R/V Revelle, cruise 1204, Lamon Bay 2,
Legaspi to Kao-hsiung, 24 April - 14 May 2012
Personnel drop off at Port Irene, Philippines on 11 May

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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, figure 1 shows stations obtained in 2011). Net tows. The sea floor sediment was sampled with gravity cores.

There are two ship based research phases linked together by an array of moorings recording ocean currents and T/S (Table 1) 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 Lamon Bay cruise #1 LB01, May/June 2011 Revelle cruise 1107. for LB01 report go to:
http://www.ldeo.columbia.edu/~agordon/Reports/LamonBay2011_Report.pdf]
The figures in this report will be (by ~25 May 2012) placed in a PowerPoint file at http://www.ldeo.columbia.edu/~agordon/Reports

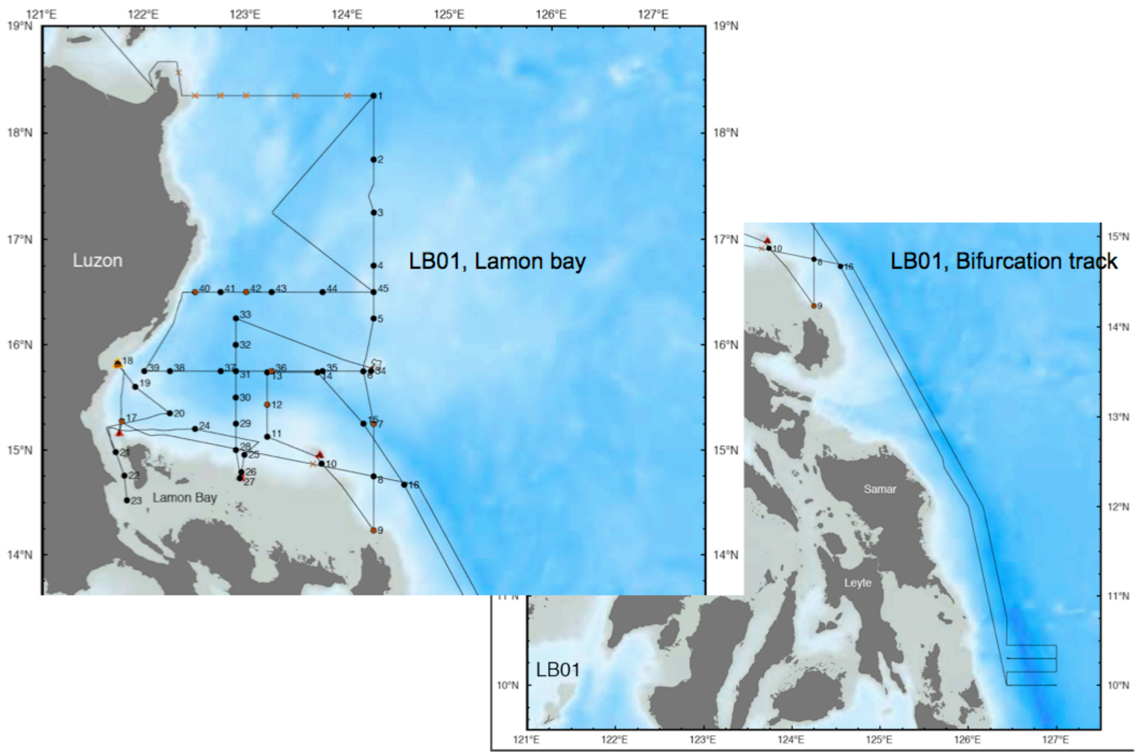


Figure 1. Station/track map of Lamon Bay 1, May/June 2011 (LB01). Red dots show drifter deployments [13 in total]; red triangles are mooring deployment sites [6 in total, see Table I]. There were 45 CTD stations most with water samples for chemistry. The track extending the coverage to the NEC bifurcation during Typhoon Songda [Philippine designated name: Chedeng]

TABLE I
Moorings deployed during Lamon Bay cruise 1 [May/June 2011]
see LB01 report for mooring configuation @
http://www.ldeo.columbia.edu/~agordon/Reports/LamonBay2011_Report.pdf

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**

III Lamon Bay Cruise 2

[A] Lamon Bay 2 work plan approach

Phase 1: Box-in Lamon Bay proper with closely spaced (~25 km) CTD/rosette to 1500 m (or shallower sea floor) along a 124.25° E N-S line from ~14.25°N to 16.5°N; an E-W line along 16.5°N, with a few vertical and oblique plankton net tow stations, listening to mooring at 15.5°, 124.25°. Two CTD/rosette to 4000 m to see what's happening within the western deep ocean trough.

Phase 2: Interior of the 'phase 2 box': CTD/rosette to 1500 m (or shallower sea floor) with one 4000 m CTD/rosette to complete the deep water trough sampling of phase 1; a few vertical and oblique plankton net tow stations; listening to moorings; gravity cores; with underway grids [surface water, hull ADCP] to expose spatial patterns of the surface layer characteristics.

Phase 3: Lamon Bay southern shelf, with CTD/rosette to shelf /upper slope floor; listen to shelf moorings; a few vertical and oblique plankton net tow stations; and gravity cores.

Phase 4: recover moorings, with CTD/rosette to 1500 m or shallower sea floor and underway survey.

Phase 5: north of 16.5°N, with priority of closely spaced (~25 km) CTD/rosette to 1500 m or shallower sea floor along 18.35°N to 124.25°E and along 124.25°E from 16.5N and 18.35N. Within this box: underway grid with possible CTD/rosette as time allows.

Phase 6: Survey [underway data and XBT] Luzon Strait, enroute to Kao-hsiung, to related .

[B] Lamon Bay cruise 2 Personnel

1	Arnold Gordon	Lamont-Doherty, Columbia U
2	Laura David	University of the Philippines Diliman
3	Aletta Yniguez	University of the Philippines Diliman
4	Ma. Lourdes McGlone	University of the Philippines Diliman
5	Gil Jacinto	University of the Philippines Diliman
6	Atsushi Watanabe	Tokyo Institute of Technology
7	Cesar Villanoy	University of the Philippines Diliman

8	Fernando Siringan	University of the Philippines Diliman
9	Jay Mar Quevedo	University of the Philippines Diliman
10	Pierre Flament	University of Hawaii
11	Ma. Teresa Escobar	University of the Philippines Diliman
12	Mary Chris Tentia	University of the Philippines Diliman
13	Rose Lopez	University of the Philippines Diliman
14	Kristina Cordero	University of the Philippines Diliman
15	Lara Sotto	University of the Philippines Diliman
16	Rhodelyn Saban	University of the Philippines Diliman
17	Dianne Deauna	University of the Philippines Diliman
18	Olivia Cabrera	University of the Philippines Diliman
19	Isabel Senal	University of the Philippines Diliman
20	Marianne Camoying	University of the Philippines Diliman
21	Iris Bollozos	University of the Philippines Diliman
22	Mayra Hernandez-Gonzalez	University of Baja California
23	Asmi Napitu	Lamont-Doherty, Columbia U
24	Paul Lethaby	University of Hawaii
25	Phil Mele	Lamont-Doherty, Columbia U
26	Allan Noveno	Observer, Philippine Navy
27	Frank Delahoyde	Computer Tech, SCRIPPS
28	Meghan Donohue	Restech, SCRIPPS
29	Brett Hembrough	Restech, SCRIPPS

LB02 scientists

[C] Data Collection Summary:

The figures in this report will be (by ~25 May 2012) placed in a PowerPoint file at http://www.ldeo.columbia.edu/~agordon/Reports

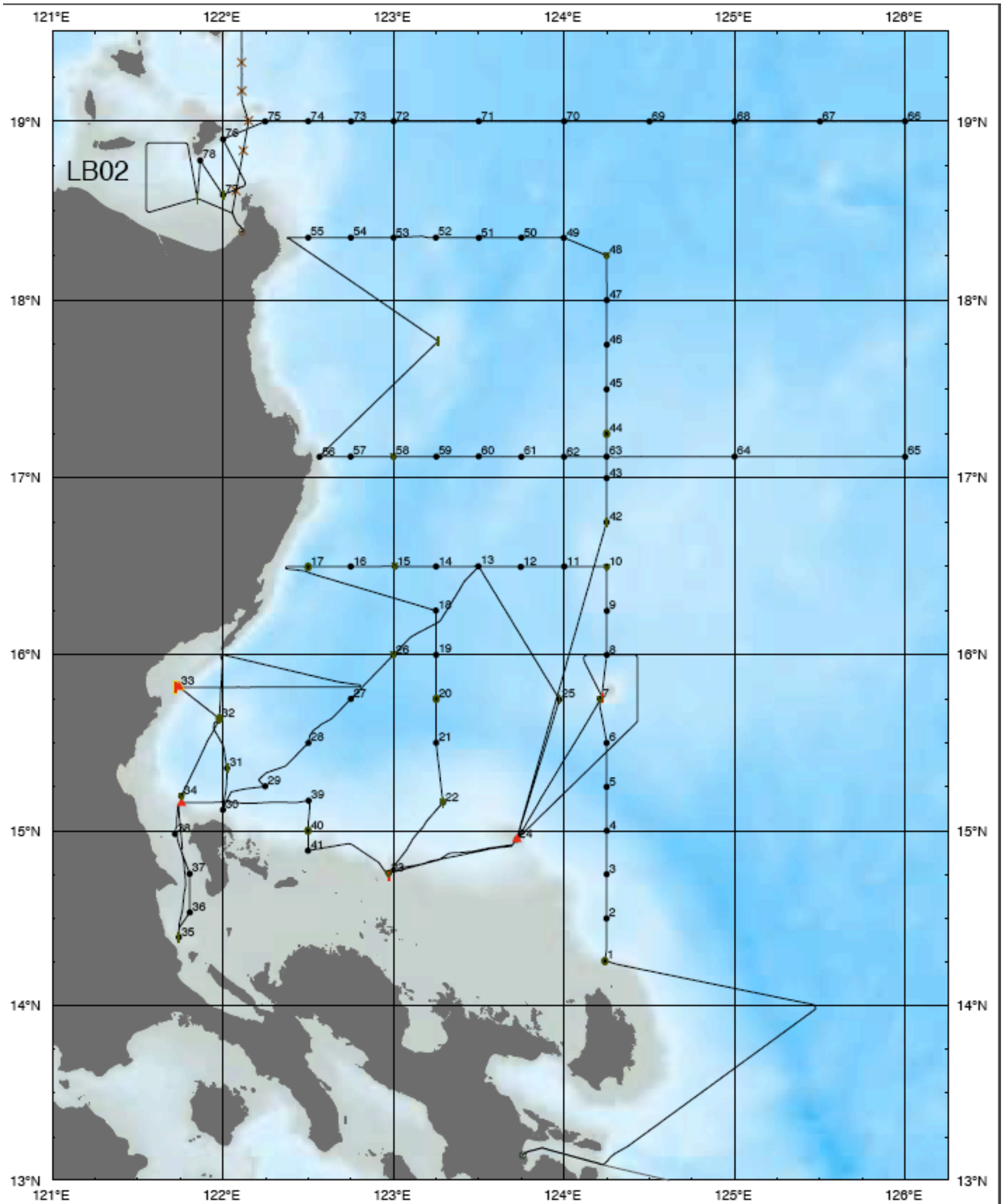


Figure 2a: Station/track map of Lamon Bay 2, April/May 2012. There were 78 CTD stations (temperature, salinity, oxygen), to 1500 m or to the shallower sea floor; 4 stations descended to 4000 meters to observe the waters within a deep ocean trough within Lamon Bay. Water samples were taken for CTD oxygen standardization and for determination of nutrient, carbon chemistry, and ecosystem parameters. Underway data, besides ADCP and Revelle 'Real-time Underway and Meteorological Data' (ocean surface temperature and salinity; oxygen; Chlorophyll-A (fluorometer);Transmissivity), included pCO_2.

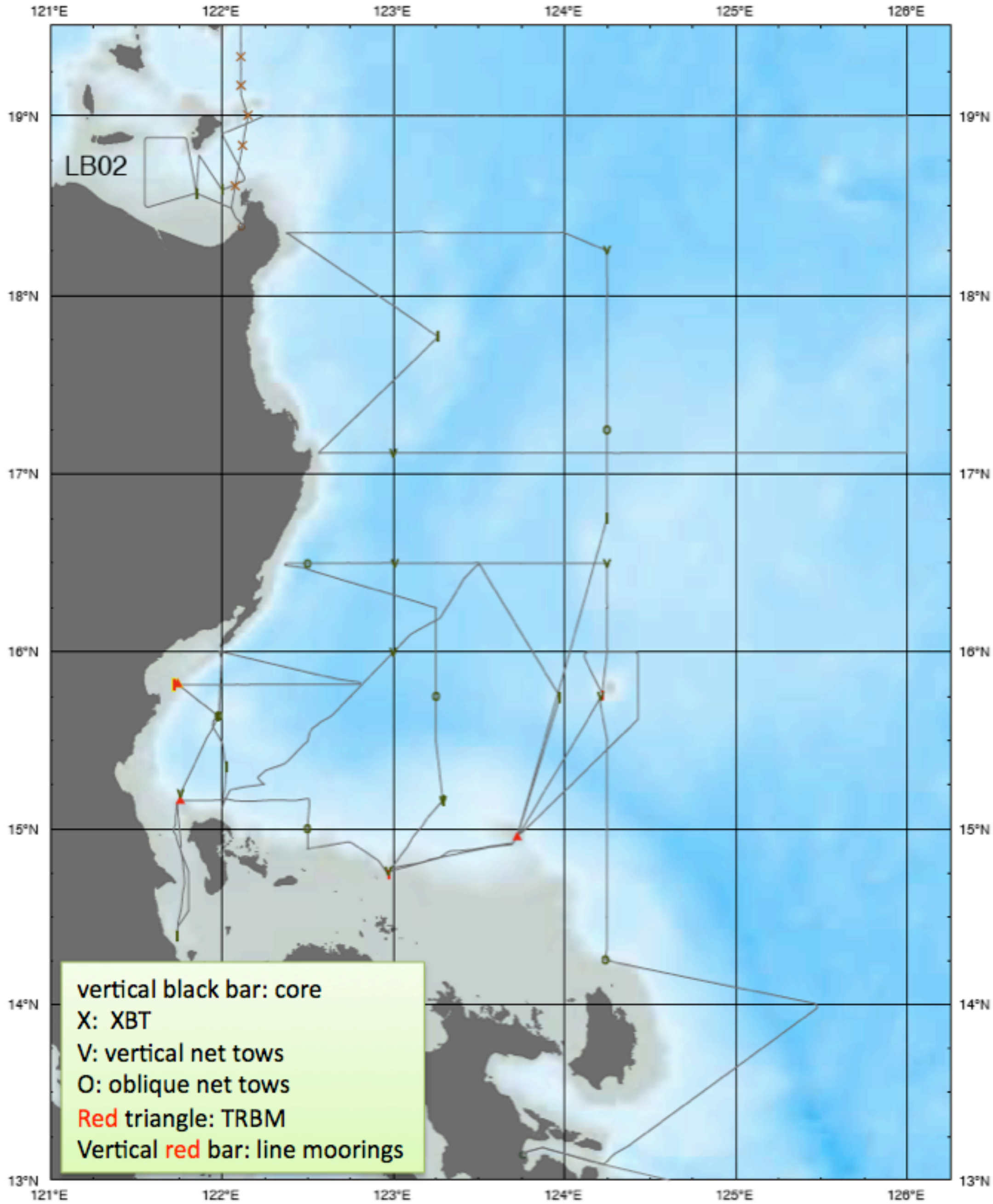


Figure 2b. A subset of stations had net tows to ~200 m to sample the 'living' component (plankton, and the occasional fish) of the upper water column. Gravity cores of the sea floor sediments were taken at 9 sites. The red font [lower map] shows the mooring deployed in LB01 (see: Table I). The Trawl Resistant Bottom Mooring [TRBM] 1 and 2 could not be recovered, all other were recovered. XBT were taken during the Luzon Strait survey.

TABLE II

Moorings recovery results in 2012 Lamon Bay cruise 2 [April/May 2012]

Mooring	recovered [local]	data recovery
TRBM1	dragged for; did not leave sea floor; did not recover	
TRBM2	dragged for; ascent to 30 m below sea surface; did not recover	
TRBM3 [with seacat]:	4/30/12 15:00	full data recovered; problem with download
T/S Bottom:	4/30/12 16:30	full data; deep S4 cm flooded
Mooring [line] 1	5/3/12 7:15	full data; deep S4 cm flooded
Mooring [line] 2	5/4/12 6:00	full data

IV Results of Lamon Bay Program:

[A] ***Summary*** *of Lamon Bay Cruise #1 (2011) key science results* [see full report at http://www.ldeo.columbia.edu/~agordon/Reports/LamonBay2011_Report.pdf]

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. During LB01 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.

The water mass and to some extent the circulation pattern observed during LB02 is quite different as observed ~11 months ago during LB01, as presented in the following overview, and as with all that changes: *blame it on El Niño.*

[B] ***Overview*** *of Lamon Bay Cruise #2 (2012) key science results* [The figures in this section will be placed by ~25 May 2012 in a PowerPoint file at http://www.ldeo.columbia.edu/~agordon/Reports]

LB02 data in comparison to Lamon Bay cruise 1 (LB01; May/June 2011) provide important new insights into the origin of the Kuroshio before it encounters Luzon Strait. I refer to this stage of the Kuroshio system as the *nascent Kuroshio*. While we see increase in the velocity/transport in comparison LB01, what may be more important are the observed changes of the source (or 'headwaters') of the nascent Kuroshio. The ENSO based changing nature of the Kuroshio source waters is excepted to have far reaching effects, as the ENSO factor effectively links the equatorial and subtropical regimes of the North Pacific during La Niña; isolating the subtropical North Pacific during El Niño.

§ LB01 & LB02 stratification profiles, potential temperature/salinity scatter:

Profiles of temperature, salinity and oxygen and the relationship of salinity and oxygen to temperature (Figures 3 and 4) reveal the diversity of water types that characterize Lamon Bay and the changes that occurred between the two ship based studies of LB01 and LB02. The distinct difference of the April/May LB02 stratification from the May/June LB01 stratification is best seen at the S-max and S-min core layers. The S-max is derived from the evaporative subtropical, spreads toward the equator below the Ekman layer; the S-min is derived from the NW North Pacific, and is designated as North Pacific Intermediate Water (NPIW).

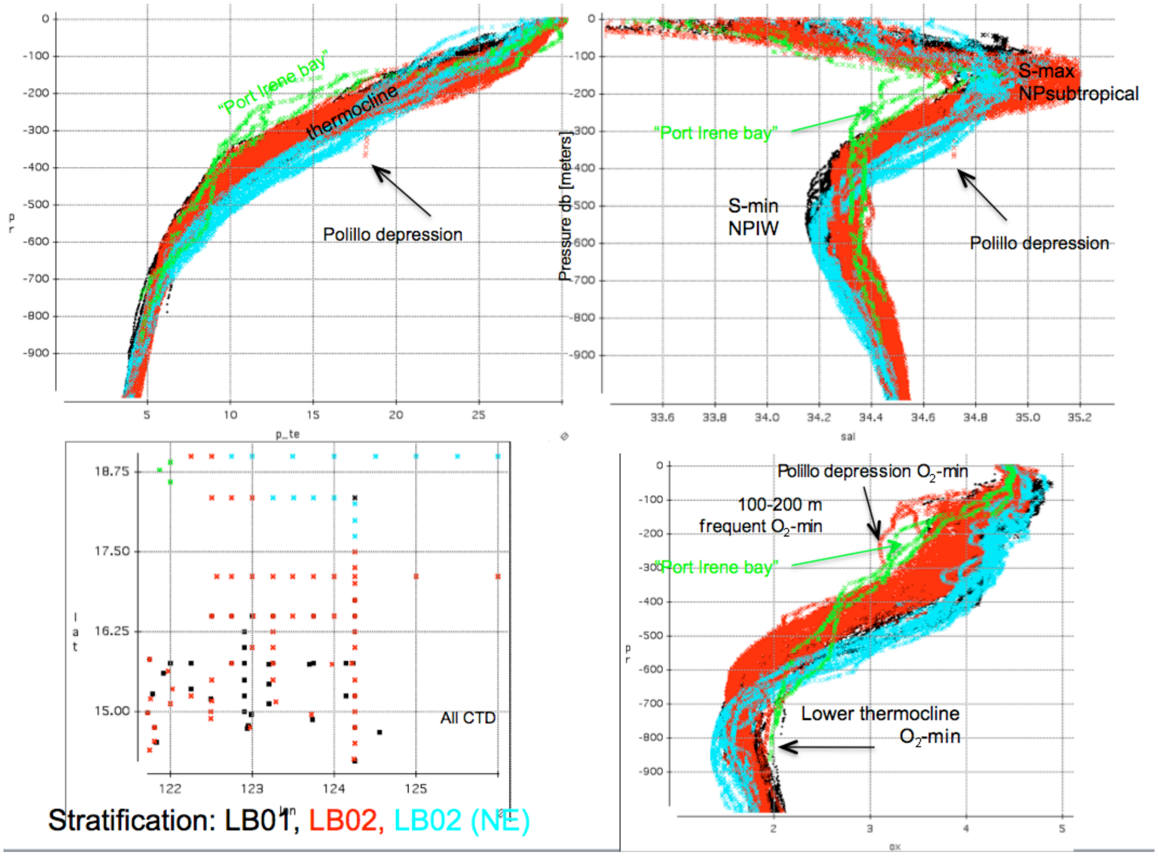


Figure 3. Potential temperature, salinity and oxygen of the upper kilometer of Lamon Bay as observed in LB01 (black symbols) and LB02 (red, cyan and green symbols). The map in lower left provides positions of the CTD profiles shown in the figure. Tropical water introduced into the Lamon Bay region by the northward flowing limb of the North Equatorial Current (NEC) bifurcation has saltier S-max within the upper thermocline and saltier S-Min at thermocline base than does the subtropical waters of the western North Pacific, identified here as Kuroshio water, which is enriched in North Pacific Intermediate Water (NPIW). The 'Polillo depression' is the ~850 m hole near 14.5°N, 121.75°E, the likely source of the low oxygen layer found over the Lamon Bay southern shelf and adjacent slope.

