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Woods Hole Oceanographic Institution

Acoustics and Oceanographic Observations Collected During the QPE Experiment by Research Vessels OR1, OR2 and OR3 in the East China Sea in the Summer of 2009

by

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Technical Report

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John Trowbridge, Chair

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Abstract

This document describes data, sensors, and other useful information pertaining to the ONR sponsored QPE field program to quantify, predict and exploit uncertainty in observations and prediction of sound propagation. This experiment was a joint operation between Taiwanese and U.S. researchers to measure and assess uncertainty of predictions of acoustic transmission loss and ambient noise, and to observe the physical oceanography and geology that are necessary to improve their predictability. This work was performed over the continental shelf and slope northeast of Taiwan at two sites: one that was a relatively flat, homogeneous shelf region and a more complex geological site just shoreward of the shelfbreak that was influenced by the proximity of the Kuroshio Current. Environmental moorings and ADCP moorings were deployed and a shipboard SeaSoar vehicle was used to measure environmental spatial structure. In addition, multiple bottom moored receivers and a horizontal hydrophone array were deployed to sample transmission loss from a mobile source and ambient noise. The acoustic sensors, environmental sensors, shipboard resources, and experiment design, and their data, are presented and described in this technical report.

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1 Introduction

The Office of Naval Research (ONR) sponsored Quantifying, Predicting and Exploiting (QPE) Uncertainty initiative was a joint venture between Taiwanese and U.S. physical oceanographers and acousticians to study uncertainty in the prediction of acoustic propagation including ocean circulation. Along with the acoustics studies, shelfbreak processes were examined, which includes onshore transport of Kuroshio water onto the outer shelf as well as the Cold Dome structure over the shelf. The QPE program employed modeling and field observations over the continental shelf and slope to quantify and predict uncertainty in sound propagation. This manuscript will present and describe the acoustic and environmental data recorded during the QPE experiment conducted from research vessels R/V Ocean Researcher 1 (OR1) of National Taiwan University (NTU), R/V Ocean Researcher 2 (OR2) of National Taiwan Ocean University (NTOU), and R/V Ocean Researcher 3 (OR3) of National Sun Yat-Sen University (NSYSU) . Other components of this multi-institutional program will be addressed separately.

The main field work effort, or intense operations period (IOP), started the first week of June with a sub-bottom survey by the R/V OR2 to acquire bottom parameters useful for performing accurate sound propagation modeling. Due to severe weather problems at this time, this survey was only partially realized.

Two cruises, which included broad scale surveys by the R/V OR2 and R/V OR3, were performed to study the large scale hydrography in the area surrounding Taiwan and gather environmental data for initializing QPE ocean models. One survey was performed prior to the program's more intensive study effort and just after a major typhoon that devastated Taiwan. The other survey was performed during the middle of the Intense Operations Period (IOP).

The main, coordinated acoustics and oceanographic field work concentrated on two sites located in the designated study area Northeast of Taiwan (Figures 1.1 and 1.2). The first site visited, labeled Site B, was near the shelfbreak at ~130-140 meters water depth. It is a geologically complex area with numerous canyons and a wide range of sub-bottom properties. This area also contains dynamic oceanographic shelf and slope processes including variability associated with the Kuroshio. This was expected to be an area of high uncertainty. The second site, labeled Site A, which was further inshore and had a flatter bottom with water depths in the range of 110-115 meters. This site was chosen for its gentle topography and more subdued ocean environment for minimizing the uncertainties in acoustics performance prediction and providing a benchmark.

This work, which was performed from the R/V OR1 during the QPE experiment, was divided into two components: Leg1 (cruise #911) and Leg2 (cruise # 912). Leg 1 took place from 8/23/09 to 9/1/09 and Leg 2 took place from 9/04/09 to 9/12/09. For Leg 1, mobile acoustic source operations were deployed to establish baseline conditions for oceanography conditions and low frequency acoustic propagation. For Leg 2, both oceanographic data from the SeaSoar transects as well as regional model fields were used for adaptive sampling of the outer shelf and upper slope in order to quantify and exploit the uncertainty and ultimately to determine which processes contribute to uncertainty in the prediction of acoustic propagation.

Because of both high levels of fishing activity and the complicated bathymetry, NTU SeaSoar operations for mapping high-resolution hydrography were performed during the day when good visibility and maneuverability was required. During the evening, mobile acoustic sources were deployed, along with drifting sonobuoys, to measure transmission loss.

In addition to the scheduled mooring deployments and ocean monitoring activities, the Taiwanese research vessel OR1 volunteered to work as necessary to recover Scripps' Restrained Moorings or other instruments which might move out of the designated study area. During Leg1, the OR1 broke off acoustics operations to recover one of the Scripps' restrained drifters which was moving towards the boundary of the QPE area.

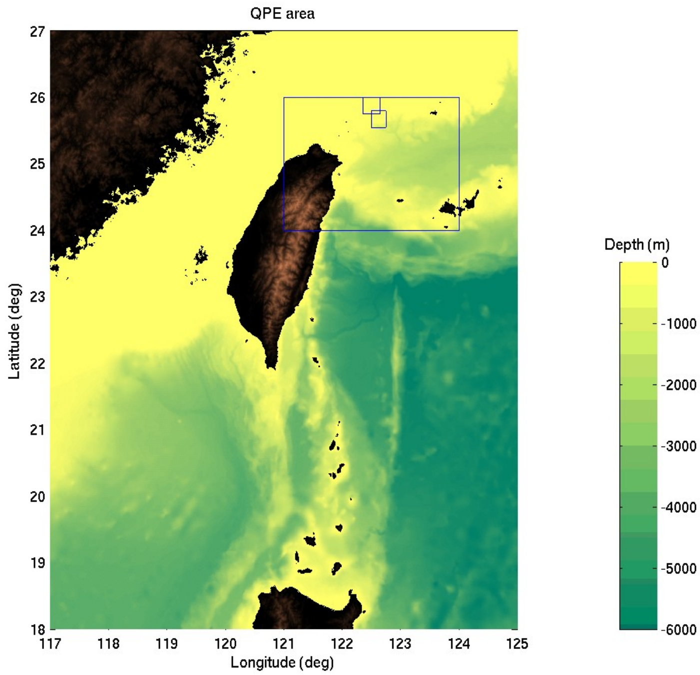


Figure 1.1. QPE area of study. Smaller boxes show areas for study sites A and B.

The cruise started ~2 weeks after Typhoon Morakot which brought torrential rains (2 m in 3 days) to southern Taiwan and caused over 1200 deaths. Logs, pieces of wood and debris washed out from the mainland, covering much of the ocean surface surrounding coastal Taiwan. This storm also freshened much of the surface water in the QPE area (see broad scale surveys and SeaSoar sections).

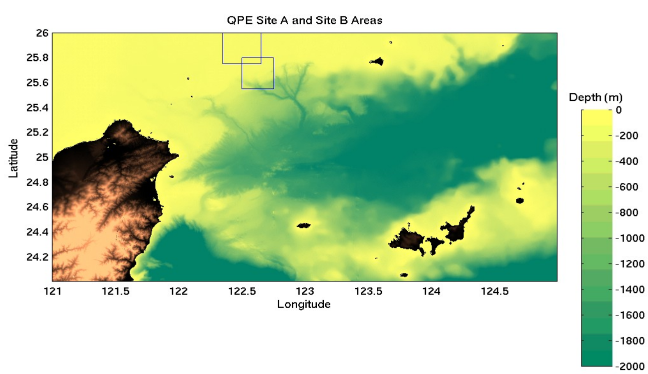


Figure 1.2. QPE area showing sites A and B. Site A is further north in a generally flat bottom location. Site B was located near the westernmost branch of the North Mien-Hua Canyon.

2 QPE experiment description

2.1 Fishing activity

A large number of boats (order 50-100), fishing for squids and hairtails, were gathered in the sea to the west of site B. Some of the fishing boats used a trawl net towed by a pair of fishing boats, called "tandem dragging". This technique is very efficient at catching most anything lying on the sea floor; and, as we were well aware, it is also good at catching oceanographic gear.

Site B had an overall medium level of fishing activity, but with a number of tandem bottom draggers (see Section 3.3). Site A had more fishing activity, in the form of squid boats, which use bright lights to draw the squid to shallow surface nets. This site was well lit at night, as were many others, as seen in a satellite picture, Figure 2.1.

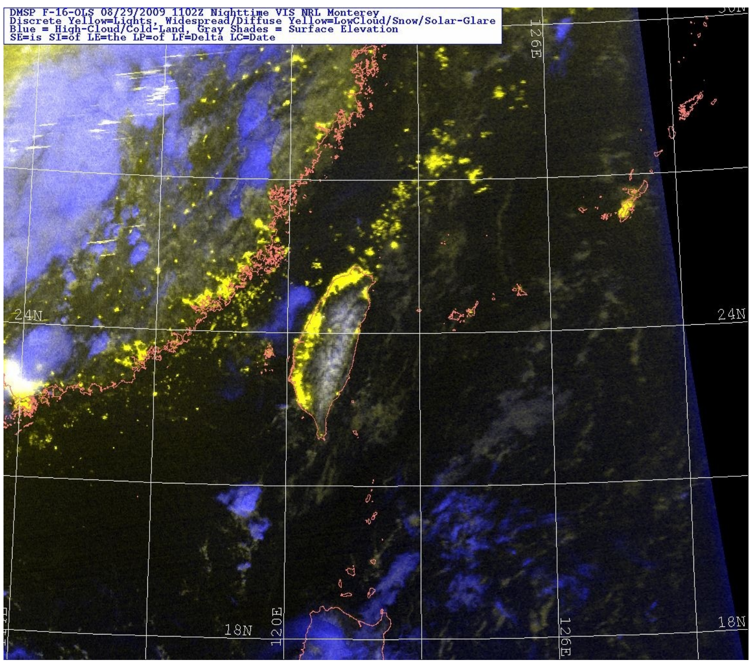


Figure 2.1: Satellite view of night lights showing squid fishing activity at the QPE area of study north of Taiwan (provided by B. Reeder, ONR).

2.2 Time convention

All instrumentation and sensors were set to Universal Time (UTC, denoted as Z). For convenience, shipboard log records were kept in local time. Also, some of the local, Taiwanese sensors were set to local time and will be specifically indicated and documented. To convert from UTC to local time in the Taiwan area, add 8 hours to UTC.

$$\text{Localtime} = \text{UTC} + 8$$

2.3 Geoacoustic and acoustic bottom survey, R/V OR2

Geo-acoustic work and the deployment of two acoustic receiver moorings were performed from the R/V Ocean Researcher 2 (OR2) of the National Taiwan Ocean University (NTOU) during the QPE experiment and were also divided into two components OR2-Leg1 (OR2 Cruise number 1639) and OR2-Leg2 (OR2 cruise number 1667). A short-term geo-survey and acoustic bottom survey were conducted in the northern region of North Mien-Hua Canyon (Figure 2.2). There was one short cruise (only two days from Aug1 to Aug 2) by OR2 called OR2-Leg1-A conducted in between Leg 1 and Leg 2 which deployed the NSYSU SHRU. More information about the NSYSU SHRU can be found in section 3.4.3. All standard OR2 ship sensors data, which includes the EK500 depth sensor, GPS position, and shipboard ADCP, were also stored and available.

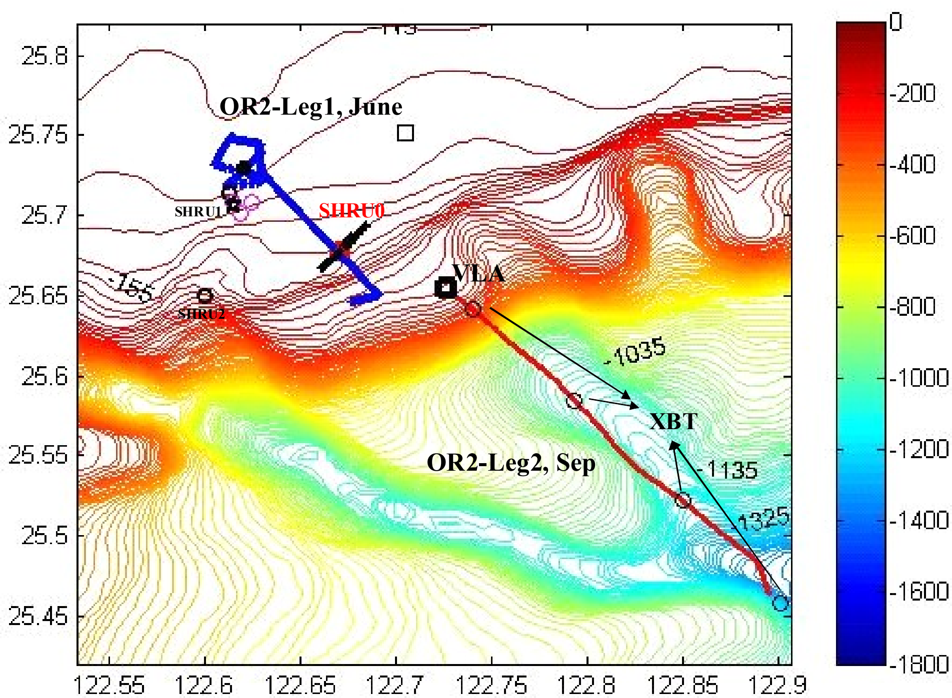


Figure 2.2: Blue line is the OR2 bottom survey track near the North Mien-Hua Canyon using the 'Boomer'. The black line is the chirp sonar bottom survey track near a WHOI SHRU and the red line is the J-9 acoustics source track. X axis is longitude (E) and Y axis is latitude (N). Bathymetry showing the canyon is included.

2.3.1 R/V OR2 Cruise no. 1639, Leg 1

OR2-Leg1 was performed from June 8th to June 12th, preceding the QPE intensive operations period (IOP). The cruise was to obtain an initial look at the geo-acoustic parameters in the bottom for inclusion into acoustic propagation modeling efforts and data analysis. The region of interest was in the Northeast region of Taiwan, with special emphasis on the shelf region of Northern Mien-Hua Canyon. Surveys by a 'Boomer' transducer and a sub-bottom profiler were the two main operations that were performed on this leg. A number of XBTs were also performed.

