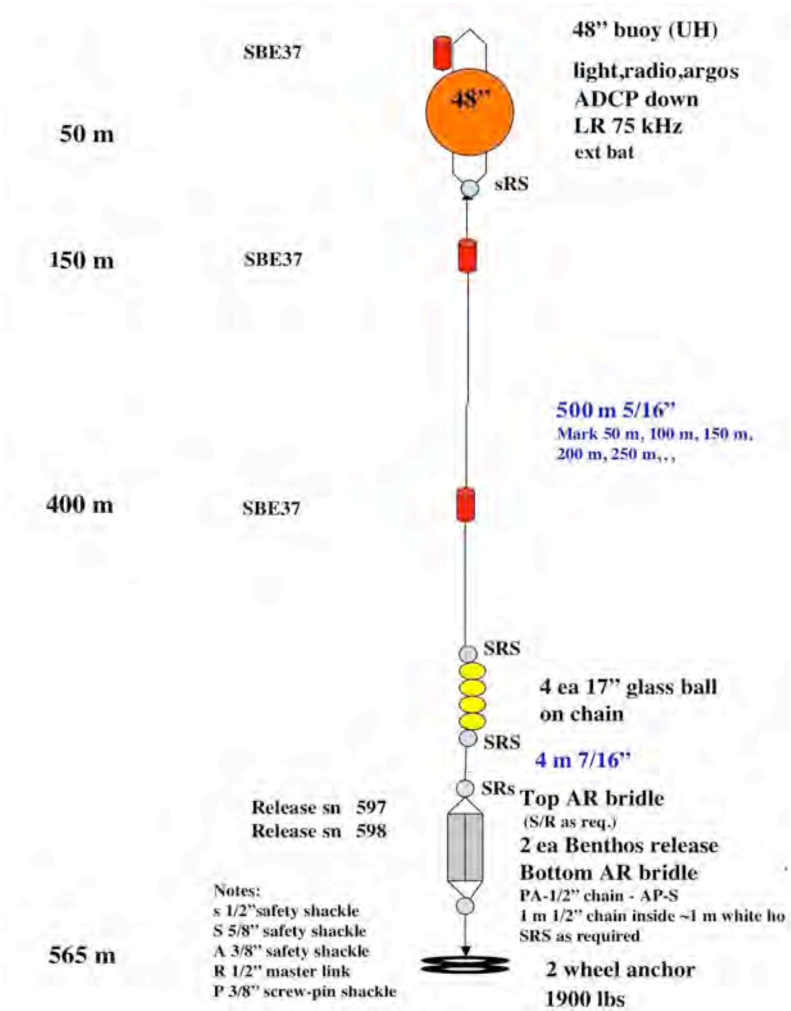
2. Approximate site: 15°45'N; 121°50'E; water depth ~ 200 m. see schematic: Nortek Continental acoustic Doppler current profiler; Sea-Bird Electronics SBE37 temperature-salinity recorder; ORE acoustic release (type yet to be determined), all installed in a Flotation Technologies trawl-resistant bottom mount (TRBM)

3. Approximate site: 15°10'N; 121°45'E; water depth ~ 200 m. see schematic: RDI 300 kHz Acoustic Doppler Current Profiler; dual Benthos acoustic release model

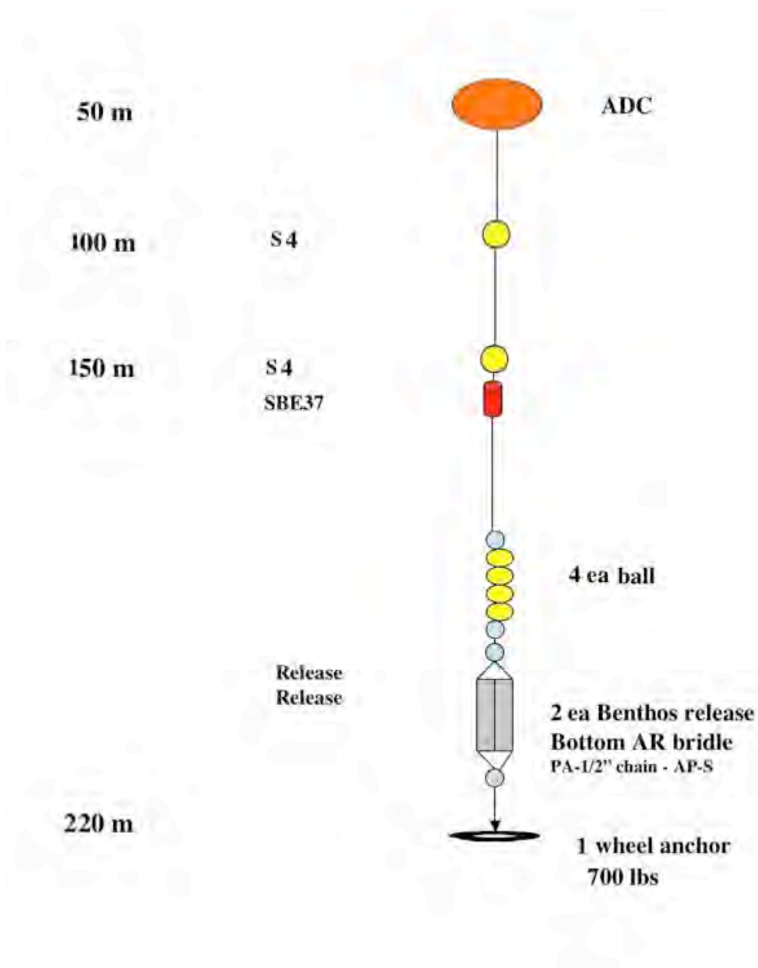
866A 12 kHz transmit, all installed in a Flotation Technologies trawl-resistant bottom mount (TRBM)

4. Approximate site: 14°50'N; 122°55'E; water depth ~ 200 m. see schematic: RDI 300 kHz Acoustic Doppler Current Profiler; dual Benthos acoustic release model 866A 12 kHz transmit, all installed in a Flotation Technologies trawl-resistant bottom mount (TRBM)

5. Approximate Site: 15°30'N; 121°35'E; water depth ~565 m. See schematics: sub-surface Flotation Technologies 48" syntactic foam sphere, thee (3 Sea-Bird Electronics SBE37 temperature-salinity recorders; RDI 75 kHz Acoustic Doppler Current Profiler with external battery pack; dual Benthos acoustic release model 865A 12 kHz transmit; 1900 lbs steel anchor, glass-ball auxiliary flotation; MetOcean GPS/Iridium surfacing detector/tracking beacon, Novatech strobe light beacon; Novatech VHF beacon, dual Novatech strobe/VHF beacon.