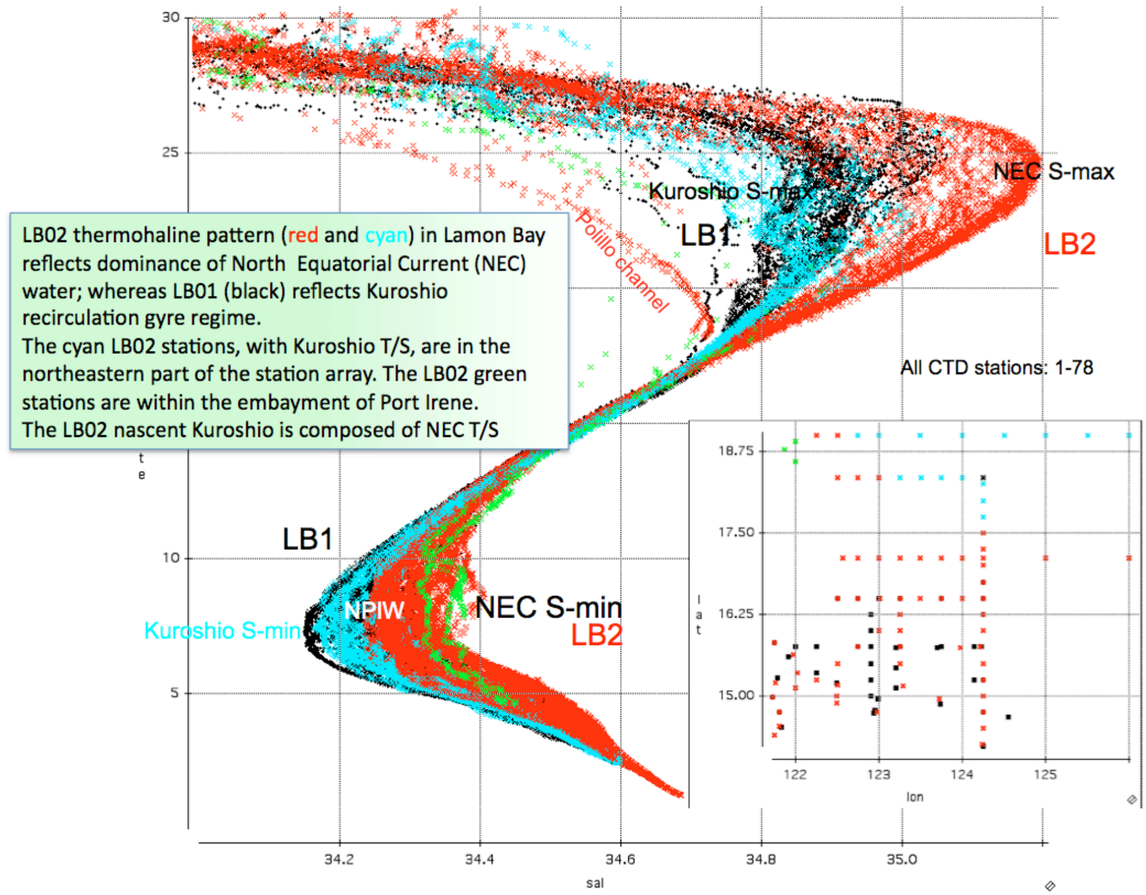


Figure 4a. Potential temperature vs. salinity scatter observed in LB01 (black symbols) and LB02 (red, cyan and green symbols). The map in lower left provides positions of the CTD stations shown in the figure. The boxes text within the figure provide identify key results in terms of the NEC vs. Kuroshio source of the Lamon Bay stratification.

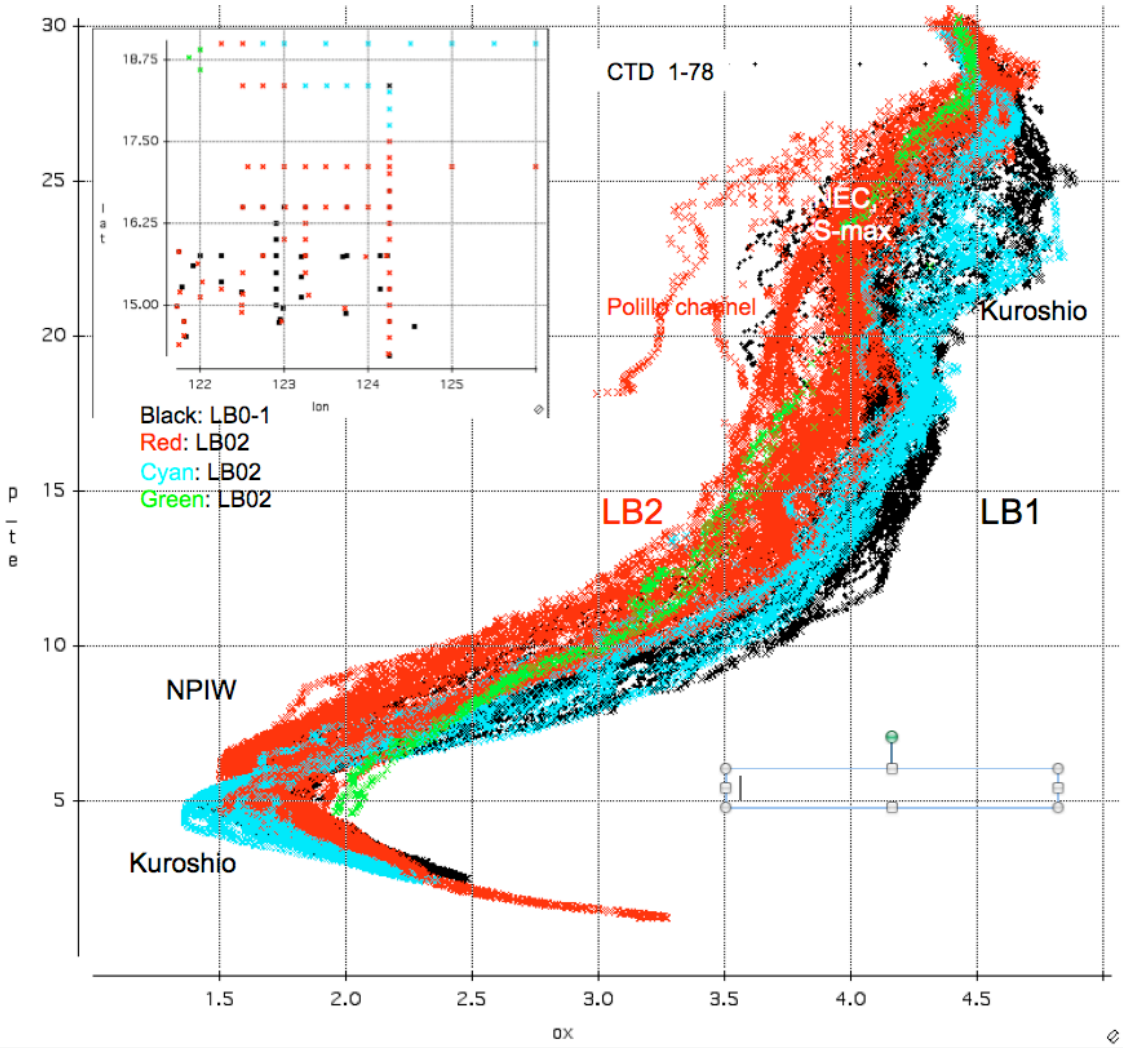


Figure 4b. Potential temperature vs. oxygen (ml/l) scatter observed in LB01 (black symbols) and LB02 (red, cyan and green symbols). The map in upper left provides positions of the CTD stations shown in the figure. Kuroshio s-max higher in oxy than NEC s-max; the Kuroshio oxy-min occurs at colder temperatures than that of the tropical NEC water.

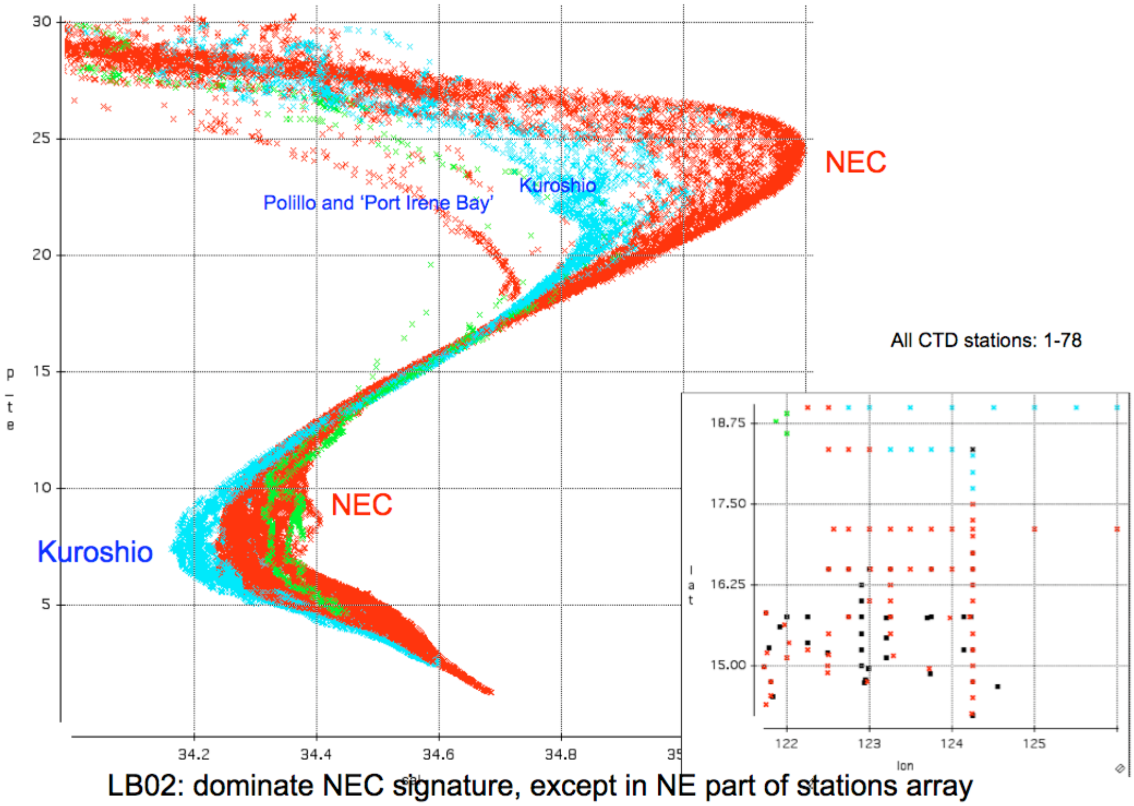


Figure 4c Same as Figure 4a, but the LB01 data points removed to show only LB02 T/S scatter. The coastal waters near Pilillo Island and in the embayment at Port Irene display strongly altered profile to a depth of ~350 m, removing the S-max and attenuating the S-min core layer, signifying more than a low salinity surface layer sweeping over the thermocline of the open ocean.

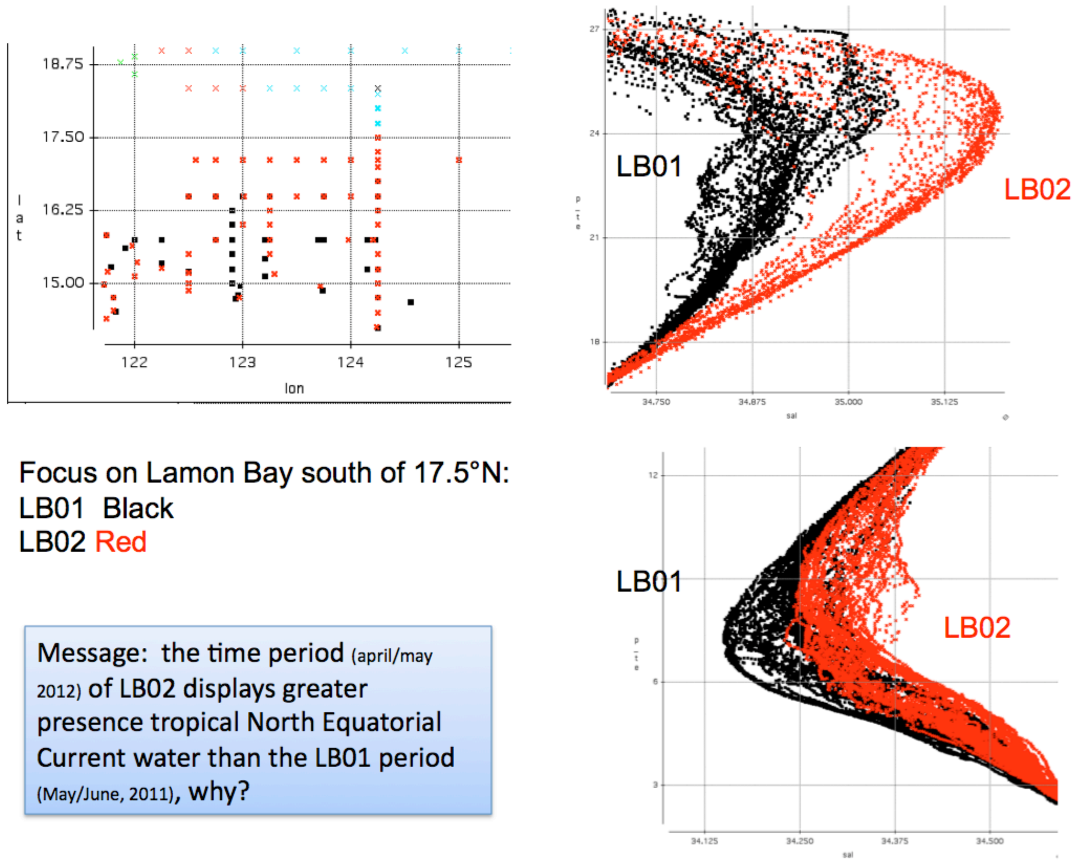
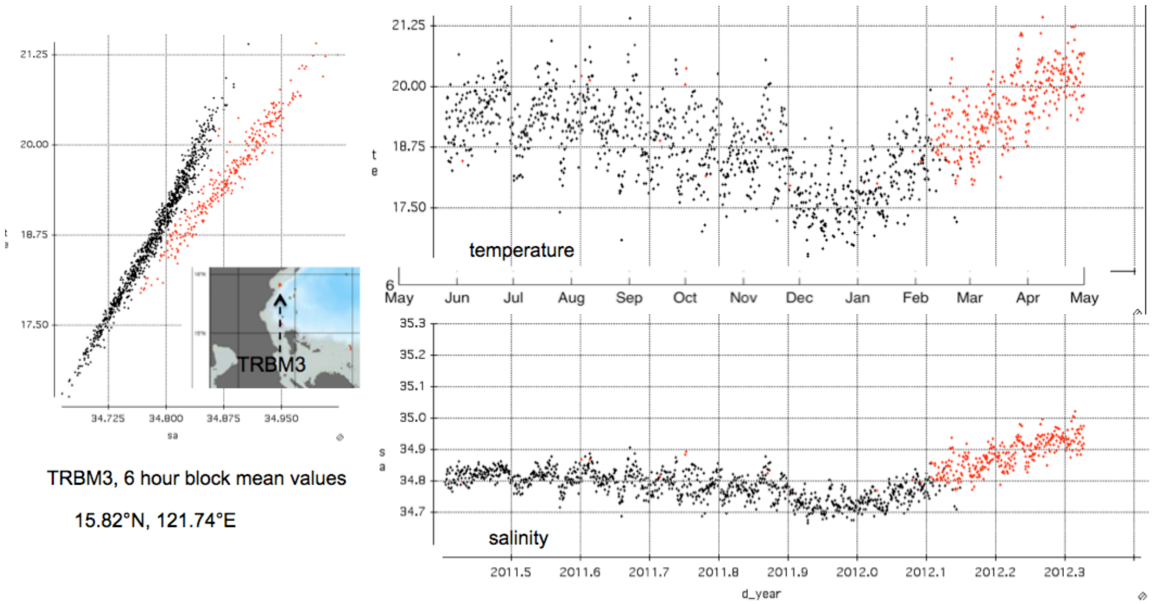


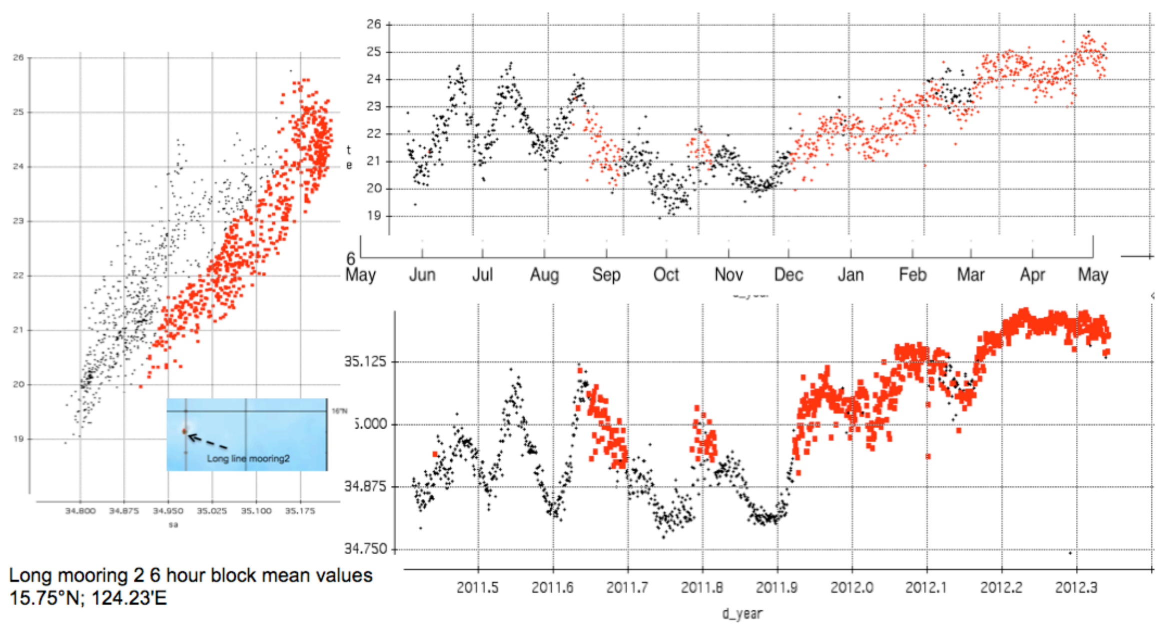
Figure 4d. Comparison of the S-max and S-min of the two LB cruises. The time period (April/may 2012) of LB02 displays greater presence tropical North Equatorial Current water than the LB01 period (May/June, 2011).

The time series T/S from the recovered mooring time (Figure 5) show that the transition within the *nascent Kuroshio* from the Kuroshio recirculation gyre regime (weak S-max; strong S-min) of LB01 to the NEC regime (strong S-max; weak S-min) observed during LB02, occurred in late December 2011 (eastern site) to early February 2012 (western site) time frame. It took ~1 month for the increased NEC injection into the Lamon Bay to invade the cyclonic dipole of the southwest corner of the Bay. The height of the La Niña phase occurred in December 2011 (see lower right panel of Figure 11).



TRBM3, 6 hour block mean values

15.82°N, 121.74°E



Long mooring 2 6 hour block mean values
15.75°N; 124.23'E

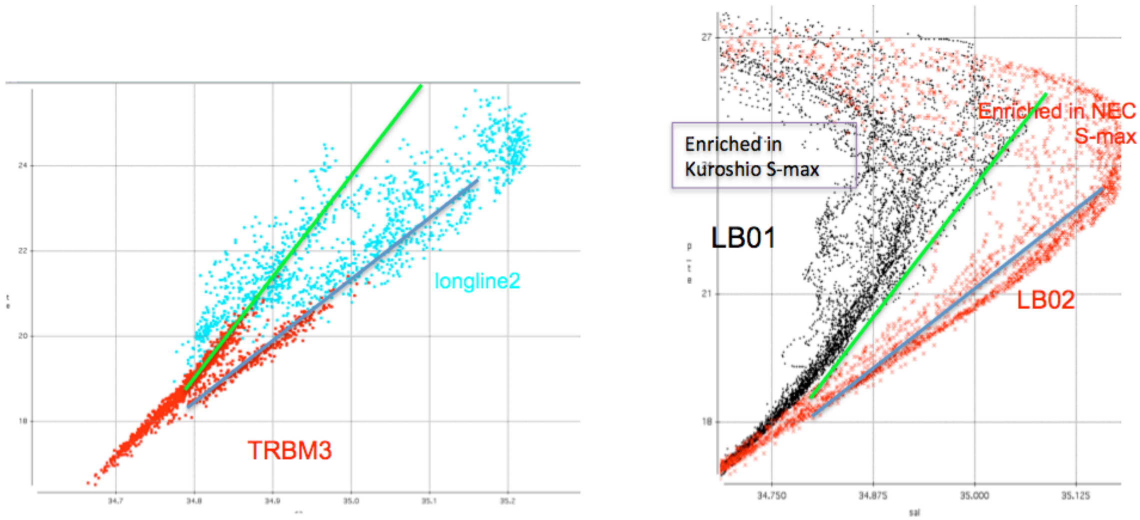


Figure 5 a,b Time series of temperature and salinity and T/S scatter from TRBM3 and the long mooring 2 (see Table I and II). Figure 5c shows the combined T/S scatter of the two moorings [left panel] with the approximate fit overlaid on the LB01 and LB02 T/S [right panel].

§ T/S stratification sections view, with ship ADCP sections:

Insight into the spatial distribution of the S-max and S-min core layers, which mark the NEC vs. Kuroshio source, can be seen in the salinity sections.

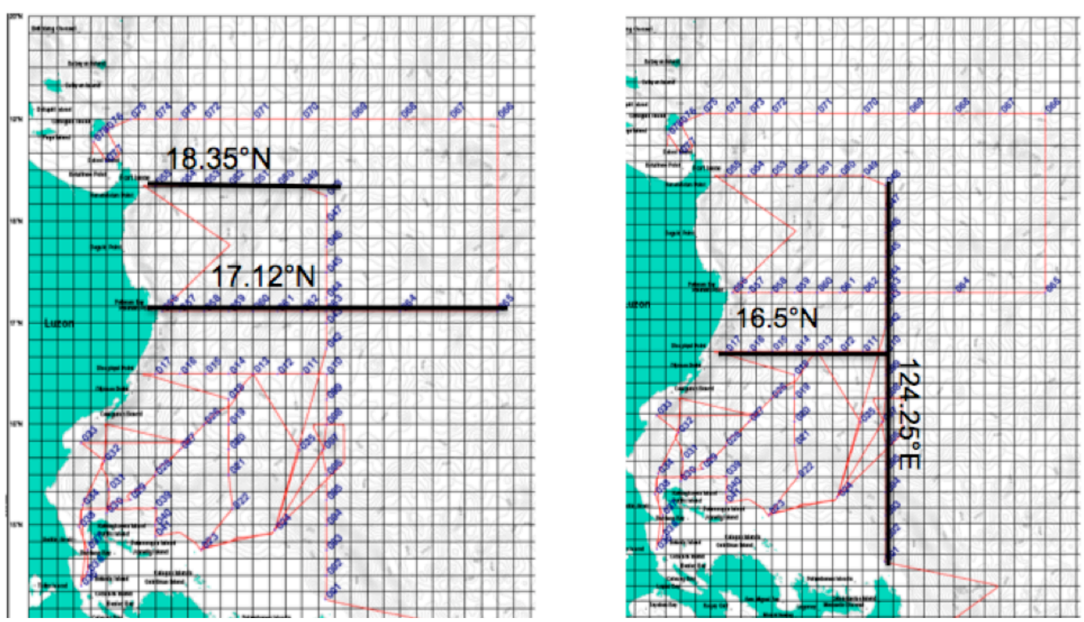
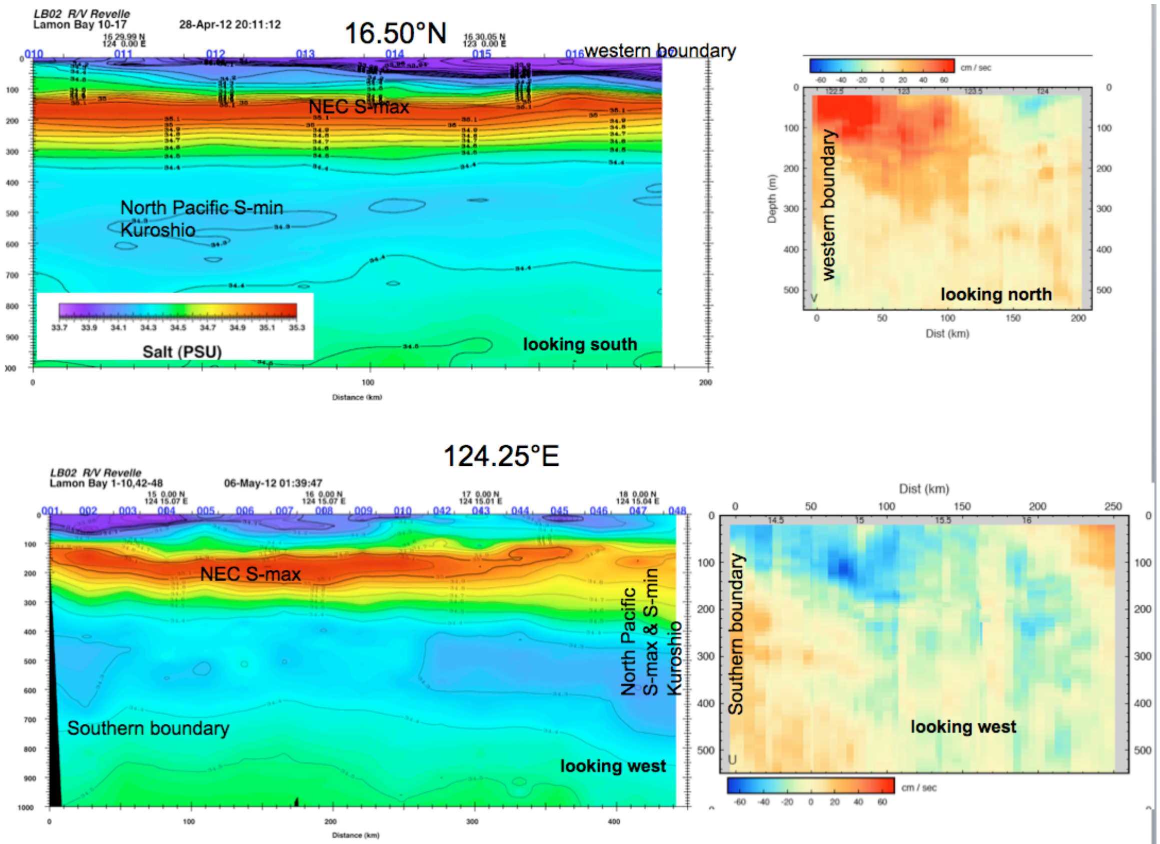


Figure 6. Position of the salinity and ship ADCP sections shown in Figure 6.



