Regional Cruise
Intensive Observational Period 2009
RIOP09
R/V Melville, 27 February – 21 March 2009
Arnold L. Gordon, Chief Scientist
Leg 2 [final] Report
Manila to Dumaguete, 9 March to 21 March 2009

"Pidgie" RIOP09 Leg 2 Mascot, Dumaguete-Manila

Preface: While this report covers RIOP09 leg 2, it also serves as the final report, thus the introductory section of the leg 1 report is repeated. For completeness within a single document the preliminary analysis [or better stated: *first impressions of the story told by the RIOP09 data set*] included in the leg 1 report are given in the appendices section of this report. Other appendices describe specific components of RIOP09: CTD-O_2; LADCP; hull ADCP; PhilEx moorings; the Philippine research program: Chemistry/Bio-optics; and sediment trap moorings.

I Introduction:

The second Regional IOP of PhilEx, RIOP09, aboard the R/V Melville began from Manila on 27 February. We return to Manila on 21 March 2009, with an intermediate port stop for personnel exchange in Dumaguete, Negros, on 9 March. This divides the RIOP09 into 2 legs, with CTD-O2/LADCP/water samples [oxygen, nutrients]; hull ADCP and underway-surface data [met/SSS/SST/Chlorophyll] on both legs, and the recovery of: 4 PhilEx, 2 Sediment Trap moorings of the University of Hamburg, and an EM-Apex profiler, on leg 2.

The general objective of RIOP09, as with the previous regional cruises is to provide a view of the stratification and circulation of the Philippine seas under varied monsoon condition, as required to support of PhilEx DRI goals directed at ocean dynamics within straits.

RIOP09 will investigate the 2009 late winter monsoon conditions, more specifically:

• to reoccupy select CTD/LADCP [Conductivity-temperature-pressure/lowered acoustical Doppler profiler] stations of the prior PhilEx regional cruises [Exploratory Cruise of June 2007; Joint cruise of Nov/Dec 2007; RIOP08 of January 2008] so as to allow for comparison of the winter monsoon to the summer monsoon conditions, and of early/mid-winter monsoon of 2007/2008 to the late winter monsoon of 2009;

• To 'check out' features in the circulation and stratification suggested by model output and remote observations gathered from the PhilEx HF Radar facility on Panay and from satellite derived data products;

• To extend the regional coverage:

§ Leg 1: into the western Pacific adjacent to San Bernardino and Surigao Straits to improve our understanding of the Pacific inflow within these shallow, very tidally active passages, linking the Philippine seas directly to the western boundary regime of the Pacific Ocean.

§ Leg 2: into the southwestern Sulu Sea, to get a sense of the Sulu gyre's equatorial limb and of its eddy field; to evaluate deep-sea ventilating flow through the Sibutu Strait of the Sulu Archipelago; to record the passage of Sulu solitons [noting that we will be in the southern Sulu Sea ~12 March, full moon, when solitons are expected to be large].

The Wrinkly Sea

II PhilEx

The complexities of the flow within the network of straits and seas composing Philippine waters, subjected to monsoonal seasonal forcing at the sea-air interface, and strong tidal conditions, cannot fully be captured solely by the snapshot views afforded by CTD/LADCP stations and underway data obtained from the ship. But when combined with time series observations from instrumented placed at key sites, from freely moving instrument packages that profile the water column, with remote observations from land based and from earth orbiting satellite; with output from an array of models, and sophisticated ship towed vehicles that obtain high horizontal resolution of sub-mesoscale features, a fuller picture of the Philippine seas oceanography emerges. The PhilEx program components are displayed in Figure 1; description of PhilEx objectives and tools and much more are provided at PhilEx WIKI web site[1].

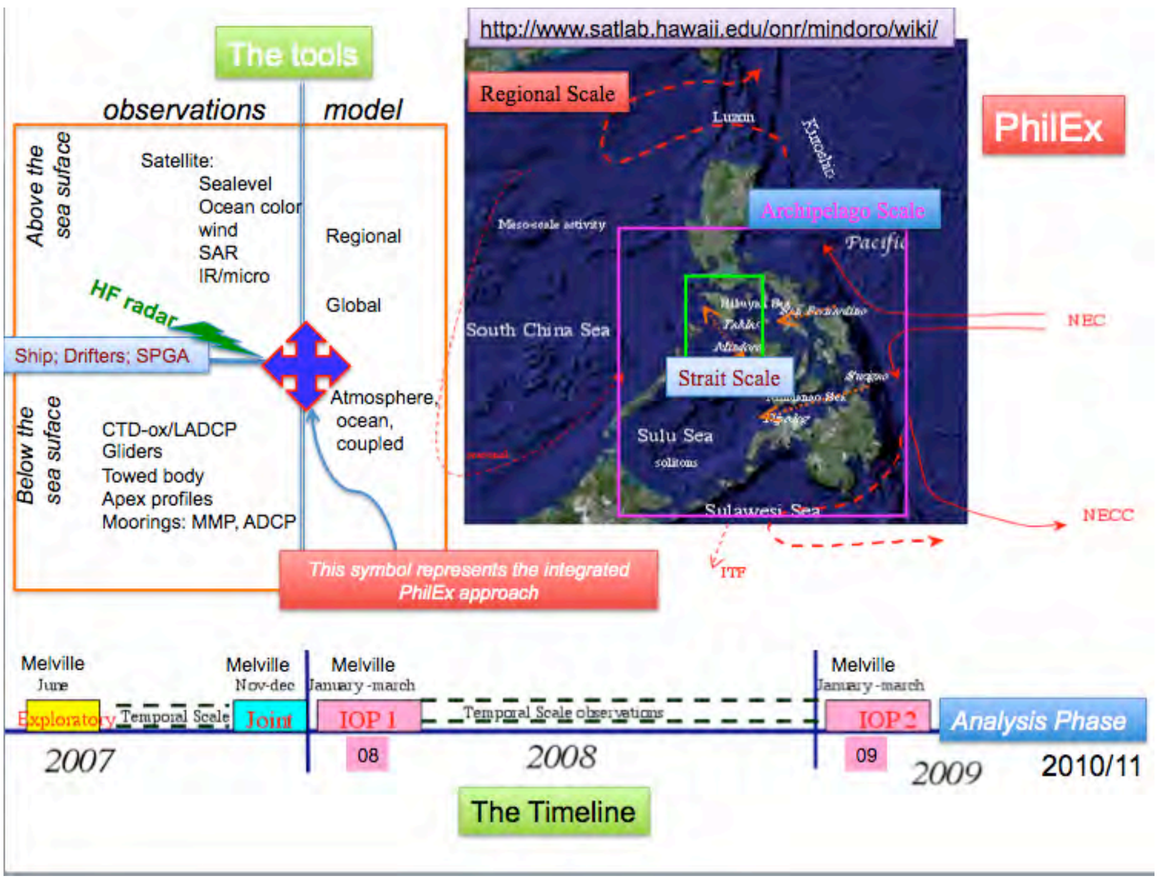


Figure 1: The scales, components and Timetable of PhilEx.

[1] http://www.satlab.hawaii.edu/onr/mindoro/wiki/index

contact A.L.Gordon for log in info [agordon@ldeo.columbia.edu]

III Leg 2 Personnel [for Leg 1 personnel see the Leg 1 summary in the Appendices]

	Last Name	First Name	Affiliation
1	BENSCH	ANNA-MARIA	University of Hamburg
2	Bernardo	Lawrence Patrick	UPD/UPMSI
3	Bo	Yuri	Philippine Navy
4	Cohen	Ben	SIO
5	COLE	DREW	SIO
6	Cordero	Gerald	Philippine Coast Guard
7	Cordero	Kristina	UPD/UPMSI
8	David	Laura	UPD/UPMSI
9	DORRANCE	JAMES	SIO
1	DRUSHKA	KYLA	SIO
2	Ferrera	Charissa	UPD/UPMSI
3	GORDON	ARNOLD	LDEO
4	HARVEY	PAUL	UCSD
5	HO	CHENG-CHUAN	LDEO
6	LAHAJNAR	NIKO	University of Hamburg
7	Magdaong	Evangeline	UPD/UPMSI
8	Martin	Marilou	UPD/UPMSI
9	MELE	PHILIP	LDEO
10	RAB GREEN	SUZANNE	LDEO
11	REPOLLO	CHARINA	University of Hawaii
12	SPRINTALL	JANET	UCSD
13	TESSLER	ZACHARY	LDEO
14	TILLINGER	DEBRA	LDEO

IV RIOP09 Track/Stations

In order to improve our regional view of the Philippine seas, a balance is needed between temporal coverage in which we repeat stations occupied during previous PhilEx regional cruises in order to investigate temporal fluctuations, with coverage that reaches into new areas not sampled on prior PhilEx cruises. A constraint during RIOP09 is that it is only 21 days long, the shortest of the regional cruises, yet there are 6 moorings to recover: 4 PhilEx moorings and 2 sediment trap moorings of the University of Hamburg.

§ Mooring Recovery:

All of the mooring were recovered [see appendices; Table 1], though the PhilEx Mindoro required a nudge from a dredging cable to knock free.

Table 1 Positions of the 6 moorings recovered during RIOP09 [Sulu East and West are sediment trap moorings; the others are PhilEx moorings]

Latitude	**Longitude**	**Mooring**	**Date recovered**
122 08.22	**8 23.009**	**SULU EAST**	**10-Mar-09**
120 57.443	**8 55.014**	**SULU WEST**	**14-Mar-09**

8° 51.9	**123° 19.95**	**Dipolog**	**9-Mar-09**
11 ° 16.74	**121° 55.464**	**Panay**	**16-Mar-09**
12° 00.288	**121° 49.608**	**Tablas**	**17-Mar-09**
11° 53.648	**121° 03.294**	**Mindoro**	**19-Mar-09**

We also recovered a EM-APEX float on 18 March at 11°19.0'N; 121°15.6E.

The CTD/LADCP stations covered by the four regional PhilEx cruises are shown in Figure 2a, with the specifics of RIOP09 shown in Figure 2b.

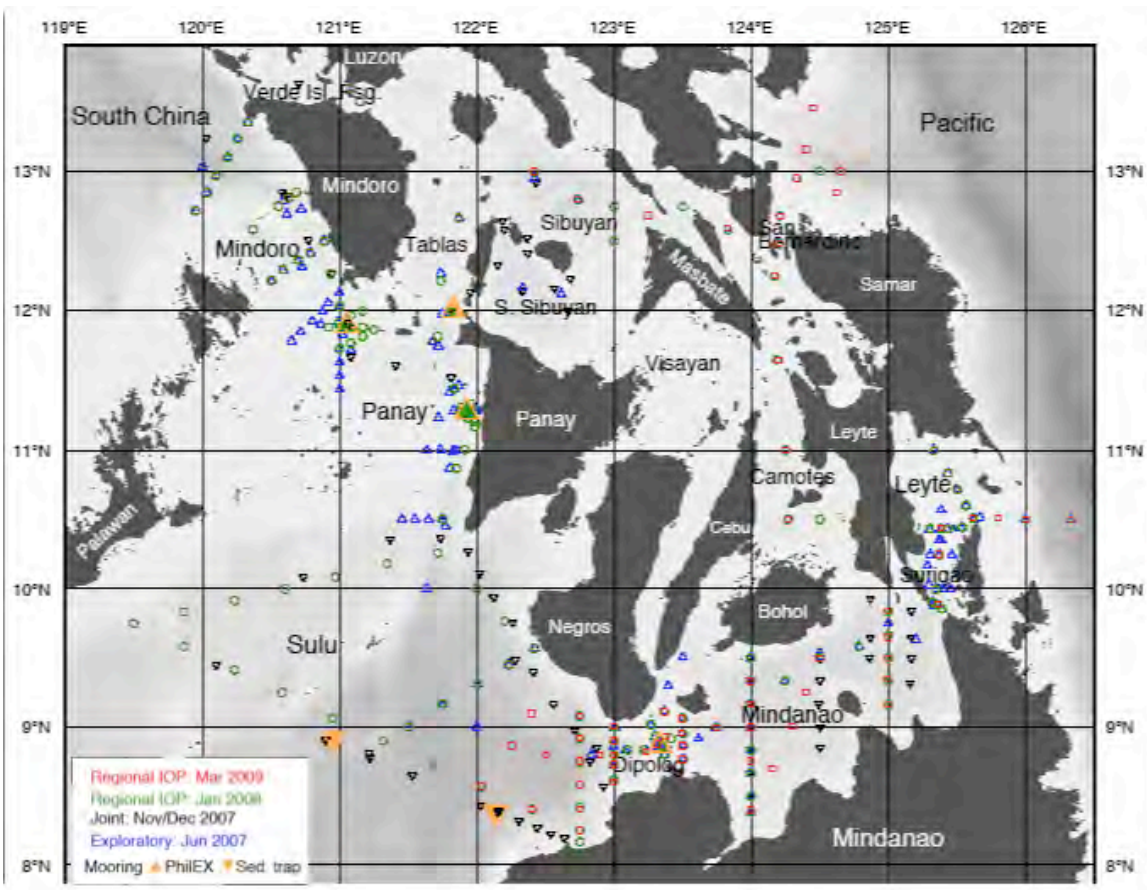


Figure 2a: Map of the Philippine Seas with names referred to in this report and position of CTD/LADCP stations of the four PhilEx cruises: Exploratory June 2007; Joint Nov/Dec 2007; RIOP08 January 2008; RIOP09 March 2009.

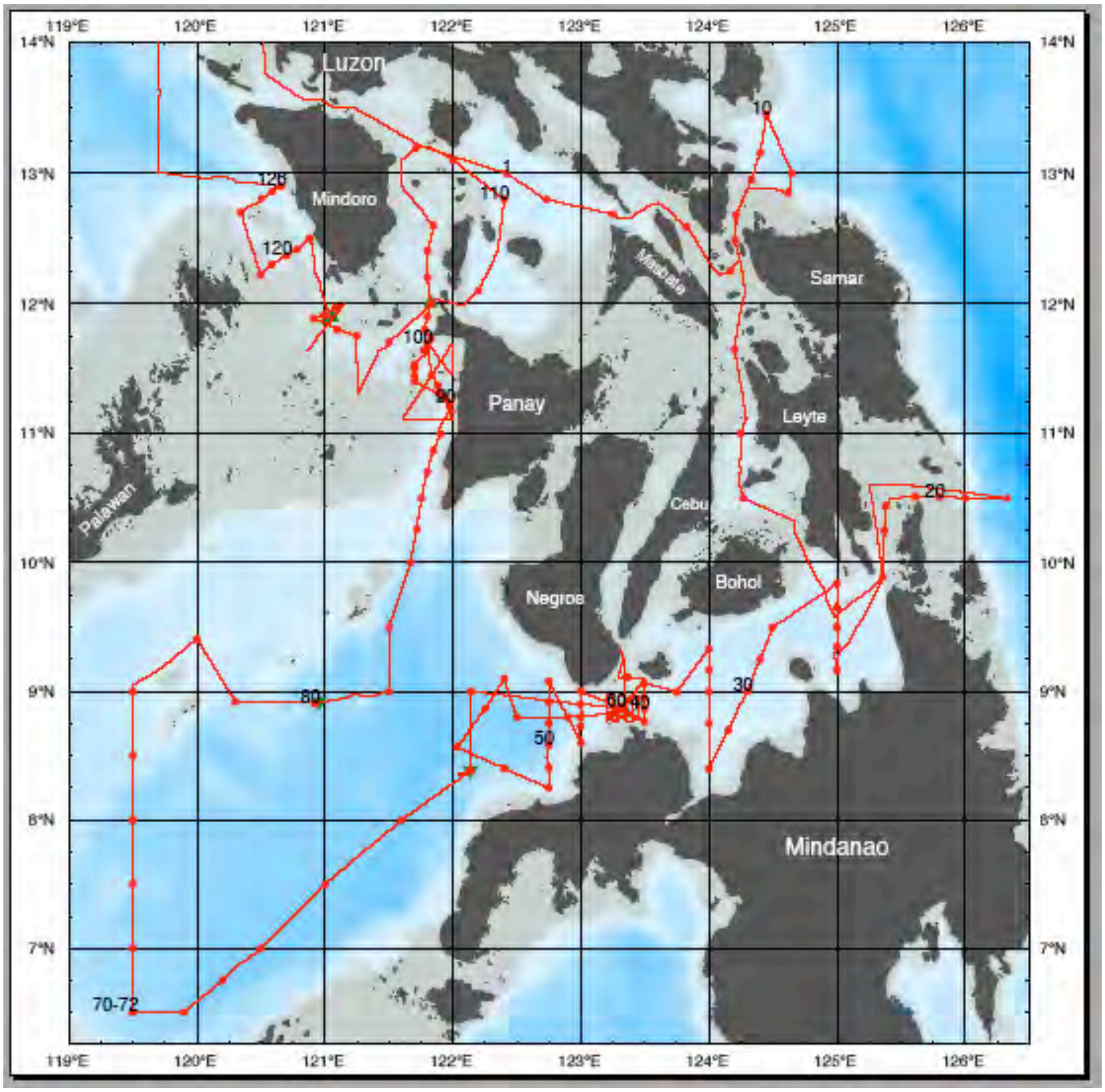
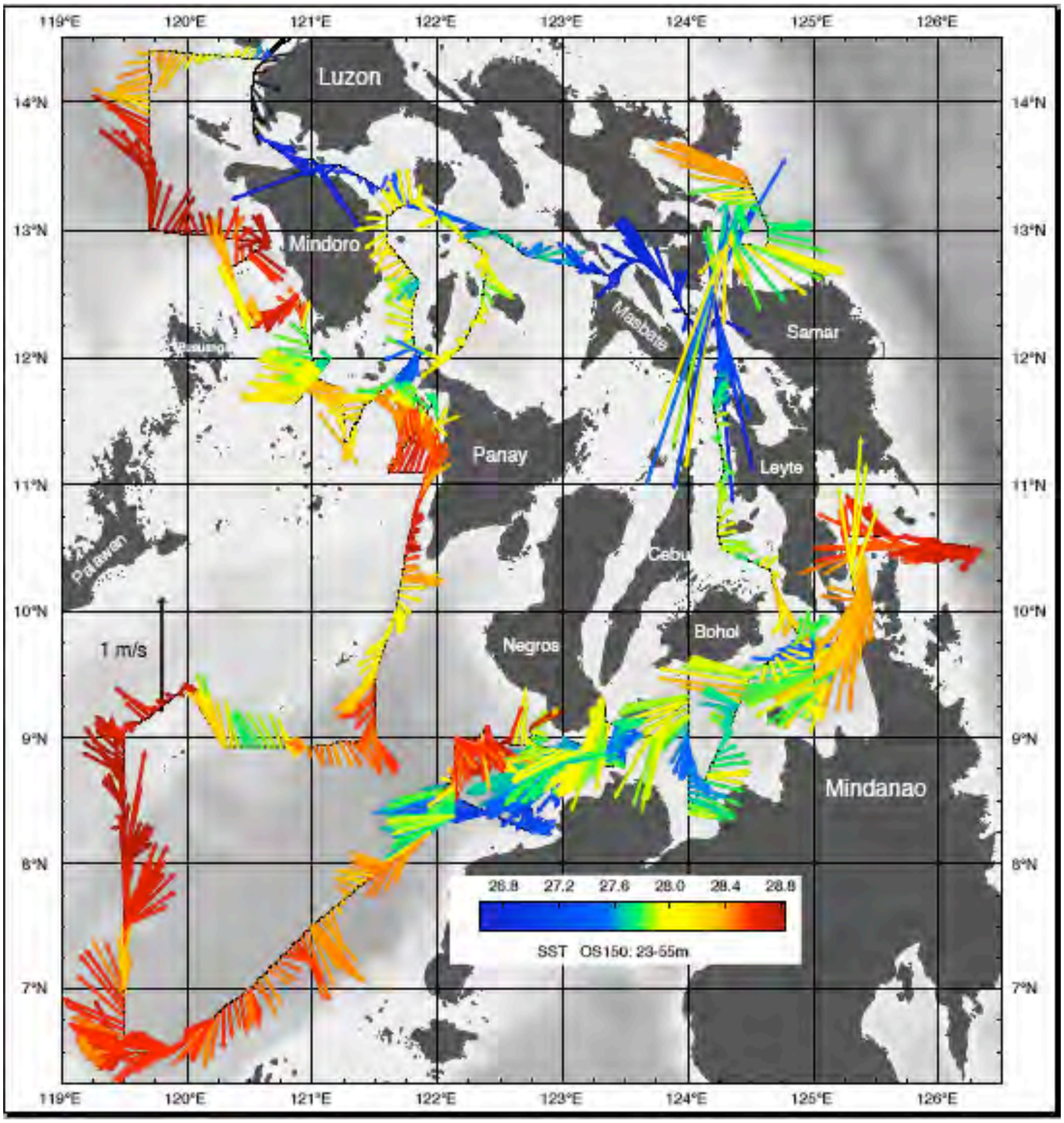


Figure 2b: RIOP09 Track and CTD/LADCP stations.



119°E
120°E
121°E
122°E
123°E
124°E
125°E
126°E
14°N
13°N
12°N
11°N
10°N
9°N
8°N
7°N
Luzon
Mindoro
Masbate
Samar
Panay
Leyte
Palawan
Cebu
Negros
Bohol
Mindanao
1 m/s
26.8
27.2
27.6
28.0
28.4
28.8
SST OS150: 23-55m

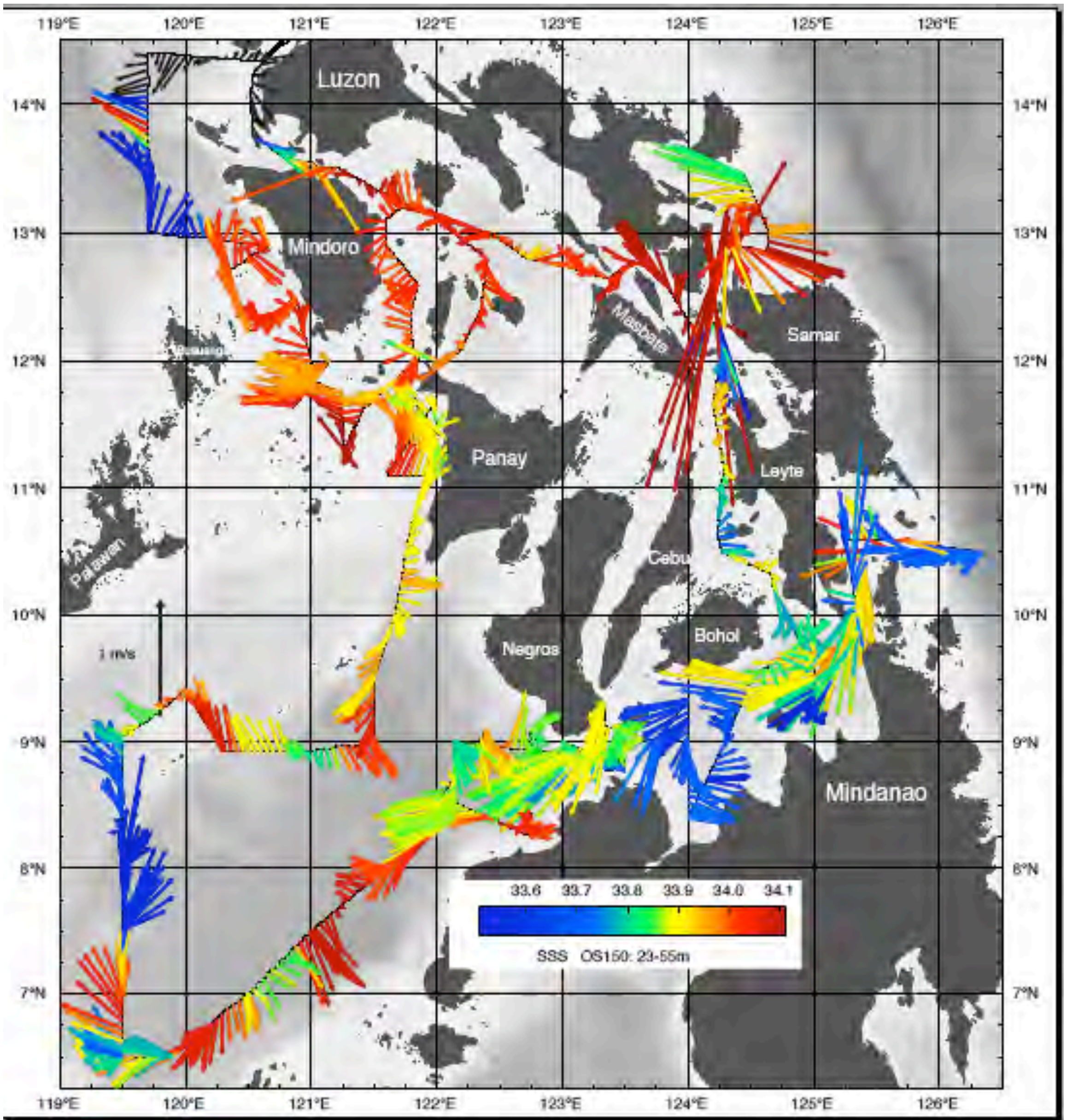


Figure 3: Surface layer, 23-55 m, currents, color-coded for sea surface temperature SST [upper panel] and sea surface salinity SSS [lower panel] of RIOP09.

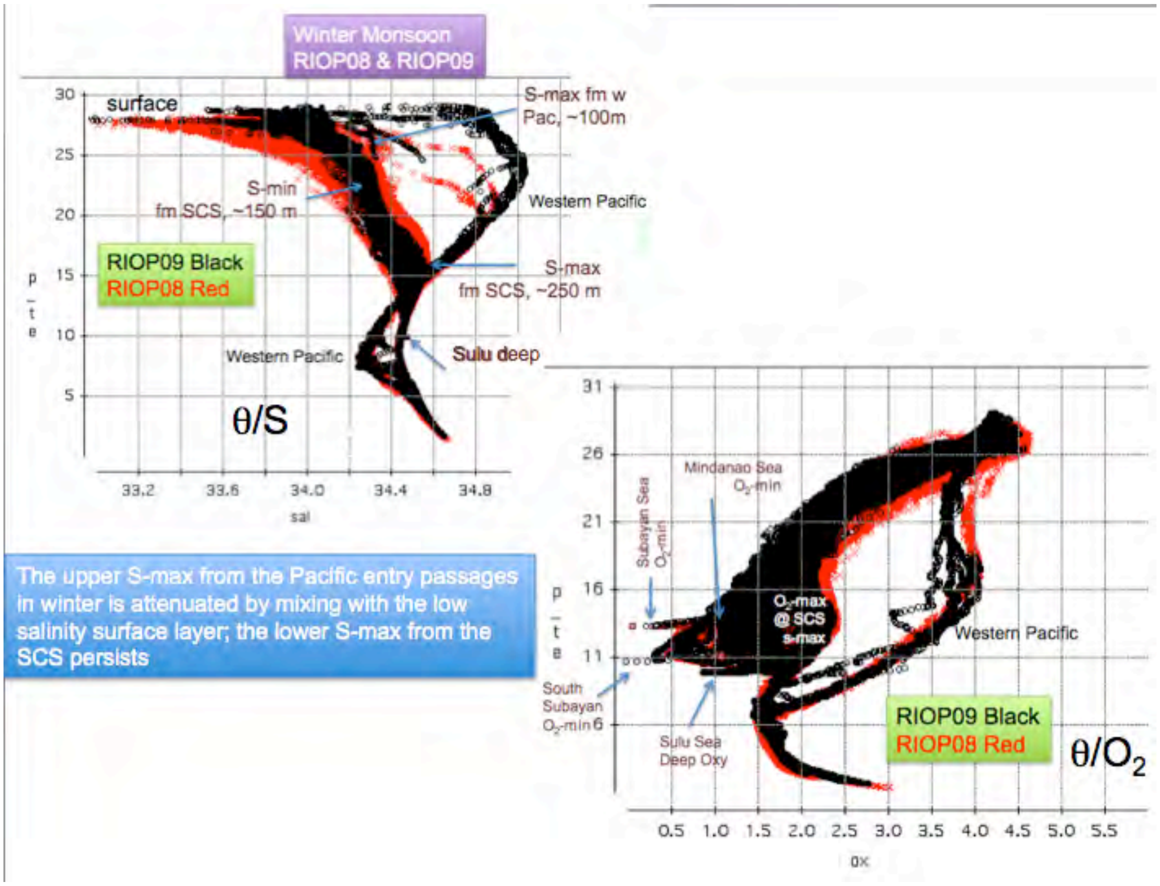


Figure 4: Property-Property plots of RIOP09 and of the RIOP08 coverage for the same areas: Potential Temperature [θ°C] vs. salinity [S] and Oxygen [O_2]

V Preliminary Data Analysis:

The reader is referred to the final report of the January 2008 RIOP08[2] for a discussion of many aspects of the Philippine Sea oceanography. Here I will touch briefly on only a few topics that were either not discussed in the RIOP08 report, or topics that can be addressed differently with the RIOP09 data. The RIOP09 Leg 1 (27 February to 9 March 2009) report is appended as Appendix A. It touches on these topics:

• Ventilation of the deep Sibuyan Sea;

• San Bernardino and Surigao Straits;

• Western Mindanao Sea and the Dipolog Strait.

[2] RIOP08_Repts_ALL.pdf on the PhilEx WIKI site @ http://www.satlab.hawaii.edu/onr/mindoro/cruises/gordon_january_08/

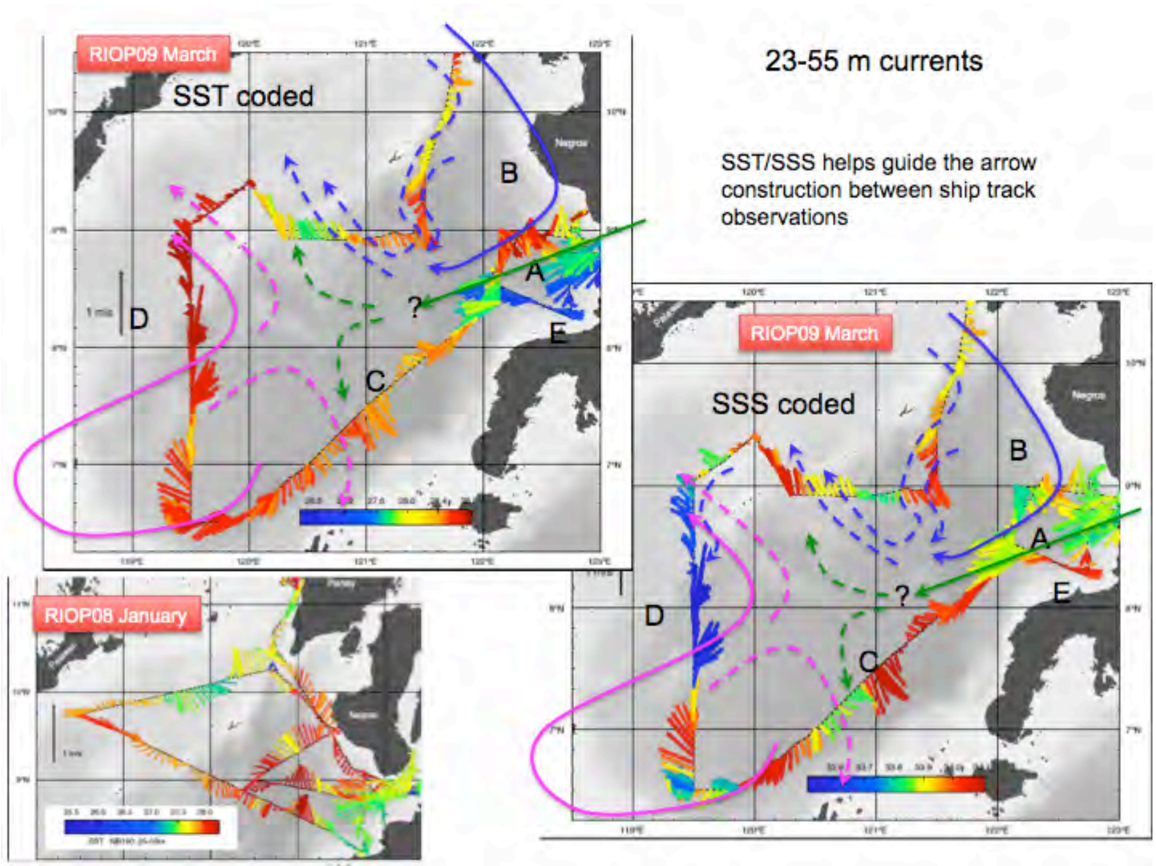
• Leg 2 Preliminary Data Analysis

[A] Sulu Sea:

§ Sulu Sea Gyre:

On RIOP09 we entered into the southern Sulu Sea as far south as 6.5N within the western half of the Sulu Sea. On prior cruises we reaching onto to ~8.5N in the eastern Sulu Sea. This enabled the investigation of the southern source of deep reaching ventilation as discussed in the RIOP08 cruise report, with the bonus of measuring spring tide generated solitons from the western passages of the Sulu Archipelago. These two items are discussed below.

Here I present the ocean current map [Fig. 5a,b].



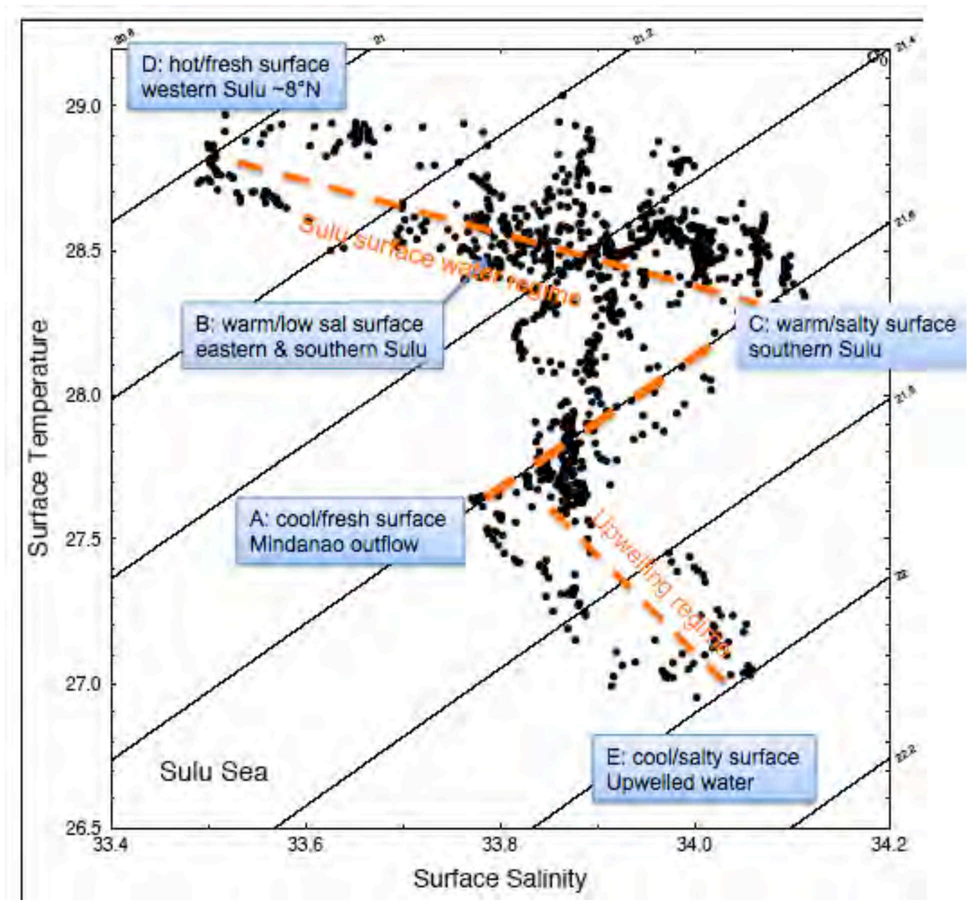


Figure 5: Upper panel (5a) shows the ocean current in the layer 23-55 m based on the ship hull mounted ADCP. The vectors are color coded for SST [upper left panel] and SSS [lower right panel. Arrows are added to show suspected circulation. Green arrow denotes the Mindanao Sea outflow and upwelling cell off Zamboanga Del Norte; the blue arrows denote the flow within the anticyclonic gyre of the northern Sulu Sea; the purple arrows form the southern anti-cyclonic gyre. The surface layer flow, color coded for SST is shown in the lower left panel of figure 5a. The lower panel (5b) is the scatter of the SST to SSS from the shipboard underway system. Three regimes are evident in T/S space: upwelling, Sulu; and the interface between that runs along the 21.6 σ density line.

The hull ADCP current vectors in the 23-55 m layer are observed along the ship track. However, sea surface temperature (SST) and salinity (SSS), which are affected by the general circulation and by sea-air fluxes, can be used to construct a regional circulation pattern. Of course, there is a bit of creativity used here, and further consideration will no doubt alter the pattern.

The winter monsoon Sulu Sea surface layer circulation pattern is characterized by two anticyclonic circulation gyres- a northern and a southern cell. The outflow from the Mindanao Sea veers to the south, but its continued path into the central Sulu Sea is not well defined by the RIOP09 data. South of the Mindanao outflow is an upwelling zone, inducing cool, high salinity surface water. There are two regimes in T/S space: the upwelling/Mindanao outflow regime and the Sulu Sea regime. The former produces a T/S scatter from cool to warmer with relatively small SSS variability; the latter is very warm, with a wide range of salinity. The low salinity of the very warm regime is likely drawn from the western margin of the Sulu Sea, where the winter monsoon leads to rainfall over eastern Malaysia that is then brought to the sea by terrestrial runoff.

The RIOP09 observed surface current pattern differs in places from that observed by RIOP08. Here the model results may shed light on the spin up and mesoscale activity within the Sulu Sea.

§ Deep Ventilation of the Sulu Sea- The Southern Source

The RIOP08 final report includes a section concerning the duel mode of ventilation of the deep Sulu Sea. A low salinity northern injection from the South China Sea entering the Sulu via the Mindoro/Panay Straits of sill depth ~570 m and a more saline southern source composed of Sulawesi Sea water entering the Sulu Sea via the Sibutu Passage, sill of ~350 m. The northern source descends to about 1250 m, which the southern source descends to the floor of the Sulu Sea. The denser southern source is made feasible by the shallower pycnocline of the Sulawesi Sea then found in the South /china Sea and by the strong tidal heaving associated with the in Spring tide, which lefts denser Sulawesi Sea water to the sill depth. This duel ventilation source leads to a unique deep stratification: while the deep temperature is about 10°C, once below 1250 m the salinity increases to the sea floor.

RIOP09 sampled the Sulu Sea stratification close to the southern source (Figure 6), at 6.5°N about 35 nm north of the northern most overflow controlling sill across the Sulu Archipelago.