48" buoy (UH)
light,radio,argos
ADCP down
LR 75 kHz
ext bat
SBE37
48"
50 m
sRS
150 m
SBE37
500 m 5/16"
Mark 50 m, 100 m, 150 m,
200 m, 250 m,,,
400 m
SBE37
SRS
4 ea 17" glass ball
on chain
SRS
4 m 7/16"
SRs
Top AR bridle
(S/R as req.)
Release sn 597
Release sn 598
2 ea Benthos release
Bottom AR bridle
PA-1/2" chain - AP-S
1 m 1/2" chain inside ~1 m white ho
SRS as required
Notes:
s 1/2"safety shackle
S 5/8" safety shackle
A 3/8" safety shackle
R 1/2" master link
P 3/8" screw-pin shackle
565 m
2 wheel anchor
1900 lbs

2. Approximate site: 15°00'N; 123°40'E; water depth ~ 220 m. See schematics: Mooring Systems sub-surface 30” syntactic foam ellipsoid, one (1) Sea-Bird Electronics SBE37 temperature-salinity recorder; one (1) Sontek Argonaut 1.2 MHz Acoustic Doppler Current meter; two (2) Interocean S4 electronagnetic current meters, dual Benthos acoustic release model 866A 12 kHz transmit, 700 lbs steel anchor.



CRUISE REPORT RR1107 (PHILIPPINE COMPONENT)

INTRODUCTION

Off the east coast of the Philippines, the NEC bifurcates into the Kuroshio and Mindanao Currents. The northern bifurcation flows just off the shelf of the Bicol Peninsula (north of 14°N) and proceeds northwestward to the northeastern Luzon coast. Chlorophyll images such as the one shown in

Figure 1 show elevated chlorophyll concentrations indicating enhanced productivity. In addition, ocean color patterns also serve as a tracer to show current patterns. For instance, a cyclonic eddy is apparent in the inshore side of the northwestward flow, which feeds into the Kuroshio current (

Figure 1). The objective of the Philippine component is to determine the effects of the complex current patterns in the origin of the Kuroshio on the productivity of the coastal waters in the vicinity of Lamon Bay.

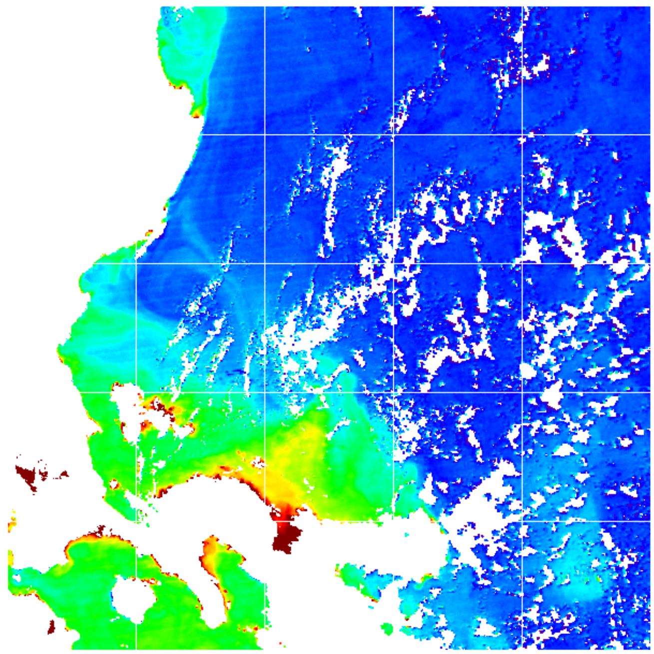


Figure 1. MODIS chlorophyll taken May 16, 2011.

PHILIPPINE PARTICIPANTS

Cesar Villanoy	Mary Chris Tentia
Gil Jacinto	Charissa Ferrera
Aletta Yniguez	Maria Teresa Escobar
Olivia Cabrera	Rhodelyn Saban
Marilou Martin	Joseph Dominic Palermo
Leilani Solera	Marianne Camoying
Sanny David Lumayno	Iris Salud Bollozos
Sheen Cabacaba	Jar Mar Quevedo
Lara Sotto	Benjamin Magura
Isabel Senal	

COMPONENTS

CHEMICAL OCEANOGRAPHY

INTRODUCTION

The eastern coast and shelf of Luzon is a unique area encompassed by the bifurcation of the western boundary North Equatorial Current (NEC) into the Kurushio and Mindanao Currents. The shelf configuration is fairly complicated with a unique shelf extension ("bump") along the edge near 15.5°N and 123.5°E as well as unusual shallowing at the edge before the depth increases at the slope. The complex topography of the Bicol shelf is hypothesized to result in the formation of westward moving eddy structures originating from northward branch of the bifurcation of the NEC. These features appear to provide nutrients to the less productive offshore areas as they entrain chlorophyll-rich waters from the shelf. The chemical oceanography component of SPIL, therefore, will pursue this suggestion and build on the earlier findings of the Pacific Seaboard Research and Development Program; thus, find a mechanism by which nutrients from beyond the shelf break can intrude well into the shelf area, and understand how the interaction between the shelf and open ocean can influence coastal processes both in the Bicol Shelf and along the coast of Aurora. We wish to characterize the chemical features (C, N, P) of the Bicol Shelf and off-shelf areas; in particular, to verify if the uplift of isotherms off the shelf break is accompanied by a corresponding increase in chlorophyll-a concentration and nutrients. In addition, we will estimate the primary productivity in these waters, and determine if the upwelling may be a significant mechanism for the apparent high biological productivity on the shelf. Finally, we seek an appreciation of the carbon and carbonate chemistry affecting the 2nd widest shelf area in the country.

Amongst others, we intend to address the following questions:

1. What chemical parameters indicate the presence of upwelling on the Bicol Shelf (e.g., sloping nutrient isolines)?
2. Is there cross-shelf exchange of nutrients (N, P, Si)?
3. If upwelling does occur, how does this feature affect the biogeochemistry of C,N, and P?
4. What forms (organic or inorganic) of C and N are exported or accumulated from the shelf to off-shelf or to the open sea and within and outside the eddies?
5. What nutrients or physical properties limit primary production in the shelf?
6. Is the Bicol shelf a source (upwelling) or sink (primary production) of carbon?
7. How much DOM is exported as new primary production in the shelf upwelling system?
8. Is ocean pH lower on the shelf (due to upwelling)? Are pH changes/differences associated with anthropogenic activities (on the shelf area and near the coast) distinguishable from water column biological processes?
9. What insights on ocean acidification can we gain from the behavior of the carbonate-related parameters (pH, alkalinity and ΣCO_2) on the shelf area and the impinging NEC?

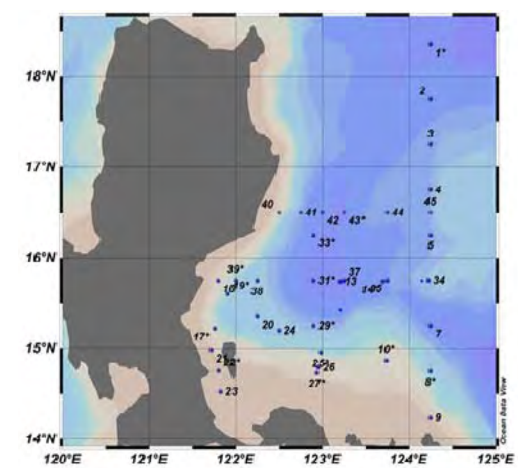


Figure 2. Stations occupied for water sampling. Full cast stations are indicated by an asterisk.