The boomer produces a sharp, repeatable "industry standard" single pulse and is deployed as a towed surface vehicle. It is ideal for inshore surveys for high resolution sediment analysis. During OR2-Leg1, the boomer was towed behind the OR2 on a heading into the current (at 3 knots) by two 6 meters ropes to avoid it from flying out of water surface. However, due to weather and high seas, only a portion of the operation was realized. It was towed on June 9th from 10:01 (local) to 12:40 (local). Figure 2.3 shows the pulse shape of the Boomer.

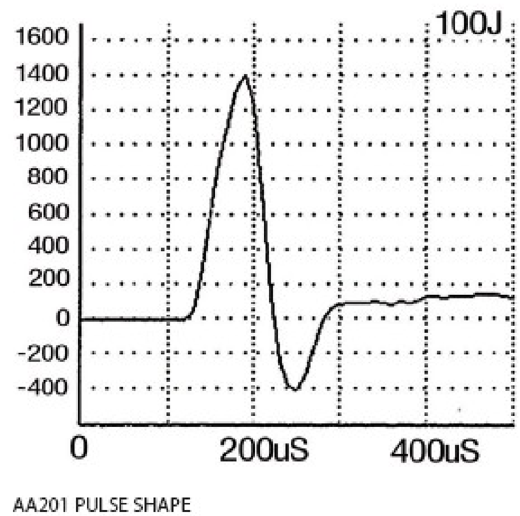


Figure 2.3. Pulse shape for the Boomer.

An Edge-Tech 3200-XS was used as a sub-bottom profiling system. It transmitted a linear frequency modulated (LFM) pulse from 500hz to 7.2kHz. The pulse length was set to 30 seconds and output power was approximately 190 dB per 1micropascal. It was deployed from June 8th at 19:00 (local) to June 9th at 06:30 (local). Figure 2.4 shows an image of the sub-bottom from that chirp survey.

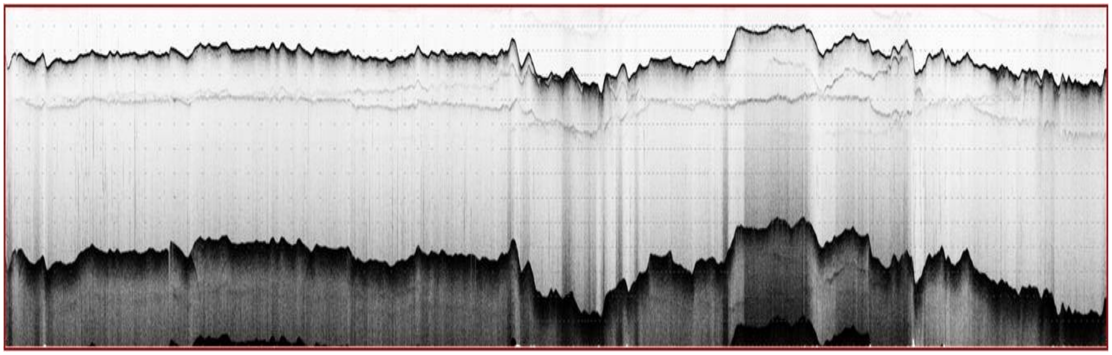


Figure 2.4: Data from chirp sonar on 22:06:10 on June 8th . Very clear sub-bottom layer were observed during the whole track

The following Table 1 provides the OR2-Leg1 participants.

Table 1. OR1-Leg1 participants

Name	Affiliation	Position
J.Y. Lou	CNA	PI
Linus Chiu	NTU	Post-doc
W. H. Ho	NTU	Senior Technician
Y. F. Ma	NTU	Senior Technician
Jan Dettmer	UVIC	Post-doc
S. L. Li	TORI	Technician
M. G. Tsai	NTU	Graduate student
C. Y. Wu	NSYSU	Graduate student

2.3.2 R/V OR2 Cruise no. 1667, Leg 2

OR2-Leg2 was performed from Sept. 4th to Sept 7th and was responsible for continuing the sub-bottom profiling, towing a J-9 source, and deploying a National Taiwan University (NTU) vertical line array (VLA). More information about the NTU VLA can be found in Section 3.5.3. Unfortunately, due to high waves and bad weather, only deployments of the the J-9 and the NTU VLA were achieved.

The signals transmitted by the J-9 towed source was a 3 second LFM sweep (350-450Hz), and M-sequences (Carrier is 400Hz with 100Hz band width). The J-9 was towed at ~3 knots from Sept. 5 at 23:25:40 to Sept. 6th at 03:30:00 (Figure 2.2). The two signals were transmitted at irregular intervals. The 400Hz carrier frequency m-sequence signal was designed using 4 cycles per digit, 2000Hz sampling frequency, and a mu law of 1473.

Participants in the OR2-Leg2 cruise are listed in the following Table 2.

Table 2. OR12-Leg2 participants

Name	Affiliation	Position
J.Y. Lou	CNA	PI
Linus Chiu	NTU	Post-doc
W. H. Ho	NTU	Senior Technician
S. D. Chiu	NTU	Senior Technician
Jan Dettmer	UVIC	Post-doc
M. G. Tsai	NTU	Graduate student
Y.X. Liu	NTU	Graduate student

2.3.3 XBT deployments, R/V OR2 Leg1 and 2

For OR2-Leg1, 5 XBT- probes were launched. One was launched in the first day and the other 4 probes were launched along the boomer track. Each XBT-probe was to monitor variation of sound speed in real time at each different location (Figure 2.5 and 2.6). The XBT probe deployed was type T-6 that is used for shallow water deployment. The locations of XBT data are along the boomer track which is shown in Figure 2.2.

Table 3. XBT stations from OR2-Leg1

Station	*Date*	*Time*	*Latitude*	*Longitude*	*Depth*
XBT-00010	*08-6-2009*	*20:41:00*	*25 43.560*	*122 38.140*	*125*
XBT-00011	*09-6-2009*	*11:26:00*	*25 41.093*	*122 40.587*	*157*
XBT-00012	*09-6-2009*	*11:53:00*	*25 40.623*	*122 40.190*	*160*
XBT-00013	*09-6-2009*	*12:33:00*	*25 40.183*	*122 39.807*	*160.7*
XBT-00014	*09-6-2009*	*12:35:00*	*25 40.295*	*122 40.768*	*162*

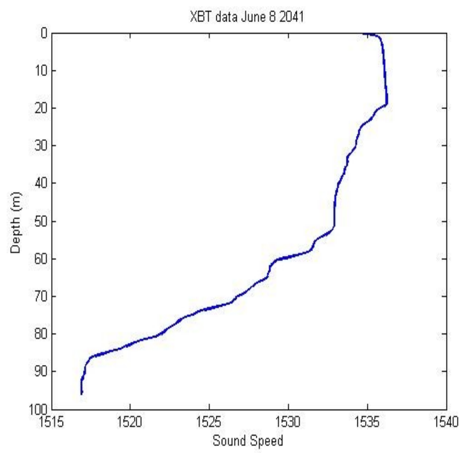


Figure 2.5: Sound speed from XBT performed on June 8th during Boomer operations.

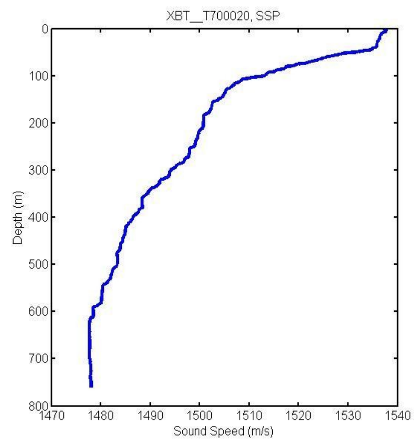


Figure 2.6 Deep XBT during OR2-Leg2

For OR2-Leg2, XBT probes were launched while the acoustic track was conducted. These 4 probes were launched along the canyon. The type of the XBT chosen were T-5, T-6 and T-7 and were selected for different local depths of the canyon. The deepest local depth along this track is 1850 meters, in which sound speed profile was successfully collected by the last launch of a T-5 probe on Sept. 6 at 03:15 (local time).

Table 4. XBT stations from OR2-Leg2

Station	Date	Time (local)	Latitude	Longitude
XBT-00015	05-9-2009	23:32:00	25 38.487	122 44.385
XBT-00017	06-9-2009	00:51:05	25 35.070	122 47.598
XBT-00020	06-9-2009	02:15:00	25 31.323	122 50.973
XBT-00022	06-9-2009	02:55:00	25 27.510	122 54.013

2.4 Large scale hydrography survey, R/V OR2 and R/V OR3

In order to provide a large-scale hydrographic conditions for modeling and examine the shelf conditions before further operations, two joint surveys using Ocean Researcher (OR) 2 and 3 were conducted during August 13 to August 17 (OR2&3-Leg 1) and August 27 to September 1 (OR2&3-Leg 2). A total of 85 CTD casts were completed during the two legs. More information about the CTD casts can be found in Section 2.4.1. Figure 2.7 shows the cast locations. The stations measured by OR2 are denoted by “C” and those by OR3 are denoted by “S”. The CTD and along-track ship-board ADCP data were prepared in ascii format for analysis. The two surveys unexpectedly observed the variation of a freshwater plume caused by a typhoon-induced torrential rain.

One week before OR2&3-Leg 1, a category 2 typhoon named Morakot transversed across central Taiwan and stalled over southern Taiwan for 2 days (8-9 August). The typhoon brought record-breaking torrential rains in the southern half of Taiwan Island with accumulated precipitation peaking at 4000 mm within two days. Figure 2.8 shows the typhoon track and rainfall of Morakot during 3-10 August. Most of the rain was gathered into rivers that discharged into the Taiwan Strait on the southwestern coast of Taiwan. River runoff monitoring stations on the Jhoushuei River recorded a peak runoff of ~18000 m^3/s during the typhoon (Figure 2.9). The Jhoushuei River is the largest river in central Taiwan and its runoff typically ranges between 50 to 200 m^3/s. Roughly estimated, the total volume of the freshwater during this period was ~32 km^3 which is similar to a volume of pouring a 1 meter thick layer of freshwater over the entire area of Taiwan (~35000 km^2). The freshwater plume caused by the typhoon Marakot was clearly captured during the OR2&3-Leg 1 survey.

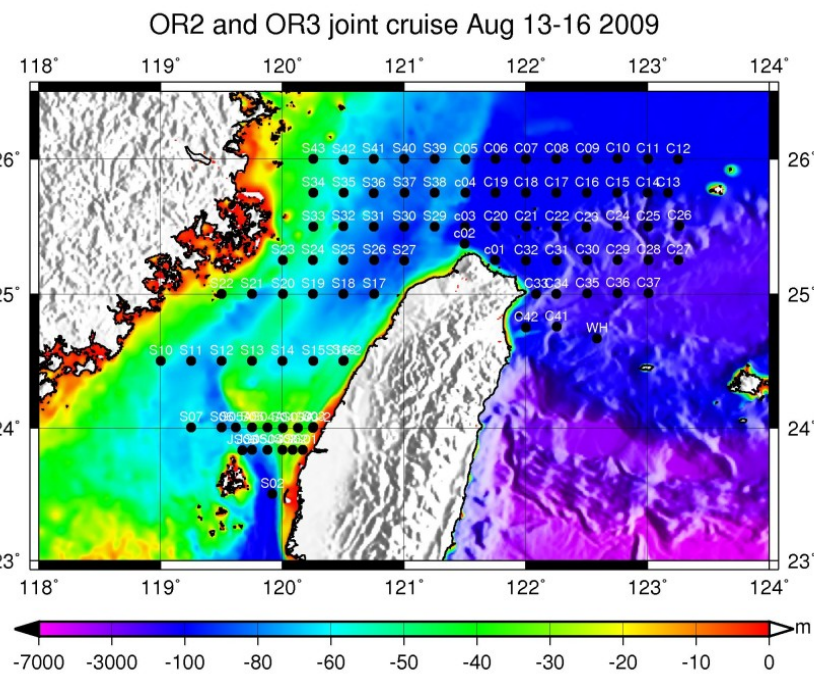


Figure 2.7: Bathymetry and location of CTD casts for the large scale hydrographic survey.

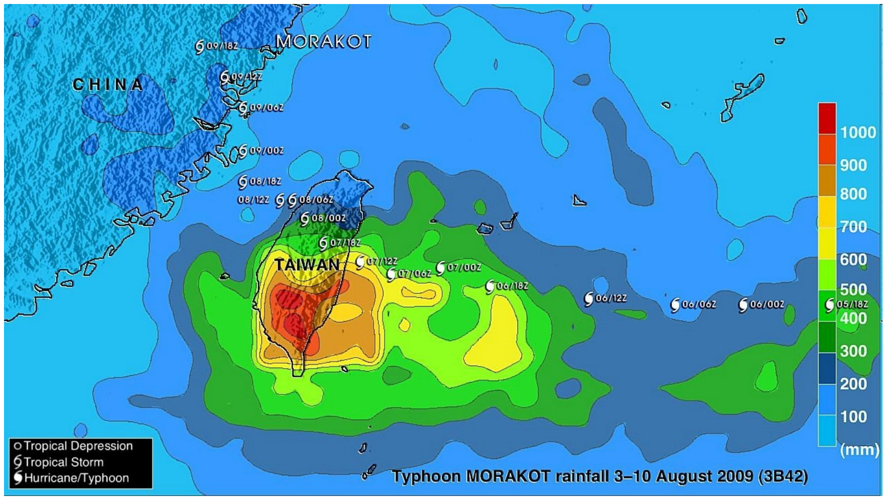


Figure 2.8: Typhoon track and rainfall of Morakot during 3-10 August 2009 (http://www.nasa.gov/mission_pages/hurricanes/archives/2009/h2009_Morakot News.html).