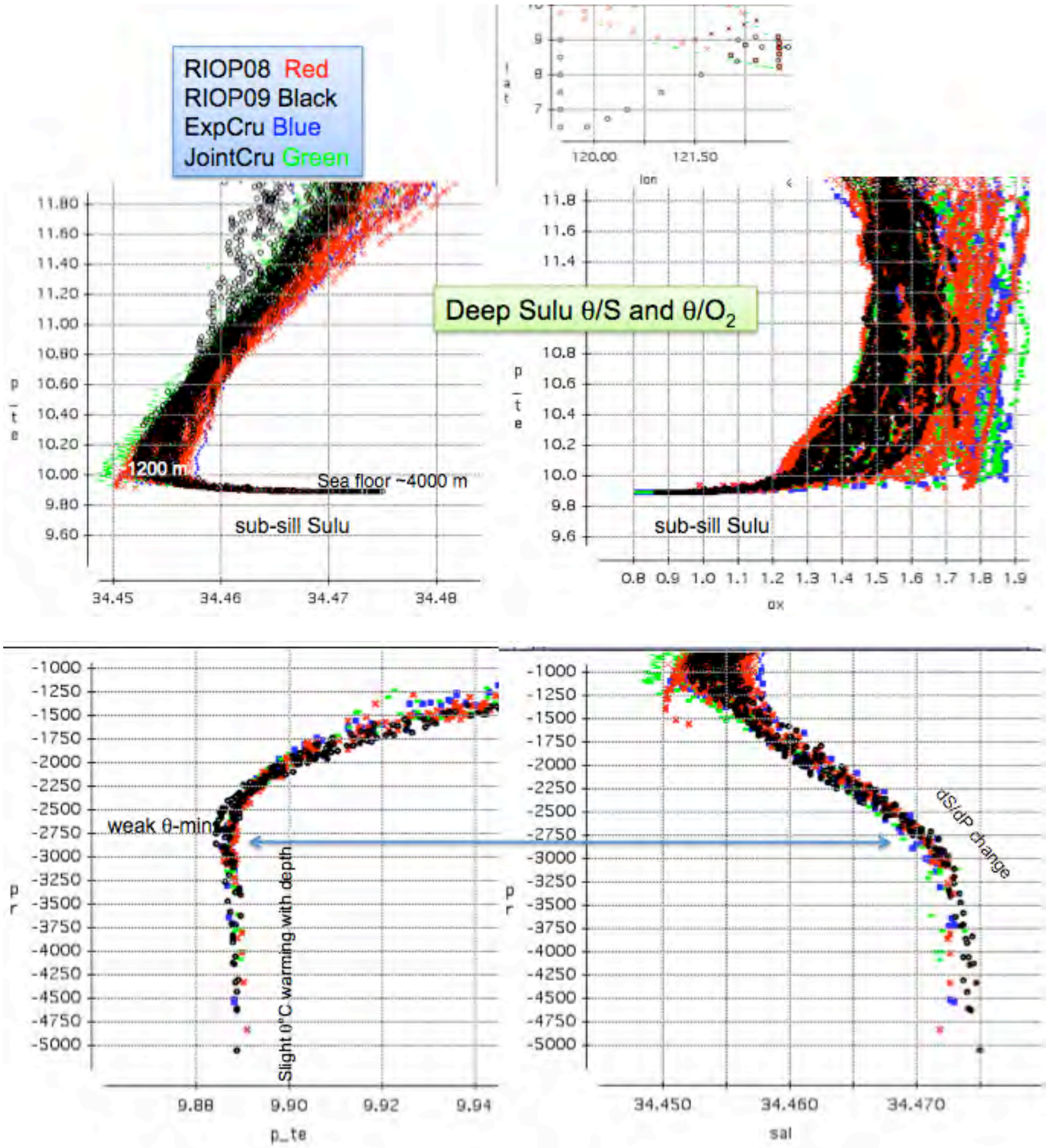


Figure 6: The upper panel (6a) shows the θ/S and θ/O₂ of the deep Sulu Sea . The lower panels (6b) shows the θ and s profiles versus pressure.

Preliminary analysis of the of the stratification suggest the following modification to the schematic presentation of deep Sulu ventilation (Figure 7) that was presented in the RIOP08 report. The Sulawesi source probably most commonly spreads across the Sulu Sea near 2500-3000 m depth, inducing a θ-min at that depth, below which the θ increases to the sea floor, but stabilized by increased salinity with depth. During strong El Niño the shallower regional pycnocline enables denser water to flow through the Sibutu Passage to the Sulu sea floor, but the longer residence time of the >3000 m water experiences warming by geothermal flux.

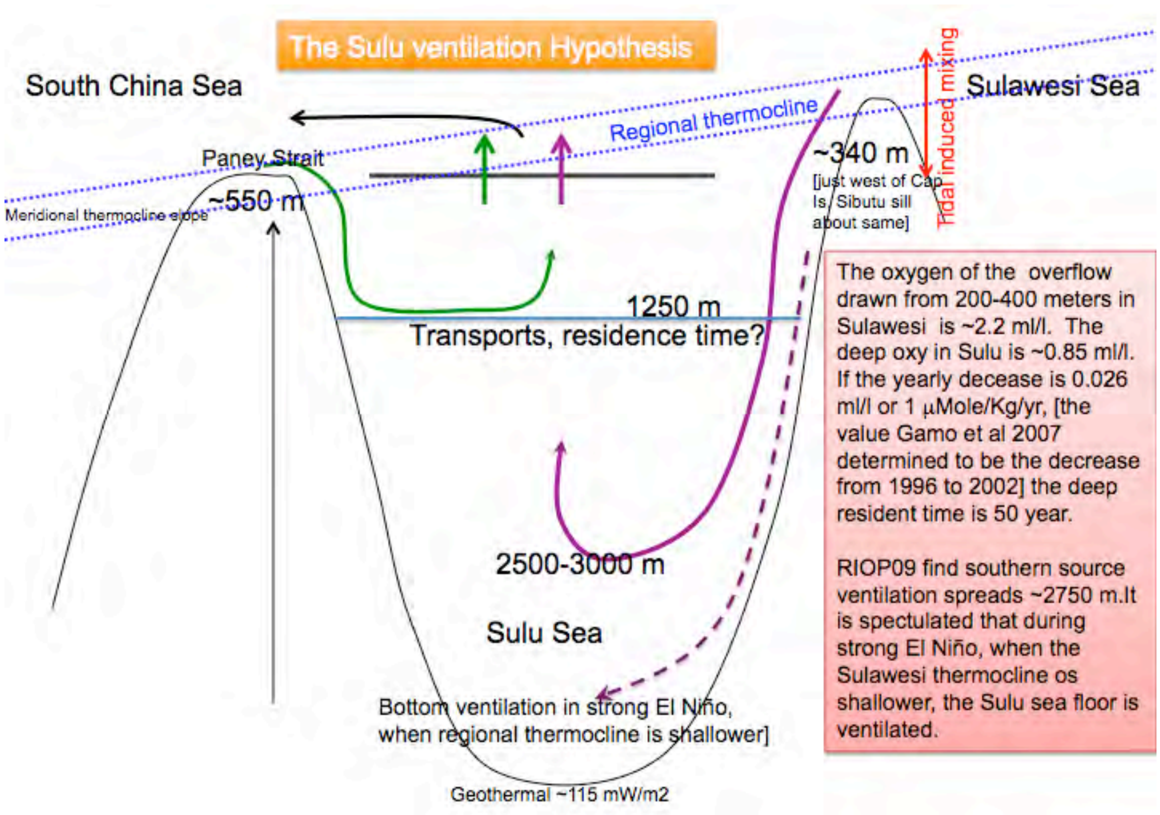


Figure 7: Schematic of the deep Sulu Sea ventilation, modified from the form presented in the RIOP08 Report by showing the southern source during RIOP09 to reach to 2500-3000 m rather than to the sea floor. During strong El Niño conditions, when the Sulawesi pycnocline is shallower, dense water overflows into the southern Sulu Seas, to ventilate the sea floor.

§ Soliton Observations

As we were at our southern position in the Sulu Sea at full moon, 11 March, we had an opportunity to observe solitons that emanates from the passages in the western Sulu Archipelago[3].

We sampled a soliton coming from the south, from ~170°, as it passed the ship during our southern-most station at 6.5°N 119.5°E (see the hull ADCP Appendix, and Figures 8, 9). As we headed northward along 119.5°E we sampled what we believe to be the same soliton at least 4 times from 12 to 13 March [CTD stations 71 to 76], as the wave travelled from 6.5°N to 8.5°N: we caught up with it on transit, and then it passed us

[3] Apel, et al (1985) JPO

while we were on station[4], each time displaying a zone of whitecaps and ‘confused’ sea [Figure 8]. Ship bridge reported changes in surface currents of around 2 kts within the soliton.

The 3-D velocity field within the soliton is displays much structure, at ~25 minutes pulses, particularly in the meridional and vertical component [Figure 9]. In addition there is much stratification of the velocity structure, with a sheet of opposing u and v values much in evidence within the main thermocline, 150-200 m [the u and v reversals are slightly off-set]. Sampling of an individual soliton as it progresses some 120 nm at a speed of slightly over 5 kts [a 24 hour period], from near its origin to the western, central Sulu Sea.

[4] Chris Jackson of Global Ocean Associates kindly provided satellite images and estimates of when we might encounter a soliton.

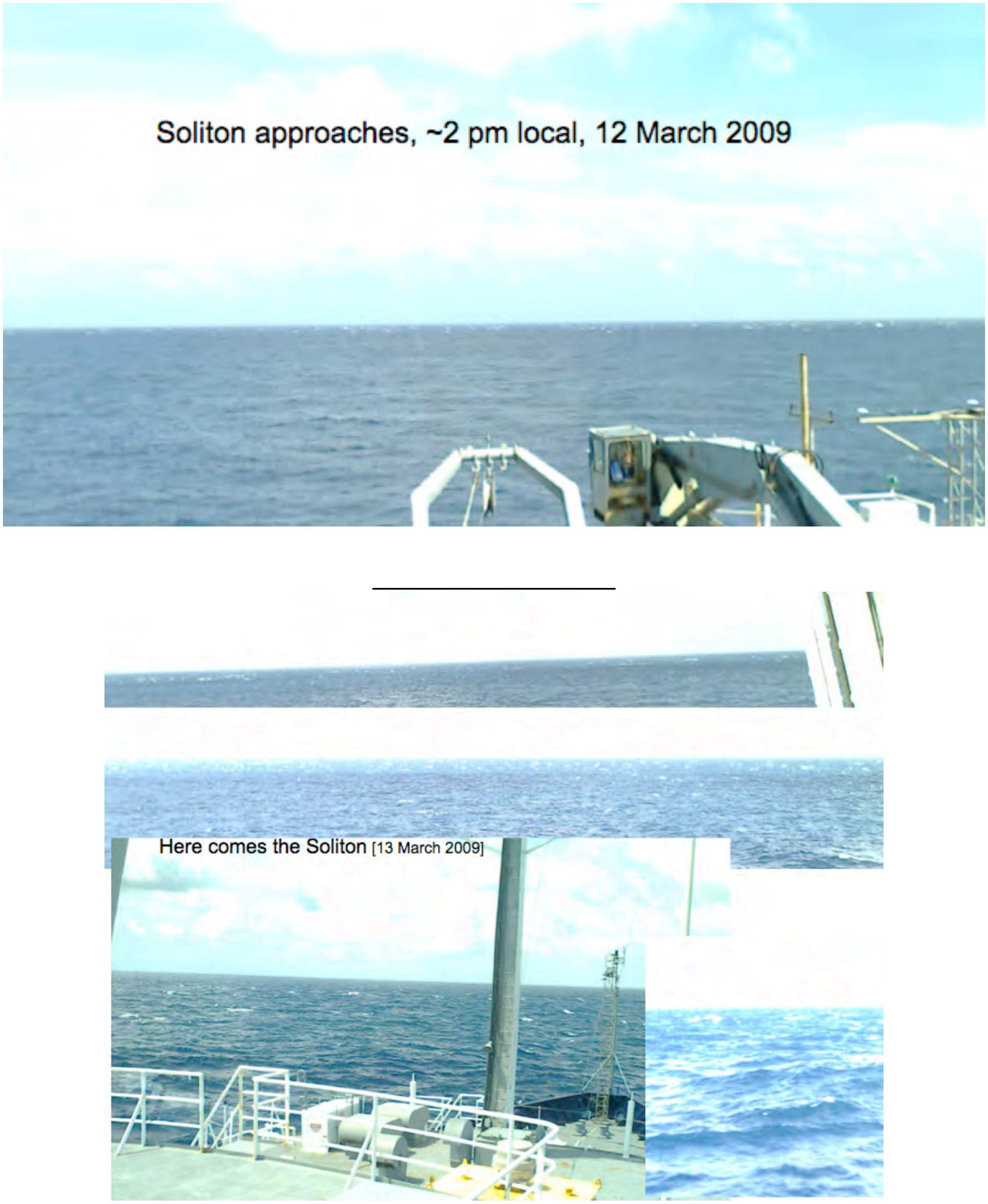


Figure 8: Soliton surface expression. The upper panel picture is just before we had our first encounter with a soliton during a 16-hour soak of the CDT/LADCP at 150 m on 12 March. The lower set of pictures is during CTD 75 at 8°N, on 13 March.

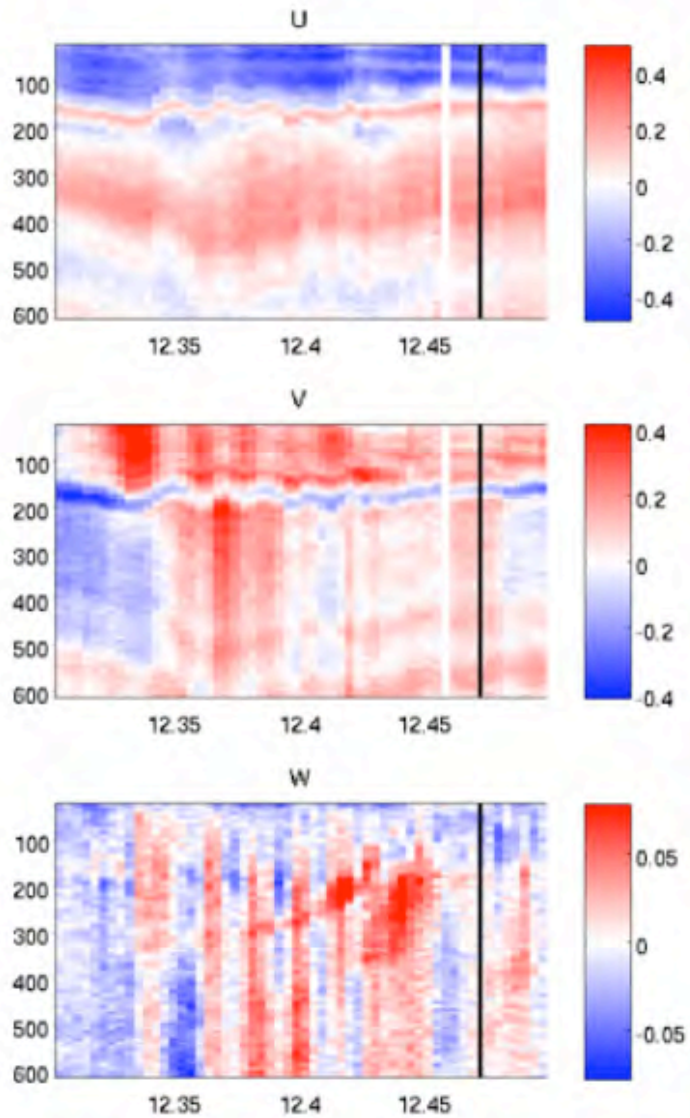


Figure 9: zonal, u, meridional, v, and vertical, w, speeds in m/sec during the 12 March soak CTD station designed as station 71, the black column represents CTD 72. The x-axis is time in day. decimal GMT. The data is taken from the hull mounted ADCP [see the Hull ADCP report in the appendices for a figure showing the full time series at 6.5°N, stations 70-72].

[B] Panay/Mindoro/Tablas: the *Dynamic Trio*

The South China Sea, the Sulu Sea and the smaller interior Sibuyan Sea are connected by a "dynamic trio" of passages of varied width: Mindoro with a topographic sill depth of ~450 m; the Panay, sill depth of 585 m; and the Tablas, sill depth of 563 m (see Figure 2). Between these passages is a small sea, in what is referred to as the 'mixing bowl', which links these passages into something perhaps akin to an electric circuit. The flow pattern through these seas is discussed in the RIOP08 report and in the June 07 Exploratory Cruise report. With the recovery of the three PhilEx moorings, one at the sill within each passage [see PhilEx mooring report in the appendices], we now have a simultaneous time series in each of these passages to investigate the temporal variability of each and their coupling with each other.

During RIOP09 the eddies induced by the strong winds between Mindoro and Panay were not as well developed as observed during RIOP08. Instead the surface layer flow was consistently towards the South China Sea (Figure 16). The subsurface flow was directed towards the Sulu Sea, feeding the Panay overflow (see figure 2 of the LADCP report in the Appendices), or injecting South China Sea water into the Philippine seas to form a S-max near the 15°C isotherm at 200-250 m.

§ Panay Strait

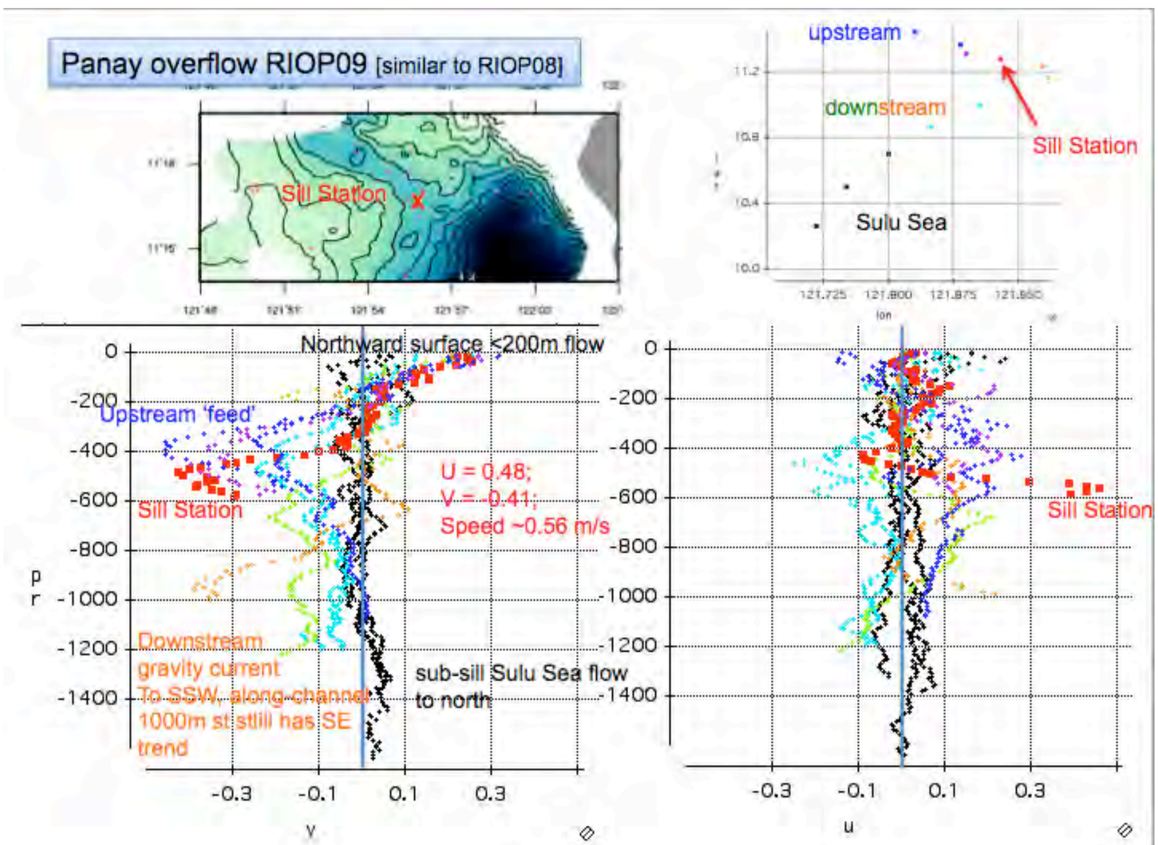


Figure 10: Profiles of zonal and meridional flow at the sill of Panay Strait. "Red" station is same as shown in Figure 2 of the LADCP report in Appendices

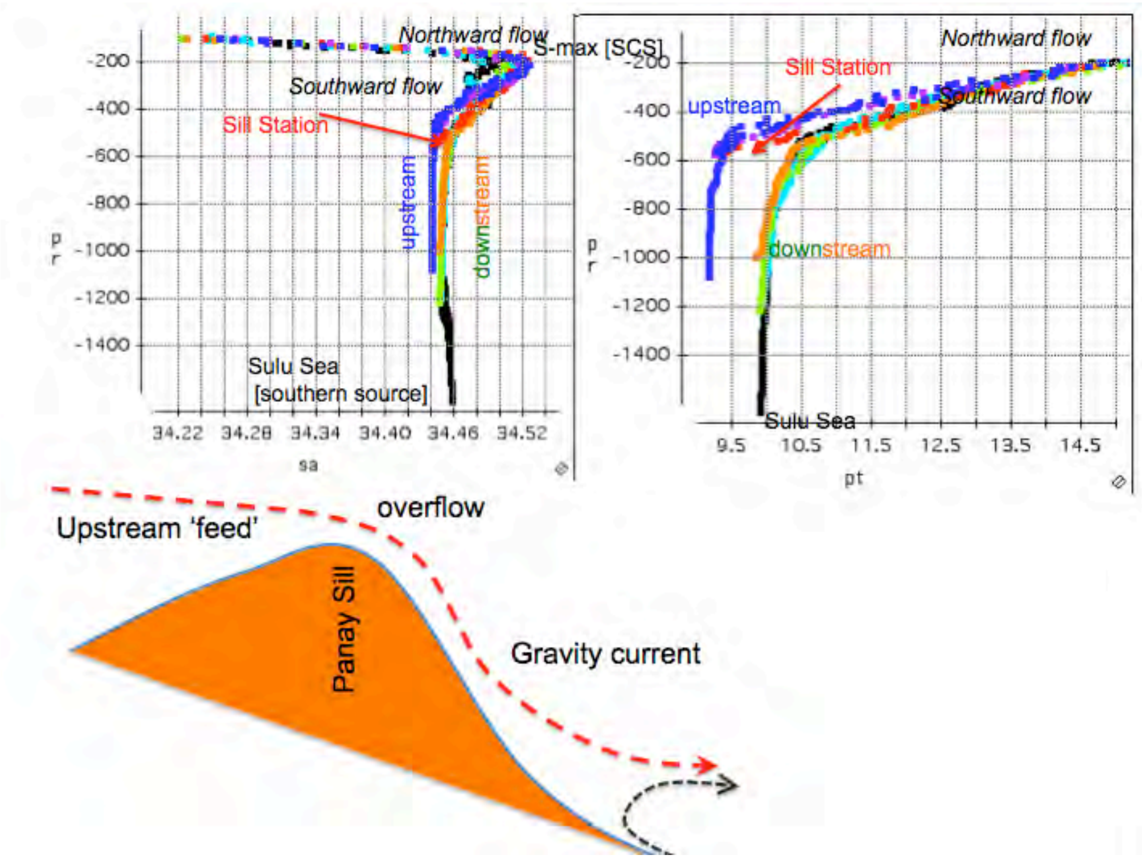


Figure 11: Stratification and simple schematic representation of the Panay spillover

The surface currents detected by the Panay based High Frequency Radar (Figure 12, left panel) on 15 March agree with the pattern revealed by the average flow between 23 and 55 m (Figure 12, right panel; also see Figure 16). They consistent with the cyclonic wind induced gyre off the west shores of the northern Panay Island.

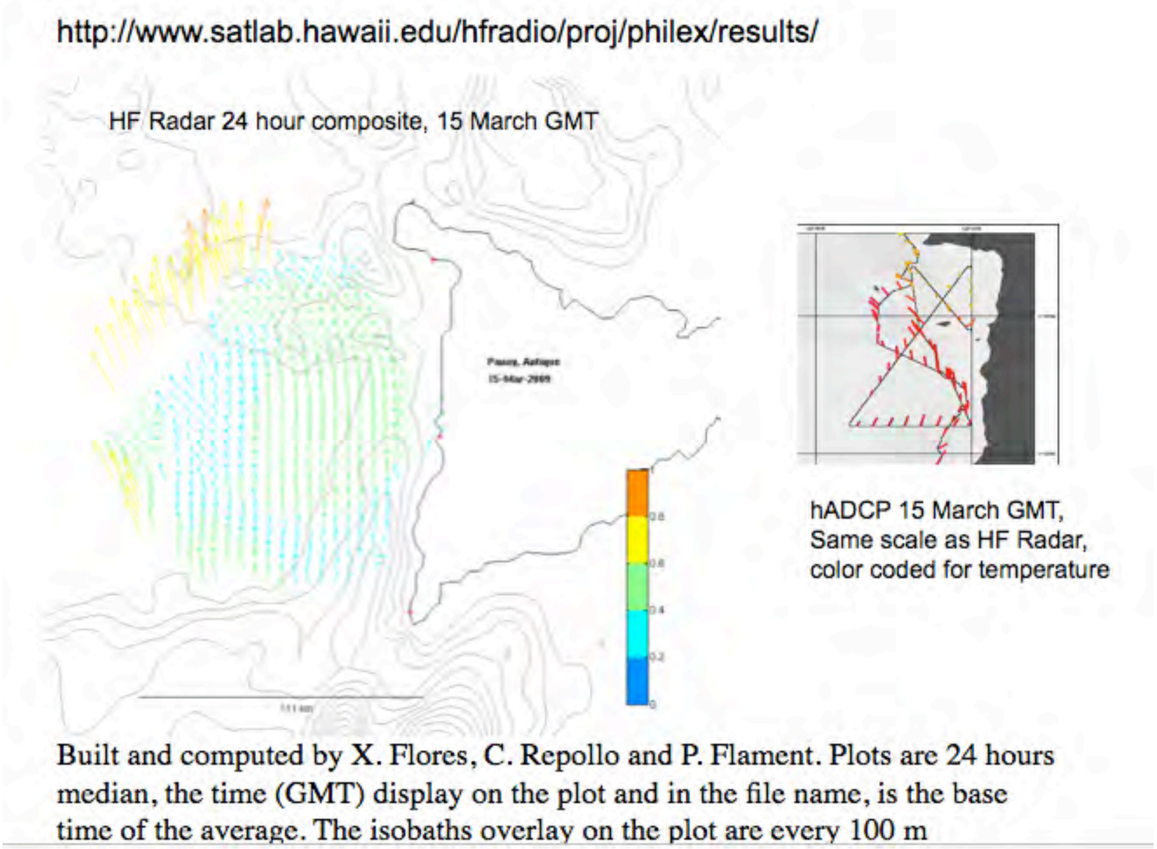


Figure 12: 24 hour average surface current on 15 March 2009 from the Panay based HF Radar system [left panel]. SST color-coded currents between 23 and 55 m from the Melville hull ADCP [right panel], shown on the same scale as the HF map.

§ Tablas Strait

The θ/S relationship for the Tablas region [Figure 13] reveals input of water types from the South China Sea, via Mindoro Strait and Verde Island Passage. The salinity maximum near 200-300 m meters is drawn from the South China Sea via Mindoro Strait, entering Tablas Strait from the south. The weak salinity maximum near 100 m is also drawn from the SCS, but via Verde Island Passage. Both s-max layers are remnant of the western Pacific subtropical stratification, which is modified by the introduction of lower salinity water mass formed in the western South China Sea [see RIOP08 Report]. The low salinity 'indent' in the θ/S relationship is observed in the 16°-24°C layer [Figure 13] represents this water. Not clear if it enters Tablas from the north or from the south of Mindoro Island, more likely from the north via Verde Island Passage.

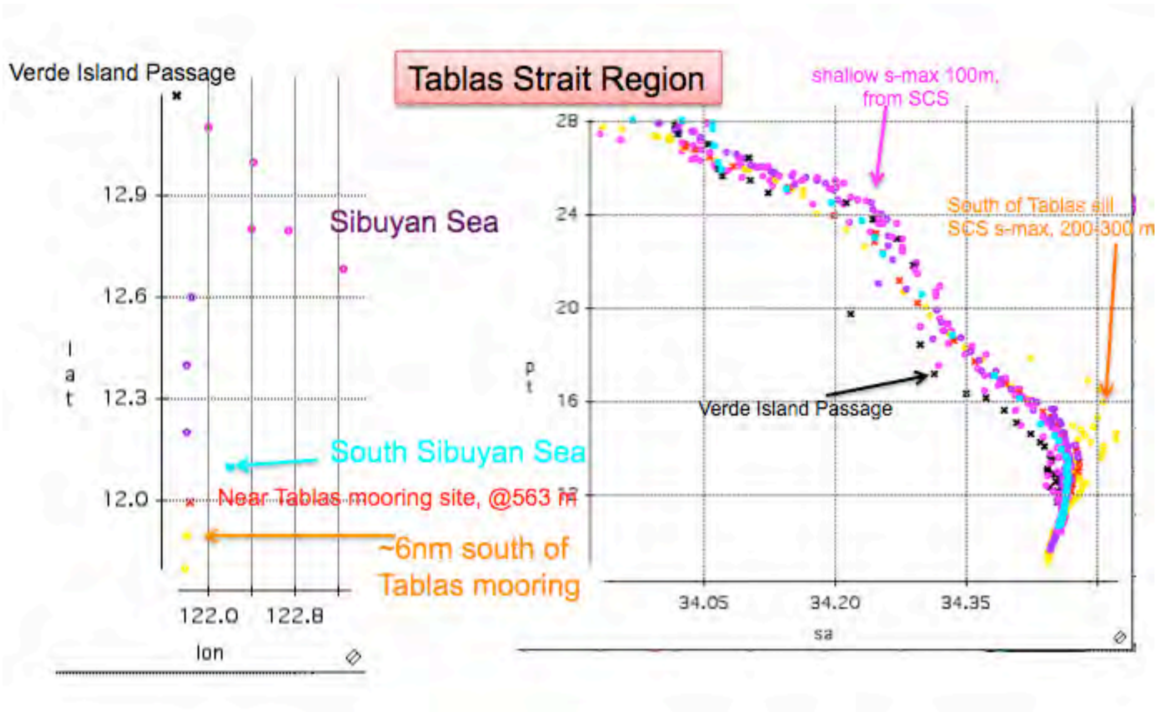


Figure 13: RIOP09 CTD/ADCP stations in the Tablas Strait region [left panel]. The θ/S scatter is shown in the right panel.

The zonal and meridional speeds near the Tablas sill in the southern Tablas Strait at the time of the RIOP09 observations reveal southward flow [Figure 14] at 400m at stat#4 near the Tablas mooring site [mooring at 563 m], and at 500-600 m at station #103 ~6 nm to the south. Yet the Tablas stations north of the sill reveal flow towards the north at these depths. The sill connecting the South Sibuyan Sea to Tablas Strait between Tablas Island and Panay Island is far too shallow (<200 m, Sandwell/Smith) to balance meridional flow within Tablas. As Tablas Strait is fairly wide north of 12°10'N there is a likelihood that it 'houses' in the mean a cyclonic circulation cell with southward flow along the western side with northward flow along the eastern side, where the RIOP09 stations were obtained.

The question remains: if the Tablas sill depth southward flow in the constriction near 12°N represents a mean field, then from where is it drawn? Verde Island Passage, San Bernardino and the interior passage connecting Sibuyan to the Mindanao Seas are all too shallow to provide the source. Simple estuary type circulation would require Tablas flow to be northward in the 400-500 depth range so as to provide overflow water into the Sibuyan Sea, over its effective sill depth of ~450 m (Figure 15), with its oxygen poor displaced water upward to eventually be exported from the Sibuyan Sea and over the Tablas sill at a depth above 400 m. While this is consistent with the oxygen profile, it is not consistent with the RIOP09 LADCP profile. However, the estuarine circulation the small interior basins is like to be quite weak relative to large fluctuations linked to the Dynamic Trio effect. I suspect the mean benthic layer transfer over the Tablas sill is weak, but with energetic fluctuations. This seems consistent with the Tablas ADCP mooring time series [see PhilEx mooring appendix]. The dynamics of the trio of straits connected to the Mixing Bowl will be a challenge to decipher.

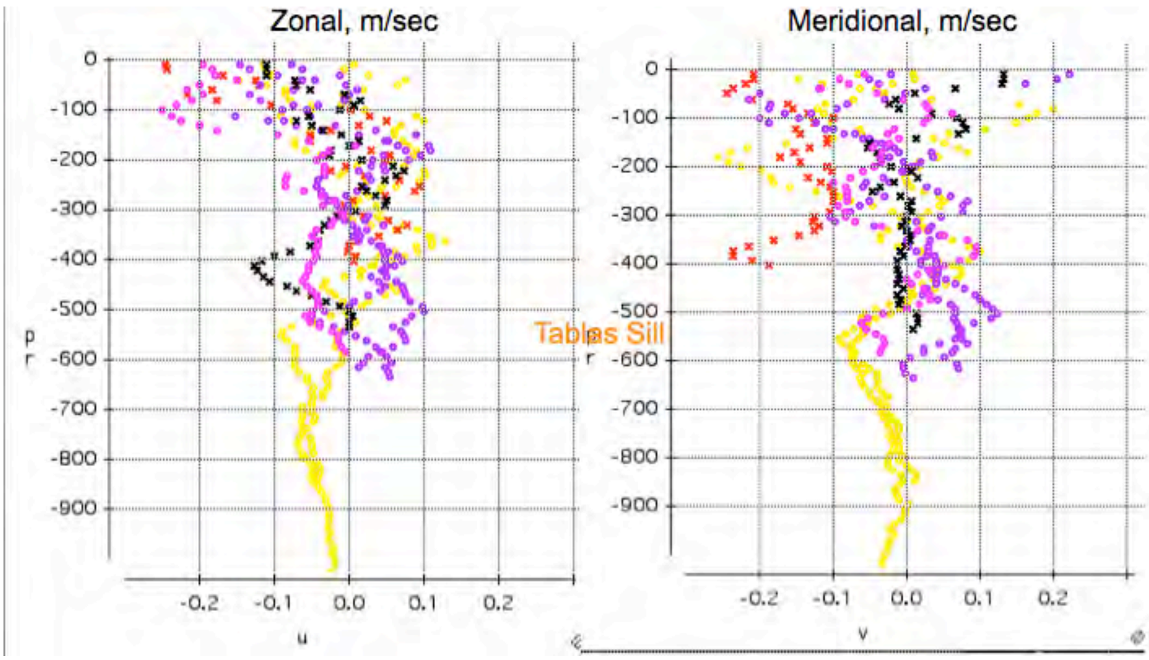


Figure 14: Zonal and meridional flow in the Tablas Strait from the LADCP. The mooring is close to the station shown in red, but at a deeper depth [sill = 563 m]. The station immediately south of the 'red' station is about 6 nm south of the sill, close to the mooring depth.

The oxygen and density profiles within the Sibuyan Sea region [Figure 15] yield effective sill depth for the Sibuyan Sea of ~450 m, and for the South Sibuyan Seas ~400 m. The South Sibuyan Sea sill matches the depth of the oxygen min of the Sibuyan, so the South Sibuyan basin has the bad luck of being ventilated by water that is already oxygen poor. This no doubt accounts for the near zero oxygen concentrations in the deep South Sibuyan Sea.

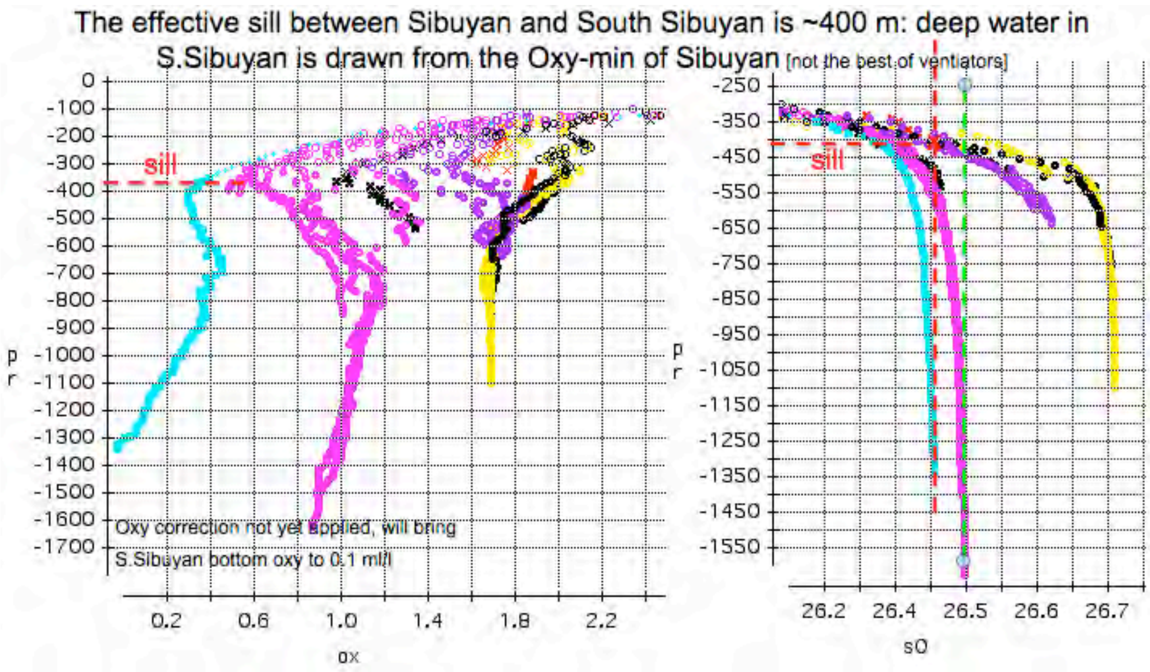


Figure 15: Oxygen profile and density profiles of the Tablas region. The sill depth of the South Sibuyan Seas [red dashed lines] is ~400 m. The sill depth of the Sibuyan Sea [green dashed line] is ~450 m.

§ Mindoro Strait

Mindoro Strait is discussed in detail in the RIOP08 Report. The only comment that can added from the RIOP09 is that the surface water was saltier in March 2009 than in January 2008, by 0.7 [Figure 4], saltier than in November 2007 by almost 0.9, and 0.5 saltier than the June 2007 exploratory cruise. The rainy season along the western region of the Philippines is in summer, beginning in early June. Before interannual variability is invoked, it is possible that the seasonal changes in the Mindoro region is such that the SSS reaches its maximum in April/May, with a minimum in September/October. This would fit the progress of SSS we observed in the 4 PhilEx cruises into the Mindoro region.

The lower salinity can be seen in the SSS color-coded surface layer current vectors from the Hull ADCP [Figure 16; the SSS scales are slightly different, as the RIOP09 map extends to higher salinity]. The SSS in RIOP08 in the region between Panay and Mindoro is about 33, while that of RIOP09 is 34. And over all the SSS in 2008 were 33.5 while in 2009 they were near 34.

The contrasting SSS is not the only difference revealed in Figure 16. In 2008 the flow is composed of a series of anticyclonic and cyclonic eddies that are induced by the highly textured wind curl as the wind is funneled between the islands and in low altitude passages across the islands. In 2009 the eddies are weak or absent **[though a cyclonic eddy northwest of Mindoro is evident, as it was at the end of January 2008, see**

RIOP08 report, and Figure 16b]. This may be due to weaker wind in late March relative to the late January winds. But a contributing factor is as follows: the lower SSS in January 2008 increased the stability of the upper thermocline thus allowing the wind stress to more easily move the buoyant surface later, though this have been offset by slightly warmer SST [not shown] in RIOP09. The conditions conducive to the generation of the wind driven sub-mesoscale features in the winter monsoon will be investigated in observations and in models.