16.50°N
western boundary
NEC S-max
North Pacific S-min
Kuroshio
Salt (PSU)
looking south
western boundary
looking north
Depth (m)
Dist (km)
cm / sec
124.25°E
NEC S-max
North Pacific S-max & S-min
Kuroshio
Southern boundary
looking west
Dist (km)
Southern boundary
looking west
cm / sec

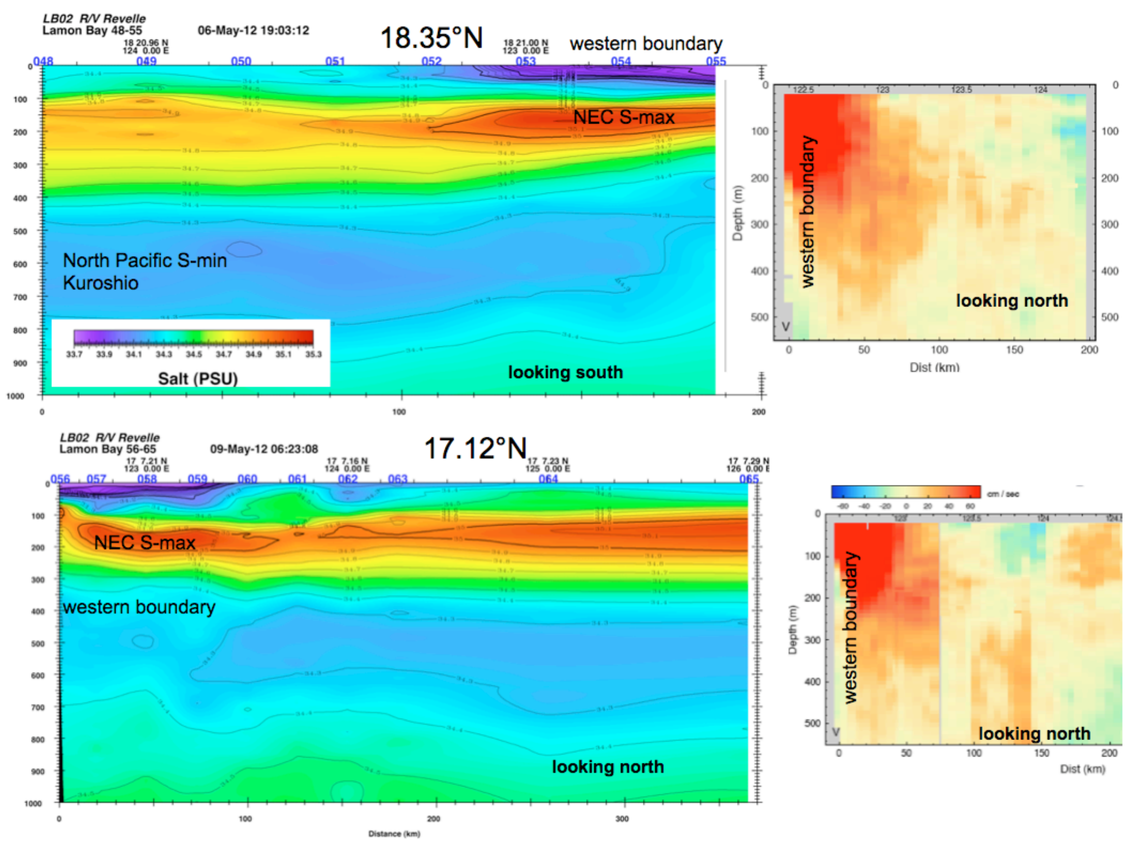


Figure 7. Salinity distribution for the upper 1000 m along the sections shown in Figure 6. *Note:* the sections are presented in order of the station number, left to right; the N-S, E-W orientation is noted within the section panel. The right panels show the current speed across the section for the upper ~550 m obtained by the ship mounted 75 kHz ADCP underway system, cm/sec (+60, red to -60, blue cm/sec). The ADCP section is often not for the full lateral length of the salinity section. The km scale is noted at the base of the sections.

The salty S-max core layer marked in the sections (Figure 7) is derived from the tropical water injected into Lamon Bay from the NEC via the bifurcation. The lower salinity S-max and fresher S-min stratum marks the western North Pacific subtropical regime of the Kuroshio recirculation gyre. The western North Pacific subtropical water is observed only in the northeastern stations of the LB02 array, in contrast to its far more pervasive distribution observed within Lamon Bay by LB01.

§ Surface Layer Circulation:

Lamon Bay 21-53 m current vectors color coded by SSS (Figure 8): The circulation pattern revealed by LB01 and LB02 are similar. A flow, referred to as the Kuroshio feeder current crosses Lamon Bay, reaching the western margin near 16°N to begin the nascent Kuroshio. The Kuroshio feeder current separates an anticyclonic dipole from a cyclonic dipole. While the patterns of LB01 and LB02 have similarities, there are some differences in amplitude, but the primary one has to do with the water characteristics feeding into Lamon Bay, as discussed above, and summaries below.

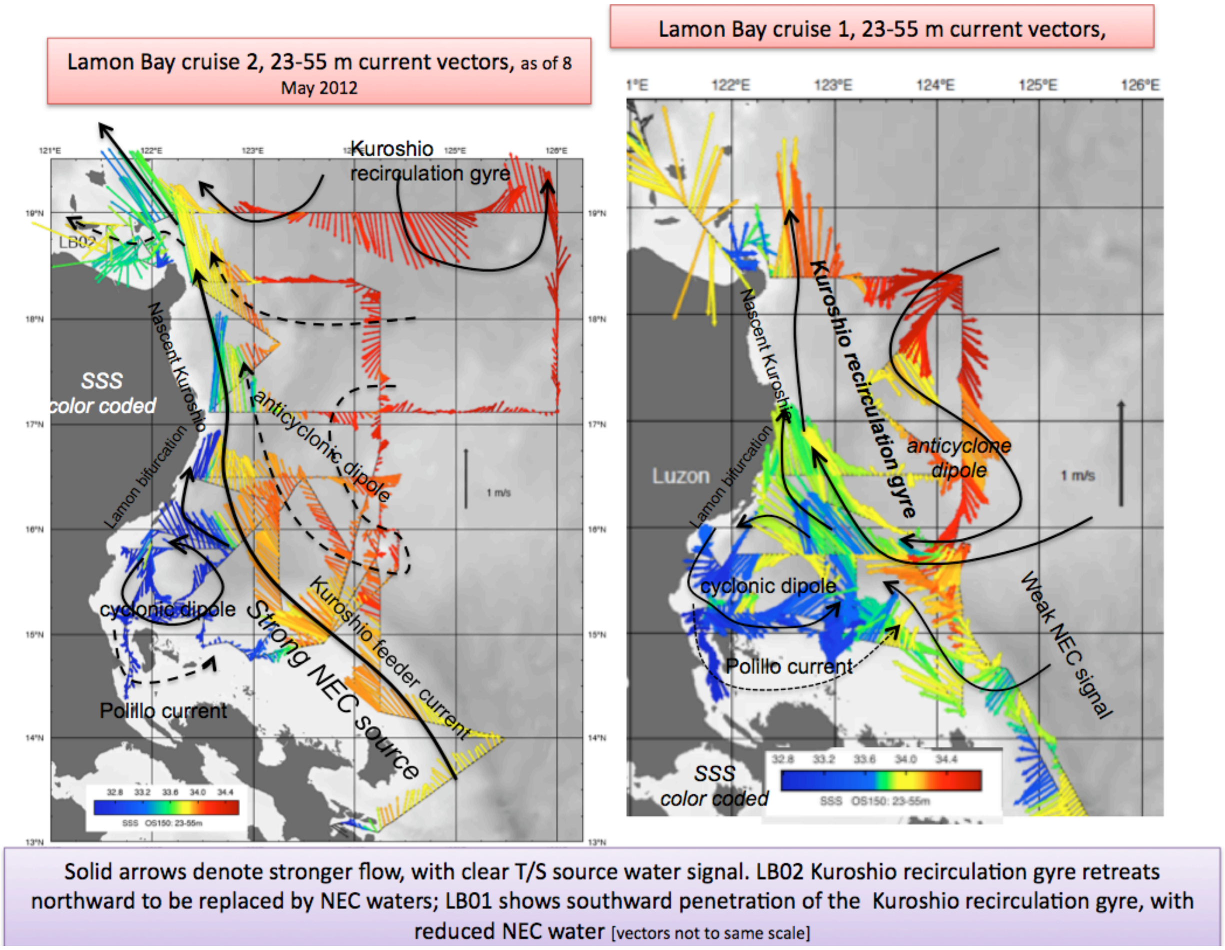


Figure 8. Sea surface salinity (SSS) color-coded current vectors within Lamon Bay for LB01 (right panel) and LB02 (left panel).

§ Transport:

The nascent Kuroshio crossing 18.35°N (Figure 9): The Kuroshio is stronger and reaches greater depths during LB02 than LB01. The transport increased from ~10-11 Sv to 15-16 Sv. The surface current speeds doubled. When the nascent Kuroshio is fed from the NEC regime rather than from the Kuroshio recirculation regime, it is strengthened. The NEC source is amplified during La Niña when the bifurcation shifts southward.

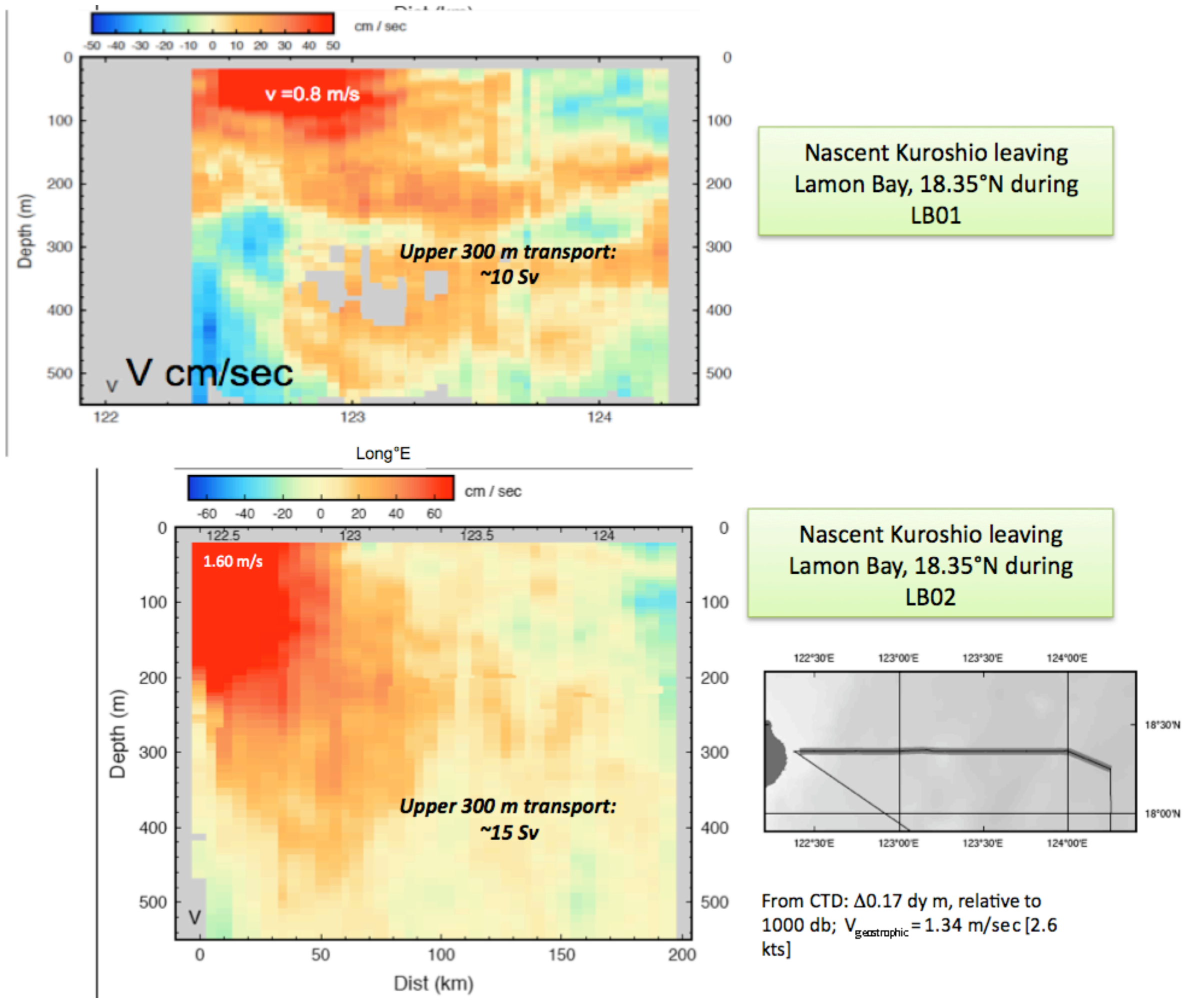


Figure 9. Comparison of the northward flow across 18.35°N of LB01 and LB02. The maximum speed of the nascent Kuroshio in LB02 was twice that of LB01 and the transport 50% greater. The geostrophic speed relative to 1000 db of the Kuroshio axis in LB02 as determined by the CTD data is 1.35 m/sec.

Transport across key sections of LB02 (Figure 10) exceed that of LB01, by ~50%, attesting to the additional injection of tropical water from the North Equatorial Current. A quick estimate of the transport of the western section of the 19°N section (not shown on figure 10, see station map Figure 2a) yield transport of ~20 Sv. It is possible that the enhanced transport relative to 18.35°N is due to greater incorporation of Kuroshio recirculation gyre water.

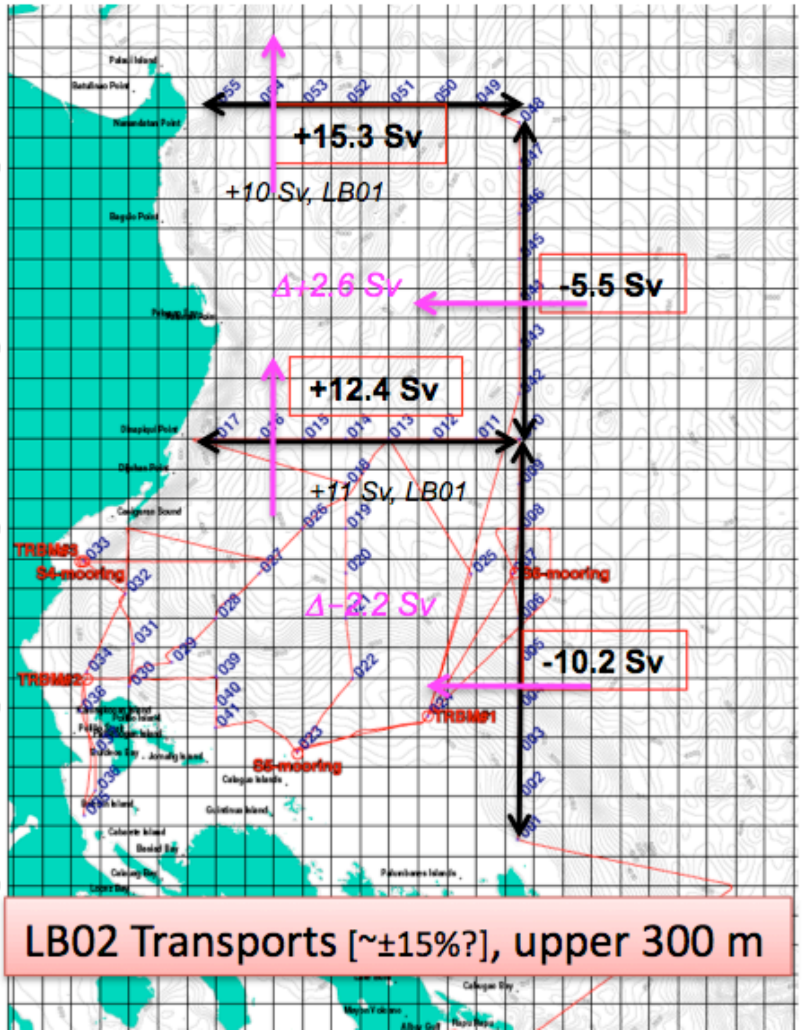


Figure 10. Transport across select zonal and meridional sections of Lamon bay

§ North Equatorial Current Bifurcation (Figure 11):

During LB01 Typhoon Songda forced the Revelle to move out of Lamon Bay towards the south, into the NEC bifurcation region. The bifurcation at that time was found to be in the 13°-14° N band. In April 2012, just prior to LB02, the bifurcation was again observed during the Revelle transit from Freemantle to Legaspi. It was observed to be further south, 10°-11°N. Southward shift of the bifurcation during La Niña [lower right panel shows the nino4 index] is expected, relative to El Niño (Qiu and Chen 2010) and presumably relative to the more neutral ENSO state of May/June 2011 LB01 period.

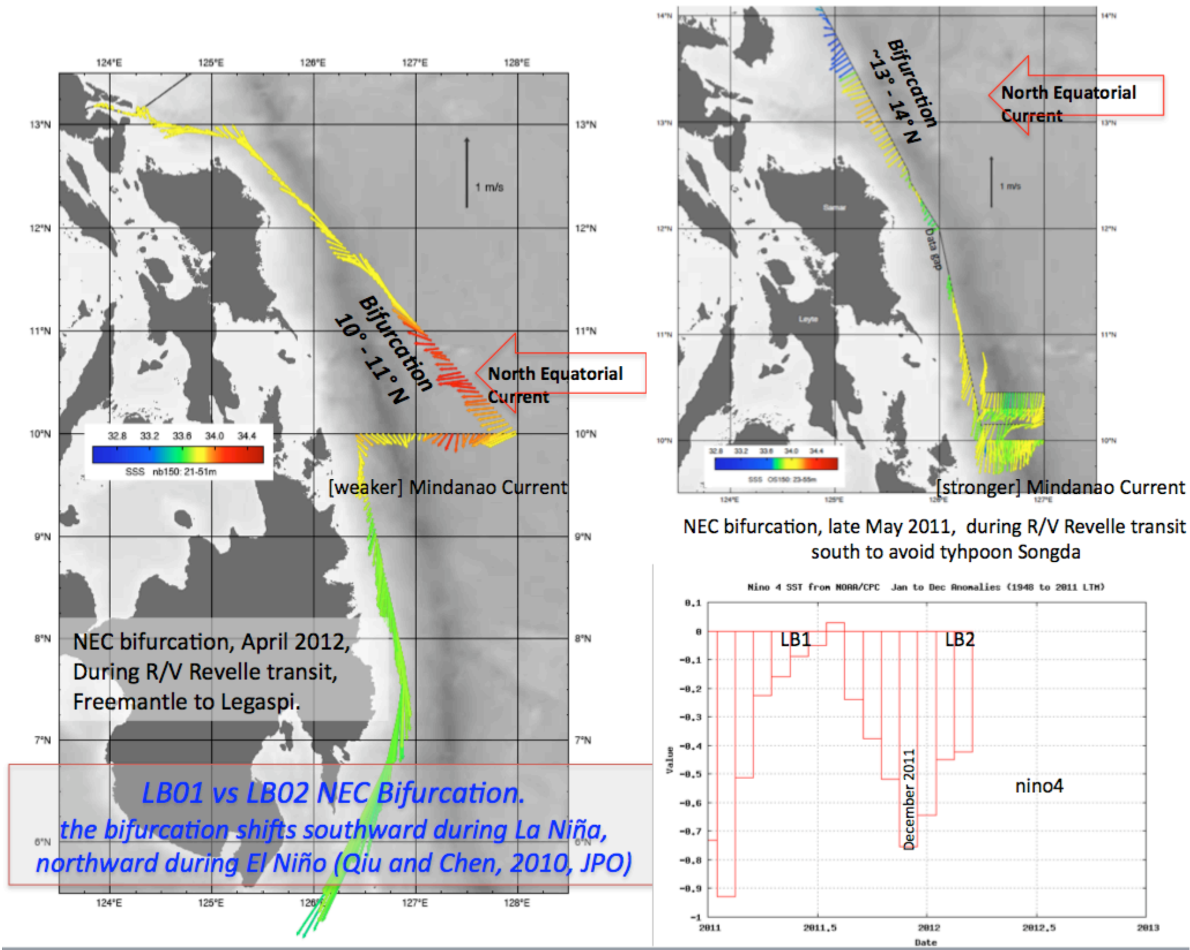


Figure 11. North Equatorial Current Bifurcation observed during LB01 and LB02.

The more southerly position of the bifurcation as expected to direct more of the NEC water into the northern limb, leading into Lamon Bay, and the nascent Kuroshio, which is consistent with the observations of LB02.

§ Summarizing Schematic (Figure 12):

The CTD data and the ship based underway data from both LB01 and LB02, plus the mooring time series can be brought together into a schematic 'conceptual' representation consistent with the broad array of data, as well on results reported in publications and model output. Such a schematic is shown in Figure 12.