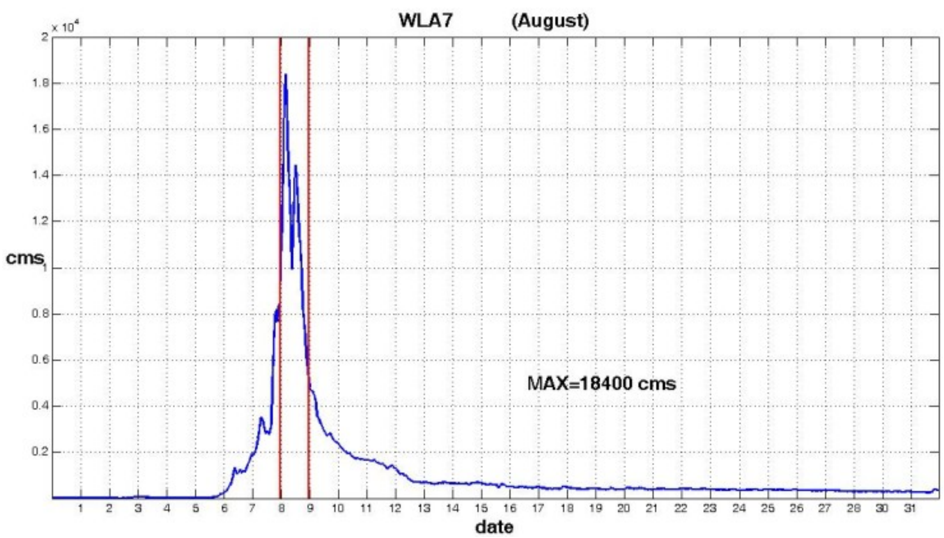


Figure 2.9: Hourly runoff recorded at Jhoushuei River in August 2009. The two vertical lines mark the period that Typhoon Morakot went across Taiwan.

Table 5. Shipboard data obtained by large scale hydrographic surveys using OR2 and OR3

Leg	R/V-Cruise no.	Number of CTD casts.	Range of sb-ADCP	Range of EK-500	Chief PI
1	OR2-1660	40	590 nm	590 nm	Y.-J. Yang
	OR3-1390	49	906 nm	906 nm	S. Jan
2	OR2-1665	42	613 nm	613 nm	J. Wang
	OR3-1394	37	853 nm	853 nm	T.-C. Liu

2.4.1 CTD casts, OR2 and OR3 Leg1

The cruise tracks for OR2 (Figure 2.10 and 2.12) and OR3 (Figure 2.11 and 2.13) during OR2&3-Leg 1 and Leg2 are shown below. Tables 6 and 7 summarize the shipboard CTD casts performed during the two legs.

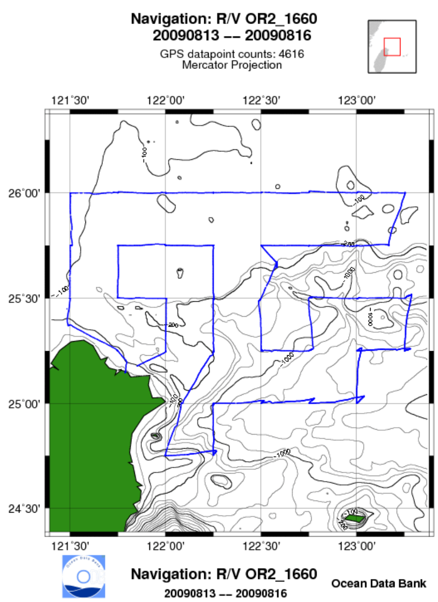


Figure 2.10: Cruise track for OR2 during OR2/OR3-Leg1.

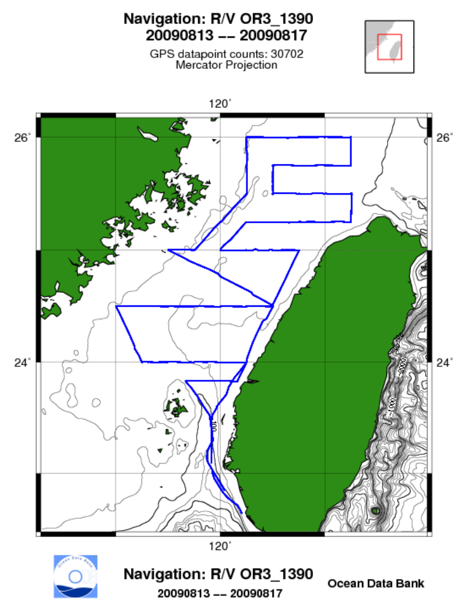


Figure 2.11: Cruise track for OR3 during OR2/OR3-Leg1.

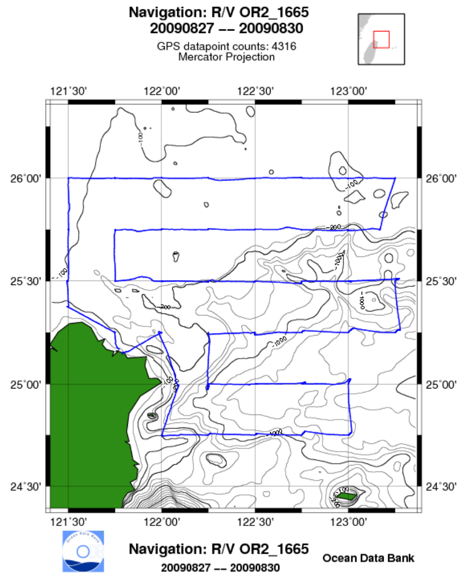


Figure 2.12: Cruise track for OR2 during OR2/OR3-Leg2.

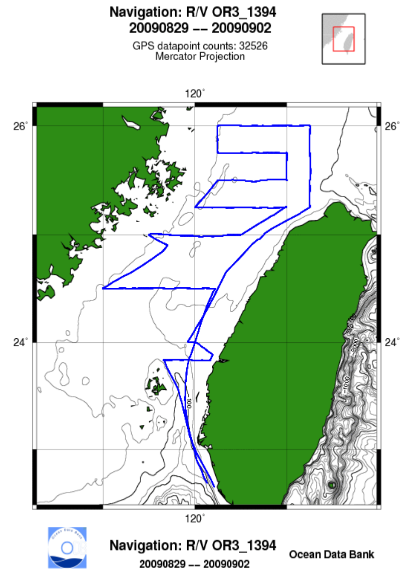


Figure 2.13: Cruise track for OR3 during OR2/OR3-Leg2.

Table 6. Location, bottom depth and maximum deployed depth for each CTD cast during OR2&3-Leg 1 (OR2-1660 & OR3-1390).

No.	*Station*	*Longitude(E)*	*Latitude(N)*	*Bottom depth (m)*	*CTD max depth (m)*
1	JS01	120.1664	23.8324	22.0	20
2	JS02	120.0845	23.8337	36.2	34
3	JS03	120.0013	23.8333	36.9	32
4	JS04	119.8752	23.8328	66.7	61
5	JS05	119.75	23.8338	78.1	73
6	JS06	119.6685	23.8309	76.4	70
7	S02	119.9178	23.5032	124.5	106
8	S03	120.2535	24.0045	24.5	20
9	S03-2	120.2513	23.9986	25.0	23
10	S03A	120.1260	23.9996	39.0	36
11	S04	120.0021	23.9999	46.2	42
12	S04A	119.8774	24.0023	50.0	46
13	S05	119.7513	24.0023	53.5	49
14	S05A	119.6178	24.0016	69.3	64
15	S06	119.5005	24.0029	65.0	60
16	S07	119.2509	24.0007	59.3	55
17	S10	119.0010	24.5001	56.7	51
18	S11	119.2505	24.5007	65.1	60
19	S12	119.5004	24.4999	70.0	66
20	S13	119.7485	24.5005	50.5	46
21	S14	120.0010	24.4993	66.5	62
22	S15	120.2529	24.4989	61.0	56
23	S16	120.5040	24.5030	58.6	54
24	S16-2	120.5005	24.5004	57.0	53
25	S17	120.7523	24.9993	78.5	73
26	S18	120.5005	24.9997	79.9	75

27	S19	120.2494	24.9999	61.6	57
28	S20	120.0020	24.9994	58.5	53
29	S21	119.7489	25.0006	71.9	69
30	S22	119.5002	25.0002	28.0	24
31	S23	120.0024	25.2502	62.0	57
32	S24	120.2504	25.2501	58.2	53
33	S25	120.5000	25.2503	76.6	72
34	S26	120.7536	25.2501	86.0	81
35	S27	120.9992	25.2475	89.0	80
36	S29	121.2501	25.5012	73.0	70
37	S30	121.0000	25.5005	94.6	90
38	S31	120.7504	25.4995	82.8	78
39	S32	120.5011	25.5016	68.6	66
40	S33	120.2529	25.4991	56.8	51
41	S34	120.2517	25.7505	55.3	51
42	S35	120.5025	25.7495	68.7	64
43	S36	120.7498	25.7486	78.0	73
44	S37	121.0026	25.7511	86.0	82
45	S38	121.2515	25.7504	80.0	76
46	S39	121.2499	25.9999	83.9	79
47	S40	121.0012	26.0008	82.9	77
48	S41	120.7487	25.9994	75.0	70
49	S42	120.5042	25.9960	68.0	57
50	S43	120.2523	26.0010	50.0	46
51	C01-1	121.7482	25.2515	96.0	90
52	C02-1	121.4963	25.3729	78.0	70
53	C03-1	121.4995	25.4996	121.0	110
54	C04-1	121.5047	25.7506	85.0	80
55	C05-1	121.5017	25.9991	73.0	68
56	C06-1	121.7507	26.0009	119.0	110
57	C07-1	122.0005	26.0002	106.0	100
58	C08-1	122.2498	25.9998	105.0	100
59	C09-1	122.5017	26.0007	112.0	105
60	C10-1	122.7518	26.0032	121.0	110
61	C11-1	123.0025	26.0007	101.0	90
62	C12-1	123.2514	25.9989	127.0	115
63	C13-1	123.1682	25.7507	130.0	120
64	C14-1	123.0005	25.7499	335.0	320
65	C15-1	122.7504	25.7497	139.0	130
66	C16-1	122.4996	25.7497	118.0	110
67	C17-1	122.2504	25.7513	119.0	110
68	C18-1	122.0000	25.7510	119.0	110
69	C19-1	121.7509	25.7499	119.0	110
70	C20-1	121.7502	25.5009	118.0	110
71	C21-1	122.0022	25.4990	123.0	115
72	C22-1	122.2520	25.4983	270.0	220
73	C23-1	122.4964	25.4946	414.0	400
74	C24-1	122.7525	25.5014	1200.0	1000
75	C25-1	123.0027	25.4992	794.0	750
76	C26-1	123.2593	25.5048	721.0	700
77	C27-1	123.2537	25.2506	1735.0	1000
78	C28-1	123.0052	25.2525	1657.0	1000
79	C29-1	122.7525	25.2513	1327.0	1000
80	C30-1	122.5020	25.2505	788.0	750
81	C31-1	122.2519	25.2496	223.0	210
82	C32-1	122.0010	25.2486	147.0	135
83	C33-1	122.0845	25.0004	233.0	210
84	C34-1	122.2501	24.9981	970.0	900
85	C35-1	122.5027	25.0017	1404.0	1000
86	C36-1	122.7549	25.0045	1521.0	1000
87	C37-1	123.0073	25.0046	1634.0	1000

88	C41-1	122.2528	24.7550	334.0	300
89	C42-1	122.0008	24.7502	101.0	90

Table 7. Location, bottom depth and maximum deployed depth for each CTD cast during OR2&3-Leg 2 (OR2-1665 & OR3-1394)

No.	*Station*	*Longitude(E)*	*Latitude(N)*	*Bottom depth (m)*	*CTD max depth (m)*
1	JS1D	120.1653	23.8328	22.0	19
2	JS2D	120.0828	23.8327	36.0	32
3	JS3D	119.9990	23.8323	36.0	31
4	JS4D	119.8753	23.8352	66.0	62
5	JS5D	119.7505	23.8352	77.0	71
6	JS6D	119.6656	23.8330	81.0	76
7	S01D	119.9974	23.0069	84.0	80
8	S02D	119.8337	23.5010	112.0	105
9	S04D	120.0013	23.9998	45.0	41
10	S10D	119.0010	24.5009	60.0	57
11	S11D	119.2491	24.4992	66.0	63
12	S12D	119.4972	24.5010	71.0	66
13	S13D	119.7486	24.4972	47.0	42
14	S14D	119.9980	24.4983	63.0	57
15	S17D	120.7524	25.0012	82.0	77
16	S18D	120.4971	24.9962	81.0	77
17	S23D	119.9994	25.2509	63.0	58
18	S24D	120.2484	25.2484	56.0	50
19	S25D	120.4975	25.2503	74.0	69
20	S26D	120.7480	25.2498	85.0	80
21	S27D	120.9946	25.2540	87.0	81
22	S28D	121.2497	25.2516	70.0	66
23	S29D	121.2494	25.5018	76.0	71
24	S30D	120.9979	25.5014	94.0	88
25	S31D	120.7474	25.5022	83.0	79
26	S32D	120.4985	25.5016	68.0	64
27	S33D	120.2503	25.4995	57.0	53
28	S34D	120.2497	25.7506	53.0	49
29	S35D	120.4995	25.7507	67.0	62
30	S36D	120.7471	25.7502	76.0	71
31	S37D	120.9952	25.7502	85.0	80
32	S38D	121.2485	25.7506	79.0	75
33	S39D	121.2498	25.9986	84.0	79
34	S40D	120.9946	26.0012	82.0	76
35	S41D	120.7458	26.6658	76.0	71
36	S42D	120.5002	25.9986	64.0	60
37	S43D	120.2494	26.0000	50.0	45
38	C01-1	121.7493	25.2512	95.0	89
39	C02-1	121.4972	25.3752	79.0	77
40	C03-1	121.4971	25.5006	119.0	111
41	C04-1	121.4994	25.7502	82.0	79
42	C05-1	121.4997	26.0000	72.0	66
43	C06-1	121.7488	26.0011	118.0	111
44	C07-1	122.0000	26.0011	105.0	101
45	C08-1	122.2496	26.0006	105.0	102
46	C09-1	122.4992	25.9987	111.0	106
47	C10-1	122.7494	26.0009	118.0	111
48	C11-1	122.9982	25.9990	101.0	95
49	C12-1	123.2505	26.0000	124.0	111
50	C13-1	123.1669	25.7501	132.0	127