METHODOLOGY

Water collection at selected depths from the CTD-rosette was done for a suite of chemical parameters (Table 1). The sampling strategy was divided into two: a "full cast" for 14 shelf and off-shelf stations where samples for all the chemical parameters were obtained; and a "normal cast" for the rest of the stations where water samples for only selected parameters were acquired (Figure 1). Water samples at varying depths (typically 5 depths including a few from 1500m) were also obtained for Winkler oxygen determination starting at Station 18 until Station 41 to calibrate the CTD DO sensor. Primary productivity measurements were done at 3 sites (representing offshore, shelf and mid-section stations; see Figure 1) using the light and dark bottle method. Table 2 summarizes the parameters obtained at the sampling stations.

Table 1. Sea water samples obtained for determination of various chemical parameters.

Parameter	Sampling strategy	Volume required (L)	Sample preparation	Analysis	Method of analysis
Dissolved oxygen (DO)	All stations, selected depths	1.0	Silicone tubing, overflow	On board	Spectrophotometric method, Winkler titration method
Dissolved inorganic carbon, total alkalinity, pH (CO_2)	14 stations, all depths	1.0	Overflow, preservation with $HgCl_2$	Lab	DIC analyzer, spectrophotometric method, titration
Onboard pH (pH)	All stations, all depths	0.05	none	On board	pH meter
Dissolved organic carbon (DOC)	14 stations, all depths	0.05	In-line filter, overflow, preservation with acid	Lab	High temperature combustion oxidation
Total dissolved nitrogen and phosphorus (TDN and TDP)	14 stations, all depths	0.15	In-line filter, overflow	Lab	Persulphate oxidation, analyze as DIN
Colored dissolved organic matter (CDOM)	14 stations, selected depths	0.2	In-line filter, overflow	Lab and on board	Fluorescence via benchtop fluorometer
Particulate organic carbon and nitrogen (POC, PON)	14 stations, all depths	4.5	Filtration (manifold)	Lab	CHN elemental analyzer
Nutrients (DIN, DIP, silicate)	All stations, all depths	0.3	none	Lab	Colorimetric method with segmented flow nutrient autoanalyzer
Chlorophyll-a (Chl-a)	All stations, selected depths	2.5	Filtration (manifold)	Lab	Fluorometric
Primary productivity	14 stations, selected depths	10	BOD bottles, incubation for 4 hours in a water bath	On board	Light and dark bottle method, Spectrophotometric method and Winkler titration

Table 2. Summary of parameters obtained per station

CTD	Lat	Long	DO	CO2	pH	DOC	TDN	PON/PN	nutrients	chl-a	CDOM	Primary Productivity	DCM depth (m)
1	18.350	124.250	●	●	●	●	●	●	●	●	●		160
2	17.750	124.250	●		●				●	●	●		120
3	17.250	124.250	●		●				●	●	●		110
4	16.750	124.250	●		●				●	●	●		120
5	16.250	124.250	●		●				●	●	●		175
6	15.750	124.150	●		●				●	●	●		125
7	15.250	124.250	●		●				●	●	●		125
8	14.750	124.250	●	●	●	●	●	●	●	●	●		125
9	14.200	124.250	●		●				●	●	●		75
10	14.870	123.740	●	●	●	●	●	●	●	●	●	●	120
12	15.433	123.207	●		●				●	●	●		125
13	15.740	123.207	●		●				●	●	●		115
14	15.740	123.700	●	●	●	●	●	●	●	●	●		125
17	15.220	121.760	●	●	●	●	●	●	●	●	●		100
18	15.750	121.800	●		●				●	●	●		70
19	15.602	121.912	●		●				●	●	●		100
20	15.350	122.250	●		●				●	●	●		90
21	14.982	121.720	●		●				●	●	●	●	75
22	14.755	121.805	●	●	●	●	●	●	●	●	●		70
23	14.522	121.890	●		●				●	●	●		45
24	15.200	122.500	●		●				●	●	●		100
25	14.955	122.983	●	●	●	●	●	●	●	●	●	●	75
26	14.790	122.954	●		●				●	●	●		50
27	14.732	122.939	●	●	●	●	●	●	●	●	●		30
28	15.000	122.900						no water sampling; CTD only					
29	15.251	122.901	●	●	●	●	●	●	●	●	●		125
30	15.500	122.899						no water sampling; CTD only					
31	15.750	122.899	●	●	●	●	●	●	●	●	●		80
32	16.001	122.899						no water sampling; CTD only					
33	16.252	122.900	●	●	●	●	●	●	●	●	●		115
34	15.753	124.225	●		●				●	●	●		
35	15.751	123.751	●		●				●	●	●		100
36	15.751	123.249	●		●				●	●	●		110
37	15.751	122.752	●		●				●	●	●		85
38	15.750	122.251	●		●				●	●	●		80
39	15.750	122.000	●	●	●	●	●	●	●	●	●		85
40	16.501	122.500	●	●	●	●	●	●	●	●	●		110
41	16.500	122.750	●		●				●	●	●		110
42	16.502	122.999	●		●				●	●	●		120
43	16.500	123.250	●	●	●	●	●	●	●	●	●		105
44	16.502	122.999	●		●				●	●	●		150
45	16.500	124.250	●		●				●	●	●		130

INITIAL RESULTS AND DISCUSSION

Dissolved oxygen calibration

A high correlation was obtained ($r^2 = 0.995$) between the CTD- and the Winkler-derived DO values (Figure 3), with a slope of ~ 1.012. This was further augmented and validated by additional DO data from the oxycline depths.

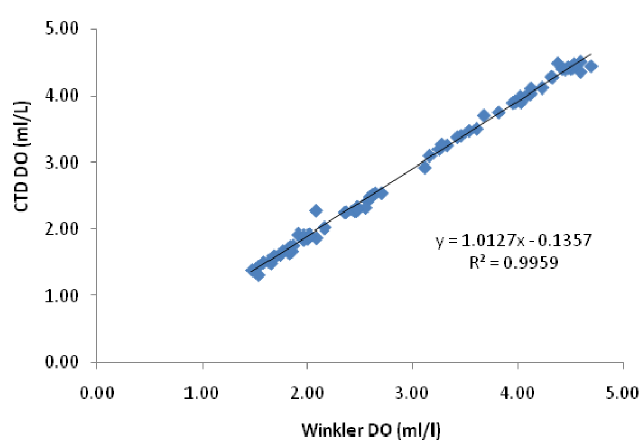


Figure 3. Comparison of DO obtained by the Winkler titration method and the CTD DO sensor

pH (onboard analysis)

Onboard analysis of pH was done on samples within two hours after collection using the method described by Dickson et al. (2007). Briefly, the buffer solutions (TRIS/HCl and AMP/HCl) as well as E of the sample were used as inputs to calculate the pH of the sample. Calculated pH using this technique is on the total hydrogen ion scale (pHT).

As expected and manifesting the exchange/dissolution of atmospheric CO_2 with/into surface waters, lower pH values were observed in surface samples (range: 8.00 – 8.15) in virtually all stations compared to pH values at ~10m (range: 8.105 – 8.16) (Figure 4). Nearshore/shelf stations also had lower surface pH values than those offshore.