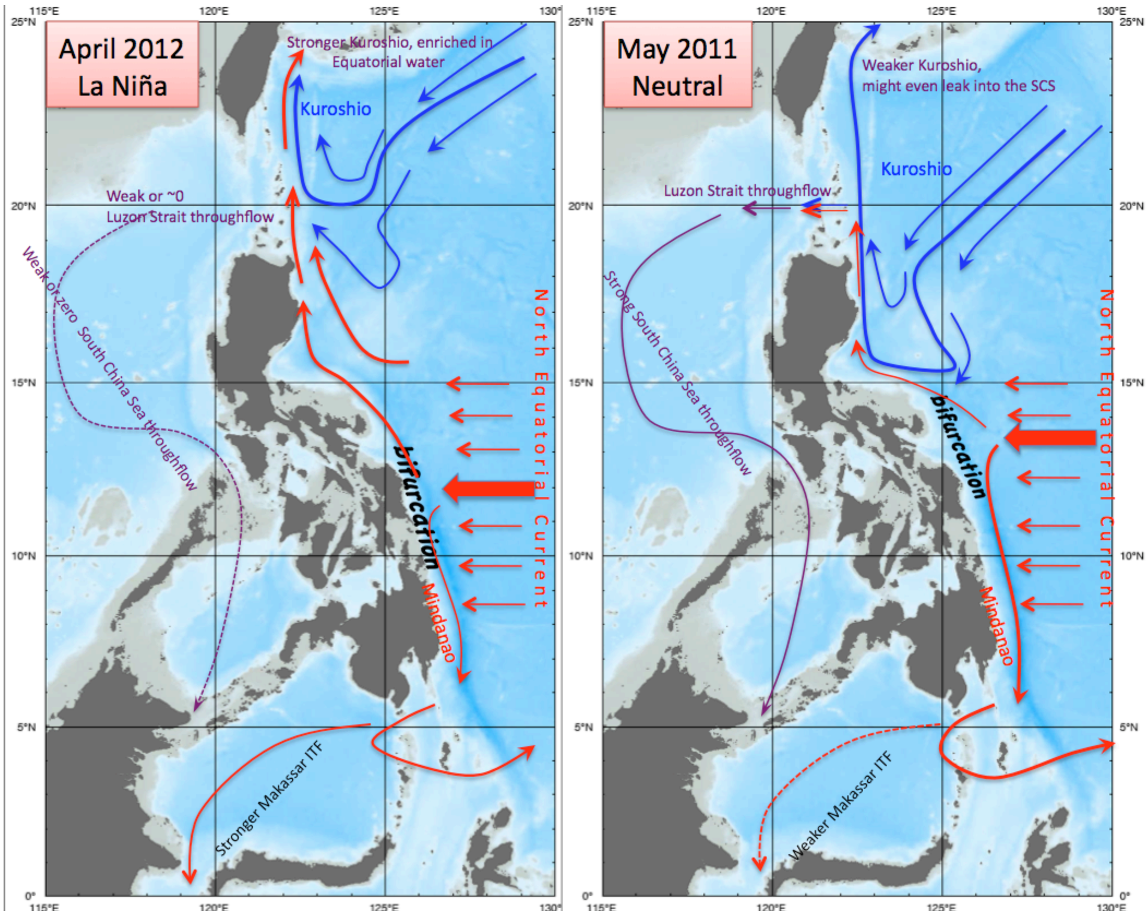


Figure 12. The schematic shown above is based on the CTD (T/S stratification) and ship-based ADCP currents of the upper ~600 m obtained by the Lamon Bay research cruises of May/June 2011 and April/May 2012, which covered the area south of ~19°N west of ~126°E and the NEC bifurcation region [typhoon detour in 2011 and transit from Fremantle in 2012]. The nino4 in May 2011 was near zero, but we take it as representative of an El Niño condition relative to the La Niña condition of April 2012. Maximum La Niña phase occurred in December 2011. The South China Sea throughflow connection is from Gordon et al, 2012, GRL; Luzon Strait throughflow and ENSO from Hurlburt, et al., 2011, Oceanography. The relationship of the NEC bifurcation to ENSO is from Qiu and Chen 2010, JPO.

During LB01 (neutral ENSO phase) the Kuroshio off the east coast of Luzon consisted mostly of Kuroshio recirculation gyre, composed of western North Pacific subtropical thermocline and Intermediate water water. Kuroshio off Luzon in LB02 (La Niña ENSO phase) is composed mainly of North Equatorial Current (NEC) water, with its characteristic a more intense S-max and weaker S-min than that of the NW Pacific subtropical stratification. The Kuroshio recirculation gyre retreated to the north. LB02 flow pattern is about the same as LB01, though of higher speeds/transport, with a Kuroshio feeder current bracketed by the anticyclonic and cyclonic dipoles, but the thermohaline stratification composing the nascent Kuroshio has changed. It is likely that the changing nature of the nascent Kuroshio within Lamon Bay is a function of the ENSO sensitive North Equatorial Current (NEC) bifurcation, as represented in the schematic.

During La Niña the nascent Kuroshio transport increases and its composition incorporates greater amounts of tropical NEC water, as the bifurcation shifts southward (Qiu and Chen, 2010, JPO). Concurrently during La Niña the Kuroshio recirculation gyre regime retreats northward from Lamon Bay. In El Niño, as suggested by the LB01 neutral ENSO conditions, the NEC input is reduced and the Kuroshio recirculation gyre projects into Lamon Bay. When the Luzon Strait westward throughflow is large during El Niño, that portion is expected to be drawn from the Kuroshio recirculation.

The Mindanao Current transport is expected to vary out-of-phase with ENSO relative to the NEC feed into Lamon Bay. This brings up interesting questions about the leakage of the Mindanao Current into the Indonesian throughflow, which decreases in El Niño, opposite to the expected Mindanao transport. This may have something to do with the leakage dynamics from retroflection structures, i.e. the Mindanao retroflection [eddy] leakage into the Sulawesi Sea and/or the South China Sea throughflow effect (Gordon et al., 2012, GRL, in press): ITF comment: During El Niño the SCS throughflow via Sibutu Passage blocks Mindanao surface layer leakage to Makassar Strait, which lowers the Makassar net transport, counteracting the greater Mindanao transport associated with the northern bifurcation position.

§ Possible Implications of an ENSO [bifurcation] dependent Kuroshio source:

• During La Niña there is increased injection of NEC tropical Pacific water into the subtropical North Pacific; during El Niño the subtropical North Pacific is more 'isolated' from the NEC.

• The NEC enhanced Kuroshio transport during La Niña, leads to greater northward heat flux into the North Pacific; and might reduce western pacific warm pool volume.

• The NEC injection into the subtropical regime, on climatic average (the integrated La Niña/El Niño phases), balances the loss of North Pacific water through the Bering Straits (~1 Sv) and through Luzon Strait (~3 Sv) into the South China Sea (that most likely advects into the Indian Ocean as part of the Indonesia Throughflow) , and to the export of North Pacific Intermediate water within the Mindanao Current (2 Sv?). During El Niño the Kuroshio recirculation gyre reaches into Lamon Bay, it may be the primary feed the westward 'leakage' into the South China Sea, (Luzon Strait westward transport is increased during El Niño, HYCOM, Hurbert et al 2011). In this way the Kuroshio recirculation gyre exports the accumulated NEC injected during the previous La Niña phases, that is not taken up by the Bering Straits and NPIW export.

• More potential implications? effect on ecosystems, linkage with PDO, impact on ITF, west Pacific warm pool, etc..

§ Luzon Strait Survey, ship underway system and XBT:

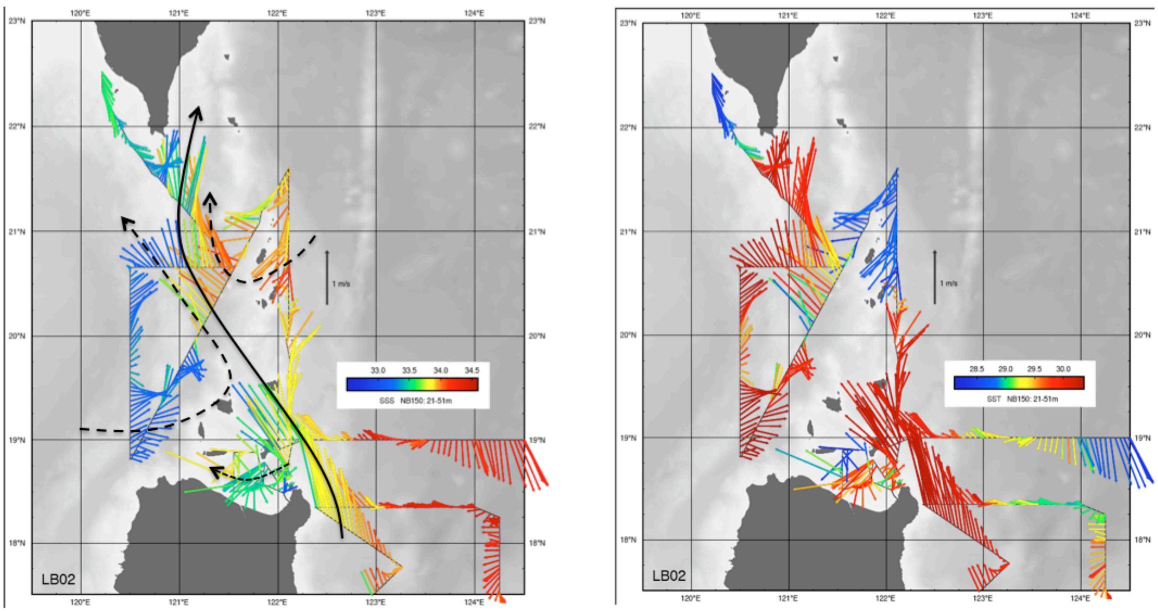


Figure 13a. ocean current vectors 21-53 meters, color coded by SST and SSS within Luzon Strait .

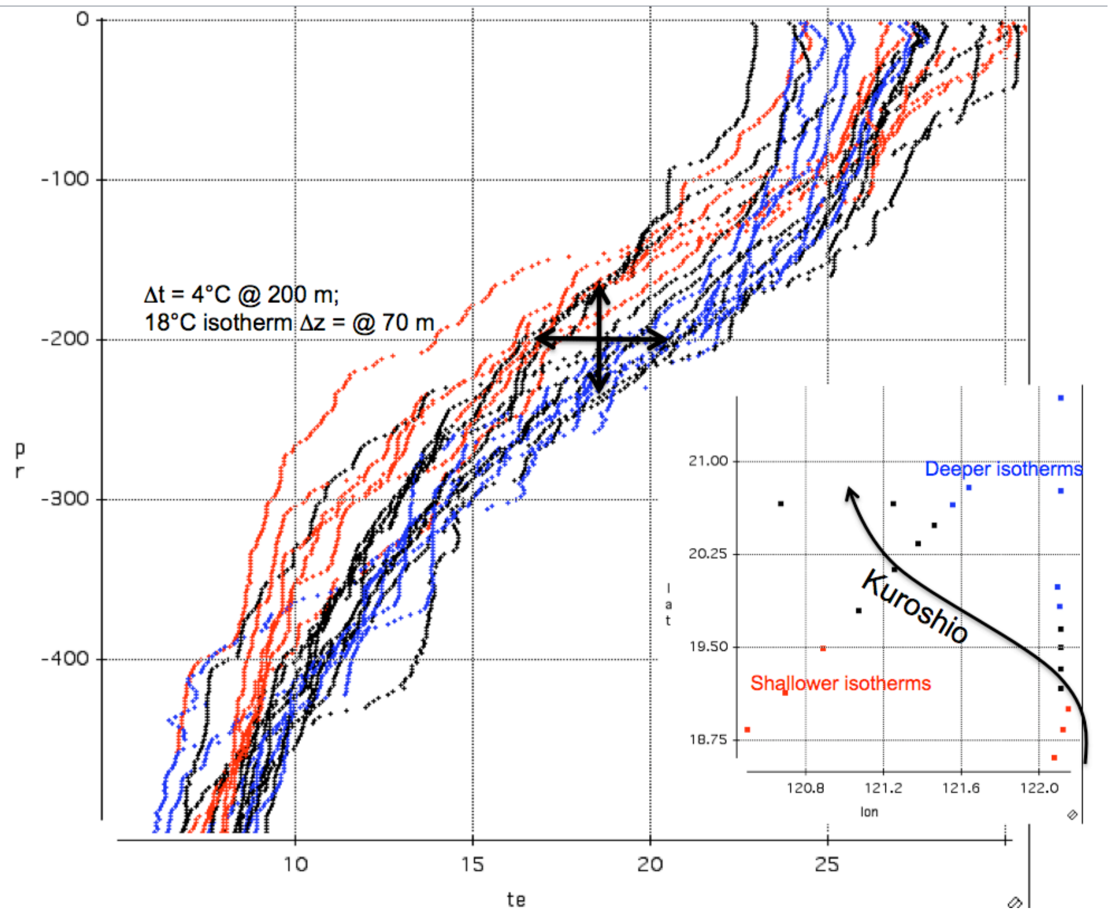


Figure 13b; XBT profiles in Luzon Strait
isotherms tilt in a geostrophic way

Acknowledgements:

Lamon Bay cruise 2 was extraordinarily productive. With calm weather , no typhoon, we met our objectives. Our knowledge of the origin of the Kuroshio has been advanced. This was achieved with the support of a great ship, operated by dedicated 'can-do' people: Captain Tom Desjardins established a good 'vibes' throughout the ship. Eric Wakeman, Melissa Turner and David Gilmartin handled the ship skillfully as the science group lowered and retrieved all sort of stuff in the ocean. The engineering group lead by chief Paul Mauricio kept things running smooth. The science team was effective, highly responsible, always there when needed. The Philippine group is a delight to work with. Special thanks is extended to my loyal, dedicated, research assistant, Phil Mele. Scripps ResTechs Meghan Donohue and Brett Hembrough are most competent and cheerful, allowing the science team to interface with the ship facilities seamlessly. It was so nice to sail again with Frank Delahoyde, who's computer support allowed us to do more. Ship food just great, thanks to Jay Erickson and Steve Lamb.

I am greatly appreciative of the assistance to the science program provided by Allan Noveno, the Philippine Navy Observer.

I cannot think of anything negative to say about Revelle and its people. Great job!

14 May 2012
Arnold L. Gordon, Chief Scientist

§ University of the Philippines Marine Science Institute: Shelf Pacific Interaction in Lamon Bay, Philippines (SPIL), University of the Philippines Diliman, coordinated by Cesar Villanoy

CTD Fluorometer LSS and Transmissometer: Olive Cabrera;
Plankton Sampling: Aletta Yniguez;
Sediment cores: Fernando Siringan;
Chemical Oceanography: Gil S. Jacinto, Maria Lourdes San Diego–McGlone, Maria Teresa L. Escobar, Maria Isabel S. Senal, Lara Patricia A. Sotto, Mary Chris L. Tentia; Atsushi Watanabe [pCO_2, Tokyo Institute of Technology]

§ Frank Delahoyde- *SIO Shipboard Technical Support* LB02 Shipboard CTD Data Acquisition and Processing

§ Phil Mele- CTD stations map/table

§ Meghan Donohue and Brett Hembrough- Research Marine Technician Group Report: RR1204 Deck Operations; Dragging for TRBMs

Philippine Component Cruise Report

Introduction

The Philippine component of the Lamon Bay Program is to investigate the interaction between the Philippine shelf and the northern branch of the North Equatorial Current (NEC) and potential implications of these interactions on the biological productivity in the area. This cruise is the 2nd and last of the oceanographic cruises for the Office of Naval Research (ONR) funded Lamon Bay program in collaboration with Arnold Gordon of Lamont Doherty Earth Observatory, Columbia University and Pierre Flament of the School of Oceanography and Earth Science and Technology, University of Hawaii. The data collected from the cruises, moorings and coastal HFRADAR will be complemented by shelf surveys on board smaller chartered fishing boats.

Data from the 2011 cruise and from satellite images have shown a strong link between the chlorophyll distribution patterns and circulation, highlighting the role of physical dynamics in shaping biological productivity patterns in this area. The Philippine component's objective for this cruise is to gain an understanding on the distribution of chlorophyll pigment concentrations, water chemistry parameters, phytoplankton and zooplankton composition and abundance relevant to biological primary productivity and to relate these distributions to the physical environment. Sediment cores were also collected to analyze long-term variations of water column productivity. The water chemistry methods and preliminary results are described in the next report.

Methods

Underway System and CTD Chlorophyll

The RV Revelle has an underway and meteorological system that automatically measures the parameters shown in Table 1. UW data are time and GPS location stamped. The UW system at the Hydrolab was flushed with freshwater at approximately 0000 H GMT everyday during the cruise to minimize biofouling of the sensors, particularly the fluorometer. Underway measurements were conducted all along the cruise track (Figure 1). Water samples from the UW system were also collected at the CTD stations and filtered using GFF filters for chlorophyll analysis in the lab for validation of the chlorophyll fluorescence measurements.

The main features of the circulation in the Lamon Bay area is the Kuroshio feeder current which is formed from the NEC and separates from the shelf at around 123.5°E. It flows northwest and at 16.5N becomes a western boundary current. Within Lamon Bay, the dominant feature is the cyclonic dipole and is a rather steady feature nased on satellite data and 2011 and 2012 cruise data. The core of the Kuroshio feeder current forms the boundary between the low chlorophyll oligotrophic waters in the anticyclonic dipole to the east and the high chlorophyll waters of the cyclonic dipole to the west (Figure 3a). The cyclonic dipole in Lamon Bay can be discerned from the chlorophyll concentration distribution patterns and is consistent with overlain underway surface velocity vectors (Figure 3b and c).

The underway data confirms what the satellite data show. Chlorophyll concentrations along the cruise track distinctly separates the Lamon Bay waters from the rest in terms of salinity and chlorophyll a (Figure 4). Chlorophyll profiles from the CTD data also confirm the difference in subsurface chlorophyll between the dipoles. A vertical section of chlorophyll from the surface to 300m depth extending from the channel between Polillo Island and Luzon to the northeast across the Kuroshio feeder shows a decrease in surface chlorophyll concentration and a weakening and deepening of the deep chlorophyll maximum (DCM) from 75m to 135m (Figure 5). The relatively higher chlorophyll concentration in Lamon Bay is most likely sustained by nutrient input from riverine sources (lower surface salinity) and from upwelling associated with the cyclonic dipole.

Table 1. RV Revelle Underway/MET Parameters

Parameter Name
Air Temperature
Barometer
Relative Humidity
Wind
Precipitation
Long Wave Radiation
Short Wave Radiation
Surface PAR
Sea surface Temperature
Sea surface salinity
Chlorophyll fluorescense
Dissolved oxygen

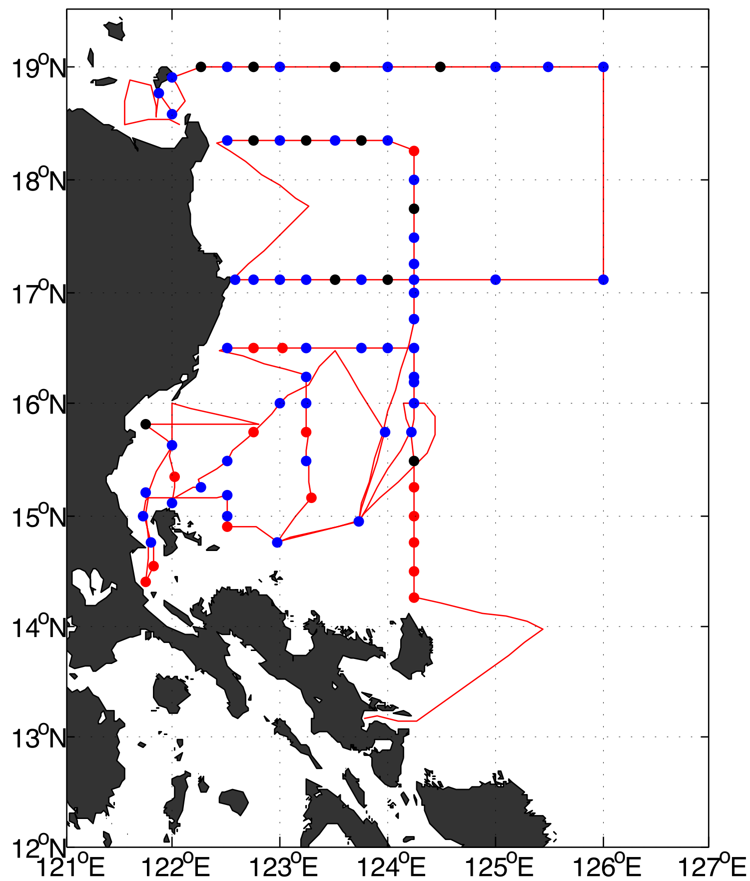


Figure 1. Cruise Track (red lines) and station locations (black - CTD only, blue - CTD + water chemistry, red - CTD + water chemistry + carbonate chemistry).

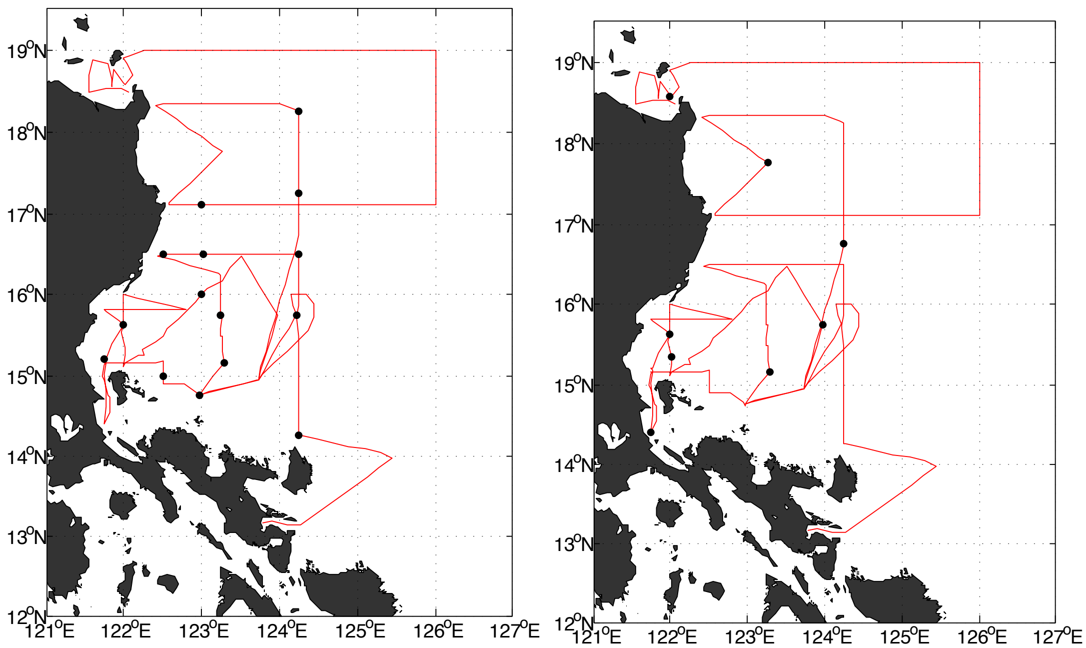


Figure 2. Plankton net tow (left) and sediment gravity core (right) stations.