51	C14-1	122.9986	25.7485	272.0	232
52	C15-1	122.7497	25.7507	139.0	131
53	C16-1	122.4999	25.7511	119.0	112
54	C17-1	122.2503	25.7522	119.0	111
55	C18-1	121.9993	25.7513	120.0	111
56	C19-1	121.7497	25.7496	117.0	111
57	C20-1	121.7495	25.5008	115.0	106
58	C21-1	122.0009	25.5002	123.0	114
59	C22-1	122.2499	25.4989	308.0	251
60	C23-1	122.4976	25.4976	427.0	401
61	C24-1	122.7499	25.4982	1059.0	951
62	C25-1	123.0016	25.4993	795.0	771
63	C26-1	123.2525	25.5035	754.0	701
64	C27-1	123.2523	25.2518	1741.0	1001
65	C28-1	123.0019	25.2528	1659.0	1007
66	C29-1	122.7517	25.2525	1313.0	1004
67	C30-1	122.4998	25.2495	798.0	771
68	C31-1	122.2509	25.2485	218.0	202
69	C32-1	121.9986	25.2488	147.0	141
70	C33-1	122.0891	24.9908	275.0	261
71	C34-1	122.2494	24.9995	968.0	951
72	C35-1	122.5019	24.9994	1492.0	1001
73	C36-1	122.7514	25.0018	1521.0	1050
74	C37-1	123.0009	25.0023	1623.0	1001
75	C38-1	123.0018	24.7509	1613.0	1001
76	C39-1	122.7520	24.7524	1367.0	1001
77	C40-1	122.5014	24.7517	1049.0	951
78	C41-1	122.2510	24.7519	335.0	301
79	C42-1	122.0019	24.7489	114.0	101

2.4.2 Oceanographic observations from OR2 and OR3 Leg1

The joint OR2 and OR3 hydrographic surveys were performed ~1 week after typhoon Morakot. Figure 2.14a shows the T-S diagram plotted with the CTD data obtained by OR2&3-Leg 1. The characteristic T-S curve of the Kuroshio water (KW), the South China Sea water (SCS) and the East China Sea water (ECS) were plotted for reference. The water mass in the sea northeast of Taiwan is normally mixed with the KW, ECS, SCS and Taiwan Strait water masses and its salinity normally ranges from 33 to 34.8 and temperature ranges from 15˚C at ~200 m depth to 29˚C at the surface. Looking at the T-S diagram, the brackish water enclosed by a blue polygon originated from the freshwater plume brought by typhoon Morakot. The diluted water must have come from the rivers in the southwest coast of Taiwan, mixed with ambient seawater by tidal currents, and carried northward along the west coast of Taiwan by the mean flow in the Taiwan Strait. Figure 2.15 shows temperature and salinity distributions at 5 m depth. The bulge of the typhoon-induced brackish warm water was found off the northern tip of Taiwan. The salinity was as low as 32 around the northwestern tip of Taiwan. Since the runoff was modest for the rivers in the northern Taiwan, this freshwater source must have originated from the southwest coast of Taiwan. Considering the mean flow velocity of the northward Taiwan Strait current, ~0.5 m/s, and a transit time scale of about 5 days, this freshwater meandered ~215 km upstream, which is the estimated distance from the observed brackish water to its potential source region. Without a doubt, this unusual brackish warm water brought sizable baroclinic effect to the circulation and physical processes such as internal waves, velocity vertical shears, etc., in the sea northeast of Taiwan. The detided (barotropic tide) ADCP measured current velocity is also shown on the Figure 2.15 for reference. Figure 2.15 further shows temperature and salinity distributions at 100 m depth. The cold and saline water occupying the shelf and slope north and northeast of Taiwan mostly originated from the Kuroshio. A northeast-southwestward Kuroshio temperature front was also observed off the shelf break.

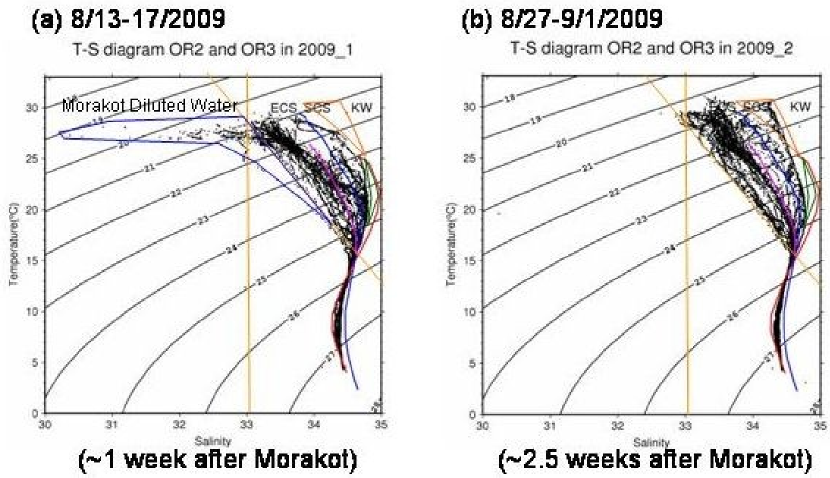


Figure 2.14: T-S diagrams plotted with CTD data obtained by (a) OR2&3-Leg 1 and (b) OR2&3-Leg 2.

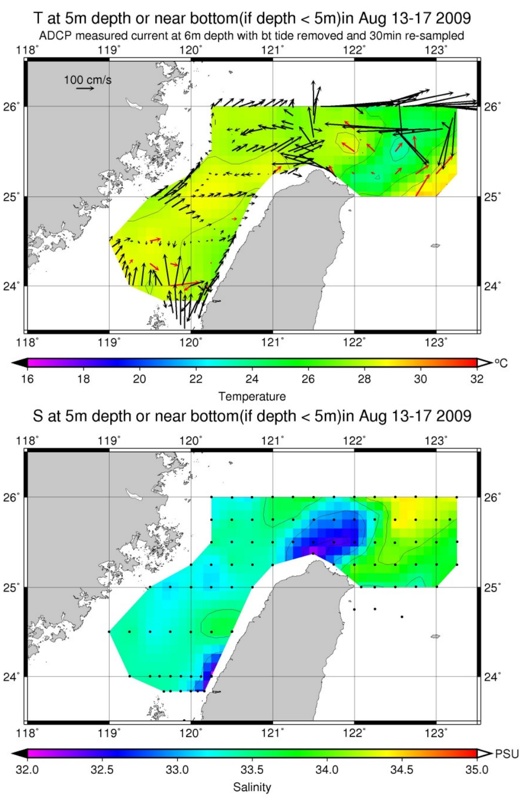


Figure 2.15: T and S distributions at 5 m depth for OR2&3-Leg 1.

2.4.3 Oceanographic observations from OR2 and OR3 Leg2

About 1.5 weeks after OR2&3-Leg 1 (2.5 weeks after Morakot), OR2&3-Leg 2 were conducted and were completed by September 1. The CTD-derived T-S diagram in Figure 2.14b shows that the water mass in the upper 200 m layer differs significantly from that in Figure 2.14a. The Morakot-caused brackish water almost disappeared. Instead, a patch of warmer and more saline water appeared in the upper layer. Inspection of the upper layer temperature and salinity distributions shown in Figure 2.16 indicates that there was a small patch of brackish water centered at 122.3˚E and 25.6˚N. Since the residence time there was one week or so, the brackish water patch may be not correlated directly to the primary freshwater plume. The high salinity and high temperature water appearing on the T-S diagram seemingly existed in the east of the observation box appears as a wavelike feature. Figure 2.17 illustrates temperature and salinity distributions at 100 m depth for OR2&3-Leg 2. The high salinity cold water still existed in the northeast region. In comparison with Figure 2.15, the Kuroshio path moved more landward than in OR2&3-Leg 1.

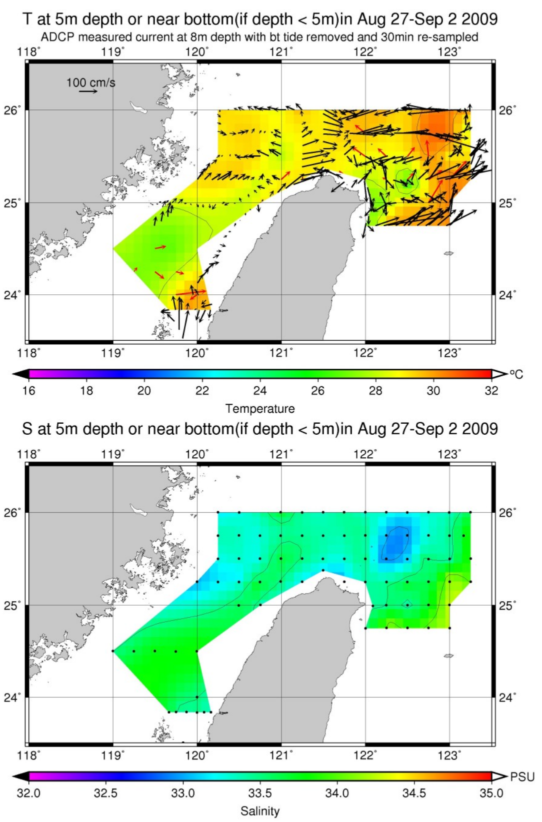


Figure 2.16: T and S distributions at 5 m depth for OR2&3-Leg 2.

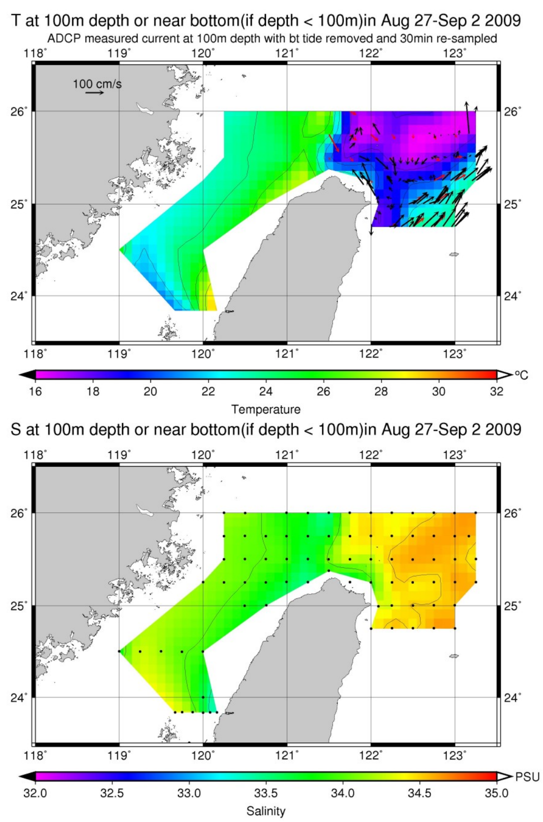


Figure 2.17. T and S distributions at 100 m depth for OR2&3-Leg

2.4.4 Hydrographic transects from OR2&3-Legs 1 and 2

Figure 2.18 shows T, S, and σt distributions obtained during the two legs at a meridional transect 122.5˚E. By comparison, the location of the upwelled domelike cold water in the upper 100 m layer differs during the two periods, suggesting the complexity of the so-called Cold Dome. Figures 2.19 and 2.20 show T, S, and σt distributions obtained during the two legs along a zonal transect 25.5˚N. The warm brackish water in the surface layer and the cold saline water uplifted from ~250 m depth (Figure 2.19 formed a strong density front on the shelf break. A sizable thermal wind must be present and in turn may modify the local circulation. The strength of the front weakened in the second leg (Figure 2.20). Similar to Figure 2.18, the locations of the cold dome looked different between the two legs on this zonal transect. The complexity of the upwelling warrants a thorough analysis of the hydrographic data.

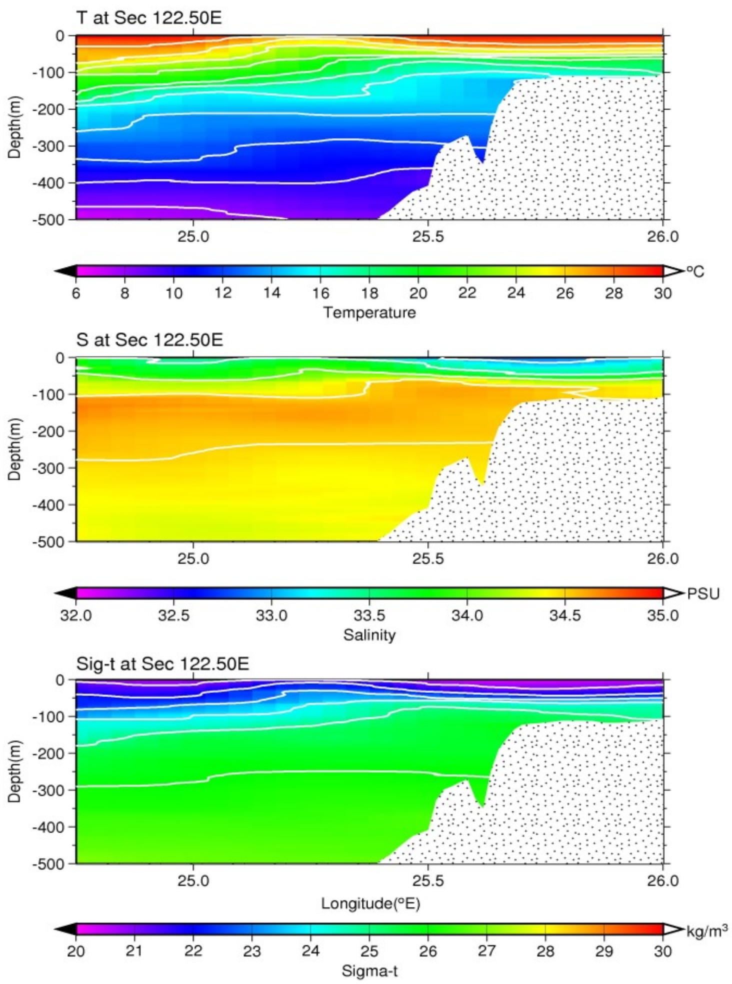


Figure 2.18: T, S, and σ_t distributions at a meridional transect 122.5˚E for OR2&3-Legs 1 (left) and 2 (right).