Values of pH at the surface were also low and steadily increased with depth at the photic layer, below which the pH decreased steadily (Figure 5). Vertical profiles indicated the pH minima roughly coinciding with depths of the oxygen minima in virtually all deep stations.

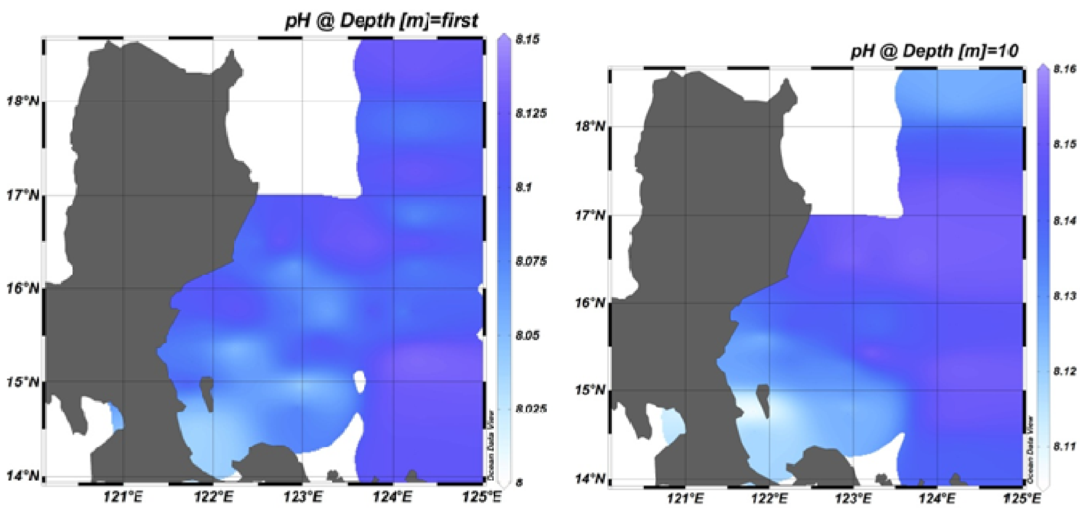


Figure 4. Contour plots of pH at the surface and at 10m depth.

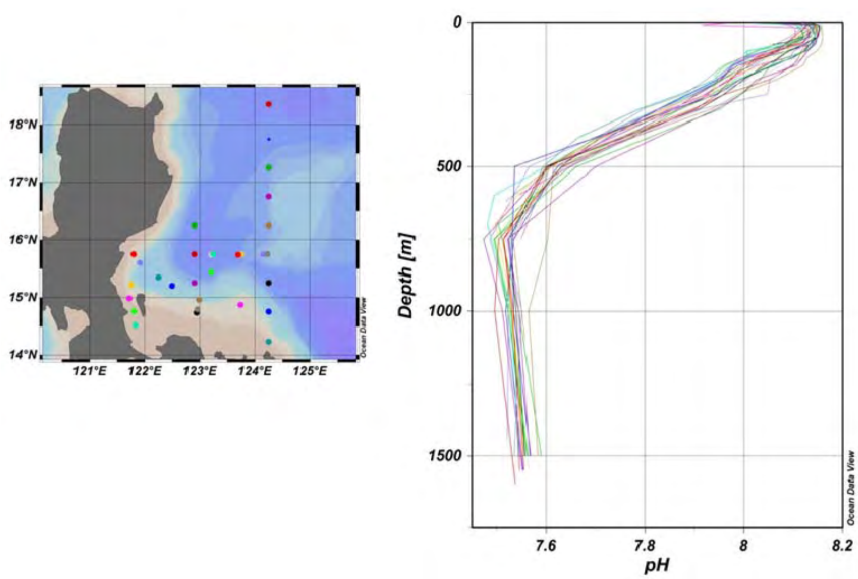
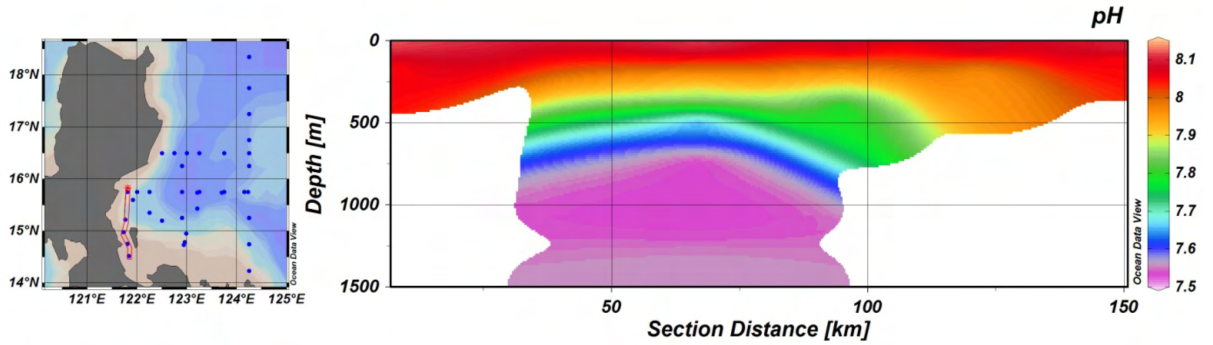
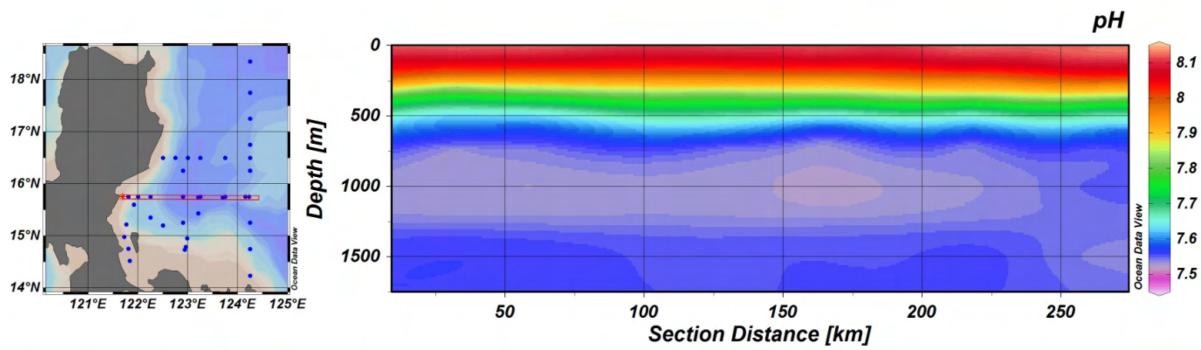


Figure 5. Vertical profiles of pH for all CTD stations.