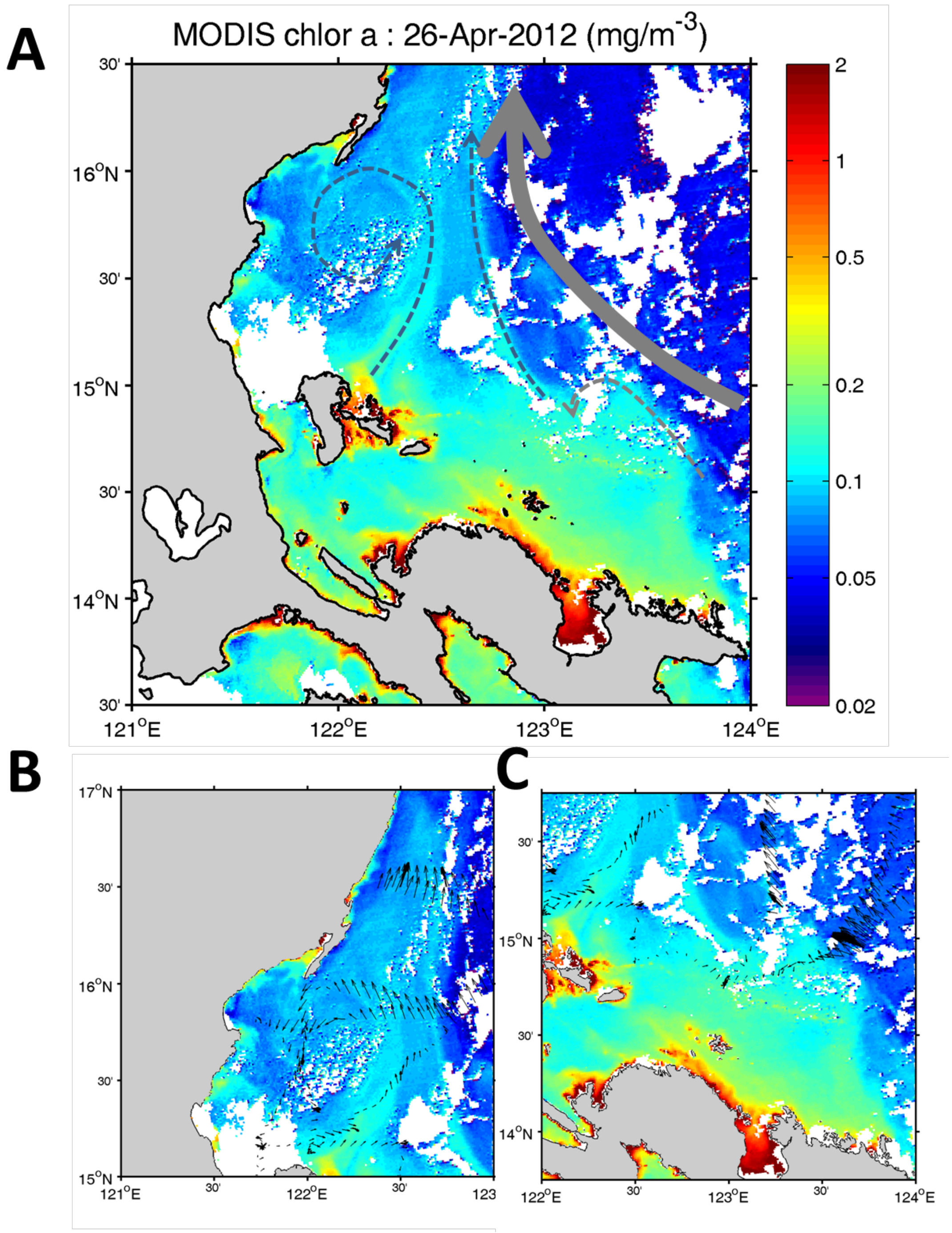


Figure 3. MODIS chlorophyll-a image for April 26, 2012 overlain with inferred circulation (A) and actual current velocities from hull-mounted Acoustic Doppler Current Profiler (B & C).

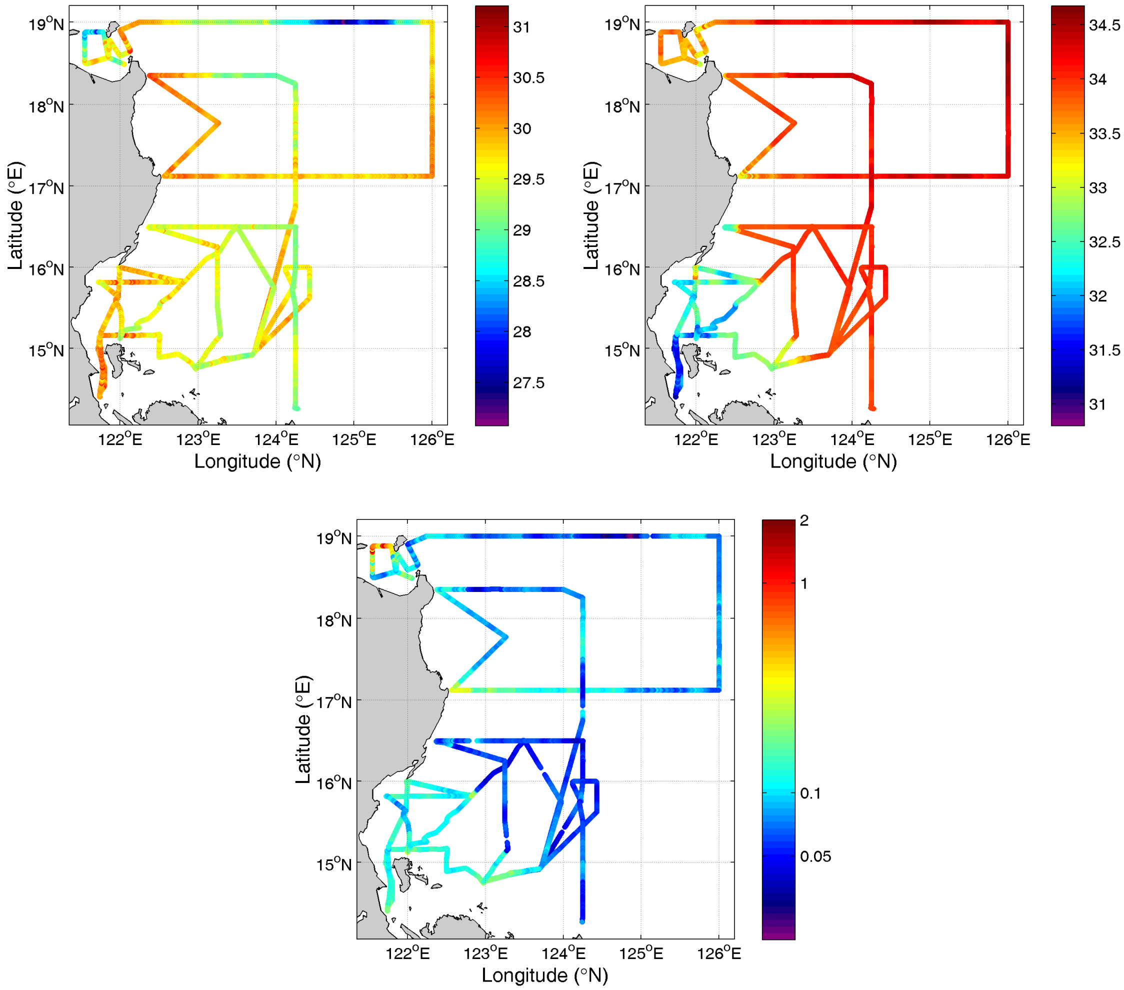


Figure 4. Underway measurements of temperature (top left, °C), salinity (top right, psu), and chlorophyll (bottom, mg/m3).

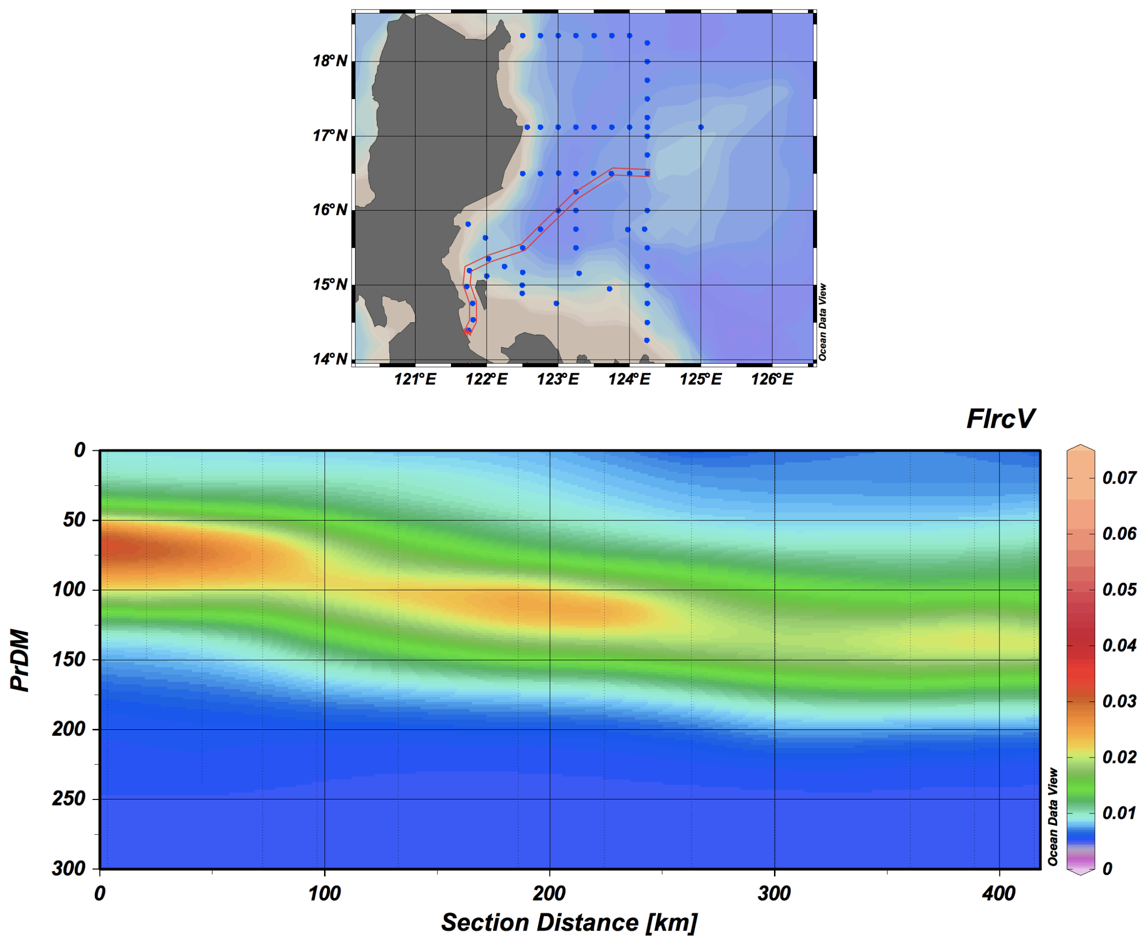


Figure 5. Chlorophyll (V) section from channel west of Polillo across the nascient Kuroshio.

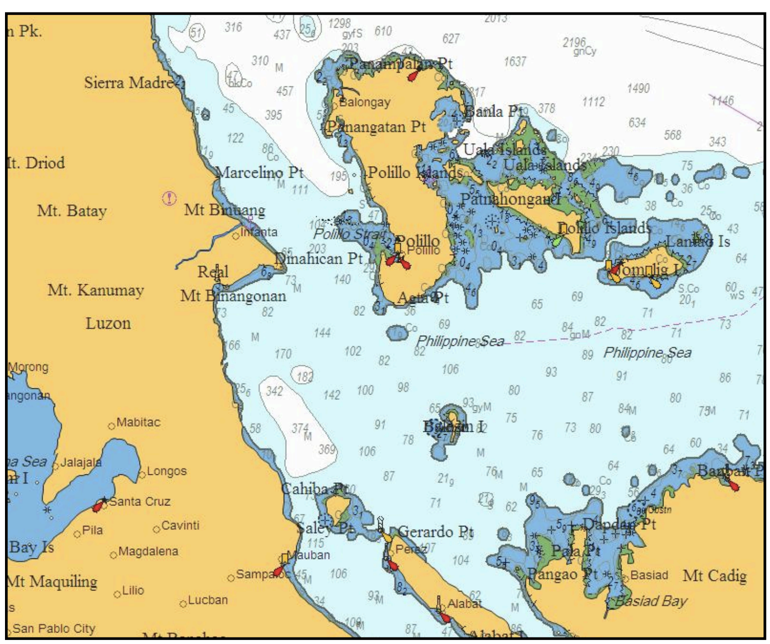


Figure 6. Map of the 400m deep hole southwest of Polillo Island.

Oxygen

While looking for potential sources of subsurface low oxygen water observed in the CTD profiles, We also investigated the small 400m deep basin within the shelf area southwest of Polillo Island (Figure 6). The deepest connection between this basin and the outside is <200m deep. This is consistent with the uniform temperature and salinity profiles within the basin at depths > 200m (Figure 7). At 380 m, the temperature difference between the basin and the adjacent Lamon Bay is about 8°C. This high temperature may be partly responsible for the difference in apparent oxygen utilization (AOU) between the basin and adjacent stations from 150-400m depth (Figure 8).

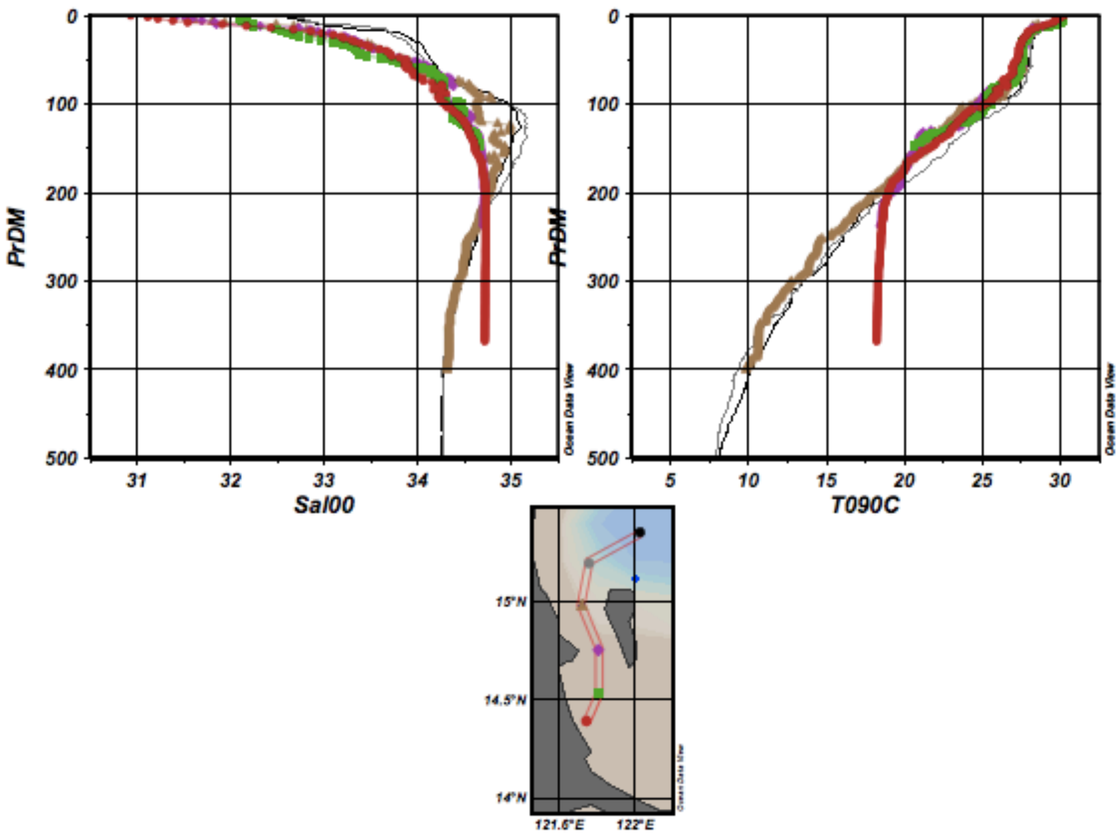


Figure 7. Along channel temperature and salinity profiles. Heavy red line represent profiles from the basin.

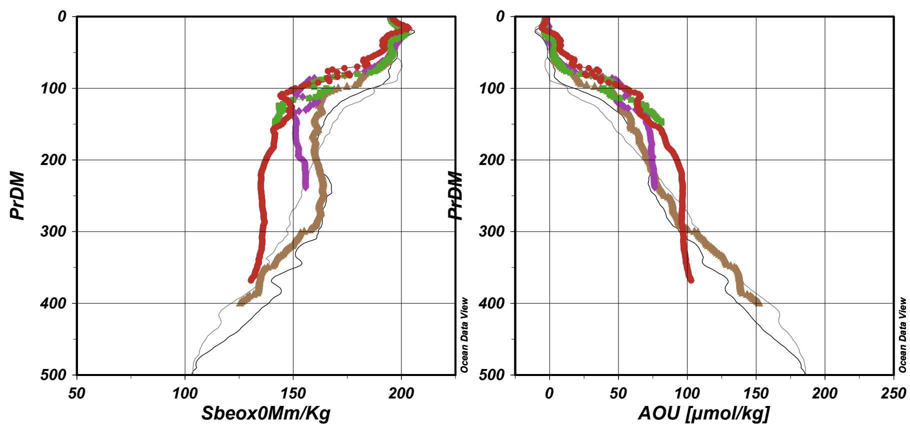


Figure 8. Dissolved oxygen concentration and AOU profiles for Stations 35-38.

Plankton Sampling and Determination

Based on the analyzed data from the cruise held last year, there was a difference in both phytoplankton and zooplankton composition for each of the identified water circulation features in Lamon Bay and the northeastern part of the Philippines. These were the Kuroshio feeder stream, anti- and cyclonic dipoles, and Polillo current. Plankton composition was based only on samples collected using Niskin bottle samplers. For this cruise, however, both bottle samplers and bongo nets were used to collect plankton samples. Sixty-six (66) CTD stations were chosen for collection using Niksin bottles and fifteen (15) stations for bongo net deployment (Figure 2). Two types (oblique and vertical) of net deployment were employed on selected stations strategically chosen to represent the different water circulation features in the study area, particularly Lamon Bay. The target taxa to be identified are the general groups of phyto-, zoo-, and ichthyoplankton. Data from both cruises would ideally answer queries such as (1) What types of fish larvae are found in the different areas? (2) What are the potential and actual prey of these fish larvae? (3) What is the general plankton composition of the bay and how abundant are they? and (4) How are the trophic dynamics affected by hydrodynamic features?

Collection and preservation of plankton samples

Niskin Bottles

Plankton sampling was done through filtration of 10L water samples per depth obtained from Niskin bottles attached to a rosette. Five general depths for deep stations were (1) subsurface (1m), (2) above the deep chlorophyll maximum (DCM), (3) DCM, (4) below the DCM and (5) 200 meters. Modifications were made for some stations 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. Samples for each depth were equally divided into two with one half sieved and fixed for phytoplankton analysis, and the other half for zooplankton. Samples for phytoplankton analysis were first subjected to a multi-excitation fluorescence sensor (Infinity-ME) before being sieved. Samples will be brought back to the lab for further analysis using the FlowCAM and conventional microscopy. Sample description and fixatives used are described in Table 2.

Bongo Nets

Bongo nets with a mouth diameter of 60cm, length of 2.5m and mesh size of 335µm were used for either oblique or vertical towing.

A total of 9 vertical tows were conducted for quantitative and qualitative analysis of ichthyoplankton. Flowmeters were placed at the center of each ring and a 20kg weight was attached in the middle of the two rings. The nets were deployed down to 200m at a rate of 30m/min and retrieved at a rate of 20m/min. Approximately 5ml of soda water was poured into each cod end and carefully mixed, before sieving of the samples. This is to prevent the fish larvae from eviscerating. Samples from each cod end were split in half using a Folsom splitter. Half of the sample was sieved with a cutout of a 64µm mesh, placed in a petri dish, sealed and placed in the freezer. These will be used for gut pigment analysis to be conducted in the lab. The other half of the sample was further split into two, sieved through a 200µm mesh and placed in wide-mouthed plastic bottles. One was fixed with ethanol and the other with neutralized formalin. Both samples will be sorted for fish larvae then analyzed for zooplankton composition and abundance using the FlowCAM and conventional microscopy.

Oblique tows were conducted for qualitative analysis of ichthyoplankton. A net depressor (~12kg) attached with additional weights (20kg) was used for these tows. Three to four pieces of menthol crystal was placed in each cod end to subtly subdue any jellies caught to prevent them from preying on any fish larvae. The nets were deployed down to 200m for 4 stations and 100m for 2 stations at a rate of 30m/min. The ship speed was kept at a range of 0.1 to 0.6 knots maintaining a 45° of the cable while simultaneously retrieving the nets at a rate of 15m/min. Samples from each cod end were transferred in separate bins and observed for fish larvae. Larvae were then isolated and fixed in ethanol with a drop of glycerin. Identification and gut analysis will be conducted back in the lab.

Details of bongo net samples are described in Table 2. All further laboratory work will be conducted at the UP-MSI lab.

Table 2. Description of samples collected

	Sampling apparatus	Sample description	Fixative	Target taxa to be analyzed
1	Niskin bottles	Filtered with 20µm sieve	Neutralized formalin	Phytoplankton
2	Niskin bottles	Filtered with 20µm sieve	Ethanol	Zooplankton
3	Bongo nets (335µm)	Filtered with 64µm sieve	frozen	Gut pigment analysis of zooplankton and ichthyoplankton
4	Bongo nets (335µm)	Filtered with 200µm sieve	Neutralized formalin	Gelatinous zooplankton and Ichthyoplankton
5	Bongo nets (335µm)	Filtered with 200µm sieve	Ethanol	Zooplankton and Ichthyoplankton
6	Bongo nets (335µm)	Isolated from oblique tows	Ethanol	Ichthyoplankton (larvae) for gut analysis

Infinity-ME Analysis

A Multi-wavlengthExcitation Fluorometer(Infinity ME) has been developed by JFE Advantech Co., Ltd, which uses 12 light-emitting diodes to illuminate nine excitation wavelengths (375, 395, 420, 435, 470, 490, 535, 570, 590 nm) and record the inherent absorption spectra of phytoplankton species, thereby obtaining a more rapid means of distinguishing phytoplankton types. The absorptions are calibrated to chl *a* units. The current calibration file from the manufacturer is based on *Chaetoceros* sp. as the representative species for diatoms, *Microcystis* sp. for cyanobacteria, and *Nannochlorophsis* sp. for green algae. This instrument was used to analyze the discrete depth samples obtained from the Niskin bottles.

Representative stations from the key circulation features (Polilio Current, Cyclonic Dipole, Anti-cyclonic dipole, and Kuroshio Feeder Stream) previously seen were initially analyzed. The very partial results from the Infinity-ME showed that cyanobacteria and diatoms concentrations were relatively high in all representative stations among the four circulation zones (Figure 9). Green algae were exhibited low concentrations in all stations. Diatoms tended to have uni-modal distribution, possibly contributing to the DCM, while the cyanobacteria had two peaks that were at depths where diatoms were not abundant (except for station 48 which only peaked above the diatom peak). The cyanobacteria group were particularly high in concentrations at station 48 located within the zone of the anti-cyclonic dipole. During some of the sample runs with the FlowCAM (see section below discussing this), the cyanobacteria *Trichodesmium* was often observed.

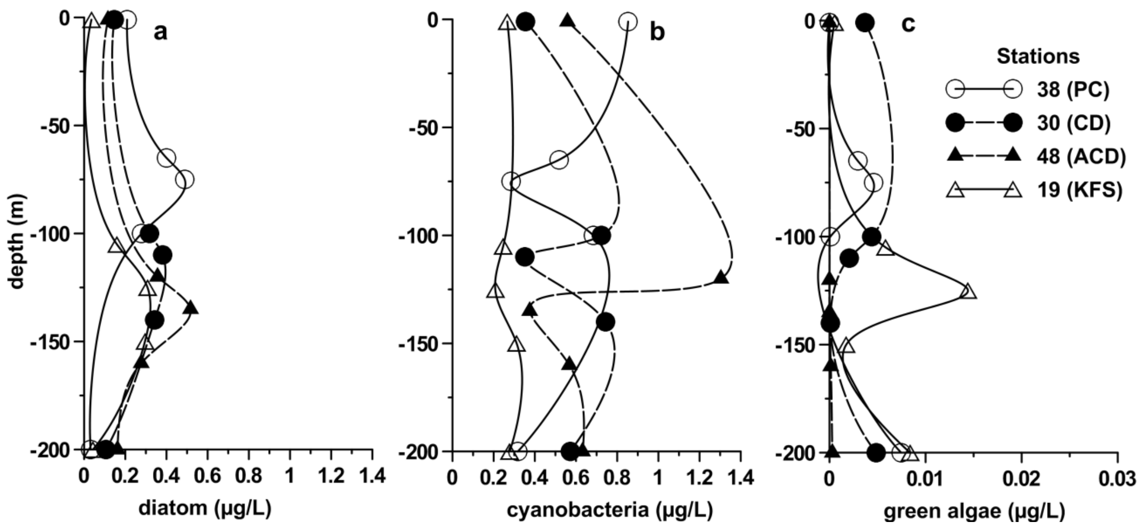


Figure 9. Vertical profiles of phytoplankton groups of representative stations for the four circulations zones: Polilio Current (PC), Cyclonic Dipole (CD), Anti-Cyclonic Dipole (ACD) and Kuroshio Feeder Stream (KFS). The (a) diatom group is represented by *Chaetoceros* sp., *Microcystis sp.* for cyanobacteria (b) and *Nannochloropsis sp.* for the green algae group (c).