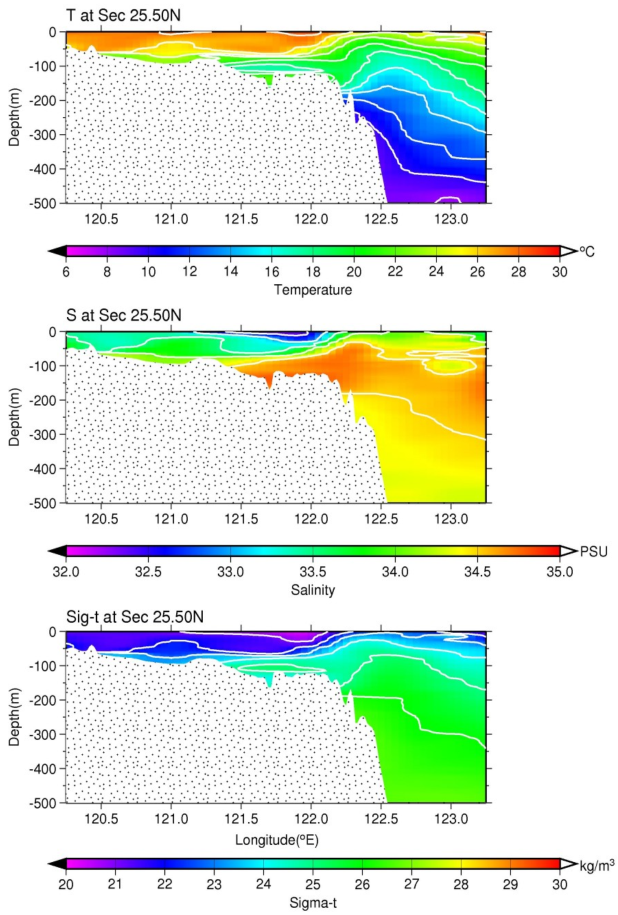


Figure 2.19: T, S, and σ_t distributions at a zonal transect 25.5°N for OR2&3-Leg 1.

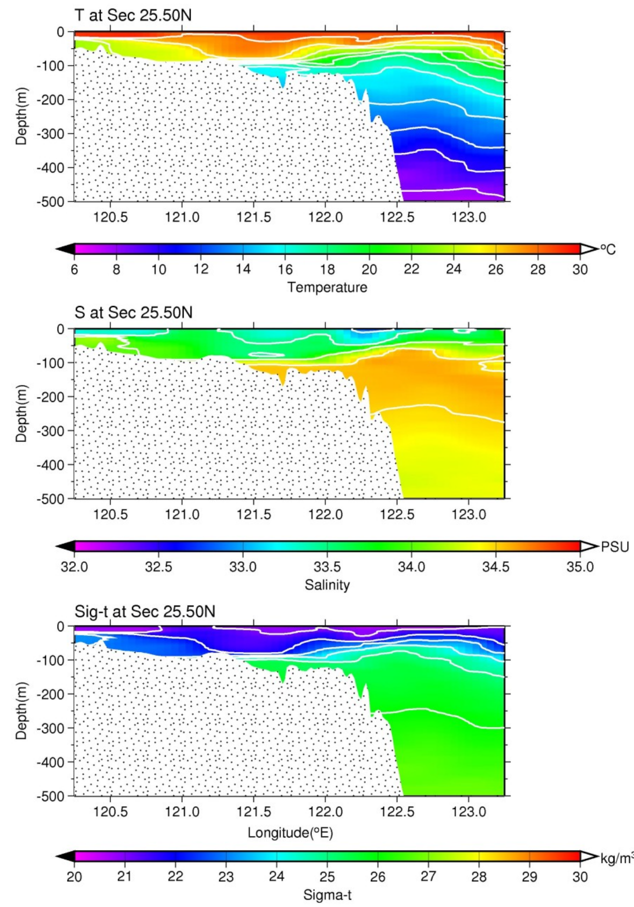


Figure 2.20: T, S, and σ_t distributions at a zonal transect 25.5°N for OR2&3-Leg 2.

2.4.5 SVP Drifters, OR2 and OR3 Leg1

Forty four Surface Velocity Program (SVP) drifters, provided by Scripps Institution of Oceanography (SIO) , were deployed using the R/V OR1 and R/V OR2 as part of the large hydrography survey. The SVP drifters are designed to track mean currents at a fixed depth beneath the ocean surface. The key elements of a drifter include the drogue, the surface float and the connecting tether. The drogue is the drag element locking the drifter to a parcel of water and in this case was set to 15 meters depth. The surface float contains the telemetry system, antenna, batteries, and sensors which will telemeter position using an installed GPS receiver.

Table 8 lists the locations and times for each drifter deployment. The ID number of each SVP drifter is also listed for identification (Figure 2.21). Figure 2.22 shows drifter trajectories during August 15th to August 30th. From Figure 2.22, we see that the drifters deployed in the northern Taiwan Strait moved towards the East China Sea and hugged the northern coast of Taiwan. The drifters that met the west flank of the Kuroshio Current were carried by the Kuroshio to the northeast.

Table 8. Time, location and drifter ID# of each deployment during OR2&3-Leg 2 (OR2-1665 & OR3-1394)

no	Sta	ID	Time(UTC)	Lon(E)	Lat(N)
SVP drifter deployed by OR3-1390					
01	S41	82029	08/14/2009 12:41	120 45.233	26 00.041
02	S40	91687	08/14/2009 13:55	121 00.204	26 00.120
03	S39	82037	08/14/2009 15:15	121 15.033	26 00.004
04	S38	83556	08/14/2009 16:51	121 15.089	25 45.024
05	S37	82023	08/14/2009 18:10	121 00.149	25 45.103
06	S36	82008	08/14/2009 19:31	120 44.923	25 44.931
07	S35	82025	08/14/2009 20:56	120 30.284	25 44.970
08	S32	82024	08/14/2009 22:33	120 30.297	25 30.204
09	S31	82022	08/14/2009 23:48	120 45.253	25 29.986
10	S30	82026	08/15/2009 01:01	121 00.294	25 30.120
11	S29	82006	08/15/2009 02:11	121 15.382	25 30.271
12	S28	82010	08/15/2009 03:55	121 15.034	25 14.930
13	S27	91684	08/15/2009 05:28	121 00.078	25 14.853
14	S26	82039	08/15/2009 06:56	120 45.305	25 15.012
15	S25	82032	08/15/2009 08:25	120 30.117	25 15.026
16	S20	82012	08/15/2009 11:52	120 00.261	24 59.960
17	S19	82021	08/15/2009 13:07	120 15.105	24 59.925
18	S18	82035	08/15/2009 14:27	120 30.167	24 59.926
19	S17	91679	08/15/2009 15:46	120 45.284	24 59.940
SVP drifter deployed by OR2-1660					
no	Sta	ID	Time(UTC)	Lon(E)	Lat(N)
01	C01	82030	08/13/2009 02:26	121 44.913	25 15.068
02	C02	91688	08/13/2009 03:56	121 29.819	25 22.391
03	C03	82033	08/13/2009 05:06	121 29.987	25 09.980
04	C04	91681	08/13/2009 06:52	121 30.244	25 45.034
05	C05	91675	08/13/2009 08:46	121 30.063	25 59.939
06	C06	91680	08/13/2009 10:08	121 45.026	26 00.031
07	C07	82034	08/13/2009 11:39	122 00.007	26 00.015
08	C08	82002	08/13/2009 13:15	122 14.987	25 59.978
09	C09	91677	08/13/2009 14:42	122 30.078	26 00.029
10	C10	91676	08/13/2009 16:08	122 45.079	26 00.144
11	C11	91686	08/13/2009 17:45	123 00.124	26 00.017
12	C12	82004	08/13/2009 19:21	123 15.062	25 59.936
13	C13	82001	08/13/2009 21:46	123 10.081	25 45.022
14	C14	82027	08/13/2009 23:02	123 00.030	25 45.005
15	C15	81999	08/14/2009 00:48	122 45.026	25 44.991
16	C16	91685	08/14/2009 02:27	122 29.968	25 44.972
17	C34	91689	08/15/2009 14:06	122 14.991	24 59.898
18	C42	41867	08/15/2009 19:12	122 00.050	24 45.033
19	C33	82028	08/15/2009 21:13	122 05.032	25 00.016
20	C31	82003	08/15/2009 23:55	122 15.085	25 15.003
21	C17	82005	08/16/2009 04:37	122 15.013	25 45.064
22	C18	82031	08/16/2009 06:27	122 00.003	25 45.053
23	C19	91678	08/16/2009 08:29	121 45.042	25 44.984
24	C20	91683	08/16/2009 10:31	121 45.019	25 30.045
25	C32	82038	08/16/2009 14:07	122 00.041	25 14.942

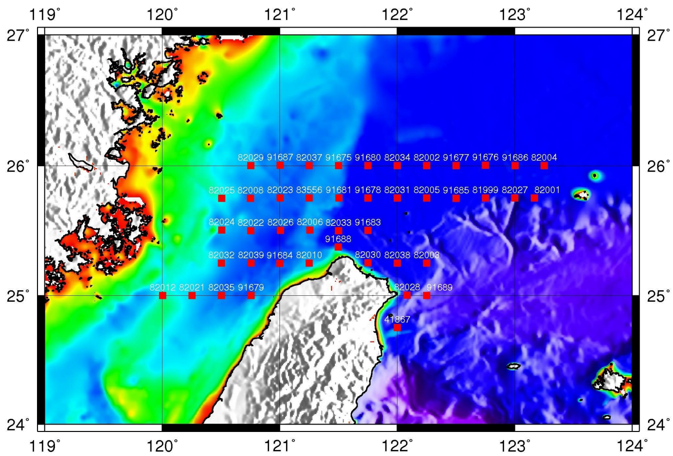


Figure 2.21: Locations and Ids of drifter deployments.

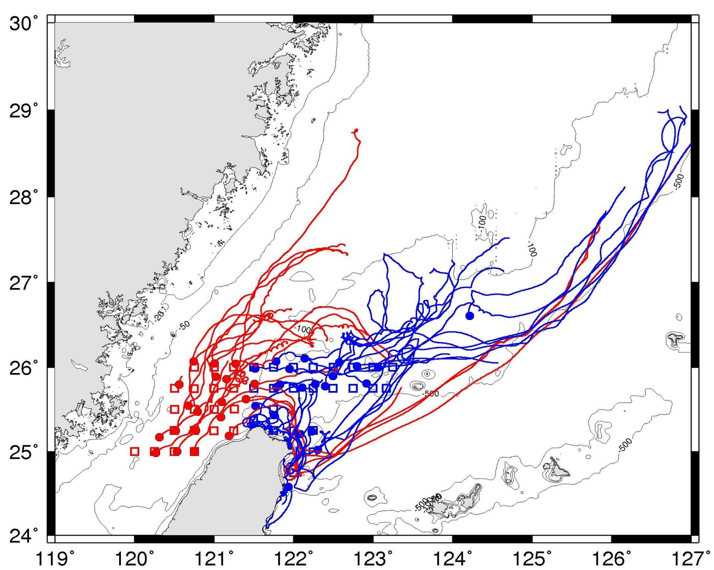


Figure 2.22: Drifter trajectories during OR2&3-Leg 1. Red lines indicate drifters deployed by OR3-1390 and blue lines indicate drifters deployed by OR2-1660. Drifters were set to follow the current at 15m depth.

2.5 Leg 1, Cruise no. 911, R/V ORI

Leg 1 (of 2) of the QPE experiment was performed from Aug 23rd to Sept 1st aboard the Taiwanese research vessel R/V Ocean Researcher 1 (OR1). Chief scientist during this leg was Dr. Jan Sen from the National Taiwan University (NTU). Leg 1 was designed, primarily, to gather joint environmental and acoustics data for real-time modeling and to study the temporal variations in the environment and their impact on acoustic propagation. Leg 1 focused on repeat observations for baseline conditions at Sites A and B.

2.5.1 Participants - R/V OR1, Cruise 911

Table 9: Leg 1 participants, R/V Ocean Researcher I , Cruise no. 911.

Name	Affiliation	Responsibilities
Jan Sen	NTU	Principal Investigator/Chief Scientist
Jim Lynch	WHOI	Principal Investigator
William Ostrom	WHOI	Operations coordinator
Neil McPhee	WHOI	Principal engineer
Linus Chiu	NTU	Scientist
Frank Bahr	WHOI	Engineer
Craig Marquette	WHOI	Engineer
David Morton	OASIS	Engineer
Jim Murray	OASIS	Engineer
Ted Abbot	OASIS	Engineer
Bee Wang	NTU	Engineer
Yu-Fang Ma	NTU	Engineer
Wen-Huei Lee	NTU	Engineer

2.5.2 Site A – physical description and deployed gear

Site A was chosen due to its flat topography (see section 3.1) and its presumed homogeneous bottom, which will give an interesting contrast to the steep, sloping bathymetry and rocky bottom at Site B. Since the conditions at Site A were more benign than Site B, and also due to time constraints, fewer assets were deployed at Site A. Mooring operations were eliminated for Site A during Leg 2 due to inclement weather. For more complete data description and specifics, see section 3.

Table 10: Deployment positions, depths and times for Site A moorings, OR1 Leg 1 (Cruise 911)

Mooring	*Deployed Position*	*Time (UTC) date*	*Depth (m)*
ADCP 'A'	25 59.323 122 31.525	10:20 8/29/09	113
ENV#1 (AB)	25 59.059 122 31.574	10:56 8/29/09	112.5
SHRU#1 (s/n 06 array 2)	25 59.290 122 31.889	11:14 8/29/09	114.0

Table 11: Recovery positions, depths and times for Site A moorings, OR1 Leg 1 (cruise 911)

Mooring	*Recovered Position*	*Time (UTC) date*
ADCP 'A'	Will recover in Leg 2	
ENV#1 (AB)	25 59.059 122 31.574	21:33 8/31/09
SHRU#1 (s/n 06 array 2)	25 59.290 122 31.889	22:00 8/31/09

2.5.3 Site B – physical description and deployed gear

The Site B deployments were the first mooring operations performed, on the nights of 8/24/09 and 8/25/09. There were seven instruments deployed: an acoustic Doppler current profiler (ADCP), three "environmental moorings" (designated ENV#1-3) bearing temperature, pressure, salinity measurement sensors, two Several Hydrophone Receiver Units (SHRU's), and a bottom mounted Horizontal Line Array (HLA). The locations of the environment moorings, after being recovered, disagreed with the deployment positions. We note that the displacement of the environmental moorings was probably due to current for ENV3 (hopping), but the displacement for environmental moorings ENV1 and ENV2 was definitely due to dragging (this was seen by the scraping on the gear and lost sensors). These moorings were actually moved many kilometers from their original positions.