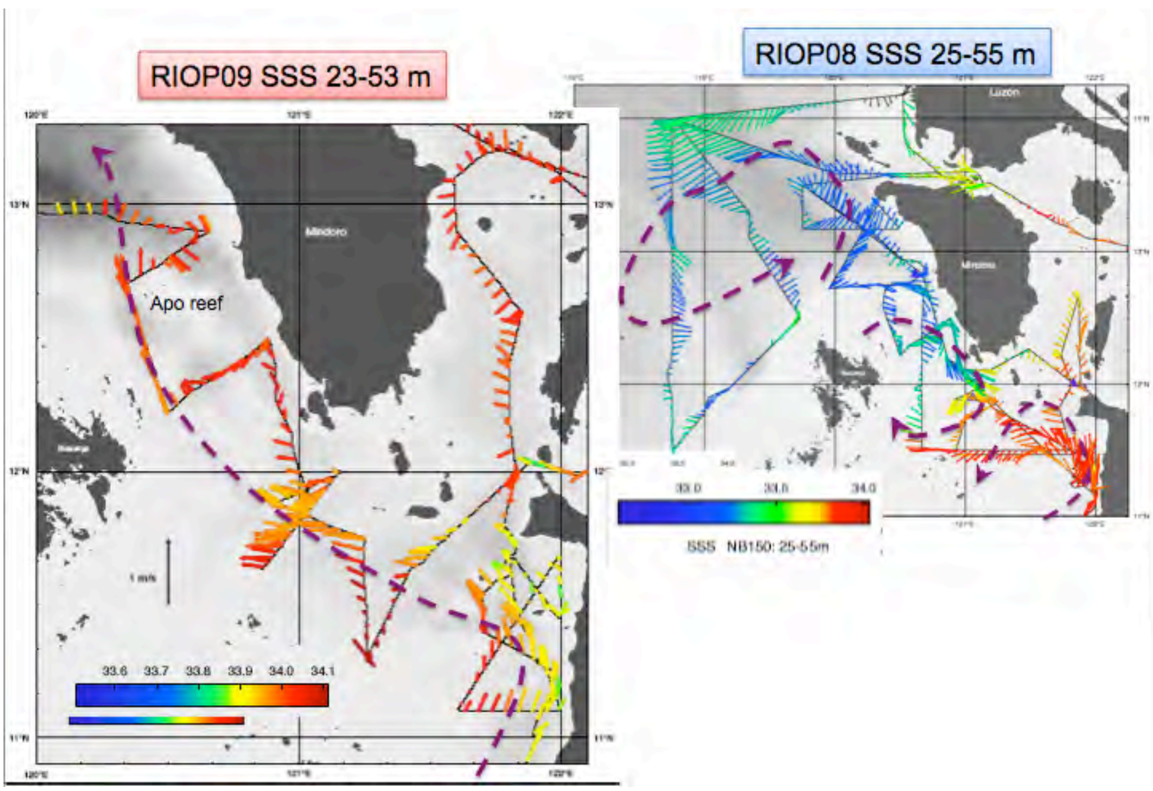


Figure 16a: Ocean current between 23 and 53 m as measured by the hull mounted ADCP color-coded by sea surface salinity [SSS]. Note that the SSS scale in 2008 extends from 32.6 to 34.0, while the 2009 scale ranges from 33.5 to 34.1, a much smaller range. The purple dashed arrows show the current pattern

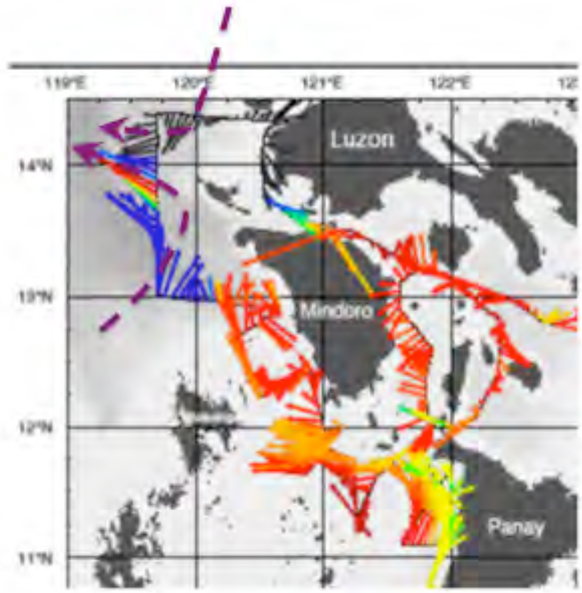


Figure 16 b: end of cruise view of 23-55 m vectors with SSS color-coding.

Summary statement:

With station and underway data, along with information from other PhilEx components, the regional cruises will greatly improve our description of the stratification and circulation within the Philippine Seas and advance understanding of issues related to PhilEx objectives. However, as typical in science, answering some questions brings up a multitude more. I would have liked to spend more time in any of the areas we surveyed. The inflow passages of San Bernardino and Surigao Straits deserve enough time to decipher the tidal vs. lower frequency fluctuations, to resolve the real throughflow and its variability with season, with ENSO, the impact of intraseasonal events [e.g. Pacific Rossby waves]. In other areas I would like to have a followed a finer scale spatial grid, e.g. the southern Mindanao Sea cyclonic eddies, and the routing of the westward surface current or 'jet' within Mindanao Sea as well as its projection into the Sulu Sea. I would have liked to better trace the flow between the small interior seas and their deep ventilation. More questions arise about Sulu Sea 3-D circulation and the role of solitons in shaping the stratification, and there is the complicated three-way junction of the "Dynamic Trio": Mindoro, Panay and Tablas Straits.

Acknowledgements: I express my appreciation for the tremendous help, provided so cheerfully, by the Melville Captain Wes Hall wonderful officers and crew of the Melville, and of the Scripps Restech and computer support. I thank them for their 'can do' attitude. The Observers from the Philippine Coast Guard and Navy were so helpful in achieving our objectives. And of course, to all of the dedicated scientists from the US, the

Philippine and Germany, who took part in RIOP09, forming a highly co-operative team approach. The cruise was very enjoyable and so much great data!

Equinox sunrise or sunset?

ALG - 20 March 2009

Appendices:

- Summary of results of RIOP09 Leg 1
- PhilEx Mooring Program
- Philippine Research Component
    - § Cruise Report
    - § Leg 1 summary
- CTD operation
- ADCP
    - § SADCP [Ship board ADCP]
    - § Lower ADCP

• Sediment Trap Recovery

APPENDIX A
Preliminary results of RIOP09
Leg 1 [personnel and preliminary assessment of finding]
Arnold L. Gordon, Chief Scientist

Manila to Dumaguete, 27 Feb to 9 March 2009

Leg 1 Personnel

	Last Name	First Name	Employer
1	Cabrera	Olivia	UPD/UPMSI
2	Drushka	Kyla	SIO
3	Ferrera	Charissa	UPD/UPMSI
4	Gordon	Arnold	LDEO
5	Ho	Cheng	LDEO
6	Mele	Philip	LDEO
7	Rab Green	Suzanne	LDEO
8	Senal	Ma. Isabel	UPD/UPMSI
9	Solera	Leilani	UPD/UPMSI
10	Tessler	Zachary	LDEO
11	Tillinger	Debra	LDEO
12	Yñiguez	Aletta	UPD/UPMSI
13	Cole	Drew	SIO
14	Dorrance	James	SIO
15	Cohen	Ben	SIO
16	Anghag	Dioesio	Philippine Navy
17	Cordero	Gerald	Philippine Coast Guard

Preliminary Data Analysis [From RIOP09 Leg 1 Report]:

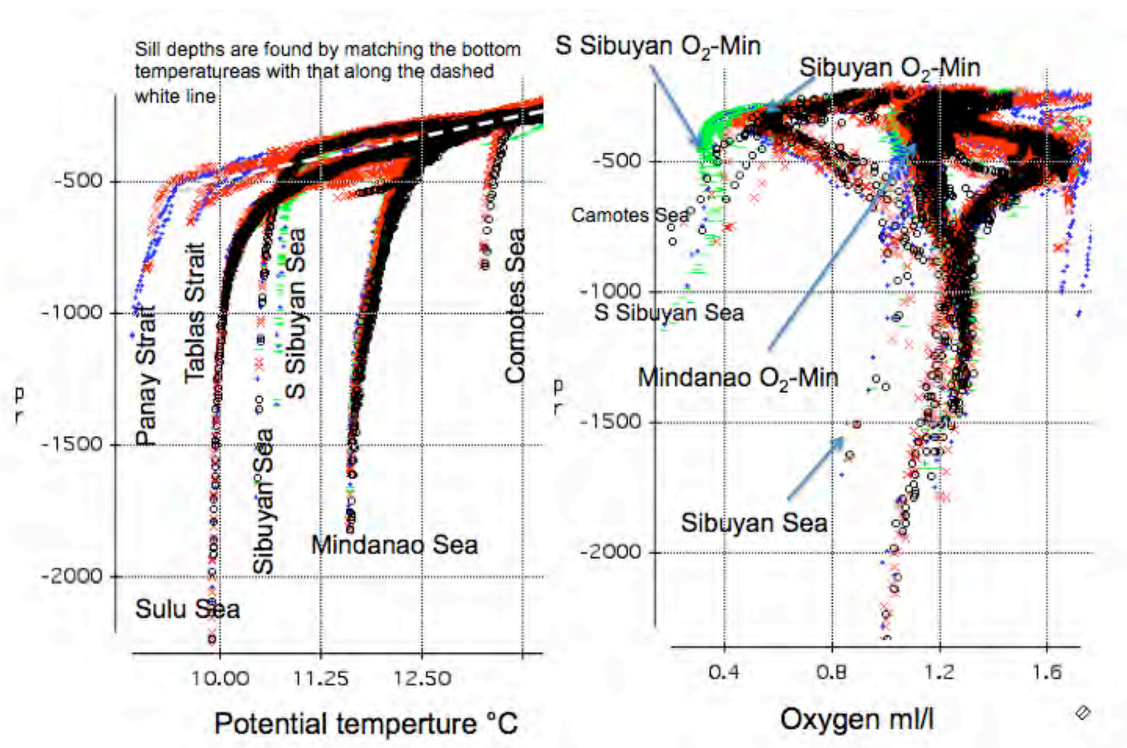
The figure numbers used in this Appendix A remain as they were in Leg 1 Report, the first being Figure 5, the last Figure 14.

[A] Ventilation of the Sibuyan Sea

The Philippine seas are composed of numerous deep basins. There is the open Pacific Ocean to the east; there are the relatively large seas to the west of the Philippines, as the Sulu Sea, South China Sea and Sulawesi Sea; and there are the smaller interior seas, most notably the Mindanao or Bohol Sea and the Sibuyan Sea, and the still smaller

Visayan, Camotes Seas, and others. These seas are ventilated by inflow of dense waters from surrounding seas that descent to the depths replacing resident water made less dense by vertical mixing, most likely due to tidal dissipation. The residence water is lifted upward as it is replaced by denser overflow gravity currents, and is subsequently exported to the surrounding seas. As these waters are reduced in oxygen by the rain of organic material from the sea surface, their spreading can be traced as an oxygen minimum. For example the Mindanao oxygen minimum near 12°C [Figure 5; referred to as the pervasive oxy-min in the RIOP08 report] is observed near 300 m throughout the Sulu Sea.

The oxygen minimum of the Sibuyan Sea is not drawn from the oxygen minimum of the Mindanao Sea via the interior Camotes Sea or by way of the Tablas Strait [as I suggested in my RIOP08 report], as the Sibuyan oxy-min thermohaline characteristics don't match that of the Mindanao oxy-min layer and there may not be a deep enough interior routing from the Mindanao to the Sibuyan Sea. It is concluded that the Sibuyan oxygen minimum is of local origin. The oxy-min of the Sibuyan Sea serves as the ventilating water source for the South Sibuyan Sea, accounting for the super-low oxygen of the southern Sibuyan Sea bottom water, <0.3 ml/l.



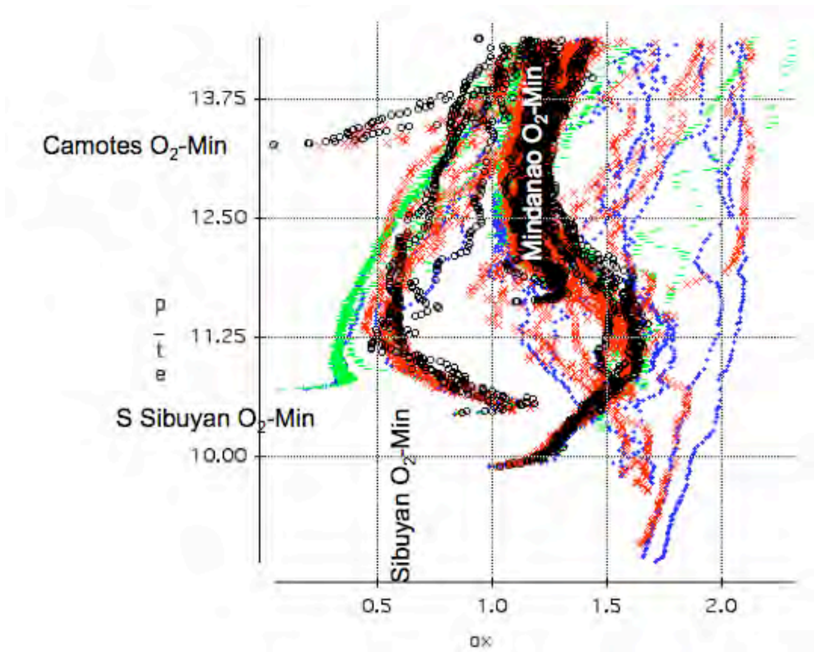


Figure 5: Potential Temperature and oxygen depth profiles in the interior seas of the Philippines [upper panel]; θ/O₂ [lower panel]

[B] San Bernardino and Surigao Straits

The direct connection of the Philippine Seas to the western Pacific is through the San Bernardino and Surigao Straits [Figure 6]. These straits are shallow, 50 to 100 m, and exhibit strong tides that induce vigorous mixing that attenuates the Pacific stratification. The sill depth for Surigao is near 50 m, at San Bernardino the sill depth is a bit more uncertain, ~80 m.

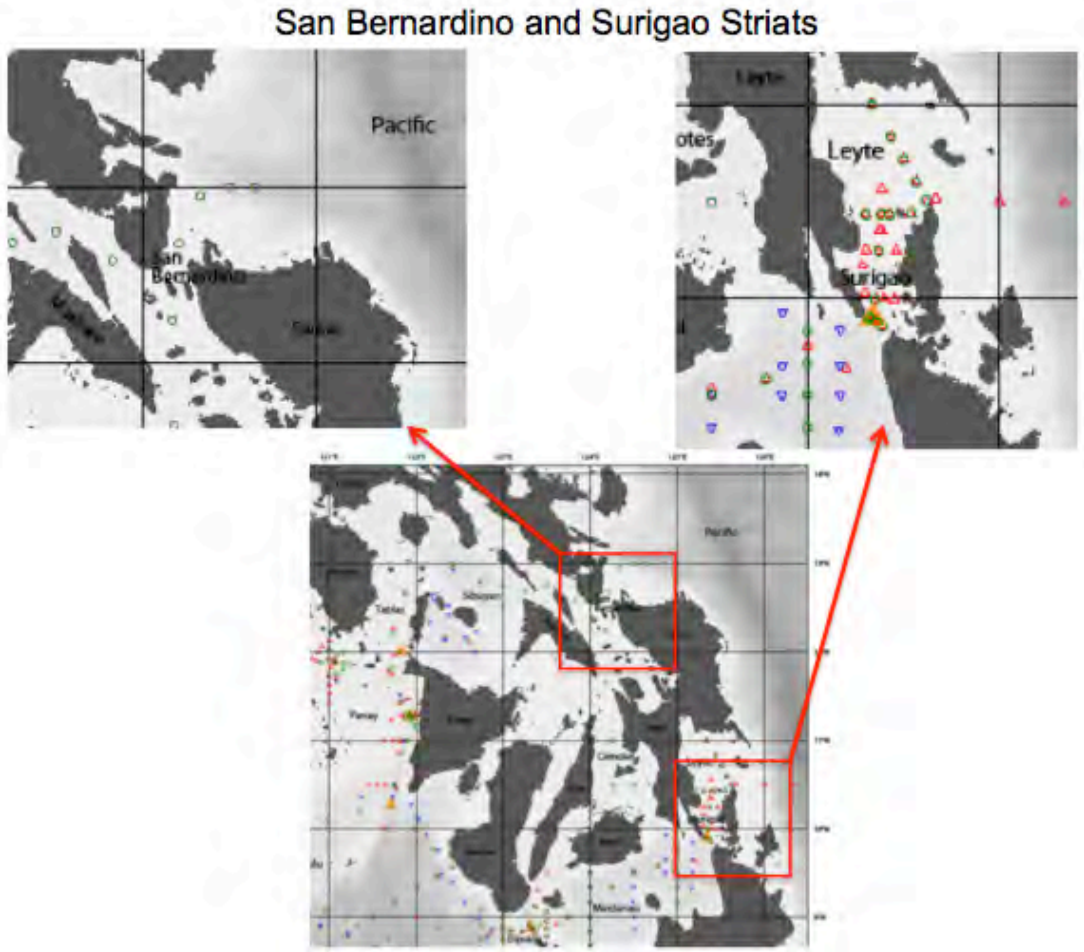
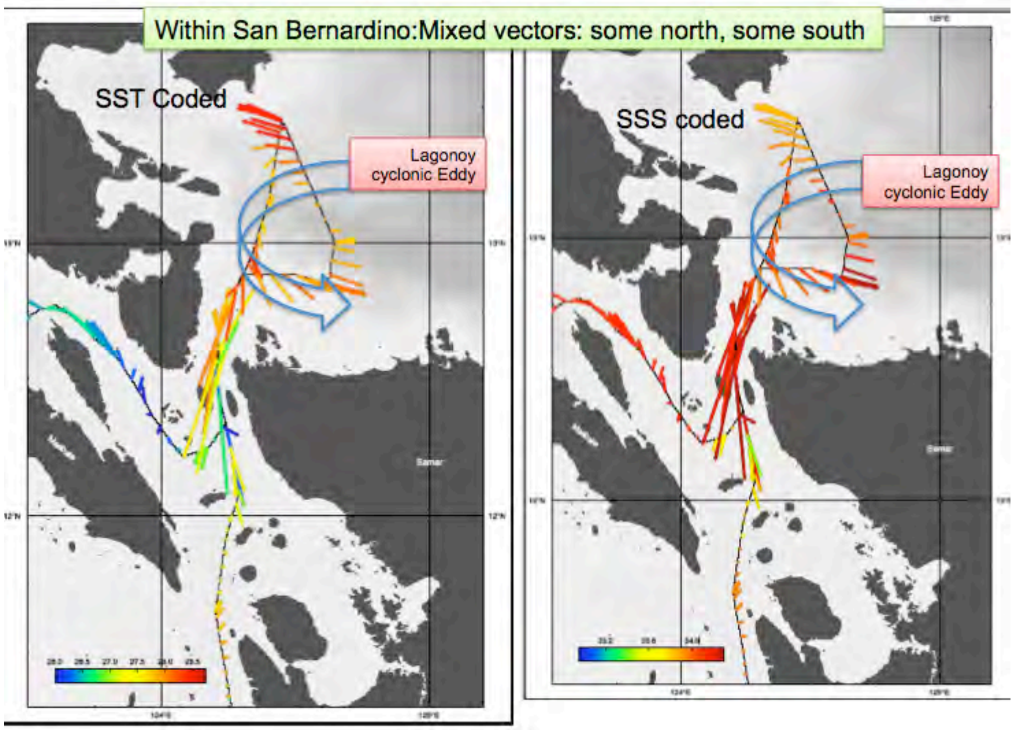


Figure 6: Map of the San Bernardino [left panel] and Surigao [right panel] Straits.

San Bernardino Strait connects the Gulf of Lagonoy with the Samar Sea [just west of Samar Island], which in turn connects with the interior seas: Sibuyan, Visayan and Camotes. The hull ADCP indicates a cyclonic flowing circulation within the Gulf of Lagonoy [Figure 7], which delivers low salinity surface water into the San Bernardino northern entrance. Vigorous mixing brings up higher salinity deeper water [Pacific water spreading over the sea floor of the Gulf of Lagonoy] boosting the surface salinity, as suggested in the upper right panel of Figure 7 and in the profiles shown in Figure 8.

Continuity [throughflow pathway] of the San Bernardino water into the interior seas is not evident [Figure 7, lower panel], though tidal currents are likely to obscure the throughflow pattern. However, there is not the expected strong westward flow in the Sibuyan Sea or of southward flow in the narrow passage between Masbate Island and the NW tip of Leyte Island, that would be needed to feed continued southward flow in the Camotes Sea or entry into the Visayan Sea, from which the San Bernardino water can spread westward into the Sibuyan Sea or south Sibuyan sea to eventually enter into Tablas Strait, either to the north or south of Tablas Island. Various PhilEx models suggest substantial San Bernardino throughflow connected to westward flow within the Visayan Sea to the passage south of Tablas Island. Based on observations from RIOP08 and from RIOP09 the continuity of the San Bernardino throughflow into Sibuyan routed either north or south of Masbate Island is not evident, nor is the continuity with southward flow in Camotes Sea. Perhaps at the time of RIOP08 and RIOP09 the San Bernardino throughflow was small, or that we missed a narrow connection with the western routing. A time-based survey of these interior seas is suggested.



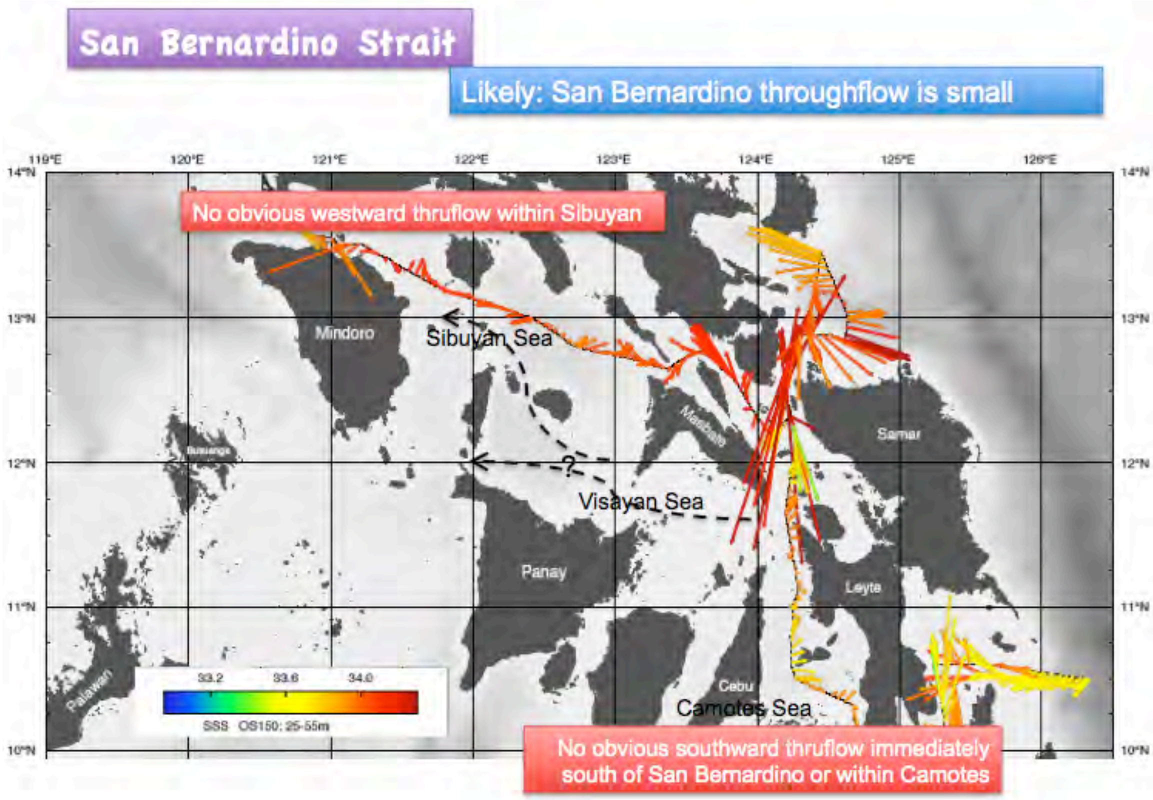


Figure 7: Hull ADCP vectors within San Bernardino Strait [upper panel] and for the larger region including the Sibuyan and Camotes Seas [lower panel]. The continuity of the San Bernardino throughflow into Sibuyan routed either north or south of Masbate Island is not evident, nor is the continuity with southward flow in Camotes Sea. Model results favor the path south of Masbate, within the Visayan Sea.

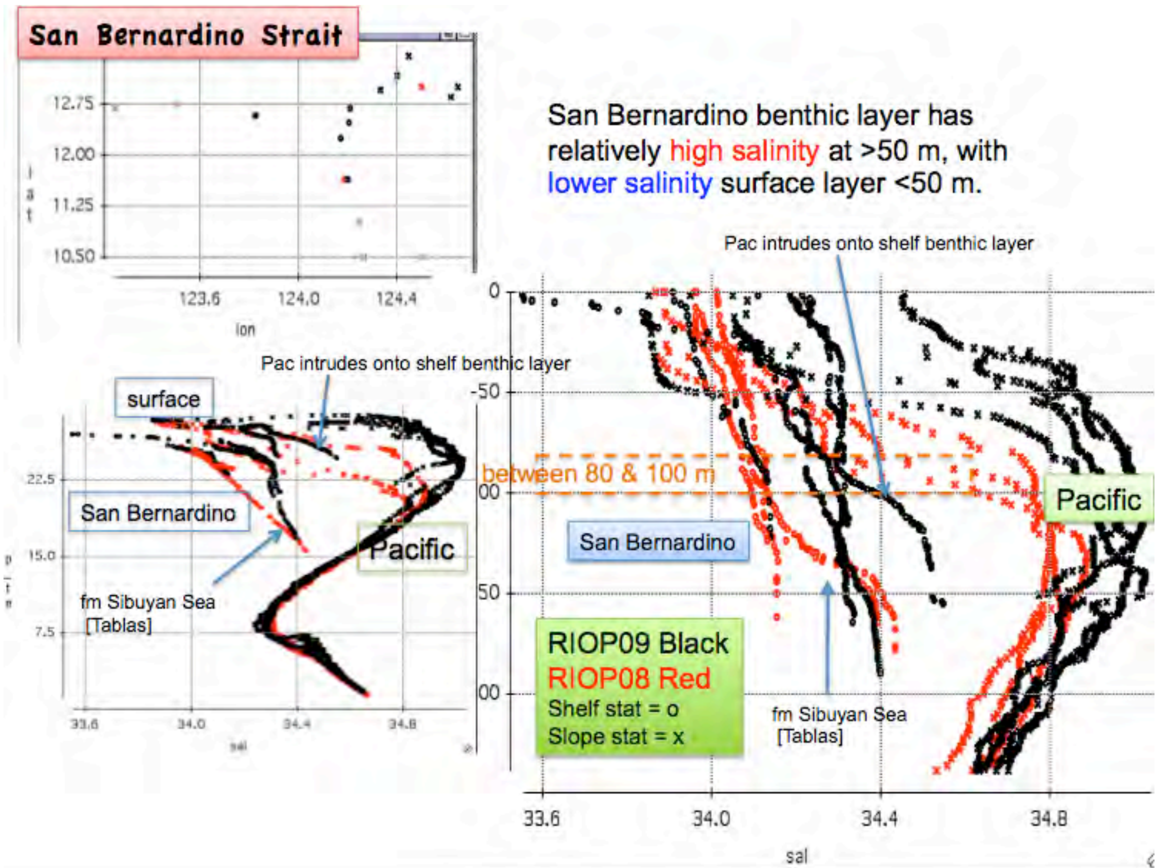


Figure 8: Potential temperature:salinity relationship [left panel] and salinity profiles [right panel] for the San Bernardino Strait. Signs of intrusion of salty Pacific water over the seafloor in the Gulf of Lagonoy are evident. This water provides the salt to attenuate the low SSS of the Gulf of Lagonoy inflow to San Bernardino Strait.

A similar situation is evident in Surigao Strait [Figures 9, 10], though there the indications of a substantial throughflow are stronger, with Surigao surface layer feeds into the westward surface layer flow that tracks along the northern Mindanao Sea [see RIOP08 final report]. The Pacific water passes into the Leyte Sea and eventually into the Surigao Strait between Homonhon Island and the NE tip of Mindanao [this is based on RIOP08 data], with a sill depth of 50 m or slightly larger than 50 m. The Pacific water executes a sharp turn to the south to pass through the Surigao Strait [Figure 9] and feeds into the Mindanao Sea westward directed surface current [RIOP08 Report and Figure 3].

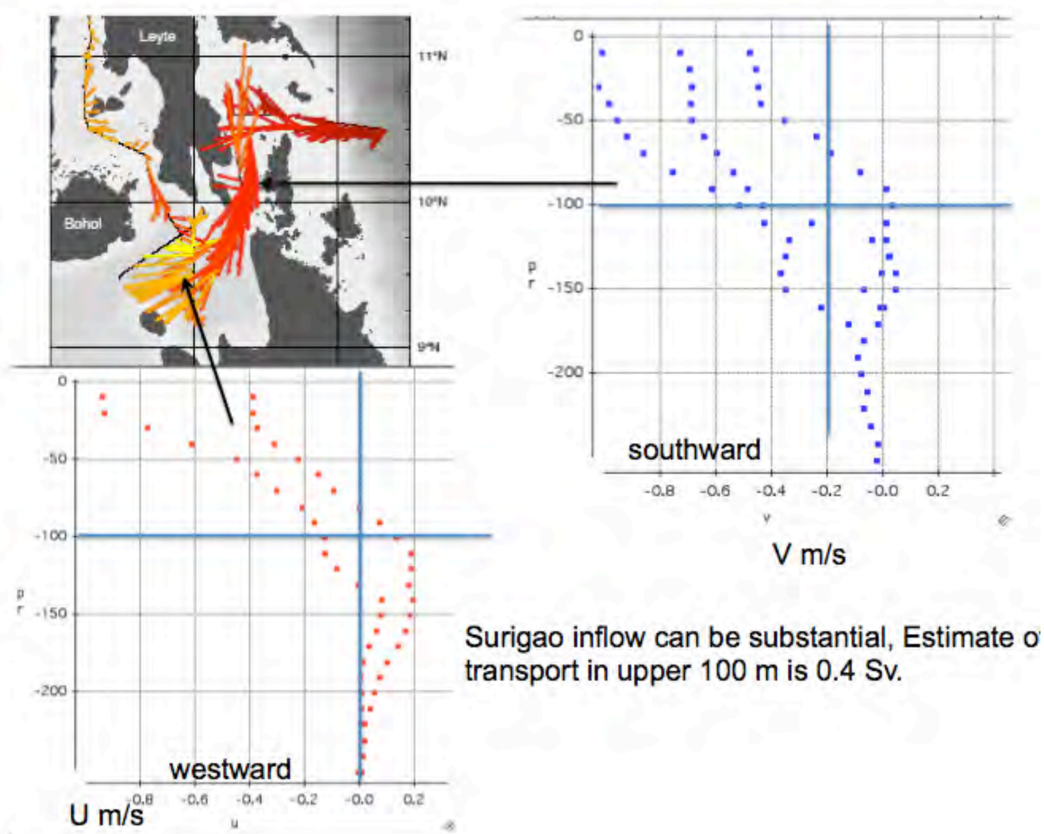


Figure 9: Vectors of flow at 23-53 m, color coded for SST [upper left panel]. The profiles of zonal [red] and meridional [blue] speed from the Lowered ADCP are shown in accompanying panels.

The hull and lowered ADCP suggest a Surigao throughflow as high as 0.4 Sv [Figure 9]. This includes the benthic intrusion of salty Pacific water, as evident by station #20 [Figure 10].

Schematics of the oceanography of the San Bernardino and Surigao straits are offered in Figure 11.

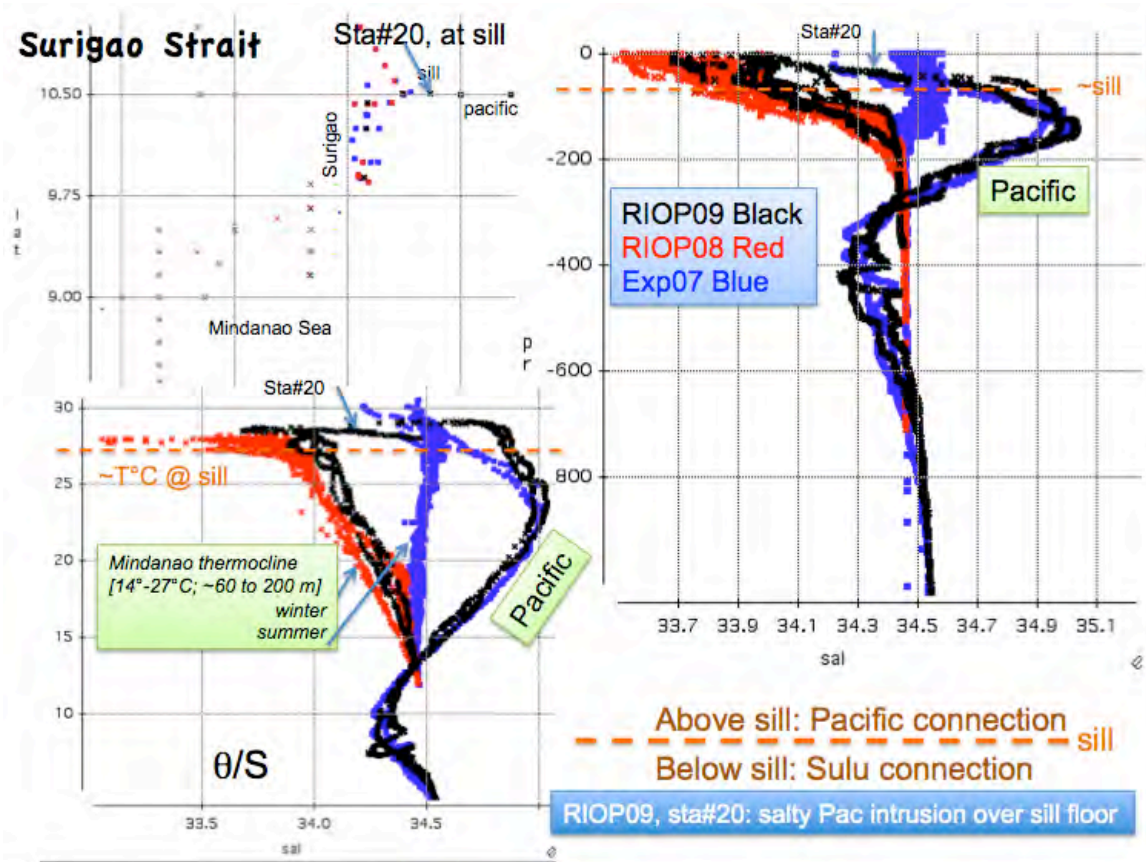
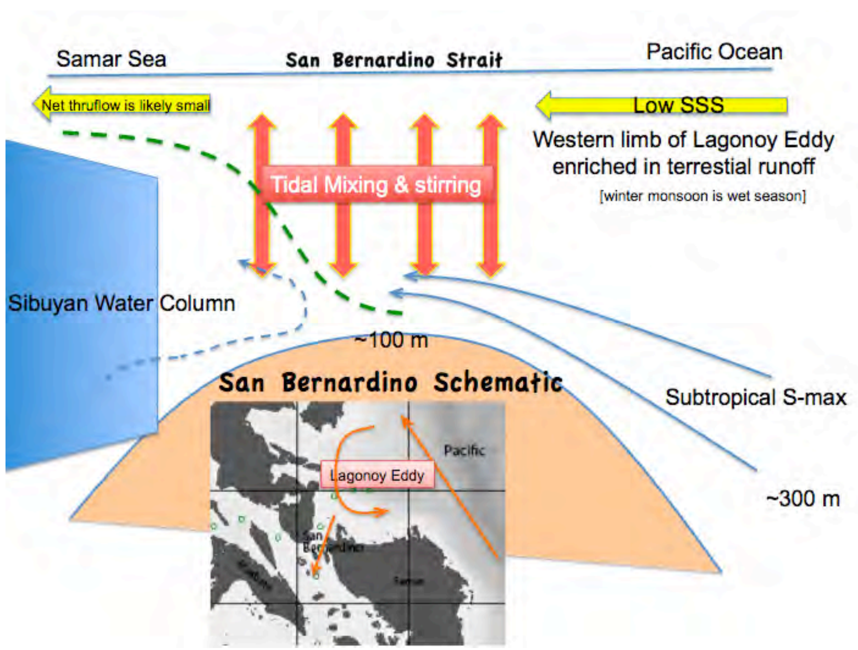


Figure 10: Stratification at Surigao Strait. Station 20, close to the topographic sill separating the Pacific from the Mindanao Sea, reveals intrusion of Pacific water along the sea floor.



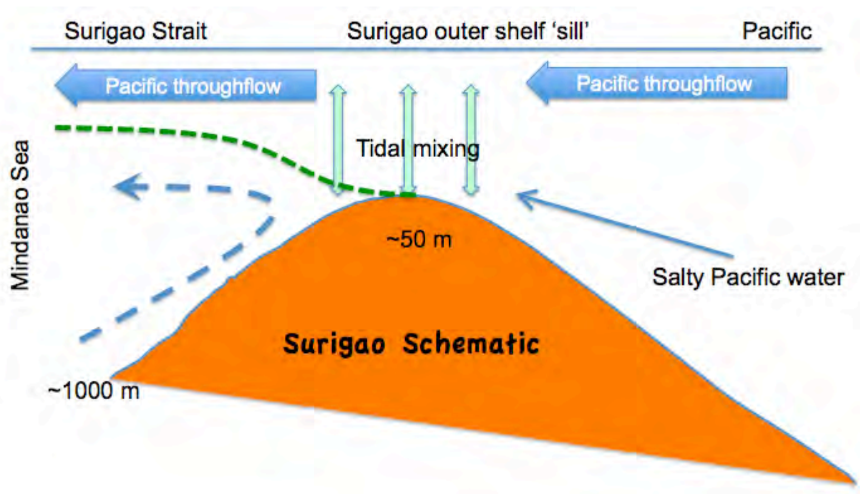


Figure 11: Schematics of oceanographic stratification and processes within San Bernardino [upper panel] and Surigao [lower panel]. The inflow of Pacific water is well mixed by local tidal energy and overrides denser sub-sill water within the interior seas of the Philippines, which are drawn from the Mindoro/Panay/Tablas Straits to the west.