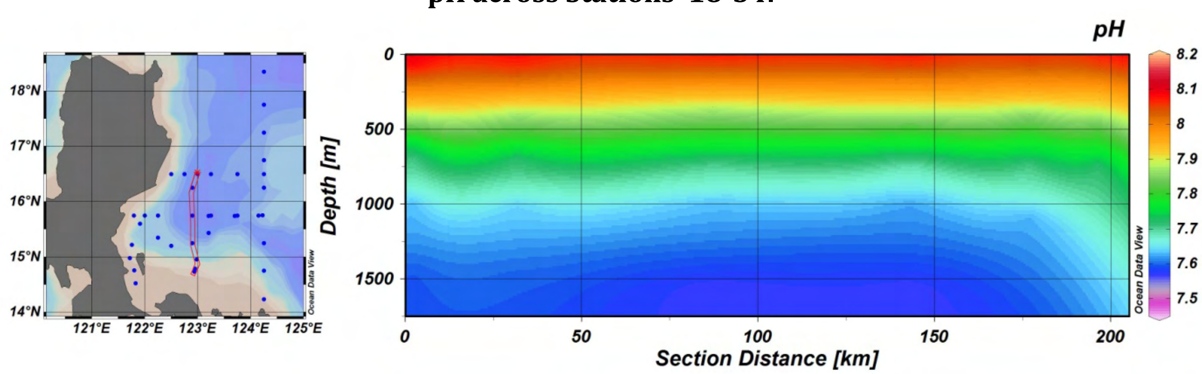
A few vertical contour plots of pH along various transects, generally from offshore to shelf stations are shown in Figure 6. At the shelf (nearshore) stations, higher pH down to depths below the photic zone were observed.



pH across Stations 18-23.



pH across Stations 18-34.



pH across Stations 42-27.

Figure 6. Contour plots of pH across transects.

PLANKTON

PLANKTON SAMPLING AND DETERMINATION

There were four spatial zones of interest identified a priori along the Bicol Shelf for plankton analyses. Figure 7 presents these four zones along with the CTD stations occupied during this May

2011 cruise. The general objectives for this component are (1) to determine the trophic interaction among three general plankton groups, namely, phyto-, zoo-, and ichthyoplankton, in the Bicol Shelf and (2) to correlate quantitative and qualitative plankton data with the hydrodynamic features of the shelf. These will be partially achieved by characterizing/identifying the dominant plankton class size and taxonomic groups and by the development of an e-library of plankton micrographs for FlowCAM analyses.

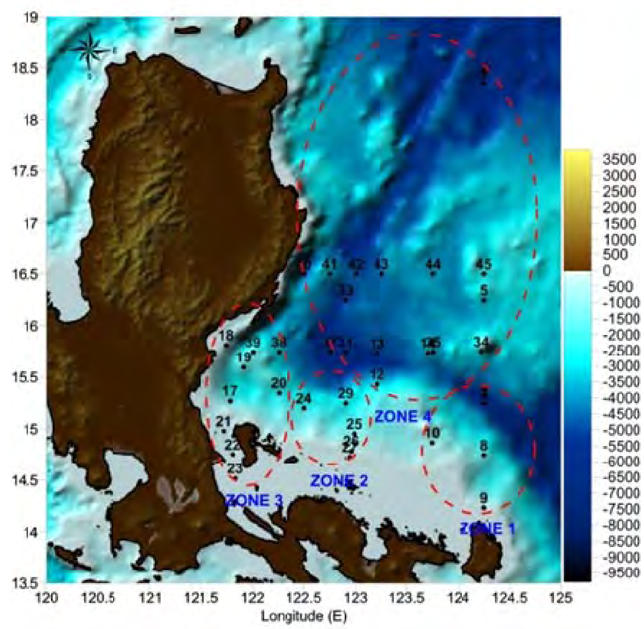


Figure 7. CTD stations in the identified zones of interest along the Bicol Shelf.

Collection and Preservation of Plankton Samples

During this cruise, plankton sampling was done through filtration of 10L water samples per depth obtained from Niskin bottles attached to a rosette. Selected CTD stations were considered for plankton sampling. The five general depths for deep stations were (1) subsurface, (2) above the deep chlorophyll maximum (DCM), (3) DCM, (4) below the DCM and (5) 200 meters. Modifications were made for shallower stations (< 200 meters) where either there were more than one DCMs observed or the DCM covered a wider depth profile. The modifications included an upper and lower DCM or an upper limit of DCM, middle of DCM and lower limit of DCM.

A set of six samples were obtained for each depth, with each sample corresponding to a target plankton component. Table 1 presents a detailed description of each sample type and fixative used. Comparison of fixatives used will be done for samples with the same target component.

Qualitative Collection of Plankton for Image Collection (E-Library)

Collection of images of live plankton specimens was done on board using the seawater from the ship's underway system. Slides were prepared and viewed in the phase-contrast compound microscope with attached ocular camera for image collection and classification (Figure 8). Images of live plankton specimen generated will later on be run through the PhytoImage/ZooImage software and/or Visual Spreadsheet which will be used in the calibration and build-up of a plankton database for automated analyses using the FlowCAM.

Table 3. Description of samples collected per depth.

	Sample description	Fixative	Purpose
1	Unfiltered	Lugol's solution	Nano Phytoplankton/Protists/Coccolithophore analyses (microscopy)
2	Unfiltered	Neutralized formalin	Nano Phytoplankton/Protists/Coccolithophore analyses
3	Filtred with 20µm sieve	Lugol's solution	> 20µm phytoplankton/protists conventional analyses (microscopy)
4	Filtred with 20µm sieve	Neutralized formalin	> 20µm phytoplankton/protists analyses using a FlowCAM
5	Filtred with 20µm sieve	Neutralized formalin	Gelatinous zooplankton analyses (either by microscopy or FlowCAM)
6	Filtred with 20µm sieve	Ethanol	Crustacean zooplankton analyses (either by microscopy or FlowCAM)

Quantitative and qualitative analyses of plankton samples

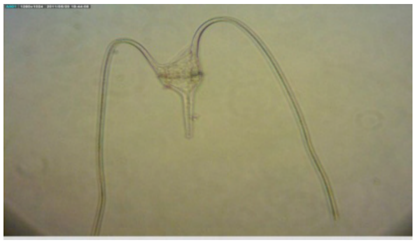
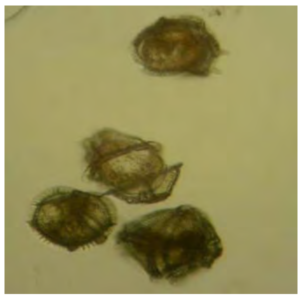
Plankton identification and density estimations will be done at the UP- Marine Science Institute after the cruise through conventional microscopy procedures and FlowCAM analyses. Density estimation and classification results from the conventional microscopy techniques will be compared to that of the FlowCAM outputs.

For the phytoplankton component, we also used a multi-excitation fluorometer (Infinity-ME) on board which we immersed into the water samples we collected to measure the specific spectral signatures of different phytoplankton functional groups. This instrument is also being optimized for more rapid assessment of phytoplankton assemblages.

Future undertaking and zones of interest

The cruise has brought focus to zones that need to be further investigated in relation to plankton dynamics and the productivity of the nearby coastal areas. In particular, potential upwelling/high mixing areas with relatively high productivity (and relatively lower sea surface temperatures) may be seen in certain sections possibly influenced by the impingement of the Kuroshio and resulting circulation gyres (Figure 9): offshore areas of Aurora, in between Polillo Island and the main land, the shelf break area,

To fully achieve the objectives of the plankton component of the Shelf-Pacific Interaction in Luzon (SPIL) project, an intensive plankton collection (using nets) within the four zones (or other zones of interest), if possible, would be necessary. Laboratory analyses of the samples will be similar to the analyses of the current samples. Presence of ichthyoplankton in the samples is expected. Gut analysis will be conducted on the dominant ichthyoplankton taxa, so as to supplement the analyses on the trophic interaction.