An additional SHRU was deployed by the R/V OR3 on Aug 3rd for a long-term ambient noise time series study. It was active during the OR1 intensive mooring deployments and was recovered by the OR1 during Leg2 (912). See Figure 2.23 for SHRU deployment location in relation to other moorings at that site.

Site B was selected to be near North Mien-Hua Canyon (see Figure 1.2). For mooring data and specifics, see section 3.

Table 12: Deployment positions, depths and times for Site B moorings, OR1 Leg 1 (Cruise 911)

Mooring	*Deployed Position*	*Time (UTC) date*	*Depth (m)*
ADCP 'B'	25 42.334 122 36.961	10:54 8/24/09	136.0
ENV#1 (A)	25 42.549 122 36.866	12:46 8/24/09	131.8
ENV#2 (B)	25 42.505 122 37.454	13:37 8/24/09	134.4
ENV#3 (C)	25 42.051 122 37.117	12:45 8/25/09	139.7
SHRU#1 (s/n 08 array 1)	25 42.866 122 36.759	11:55 8/24/09	126.1
SHRU#2 (s/n 07 array 2)	25 38.993 122 36.014	11:52 8/25/09	208.4
WHOI HLA	25 45.097 122 42.285	10:05 8/25/09	133.1
SHRU – NSYSU (OR3 deployed)	25 41.910 122 38.940	08:30 8/01/09	134.0

Table 13: Recovery positions, depths and times for Site B moorings, OR1 Leg 1 (Cruise 911)

Mooring	***Recovered Position***	***Time (UTC) date***	***status***
ADCP 'B'	Not recovered this leg		
ENV#1 (A)	25 43.747 122 40.213	05:48 8/28/09	
ENV#2 (B)	25 42.855 122 39.619	02:57 8/28/09	moved
ENV#3 (C)	25 42.153 122 37.043	00:50 8/28/09	moved
SHRU#1 (s/n 08 array 1)	25 42.866 122 36.759	08:48 8/28/00	moved
SHRU#2 (s/n 07 array 2)	25 38.993 122 36.010	09:38 8/28/09	
WHOI HLA	25 45.097 122 42.285	07:38 8/28/09	

The distances from deployment positions to the recovered location (Figure 2.23) for the ENV moorings follow:

ENV#1	6020m
ENV#2	885m
ENV#3	225m

More than thirty temperature sensors were lost when ENV1 and ENV2 were dragged. ENV1 was almost completely stripped of sensors.

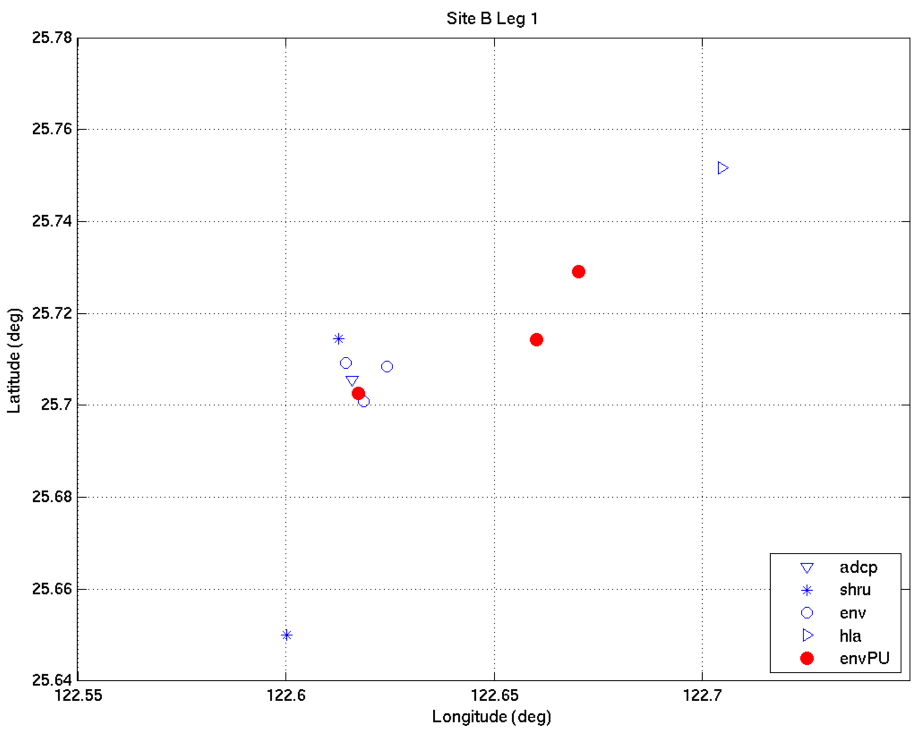


Figure 2.23. Recovery locations in solid circles are the ENV moorings deployed by R/V OR1. ENV #2 and ENV#3 were dragged hundreds of meters from their deployed position.

2.6 Turnaround between R/V OR1 legs 1 and 2

A few days between Leg1 and Leg 2 of the QPE acoustics field work were allotted to quickly study the in situ instrumentation data and to numerically model acoustic and oceanographic fields for Leg2 planning. This was important to adaptively define the next set of experiments to address and exploit the spatial and temporal uncertainty in the area. Arthur Newhall from WHOI arrived specifically for examining the mooring data, which can be seen in Section 3.

2.7 Leg 2, Cruise no. 912, R/V OR1

Leg 2 started on Sept 4th and ended on Sept 12th. Glen Gawarkiewicz took over for Jim Lynch as co-Chief Scientist with Prof. Y. J. Yang from NTU. Since Site B was closer to the continental shelfbreak and the North Mien-Hua Canyon, where uncertainties in transmission loss would be larger. Site B was visited first.

Table 14: Leg 2 participants, R/V Ocean Researcher I, Cruise no. 912.

Name	**Affiliation**	**Responsibilities**
Y. J. Yang	CNA	Principal Investigator/Chief Scientist
Glen Gawarkiewicz	WHOI	Principal Investigator
Tim Duda	WHOI	Scientist
William Ostrom	WHOI	Operations coordinator
Neil McPhee	WHOI	Principal engineer
Frank Bahr	WHOI	Engineer
Craig Marquette	WHOI	Engineer
David Morton	OASIS	Engineer
Chris Emerson	OASIS	Engineer
Ted Abbot	OASIS	Engineer
Bee Wang	NTU	Engineer
Yu-Fang Ma	NTU	Engineer
Wen-Huei Lee	NTU	Engineer
Chih-Hao Wu	NTU	Student
C.M. Liou	NSYSU	Student
C.F. Wu	NSYSU	Student

2.7.1 Site A

As in Leg 1, Site A was visited after Site B. Unfortunately, the weather turned worse at this time, so none of the environmental or SHRU moorings were deployed due to high seas. Standard SeaSoar runs and CTD casts were conducted in their place, since they can be performed in poorer conditions. The Site A ADCP mooring was recovered (Table 15) during a good weather window.

Table 15: Recovery positions only, depths and times for Site A moorings, OR1 Leg 2 (Cruise 912). No moorings were deployed due to sea and weather conditions.

Mooring	***Recovery Position (approx)***	***Time (UTC) date***
ADCP 'A' (110m Z)	25 59.280 122 31.550	08:37 9/09/09

2.7.2 Site B

The initial mooring operations for Leg 2 were at Site B (Figure 2.24). Environment and SHRU moorings were deployed in approximately the same locations as Leg 1 (Table 16). Prior to heading to Site A, all moorings, including the ADCP moorings deployed during Leg 1, were recovered (Table 17).

Table 16: Deployment positions, depths and times for Site B moorings, Leg 2 (OR1 Cruise 912)

Mooring	***Deployed Position***	***Time (UTC) date***	***Depth (m)***
ENV#1 (AB)	25 42.541 122 36.842	10:34 9/04/09	n/a
ENV#2 (BB)	25 42.519 122 37.444	11:40 9/04/09	n/a
ENV#3 (C)	25 42.049 122 37.104	12:20 9/04/09	140
SHRU#1 (s/n 07 array 2)	25 42.841 122 36.724	13:03 9/04/09	126
SHRU#2 (s/n 08 array 1)	25 37.563 122 35.924	13:58 9/04/09	337
WHOI HLA	25 45.429 122 42.019	22:32 9/04/09	133.7

Table 17: Recovery positions, depths and times for Site B moorings, Leg 2 (OR1 Cruise 912)

Mooring	***Recovered Position (approx)***	***Time (UTC) date***
ADCP 'B' (130m Z)	25 42.240 122 36.960	11:15 9/09/09
ADCP (NTU, 186m Z)	25 40.340 122 35.240	11:59 9/09/09
ENV#1 (AB)	25 42.570 122 36.850	23:43 9/08/09
ENV#2 (BB)	25 42.470 122 37.340	23:15 9/08/09
ENV#3 (C)	25 41.920 122 36.960	22:04 9/08/09
SHRU#1 (s/n 07 array 2)	25 43.130 122 36.270	00:15 9/09/09
SHRU#2 (s/n 08 array 1)	25 37.800 122 35.550	03:25 9/09/09
WHOI HLA	25 45.330 122 42.150	05:10 9/09/09
SHRU - NSYSU	25 42.580 122 38.330	01:00 9/10/09

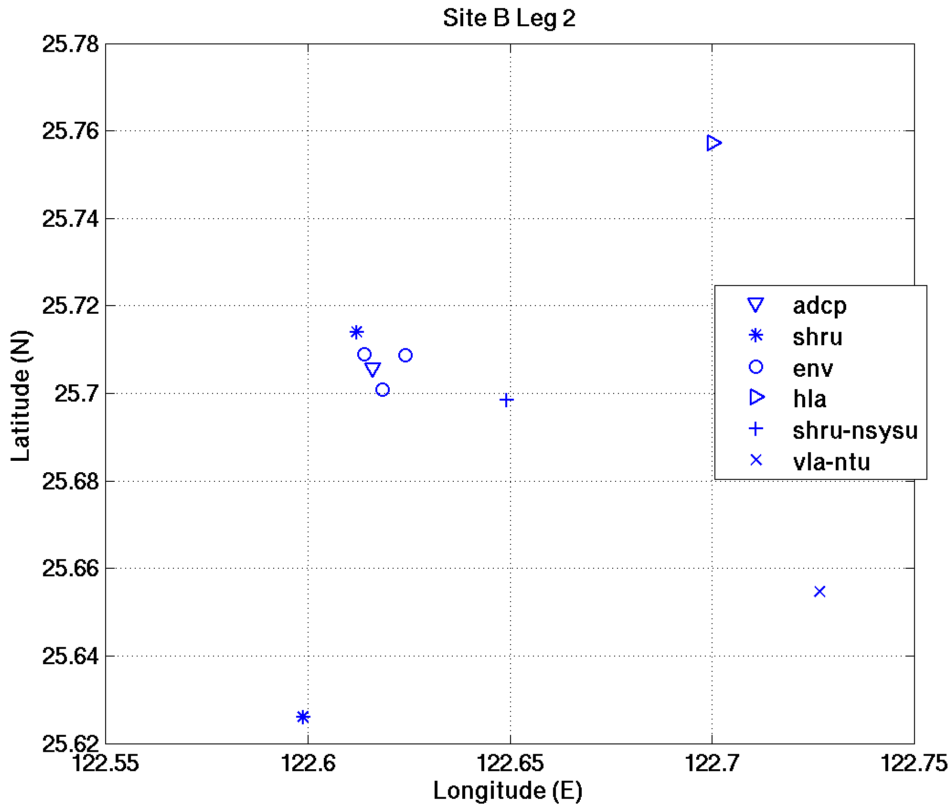


Figure 2.24. Deployed mooring locations for OR1 Leg2 at Site B.

2.8 QPE Instrumentation from R/V OR1

This section introduces the array of instrumentation that was used during the QPE acoustics program. Description of this data can be seen in Section 3.

2.8.1 Moorings

During Leg 1, two separate deployments and recoveries of equipment at acoustics Sites A and B respectively were done, starting with Site B, since that site was considered to be more dynamic and diverse (thus a high priority was to complete Site B operations). Site B is at the 125 m isobath near the shelfbreak, centered at 25.7139 N, 122.6130 E. Three thermistor chains were deployed at Site B along with one 300 kHz bottom-mounted ADCP, 2 SHRUs (Several Hydrophone Recording Unit) and a horizontal line array (HLA). Site A is near the northern edge of the study area and is centered at 25.9890 N, 122.5259 E. It is anticipated that Site A will have low uncertainty in terms of prediction of acoustic propagation characteristics and Site B will have high uncertainty. The thermistor chains, HLA, and SHRUs were recovered at each site in Leg 1 and the two ADCPs were left until the end of Leg 2. A National Taiwan University ADCP mooring placed by Y.J. Yang was also recovered at the end of Leg 2.

2.8.2 NTU SeaSoar (OR1)

The NTU SeaSoar is a towed, undulating vehicle that was used during the experiment to measure the thermohaline structure in the vicinity of sites A and B. It provided repeated snapshots of the upper ocean dynamics in the area. Sampling consisted of a mixture of along-shelf and cross-shelf sections with the scientific goal of identifying both potential Kuroshio Intrusions onto the shelf as well as the Cold Dome structure. The data from Leg 1 was processed after recovery and sent to MIT for assimilation into the regional model. This data was used to identify likely features such as the edge of the Cold Dome, a Kuroshio Intrusion, thermohaline intrusions, etc. for exploiting placement of assets for leg 2. SeaSoar data and description are available in Section 3.7.

2.8.3 Mobile acoustic sources

The mobile acoustic sources are small, expendable autonomous vehicles that send acoustic signals at pre-set frequencies. These are pre-programmed before launch. Please refer to the section 3.10 for more information.

2.8.4 Shipboard resources

All Ocean Researcher vessels had a suite of shipboard ocean sensors available. Over 3000 km of shipboard transect data was collected, since all the shipboard sensors were operating during the entire QPE experiment. The most useful are mentioned below and data from these will be examined in Section 3.