[C] Western Mindanao Sea and the Dipolog Strait [See the RIOP08 Report for discussion of the Mindanao Sea horizontal and overturning circulation, a summary schematic is shown in Figure 12]

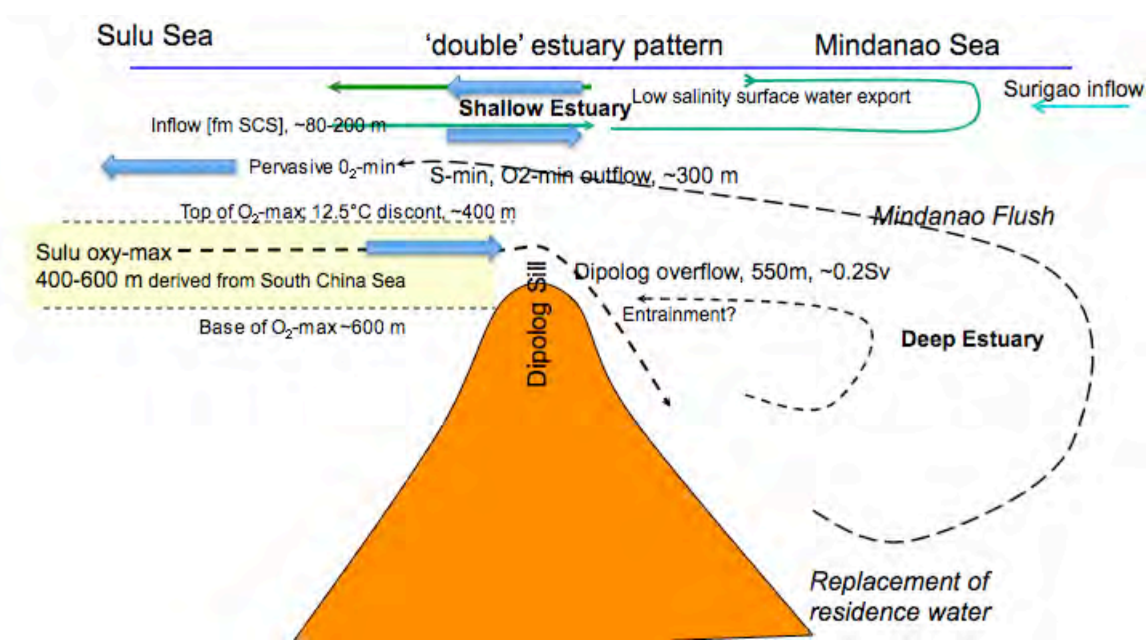


Figure 12: Schematic of the flow patterns in the western Mindanao Sea and Dipolog Strait.

Topics-

§ Deeper thermocline in March 2009 relative to January 2008: One of the most noticeable differences within the Dipolog Strait between the data we are collecting now vs. Jan 2008 data is the presence of a thicker surface layer in 2009, which has the effect of inducing a deeper thermocline [Figure 13]. Perhaps the change is just due to the 2 month difference of RIOP09 and RIOP08 as a sign of the maturing of the winter monsoon stratification, but interannual effects may also be possible: the RIOP08 occurred during the wettest winter in over 30 years. The lower surface salinity in that year relative to winter 2009 may have limited the downward mixing of surface water, leading to a shallower pycnocline. [I've not checked the rainfall conditions in winter 2009, so this remark is speculative.]

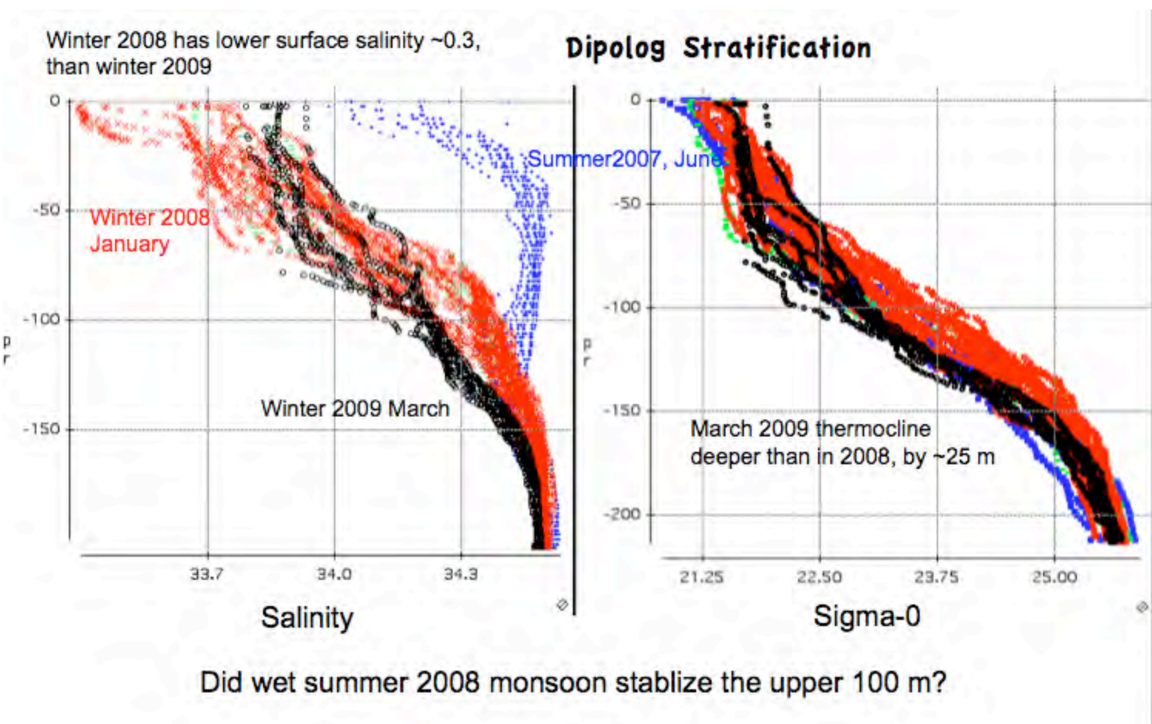


Figure 12: Salinity and density profiles in the Dipolog Strait from RIOP08 and RIOP09

§ Routing of the Mindanao surface flow into Dipolog Strait: Another issue is the routing of the Mindanao Surface Jet into Dipolog Strait. Does it pass to the north or to the south of Siquijor Island [Figure 13]? The RIOP09 hull ADCP clearly shows that at the time of RIOP09 presence the Mindanao surface current jet passes between Siquijor and Negros. The branch of the Mindanao surface current jet that curls to the south along the east side of Siquijor is part of the cyclonic gyre centered near 123°E. Which may be referred to as the Iligan Gulf gyre.

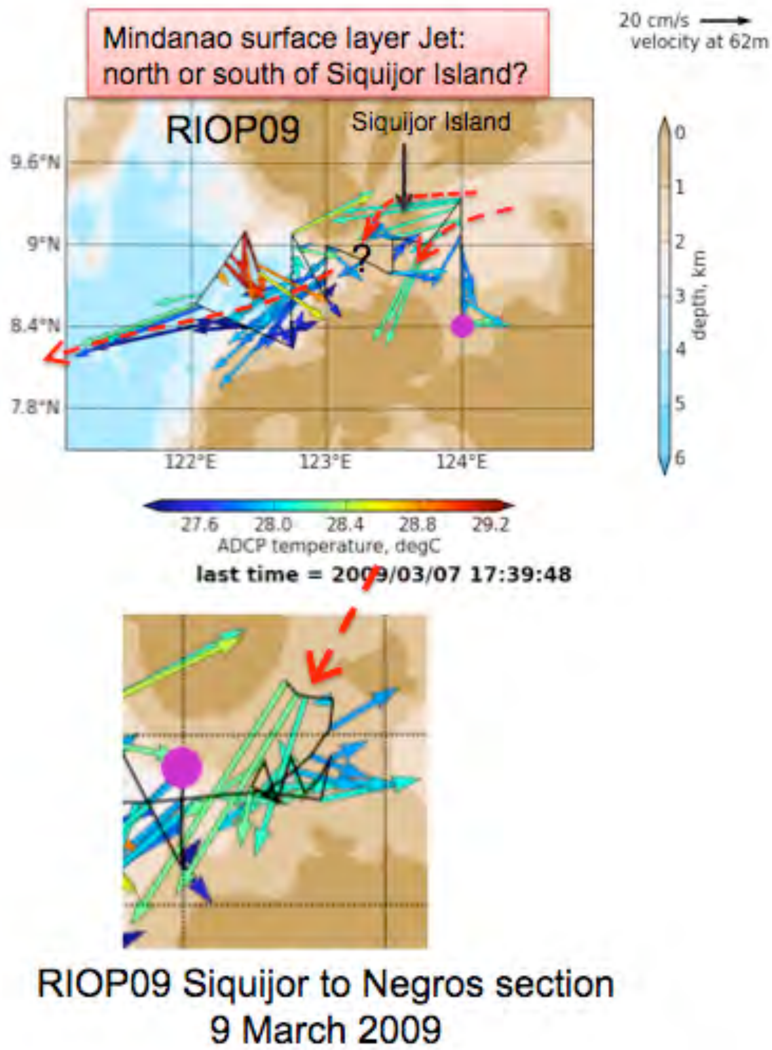


Figure 13a: The Westward flowing surface layer (<80 m in thickness) in Mindanao Sea, the "Mindanao Surface Jet" can approach Dipolog Strait by passing either south or north of Siquijor Island. The observations and model results favor the north routing, but the route may be time dependent. The lower panel obtained on the way towards Dumaguete reveals strong southward flow within the Siquijor/Negros Passage. Western intensification is evident. The vectors shown are from the ship board hull ADCP NB150 and OS75 ADCP Data web page. Figure 13b for vectors for a shallower 23-55 layer.

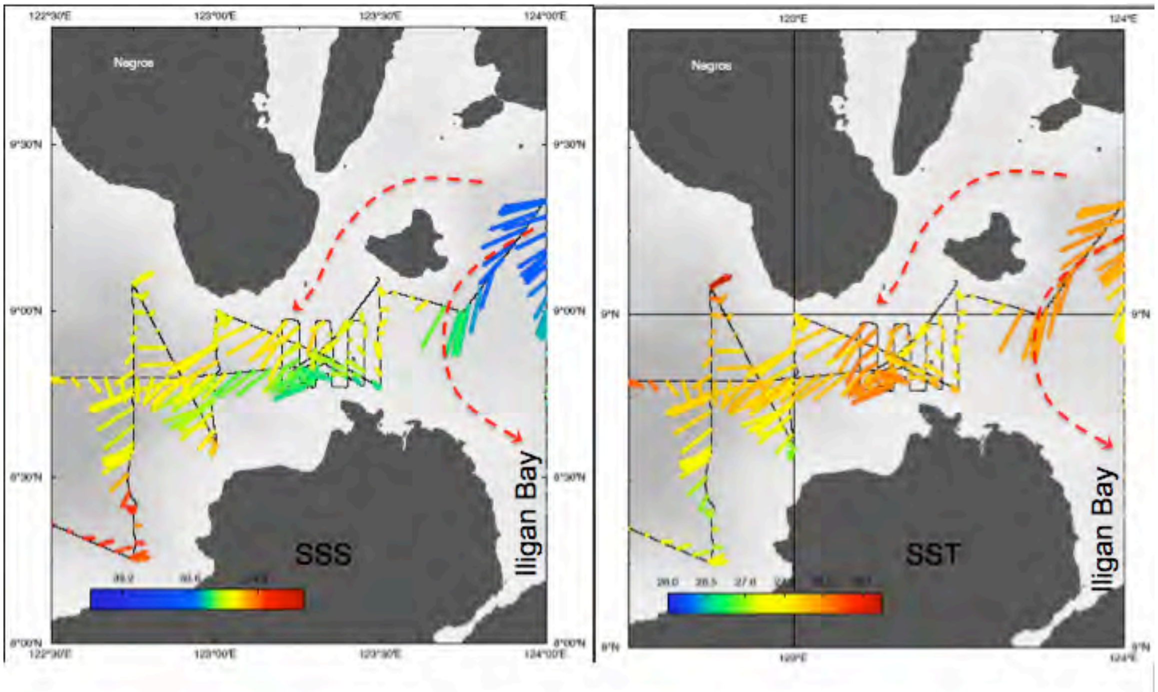


Figure 13b: Hull ADCP color codes for SST [right panel] and SSS [left panel]. Vectors are 23-55 m average. For vector scale see figure 3. This figure was constructed before the ship did the track between Siquijor Island and Negros [to be added after Dumaguete], but the dashed red arrow in the Siquijor/Negros passage is taken from figure 13a. The Mindanao surface jet that does not pass to the north of Siquijor is likely the west limb of the cyclonic gyre in the Iligan Bay region [see Figure 3].

§ Silino Island: About 5 nm east of the Dipolog mooring is the flat island of Silino, sitting on the southeast side of a coral plateau [reef] of 3 nm diameter. As the surface layer flow is strong towards the west, it is expected that the coral platform will generate eddies, perhaps much like Apo reef in Mindoro Strait. Alighay Island is a similar flat island 4 nm to the south of the Dipolog mooring site.

Multibeam figure

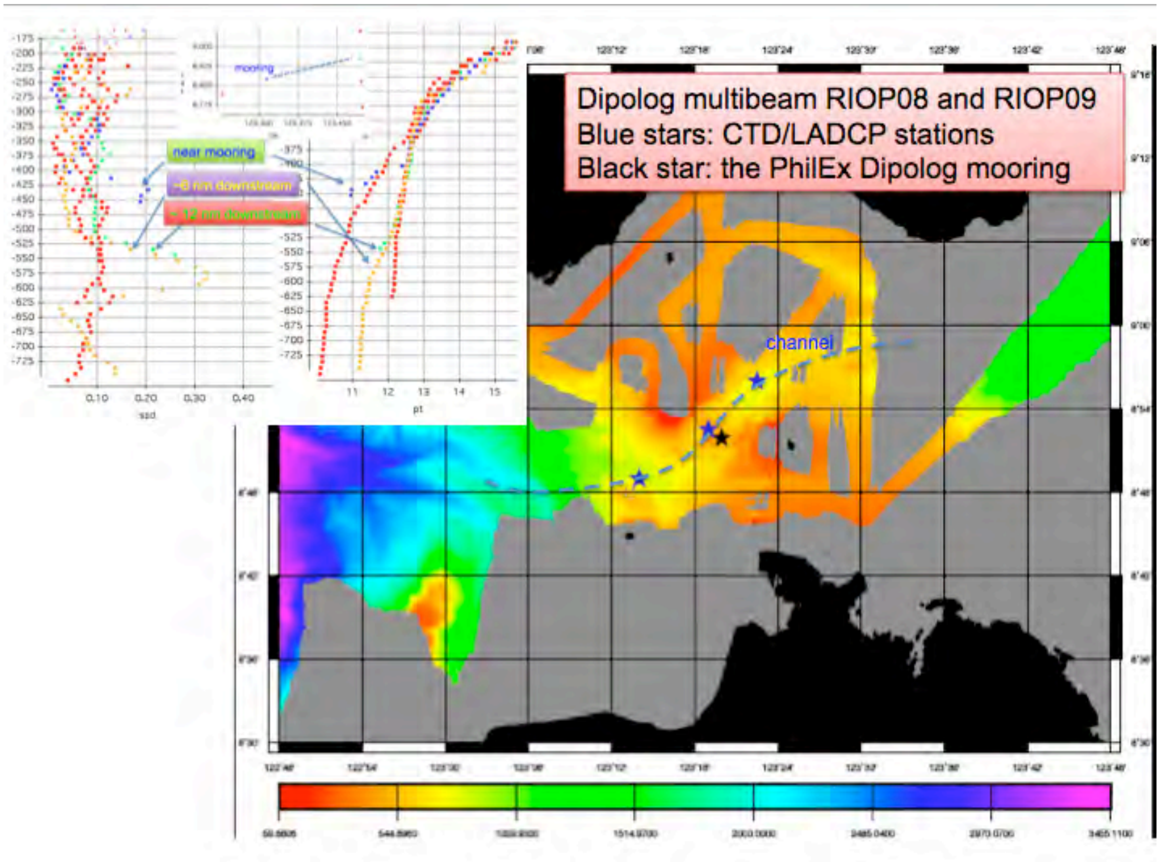


Figure 14 [added after figure sequence prepared]: Sea floor depths from RIOP08 and RIOP09 multibeam surveys. The blue stars mark the CTD/LADCP stations along the deep passage. The dashed blue line marks the approx channel axis. The black star is the position of the PhilEx Dipolog ADCP mooring, at 490 meters depth. The profiles of speed and temperature are shown in upper left panel. At the stations ~6 nm downstream of the moorings the speed maximum near 590 m is about 150 m above the sea floor, indicating that the overflow at least at times does not slide along the sea floor to great depths in the Mindanao Sea, perhaps the input dense varies with tidal effect [heaving]?

The topics discussed above are based on a first look at the data collected during RIOP09 Leg 1. A more complete description of the regional oceanography is provided in my report from RIOP08. The above comments, as well as those from RIOP08 are preliminary, and detailed study during the PhilEx evaluation phase will no doubt alter the picture. It is offered in this cruise report and in the RIOP08 report [and Exploratory June 2007 Cruise report] to encourage consideration and collaboration between the many components of PhilEx.

ALG - 9 March 2009

Cruise Report: ADCP Mooring Deployments

PI: Janet Sprintall
Scripps Institution of Oceanography, UCSD

Phil-Ex IOP 2009 Cruise

Leg 2: Dumaguete – Manila, Philippines
9 March 2009 – 21 March 2009
R/V Melville

1. Introduction:

Scientific and Cruise Objectives:-

The scientific objective of the ADCP mooring component of PhilEx is to observe and understand the processes that govern the mesoscale and submesoscale variability in straits, and relate this to the large-scale flow in which it is embedded. The effort will focus on a multi-year time-series array of *in situ* velocity and property observations in order to characterize the spatial and temporal variability of these small-scale features, and how they may vary intraseasonally to annually as the remote and local forcing changes.

During the PhilEx Intense Observational Phase (IOP) 2009 Cruise, the cruise objectives are to recover the Dipolog, South Mindoro (Panay), Tablas and North Mindoro moorings deployed during the December 2007 Joint USA-Philippines cruise.

Itinerary:
Leg 2:
Depart: Dumagete, 11:00 9 March 2009
Arrive: Manila, 08:00 21 March 2009

Personnel:
Arnold Gordon (LDEO, Chief Scientist)
Janet Sprintall (Scripps Institution of Oceanography, PI ADCP mooring deployments)
Paul Harvey (Scripps Institution of Oceanography, Marine Engineer for deployments)
Kyla Drushka (Scripps Institution of Oceanography, Grad Student for deployments).

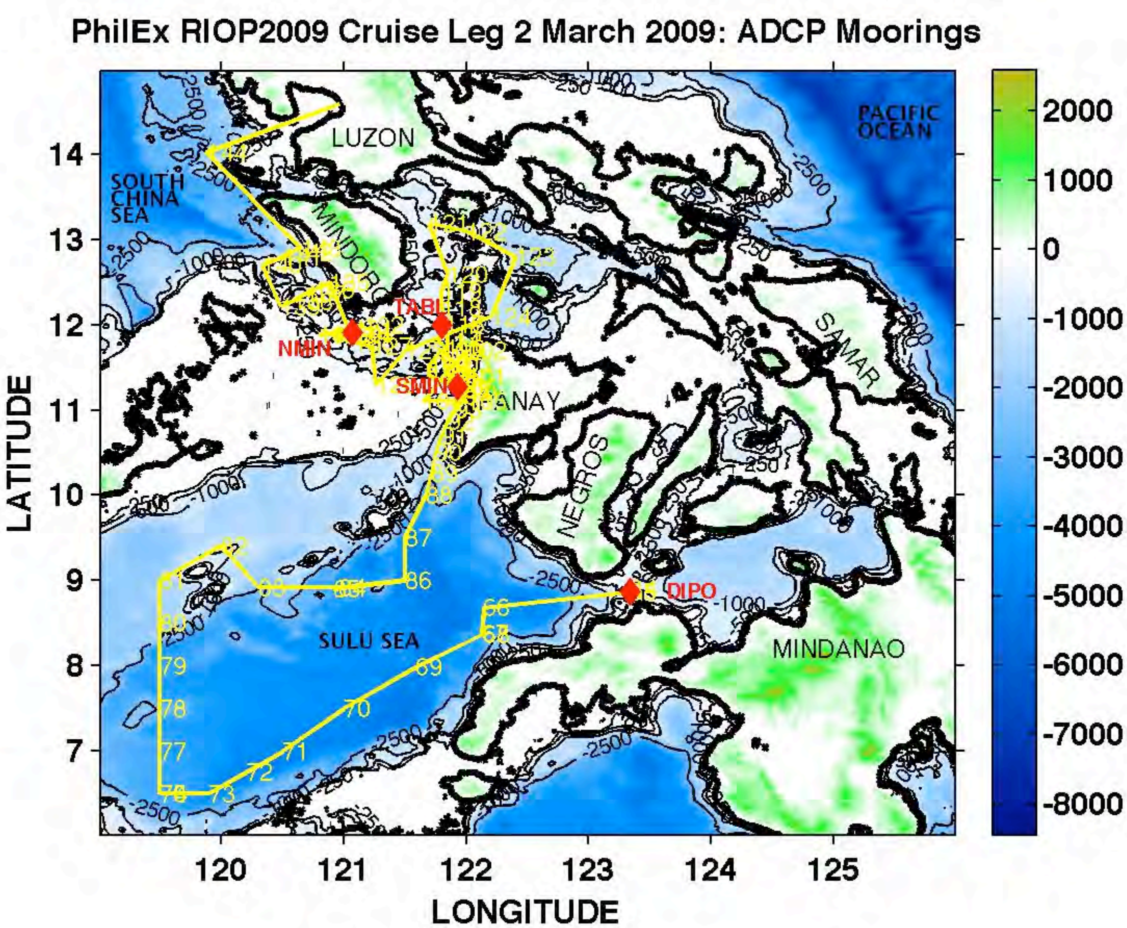


Figure 1: Location of Hydrographic Stations (yellow) and ADCP moorings recovered during Leg 2 (solid red diamonds) of the PhilEx RIOP2009 cruise (March 2009).

II Chronological Cruise Narrative

A brief narrative of the daily events of the cruise is given in this section (unless specified, local time is used, GMT + 8 hours). The cruise track and the location of the mooring recoveries are shown in Figure 1. Mooring locations and recovery times (given as buoy on surface) are given in Table 1. Total recovery time is time from on site to time of mooring on deck and secured.

9 March 2009 – Dipolog Mooring:

Arrived at Dipolog mooring site at 12:50 after leaving Dumaguete harbour at ~11:00. Not too much ship or ferry traffic. Manoeuvred to be around 500 m to south of mooring on the starboard side. Sent signal release to both acoustic releases around 13:00 but without any luck from Benthos box. Set up ORE deck unit but couldn't figure out how to send enable/disable release codes. Finally at 14:00 repositioned back just south of mooring site and sent release codes and saw buoy popped up at 14:07. Alongside and hooked by 14.21 and on-board by 14:25. Not too much growth on transducer heads – just a bit of weed. Acoustic release 597 did not release.

Dipolog Strait:

Recovered GMT 06:07 03/09/09 (LT 14:07 03/09/09)

Total time for recovery:1 hour 35 minutes

Depth = 490 m (multibeam)

Latitude: 8° 51.922'N

Longitude: 123° 19.970'E

Ranged in Position: 123° 51.9'E, 8° 19.95' N

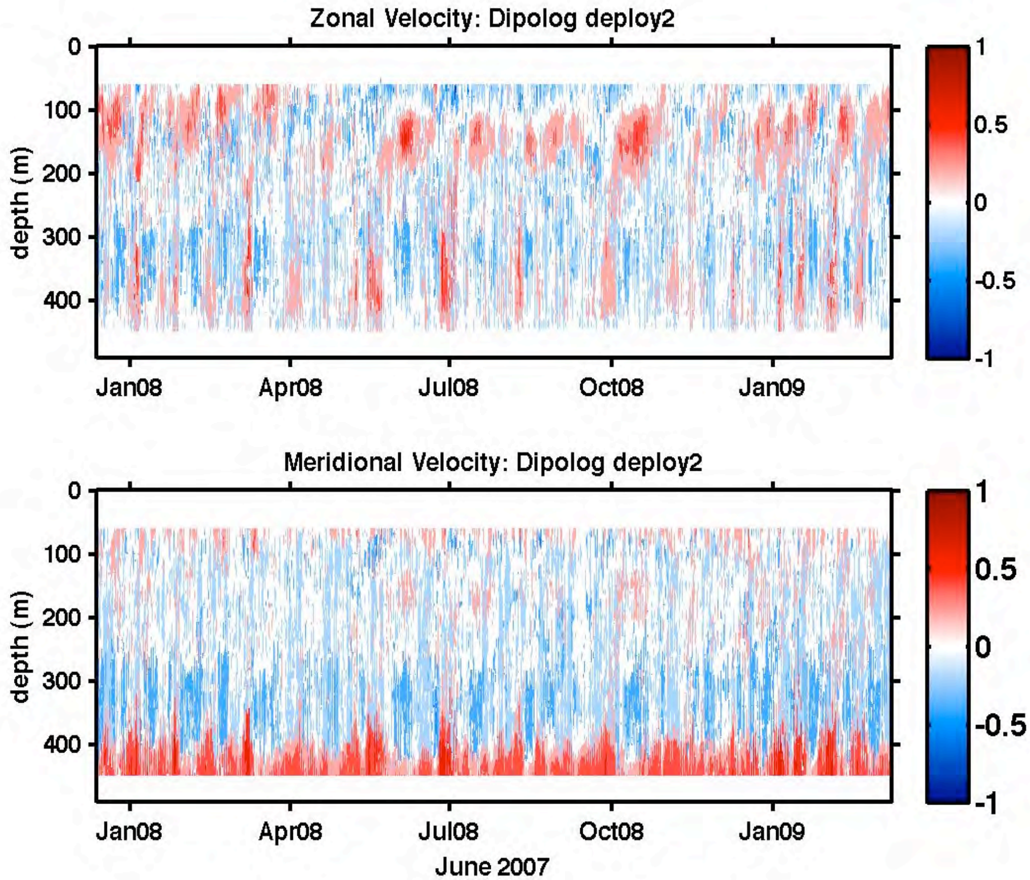


Figure 2: Zonal (top) and meridional (bottom) velocity from the Dipolog Strait mooring.

Figure 2 shows a preliminary plot of the raw velocity data from the Dipolog mooring in geographic co-ordinates. The along-channel flow is around 40°T at depth on the sill, and so the strong meridional flows seen below 400 m will be in the along-strait flow direction. Unlike the bottom intensified flow observed from the first deployment at Panay (aka South Mindoro), there does not appear to be any preferential period to this bottom flow. The surface to thermocline flow is very similar to that observed at Dipolog during the first mooring deployment. At thermocline depths (100-200 m) the flow is primarily eastward and into the Bohol Sea, and consists primarily of salinity minimum water from the South China Sea (see A. Gordon cruise report). Note the strong peridiocity associated with the flow at this depth – strong bursts are evident every 4 weeks or so, and is probably tidally related. During the NorthEast monsoon (DJF) the thermocline eastward flow is nearer the surface, whereas during the SouthWest (JJA) monsoon there is clear westward flow occurring in the upper 100 m (as found during the first deployment period). (Note: unfortunately the side-lobe reflection of the ADCP prevented us form attaining the upper 50 m during this deployment at Dipolog).

16 March 2009 – Panay Mooring:

On site at South Mindoro at 14:50, with choppy seas and a fairly pesistent wind out of the north. Sent release signal to A/R 32296 at 15:05 and spotted off starboard bow (to NW) at 15:09. Hooked up, on board and secured by 15:40. Slight whispy weed present on T-logger and releases.

South Mindoro Strait:

Recovered GMT 0705 03/16/09 (LT 1505 03/16/09)

Total time for recovery: 50 minutes

Depth = 585 m (multibeam)
Latitude: 11° 16.810'N
Longitude: 121° 55.435'E
Ranged in Position: 121° 55.464'E, 11° 16.74' N
Ranged depth: ~ 585 m

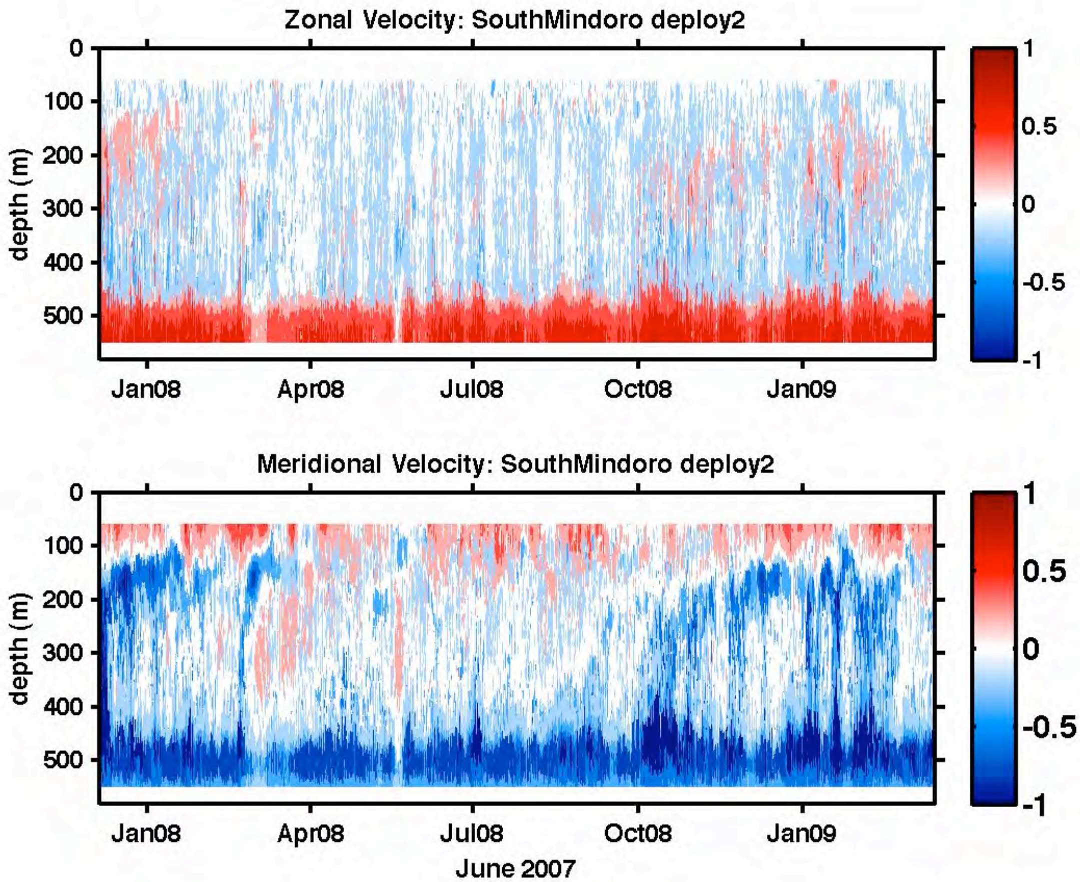


Figure 3: Zonal (top) and meridional (bottom) velocity from the Panay Strait mooring.

Figure 3 shows that the strong bottom pulses that were found from September 2007 till the recovery of the deployment 1 mooring (5 December 2007) continue through till ~ March. The full 18-month record shows these southward pulses that extend from the bottom up to ~150 m depth are also seasonally controlled being strongest in the Northeast monsoon. Flow in the depth range 150-450 m is weak during the southwest monsoon. In the upper layer (<150 m) flow is primarily northward.

<u>17 March 2009 – Tablas Mooring:</u>
Lovely early morning light just off the resort island of Boracay with very light breeze blowing from northwest, and slight surface current set to NW as well. Ideal conditions for mooring recovery – no white caps and excellent visibility. Release signal sent to A/R 3229? at 06:04 and spotted off starboard bow (to E) by bridge at 06:07. Captain Hill brought us effortlessly alongside and the buoy was hooked at 06:18 and on board by 06:25. At ~ 200 m depth, these WH300 kHz were shallower than our previous moorings and the biofouling was heavier – with the wormy bivalves, slimy red jellies and the stinging whispy "coralline" weed all over the nearer-surface instruments. It appeared that none of the 7 SIO T-Loggers had slipped down the line. Nice carefree, uneventful recovery.

Tablas Strait:
Recovered GMT 22:04 03/16/09 (LT 06:04 03/17/09)
Total time for recovery: 1 hour 45 minutes
Depth = 563 m
Latitude: 12° 00.363'N
Longitude: 121° 49.615'E
Ranged in Position: 121° 49.608'E, 12° 0.288' N

The instrumentation on this mooring consists of up/down looking ADCPs at 200 m and an upward ADCP at the bottom. The combination of the velocity from these ADCPs therefore takes some time and hence we only present the velocity from the up/down looking pair that was located at ~200 m depth (Figure 4). The upward-looking ADCP was flooded although this appeared to happen only recently as the innards of the instrument and the card-reader looked in fairly good condition and not excessively water logged. The card was dried out and warmed and will be interrogated back in the SIO lab.

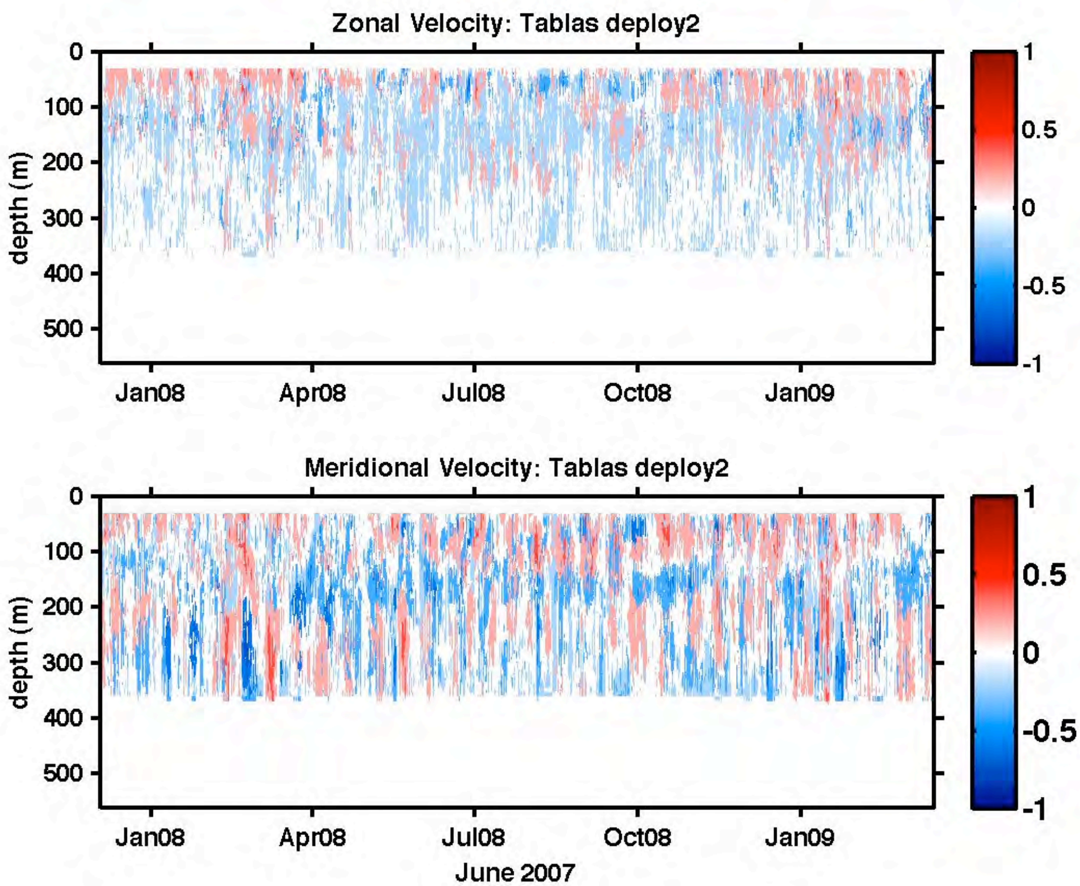


Figure 4: Zonal (top) and meridional (bottom) velocity from the Tablas Strait mooring.

There is weak north-eastward flow < 100 m and the south-westward (along-strait) flow at thermocline depth that probably is the Smax inflow from the South China Sea. At depths of 200-375 m the flow is highly variable with occasional strong pulses of southwestward flow especially during the NorthEast monsoon (as in Panay). The information from the bottom-mounted ADCP will be extremely useful for interpreting the inflow/outflow from the Sibuyan Sea. The sill depth at Tablas is ~550 m, and the only entry point for water >150 m is at the SCS entry between Luzon and Mindoro Islands. The LADCP data suggest that the deep flow is southward across

Tablas, but the mooring data will be key for determining any seasonal and subseasonal variability to this flow.

19 March 2009 – Mindoro Mooring:

North Mindoro mooring is deployed in the major shipping lane for Japan-Western Australia and ship traffic was heavy in the early morning. Mooring sounding of acoustic releases began ~06:00 LT once there was a lull in the traffic. Only a weak signal was heard by the Benthos deck box from the two Benthos releases (~450 m depth), and the two A/Rs did not respond to release commands. Similar results were found for the ORE deck-box. Niko set-up his new Benthos deck box ~08:30 and had quite a strong signal from both releases but still no definite response from A/R.

The decision was made ~ 09:30 to drag for the mooring and while the deck was being prepared for the dragging, the mooring position was ranged in on (not achieved during the December 2007 deployment) and its location was confirmed as being ~40 m of the deployed GPS position. The wire had a strong large grapple (grapnel?) hook at the end, followed by heavy weight attached by chain, then weak link (~16000 lbs tension) and two smaller grappling hooks. At 10:45, ship moved 500 m to SW of mooring position, and we began paying out wire to lasso the mooring (Figure 5). We eventually paid out ~3100 m of wire (at a ship speed of ~1 knot) and arrived at Point A (Figure 5) about 13:50 doing a radius of ~ 250 m in the inner circle of ship. Then we started pulling in wire at various speeds (5-25 metres per minute) dependent on tension of the wire. We hit quite a few snags along the way, which might have been due to large rocks on sea floor etc. A couple of times wire tension would rise to ~12000 lbs, winch would stop, and the ship brought around until tension lowered to ~ 1000 lbs. About 1.5 hours into the drag, wire tension increased, and then released and the Captain and Janet sighted the top syntactic mooring at 15:20 from the bridge (accompanied by strong signal from the mooring radio), followed shortly after by the bottom float. Ed Keenan kept a watchful eye on the buoy from the bridge, while the remaining ~2400 m of wire was then recovered and the pig-tail was finally on board ~ 17:00.

Figure 5: Schematic of dragging for the North Mindoro mooring.

Mooring recovery began after dinner at 17:30 with a glorious sunset in the background and a lovely cool breeze. Amazingly, all instrumentation was recovered from the mooring, and the two A/R appear to have been released. They may have been snagged and not fully opened and this will be investigated back in the lab. There was no evidence of any fishing line or nets on the mooring. Mooring recovery was completed ~18:45 and we were underway shortly thereafter.

I am sincerely indebted to Captain Wes Hill and ***everyone*** on board the Melville – crew and scientists alike - for the successful recovery of this mooring. Throughout the (long) day everyone remained calm, optimistic, very hard-working, and never voiced a doubt (to me at least!) that we would not recover this mooring. I'm sure that this wonderful attitude strongly contributed to the recovery of this mooring, which will provide vital information on this important passage for myself and the PhilEx program. Big thanks to all!

The mooring data was downloaded and preliminary checks done to the data, but timing of arrival in port means that there is no time for producing figures for this report. However, a plot of the pressure measured by and SBE39 located at ~443 m, just 4 m above the acoustic releases offers some diagnostic insight as to the mooring behaviour on recovery (Figure 6).