DINOFLAGELLATES	
	
	
	
DIATOMS	
	
	

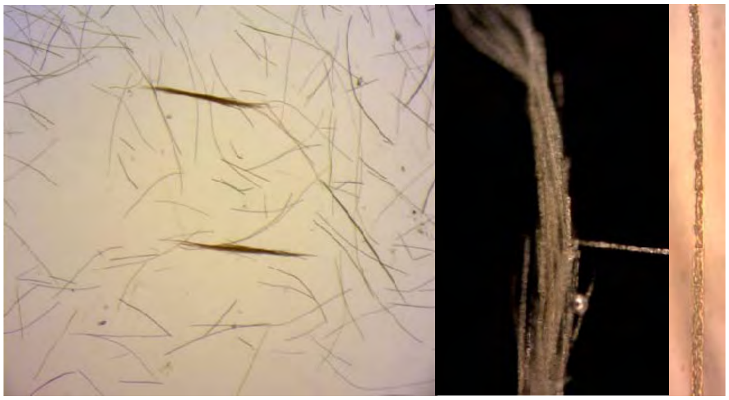
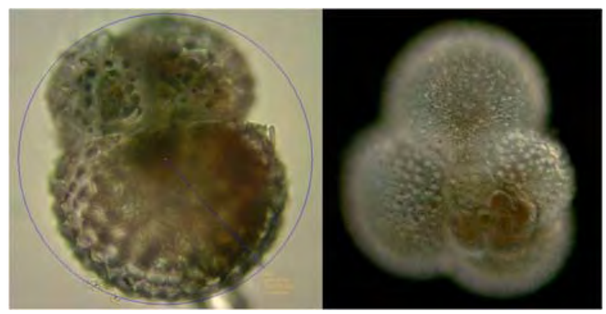
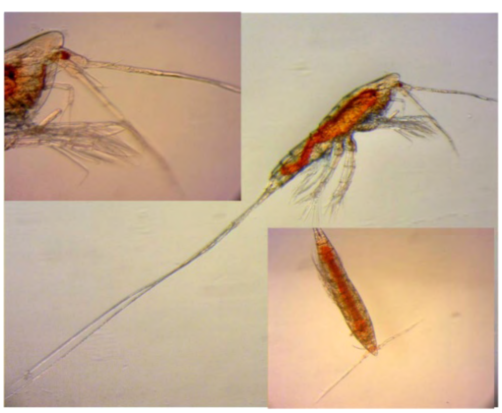
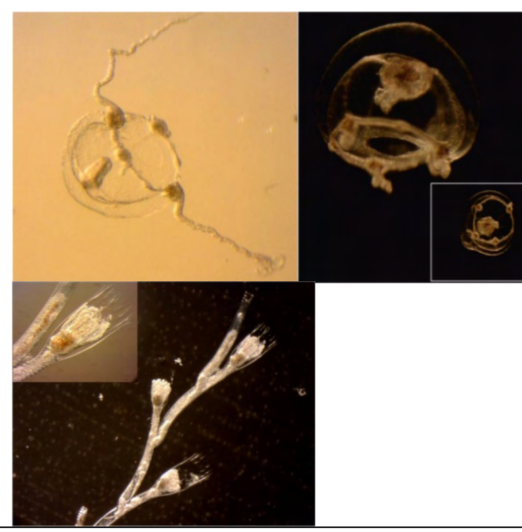
CYANOBACTERIA	
Trichodesmium erythraeum 	
RADIOLARIA	**FORAMINIFERA**
	
ZOOPLANKTON - CRUSTACEA	**ZOOPLANKTON - JELLY**
	

Figure 8. Sample micrographs of various plankton groups taken during the cruise.

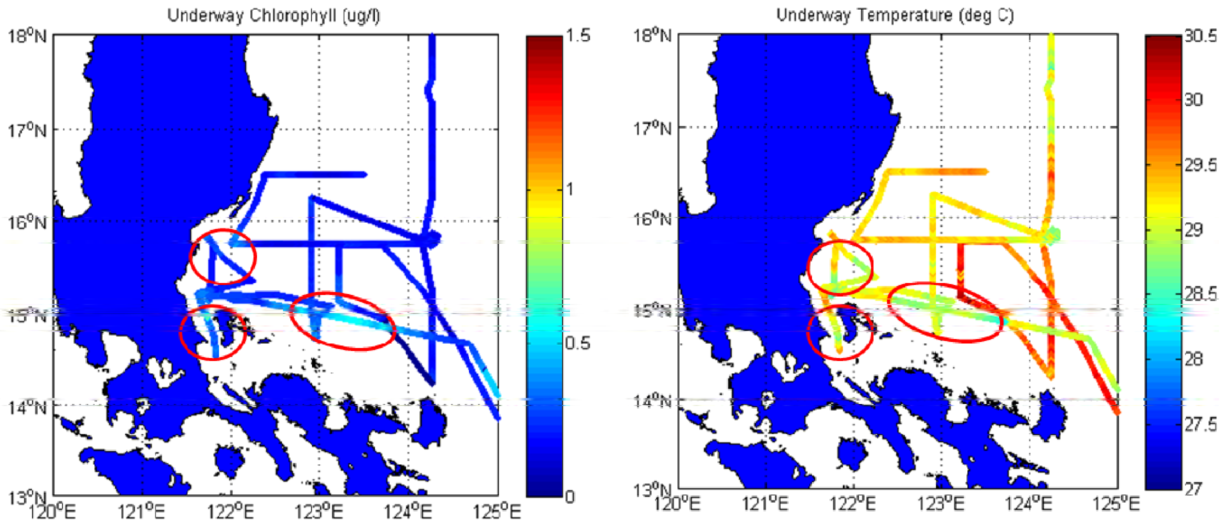
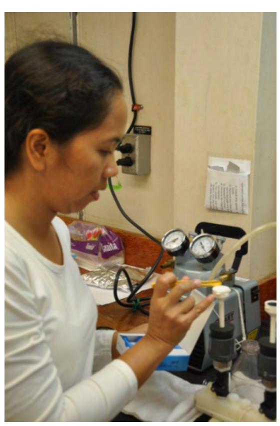


Figure 9. Underway chlorophyll and temperature east of Luzon.

CTD AND UNDERWAY OPTICS

The RV Revelle's underway system provides a comprehensive suite of surface parameters along the ship track and this information will be valuable in relating observed surface parameters with satellite data such as MODIS chlorophyll of the area. Plots of some of the underway variables along the cruise track are shown in Figure 10. It is worthwhile to note the large difference in surface temperature and chlorophyll in the tracks going south to Mindanao to avoid the typhoon. Sea surface temperature is cooler and chlorophyll is higher on the way back north after the typhoon, which suggests strong vertical mixing of the water column. Regional scale surface salinity distributions also reflect the regional scale features such as the high salinity of the NP recirculation, the low salinity of the cyclonic eddy in Lamon Bay and the intermediate salinity of the Kuroshio feeder current (see main report for description). The underway data also shows the high surface chlorophyll values at the Lamon Bay area, likely associated with upwelling processes associated with the cyclonic eddy and slope currents interacting with topography.