FlowCAM analysis

A FlowCAM (Flow Cytometer and Microscope) purchased through ONR funds was used on board to optimize analysis of live samples, and to develop a library for future automated classification of plankton. Extra water from DCMs of selected stations were collected, sieved with a 20µm and diluted to ~10ml. Serial sieving (300µm, 100µm and 20µm) was then done to sort the samples according to size.

Autoimage mode

Samples less than 300µm but greater than 100µm were run through a 300µm flowcell under 4X magnification. Particles or organisms are photographed as they flow through the flow cell at a rate of 0.100ml/min. Figure 10 is a partial visual spreadsheet of one of the runs on autoimage mode.

Trigger mode

Samples less than 100µm but greater than 20µm were run through a 100µm flowcell under 100X magnification. Particles or organisms with pigments that react to the laser and fluoresce are photographed as they flow through the flow cell at a rate of 0.080ml/min. Figure 11 is a partial visual spreadsheet of one of the runs on trigger mode.

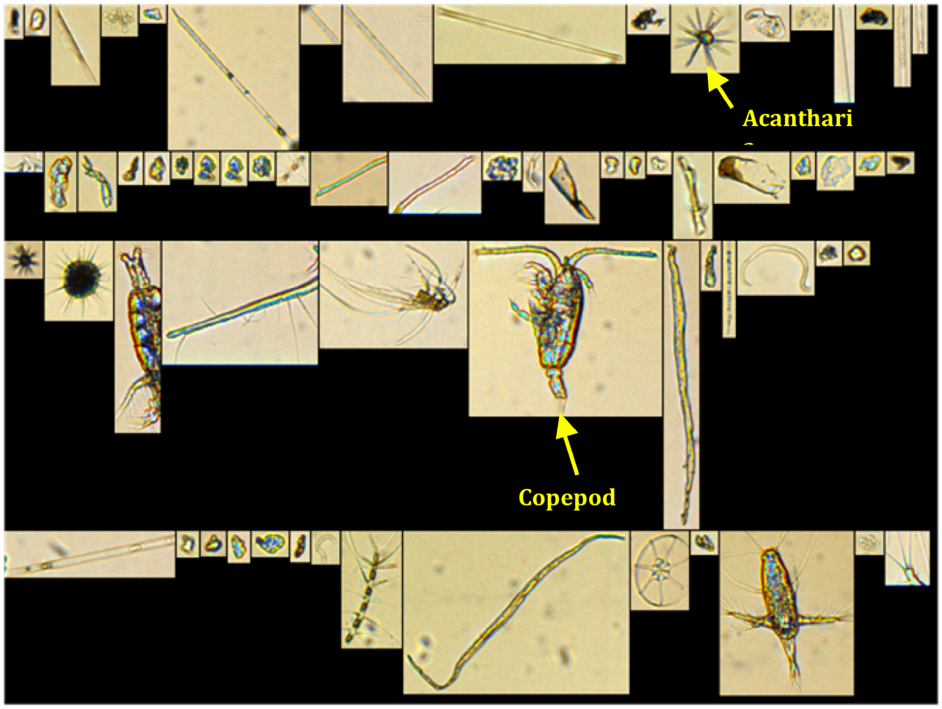


Figure 10. Samples from DCM of Station 57 under autoimage mode.

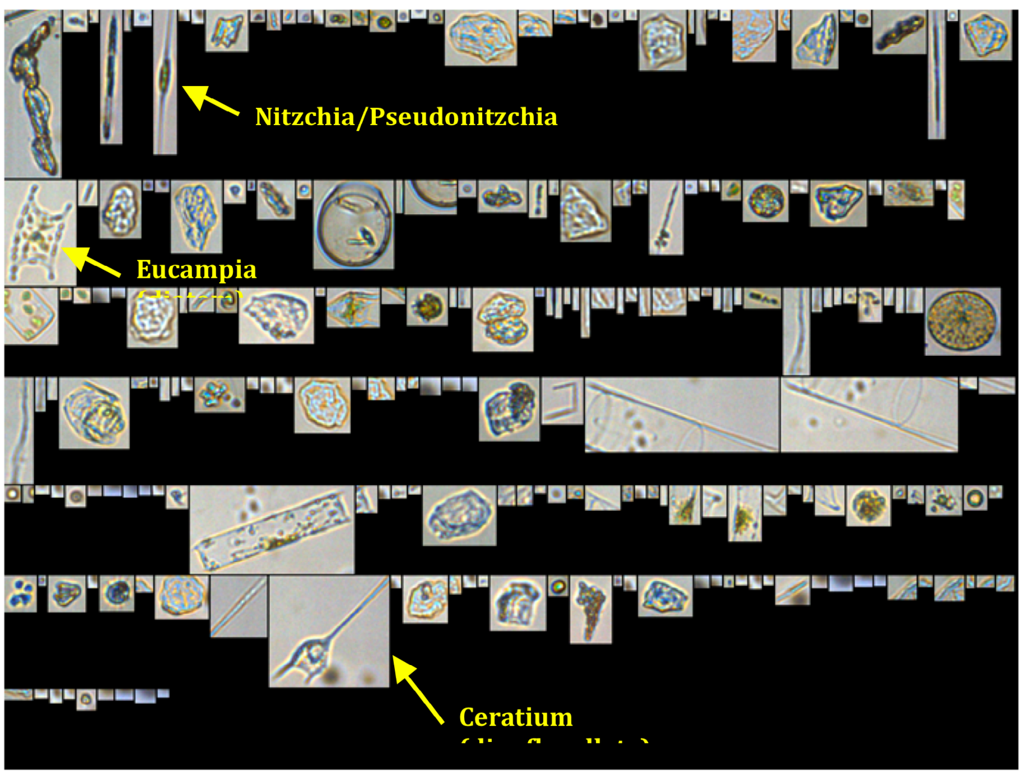


Figure 11. Samples from upper DCM of Station 68 under trigger mode.

Sediment Coring

The OSU gravity corer was used to obtain sediment samples during the Lamon Bay 2012 Cruise (Figure 12 and Figure 13). Figure 14 shows the nine sampling stations that were occupied during the cruise. Out of the nine stations, eight were successfully sampled. After the collection of the sediment cores, styro plugs were placed in the pipes as stoppers and then covered with core caps in both ends. The sediment cores were sealed using a duct tape and were stored at room with 42°F (5.56°C). The coordinates, core lengths and water depths of each sampling were recorded. Table 3 shows the summary of samples acquired during the cruise.

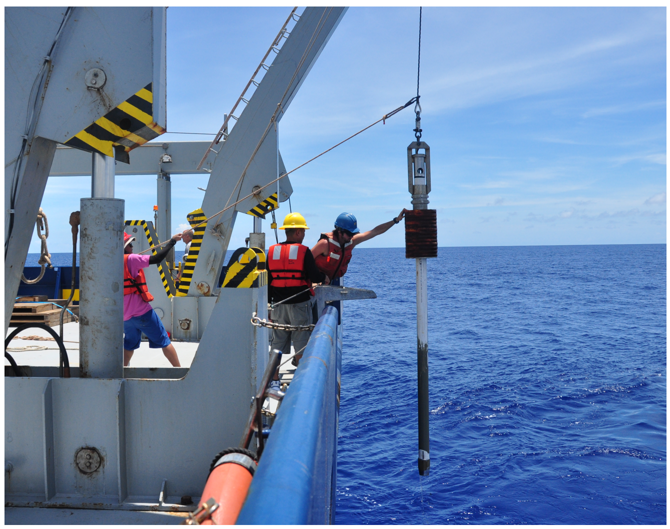


Figure 12. The OSU gravity corer during retrieval.

Figure 13. One of the sediment cores and the top view of its sediment.

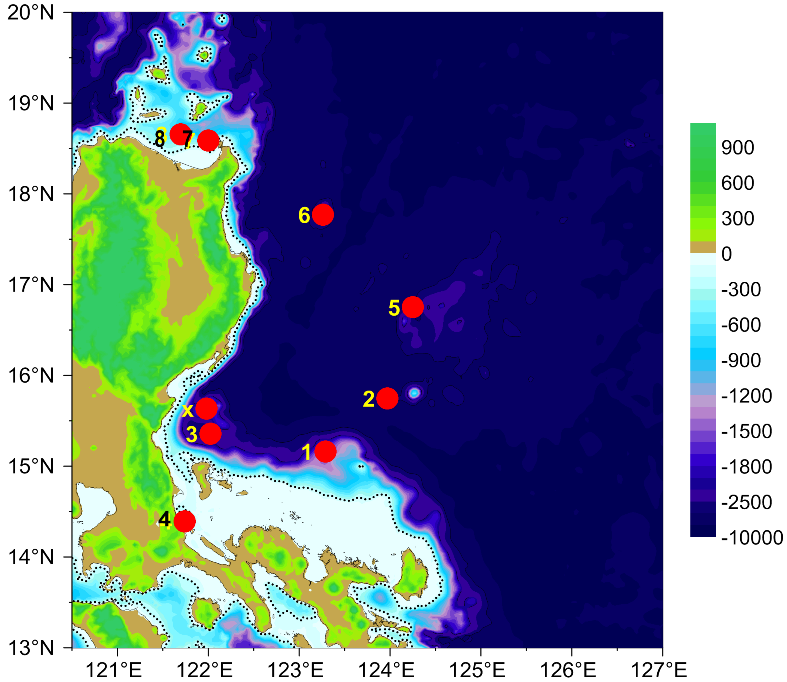


Figure 14. Core stations

Table 3. Core sampling stations.

Sampling Date	Core ID	Latitude	Longitude	Water Depth (m)	Length (m)
April 28, 2012	1	15 9.7044 N	123 17.4024 E	1580	1.75
April 28, 2012	2	15 44.7660 N	123 58.3686 E	2990	1.35
April 30, 2012	3	15 21.3690 N	122 1.4268 E	2228	1.45
April 30, 2012	x	15 38.1408 N	121 58.7850 E	2500	X
May 1, 2012	4	14 23.6112 N	121 44.5080 E	388	2.15
May 4, 2012	5	16 45.0276 N	124 15.0042 E	2820	2.30
May 6, 2012	6	17 46.2018 N	123 15.7290 E	2600	0.96
May 10 ,2012	7	18 35.3148 N	122 0.0150 E	550	1.96
May 10, 2012	8	18 57.0000 N	121 0.0850 E	325	0.30

Note: x- indicates that no sediment was retrieved

Future Analysis

The sediment cores will be used to reconstruct primary productivity, upwelling and paleoclimate during the last few thousand years. It is expected that the cores will yield different temporal resolutions. Of specific interest is the past 2000 years. An XRF-core scanner will be used for the initial analysis to help pick which cores to analyze in detail. Combinations of geochemical proxies, paleontological and biomarker indicators will be utilized for the reconstructions.

Shelf Pacific Interaction in Lamon Bay, Philippines (SPIL)

Chemical Oceanography

R/V Roger Revelle

Marine Science Institute, University of the Philippines and Tokyo Institute of Technology

24 April – 12 May 2012

Cruise Report

Introduction

The cruise in 2012 offered another opportunity to study Lamon Bay and the Bicol Shelf area. This 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 aims to understand how the interaction between the shelf and open ocean and its influence on coastal processes are characterized by chemical features (C, N, P) of the Bicol Shelf and off-shelf areas. The following are some questions this component hopes to address:

1. Which chemical parameters indicate the presence of upwelling on the Bicol Shelf?
2. Is there cross-shelf exchange of C, N, and P?
3. How do physical processes (e.g. upwelling) 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 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. 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?
8. What insights on ocean acidification can we gain from the behavior of the carbonate-related parameters (pH, alkalinity and DIC) on the shelf area and the impinging NEC?

Methodology

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Maria Isabel S. Senal, Lara Patricia A. Sotto, Mary Chris L. Tentia
Tokyo Institute of Technology:
Atsushi Watanabe

Collection of water samples from selected depths using the CTD-rosette was done for a suite of chemical parameters (Table 1). Sampling strategy was either a "full cast" or "normal cast". There were 13 "full casts" from shelf and off-shelf stations where samples for all the chemical parameters were obtained. The rest of the stations had "normal casts" where water samples for only selected parameters were acquired (Figure 1). Water samples at varying depths (typically 4 depths including a few from 1500m) were also obtained for Winkler oxygen determination starting at Station 10 until Station 40 at intermittent stations (total of 14) to calibrate the CTD DO sensor. Primary productivity measurements were done at 3 sites (representing offshore, shelf and mid-section stations) using the light and dark bottle method. Table 2 summarizes the parameters obtained at the sampling stations.

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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
Chromophoricdis solved 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

Underway pCO_2 measurement

Seawater pumped up from 3-4m below sea level by the ship at a flow rate of ca. 20L min^{-1} was continuously fed to a plastic container (approx. 100L) set on the deck outside Hydro Lab. Inside the container, an equilibrator for pCO_2 analyzer was set. A gas-permeable membrane tube was used to equilibrate seawater CO_2 with sample air [Saito et al., 1995]. Then the equilibrated CO_2 in the dry air was measured with a non-dispersive infrared analyzer (NDIR: Li-Cor 820) set in the Hydro Lab (Kimoto CO2-09). The NDIR was calibrated every 6-hr using a series of CO_2 standard gases (0, 498ppm). Atmospheric CO_2 was measured 10 min every hour, and rest of the time seawater CO_2 was measured.

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Temperature & salinity meter (Compact-CT, JFE Advantec), Chl-a & Turbidity meter (Compact-CKU, JFE Advantec), and DO meter (AROW, JFE Advantec) were also set in the container. TS was measured every 1 min, Chl-a&Turb, DO were measured every 5 min, respectively. Samples for carbonate system parameters were collected from the container at all the stations except for Stations 33, 71 and 78 (N =75). Samples for Chl-a and DO were also collected from the container 2 times or 3 times every day from May 4 to May 9 (N =14) in order to calibrate the sensors.

Water collections from the CTD/rosette

Waters for carbonate system parameters and H_2O isotopes ($\delta^{18}O$ and $\delta^{2}H$) were collected from the CTD/rosette at 1m depth on all stations except for Stations 33, 73 and 78 (N=75). Vertical samplings were conducted at Stations 5,10,15,20,25,30,35,40,45,50,55,59,65, and 70 (N =195).
All the samples for carbonate system parameters (total alkalinity, dissolved inorganic carbon, pH) were analyzed on board within 12 hours after collection, using a close-cell titration system (Kimoto ATT05). Samples were kept in a water bath at 25 °C until just before the analysis.

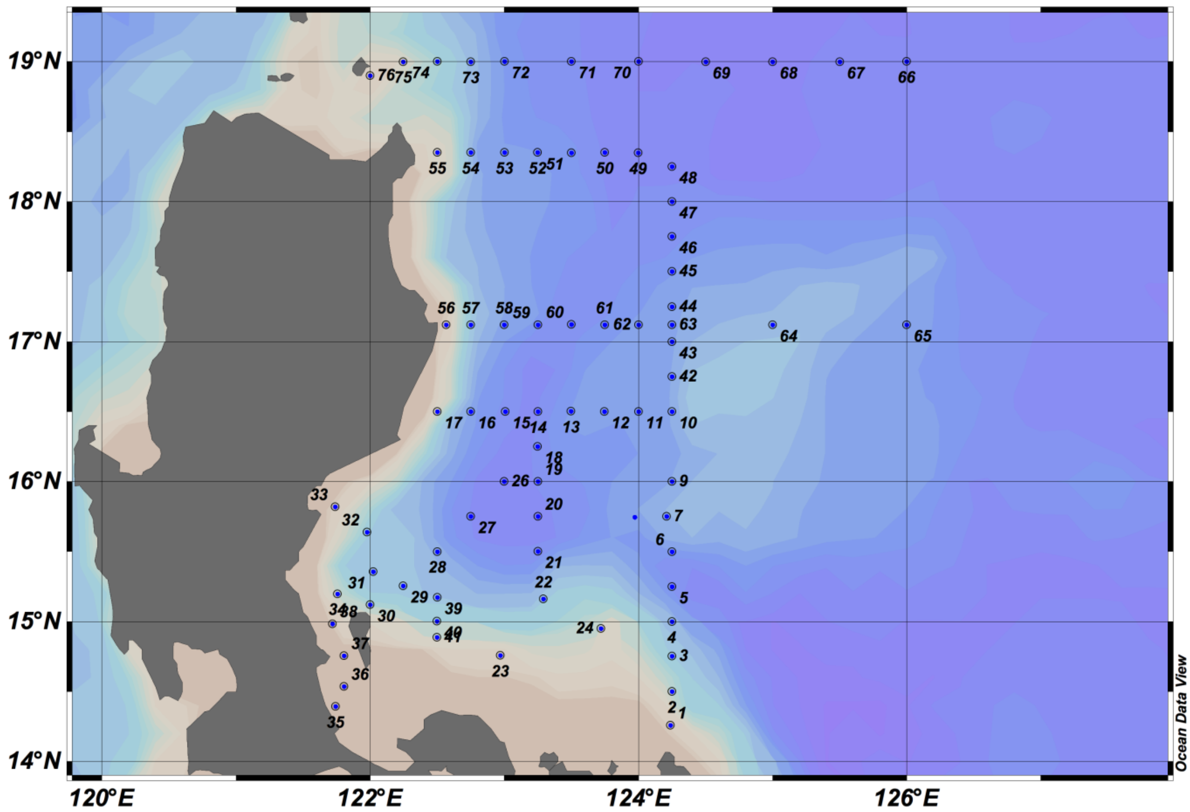

Figure 1. Stations occupied for water sampling

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Table 2. Summary of parameters obtained per station

CTD	Lat	Long	DO	pH	nutrients	chl-a	CDOM	CO2	DOC	TDN	POC/ PN	primary prod	DCM depth (m)
1	14.26	124.239	I	I	I	I	I	I	I	I	I		100
2	14.50	124.249	I	I	I	I	I						105
3	14.75	124.250	I	I	I	I	I	I	I	I	I		105
4	15.00	124.251	I	I	I	I	I						
5	15.25	124.250	I	I	I	I	I	I	I	I	I		140
6	15.50	124.250					SKIPPED						
7	15.75	124.211	I	I	I	I	I						140
8	16.00	124.251	I	I	I	I	I						145
9	16.00	124.251	I	I	I	I	I						140
10	16.50	124.251	I	I	I	I	I						140
11	16.50	124.002	I	I	I	I	I						135
12	16.50	123.747	I	I	I	I	I						135
13	16.50	123.498	I	I	I	I	I						135
14	16.50	123.250	I	I	I	I	I						140
15	16.50	123.009	I	I	I	I	I	I	I	I	I		135
16	16.50	122.750	I	I	I	I	I	I	I	I	I		105
17	16.50	122.500	I	I	I	I	I						105
18	16.25	123.249	I	I	I	I	I						145
19	16.00	123.250	I	I	I	I	I						125
20	15.75	123.250	I	I	I	I	I	I	I	I	I	I	125
21	15.50	123.250	I	I	I	I	I						100
22	15.16	123.290	I	I	I	I	I	I	I	I	I		90
23	14.76	122.972	I	I	I	I	I						65
24	14.95	123.722	I	I	I	I	I						120
25	15.75	123.973	I	I	I	I	I						140
26	16.00	123.000	I	I	I	I	I						135
27	15.75	122.750	I	I	I	I	I	I	I	I	I		135
28	15.50	122.501	I	I	I	I	I						135
29	15.25	122.247	I	I	I	I	I						135
30	15.12	122.000	I	I	I	I	I					I	110
31	15.36	122.024	I	I	I	I	I	I	I	I	I		100
32	15.64	121.978	I	I	I	I	I						100
33	15.82	121.741					SKIPPED						
34	15.20	121.756	I	I	I	I	I						95
35	14.39	121.742	I	I	I	I	I	I	I	I	I		60
36	14.53	121.806	I	I	I	I	I	I	I	I	I		75
37	14.76	121.805	I	I	I	I	I						75
38	14.98	121.719	I	I	I	I	I						75
39	15.17	122.502	I	I	I	I	I						75
40	15.00	122.499	I	I	I	I	I						70
41	14.89	122.499	I	I	I	I	I	I	I	I	I		91
42	16.75	124.250	I	I	I	I	I						130

43	17.00	124.250	I	I	I	I	I						140
44	17.25	124.250	I	I	I	I	I						125
45	17.50	124.250	I	I	I	I	I						115
46	17.75	124.251	I										100
47	18.00	124.251	I	I	I	I	I						100
48	18.25	124.250	I	I	I	I	I	I	I	I	I		135
49	18.35	123.999	I	I	I	I	I						138
50	18.35	123.750	I										
51	18.35	123.501	I	I	I	I	I						125
52	18.35	123.249	I										
53	18.35	123.001	I	I	I	I	I						135
54	18.35	122.750	I										130
55	18.35	122.500	I	I	I	I	I						105
56	17.12	122.567	I	I	I	I	I						75
57	17.12	122.749	I	I	I	I	I						110
58	17.12	123.000	I	I	I	I	I						
59	17.12	123.251	I	I	I	I	I						150
60	17.12	123.500	I										
61	17.12	123.750	I	I	I	I	I						140
62	17.12	124.000	I									I	100
63	17.12	124.250	I	I	I	I	I						
64	17.12	125.000	I	I	I	I	I						135
65	17.12	126.000	I	I	I	I	I						130
66	19.00	126.000	I	I	I	I	I						120
67	19.00	125.500	I	I	I	I	I						
68	19.00	125.000	I	I	I	I	I						110/ 120
69	19.00	124.500	I										
70	19.00	124.000	I	I	I	I	I						120
71	19.00	123.500	I										
72	19.00	123.000	I	I	I	I	I						115
73	19.00	122.750	I										
74	19.00	122.500	I	I	I	I	I						130
75	19.00	122.250	I										130
76	19.00	122.000	I	I	I	I	I						
77	18.35	122.002		I	I		I						
78	18.47	121.520		I	I		I						

Initial Results and Discussion

Dissolved oxygen calibration

A good correlation was obtained ($r^2 = 0.9934$) between the CTD- and the Spectrophotometer-derived DO values, with a slope of 1.0502 (n=248) (Figure 2).