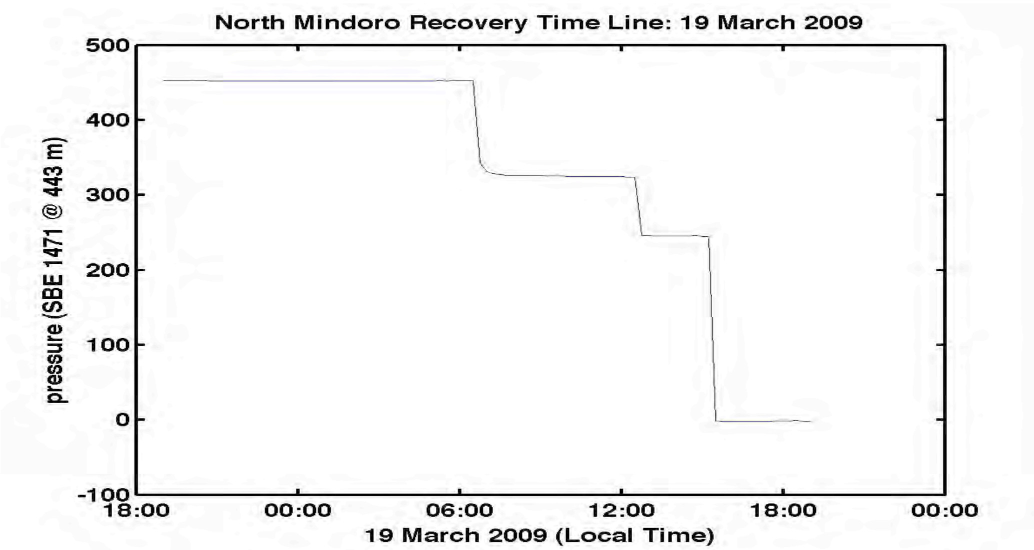


Figure 6: Pressure measured by instrument SBE SN 1471 deployed at 443 m on the day of recovery (19 March 2009).

The two acoustic releases have responded to the command to release sent ~ 6.30 am (local time) using the original Benthos deck box. The mooring then must have snagged on trawl line or whatever to get hung at ~320 m depth for the next 6.5 hours until 12:30 pm when it moved up another 50 m to ~250 m depth, before responding to the dragging and surfacing at ~15:20.

Table 1: PhilEx mooring recovery data.

Mooring	Date/Time (GMT) Deployed	Date/Time (GMT) Recovered	Anchor Drop	Ranged in Position	Depth
Tablas	12/03/2007 03:21	03/16/2009	121° 49.615'E 12° 00.363'N	121° 49.608'E 12° 00.288'N	563 m
South Mindoro	12/05/2007 07:03	03/16/2009 07:05	121° 55.435'E 11° 16.810'N	121° 55.464'E 11° 16.74'N	585 m
Dipolog	12/13/2007 05:09	03/09/2009 06:07	123° 19.97' E 8° 51.922' N	123° 19.95' E 8° 51.9' N	490 m
North Mindoro	12/21/2007 23:24	03/19/2009 23:20	121° 03.294'E 11° 53.648'N	121° 03.282'E 11° 53.698'N*	450 m

* Mooring was ranged on after releases failed to respond, and before dragging began.

Acknowledgements:
Special thanks to Captain Wes Hill, the able crew of the R/V Melville, and STS Resident Technicians Jim Dorrance and Drew Cole. Paul Harvey of the SIO Hydro Lab facility is a gem for doing all the instrument prep and particular adeptness on the deck, along with his team for all the pre-cruise and post-cruise hard-work, and Kyla Drushka was enthusiastic and hard-working in all cruise-related tasks! All the Filippino and US science crew are appreciated who assisted with mooring preparation and tag lines and other aspects of the recovery. US Office of Naval Research for funding of the ADCP mooring component of PhilEx through ONR Award Number N00014-06-1-0690.

PDF-XCHANGE Click to buy NOW! www.docu-track.com

Philippines Straits Dynamics Experiment [PhilEx]
RIOP2 Gordon Cruise Leg 2 (9-21 March 2009)
Cruise Summary

Vessel: R/V Melville, Scripps Institute of Oceanography, U.S.A

Chief Scientists:
United States:
Arnold L. Gordon
Professor of Oceanography
Columbia University;
Associate Director of the Lamont-Doherty Earth Observatory
tel: +1 845 365-8325; fax:+1 845 365-8157

The Philippines:
Laura T. David
Marine Science Institute
University of the Philippines
Diliman, Quezon City 1101 Philippines
Tel +63-2-9223957 Fax +63-2-9247678

OVERALL OBJECTIVE of PhilEx Cruise: Improve the understanding and ability to model the circulation within the Philippine archipelago with emphasis on oceanographic processes and features arising in and around straits

OVERALL FIELD PROGRAM: This study involves four planned oceanographic cruises in the Philippines (Figure 1). The first phase, named the EXPLORATORY CRUISE (PhilEx01) was from 6 June to 3 July 2007. The second phase, named JOINT CRUISE (PhilEx02) was conducted from 29 December 2007 to 4 January 2008. The third phase, named REGIONAL IOP CRUISE (PhilEx03) aimed to obtain a regional view of the stratification and circulation of the Philippine Seas was conducted from 9 January to 1 February 2008. The fourth phase, called REGIONAL IOP CRUISE II (PhilEx04-RIOP2) was divided into 2-leg shifts (Figure 2). The first leg of RIOP09 involved the investigation of the internal Philippine seas (including Mindanao Sea) and the straits of San Bernardino and Surigao (27 February-9 March 2009) while the second leg involved oceanographic studies of the Sulu Sea, Sibuyan Sea and the straits near Mindoro (9-21 March 2009). This report pertains to activities of PhilEx 04-RIOP2- LEG 2.

Figure 1. PhilEx overview

PDF-XCHANGE Click to buy NOW! www.docu-track.com

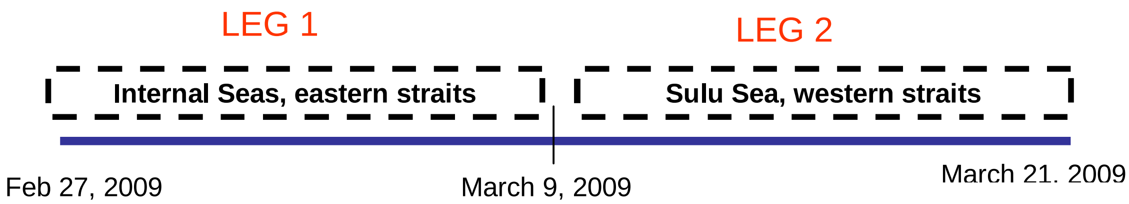


Figure 2. PhilEx2 overview

SUMMARY of ACTIVITIES of PhilEx02 LEG4
(please look at the appendices for more details on each sampling activity)

[1] CTD/LADCP/optics: Lowering of the CTD [Temperature, salinity, oxygen profiles], LADCP [shear profiles], were made to collect profiles of ocean characteristics. CTD/LADCP stations (64 in all) are given in dots in Figure 3. Special attention was paid to determine the profile or the DCM in the Sulu Sea.

[2] Repeat hull ADCP across specific passages over a 13 hour cycle was also conducted at west of Panay to calibrate the currents measured using the radio antennas in Panay. Areas surveyed and the locations of the antennas are highlighted in Figure 3.

[3] Water Sampling: A 9-bottle rosette with a capacity of 10 liters each was lowered with the all the CTD cast. From 45 of these 64 casts 6 of bottles were used for nutrient analysis (nitrate, nitrite, silicate, phosphate). From another 1 CTD cast, 3 bottles corresponding to the DCM, at the 100 signal strength for the 150-ADCP (hereby referred to as TRANSMAX) and at the oxygen minimum were also sampled for nutrient analysis.

[4] Vertical Zooplankton Sampling: From the same 45 CTD casts used for water sampling 3 out of the 9-bottle rosette were also sampled for zooplankton [at the deep chlorophyll maximum (DCM), and at TRANSMAX. From another 3 CTD casts, 6 out of the 9-bottle rosette were sampled again sampled for zooplankton [at the DCM, at the TRANSMAX and at the oxygen minimum].

[5] Vertical Ichthyoplankton Sampling: From 11 CTD casts, ichthyplankton samples were also collected at the DCM and at another depth below DCM (corresponding to either the TRANSMAX or salinity max or oxygen low).

[6] Vertical Bacteria Sampling: From 18 CTD casts, bacteria samples were collected at DCM, at a depth below DCM (corresponding to either TRANSMAX or salinity max or oxygen low) and at the bottom.

[7] Horizontal Plankton Sampling: Between CTD stations surface water was collected and filtered for ichthyoplankton and zooplankton. Total of 9 collections.

PDF-XCHANGE
Click to buy NOW!
www.docu-track.com

[8] Winds: Wind data was logged every 5-30 minutes for the entire duration of the cruise.

[7] Underway data: Aside from the 6 activities outlined above the R/V Melville routinely collects a suite of data while underway, including hull ADCP, multi-beam, sea surface temperature and salinity, chlorophyll.

All data collected during the PhilEx04 data shall be provided to the participating agencies in DVD format.

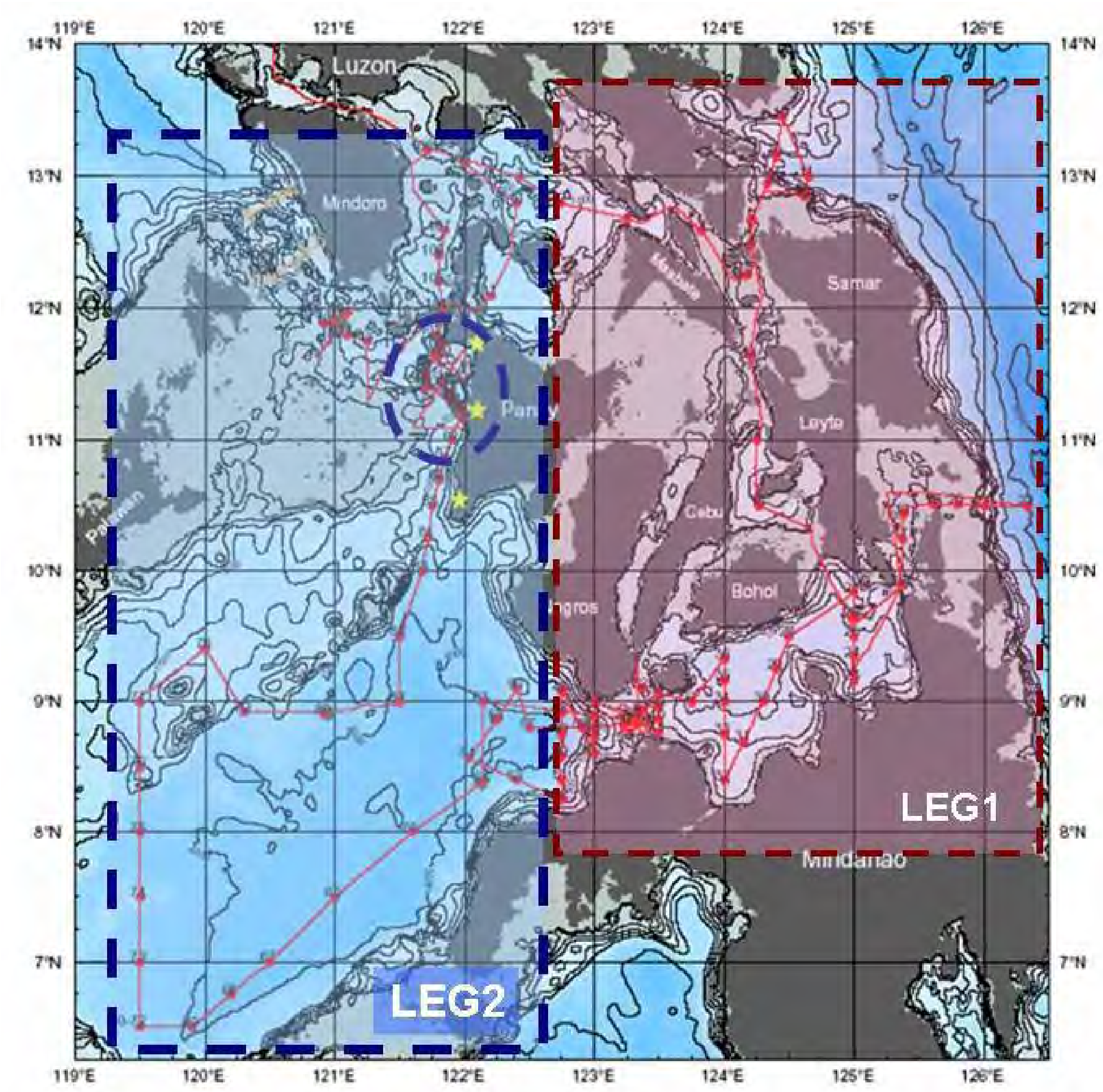


Figure 3. Location of 64 CTD stations (Sulu and Mindoro -BLUE) with the additional 62 stations from the first leg (PINK). Also shown is the repeat-hull ADCP survey (encircled) done to calibrate the radio antennas at Panay (stars)

PDF-XCHANGE Click to buy NOW! www.docu-track.com

PERMITS: Permit to conduct the Exploratory cruise was obtained from the Philippine Department of Foreign Affairs (DFA). Additional permits were obtained from LGUs of Panay where ships activities were deemed intensive so as to ensure local fishers and coastal managers were made aware of the scientific nature of the expedition.

Total Steaming Time (TST)

Total Miles Covered (TMC)

USA participants:

Lamont-Doherty Earth Observatory, Columbia University
    Dr. Arnold Gordon
    Phil Mele, Cheng-Chuan Ho, Debra Tillinger,
    Zachary Tessler, Kyla Drushka, Suzanne Rab Greene
U. of Hawaii
    Charina Amedo-Repollo
Scripps Institute of Oceanography
    Dr. Janet Sprintall, Paul Harvey

Philippine participants:
Marine Science Institute, UP Diliman
    Dr. David Laura
    Lawrence Bernardo, Kristina Cordero-Bailey, Charissa Ferrera,
    Evangeline Magdaong, Marilou Martin
OLAG, Philippine Navy
    LTJG Yuri Bo
Philippine Coast Guard
    LTJG Gerald Cordero

German Participants
University of Hamburg
    Dr. Niko Lahajnar, Anna-Maria Bensch

R/V Melville Science Crew
Research Technician
    Drew Cole, James Dorrance
Computer Technician
    Ben Cohen

PDF-XCHANGE
Click to buy NOW!
www.docu-track.com

Appendix 1: DETAILS for CTD casts and SUMMARY TABLE for samples taken at each station

A total of 64 stations were occupied. A summary of the sampling stations and parameters taken at each depth per station is given in Table 1.

Station	Lat	Lon	Depth	Start Date	UTC	Bottle1	B2	B3	B4	B5	B6	B7	B8	B9
63	08 59.96	121 45.094	3781	9-Mar-09	1236	3785 (N,B)	3000 (N)	2000 (N)	200 (N,B)	110 (Z)	70 (Z)	70 (Z)	70 (N,B)	10 (N)
64	08 22.948	122 08.066	4022	10-Mar-09	0222	3995 (N,B)	2500 (N)	1000 (N)	200 (N,B)	100 (Z)	48.6 (Z)	48.6 (Z)	48.6 (N,B)	10 (N)
65	7 59.967	121 35.811	4991	10-Mar-09	0808	4966 (N)	3800 (N)	2700 *	100 (N)	100 (Z)	35 (Z)	35 (Z)	35 (N)	10 (N)
66	7 29.910	121 00.020	4397	10-Mar-09	1509	4966 (N,B)	3000 (N)	1500 (N)	100 (N,B,I)	100 (Z)	45 (Z)	45 (Z)	45 (N,B,I)	10 (N)
67	6 59.951	120 29.829	4574	10-Mar-09	2131	4545 (N)	3000 (N)	2000 (N)	200 (N)	80 (Z)	50 (Z)	50 (Z)	50 (N)	10 (N)
68	6 44.850	120 29.829	4566	11-Mar-09	0221	4539 (N)	3500 (N)	2000 (N)	200 (N)	60 (Z)	35 (Z)	35 (Z)	35 (N)	10 (N)
69	6 30.007	119 53.797	4261	11-Mar-09	0722	4239 (N,B)	2500 (N)	2000 (N)	180 (N,B,I)	85 (Z)	35 (Z)	35 (Z)	35 (N,B,I)	10 (N)
70	6 30.132	119 29.935	3314	11-Mar-09	1212	3294 (N)	2000 (N)	1000 (N)	190 (N)	80 (Z)	50 (Z)	50 (Z)	50 (N)	10 (N)
71	6 30.008	119 30.006	3313	12-Mar-09	**	0801 (N)	0801 (Z)	0801 (Z)	0901 (N)	0901 (Z)	0901 (Z)	0929 (N)	0929 (Z)	0929 (Z)
72	6 29.957	119 30.010	3310	12-Mar-09	1115	3315 (N,B)	2000 (N)	1000 (N)	190 (N,B)	100 (Z)	35 (Z)	35 (Z)	35 (N,B)	10 (N)
73	7 0.093	119 29.869	3372	12-Mar-09	1601	3329 (N)	2700 (N)	2000 (N)	250 (N)	80 (Z)	55 (Z)	55 (Z)	55 (N)	10 (N)
74	7 30.241	119 30.071	2562	12-Mar-09	2044	2555 (N,B)	2000 (N)	1000 (N)	250 (N,B,I)	100 (Z)	70 (Z)	70 (Z)	70 (N,B,I)	10 (N)
75	8 0.198	119 30.020	3595	13-Mar-09	0110	3575 (N)	2700 (N)	2000 (N)	250 (N)	100 (Z)	70 (Z)	70 (Z)	70 (N)	10 (N)
76	8 30.158	119 30.063	1956	13-Mar-09	0630	1955 (N)	1400 (N)	700 (N)	130 (N)	90 (Z)	60 (Z)	60 (Z)	60 (N)	10 (N)
77	8 59.904	119 29.972	1958	13-Mar-09	1040	1958 (N)	1400 (N)	700 (N)	80 (N)	80 (Z)	55 (Z)	55 (Z)	55 (N)	10 (N)
78	9 24.557	119 59.959	1431	13-Mar-09	1539	1411 (N)	1000 (N)	200 (N)	100 (N)	75 (Z)	50 (Z)	50 (Z)	50 (N)	10 (N)
79	8 55.308	120 17.992	2466	13-Mar-09	2000	2445 (N)	1700 (N)	1000 (N)	200 (N)	100 (Z)	80 (Z)	40 (Z)	40 (N)	10 (N)
80	8 54.094	120 55.24	3837	14-Mar-09	0453	3837 (N,B)	2500 (N)	1000 (N)	220 (N,B,I)	90 (Z)	55 (Z)	55 (Z)	55 (N,B,I)	10 (N)
81	8 59.946	121 30.003	4546	14-Mar-09	1042	4529 (N)	3000 (N)	1500 (N)	65 (N)	65 (Z)	50 (Z)	50 (Z)	50 (N)	10 (N)
82	9 29.954	121 30.007	4402	14-Mar-09	1622	4429 (N)	3000 (N)	2000 (N)	200 (N)	100 (Z)	55 (Z)	55 (Z)	55 (N)	10 (N)
83	9 59.978	121 40.142	3824	14-Mar-09	2221	3802 (N,B)	2600 (N)	1400 (N)	200 (N,B,I)	100 (Z)	60 (Z)	60 (Z)	60 (N,B,I)	10 (N)
84	10 15.632	121 43.037	1654	15-Mar-09	0226	1620 (N)	1100 (N)	600 (N)	170 (N)	100 (Z)	70 (Z)	70 (Z)	70 (N)	10 (N)

Station	Lat	Lon	Depth	Start Date	UTC	Bottle1	B2	B3	B4	B5	B6	B7	B8	B9
85	10 29.994	121 45.075	1386	15-Mar-09	0512	1386	1386 *	1386 *	160 (B,I)	160 (Z)	100 (Z)	100 (Z)	60 (Z)	60 (Z)
86	10 42.062	121 47.989	1330	15-Mar-09	0727	1330 (N)	650 (N)	65 (N)	65 (Z)	65 (Z)	50 (Z)	50 (Z)	50 (N)	10 (N)
87	10 52.083	121 50.977	1206	15-Mar-09	0934	300 (B,I)	300 (Z)	300 (Z)	130 (B,I)	130 (Z)	130 (Z)	55 (B,I)	55 (Z)	55 (Z)
88	10 59.74	121 54.289	1204	15-Mar-09	1119	1204 (N)	600 (N)	200 (N)	90 (N)	90 (Z)	55 (Z)	55 (Z)	55 (N)	10 (N)
89	11 10.05	121 59.09	1227	15-Mar-09	1348	1227 (N,B)	600 (N)	290 (N)	95 (N,B)	95 (Z)	60 (Z)	60 (Z)	60 (N,B)	10 (N)
90	11 14.07	121 58.68	1002	15-Mar-09	1520	***	***	***	***	***	***	***	***	***
91	11 16.685	121 55.827	595	15-Mar-09	1638	583 (N,B)	500 (N)	400 (N)	200 (N)	100 (N,B)	100 (Z)	50 (Z)	50 (Z)	50 (N,B)
92	11 18.576	121 53.419	582	15-Mar-09	1745	***	***	***	***	***	***	***	***	***
93	11 22.124	121 52.963	571	15-Mar-09	1843	***	***	***	***	***	***	***	***	***
94	11 26.757	121 49.834	1090	15-Mar-09	1951	1068 (N,B)	700 (N)	400 (N)	100 (N,B,I)	100 (Z)	45 (Z)	45 (Z)	45 (N,B,I)	10 (N)
95	11 24.066	121 41.956	240	16-Mar-09	0921	***	***	***	***	***	***	***	***	***
96	11 26.827	121 41.925	715	16-Mar-09	1012	715 (N)	350 (N)	120 (N)	60 (N)	60 (Z)	40 (Z)	40 (Z)	40 (N)	10 (N)
97	11 29.975	121 41.922	622	16-Mar-09	1124	***	***	***	***	***	***	***	***	***
98	11 31.842	121 41.945	890	16-Mar-09	890	890 (N)	450 (N)	195 (N)	80 (N)	80 (Z)	80 (Z)	45 (Z)	45 (N)	10 (N)
99	11 38.397	121 46.309	768	16-Mar-09	1415	***	***	***	***	***	***	***	***	***
100	11 41.394	121 48.002	1263	16-Mar-09	1521	1247 (N,B)	600 (N)	200 (N)	100 (N,B,I)	100 (Z)	60 (Z)	50 (Z)	50 (N,B,I)	10 (N)
101	11 43.775	121 49.779	904	16-Mar-09	1652	890 (N)	650 (N)	400 (N)	100 (N)	100 (Z)	40 (Z)	40 (Z)	40 (N)	10 (N)
102	11 47.973	121 46.805	1109	16-Mar-09	1815	1089 (N)	700 (N)	450 (N)	120 (N)	120 (Z)	40 (Z)	40 (Z)	40 (N)	10 (N)
103	11 53.883	121 48.003	864	16-Mar-09	1947	***	***	***	***	***	***	***	***	***
104	11 59.762	121 49.411	411	16-Mar-09	2111	402 (N,B)	300 (N)	250 (N)	80 (N,B)	80 (Z)	60 (Z)	30 (Z)	30 (N,B)	10 (N)
105	12 12.001	121 47.971	644	17-Mar-09	0054	***	***	***	***	***	***	***	***	***
106	12 24.038	121 47.989	627	17-Mar-09	0235	610 (N,B)	450 (N)	250 (N)	80 (N,B,I)	80 (Z)	55 (Z)	55 (Z)	55 (N,B,I)	10 (N)
107	12 59.83	121 8.49	594	17-Mar-09		***	***	***	***	***	***	***	***	***

PDF-XCHANGE Click to buy NOW! www.docu-track.com

Station	Lat	Lon	Depth	Start Date	UTC	Bottle1	B2	B3	B4	B5	B6	B7	B8	B9
108	13 11.637	121 42.557	547	17-Mar-09	0846	547 (N)	275 (N)	200 (N)	140 (N)	140 (Z)	60 (Z)	60 (Z)	60 (N)	10 (N)
109	13 6.007	122 0.017	592	17-Mar-09	1111	170 (Z)	170 (Z)	170 (N)	75 (Z)	75 (Z)	75 (N)	50 (Z)	50 (Z)	50 (N)
110	12 47.987	122 23.950	1405	17-Mar-09	1427	1398 (N)	700 (N)	200 (N)	90 (N)	90 (Z)	45 (Z)	45 (Z)	45 (N)	10 (N)
111	12 5.986	122 11.992	1350	17-Mar-09	1916	1333 (N,B)	900 (N)	500 (N)	100 (N,B,I)	100 (Z)	70 (Z)	70 (Z)	70 (N,B,I)	10 (N)
112	11 42.039	121 29.977	660	18-Mar-09	0038	643 (N)	450 (N)	250 (N)	60 (N)	60 (Z)	50 (Z)	50 (Z)	50 (N)	10 (N)
113	11 45.077	121 14.983	323	18-Mar-09	0727	323 (N)	230 (N)	100 (N)	75 (N)	75 (Z)	45 (Z)	45 (Z)	45 (N)	10 (N)
114	11 48.116	121 5.831	483	18-Mar-09	0858	***	***	***	***	***	***	***	***	***
115	11 53.080	120 54.849	475	18-Mar-09	1032	***	***	***	***	***	***	***	***	***
116	11 54.882	120 59.700	466	18-Mar-09	1142	466 (N,B)	220 (N)	170 (N)	100 (N,B)	100 (Z)	60 (Z)	60 (Z)	60 (N,B)	10 (N)
117	11 57.972	121 5.057	461	18-Mar-09	1042	***	***	***	***	***	***	***	***	***
118	12 29.949	120 52.952	599	19-Mar-09	1402	323 (N)	230 (N)	100 (N)	75 (N)	75 (Z)	45 (Z)	45 (Z)	45 (N)	10 (N)
119	12 24.993	120 46.854	658	19-Mar-09	1536	***	***	***	***	***	***	***	***	***
120	12 22.112	120 41.955	1129	19-Mar-09	1649	323 (N)	230 (N)	100 (N)	75 (N)	75 (Z)	45 (Z)	45 (Z)	45 (N)	10 (N)
121	12 17.959	120 35.053	778	19-Mar-09	1838	***	***	***	***	***	***	***	***	***
122	12 13.053	120 29.674	493	19-Mar-09	2000	323 (N)	230 (N)	100 (N)	75 (N)	75 (Z)	45 (Z)	45 (Z)	45 (N)	10 (N)
123	12 42.058	120 20.355	900	19-Mar-09	0900	323 (N)	230 (N)	100 (N)	75 (N)	75 (Z)	45 (Z)	45 (Z)	45 (N)	10 (N)
124	12 48.289	120 30.278	1080	20-Mar-09	0113	***	***	***	***	***	***	***	***	***
125	12 51.667	120 35.428	1938	20-Mar-09	0246	323 (N)	230 (N)	100 (N)	75 (N)	75 (Z)	45 (Z)	45 (Z)	45 (N)	10 (N)
126	12 54.040	120 39.590	553	20-Mar-09	0446	323 (N)	230 (N)	100 (N)	75 (N)	75 (Z)	45 (Z)	45 (Z)	45 (N)	10 (N)

N- nutrients;
B- bacteria;
I- ichthyoplankton;
Z- zooplankton;
*** bottle did not close – no sample obtained;**
**** internal wave time series;**
***** no collection**

Appendix 2 DETAILS for DCM characterization from the CTD casts

Chlorophyll(Chl) profiles obtained from CTD casts were processed through Sea-Bird Electronics Data Processing. To convert the fluorometer volt output to µg/L, the following equation taken from a previous Wetlabs Fluorometer calibration sheet was used:

Chl (µg/L) = Scale Factor x (Output – Clean Water Offset)

where Clean Water Offset = 0.054 V and Scale Factor = 1.5. The most recent calibration sheet has not been received from SIO and thus the following results may, in future, be recalculated with the appropriate values for CWO and SF.

Average DCM depth for the entire leg was approximately 50-80m, with Chl maximum at DCM ranging from 1 – 4 µg/L. The vertical Chl distributions were scrutinized based on the similar criteria as done in the RIOP08 Leg 2 cruise. Five general distribution types were observed:

(1) The normal Gaussian distribution (Fig. 4) was seen in stations located at the western part of Panay, within the Tablas Strait and most stations within the Mindoro Strait (see Fig.5).
(2) Higher phytoplankton biomass above the DCM (Fig. 4b) in stations nearing the Tubbataha Reefs as well as one station of the island of Basilan may indicate higher primary production in the upper layer, either from the reef area or this could have instances when the internal waves may have passed, resulting in possible higher nutrient availability to the upper layer. For Stns. 118 and 126 off Mindoro, the high phytoplankton biomass could be attributed to freshwater runoff from the island.
(3) Upwelling was probable in most stations off Panay, particularly where the 12-hour survey was conducted, as exhibited by the bulk of Chl biomass below the DCM (Fig.4c).
(4) Two stations within the Sulu Sea (Stn. 80 and 69) showed a sharp decrease in the Chl profile below the DCM (Fig.4d), implying a sudden depletion in nutrients with depth.
(5) Only two stations revealed a mixed water column with Chl profiles without any clear DCM (Fig.4e), most likely due to high wind stress.

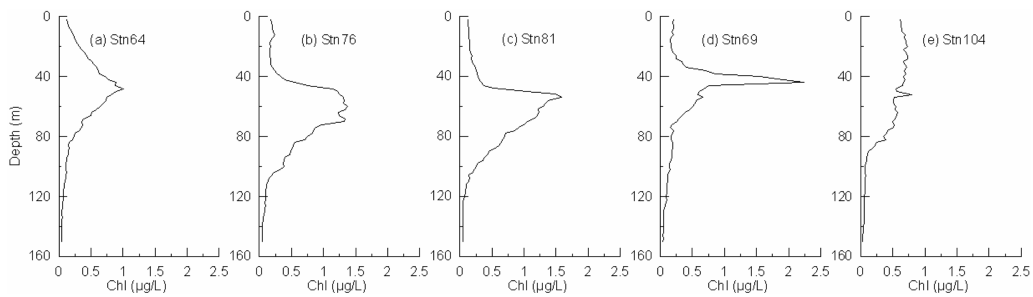


Figure 4. Identified types of Chl profiles: (a) Normal distribution (b) High biomass above DCM (c) High biomass below DCM (d) Sharp decrease below DCM (e) Well mixed layer.

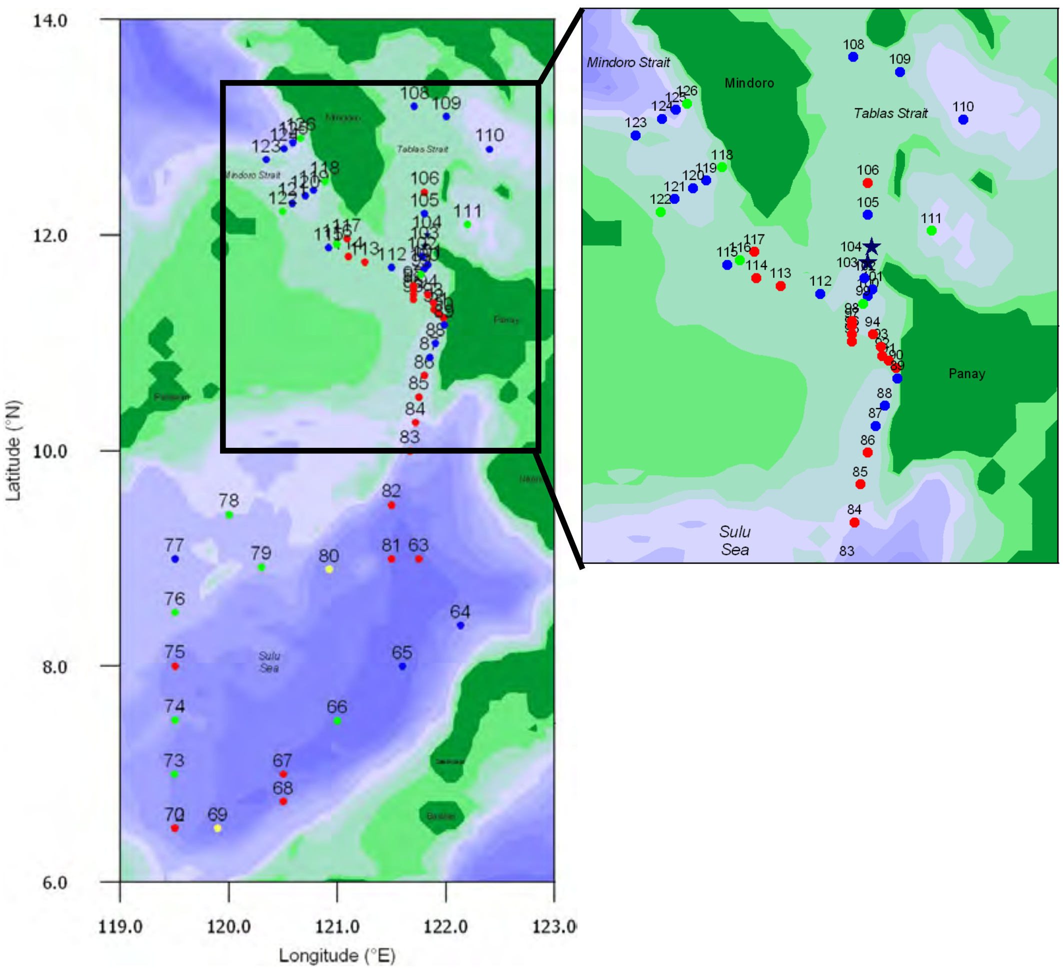


Fig.2. CTD stations on RIOP09 Leg 2 characterized by DCM profiles:

- Normal distribution
- High biomass above DCM
- High biomass below DCM
- Sharp decrease
- ★Well mixed layer

Figure 5. Identified location of the different types of Chl profiles observed in the Sulu Sea.

Appendix 3 DETAILS of repeat hull ADCP

Repeat hull ADCP across northwestern Panay was done over a 13 hour cycle was also conducted at west of Panay to calibrate the currents measured using the radio antennas in Panay. Sample comparison of the hull ADCP and the currents predicted by the radio array are given in Figure 6 for March 14 and 15, respectively.

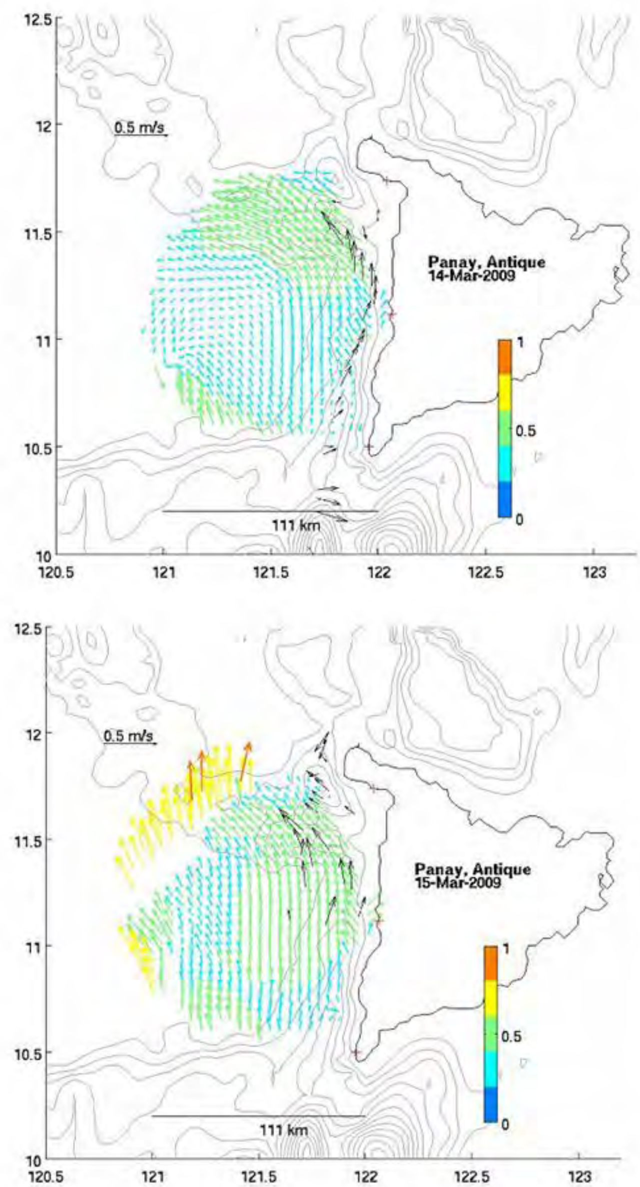


Figure 6. Predicted currents from the radio array are shown in color with the change in color corresponding to changes in current magnitude and the direction of arrows showing the direction of flow. The black arrows correspond to actual currents as measured by the hull ADCP.

In addition, a single transmitter antenna consisting of a loaded short wave radio monopole made of bamboo was installed on the ship. This was used for beam calibration that will allow refocus of the beam forming with more precision for both past and future acquisition. The heading measured by the radar will be compared with the real heading of the ship, taking into consideration signal attenuation as a function of distance.

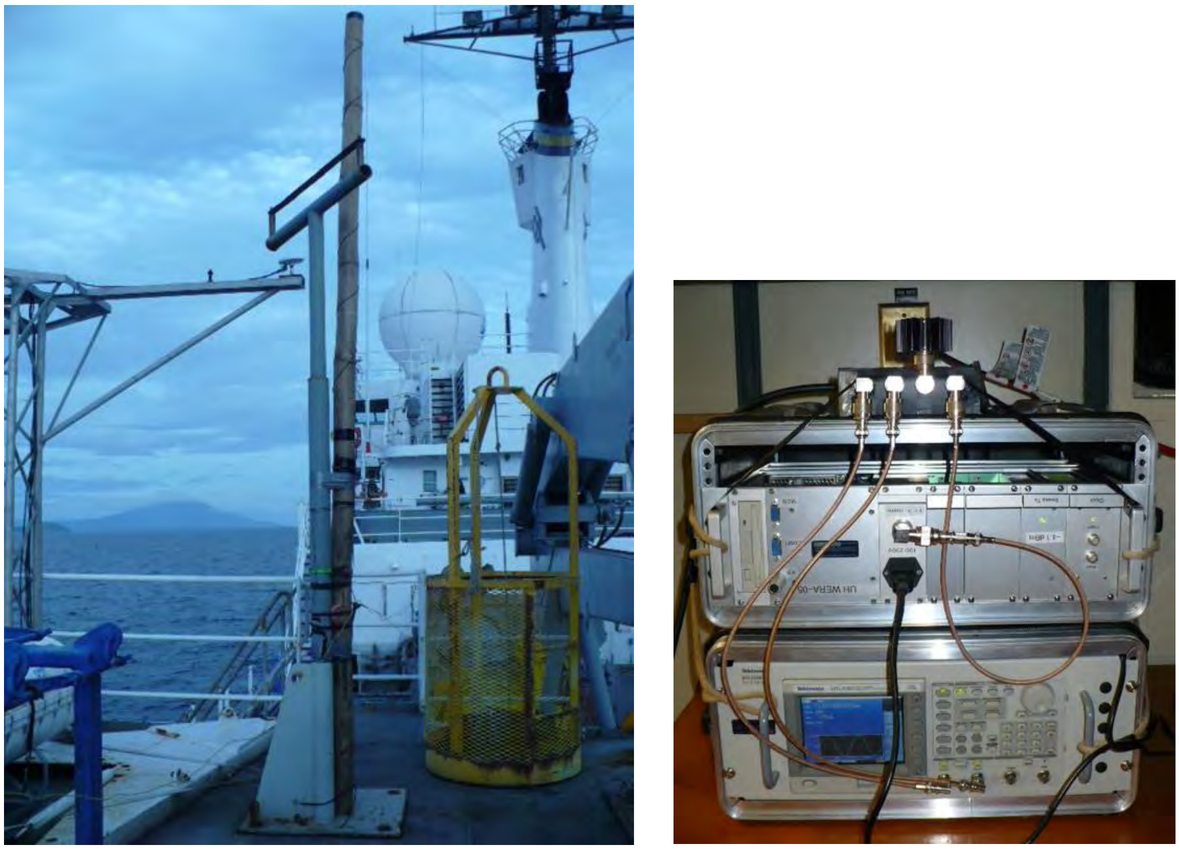


Figure 7 . The single transmitter antenna mounted near aft and the radar and frequency regulator.