* Over 200 SBE-9/11 CTD casts were performed during the entire QPE exercise. The CTD sensors measured: conductivity, salinity, temperature, depth, sound speed, acidity, oxygen, transmissometry, flourometry, and carbon dioxide.

* To sample continuous current velocity from shipboard, the OR1 was equipped with an RDI Ocean Surveyor acoustic Doppler current profiler (ADCP). It used the following settings: bin length was 8 meters, bin#1 was set to depth 8.27m, blanking depth was set to 4 meters, and it operated in broad band mode with an ensemble average of 2 minutes.

* Surface temperature and salinity were continuously measured on board.

* A Simrad EK500 single beam echosounder data sampling at 38 kHz provided over the bottom depth and reverberation from fish populations, as well as capturing microstructure.

3 QPE Data - R/V OR1, OR2, and OR3

3.1 Bathymetry

In order to provide a common bathymetric context for planning and operations, the Center for Coastal and Ocean Mapping (CCOM) at the University of New Hampshire prepared a set of maps of the best available bathymetry in the QPE area of interest. These data are available at two resolutions: low (ca. 500m spacing) over a wider area, and high (ca. 100m) over an area closer to the operations area around the Mien-Hua Canyon. The data was prepared in projected and unprojected coordinate systems, and in various different formats to suit the variety of software packages being used in the community.

The following briefly describes the map construction process provided by CCOM for the data, and the parameters required to interpret it.

3.1.1 Bathymetry construction

The basic source data consisted of two grids, precomputed in unprojected coordinates (i.e., as a latitude-longitude grid). The first was gridded at approximately 500m (0.0045 deg) and covers the area around Taiwan (figure 1.1 and figure 1.2), while the second was gridded at approximately 100m (0.000917 degrees) and covers the area to the northeast of Taiwan in more detail (figure 1.2).

Inspection of the data showed that there were a few missing points in the 100m grid, and a somewhat greater number of missing points in the 500m grid. The 100m grid had holes that were insignificant; the 500m grid was re-computed to fill in the holes using Fledermaus' AvgGrid utility (with default parameters), which applies a little extra smoothing to the output. The outputs were then converted into Fledermaus SD objects directly without further processing. This formed the basis for further object construction.

The area of interest is sufficiently large that differences in distance represented by uniformly sampled latitude and longitude are significant. In order to provide a representation which could be used for computation without compensating for these problems, we converted the grids into projected coordinates using Mercator's projection by dumping the grids as ASCII XYZ values in geographic coordinates, then projecting the coordinates with a central Meridian of 123 degrees east longitude and a true-scale parallel of 25 degrees north latitude. We assumed that the data was originally positioned with respect to the WGS-84 ellipsoid, although this is not directly attested to in any metadata associated with the source. No false northing or easting was applied. We then re-gridded the data using Fledermaus' AvgGrid with size set to exactly 100m or 500m as appropriate; the slight interpolation implicit in AvgGrid's default behavior allows sufficient leeway to make consistent grids after projection. The grids were converted to Fledermaus SD object format.

This process resulted in four grids:

1. bathy_100m_equiv.geo.sd: high-resolution grid in geographic (unprojected) coordinates at a resolution of roughly 100m.

2. bathy_500m_equiv.geo.sd: low-resolution grid in geographic (unprojected) coordinates at a resolution of roughly 500m.

3. bathy_100m_equiv.merc.sd: high-resolution grid in Mercator coordinates at a resolution of exactly 100m.

4. bathy_500m_equiv.merc.sd: low-resolution grid in Mercator coordinates at a resolution of exactly 500m.

3.1.2 Data format

From the unprojected and projected grids, we used the Fledermaus DMagic tools to export the data as:

1. Plain ASCII XYZ files with file extension '.llz' for unprojected and '.xyz' for projected grids.

2. ArcView ASCII Grid files with file extension '.asc' for all grids.

3. GMT GRD (NetCDF) files with file extension '.grd' for all grids.

All have inherent georeferencing included directly in the files. We then used an intermediate step to make files readily readable in MATLAB, loaded those into MATLAB R2008a and output:

4. MATLAB binary matrix (.mat) files with file extension '.mat' for all grids.

The MATLAB files contain an object for the bathymetry, and a parameter structure that provides bounds, projection parameters and resolutions for the object so that georeferencing is preserved.

The conversion between the different data formats should be exact, but the possibility exists that small differences may accumulate in making the translations. In case of discrepancy, the Fledermaus SD objects should be considered as reference.

3.1.3 Bathymetry data caveats

The source data was not constructed by the Center for Coastal and Ocean Mapping (CCOM) at the University of New Hampshire, and we have no control over the construction methods. It is clear, on inspection, that there are a number of artifacts in the data that require careful interpretation to avoid mistaken assumptions about the geomorphology of the seafloor in the area of interest.

In particular, the dataset has clearly been assembled from a set of different data sources including single-beam echosounders, multibeam echosounders and possibly some re-digitized contours. These have all then been combined using some interpolation scheme, most likely a constrained spline surface. Users should employ caution in closely interpretating the data, since there are a number of artifacts due to the original grid's construction which are evident as ridges, sharp changes in gradient, small pock-marks and other potentially interpretable features that are not expected to be observed in the field. In particular, users should carefully examine any area of interest for evidence of sudden reduction in resolution and/or decrease in observed roughness of bathymetry, which typically indicates that the data has been constructed using the smoothing spline based on the observations around the edges of the area, rather than from actual observations.

As a result of these limitations, the grids should be considered more a general description of the bathymetry than a definitive estimate of depth and representation of geomorphology.

3.1.4 Bathymetry for Site A

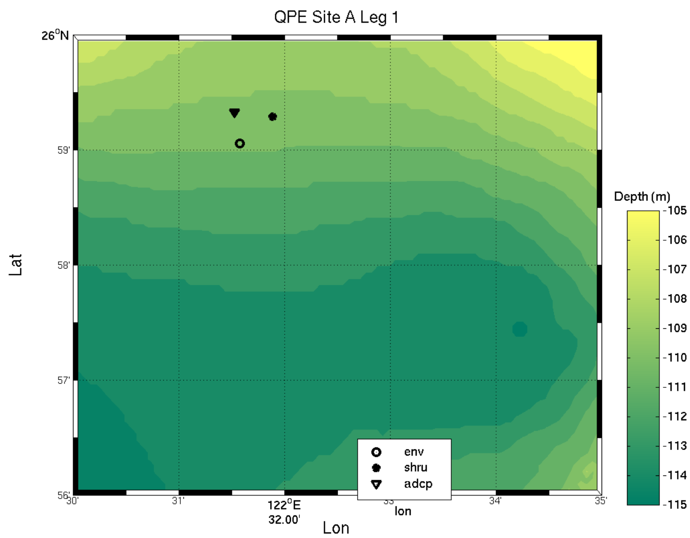


Figure 3.1 Bathymetry for relatively flat Site A, with mooring positions for OR1 Leg 1 included.

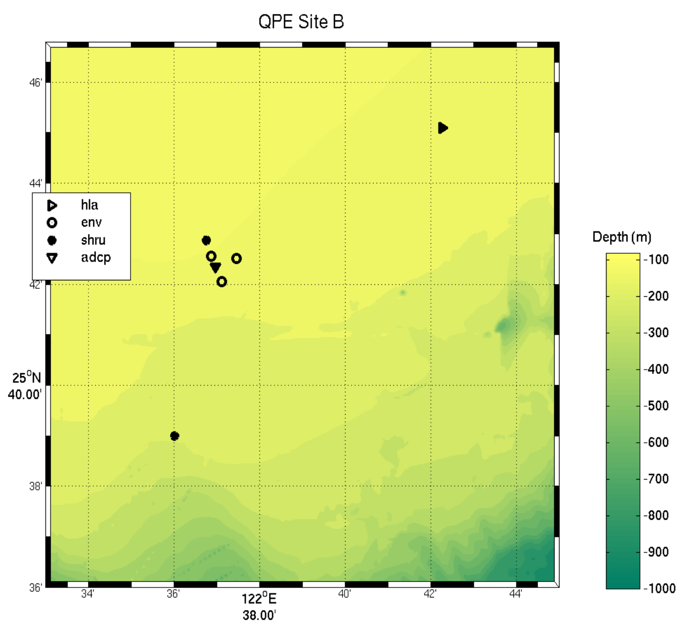


Figure 3.2. Bathymetry for Site B with mooring locations for OR1 leg 1.

3.2 Shipboard

3.2.1 Sea State

The sea state (or wave height) for each day is listed here for both legs. The sea state affects the acoustics and the ability to perform mooring operations. The following sections describe the wave height for each R/V OR1 leg taken at 8:00AM local.

3.2.1.1 Leg1 (OR1 911)

The sea state during leg 1 was nearly perfect for deployment operations. Table 18 shows the sea state for leg 1.

Table 18: OR1 Sea State (or wave height) for Leg 1.

Date	Sea State (ft)
8/23 - 8/28	1-2
8/29	2-3
8/30	3-4
8/31	4-6

3.2.1.2 Leg2 (OR1 912)

Table 19 shows the sea state for leg 2. The weather and sea state hampered mooring and acoustics operations towards the end of the exercise. However, SeaSoar operations and CTD casts were substituted in their place.

Table 19: Sea State for OR1 Leg 2.

Date	Sea State (ft)
9/04	4-6
9/05	2-4
9/06	2-3
9/07	1-2
9/08	2-3 (AM) 4-6 (PM)
9/09	2-3 (AM) 8-10 (PM)
9/10	4-5
9/11	2-4

3.2.2 CTD

The following tables (20 and 21) list the casts performed during QPE from the OR1 along with their location, depth, and date. The locations of these casts are displayed on charts for Leg 1 (Figure 3.3) and Leg 2 (Figure 3.4). CTD cast information for the large scale hydrography survey that was performed earlier can be found in Section 2.4.1

3.2.2.1 Leg 1 (OR1 911)

Table 20: CTD stations from OR1 Leg1

Station	Date	Time	Latitude	Longitude	Depth	Station	Date	Time	Latitude	Longitude	Depth
1ad1	24-8-2009	14:08:13	25 43.020	122 36.980	125	5a-ad	28-8-2009	13:05:28	26 2.000	122 31.990	114
1au1	24-8-2009	14:12:45	25 43.020	122 36.990	125	5a-au	28-8-2009	13:09:06	26 1.980	122 31.970	114
1cd1	24-8-2009	16:03:41	25 43.630	122 37.730	129	5ab-2d1	29-8-2009	12:29:59	26 2.690	122 32.800	113
1cd2	24-8-2009	16:57:56	25 43.670	122 37.700	129	5ab-2u1	29-8-2009	12:33:18	26 2.680	122 32.850	113
1cd3	24-8-2009	17:57:39	25 43.620	122 37.670	127	5a-bd	28-8-2009	12:28:24	26 1.320	122 31.420	1112
1cd4	24-8-2009	18:56:28	25 43.670	122 37.690	128	5a-bd	28-8-2009	12:33:24	26 1.310	122 31.410	112
1cd5	24-8-2009	19:57:50	25 43.690	122 37.660	126	5ac2d10	30-8-2009	02:01:31	26 1.750	122 36.290	108
1cu1	24-8-2009	16:07:24	25 43.570	122 37.720	129	5ac2d11	30-8-2009	03:01:10	26 0.370	122 39.610	108
1cu5	24-8-2009	20:01:23	25 43.700	122 37.660	126	5ac2d12a	30-8-2009	04:27:48	26 0.570	122 34.110	109
2ad1	25-8-2009	15:24:25	25 43.020	122 36.970	124	5ac2d1	29-8-2009	12:54:34	26 1.920	122 33.220	112
2au1	25-8-2009	15:28:01	25 42.990	122 36.990	124	5ac2d2	29-8-2009	14:02:29	26 1.030	122 33.510	112
2bd1	25-8-2009	14:20:02	25 48.320	122 34.990	116	5ac2d3	29-8-2009	15:00:46	26 0.660	122 33.710	111
2bu1	25-8-2009	14:24:43	25 48.300	122 34.970	116	5ac2d4	29-8-2009	15:58:52	26 0.420	122 33.860	111
3a-ad1	26-8-2009	14:44:44	25 37.970	122 36.980	245	5ac2d5	29-8-2009	16:59:14	26 0.130	122 33.830	112
3a-au1	26-8-2009	14:51:24	25 37.990	122 37.000	245	5ac2d6	29-8-2009	17:56:26	25 59.940	122 33.610	113
3a-bd1	26-8-2009	13:58:39	25 38.000	122 35.980	498	5ac2d7	29-8-2009	19:00:21	25 59.820	122 33.360	114
3a-bu1	26-8-2009	14:11:17	25 37.990	122 35.980	498	5ac2d8	29-8-2009	20:07:39	26 2.040	122 31.920	112
3a-cd1	26-8-2009	15:25:50	25 39.020	122 36.450	212	5ac2d9	30-8-2009	01:25:45	26 2.150	122 39.090	108
3a-cu1	26-8-2009	15:33:21	25 39.010	122 36.460	212	5ac2u10	30-8-2009	02:05:00	26 1.770	122 36.290	108
3b-ad1	27-8-2009	10:36:34	25 45.010	122 35.050	127	5ac2u11	30-8-2009	03:04:26	26 0.390	122 39.600	108
3b-au1	27-8-2009	10:39:53	25 45.030	122 35.070	127	5ac2u12a	30-8-2009	04:30:56	26 0.620	122 34.120	109
3b-bd1	27-8-2009	11:00:14	25 45.720	122 35.730	124	5ac2u1	29-8-2009	12:57:54	26 1.920	122 33.220	112
3b-bu1	27-8-2009	11:03:40	25 45.760	122 35.740	124	5ac2u2	29-8-2009	14:05:46	26 1.000	122 33.510	112
3b-cd1	27-8-2009	11:29:31	25 45.670	122 34.330	124	5ac2u3	29-8-2009	15:04:05	26 0.650	122 33.720	111
3b-cu1	27-8-2009	11:32:49	25 45.680	122 34.340	124	5ac2u8	29-8-2009	20:10:53	26 2.050	122 31.890	112
5aa2d13	30-8-2009	05:01:50	26 2.130	122 31.990	113	5ac2u9	30-8-2009	01:29:11	26 2.160	122 39.140	108
5aa2d14	30-8-2009	05:59:13	26 2.200	122 30.350	110	5a-cd	28-8-2009	13:35:44	26 2.620	122 31.330	109
5aa2d15	30-8-2009	07:19:49	26 3.110	122 40.390	114	5a-cu	28-8-2009	13:39:18	26 2.580	122 31.320	109
5aa2d16	30-8-2009	08:15:34	26 3.140	122 40.040	110	c1d1	26-8-2009	16:45:39	25 36.980	122 29.910	529
5aa2d17	30-8-2009	09:03:33	26 3.350	122 40.010	112	c1u1	26-8-2009	16:58:33	25 36.960	122 29.950	529
5aa2d18	30-8-2009	10:14:25	26 3.730	122 40.220	114	c2d1	26-8-2009	17:46:40	25 36.090	122 32.300	589
5aa2d19	30-8-2009	12:14:29	26 4.300	122 30.240	106	c2u1	26-8-2009	18:01:33	25 36.080	122 32.430	589
5aa2d20	30-8-2009	13:08:03	26 2.670	122 31.550	111	c3d1	26-8-2009	18:43:29	25 35.100	122 34.620	800