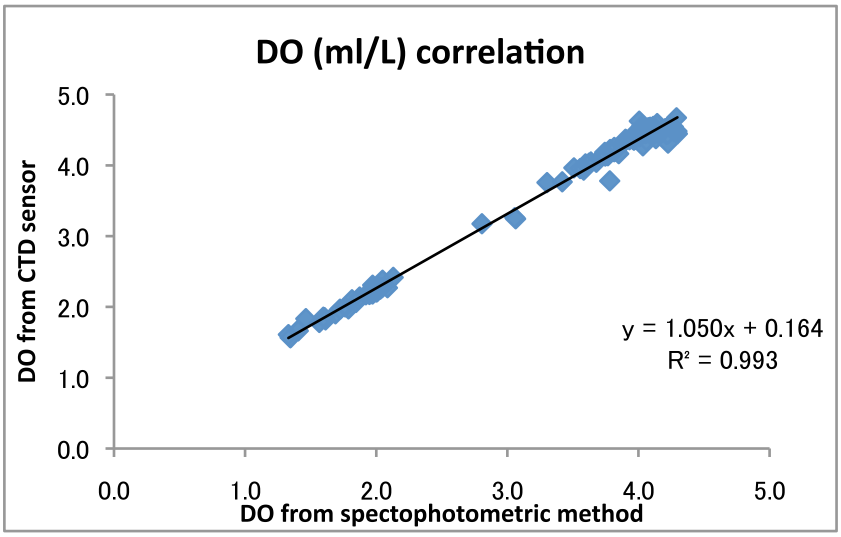

Figure 2. Comparison of DO obtained using the Spectrophotometric method and the CTD DO sensor

pH calibration

Good correlation (r=0.9972) was also obtained between pH measured using the pH meter (Metrohm 654) and the Total Alkalinity titrator (Kimoto ATT-05) (Figure 3). Calibration line: y=0.9724x + 0.2346; n=134.

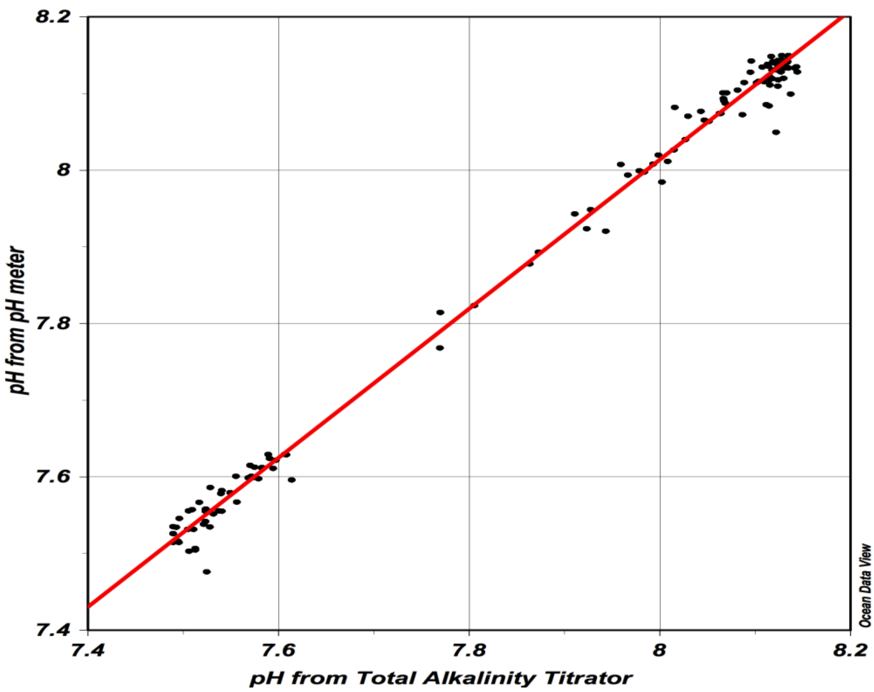

Figure 3. Comparison of pH obtained using the pH meter and total alkalinity titrator

<u>Verical profiles</u>

DO profiles

DO values were high at the surface and decreased at lower depth with a minimum at approximately 750m (Figure 4).

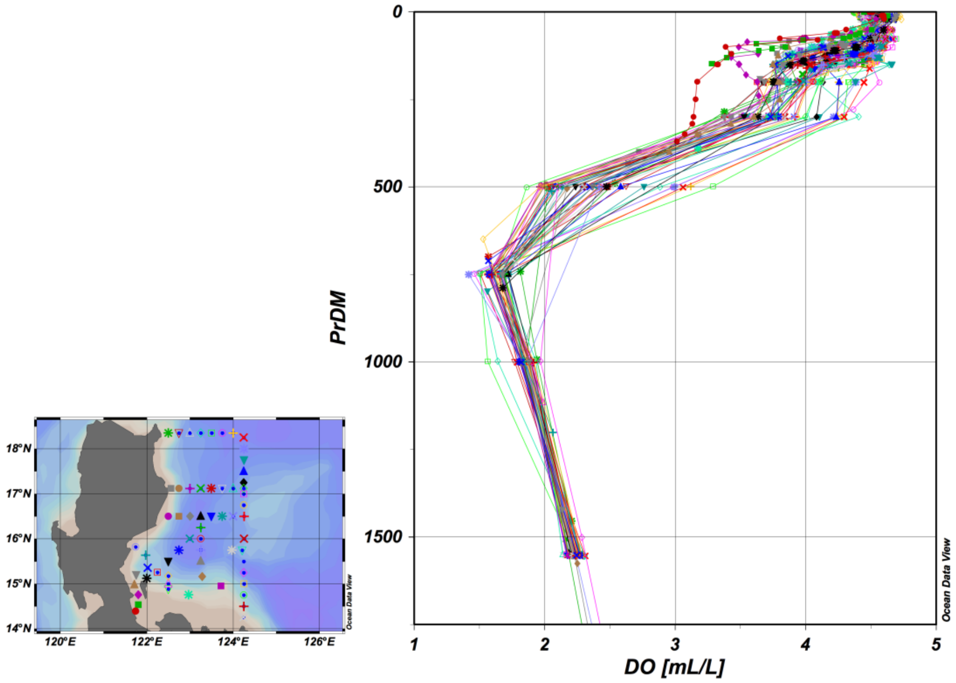

Figure 4. Vertical profiles of DO (from CTD) for all CTD stations

pH profiles

pH values at the surface were high and steadily decreased with depth at the photic layer, below which the pH remained uniform (Figure 5). The depth of the pH minima roughly coincided with depth of the DO minima at ~750m (Figure 4). Processes that consume carbonic acid (e.g. photosynthesis in upper layers) increase pH, while processes that produce carbonic acid (e.g. respiration) decrease pH values.

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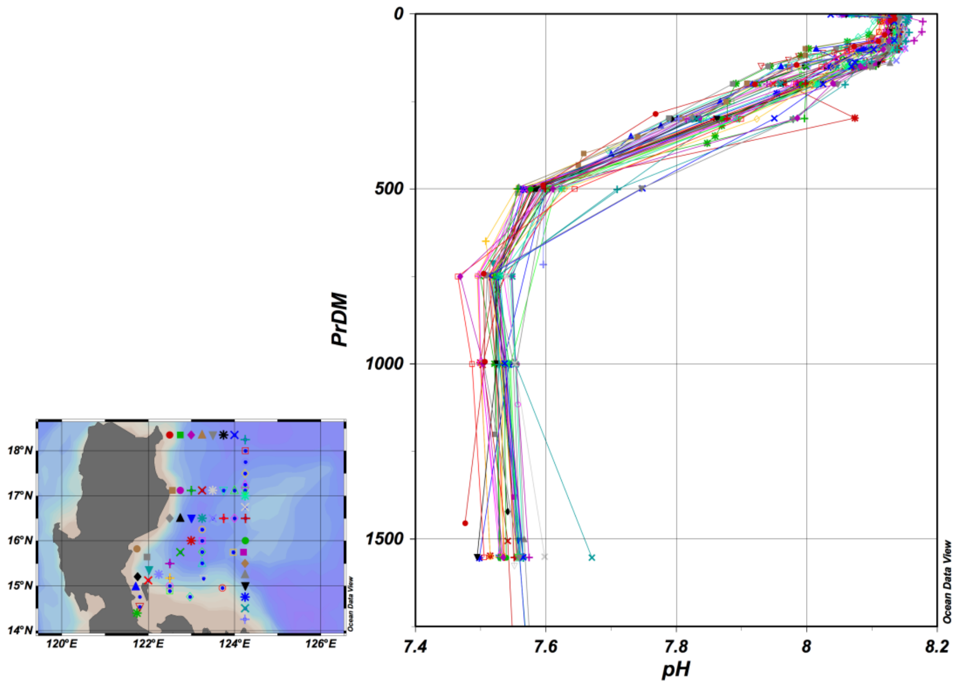

Figure 5. Vertical profiles of pH (uncorrected) for all CTD stations

CDOM profiles

Chromophoric DOM (CDOM) considered a bio-refractory fraction of DOM, is low at the surface and increased with depth (Figure 6). This is a consequence of photodegradation of CDOM at the surface and remineralization of biogenic sinking particles at lower depths.

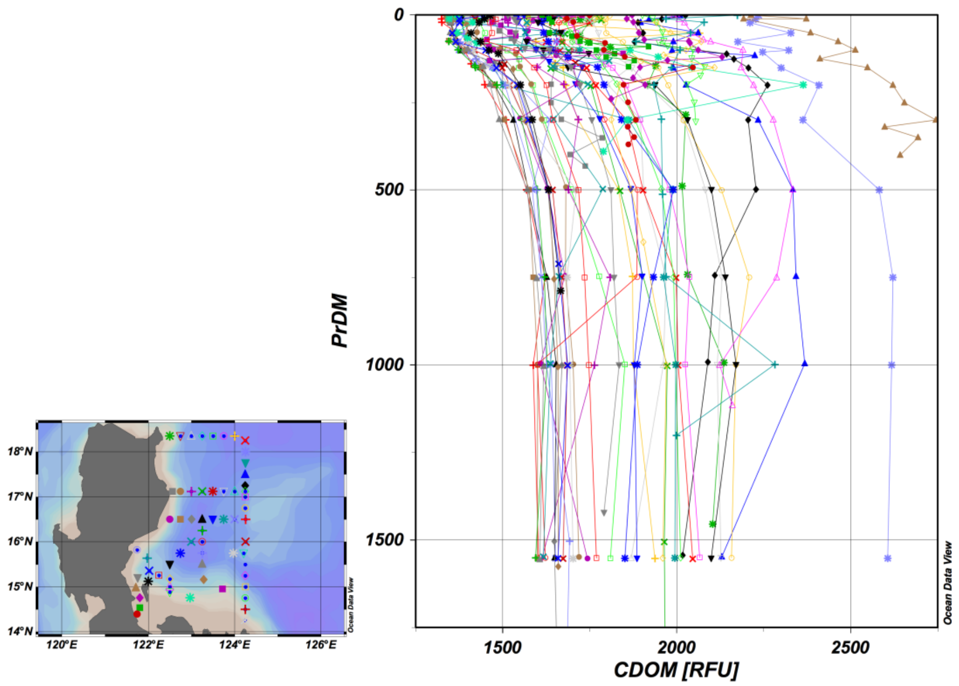

Figure 6. Vertical profiles of **Chromophoric DOM (CDOM)** (uncorrected) for all CTD stations

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Correlations

pH vs AOU

pH values correlated well with AOU (r=0.9934) (Figure 7), which suggests that similar processes (photosynthesis, respiration) affect both parameters. The empirical relationship was determined to be: pH = -0.00258 AOU + 8.122 (n= 746).

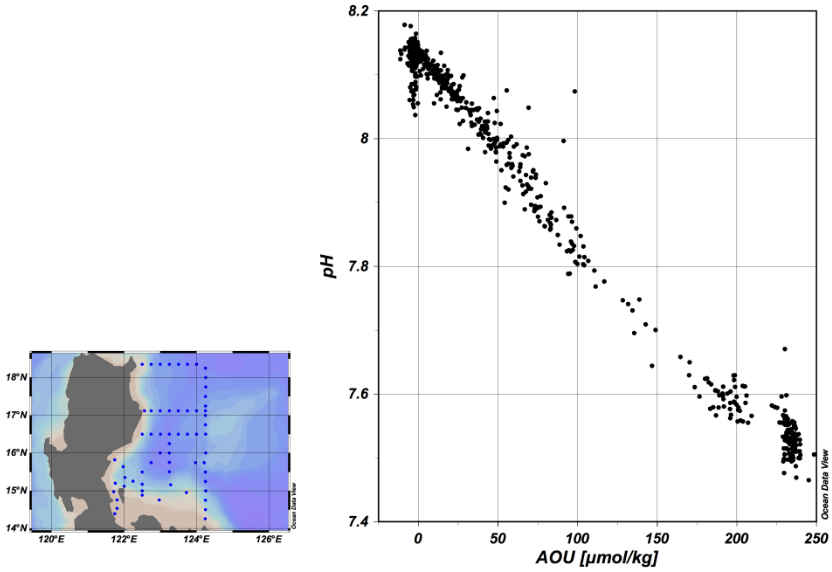

Figure 7. Correlation of pH and AOU

CDOM vs AOU

For more offshore stations, CDOM correlated well with AOU (r=0.9353) (Figure 8). This suggests that production of CDOM can be coupled to the remineralization of biogenic sinking particles. The empirical relationship was determined to be: CDOM = 1.073 AOU + 1398 (n= 138).

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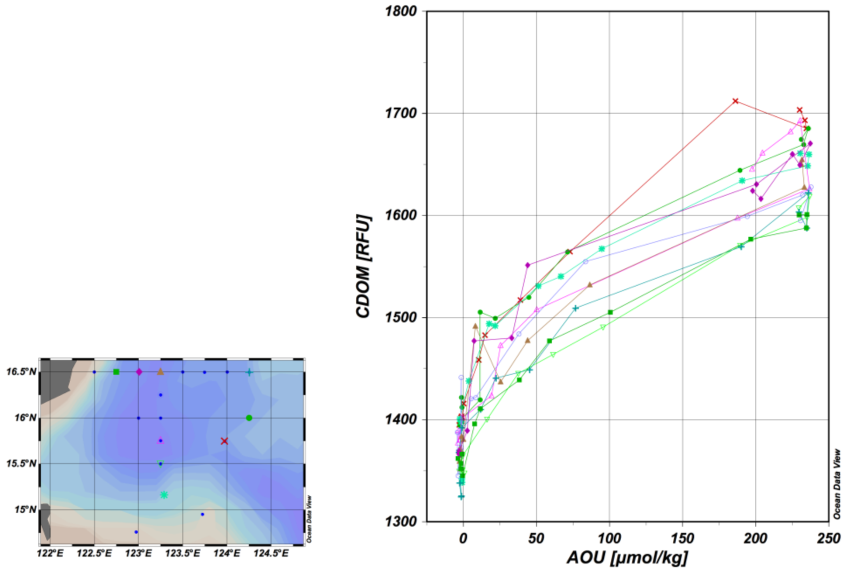

Figure 8. Correlation of CDOM and AOU

For stations closer to the coast, CDOM can be associated with land derived organic matter from rivers and runoff. This was seen in the higher CDOM values in the 400m basin (Stn 35) and adjacent shelf area (Figure 9). When CDOM was correlated with AOU, an r value of 0.66846 was obtained. The relatively lower DO in the basin and the higher AOU suggests that the organic matter introduced into the shelf and 400m basin uses up DO in the remineralization process. Water from this basin may then be the source of the local subsurface DO minimum observed in outlying areas.

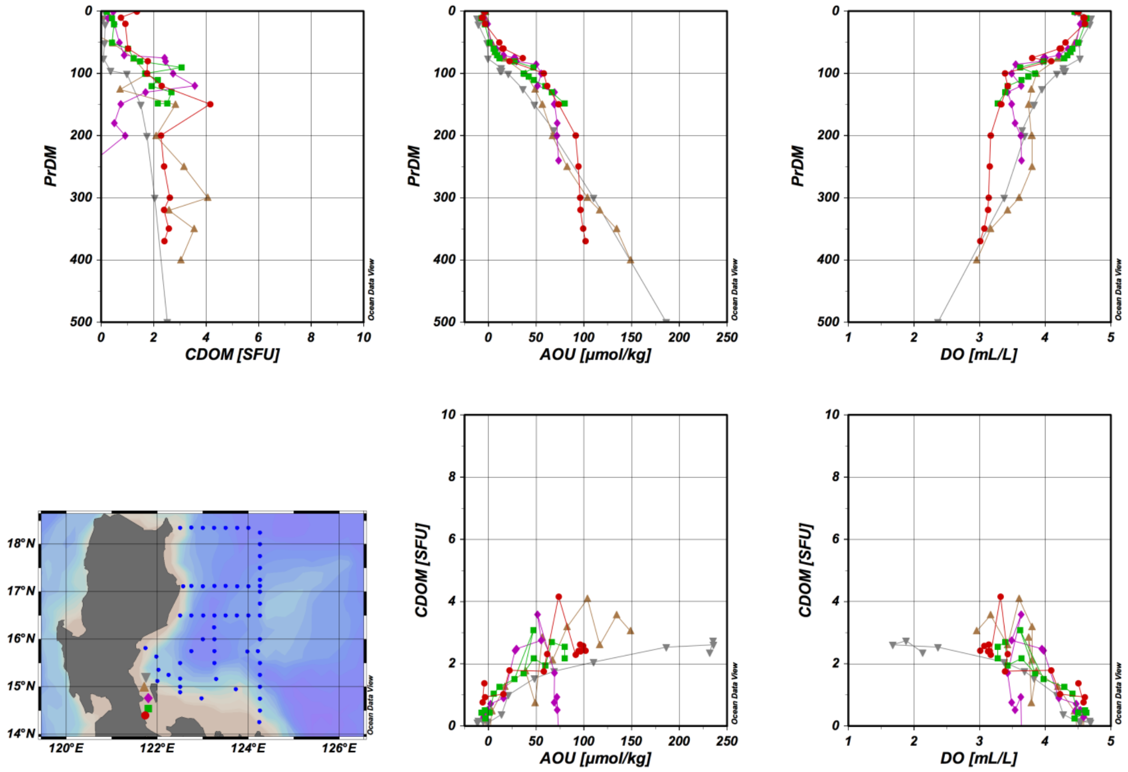

Figure 9. CDOM, DO, AOU trends in the deep basin (Stn 35) and adjacent shelf area

Atmospheric xCO_2 (mole fraction of CO_2 in dry air) was 400.6 +- 3.4 (N=4003) ppm during the cruise, which is about pCO_2 = 384 µatm at SST 30°C. Because the temperature differences were found between the ship's underway data and water temperature in the container, measured xCO_2 was corrected to the in-situ temperature using the relation presented by Takahashi et al. [1993]. The obtained pCO_2 was close to equilibrium in the offshore side and high in the inner Lamon Bay region (Figure 10 (A)). Lower pCO_2 was found especially along the 19°N transect possibly related to low SST.

Total alkalinity (TA) and dissolved inorganic carbon (DIC) obtained from surface 50m were compared with salinity in Figure 11. Tight linear relationships were obtained (TA = 58.81*SALINITY + 232.6, R^2 = 0.982, DIC = 44.05*SALINITY + 402.6, R^2 = 0.964, N=109). Higher intercept of DIC compared with TA indicates organic matter remineralization in low salinity range, which possibly explains partially the higher pCO_2 found in inner Lamont Bay where salinity was low.

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LB02 Shipboard CTD Data Acquisition and Processing

SIO Shipboard Technical Support

A total of 78 CTD/rosette casts were made on LB02, usually to 1500m or within 10m of the bottom. Four casts were made to 4000m: 005/01, 015/01, 020/01 and 059/01. There were no major problems with any of the deployments.

A Seabird Electronics SBE911 CTD system, SIO STS S/N 401, was used for all casts. This system had secondary temperature and conductivity, dissolved oxygen, fluorometer, transmissometer, altimeter and SPAR sensors in addition to the primary temperature, conductivity and pressure sensors. The primary temperature and conductivity sensors were used for all reported CTD measurements.

CTD 401 Sensor Configuration

Sensor	***Serial Number***	***Calibration Date, Location***
SBE 9 Digiquartz Pressure	401	2011-12-02, SIO ODF
SBE 3 Temperature (primary)	03-4941	2011-11-02, SBE
SBE 4 Conductivity (primary)	04-1870	2011-11-29, SBE
SBE 3 Temperature (secondary)	03-4943	2011-11-22, SBE
SBE 4 Conductivity (secondary)	04-1919	2011-11-29, SBE
SBE 43 Dissolved Oxygen	43-0255	2011-11-23, SBE
Seatech Transmissometer	CST-1189DR	2008-11-03, Seatech
Seapoint Fluorometer	SCF 3003	
Benthos Altimeter	41832	
Surface PAR	QSR-2200 202227	2006-02-02, SBE

The CTD was mounted horizontally in a rosette frame which also held 24 2.5L Niskin bottles and a SBE32 Carousel water sampler. The rosette was deployed from the Revelle starboard side squirt boom using the aft Desh-5 Markey winch with a 0.322” conducting sea cable.

The CTD data were acquired using Seabird SeaSave-7.21d acquisition software running on a Windows PC. The acquisition directory was shared on the network and watched by sioodf-5.1.6 software running on a Linux system. At the end of each deployment, the Linux system made a copy of the acquired CTD data, then processed it. The processed data were then made available for plotting, reporting and downloading from a shipboard website.

CTD data processing consisted of applying calibrations, filtering for noise and artifacts and adjusting the phase and amplitude of sensors to match response times. A 0.5 second time series was made of the whole cast, then a 2.0 db pressure series was made of the down cast.

Problems encountered on two deployments (005/01 and 033/01) resulted in unrecoverable bad data for portions of the down casts. For these casts, the up cast pressure series data were reported. The rosette hit the bottom on 055/01, but the data and sensor calibrations were not affected. The sea cable was reterminated prior to 056/01.

The temperature and conductivity sensor calibrations were monitored by comparing primary and secondary sensors on each cast. The temperature sensors had a mean difference of 0.00303ºC for all pressures with a standard deviation of 0.00601ºC (N=1772). The conductivity sensors had a difference of 0.001025mS/cm for all pressures with a standard deviation of 0.005443mS/cm (N=1761). Since these differences were nearly constant on the timescale of this cruise, no corrections were made to either the temperature or conductivity calibrations.

The dissolved oxygen sensor calibration was monitored by examining calibrated O2 as a function of potential temperature for groups of adjacent casts. Although some dissolved oxygen samples were taken from the rosette bottles and analyzed during the cruise, both the number of samples taken and the generally shallow depth of the samples substantially reduced their utility for CTD sensor calibration. Since no other independent dissolved oxygen measurements were made, the accuracy of the CTD O2 measurements cannot be quantified.

LB02 Shipboard Instruments and Measurements

SIO Shipboard Technical Support

The R/V Revelle has a collection of permanently installed sensors and instruments. Data from these systems were collected on LB02.

Meteorological and sea surface measurements were made with the Met system, which acquires the data from various shipboard sources and generates a continuous time series. These data include: wind speed and direction, solar radiation, dew point and relative humidity, precipitation, air temperature, barometric pressure, sea surface temperature, sea surface salinity, sea surface sound speed, dissolved oxygen, fluorometer (chlorophyll A), latitude, longitude, speed over ground, course over ground, heading and bottom depth. The data are continuously displayed on a shipboard website.

Two RDI ADCP systems, an OS75 and a NB150, were used by a system running the UHDS software from University of Hawaii to make continuous underway ADCP measurements. The OS75 system has a range of up to 800m, the NB150 up to 250m. The data are continuously displayed on a shipboard website.

Two SIO-built hydrographic doppler sonar systems (HDSS) were used to collect data during LB02. These systems measure current shear to very high precision. The systems operate at 50kHz and 140kHz.

WAMOS is an X-band RADAR based ocean wave height measurement system that calculates wave periods and deduces swell components. Data from this system were collected during LB02.

The Bell Aero BGM-3 gravimeter measures earth's gravity to very high precision. A time series of the gravity data was collected during LB02.