PDF-XCHANGE Click to buy NOW! www.docu-track.com

Appendix 4 DETAILS for WATER SAMPLING

The objective of the water sampling is study is to describe the chemical features of the Sulu Sea using nutrients, (nitrate, nitrite, silicate, phosphate).

A total of 45 stations were occupied in the Sulu Sea. A summary of the sampling stations and parameters taken at each depth per station is given in Table 1. There were 6 depths taken from surface to bottom for determination of nutrients. These depths include 10m below surface, the deep chlorophyll maximum (DCM), at a depth below DCM (corresponding to either the TRANSMAX or salinity max or oxygen low), and at the bottom. Samples were kept at 4-10ml tightly sealed bottles (1 bottle per nutrient) and kept refrigerated at 4ºC for later analysis in the lab.

Phosphate, nitrate, and nitrite determination will follow the method of Strickland and Parsons (1984). Silicate was determined using the Queensland Health Scientific Services In-House procedure (2006).

Appendix 5 DETAILS for VERTICAL ZOOPLANKTON sampling

Samples for plankton were collected all 45 CTD Stations. Samples were taken using Niskin bottles mounted on a Rosette sampler system. Sampling depths were identified based on (1) DCM profiles generated per station and the (2) 100 signal strength for the 150-ADCP (also referred to as TRANSMAX)

From another 3 CTD casts, 6 out of the 9-bottle rosette were sampled again sampled for zooplankton [at the DCM, at the TRANSMAX and at the oxygen minimum].

10 L water samples were collected from the 2 depths, filtered through 64 µm mesh and then preserved in 10% formalin. Plankton identification and estimation of relative abundances will be performed at the University of the Philippines Marine Science Institute.

Appendix 6 DETAILS for VERTICAL ICHTHYOPLANKTON sampling

From 11 CTD casts, ichthyoplankton samples were also collected at the DCM and at another depth below DCM (corresponding to either the TRANSMAX or salinity max or oxygen low). The samples were collected from 8L water samples and filtered through a stack sleeve of 500um and 200 um. Samples were then backwashed into separate plastic containers using 95% analysis-grade ethanol and stored for later DNA analysis. Samples were topped with additional ethanol a week after collection. The goal of the collection is to contribute to the Census of Marine Life Program.

Appendix 7 DETAILS for VERTICAL BACTERIA sampling

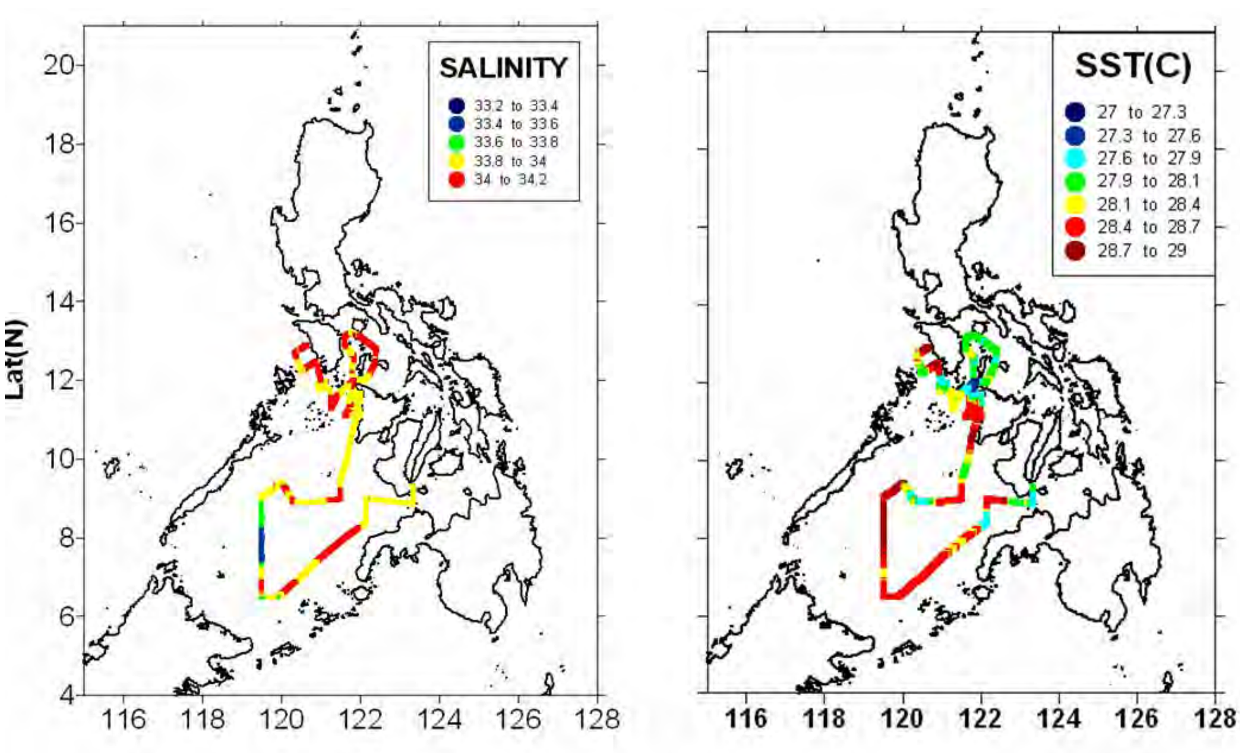
From 18 CTD casts, bacteria samples were collected at DCM, at a depth below DCM (corresponding to either TRANSMAX or salinity max or oxygen low) and at the bottom. 300 ml water samples from each of these depths were filtered through a 0.2 um Millipore filter. The filtrate is then pickled with 5 ml of 95% analysis-grade ethanol. The filter papers are then stored separately in sealed scintillation vials for DNA analysis in the lab.

Appendix 8 DETAILS for UNDERWAY PLANKTON sampling

Plankton samples were collected from the surface waters through the underway flow through sample system (UTSS). A 64 um sieve was placed at the outflow of UTSS at a flow rate set at 200 ml/sec. The time of start and end of collection was noted to be able to calculate the total volume filtered. Samples were immediately re-sieved using a stack sleeve of 500 um, 200um and 64 um. The 500 um and 200 um filtrate were backwashed into separate plastic containers using 95% analysis-grade ethanol and stored for later DNA analysis (ichthyoplankton) while the 64um filtrate was preserved in 10% formalin for zooplankton identification.

Appendix 9 DETAILS for the UNDERWAY data

Surface salinity and temperature underway data collected during leg 2 of the PhilEx4 cruise are shown below (Figure 8 below).



PHILEX IOP Regional 2009

Leg 1 Report
Manila to Dumaguete, 27 Feb to 9 March 2009

Chemical & Bio-optical Component
Prepared by Olivia Cabrera & Ma. Isabel Senal
Marine Science Institute
University of the Philippines, Diliman

Chief Scientist: Arnold L.Gordon (LDEO)
Co-Chief Scientist: Aletta Yñiguez (UP-MSI)
Philippine Participants:
Olivia Cabrera (UP-MSI)
Charissa Ferrera (UP-MSI)
Ma. Isabel Senal (UP-MSI)
Leilani Solera (UP-MSI)
Gerald Cordero (Phil Coast Guard)
Dionesio Anghag (Phil Navy)

Cruise Track

An oceanographic cruise (mainly consisting of CTD-rosette casts) was conducted onboard R/V Melville from February 27 to March 9, 2009. A total of 61 stations were occupied in the various seas of the Philippines, including Sibuyan Sea, Philippine Sea, Camotes Sea, Mindanao Sea, and Bohol Sea (Figure 1). Water samples at various depths were collected for analysis of dissolved oxygen, nutrients (nitrate-nitrite, phosphate, and silicate), chlorophyll, particulate organic carbon (POC), and total suspended materials (TSM). Dissolved oxygen samples were fixed onboard following JGOFS protocol but readings of Iodine-iodide were made not through Winkler titration but through the spectrophotometer method of Labasque et al (2004). All other samples will be brought back to the Marine Science Institute for further analysis.

Underway Data

Various optical sensors were connected to the ship's underway system for recording near-surface inherent optical properties (IOPs) of the waters along the cruise track. These sensors include a transmissometer, 2 fluorometers (chlorophyll and CDOM), a backscatter sensor, and an in-situ spectrophotometer for measuring absorption and attenuation at 400-730nm (see Appendix for sensor specifications and units of measurements). All sensors were in flow-through mode, with an automated valve system that switches hourly from total to filtered mode (passed through a 0.2um filter for 10 minutes) to account for the dissolved signals, instrumental drifts, and biofouling of sensors.

Preliminary Results

Dissolved Oxygen analysis

A total of 168 water samples at 42 stations were collected at various depths for spectrophotometric analysis of dissolved oxygen (DO). A slight overestimation of the DO values is seen in the Seabird CTD-DO sensor versus spectrophotometric values (Fig. 1) although a very high correlation is apparent between the two (r^2 = 0.988).

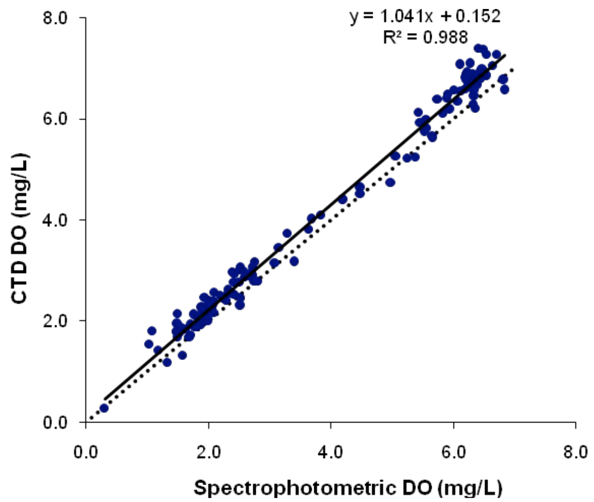


Fig. 1. Correlation of dissolved oxygen measured by the CTD DO sensor and spectrophotometric analysis of bottle samples. Dashed line is the 1:1 correlation.

Flowthrough optics system

Inherent optical properties (IOPs) are dependent upon the composition and concentrations of the **particulate** and **dissolved** substances in the water and the **water** itself. As such, IOPs can provide important insights in the distribution and dynamics of particulate and dissolved matter in the ocean which is in turn affected by biophysical-biogeochemical processes. For example, it is possible to obtain estimates of phytoplankton biomass through absorption at selected wavelengths (e.g. 675nm). This augments the traditional and most-often used method of estimating phytoplankton biomass through chlorophyll fluorescence which has the disadvantage of suffering from underestimations due to photochemical quenching. Furthermore, particulate beam-attenuation coefficient (*cp*) at 660nm wavelength has been shown to correlate with Particulate Organic Carbon (POC) while absorption and fluorescence of Colored Dissolved Organic Matter (CDOM) can be correlated with riverine input.

The coverage of this leg of the cruise has provided us with an extensive data set of IOPs of Philippine waters. After post-processing and 1-minute averaging, a total of 8667 spectra of particulate absorption and attenuation were obtained all along the shiptrack (Fig. 2). A similar number of backscatter data (at 470, 526 and 656 nm wavelengths) were also obtained although post-processing is still needed to convert digital counts into physical values.

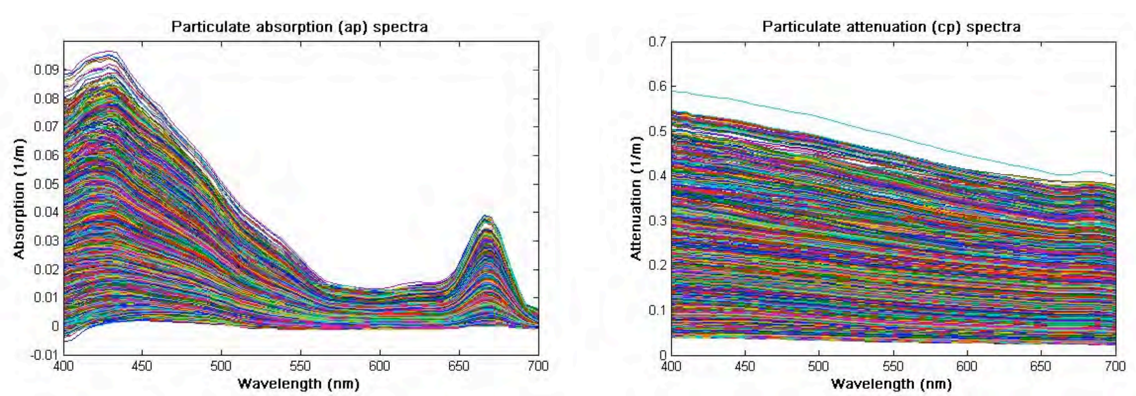


Fig. 2. Particulate absorption and attenuation spectra collected along the cruise track.

The absorption peak in the red portion of the wavelength is mainly due to absorption by the phytoplankton pigment chlorophyll a and thus was used to estimate chlorophyll a concentrations: [chl] = {ap(676) – (39/65*ap(650) + 26/65*ap(715))}/0.014; equation from Davis et al., 1997 as cited by Boss et al., 2007). With this equation, chlorophyll concentrations were found to range from 0.01 to 1.5 mg/m3, with lowest values found in the waters of the Sibuyan Sea and Philippine Sea (outside San Bernardino and Surigao Straits) and highest values found in Verde and Ticao Pass and off Zamboanga. These estimates were found to correlate highly with chlorophyll fluorescence (Fig. 3).

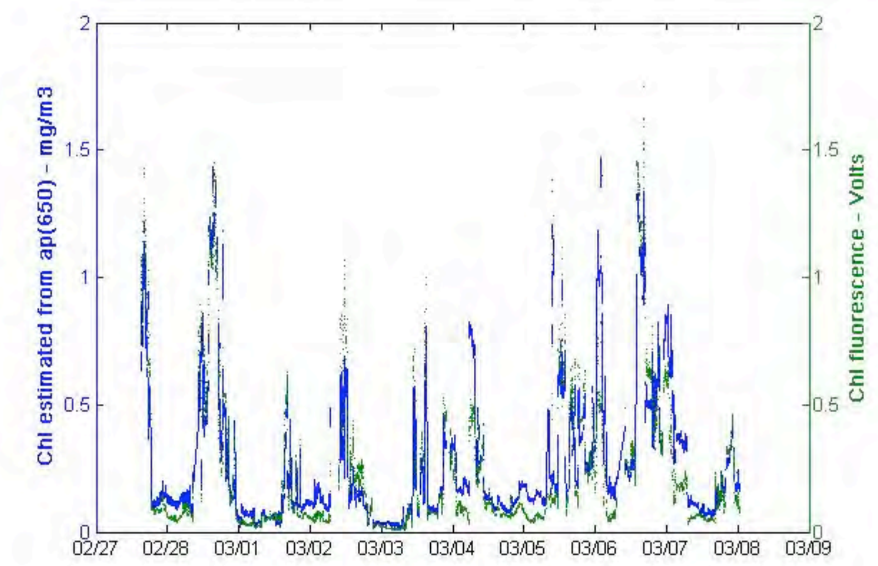


Fig. 3. Time series of chlorophyll concentrations estimated from the absorption peak at 650nm and chlorophyll fluorescence (values are still in volts and still to be converted to mg/m3 as soon as filtered water samples are analyzed for chlorophyll in the lab).

Estimates of attenuation coefficient at 660nm or *cp*(660nm) provided by both the Wetlabs ACS and the Cstar transmissometer are well correlated (Fig 4). Studies have shown that phytoplankton could account for most of *cp* (up to 50 to 60%, papers cited by Dall'olmo et al, 2009). Visual comparison of the peaks and troughs in the chlorophyll values and *cp*(660nm) in Figures 3 and 4 seem to imply the same thing, i.e., that the phytoplankton variability drives *cp* variability. These are initial findings and more insights can be gleaned on distributions and physiological properties of phytoplankton as soon as chlorophyll and POC samples have been analyzed.

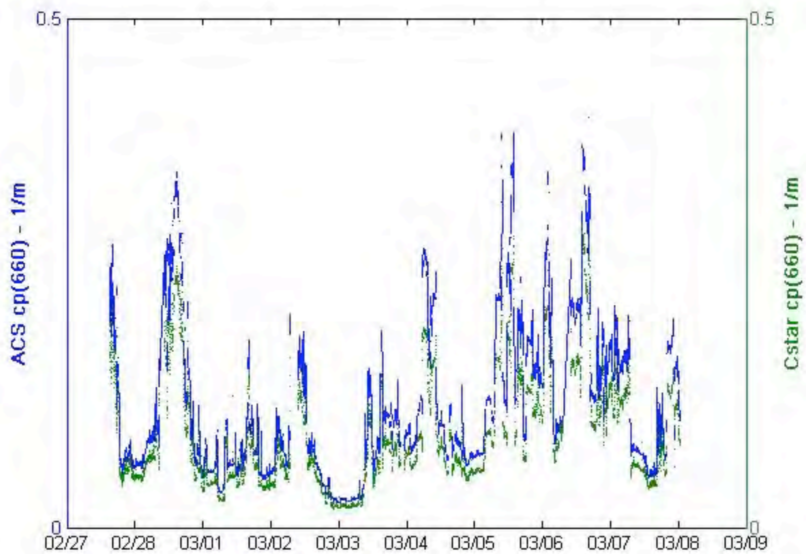


Fig. 3. Time series of particulate attenuation at 660nm wavelength or cp(660), provided by the Wetlabs ACS and Cstar transmissometer.

We passed through several interesting features during this leg of the cruise as can be seen in a composite of recent MODIS images (Fig.4). As mentioned earlier, elevated chlorophyll concentrations were observed in Verde passage, Ticao Pass, and off the northern coast of Zamboanga with the underway data of chlorophyll concentrations confirming these high values (Fig. 5). These high-chlorophyll areas also coincided with areas of lowered temperatures (Fig. 6) indicating that either intense vertical mixing (through hydraulic control due to presence of topographic sills in Verde and Ticao Pass) or upwelling may be the mechanism by which nutrients and hence phytoplankton biomass are enhanced in these areas.

River-borne sediments and nutrients may influence *cp* and *ap*. This is apparent in the southeastern side of the Mindanao Sea where the lowest salinities were recorded (Fig. 7). Absorption or *ap*(675) was not noticeably higher but attenuation or *cp*(650) was found to be enhanced, indicating that particles other than phytoplankton may be causing the variability here. It would be interesting to determine whether CDOM is elevated here but CDOM fluorescence data provided by the Wetlabs CDOM fluorometer was found to be noisy.

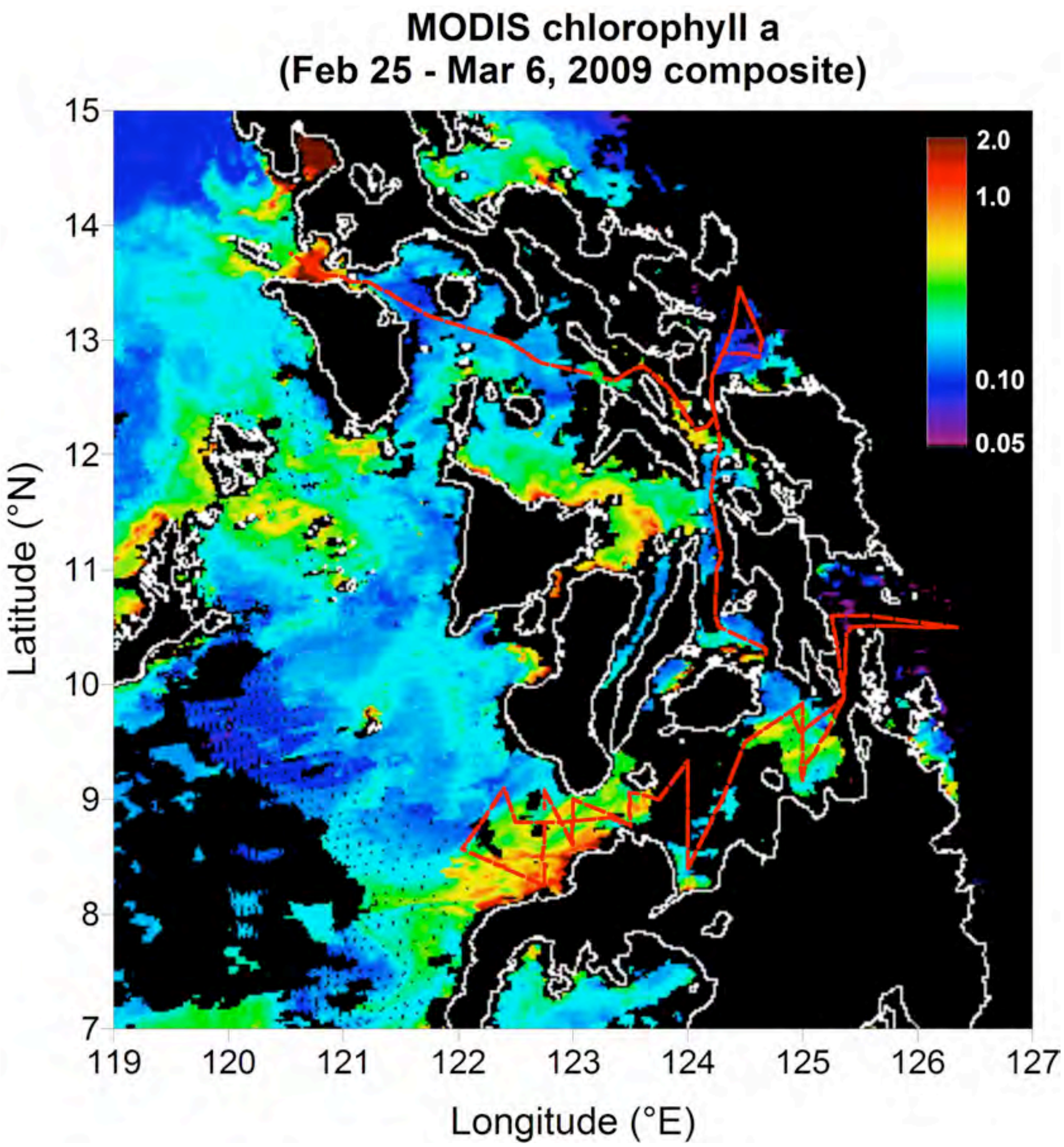


Fig. 4. MODIS chlorophyll a, composite image for February 25 to Mar 6, 2009

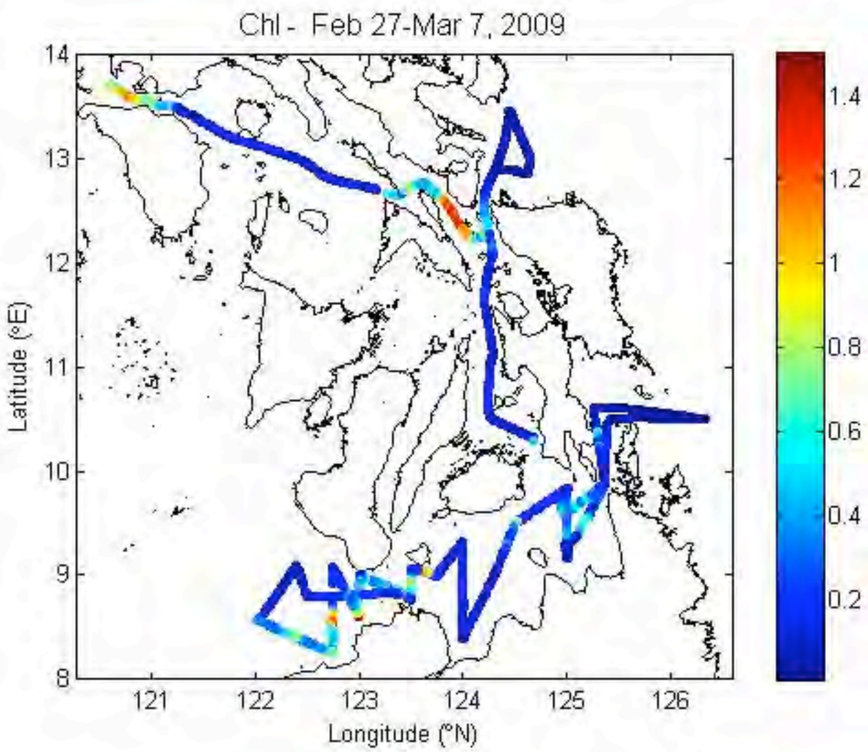


Fig. 5. Near-surface chlorophyll concentrations estimated from particulate absorption peak at 650nm.

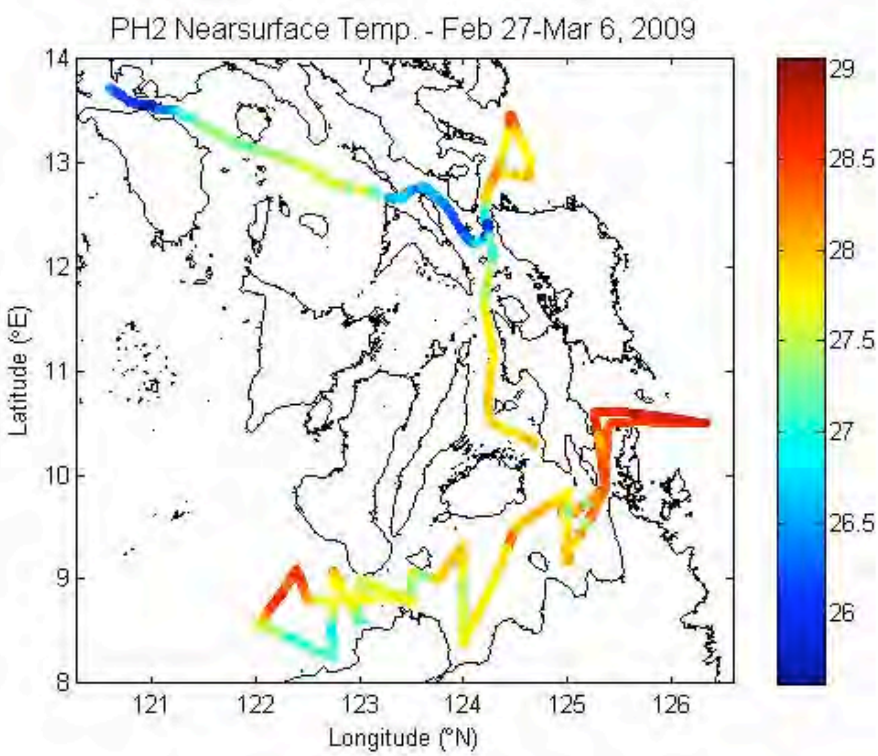


Fig. 6. Near-surface temperatures recorded while ship is underway.

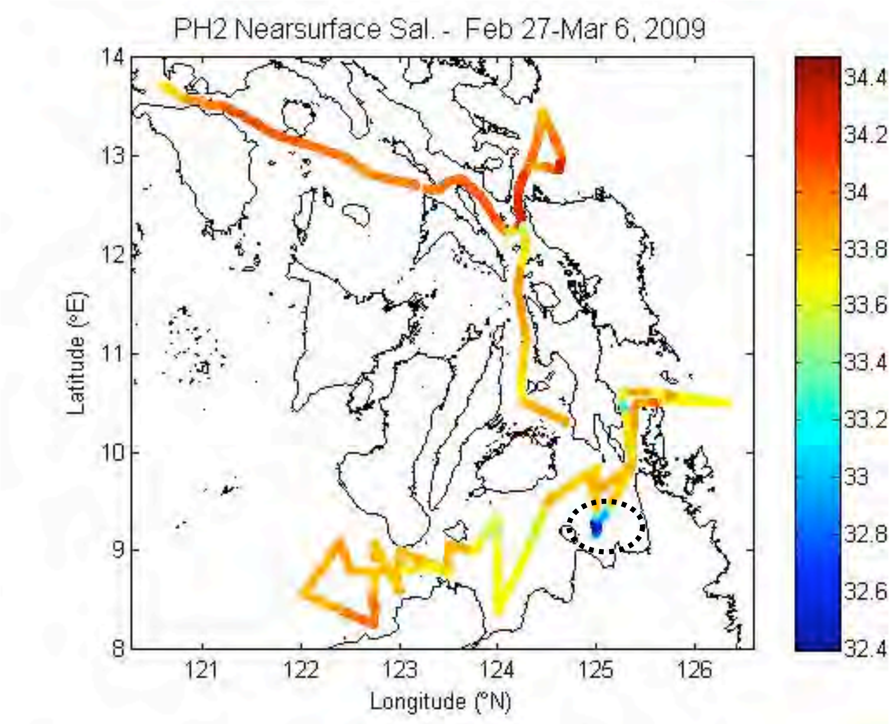


Fig. 7. Near-surface salinity recorded while ship is underway. Dashed circle indicates lowest salinities recorded at the southeastern portion of the Mindanao Sea probably influenced by the nearby Agusan river.

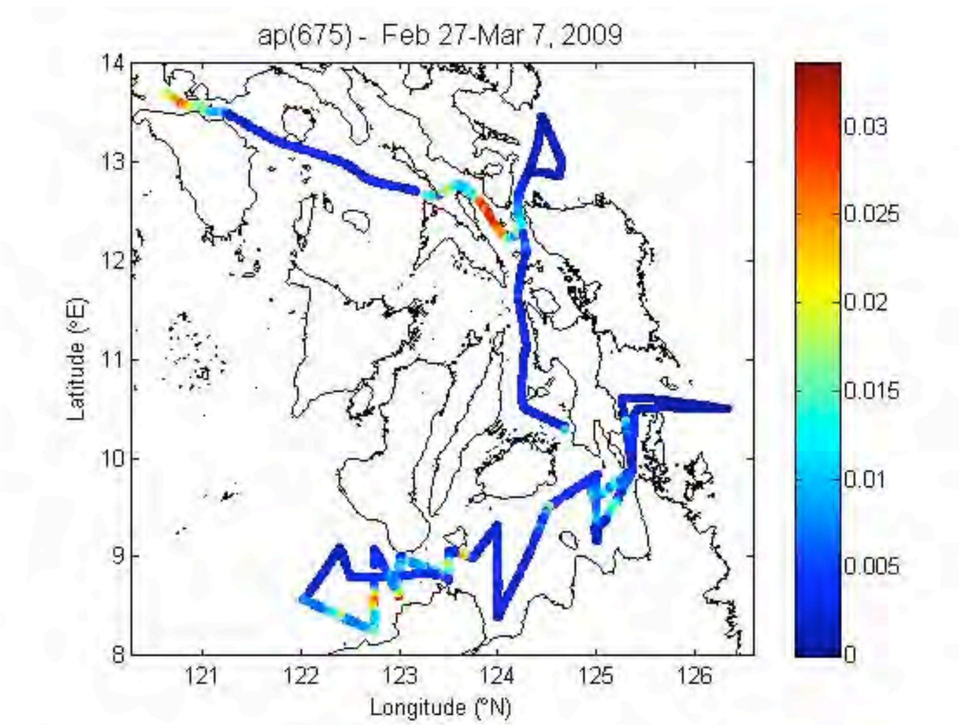


Fig. 8. Near-surface absorption coefficient at 675 nm wavelength.

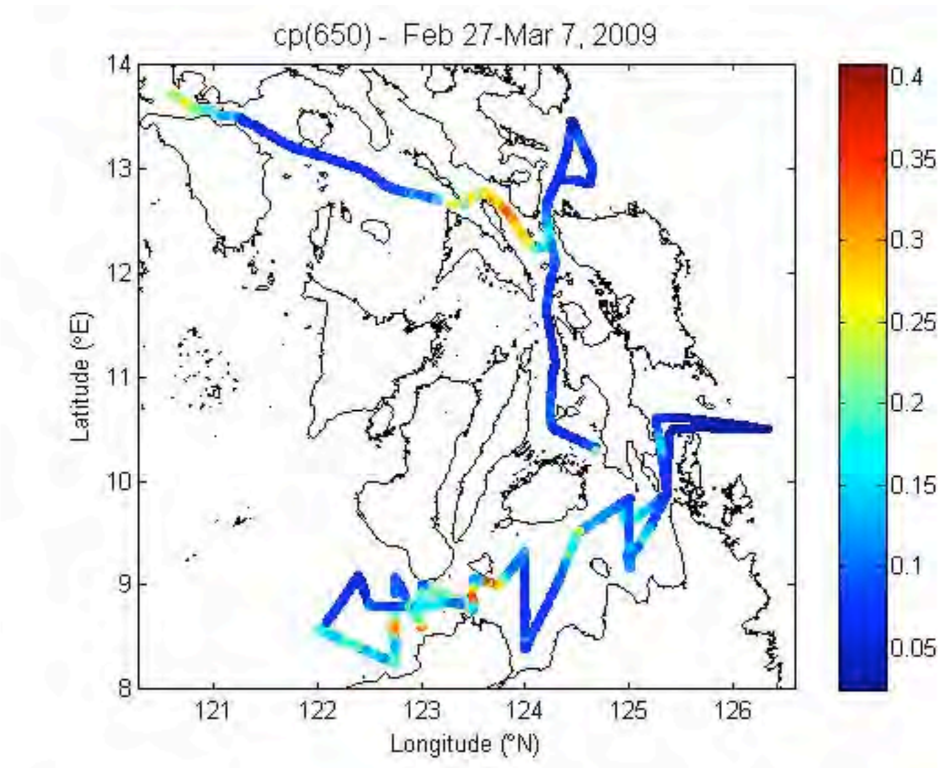


Fig. 9. Near-surface attenuation coefficient at 650 nm wavelength.

References:

Boss, E., R. Collier, G. Larson, K. Fennel, and W.S. Pegau, 2007. Measurements of spectral optical properties and their relation to biogeochemical variables and processes in Crater Lake National Park, OR. Hydrobiologia 574:149-159.

Dall'Olmo, G., T. K. Westberry, M.J. Behrenfeld, E. Boss, and W.H. Slade, 2009. Direct contribution of phytoplankton-sized particles to optical backscattering in the open ocean. Biogesciences Discussion 6: 291-340.

Labasque, T., C. Chaumery, A. Aminot, and G. Kergoat, 2004. Spectrophotometric Winkler determination of dissolved oxygen: Re-examination of critical factors and reliability. Marine Chemistry. 88 (1-2): 53-60.

Appendix

Sensor	Manufacturer & Specifications	Measurement (unit)
1. C-star Transmissometer	Wetlabs (USA) 25cm pathlength	Beam attenuation at 660nm (m^{-1})
2. CDOM fluorometer	Wetlabs (USA)	Fluorescence : $\square_{ex}$ = 370nm $\square_{em}$ = 695nm
3. Chlorophyll fluorometer	Seapoint (USA)	Fluorescence : $\square_{ex}$ = 470nm $\square_{em}$ = 685nm
4. ACS (AC-spectra)	Wetlabs (USA) 25cm pathlength	Absorption and attenuation (m^{-1}) at 80+ wavelength output from 400–730 nm
5. Eco-BB3	Wetlabs (USA)	Volume scattering function at angle 117° at wavelengths 470, 526 and 656 nm

RIOP09 CTD Report

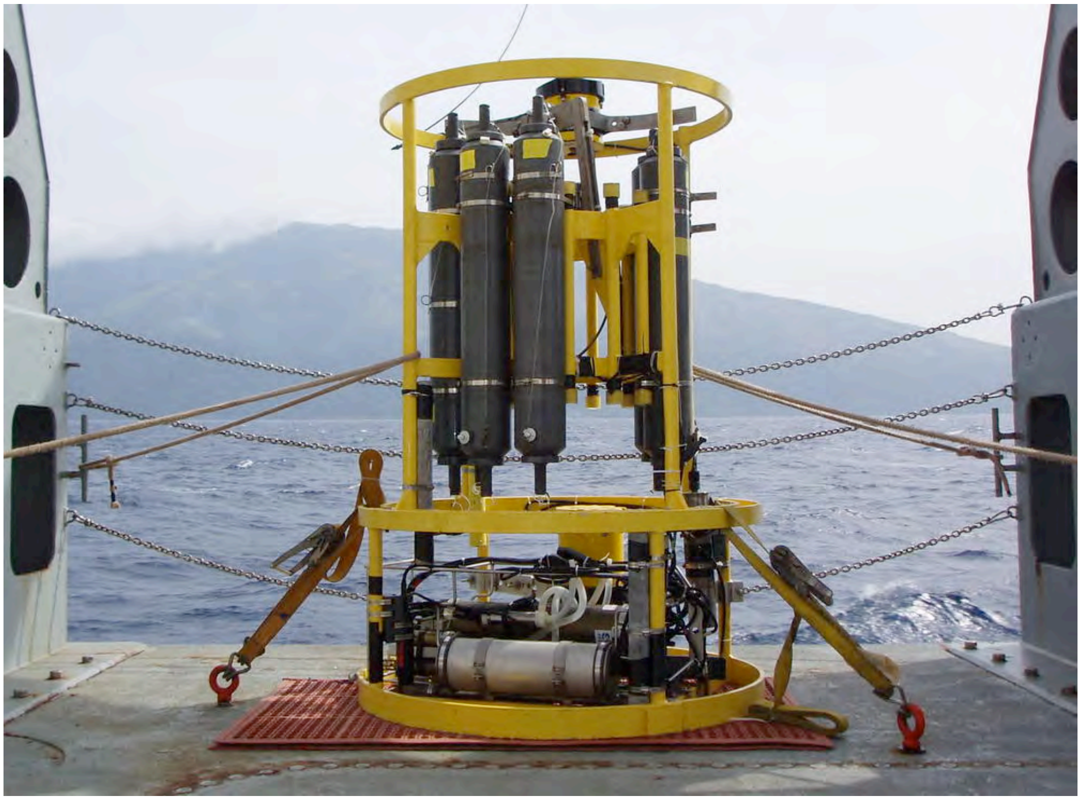
Phil Mele
Lamont-Doherty Earth Observatory
Palisades NY, 10964

A total of 126 profiles of temperature, salinity and dissolved oxygen were obtained during the RIOP09 cruise 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. LADCP data were collected separately. Data were acquired using a Windows PC and SeaBird Seasave software. Data was processed using the SeaBird processing suite.

The CTD package remained on deck during the cruise.