At each CTD station,3 replicates of 2-liter samples were filtered and will be analyzed for chlorophyll concentration in the lab. These measurements will be used to calibrate the underway fluorometer.

The chlorophyll fluorescence profiles measured using the CTD system also show some variations that appear to be consistent with the different physical regimes in the Lamon Bay area. Stations were grouped into the cyclonic dipole/shelf area, the Kuroshio feeder stream area and the Kuroshio recirculation, and the chlorophyll profiles were plotted (**Error! Reference source not found.**). The depths of the deep chlorophyll maximum are shallowest in the shelf/cyclonic dipole area, intermediate in the Kuroshio feeder and deepest in the recirculation. The difference between the Kuroshio feeder and the recirculation is small, however but is consistent with the idea that the Kuroshio feeder stream acts as a barrier for strong water exchange with Pacific water.

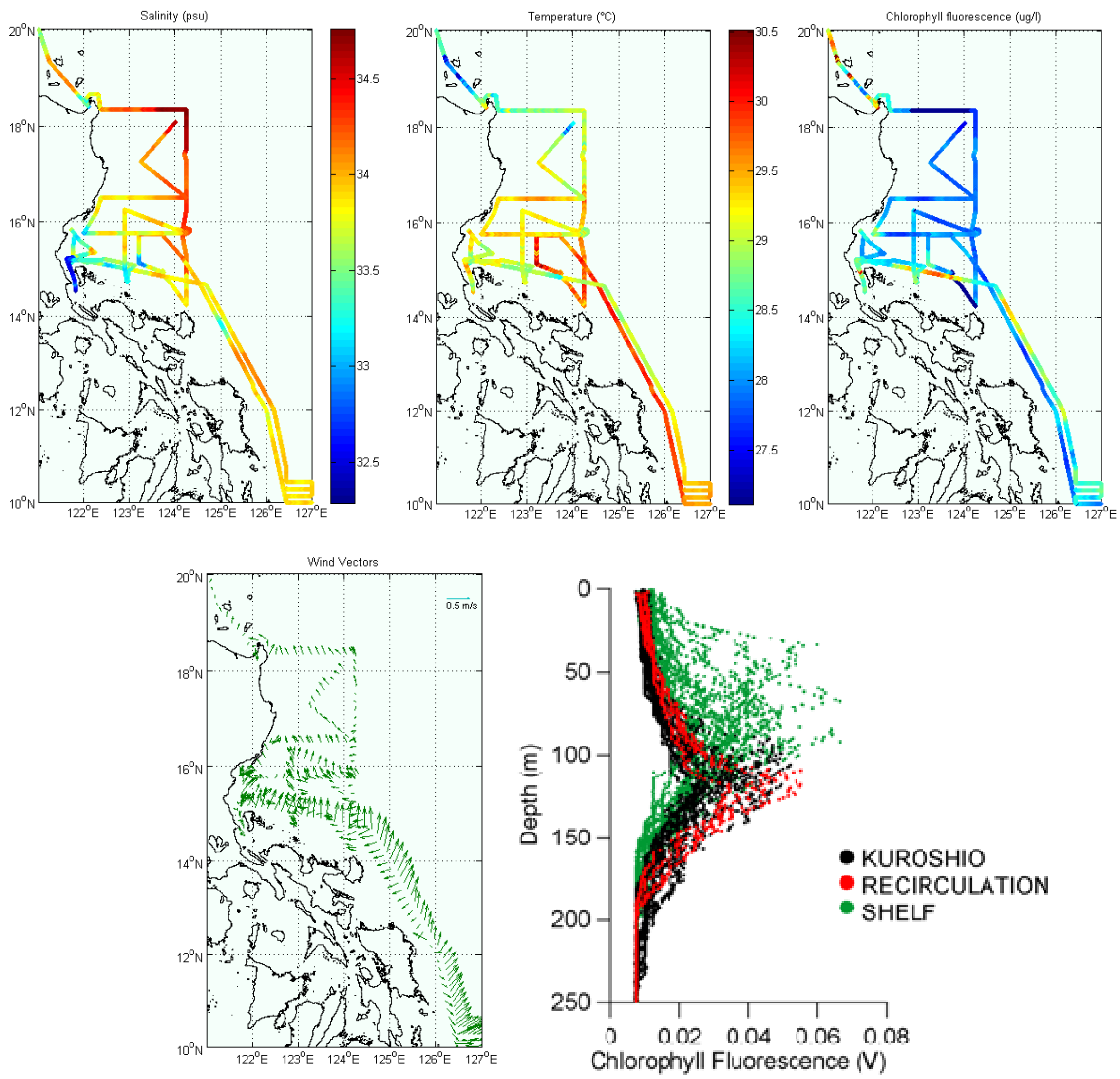


Figure 10. Plots of underway variables: salinity (top left), temperature (top center), chlorophyll (top right) and wind velocity (bottom left). Vertical profiles of chlorophyll fluorescence from CTD (bottom right) Black represents measurements at the Kuroshio feeder stream, red is from the Kuroshio recirculation and green is from the shelf and cyclonic dipole.

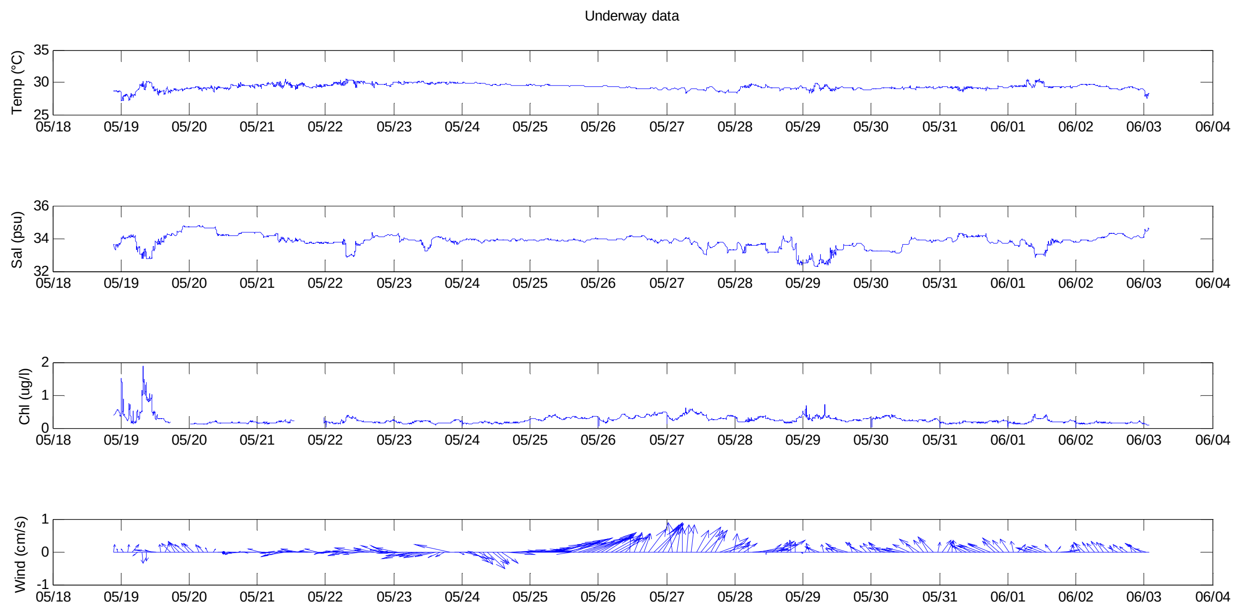


Figure 11. Plots of underway variables as a function of time.