Three echosounder systems are installed on Revelle and were used during LB02. The Kongsberg EM122 multibeam echosounder is a 12kHz multibeam system and generates swath maps of bathymetry. It was run continuously and additionally used for depth estimates during CTD deployments. Sound speed profiles used to calibrate the echosounder were derived from CTD profiles. The 3.5kHz and 12kHz Knudsen single beam echosounders were used intermittently to obtain bottom estimates. The 3.5kHz echosounder is a sub-bottom profiler and was frequently used during gravity cores. The 12kHz echosounder was used during mooring recoveries to detect and range the moorings.

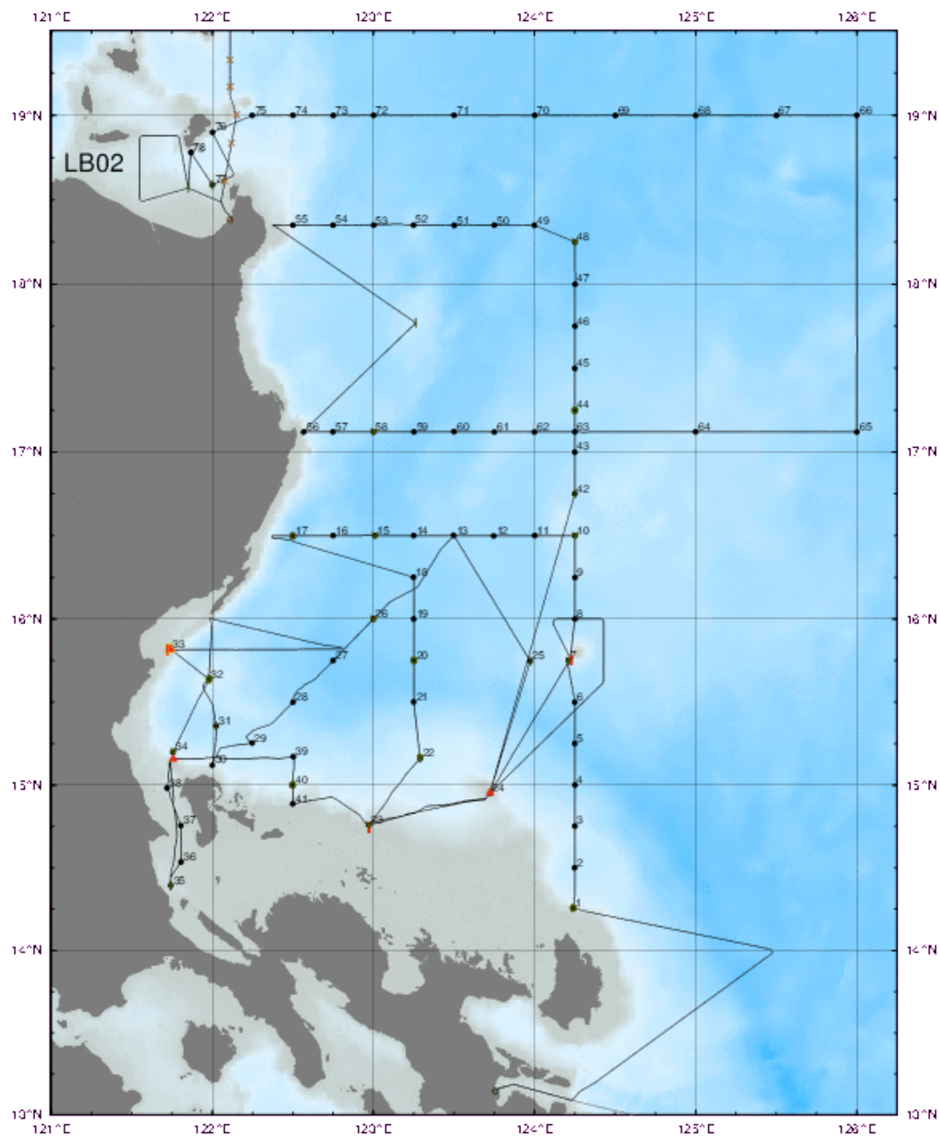
Navigation instruments on Revelle include Furuno GP150, Ashtech ADU3, Leica MX420 and Trimble SPS461 GPSes, and Ixsea Hydrins and Phins inertial guidance and motion reference units. Data from these instruments were collected on LB02.

Lamon Bay cruise 2 [LB02] CTD/rosette Phil Mele

78 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 was 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.

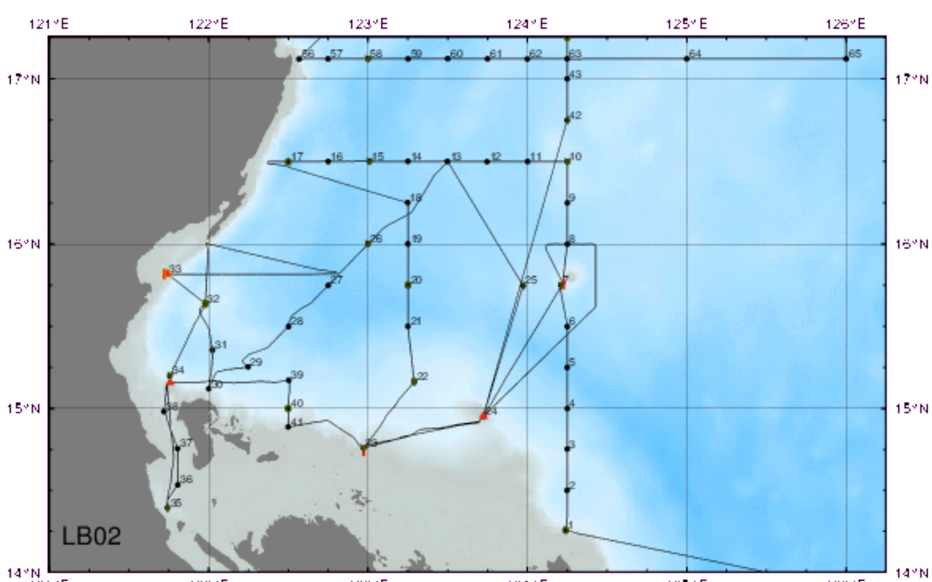
Most profiles were to 1500 m or to within 10 m of the bottom. Four stations were to 4000 m. Approach to the bottom was guided by a Benthos altimeter mounted on the frame.

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 disolved oxygen for standardizing the CTD data, determined by modified Winkler method for a spectrophotometer.



CTD Summary Table:

sta	lat (N)	lon (E)	yyyy/mm/dd	hh:mm
1	14 15.54	124 14.35	2012/04/25	00:39
2	14 30.02	124 14.93	2012/04/25	04:01
3	14 45.17	124 15.03	2012/04/25	06:33
4	14 59.99	124 15.07	2012/04/25	09:11
5	15 15.00	124 15.01	2012/04/25	11:51
6	15 29.97	124 15.01	2012/04/25	16:40
7	15 44.97	124 12.67	2012/04/25	19:25
8	15 59.99	124 15.07	2012/04/25	23:51
9	16 14.92	124 15.08	2012/04/26	02:34
10	16 29.93	124 15.07	2012/04/26	05:15
11	16 29.99	124 0.10	2012/04/26	08:23
12	16 29.90	123 44.81	2012/04/26	11:09
13	16 30.08	123 29.89	2012/04/26	14:10
14	16 30.02	123 15.01	2012/04/26	17:09
15	16 30.05	123 0.51	2012/04/26	20:00
16	16 30.01	122 45.02	2012/04/27	00:35
17	16 29.95	122 30.00	2012/04/27	03:11
18	16 15.05	123 14.96	2012/04/27	10:15
19	16 0.02	123 14.99	2012/04/27	13:02
20	15 45.12	123 15.01	2012/04/27	16:09
21	15 30.04	123 14.99	2012/04/27	21:36
22	15 9.70	123 17.40	2012/04/28	00:51
23	14 45.52	122 58.31	2012/04/28	07:33
24	14 57.05	123 43.34	2012/04/28	12:45
25	15 44.77	123 58.37	2012/04/28	17:28
26	16 0.03	123 0.02	2012/04/29	05:43
27	15 44.97	122 45.03	2012/04/29	09:21
28	15 29.98	122 30.06	2012/04/29	12:42
29	15 15.22	122 14.83	2012/04/29	16:50
30	15 7.18	122 0.02	2012/04/29	20:19
31	15 21.37	122 1.43	2012/04/29	22:39
32	15 38.24	121 58.68	2012/04/30	03:42
33	15 49.09	121 44.47	2012/04/30	06:27
34	15 11.87	121 45.33	2012/05/01	00:11
35	14 23.60	121 44.51	2012/05/01	10:12
36	14 32.06	121 48.34	2012/05/01	13:22
37	14 45.31	121 48.29	2012/05/01	15:17
38	14 58.90	121 43.12	2012/05/01	17:21
39	15 10.33	122 30.11	2012/05/02	13:32
40	15 0.07	122 29.94	2012/05/02	16:06
41	14 53.24	122 29.96	2012/05/02	18:39
42	16 45.02	124 14.99	2012/05/04	19:14



sta	lat (N)	lon (E)	yyyy/mm/dd	hh:mm
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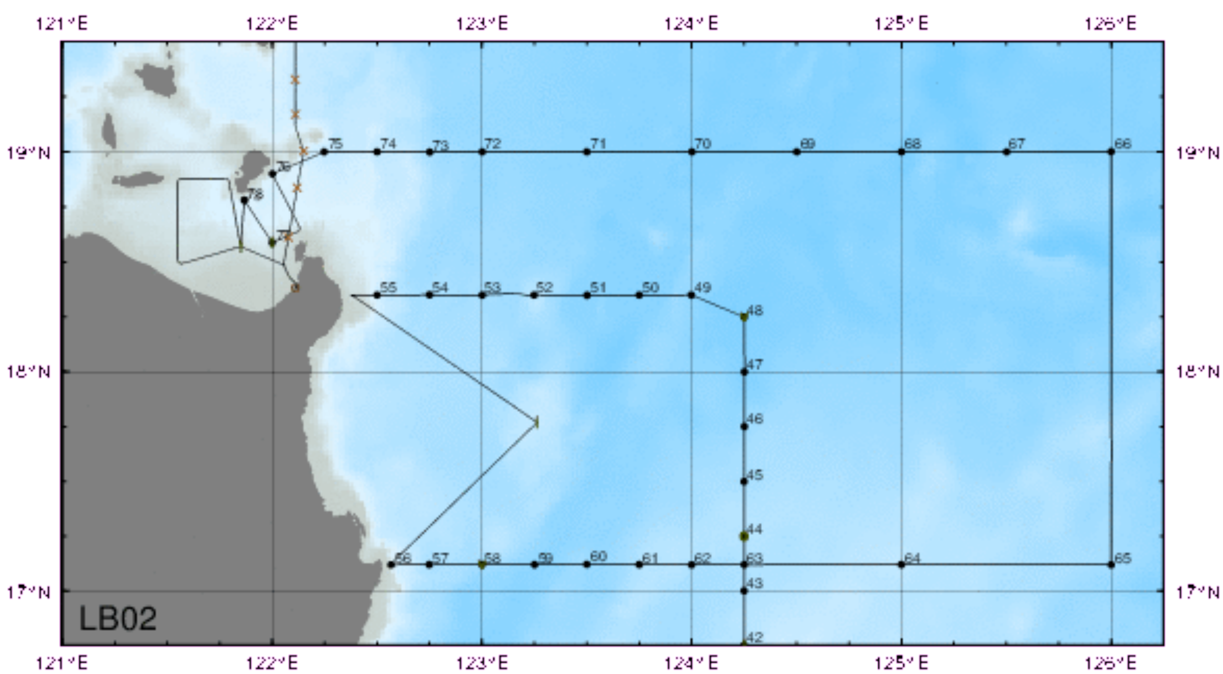
44	17 14.95	124 15.02	2012/05/05	03:19
45	17 29.98	124 15.02	2012/05/05	06:26
46	17 45.03	124 15.04	2012/05/05	08:59
47	18 0.02	124 15.04	2012/05/05	11:39
48	18 14.98	124 15.00	2012/05/05	14:48
49	18 20.97	123 59.96	2012/05/05	18:07
50	18 21.01	123 45.01	2012/05/05	20:45
51	18 20.95	123 30.09	2012/05/05	23:02
52	18 21.01	123 14.95	2012/05/06	01:28
53	18 21.00	123 0.04	2012/05/06	03:59
54	18 21.05	122 45.02	2012/05/06	06:27
55	18 21.01	122 29.99	2012/05/06	08:59
56	17 7.15	122 34.01	2012/05/07	00:34
57	17 7.22	122 44.92	2012/05/07	02:12
58	17 7.21	122 59.98	2012/05/07	04:46
59	17 7.22	123 15.07	2012/05/07	07:39
60	17 7.28	123 30.02	2012/05/07	11:39
61	17 7.18	123 45.01	2012/05/07	14:33
62	17 7.15	124 0.02	2012/05/07	17:24
63	17 7.22	124 14.99	2012/05/07	20:13
64	17 7.23	124 59.99	2012/05/08	01:05
65	17 7.17	126 0.01	2012/05/08	07:07
66	19 0.05	125 59.99	2012/05/08	17:01
67	18 59.98	125 30.08	2012/05/08	20:54
68	18 59.99	125 0.02	2012/05/09	00:43
69	18 59.98	124 30.08	2012/05/09	04:41
70	19 0.02	124 0.07	2012/05/09	08:31
71	19 0.03	123 29.99	2012/05/09	12:16
72	19 0.01	123 0.07	2012/05/09	16:16
73	18 59.95	122 45.04	2012/05/09	18:52
74	19 0.01	122 29.98	2012/05/09	21:26
75	18 59.99	122 14.85	2012/05/09	23:51
76	18 54.02	122 0.05	2012/05/10	02:29
77	18 35.32	122 0.01	2012/05/10	06:14
78	18 46.90	121 51.97	2012/05/10	10:10



Scripps Institution of Oceanography **Research Marine Technician Group**

RR1204 Deck Operations

Multiple operations were conducted on board *R/V Roger Revelle* by the Research Marine Technicians (Restechs) for the recovery of scientific data. The majority of deck operations were CTD casts. Additional operations included vertical and oblique bongo net tows, OSU style gravity cores, traditional subsurface mooring recoveries, TRBM recoveries, dragging, and dredging. The bongo net was provided by the University of the Philippines. The moorings and TRBMs were owned by University of Hawaii and Lamont Doherty Earth Observatory. All other equipment was provided by the SIO Restechs.

CTD and 24 Place Bottle Rosette

The CTD and sensors were attached to a 24 place bottle rosette frame. A mount was developed for mounting the par sensor safely above the bottle tops and inside of the outer ring. Throughout the cruise various o-rings on the bottles were replaced as they broke. Two bottle spouts were also replaced after they broke early in the cruise. Bottle #5 had its lanyard slightly shortened after it likely stretched during use, which led to a single misfire. The par sensor was removed for all casts over 2000m depth and reinstalled after cast completion.

Bongo Net

The bongo net was not sufficiently weighted for both vertical and oblique tows. A lanyard was made for their depressor weight and dive weights were added to help add some more necessary weight. For the vertical tows a 50lb weight was added to the center of the bongo net frame that is needed to keep it vertical. This bongo net frame is not engineered to be strong enough to add the necessary weight needed to properly operate vertical and oblique tows. The largest amount of weight was added to the frame that would not cause structural damage. It would be best for this bongo frame to be redesigned to hold a 100-150lbs weight in the center of the frame and the depressor weight should be around 75-100lbs. The net was deployed to 200m at a speed of 30m/min.

OSU Style Gravity Corer

The OSU style gravity corer is the preferred type of gravity corer used by the restechs. It can be adapted to various environments easily with its adjustable weights and use of a schedule 40 PVC pipe. The machined corer parts are attached to a 10ft long PVC pipe for each deployment. The PVC pipe acts as the liner, which can quickly and easily be removed once the instrument is recovered. The gravity corer was deployed on the 9/16" mechanical wire at a max speed of 55m/min with a ground penetrating speed averaging 15-20m/min. The core is recovered with a 5-10m/min pull out from the seafloor. Once the corer is safely in the water column the wire may come in between 40m/min and 55 m/min.

Traditional Subsurface Mooring Recoveries

Three subsurface moorings were recovered with the restech directing operations. The moorings were hooked into as they came along the side of the ship with a line leading through the A-frame to the TSE winch. The TSE winch hauled in the mooring line as instruments were safely removed. One very short mooring was recovered by hand in the ship's small workboat.

TRBM Recovery

Once the TRBM surfaced, the ship's small workboat went over to it to hook a line into it. There is no way to hook into the TRBM from the ship like a normal mooring. The small boat then slowly dragged the TRBM float to the stern of the ship. A line hooked to the lifting point of the TRBM float was tossed to the restech on the stern and attached to a lifting line on the capstan. Once the float was secured on deck with stopper lines, a yale grip was attached to the 400m spectra line connecting the float to the anchor. The float was then disconnected from the spectra line. The yale grip was attached to the TSE winch to haul the 400m of spectra and anchor in. The tagging points on the anchor are not large enough even for our small hooks to be able to hook a tagline on. In a few locations tangling and knotting of the spectra line was observed. These all appeared to be caused by the coiling jobs held together by rubber bands. Recovery of the TRBM was smooth, but must be done with the assistance of a small boat.

Dragging and Dredging

The *Roger Revelle* and the Scripps Institution of Oceanography Research Marine Technician Group do not regularly carry dragging equipment onboard. Usually dragging has been predetermined as an event that will occur on a cruise during a pre-cruise meeting. However, there is always a chance that dragging will be requested in the midst of a cruise when there are no other options available. In these circumstances the restech on board utilizes any equipment that is available or can be quickly created onboard that can apply to a general concept of dragging.

Dragging is typically a last resort technique for the recovery of oceanographic instruments. It is performed by laying a wire with a hooking device and weight attached onto the seafloor, which is then pulled along bottom by winch and ship in a specified pattern. Dragging is similar to rock dredging in that they share the same winching techniques and wire is being placed on the seafloor. There are various methods and techniques that range from being specific to the instrument to general use. The success rate for dragging varies from technician to technician, institution to institution as well as instrument to instrument. For the most part though it is believed that the success rate for dragging is less than 50% (no official data has ever been collected).

Dredging is a technique used to recover rocks from the seafloor. An SIO style dredge has a toothed mouth opening of about 3ftx1.5ft with a 5ft chain basket. It weighs about 800lbs and has a 50lb weight added to the basket just prior to deployment. Dredging is performed by setting wire down in a straight line over a set distance on the seafloor in an upslope direction. At the end of the line the ship stays stationary while the winch wire is hauled in. The restech pays very careful attention to the tension and constantly adjusts the wire speed to maintain the dredge on the seafloor with the best tension to gather rocks.

During this cruise the restechs used an I-beam with and without hooks for dragging and a dredge to try to recover two TRBMs. Overall a total of seven drag attempts and 2 dredges were completed. None of these attempts brought the TRBM floats to the surface. All drags and dredges were performed in straight paths do to the design of the TRBMs. Do to strong currents at one sight the dredges were pulled downslope.

Dragging for TRBMs
Cruise RR1204
May 1, 2012 to May 4, 2012

Pounding, dragging, and dredging exercises were conducted for two Flotation Technologies TRBMs at locations 15° 9.486'N 121° 45.432'E and 14° 57.102'N 123° 43.398'E that failed to surface after the dual acoustic releases confirmed release. Both of the releases were owned by Dr. Pierre Flament of the University of Hawaii. The water depth measured via the ships multibeam and echosounders at these two locations were 148m and 191m respectively.

The *R/V Roger Revelle* carries an assortment of rigging and dragging gear aboard for unplanned retrieval attempts of lost moorings. The ship also has the ability to weld, adapt, and create items with the resources currently on board at a given time. The equipment available during RR1204 were 3 large weighted dragging hooks, 100lb clump weight, Benthos Acoustic Pinger Model 2216, weak links, and an SIO style dredge. Using various resources on board a 19ft I-Beam dragger was developed. The ship also has two winches full of 3x19 mechanical wire in ¼" and 9/16" diameters. The advantage of performing dragging exercises off of *Revelle* is the dynamic positioning system that allows the ship to precisely maneuver around an instrument on the seafloor.

<u>TRBM 15° 9.486'N 121° 45.432'E</u>

At the direction of Dr. Flament, the first tactic used involved attaching a 100lb weight to the ¼" hydro wire with the pinger placed 10m above. The weight was then pounded into the seafloor every 10 to 20m and dragged around the TRBM in a 40m square trying to jolt the float into surfacing. Throughout this process the science party was constantly tracking the TRBM using their acoustic transducer with the acoustic releases attached to the TRBM. The research technicians were tracking our pinger and wire via the 12kHz hull transducer, the MET winch display, LCI-90s, and ship's navigation system. Do to the restrictions of daylight, proximity to shore, and the shallow waters we were in we left the first Flament TRBM station to return before first light to start beam dragging operations. The TRBM float was still on the seafloor upon departure.

Do to the design of the TRBM traditional dragging methods did not seem like the best way to approach ways to recover the TRBM. It was understood by all that our chances were low for retrieving the instrument by dragging and we did not want to turtle the TRBM either. A spare 20ft long I-beam was adapted into a dragging bar by drilling holes at either end. A two-part wire bridle was attached to the beam, which was then attached to the 9/16" trawl wire. The beam drag was lowered to the seafloor and wire laid out in straight line passes over the instrument position using our DP system. The goal of this method was to hopefully just bump the instrument causing the foam block to dislodge and surface. After each pass the wire was hauled in being carefully monitored by the research technician for tension spikes. Again the scientists continued to monitor the instrument acoustically. On the third pass tension increased significantly leading the tech to presume that they had bumped the TRBM as intended. The acoustic signal changed causing us to put the ship's workboat in the water. The workboat acoustically monitored the instrument and found the exact position where the instrument was floating 30m below the surface. A large grapple was added to each end of the beam before deploying it to try to snag the TRBM line between the float and the anchor. Two passes were made one midwater and another was made at depth. There were no indications via tension that we had made contact with the TRBM.

A total of 5 dragging attempts were made on this TRBM without success. It is believed that the instrument is securely floating at 30 to 40m below the surface still attached to the anchor as designed with its line knotted. Thus causing its inability to rise fully to the surface.

TRBM 14° 57.102'N 123° 43.398'E
Similarly to the previous TRBM, after both acoustic releases indicated release the TRBM did not start to rise to the surface. Unlike the previous station this instrument was not on a topographically flat seafloor. There was a 1/3 slope with a 1.6 knot current. A few other topographic mounds were nearby as well. These all made it difficult for our preferred dragging approaches on this TRBM.

Two dragging and two dredging attempts were made. Do to the current going up slope we had to conduct these drags going down slope and into the current for the ship to have the best maneuverability. The first drag was done with just the beam. The second drag was done with the beam and three dragging hooks. Several tension nibbles were observed, but no large tension spikes on both drags. Upon recovery of the beam with hooks, two hooks showed evidence of being hung up on something. These hooks were bent back and had busted welds indicating a hard substrate.

The dredging attempts were very similar to the beam dragging efforts. The SIO style rock dredge was attached to the 9/16" trawl wire and set on the seafloor with the wire paid out over the seafloor in straight passes before being hauled in. Both dredging pulls had small nipples as it dug along the surface of the seafloor. On both attempts it recovered coral rock. The first dredge also got a biological bonus of a small skinny snake like fish that will be identified by the science party on shore. The second dredge pulled up a small amount of 100lb test monofilament that was poorly knotted and showed evidence of use as a hand line.

After all of theses attempts the acoustic signal from the TRBM still indicated a released instrument stuck on the seafloor. The slope and the presence of fishing gear could be the cause of the instrument not surfacing.