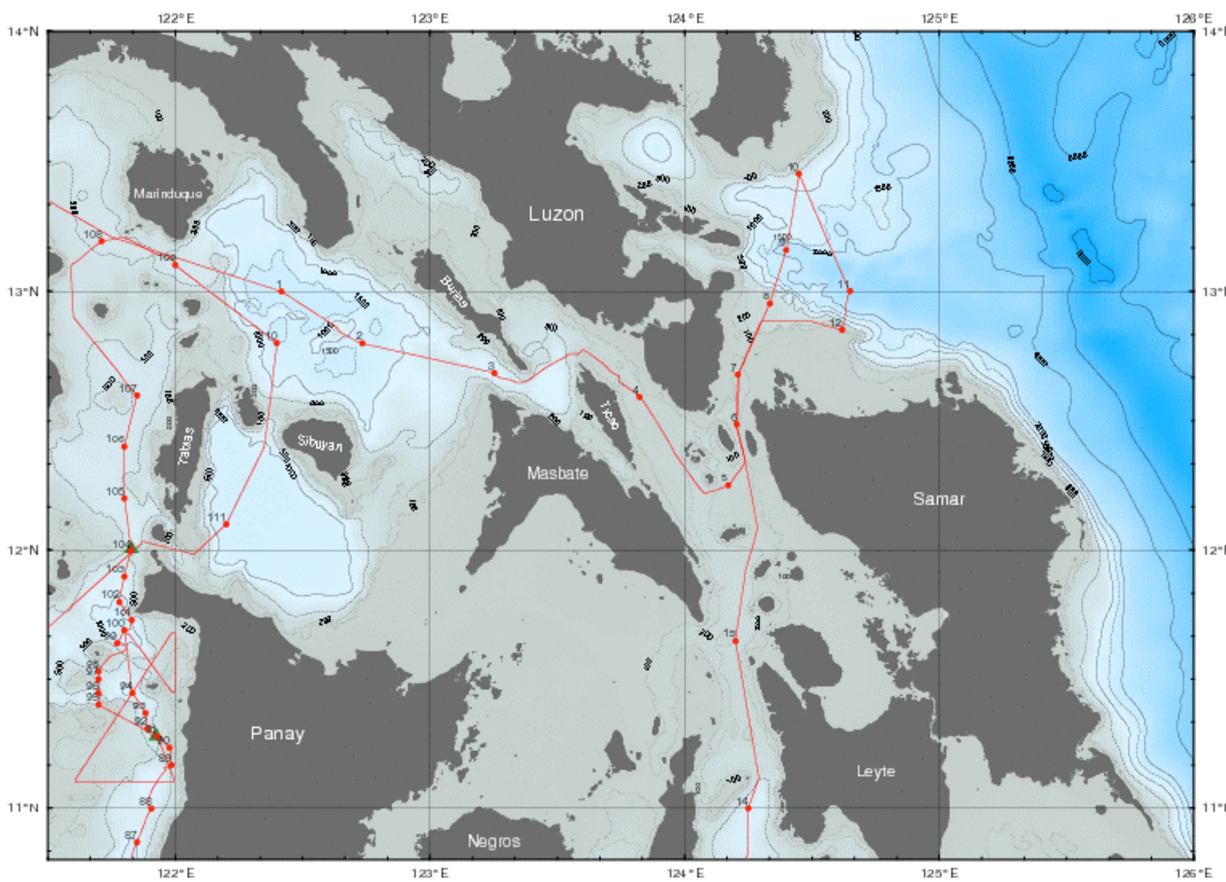
Most profiles were planned to reach within 10 m of the bottom. Approach to the bottom was guided by a Benthos altimeter mounted on the frame. The altimeter worked well for most casts.

Water samples were collected using a 24-position carousel fitted with nine 10 liter water sample bottles. Water samples were collected for on board analysis of salinity and disolved oxygen for standardizing the CTD data. Water sample salinity was determined using a Guildline Autosal 8400A laboratory salinometer, standardized with batch P148 standard water from OSIL, date: 10-Oct-2006 and batch P149, date: 5-Oct-2007. The salinometer was housed in a temperature controlled lab. Water sample dissolved oxygen was determined by modified Winkler method for a spectrophotometer.

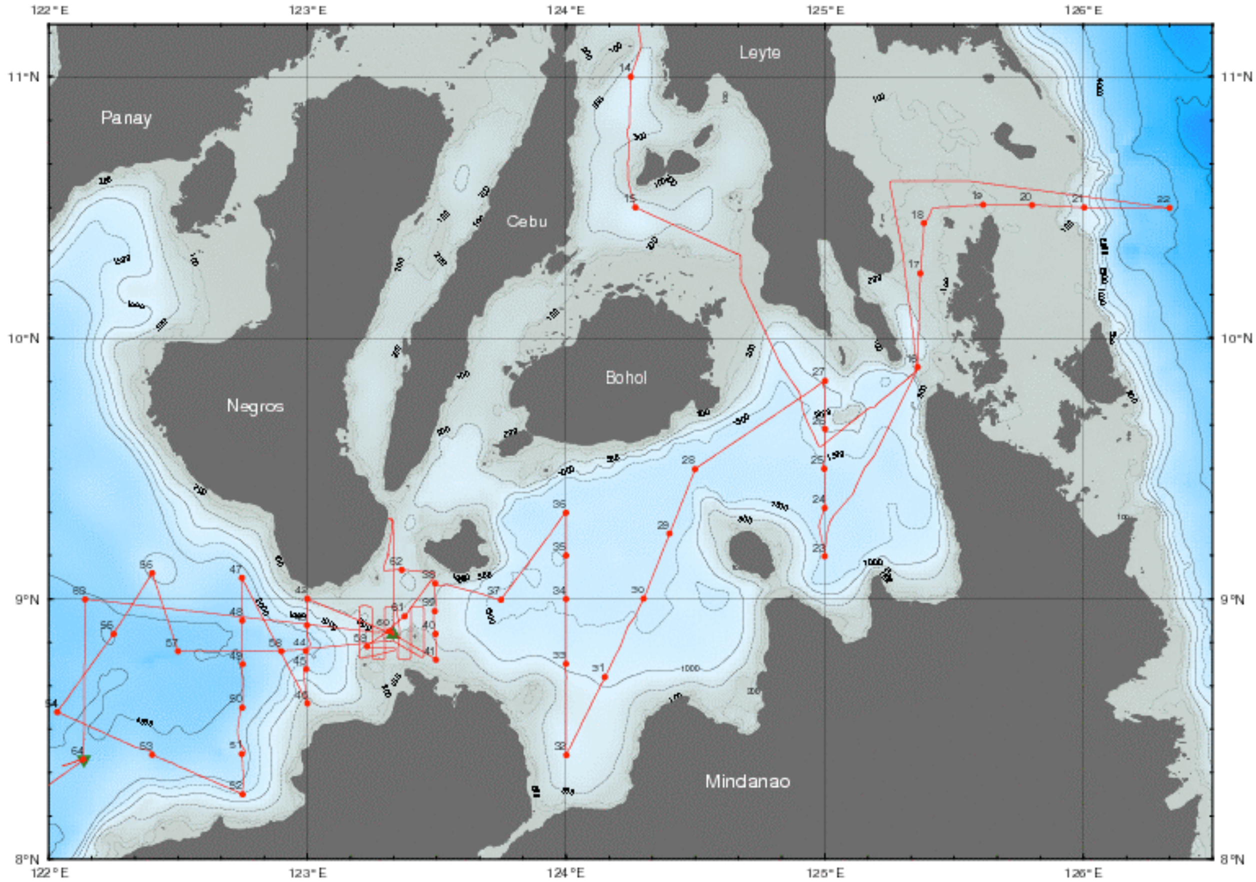


CTD Summary Table:

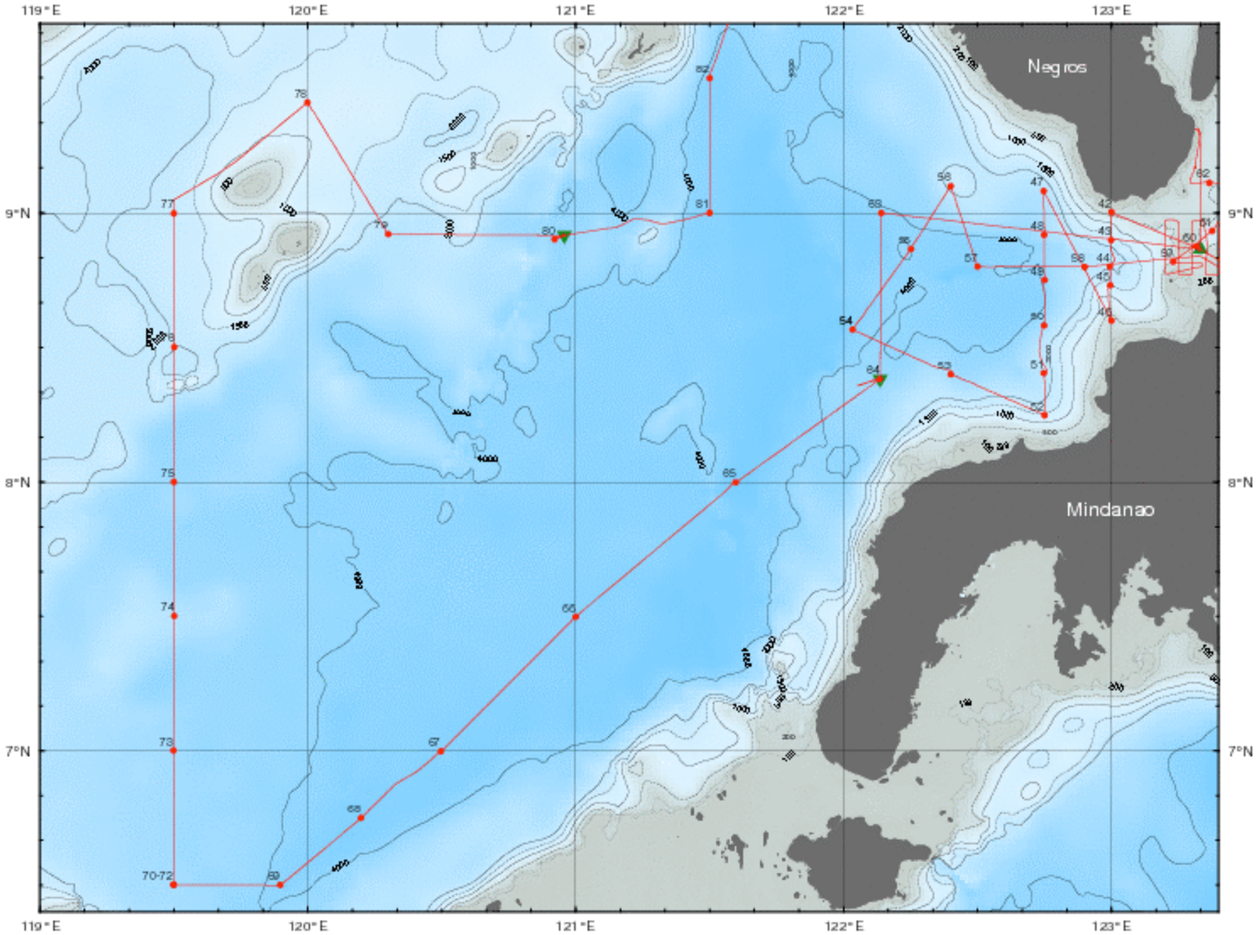
sta	lat (N)	lon (E)	yyyy/mm/dd	hh:mm
1	12 59.93	122 25.00	2009/02/28	01:06
2	12 47.88	122 44.06	2009/02/28	04:56
3	12 41.07	123 15.18	2009/02/28	09:22
4	12 35.47	123 49.37	2009/02/28	14:06
5	12 15.04	124 10.23	2009/02/28	17:42
6	12 29.18	124 12.23	2009/02/28	19:48
7	12 40.73	124 12.57	2009/02/28	21:18
8	12 57.14	124 20.07	2009/02/28	23:37
9	13 9.48	124 23.94	2009/03/01	01:43
10	13 27.12	124 26.91	2009/03/01	05:46
11	13 0.04	124 38.96	2009/03/01	09:48
12	12 51.00	124 37.06	2009/03/01	12:11
13	11 38.89	124 11.97	2009/03/01	19:46
14	10 59.96	124 14.97	2009/03/01	23:51
15	10 29.97	124 16.10	2009/03/02	03:31
16	9 53.32	125 21.54	2009/03/02	13:32
17	10 14.89	125 22.21	2009/03/02	16:26
18	10 26.39	125 22.97	2009/03/02	18:16
19	10 30.60	125 36.70	2009/03/02	20:23
20	10 30.58	125 48.11	2009/03/02	21:57
21	10 29.97	126 0.17	2009/03/02	23:33
22	10 29.88	126 19.96	2009/03/03	02:37
23	9 9.87	125 0.01	2009/03/03	16:43
24	9 20.94	125 0.02	2009/03/03	19:16
25	9 29.97	124 59.93	2009/03/03	21:23
26	9 39.07	125 0.05	2009/03/03	23:48
27	9 50.22	125 0.10	2009/03/04	01:32
28	9 29.93	124 29.87	2009/03/04	05:51
29	9 15.07	124 24.00	2009/03/04	08:56



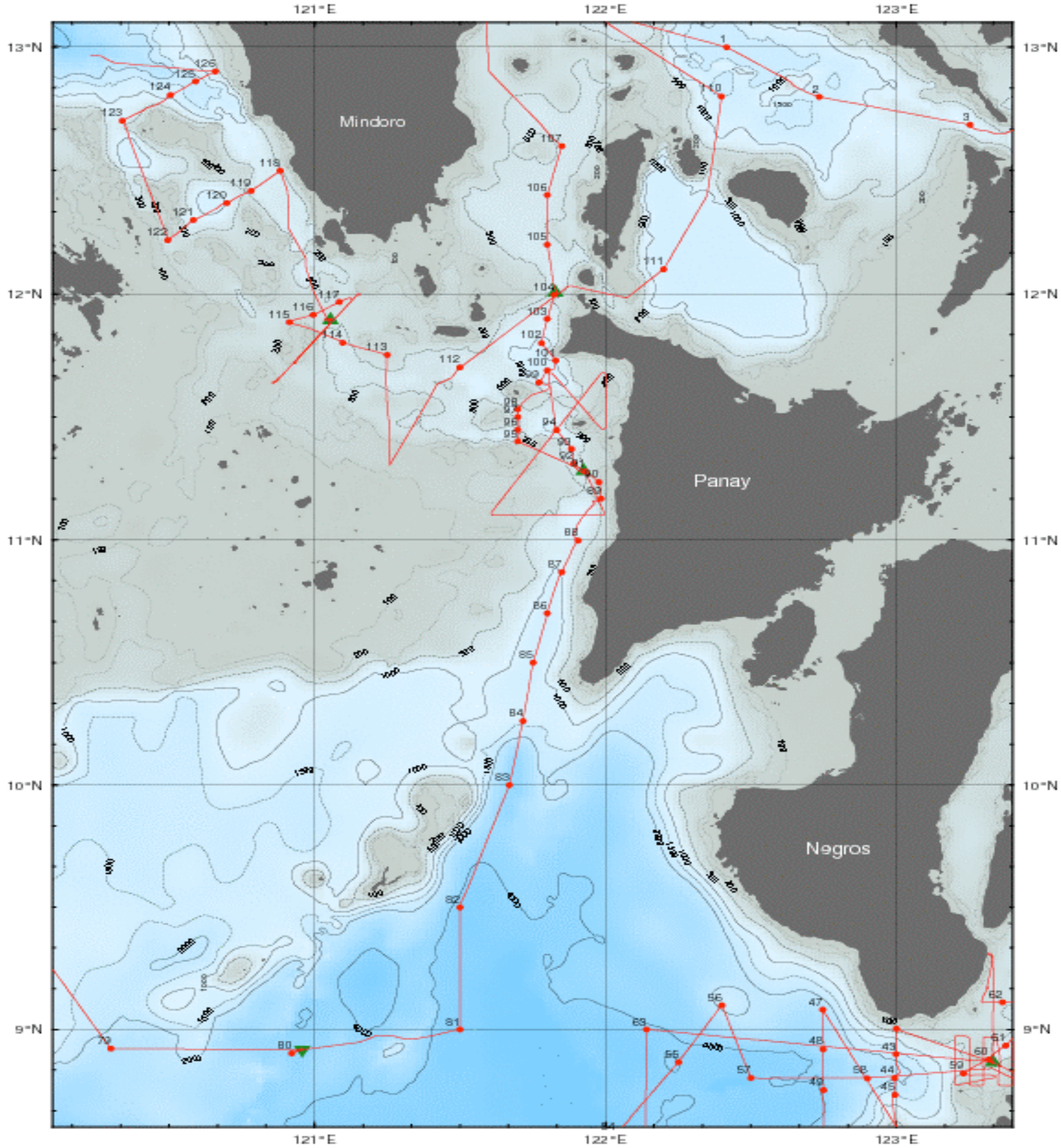
sta	lat (N)	lon (E)	yyyy/mm/dd	hh:mm
30	9 0.13	124 18.03	2009/03/04	11:39
31	8 42.04	124 9.04	2009/03/04	14:54
32	8 23.97	124 0.07	2009/03/04	17:52
33	8 45.05	124 0.04	2009/03/04	20:49
34	8 59.99	124 0.02	2009/03/04	23:19
35	9 10.01	123 59.97	2009/03/05	01:37
36	9 19.85	123 59.97	2009/03/05	03:56
37	8 59.81	123 44.90	2009/03/05	07:43
38	9 3.64	123 29.63	2009/03/05	10:27
39	8 57.23	123 29.55	2009/03/05	11:46
40	8 51.99	123 29.77	2009/03/05	13:03
41	8 45.96	123 29.86	2009/03/05	14:16
42	9 0.11	123 0.04	2009/03/05	17:28
43	8 53.92	122 59.88	2009/03/05	18:40
44	8 48.04	122 59.67	2009/03/05	20:39
45	8 43.85	122 59.71	2009/03/05	22:55
46	8 35.99	123 0.00	2009/03/06	00:55
47	9 4.86	122 44.84	2009/03/06	04:48
48	8 55.07	122 44.93	2009/03/06	07:22
49	8 45.03	122 44.97	2009/03/06	10:15
50	8 34.95	122 44.91	2009/03/06	14:02
51	8 24.31	122 44.83	2009/03/06	17:19
52	8 14.94	122 44.96	2009/03/06	19:45
53	8 24.06	122 23.98	2009/03/06	22:55
54	8 33.98	122 1.99	2009/03/07	03:16
55	8 51.92	122 15.06	2009/03/07	08:31
56	9 5.94	122 23.99	2009/03/07	13:08
57	8 48.00	122 29.99	2009/03/07	16:23
58	8 47.94	122 54.03	2009/03/07	20:13
59	8 49.10	123 13.82	2009/03/08	09:40



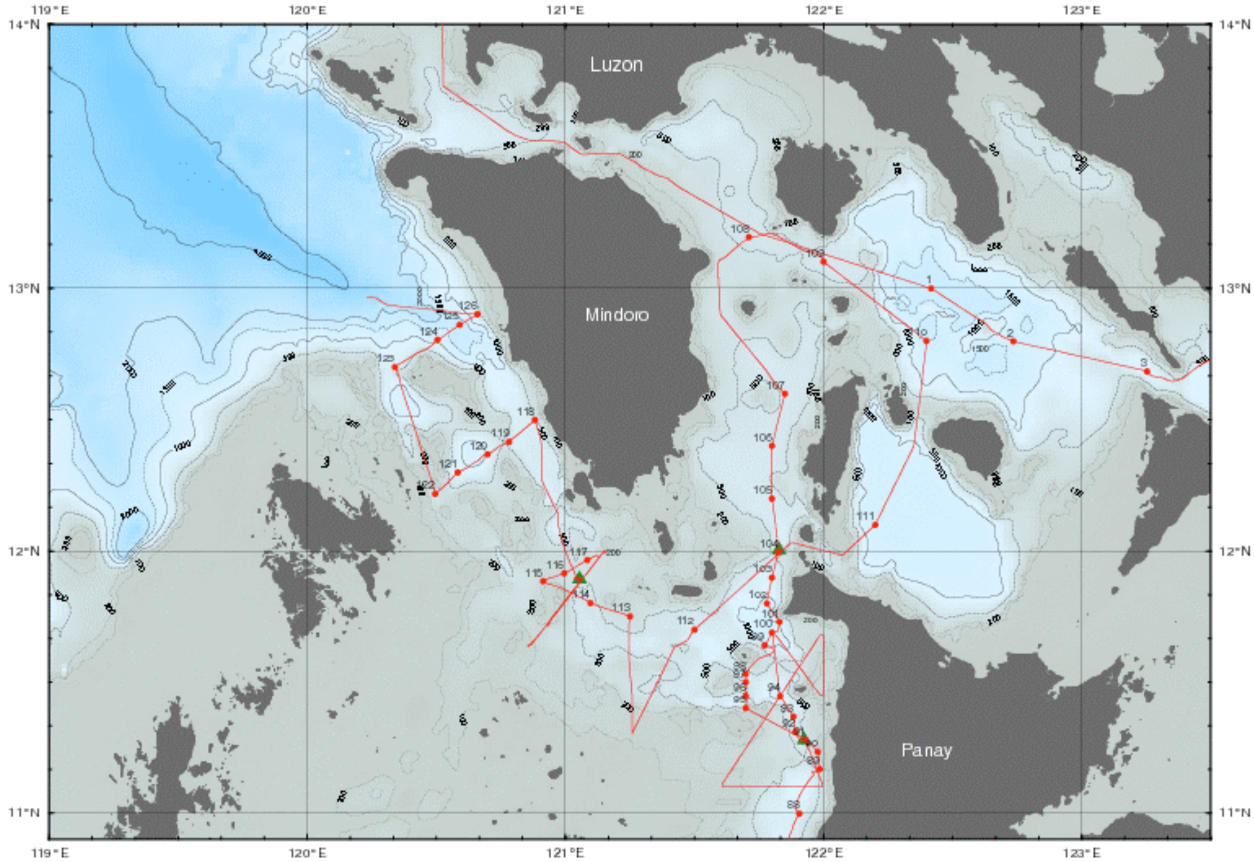
sta	lat (N)	lon (E)	yyyy/mm/dd	hh:mm	
60	8 52.57	123 18.98	2009/03/08	11:21	
61	8 56.03	123 22.50	2009/03/08	12:30	
62	9 6.67	123 21.92	2009/03/08	15:40	
63	8 59.95	122 8.45	2009/03/09	12:23	
64	8 22.97	122 8.11	2009/03/10	02:15	
65	7 59.96	121 35.81	2009/03/10	08:07	
66	7 29.91	121 0.02	2009/03/10	15:09	
67	6 59.94	120 29.82	2009/03/10	21:26	
68	6 44.96	120 11.92	2009/03/11	02:18	
69	6 30.00	119 53.79	2009/03/11	07:21	
70	6 30.13	119 29.93	2009/03/11	12:12	
71	6 30.00	119 30.00	2009/03/11	18:26	15.5 hour 150 m time series
72	6 29.96	119 30.01	2009/03/12	11:11	
73	7 0.08	119 29.91	2009/03/12	15:56	
74	7 30.16	119 30.06	2009/03/12	20:39	
75	8 0.05	119 30.03	2009/03/13	01:06	
76	8 30.15	119 30.07	2009/03/13	06:27	
77	8 59.89	119 29.97	2009/03/13	10:39	
78	9 24.55	119 59.94	2009/03/13	15:40	
79	8 55.27	120 17.99	2009/03/13	19:56	
80	8 54.09	120 55.24	2009/03/14	04:53	
81	8 59.94	121 30.00	2009/03/14	10:42	
82	9 29.94	121 30.02	2009/03/14	16:18	
83	9 59.98	121 40.19	2009/03/14	22:17	
84	10 15.64	121 43.04	2009/03/15	02:21	
85	10 29.99	121 45.07	2009/03/15	05:11	
86	10 42.05	121 47.98	2009/03/15	07:27	
87	10 52.07	121 50.97	2009/03/15	09:33	
88	10 59.84	121 54.33	2009/03/15	11:23	
89	11 10.04	121 59.09	2009/03/15	13:48	



sta	lat (N)	lon (E)	yyyy/mm/dd	hh:mm
90	11 14.06	121 58.68	2009/03/15	15:16
91	11 16.69	121 55.82	2009/03/15	16:34
92	11 18.57	121 53.41	2009/03/15	17:41
93	11 22.12	121 52.97	2009/03/15	18:38
94	11 26.75	121 49.89	2009/03/15	19:47
95	11 24.06	121 41.95	2009/03/16	09:20
96	11 26.82	121 41.92	2009/03/16	10:09
97	11 29.97	121 41.92	2009/03/16	11:24
98	11 31.84	121 41.93	2009/03/16	12:15
99	11 38.39	121 46.30	2009/03/16	14:14
100	11 41.39	121 47.99	2009/03/16	15:17
101	11 43.77	121 49.77	2009/03/16	16:47
102	11 47.97	121 46.79	2009/03/16	18:11
103	11 53.88	121 48.00	2009/03/16	19:47
104	11 59.76	121 49.45	2009/03/16	21:07
105	12 12.00	121 47.96	2009/03/17	00:50
106	12 24.02	121 47.99	2009/03/17	02:30
107	12 35.90	121 50.96	2009/03/17	04:23
108	13 11.57	121 42.61	2009/03/17	08:41
109	13 6.01	122 0.01	2009/03/17	11:09



sta	lat (N)	lon (E)	yyyy/mm/dd	hh:mm
110	12 47.98	122 23.95	2009/03/17	14:24
111	12 5.98	122 11.98	2009/03/17	19:13
112	11 42.02	121 29.97	2009/03/18	00:33
113	11 45.07	121 14.98	2009/03/18	07:27
114	11 48.10	121 5.83	2009/03/18	08:57
115	11 53.07	120 54.85	2009/03/18	10:32
116	11 54.87	120 59.70	2009/03/18	11:38
117	11 57.97	121 5.05	2009/03/18	12:55
118	12 29.95	120 52.95	2009/03/19	14:03
119	12 24.99	120 46.90	2009/03/19	15:28
120	12 22.09	120 41.94	2009/03/19	16:45
121	12 17.94	120 35.03	2009/03/19	18:34
122	12 13.07	120 29.69	2009/03/19	19:56
123	12 42.05	120 20.35	2009/03/19	23:01
124	12 48.29	120 30.28	2009/03/20	01:09
125	12 51.65	120 35.41	2009/03/20	02:41
126	12 54.04	120 39.58	2009/03/20	04:46


Luzon
Mindoro
Panay
119°E
120°E
121°E
122°E
123°E
14°N
13°N
12°N
11°N

RIOP09
Shipboard Acoustic Doppler Current Profiler (SADCP)
R/V Melville
February 27 – March 21, 2009

Primary Onboard Personnel:
Zachary Tessler & Debra Tillinger
Lamont-Doherty Earth Observatory
Palisades NY 10964

1. Summary

The SADCP system on the R/V Melville consists of two hull-mounted RDI Ocean Surveyor ADCPs, one operating at 75kHz (OS75) and the other at 150 kHz (OS150). At the start of the cruise, the OS150 was in broadband mode and the OS75 was in interleaved mode. When it was determined that the narrowband pings were not needed, the instrument was switched to broadband mode for the remainder of the cruise. The relevant command files are at the end of this report. Although the OS150 is known to have problems with bubbles becoming trapped against its transducers, this rarely occurred, possibly because this cruise did not use dynamic positioning.

2. Preliminary Processing

The preliminary processing of SADCP data is carried out on the ship by the UHDAS programs. For most of the cruise, the OS150 produced data down to 150-180 m, and the OS75 produced data to 500-600 m. Both instruments failed to produce data a few times during the cruise, possibly due to bubbles or low scattering conditions.

3. Preliminary Results

The SADCP produced excellent data in regions of internal wave activity. Figure 1 shows the backscatter amplitude during a period of internal wave activity in Surigao Strait. Figures 2 and 3 shows the amplitude and velocity that were measured while solitons were observed in the Sulu Sea.

6. Files and Directories

The ADCP datasets should contain the following directories, which contain everything that is needed in order to re-process the ADCP data:

raw: logging goes on here in directories named by instrument
- ADCP (wh300, nb150, os150, os75, os38)
- ancillary (gpsnav, gyro, ashtech, posmv, seapath, mahrs, phins…)
- config (configuration directory)
- log (diagnostics directory)

rbin: intermediate version of ancillary ascii data in "raw" subdirectory, stored as binary.
- ancillary only (gpsnav, gyro, ashtech, posmv, seapath, mahrs, phins…)

gbin: time-matched ADCP, navigation, attitude; time in UTC
proc: one processing directory for each instrument+pingtype possible
- standard CODAS processing subdirectories

- config (instrument configurations used at sea)
- png_archive (figures from the web site)

7. Acknowledgements

We would like to thank Jules Hummon at the University of Hawaii for all of her help and advice.

Appendix A: Command Files

```
#
#   An Ocean Surveyor configuration file
#   for UHDAS must contain only the commands listed here,
#   although the values may vary.  This file is not
#   necessary; defaults are set in rdi_setup.py,
#   which is called by DAS.py.  Additional commands may
#   be specified in /home/adcp/config/sensor_cfg.py.
#

# Bottom tracking
BP0        # BP0 is off, BP1 is on
BX10000    # Max search range in decimeters; e.g. BX10000 for 1000 m.

# Narrowband watertrack
NP0        # NP0 is off, NP1 is on
NN70       # number of cells
NS800      # cell size in centimeters; e.g. NS2400 for 24-m cells
NF400      # blanking in centimeters; e.g. NF1600 for 16-m cells

# Broadband watertrack
WP1        # WP0 is off, WP1 is on
WN75       # number of cells
WS400      # cell size in centimeters
WF400      # blanking in centimeters

# Interval between pings
TP00:01.10  # e.g., TP00:03.00 for 3 seconds


#
#   An Ocean Surveyor configuration file
#   for UHDAS must contain only the commands listed here,
#   although the values may vary.  This file is not
#   necessary; defaults are set in rdi_setup.py,
```

```
#   which is called by DAS.py.  Additional commands may
#   be specified in /home/adcp/config/sensor_cfg.py.
#

# Bottom tracking
BP0         # BP0 is off, BP1 is on
BX10000     # Max search range in decimeters; e.g. BX10000 for 1000 m.

# Narrowband watertrack
NP1         # NP0 is off, NP1 is on
NN60        # number of cells
NS1600      # cell size in centimeters; e.g. NS2400 for 24-m cells
NF800       # blanking in centimeters; e.g. NF1600 for 16-m cells

# Broadband watertrack
WP1         # WP0 is off, WP1 is on
WN75        # number of cells
WS800       # cell size in centimeters
WF800       # blanking in centimeters

# Interval between pings
TP00:03.00  # e.g., TP00:03.00 for 3 seconds
```

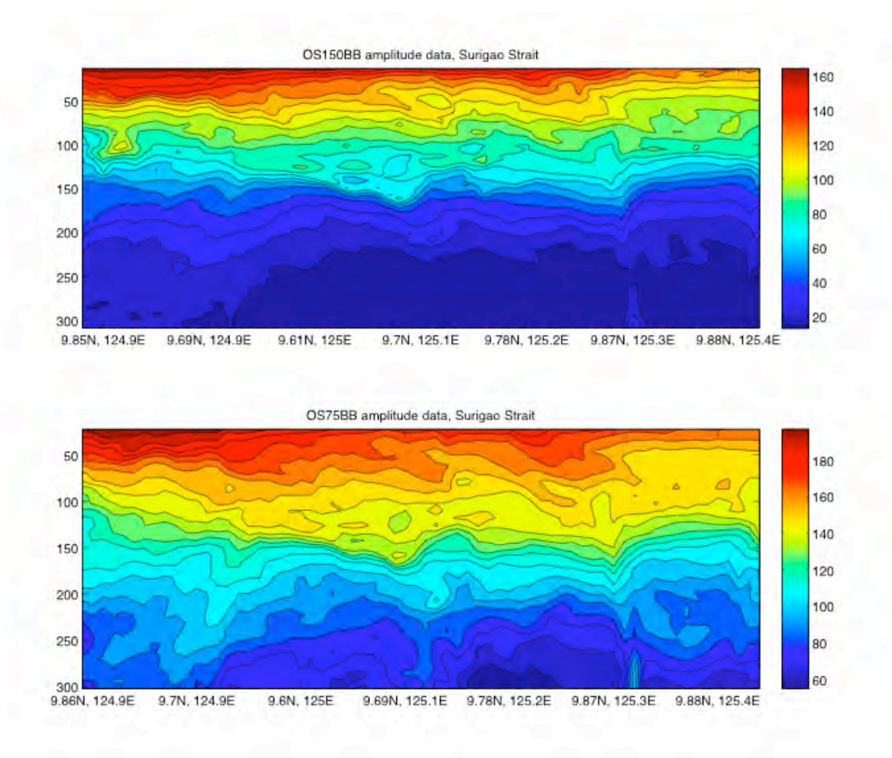


Figure 1 Backscatter amplitude during a period of internal wave activity in Surigao Strait

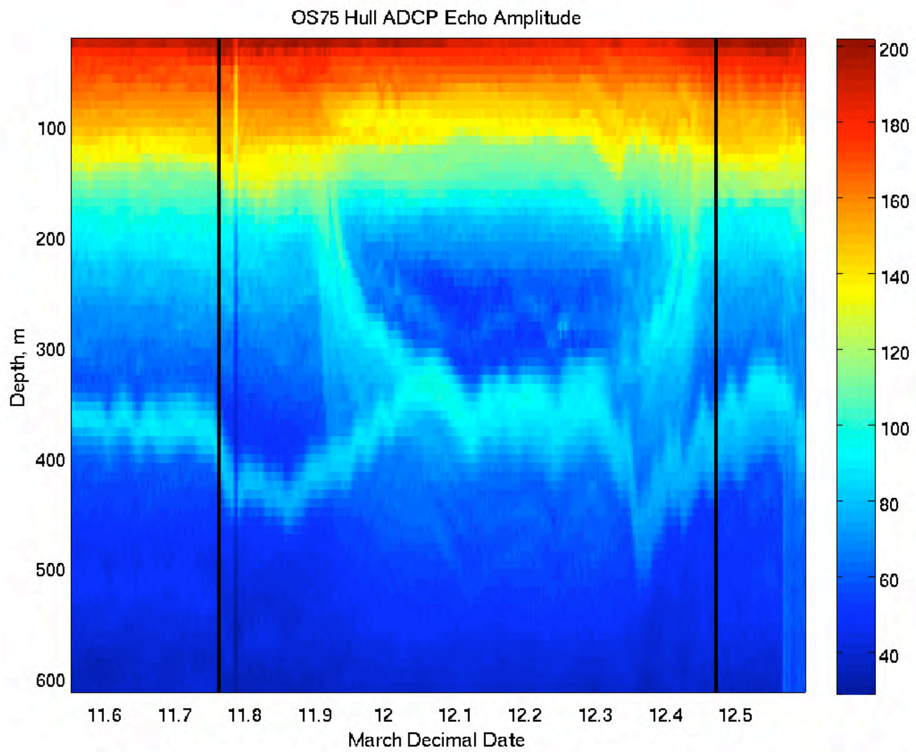


Figure 2 Amplitude of return beam while solitons were observed in the Sulu Sea [day.decimal in GMT]

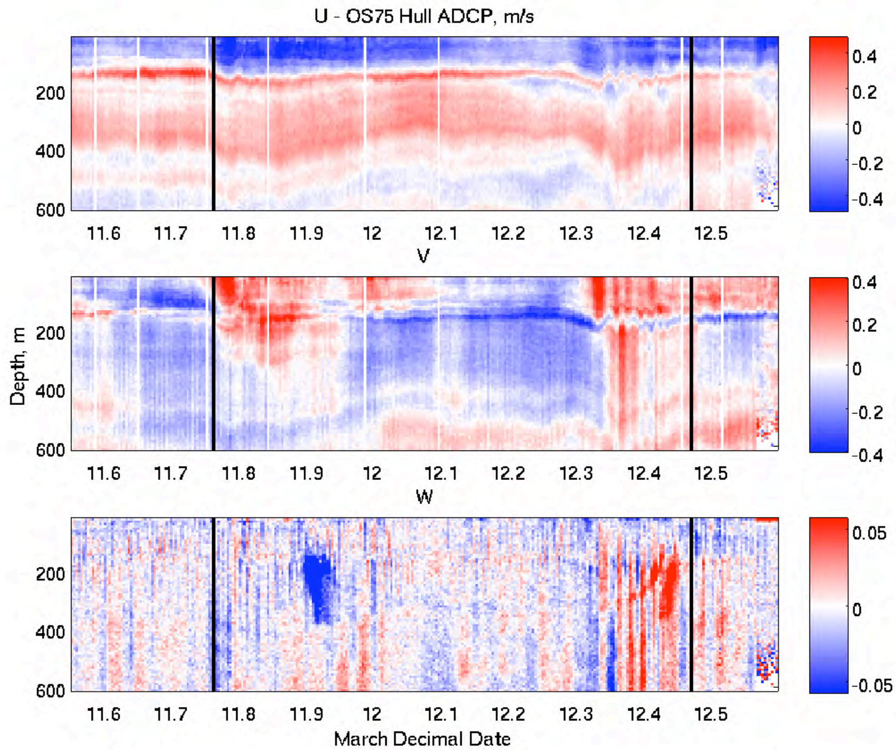


Figure 3 Velocity measured while solitons were observed in the Sulu Sea [day.decimal in GMT]

RIOP09
Lowered Acoustic Doppler Current Profiler (LADCP)
R/V Melville
February 27 – March 21, 2009

Primary Onboard Personnel:
Zachary Tessler & Debra Tillinger
Lamont-Doherty Earth Observatory, Palisades NY 10964

1. Summary

One upward and one downward looking LADCP were mounted on the CTD rosette. Due to extensive technical problems, data from this dual head system was collected at the following stations only: 1-3, 16-36, 38-44, and 63-??. For stations 4-9, 13-15, 45-62, single head data were collected. At the remaining stations (10, 11, 12, 37), no data could be recorded. Preliminary processing was completed during the cruise using the LDEO LADCP software. The LADCP processing included shipboard ADCP data from the RDI 75 kHz Ocean Surveyor ADCP running in broadband mode.

2. Equipment

There were four LADCPs used on the cruise. Three of them, serial numbers 3441, 149, and 299/149 are Teledyne RDI Workhorse 300 kHz instruments. The fourth, serial number 7322, is a custom made high-powered version of the other instruments. At the start of the cruise, a dual head system was mounted on the CTD rosette and connected via an octopus cable to a disposable 56V battery pack. On deck communication with the LADCP was accomplished via an RS-232 deck cable connected to a Keyspan 4-port RS-232 to USB adapter. This was connected to an iMac running Mac OS 10.4.10.

During testing for the initial setup, it became apparent that the new octopus cable, purchased for this cruise, was defective. It was later confirmed that the cable was built to the wrong specifications. The initial setup used 7322 as the downlooker and 299/149 as the uplooker. That setup failed after station 3. It was determined that the octopus cable had failed. We therefore switched to a single head system, using the deck cable to communicate directly with the downlooker. The deck cable failed almost immediately after, but we were able to replace it with a working backup cable. After bad data on cast 9, we tried using only 299/149, but were still unable to collect data. We then switched to 149 as the uplooker and were able to collect data starting at station 13. We tried 7322 one more time, at station 14, and were still unable to use it. At that point, we determined that the high-powered unit, 7322, was damaged. Upon opening it, we found salt and evidence of water damage inside the instrument, implying that a transducer was leaking.

At station 15, we returned to using 149 only and were able to collect data.

With the help of the resident marine technician, Drew Cole, we used the incorrectly made octopus to build a new one. In the process, we found rust in some of the older cables and saw that the armor inside of them had disintegrated. Starting with station 16, we returned to a dual head system using 3441 and 149.