Geological Oceanography

Sampling Procedure and Future Analyses

CORE SEDIMENT SAMPLES

Eleven core sediment stations were planned to be sampled during the cruise in the Lamon Bay. Five sediment cores were obtained. After the retrieval of cores, the barrel of the sediments were stoppered and closed with core caps. They were sealed with duct tapes and stored at 37°F (2.77°C). Movement is minimized to avoid the mixing of the sediment. Sampling coordinates, length and kind of sediment of each core and the water depths were recorded. Below is a summary of the stations arranged according to the sampling date.

Table 4. Core Sampling Stations

DATE OF SAMPLING	CORE	LAT	LON	WATER DEPTH (m)	LENGTH (m)	
29-May-11	1S	14 31.2718	121 49.7549	122	1.13	Shelf
29-May-11	4S	15 11.5390	121 44.6810	1277	1.74	Shelf
30-May-11	4D	15 4.6122	123 7.3878	1438	0.81	Off-shelf
01-Jun-11	1D	15 44.9985	122 0.0225	1665	0.36	Off-shelf
02-Jun-11	2D	16 29.8995	122 22.6997	1362	0.92	Off-shelf

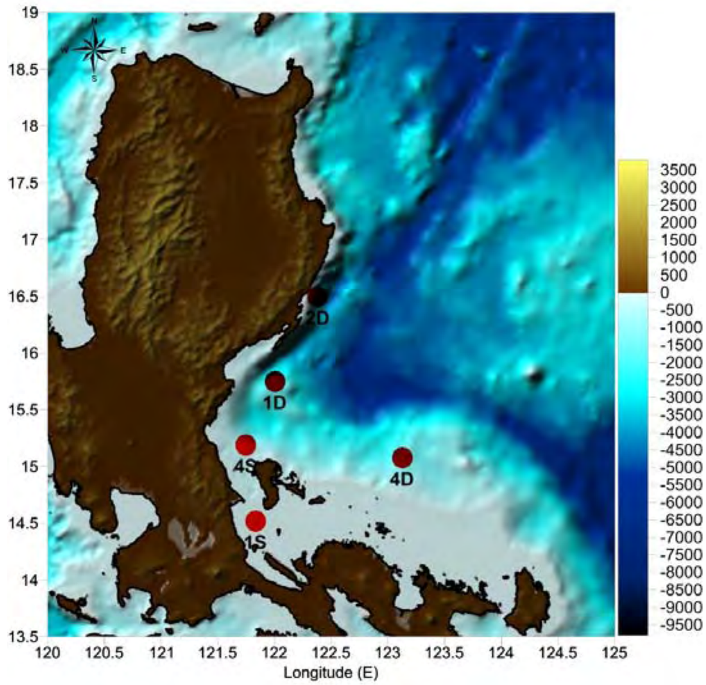


Figure 12. Core stations.

Sediment cores will be analysed to look at the primary productivity in relation to upwelling and Kurushio current and infer changes in the Kurushio – North Equatorial Current correlation with El Nino Southern Oscillation-Pacific Decadal Oscillation (PDO) cycles. Sediments will be analysed for their bulk geochemistry, organic, carbonate and lithic content using the Loss on Ignition Method (LOI) and elemental trends using the XRF core scanner. The results will be correlated to the analysis of carbon-nitrogen isotope and biological indicators such as nannoplankton, diatom and dinoflagellate. Radiocarbon dating using 210 Pb and 137 Cs will be used to date the sediments. Data from the multibeam echosounder and seismic from the single beam echosounder will also be correlated.

UNDERWAY WATER SAMPLES

One hundred liter water samples from the underway system were collected for isotope analysis into carbuoy containers in each six stations. The coordinates of the site, temperature, salinity and conductivity of the water were recorded. Another one liter of sample in each site were collected and filtered through pre-weighed 0.45 um membrane filter using hand pump filtration set-up. The volumes of filtered water were recorded and were preserved with 1/1000 (V/V) of hydrochloric acid. The filters were refrigerated at -800°C. The map of water samples are shown below.

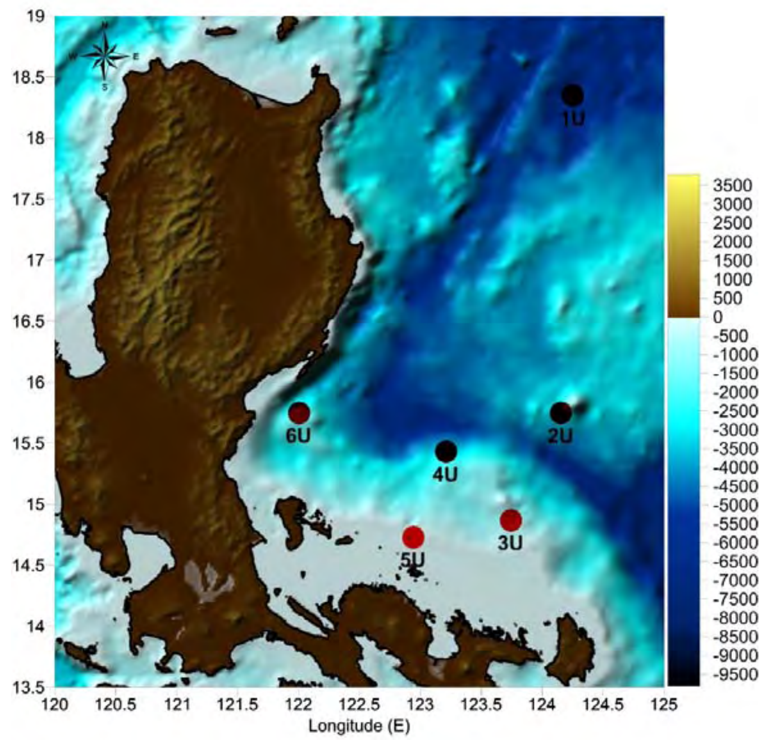


Figure 13. Collection sites for underway water samples.

WATER SAMPLES FOR CALCAREOUS NANNOPLANKTON ANALYSIS

One liter of seawater were collected at depths of 10 m, deep chlorophyll maximum (DCM) and 150 m. There were twenty-two sites chosen within the bay. Samples were filtered into the catcher of the filter set-up with membrane filter. Then, filters were air dried and stored for nannoplankton analysis under the microscope. The sampling coordinates and CTD measurements of water such as pressure, temperature, salinity and conductivity were recorded.