At station 37, we were no longer able to communicate with the instruments. Although the cause of the problem was not diagnosed, communications were resumed at station 38 but the data returned by 149 began to decrease in quality. At station 40, 149 failed completely. At that point, 149 was replaced with 149/299, but the data were still bad. At station 45, we stopped attempting to use a dual head system and returned to a single head system with 3441. Upon consultation with Darryl Symonds at RDI, LADCP 149/299 was found to have an improperly connected wire, which was then repaired.

Janet Sprintall was able to bring a replacement octopus cable from RDI to the Melville in Dumaguete. At station 63, we assembled the new octopus, 3441, and 149/299 in a dual head system. After station 96, the deck cable failed and was replaced with the deck cable that had failed earlier but was repaired onboard.

3. Sampling

The LADCP was deployed at CTD stations as listed in the summary section. A command file was uploaded to the instrument approximately five minutes before each deployment. By convention, the downlooker was designated as master and the uplooker as slave in the dual head system. Twenty-five 8m cells were measured. The LADCPs used staggered single ping ensembles every 1.5/2.0 seconds.

4. Preliminary Processing

Preliminary processing of the data was performed between casts using the LDEO LADCP software version IX_5 written by Martin Visbeck and Andreas Thurnherr, and Bruce Huber. An LADCP acquires multiple velocity profiles as it is lowered into the ocean. Much of the processing of LADCP data consists of combining these overlapping profiles into a single profile of absolute velocities for the entire water column. Other steps in the preliminary processing are the correction of velocity directions for local magnetic variation and range corrections made using sound speed profiles calculated from the contemporaneous CTD data. Shipboard ADCP data from the OS75 was used as another constraint on absolute current velocity. Bottom tracking was successful on most casts but failed when the bathymetry was too rough or the cast was too shallow relative to the water depth. LADCP data may be further processed, but the preliminary processing that was performed during RIOP09 is sufficient to produce plots of velocities as a function of depth.

5. Preliminary results

The Southern Sulu Sea showed high velocities and high shear deep in the water column. Figure 1 shows high velocities at 2000, 2500, and 3000m within the southern Sulu Sea. Strong benthic layer overflows at topographic sills flows were measured, as shown in figure 2.

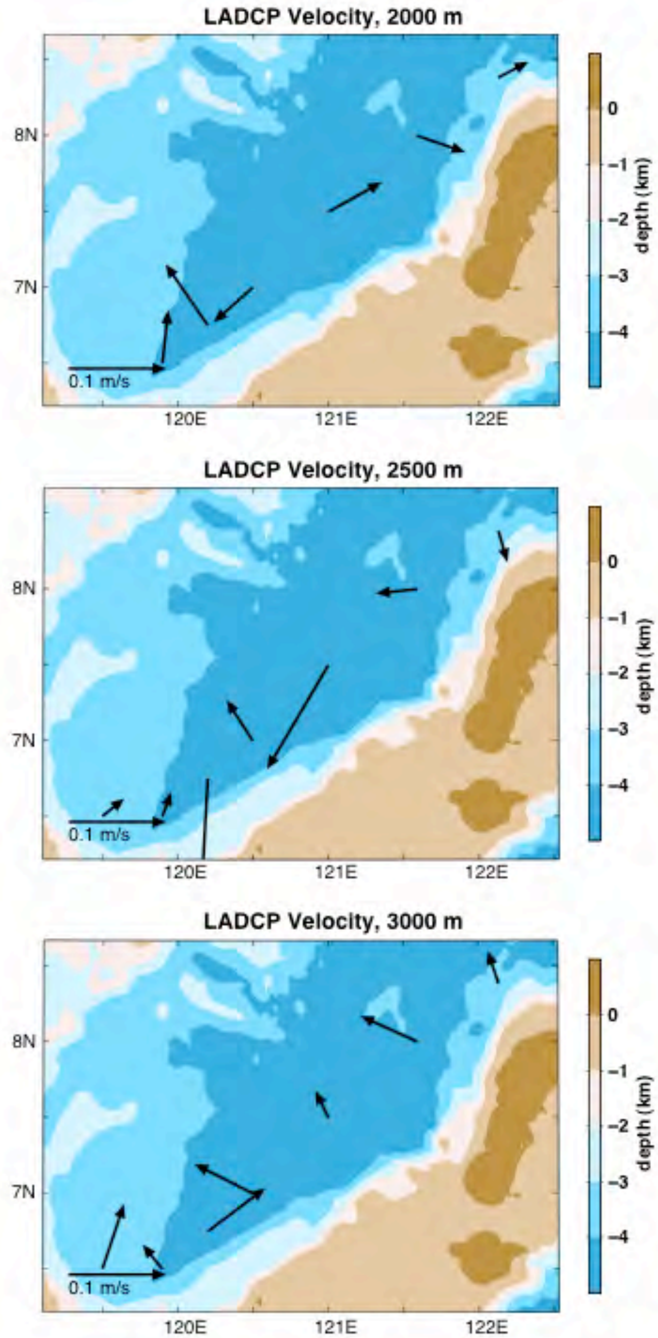


Figure 1 Abyssal layer currents in the southern Sulu Sea

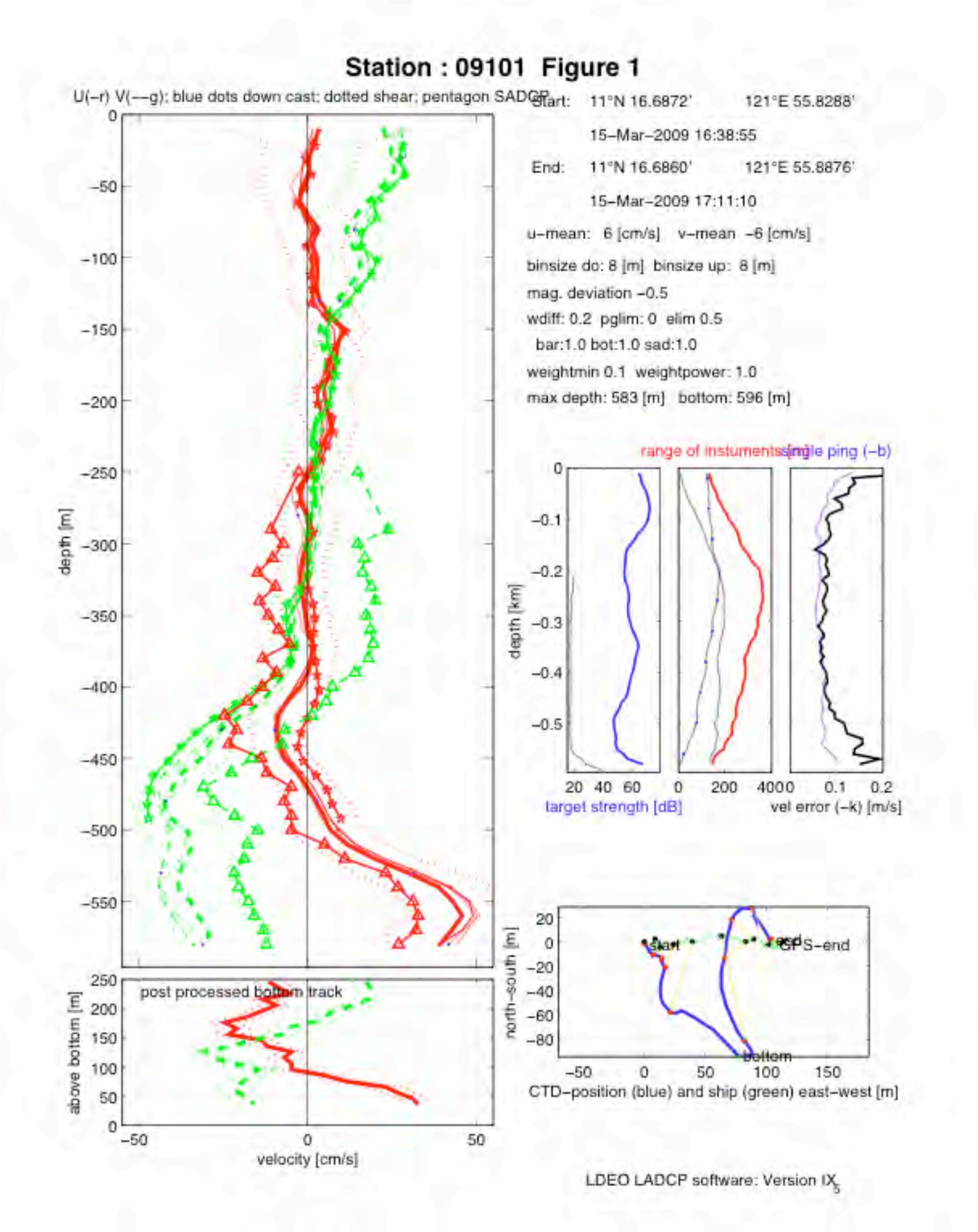


Figure 2 Panay sill overflow

6. Files and Directories

The LADCP datasets should contain the following directories, which contain everything that is needed in order to re-process the LADCP data: raw
raw data, instrument-setup command files, communication logfiles CTD_0.5s

CTD half-second time series and profiles used for LADCP processing os75bb shipboard ADCP data used for LADCP processing data files and processing figures as postscript files.

7. Acknowledgements

We would like to thank Andreas Thurnherr and Bruce Huber at Lamont-Doherty Earth Observatory and Darryl Symonds at RDI for their continued support via email. We would also like to thank our computer technician, Ben Cohen, for his help in diagnosing our electrical problems and our resident marine technician, Drew Cole, for his tireless efforts in switching LADCPs on the rosette, diagnosing equipment malfunctions, and building us a new octopus cable.

Regional Cruise
Intensive Observational Period 2009
RIOP09 / PHILEX09 - Leg 2
R/V Melville, 09 to 21 March 2009 (Dumaguete - Manila)

Work Report: Sediment Trap Studies in the Sulu Sea

Niko Lahajnar and Anna-Maria Bensch
University of Hamburg, Bundesstrasse 55, D-20146 Hamburg, Germany

1. Introduction and Overview

Major goal of sediment trap deployments is to investigate the magnitude and biogeochemical variation of particulate matter settling through the water column in space and time. Therefore, particle flux studies represent a key link between surface ocean processes (e.g., primary productivity) and particle sedimentation and accumulation at the seafloor and thus are an invaluable tool for understanding paleoceanographic records. Detailed analyses of bulk composition and organic compounds provide information on the sources, alteration and transport processes of the particulate organic and inorganic matter in the water column. These investigations are closely linked to plankton and microbiological investigations. Moreover, the sediment trap deployments allow us to describe the particulate matter fluxes reaching the bottom and are therefore a valuable prerequisite to understand early diagenetic processes and organic matter degradation in surface sediments.

The Sulu Sea is considered to be - at least partially - a stratified marginal basin with reduced ventilation and thus reduced oxygen concentrations in deeper layers. In addition, it is strongly influenced by the SE-Asian monsoonal system. Seasonally changing wind speeds and directions are considered to have a major impact on the particle flux in this area.

To our knowledge it is the first time that seasonal particle flux studies of more than one year have been conducted in the Sulu Sea. During PHILEX 2007-2008 two sediment trap moorings had been deployed off Zamboanga in the SE part and in the central Sulu Sea, respecitvely. These deployment sites had been chosen in order to catch the upwelling-induced particle flux signal off Zamboanga and to compare the results with a *true* open-ocean record in the central Sulu Sea. Moreover, these results will be compared with particle flux studies carried out in the South China Sea region (Lahajnar et al., 2007, Deep-Sea Research I, 54, 2120-2142) and its adjacent basins.

2. Location and Methods

A mooring system "Sulu-East-01" had been deployed off Zamboanga peninsula (08°23.009' N 122°08.220' E) at 4000 m water depth on Jan 01 2008 consisting of two sediment traps McLane PARFLUX MARK 7 at 1127 m (Sulu-East-01 Shallow) and 3459 m (Sulu-East-01 Deep) water depth, respectively. Three meter below Sulu-East-01 Shallow an Aanderaa Doppler Current Meter RCM-9 MKII was installed in order to measure the current speed and direction as well as the ambient temperature during the deployment. An older version Aanderaa Current Meter (RCM-8) was attached to the mooring below Sulu-East-01 Deep.

A second mooring “Sulu Central-01” had been deployed in the open Sulu Sea (08°55.014’ N 120°57.443’ E) at 3850 m water depth on Jan 02 2008 consisting of two sediment traps McLane PARFLUX MARK 7 at 1089 m (Sulu-Central-01 Shallow) and 3317 m (Sulu-Central-01 Deep) water depth, respectively. An Aanderaa Current Meter (RCM-8) was attached below both sediment traps, respectively

The sediment trap cups had been filled with distilled water; 70 g l^{-1} NaCl and 3.3 g l^{-1} $HgCl_2$ were added to avoid diffusion and bacterial decomposition during the deployment. All supernatant samples were analyzed on salinity, pH and oxygen after recovery. Sampling period started on January 4, 2008 and ended on February 27, 2009. The particle flux was sampled on intervals of 21 days.

Tab. 1: Rotation schedule sediment trap deployments. Central-01 Shallow did not sample the last three intervals.

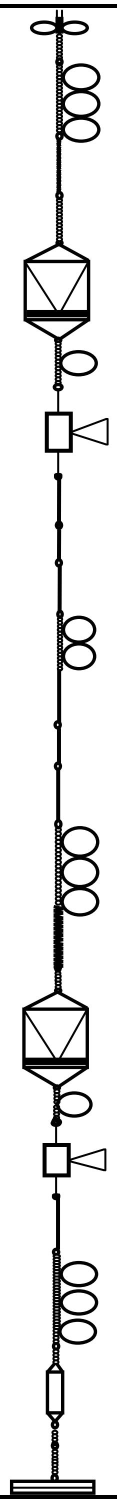
Cup-No	Date Open	Date Close	Days	East-01 Shallow	East-01 Deep	Central-01 Shallow	Central-01 Deep
01	01/04/2008	01/24/2008	21	x	x	x	x
02	01/25/2008	02/14/2008	21	x	x	x	x
03	02/15/2008	03/06/2008	21	x	x	x	x
04	03/07/2008	02/27/2008	21	x	x	x	x
05	03/28/2008	04/17/2008	21	x	x	x	x
06	04/18/2008	05/08/2008	21	x	x	x	x
07	05/09/2008	05/29/2008	21	x	x	x	x
08	05/30/2008	06/19/2008	21	x	x	x	x
09	06/20/2008	07/10/2008	21	x	x	x	x
10	07/11/2008	07/31/2008	21	x	x	x	x
11	08/01/2008	08/21/2008	21	x	x	x	x
12	08/22/2008	09/11/2008	21	x	x	x	x
13	09/12/2008	10/02/2008	21	x	x	x	x
14	10/03/2008	10/23/2008	21	x	x	x	x
15	10/24/2008	11/13/2008	21	x	x	x	x
16	11/14/2008	12/04/2008	21	x	x	x	x
17	12/05/2008	12/25/2008	21	x	x	x	x
18	12/26/2008	01/15/2009	21	x	x		x
19	01/16/2009	02/05/2009	21	x	x		x
20	02/06/2009	02/27/2009	21	x	x		x

Tab. 2: Current Meter performance during deployment. Central-01 Deep stopped recording after 24 Feb. 2008 due to water leakage.

	Temperature	Current Speed	Current Direction	Recording Period
East-01 Shallow	x	x	x	01/01/2008 - 03/10/2009
East-01 Deep	x	x	x	01/01/2008 - 03/10/2009
Central-01 Shallow	x	x	x	01/02/2008 - 03/10/2009
Central-01 Deep	x	x	x	01/02/2008 - 02/24/2008

Mooring-I.D.: Sulu-East-01

Release Code:	Enable: 6 C Release: 6 A (Benthos 865-A SN 508)	**Deployment Date:**	Jan 01 2008
Strobe Light:	2 Burst Mode	**Start:**	08:00 (local)
Radio Frequency:	Channel 68; 156.425 MHz; 2 s on, 4 s off	**Anchor Drop:**	10:45
Float Color:	Topfloat: yellow, Floats: yellow	**Topfloat u. water**	10:54
Deployment Position:	**08°23.009' N 122°08.220' E (Triangulation)**	**End of Triangulation**	12:36
Buoyancy speed:	Deployment: -117 m/min	**Recovery Date:**	March 10 2009
	Recovery: +75 m/min	**Start:**	05:55 (local)
		End:	09:38



Mooring Diagram m.a.b.	Mooring Diagram m.b.s.	Mooring Description	Deployment Time out [local]	Recovery Time in [local]
2906 m	1094 m	3 Ball Radio Float (yellow) + Flasher +Radio	08:01	06.56
2904 m	1096 m	10 Benthos 17'' Floats (yellow) on chain, 10 m		07:08
		Nylon Rope, 20 m		07 :15
		Chain, 2 m		
2873 m	1127 m	Mark 78G-21 Sediment Trap 11373.00 SCS-SW-06 Shallow SN 11373-01	08:08	07:24
		1 Benthos 17'' Float		
2867 m	1130 m	Aanderaa RCM 9 Current Meter S/N 574	08:08	07:35
		Wire 3/16'', 500 m (new)	08:24	07:55
		Wire 3/16'', 200 m (new)		
		Wire 3/16'', 500 m (old)	08:43	08:02
1667 m	2333 m	2 Benthos 17'' Floats (yellow) on chain 2 m	08:49	08:18
		Wire 3/16'', 500 m (old)	09:03	
		Wire 3/16'', 100 m (old)	09:06	08:39
		Wire 3/16'', 500 m (new)	09:21	
564 m	3435 m	7Benthos 17'' Floats on chain, 6m	09:30	08:55
		Nylon Rope, 20 m		Entanglement
		Chain, 2 m		
539 m	3459 m	Mark 7G-21 Sediment Trap 10414-2 SCS-SW-06 Deep Timer: ML 11616-02	09:45	08:55
				Entanglement
		1 Benthos 17'' Float on		
536 m	3464 m	Aanderaa RCM 8 Current Meter S/N 9815	09:45	08:55
		Wire 3/16'', 500 m (new)	10:03	
33 m	3967 m	6 Benthos 17'' Floats on chain, 6m	10:18	
25 m	3975 m	Benthos Release 865 S/N 508, 13 V		09:38
		Nylon Rope 20 m		
0 m	4000 m	Anchor (3 Railroad Wheels)	10:46	

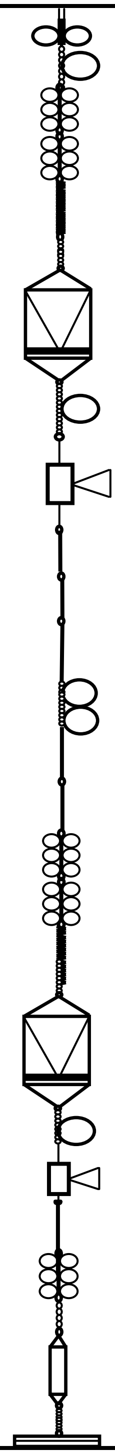
Fig. 1: Mooring Diagram Sulu-East-01

Mooring-I.D.: Sulu-Central-01

Deployment Date: Jan 02 .2008
Start: 06:43 (local)
Anchor Drop: **09:40**
Topfloat u. water: 10:10

Release Code: Enable: 1 C Release: 1 A Benthos 865-A SN 756, 13V
Strobe Light: 2 Burst-Mode
Radio Frequency: none
Float Color: Topfloat: yellow, Floats: red
Deployment Position: **08°55.014'N 120°57.443'E (Triangulation)**
Buoyancy speed: Deployment: -120 m/min
Recovery: +80 m/min

Recovery Date: Mar 14 2009
Start: 09:15
Pickup: 10:15
End: 12:38



Mooring Diagram m.a.b.	m.b.s.	Mooring Description (Time out [UTC])	Deployment Time out [local]	Recovery Time in [local]
2787 m	1063 m	3 Ball Radio Float + Flasher (yellow)	06:43	10:28
		Chain with 2 Benthos Floats 17''		
2785 m	1065 m	G-6600-3 Triple Float (red)	06:45	10:28
2783 m	1067 m	G-6600-3 Triple Float (red)		
		Nylon Rope 20 m	07:10	10 :28
2761 m	1089 m	Mark 7G-21 Sediment SCS-SW2-01 Shallow S/N 10426-1; Timer:	07:10	10:38
		Chain with Benthos Float 17''		
2759 m	1091m	Aanderaa RCM8 Current Meter S/N 11708	07:10	10:46
		Wire 3/16'' 500 m (new)	07:25	11:10
		Wire 3/16'' 200 m (new)	07:30	11:15
		Wire 3/16'' 500 m (old)	07:49	11.31
1558 m	2292 m	Chain with 2 Benthos Floats 17''	07:49	11:32
		Wire 3/16'' 500 m (new)	08:12	11:50
		Wire 3/16'' 500 m (new)	08:46	12:03
556 m	3294 m	G-6600-3 Triple Float (red)	08:46	12:25
		G-6600-3 Triple Float (red)		
		Nylon Rope 20 m		Entanglement
533 m	3317 m	Mark 7G-21 Sediment SCS-SW2-01 Deep S/N 10426-2; Timer: 11616-01	08:58	12:25
				Entanglement
		Chain with Benthos Float 17''		
530 m	3320 m	Aanderaa RCM 8 S/N 11775	08:59	12:25
		Wire 3/16'' 500 m (new)	09:24	12:38
27 m	3823 m	G-6600-3 Triple Float (orange)	09:24	12:38
25 m	3825 m	Benthos Release 865 A S/N 756, 13V		12:38
		Nylon Rope 20 m	09:40	
0 m	3850 m	Anchor (3 Railroad Wheels)	09:40	

Fig. 2: Mooring Diagram Sulu-Central-01

3. Sediment Trap Mooring Sulu-East-01

3.1. Sediment Traps

The mooring was recovered on 10 March 2009 at CTD station 64. It was released just after sunrise at 05:50 local ship time. After 15 minutes the top float was spotted in front of the ship at about 200 m to the NW. The system was hooked up at 06:40; recovery was completed at 09:38 when the release was retrieved on board.

Recovery procedure was carried out without any severe problems. However, the radio beacon got broken during the ascent of the system (the bridge noticed two single beeps when the topfloat first came to the surface) as well as one glass sphere of the topfloat cracked. This was also the case for one float above the release. In addition, the lower sediment trap (Sulu-East-01-Deep) was entangled with the adjacent current meter. Subsequent inspection of the data and overhauling clearly indicated that the entanglement took place during the recovery itself and did not affect the recording efficiency during the deployment.

In order to get a first impression of the flux magnitude, the sediment load in the cups were measured in mm. This is not a true particle flux in mg m^{-2} d^{-1}; however, it provides a rough estimate of the relative particle flux in this region. It turned out that East-01-Deep is characterized by a steady and varying particle flux over the deployment period with peak fluxes during the late NE monsoon (March 2008) and significant lower fluxes during the intermonsoons and SW-monsoon. Further biological and organic-geochemical analyses in our home laboratories will reveal if this flux pattern is a result of changing primary productivity rates or if the particle composition also indicates lateral (and thus resuspended) inputs from the adjacent continental margin. In comparison to this "regular" flux pattern, East-01-Shallow shows a very unusual flux record. The first two cups at the beginning of 2008 were almost completely filled; then the particle flux nearly ceased over the year. Such flux pattern is very unrealistic and would indicate technical problems. However, the log-files and electronic/mechanical inspection of the timer and motor unit did not reveal any problems or malfunctioning. Nonetheless, so far we attribute the flux rates of East-01 Shallow to some unknown technical problems.

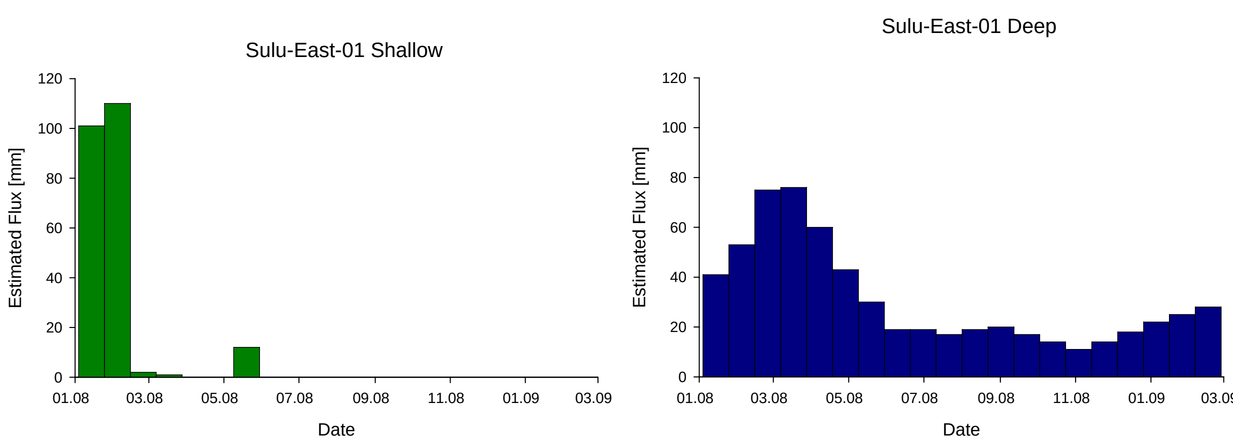


Fig. 3: Particle flux estimates at Sulu East-01 derived from trap cup loadings. It remains unclear if technical problems were responsible for the very unusual fluxes at East-01 Shallow.

3.2. Current Meters

The current meter data at Sulu-East-01 Shallow reveal a stable water mass throughout the deployment period. Generally, water temperature was slightly above 10.09 °C. Interestingly, the temperature only dropped but never increased. There were two short periods when the temperature decreased of about 0.02°C (late March 2008 and late January 2009) which is considered to be significant for deep water masses. Current speed averaged at about 1.5 cm s^{-1} with some minor increases during late March, beginning of June and beginning of November 2008. The first two current speed increases led to a decrease in temperature in contrast to the last one which apparently resulted in a temperature rise. The currents mostly directed to the north (NW to NE); there were only shorter periods when the currents significantly changed their direction. These changes coincided with slight increases in current speeds.

Compared to the shallow current meter, East-01-Deep recorded very stable conditions throughout the deployment. Temperatures varied at approx. 9.36-9.37 °C without any significant peaks up or down. The current speed was below the detection limit (1.10 cm s^{-1}) of the RCM-8. In contrast to the shallow record, the currents directed to the north until late August 2008 and then changed more to the south (SE to SW).

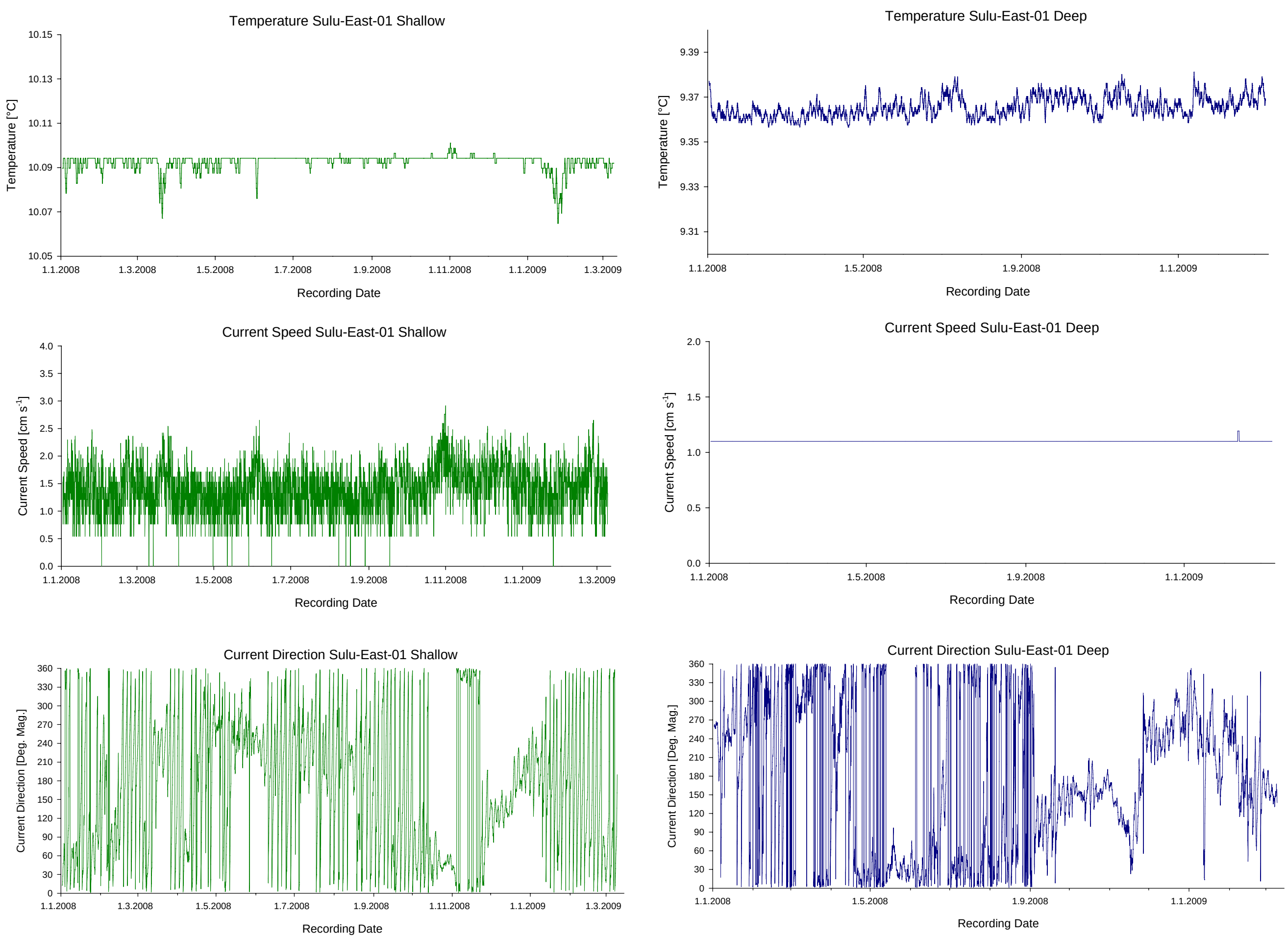


Fig. 4: Current Meter Data from Sulu East-01 Shallow (left) and Sulu East-01 Deep (right). Note that the current speed at East-01 Deep was below detection limit of 1.10 cm s^{-1}. All values are given as a 28-h-running-mean.

4. Sediment Trap Mooring Sulu-Central-01

4.1. Sediment Traps

The mooring was recovered on 14 March 2009 at CTD station 80. It was released at 09:15 local ship time. The topfloat came up in NE direction, directly in the sunlight at about 400 m distance so that it took about 40 min to find it. The system was hooked up at 10:15; recovery was completed at 12:38 when the release was retrieved on board.

Recovery procedure was carried out without any problems until the lower sediment trap (Sulu-Central-01-Deep). The 500 m wire above the sediment trap was severely entangled with the wire below the current meter. However, subsequent inspection of the data and overhauling clearly indicated that the entanglement took place during the recovery itself due to the mooring design with 2200 m wire between both sediment traps and due to the fact that the currents were very weak in this area. Apparently recording efficiency had not been biased during the deployment. The entanglement was so bad that one wire had to be cut during spooling.

Flux estimates were carried out in the same way as at Sulu-East-01. It turned out that Central-01-Shallow and Deep showed the same flux pattern over the deployment period; however, fluxes were significantly higher in the shallow trap. This deployment somehow represents a text-book like sediment trap study in the open ocean: Fluxes are always higher in shallower traps as particles disaggregate during their descent. In addition, peaks are “phase-delayed” (one cup difference between the shallow and deep trap) which is a result of the settling time between the upper and lower trap (sinking speed in the open ocean is considered to be between 50 and 300 m per day). All these indications lead to the conclusion that the deployment trapped the true vertical particle flux without any significant influence from lateral advection. Similar to Sulu East-01-Deep fluxes also peaked during the late NE-monsoon (February to March 2008) and were characterized by low fluxes throughout the rest of the year (SW-monsoon and intermonsoons) and a moderate increase in January 2009 again. Due to programming problems with the timer unit of Central-01-Shallow the last three cups at the end of the deployment period were not filled.

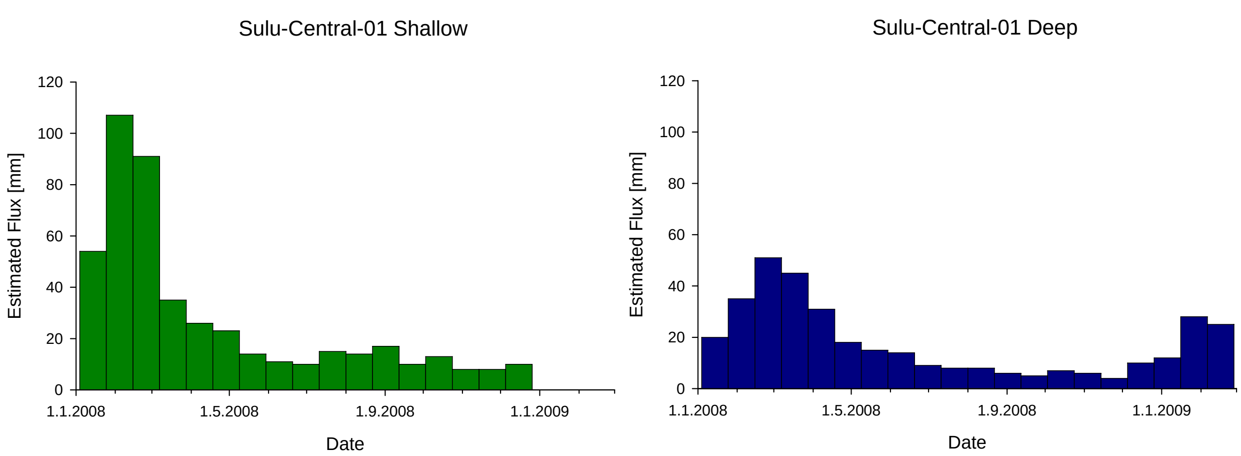


Fig. 5: Particle flux estimates at Sulu-Central-01 derived from trap cup loadings. Peak fluxes were recorded during late NE-monsoon. Sulu-Central-01 missed the last three rotation events due to a timer programming error.

4.2. Current Meters

The Aanderaa RCM-8 current meter data at Sulu-Central-01 Shallow revealed a very stable water mass throughout the deployment period; changes or variations were not observed. Generally, water temperature was slightly above 10.09 °C, very similar to East-01-Shallow deployed at the same water depth (about 1100 m). Fluctuations were less pronounced compared to the eastern part. A very small but steady temperature increase from December 2008 onwards could be detected; however, this rise was still less than 0.01°C and is thus difficult to be interpreted as a valid trend. Current speed at Central-01 Shallow is below the detection limit of 1.10 cm s^{-1} and significantly lower than at East-01-Shallow. The current flow mostly directed to the north (NW to NE) except for period between April and May 2008 where the mean direction was to the SE.

The RCM-8 current meter at Central-01-Deep recorded data only until 24 Feb 2008 due to a water leakage (or flood?) of the instrument. As a result the battery went out of power; fortunately, the data storage unit saved the recorded values until recovery as the instrument was not completely flooded. It remains very strange though why the instrument was only partially filled with water. Even a very thorough check of the instrument on board did not reveal the reason for the leak. For the recorded time period temperature variations were small but more pronounced than in the upper part. Unlike Central-01 Shallow or East-01 Deep, there were three short events within 6 weeks when the current speed significantly increased. These peaks, however, were not correlated to any prevailing current direction.

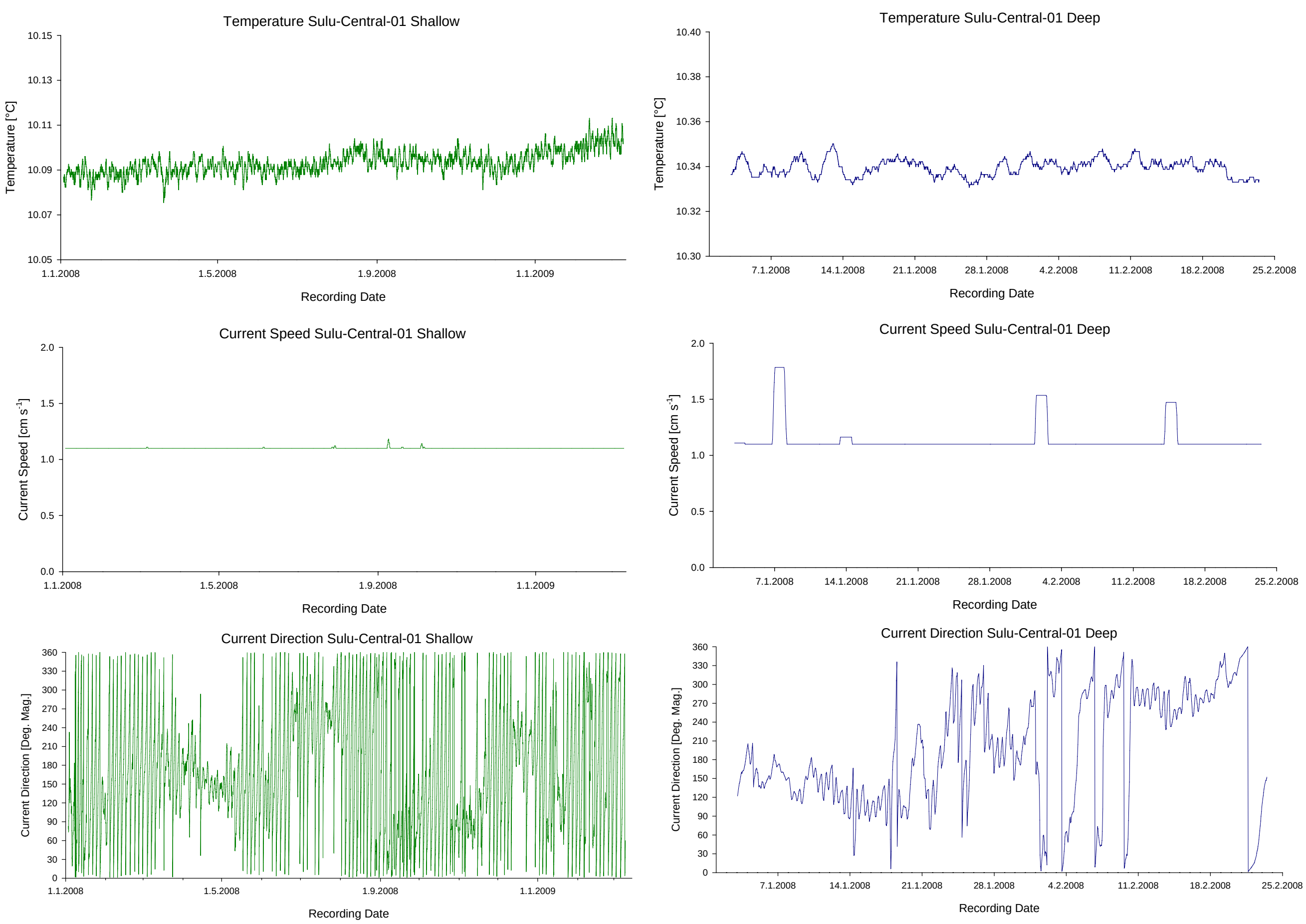


Fig. 6: Current Meter Data for Sulu Central-01 Shallow (left) and Sulu Central-01 Deep (right). Note that the detection limit for current velocities is 1.10 cm s^{-1}. All values are given as a 28-h-running-mean.