Table 20: CTD stations from OR1 Leg1

5aa2d21	30-8-2009	14:00:31	26 2.060	122 31.710	112	c3u1	26-8-2009	19:04:21	25 35.120	122 34.640	800
5aa2d22	30-8-2009	14:59:43	26 1.270	122 33.070	113	c4d1	26-8-2009	19:57:27	25 34.140	122 36.810	711
5aa2d23	30-8-2009	15:58:00	26 0.420	122 32.720	114	c4u1	26-8-2009	20:16:11	25 34.110	122 36.860	711
5aa2d24	30-8-2009	16:57:54	26 2.010	122 32.360	113	c5d1	26-8-2009	20:55:15	25 33.480	122 38.430	1081
5aa2d25	30-8-2009	17:57:32	26 1.460	122 31.260	111	c5u1	26-8-2009	21:15:26	25 33.520	122 38.450	1081
5aa2d26	30-8-2009	19:02:44	26 0.920	122 30.020	108	s1d1	26-8-2009	11:29:48	25 48.130	122 37.670	112
5aa2d27	30-8-2009	20:02:55	26 0.510	122 28.770	110	s1u1	26-8-2009	11:32:59	25 48.110	122 37.600	112
5aa2u13	30-8-2009	05:05:04	26 2.200	122 32.020	113	s2d1	26-8-2009	12:15:02	25 44.640	122 37.250	123
5aa2u14	30-8-2009	06:02:18	26 2.220	122 30.330	110	s2u1	26-8-2009	12:18:37	25 44.650	122 37.260	123
5aa2u15	30-8-2009	07:23:07	26 3.070	122 40.390	114	s3d1	26-8-2009	13:05:46	25 41.110	122 36.630	172
5aa2u16	30-8-2009	08:18:39	26 3.110	122 40.080	1105	s3u1	26-8-2009	13:10:36	25 41.130	122 36.620	172
						5a-a-d1	29-8-2009	12:06:08	26 2.100	122 32.060	114
						5a-a-u1	29-8-2009	12:09:47	26 2.150	122 32.080	114

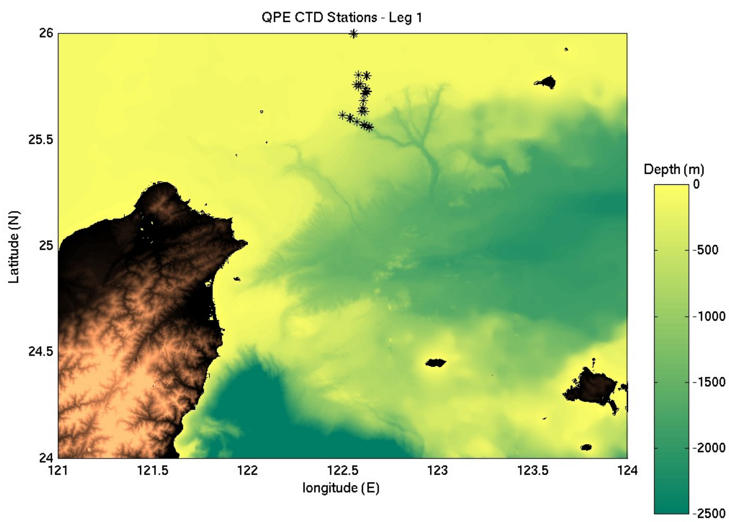


Figure 3.3. CTD casts during QPE OR1 Leg 1.

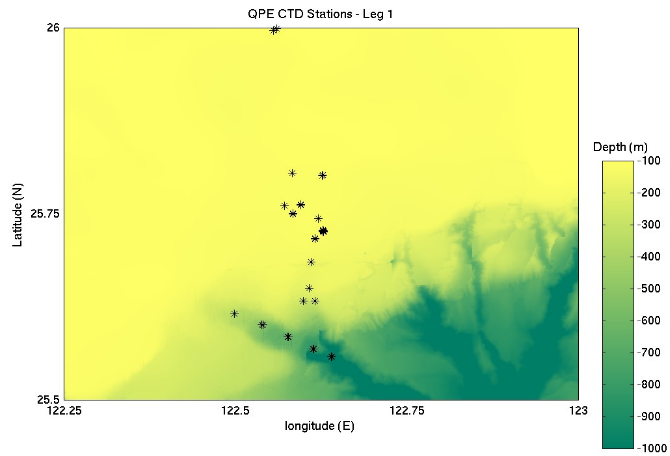


Figure 3.4. Close up view of the CTD casts performed during OR1 Leg 1.

Figure 3.5 displays the temperature and salinity from CTD casts performed during Leg 1 as the OR1 heads down the Mien-Hua Canyon. Figure 3.6 combines the temperature of ALL the casts for leg 1 into a single plot. This clearly shows two different water masses between the 15 and 25 degree range.

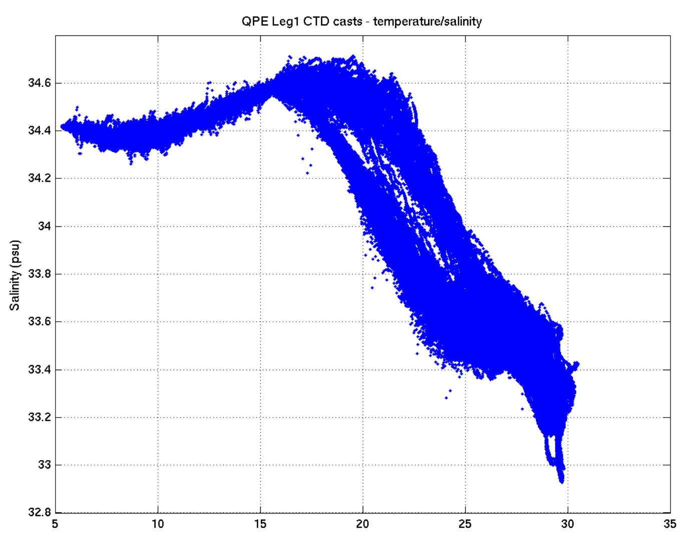


Figure 3.5. OR1 Leg 1 S/T plot from ALL casts.

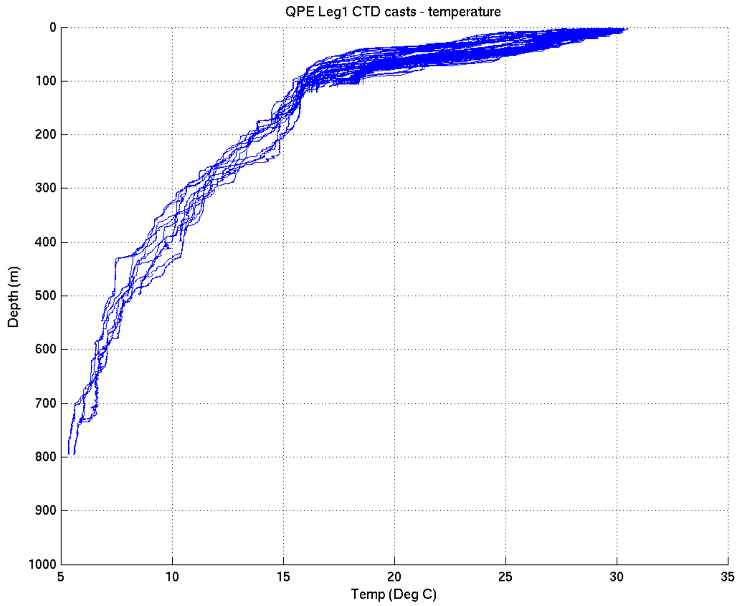


Figure 3.6. Temperature from all CTD casts for OR1, Leg1.

3.2.2.2 Leg 2 (OR1 912)

Table 21: R/V OR1 CTD stations from Leg2

Station	Date	Time	Latitude	Longitude	Depth	Station	Date	Time	Latitude	Longitude	Depth
10CD1	07-9-2009	13:58:10	25 43.490	122 37.880	134	64D1	11-9-2009	08:57:05	25 53.980	122 15.010	113
10CD2	07-9-2009	14:54:09	25 43.460	122 37.410	125	64U1	11-9-2009	09:00:35	25 53.980	122 15.010	113
10CD3	07-9-2009	16:04:08	25 42.540	122 36.950	130	65D1	11-9-2009	09:54:08	25 47.980	122 15.000	118
10CD4	07-9-2009	17:03:24	25 40.980	122 37.020	183	65U1	11-9-2009	09:58:10	25 47.980	122 14.980	118
10CD5	07-9-2009	18:01:50	25 38.840	122 37.270	158	66D1	11-9-2009	10:48:51	25 41.960	122 14.990	105
10CD6	07-9-2009	19:03:08	25 36.360	122 37.060	746	66U1	11-9-2009	10:53:37	25 41.950	122 14.990	105
10CD7	07-9-2009	22:52:55	25 45.440	122 42.000	132	67D1	11-9-2009	12:36:01	25 42.000	121 59.960	135
10CU1	07-9-2009	14:01:44	25 43.510	122 37.830	134	67U1	11-9-2009	12:39:31	25 42.050	121 59.940	135
10CU2	07-9-2009	14:57:17	25 43.440	122 37.400	125	68D1	11-9-2009	13:24:34	25 48.020	121 59.970	108
10CU3	07-9-2009	16:08:10	25 42.460	122 36.920	130	68U1	11-9-2009	13:27:19	25 48.080	121 59.940	108
10CU4	07-9-2009	17:08:50	25 40.810	122 37.060	183	69D1	11-9-2009	14:13:21	25 54.090	122 0.030	108
10CU5	07-9-2009	18:06:29	25 38.650	122 37.260	158	69U1	11-9-2009	14:16:11	25 54.140	122 0.010	108
10CU6	07-9-2009	19:20:22	25 35.730	122 36.940	746	70D1	11-9-2009	15:00:20	26 0.020	121 59.970	104

Table 21: R/V OR1 CTD stations from Leg2

10CU7	07-9-2009	22:56:18	25 45.490	122 41.900	132
12BD1	08-9-2009	16:53:01	25 35.170	122 38.620	553
12BU1	08-9-2009	16:58:59	25 35.030	122 38.630	553
12CD1	08-9-2009	11:55:14	25 34.180	122 38.810	992
12CD2	08-9-2009	12:52:59	25 34.220	122 39.300	873
12CD3	08-9-2009	13:58:01	25 33.640	122 39.700	822
12CD4	08-9-2009	14:58:52	25 34.230	122 38.580	1032
12CD5	08-9-2009	16:03:16	25 33.180	122 38.570	1087
12CU1	08-9-2009	12:00:42	25 34.190	122 38.850	992
12CU2	08-9-2009	12:58:20	25 34.200	122 39.330	873
12CU3	08-9-2009	14:03:17	25 33.570	122 39.710	822
12CU4	08-9-2009	15:04:10	25 34.170	122 38.560	1032
12CU5	08-9-2009	16:09:06	25 33.060	122 38.550	1087
13AD1	09-9-2009	18:19:44	26 1.750	122 32.030	111
13AU1	09-9-2009	18:23:02	26 1.680	122 32.010	111
13CD1	09-9-2009	11:18:53	26 2.010	122 32.920	113
13CD2	09-9-2009	12:15:07	26 2.080	122 33.760	109
13CD3	09-9-2009	12:58:24	26 2.260	122 32.710	114
13CD4	09-9-2009	13:51:08	26 2.550	122 31.440	107
13CD5	09-9-2009	14:56:32	26 2.740	122 30.080	111
13CD6	09-9-2009	16:07:46	26 2.380	122 28.980	109
13CD7	09-9-2009	17:28:26	26 4.440	122 27.930	110
13CU1	09-9-2009	11:22:01	26 1.990	122 32.850	113
13CU2	09-9-2009	12:17:55	26 2.080	122 33.700	109
13CU3	09-9-2009	13:01:22	26 2.280	122 32.630	114
13CU4	09-9-2009	13:53:59	26 2.570	122 31.370	107
13CU5	09-9-2009	14:59:22	26 2.740	122 30.030	111
13CU6	09-9-2009	16:11:17	26 2.350	122 28.940	109
13CU7	09-9-2009	17:31:43	26 4.400	122 27.910	110
14CD1	10-9-2009	11:57:46	25 35.990	122 17.310	107
14CD2	10-9-2009	14:01:44	25 36.970	122 17.310	106
14CD3	10-9-2009	14:57:20	25 38.400	122 15.770	107
14CD4	10-9-2009	16:02:46	25 40.050	122 14.320	111
14CD5	10-9-2009	17:00:13	25 40.820	122 13.620	106
14CD6	10-9-2009	18:22:52	25 42.140	122 11.370	123
14CU1	10-9-2009	12:00:37	25 35.980	122 17.230	107
14CU2	10-9-2009	14:04:30	25 37.030	122 17.230	106
14CU3	10-9-2009	15:00:09	25 38.470	122 15.700	107
14CU4	10-9-2009	16:06:20	25 40.110	122 14.260	111
14CU5	10-9-2009	17:03:50	25 40.850	122 13.580	106
14CU6	10-9-2009	18:26:47	25 42.130	122 11.400	123
54D1	08-9-2009	04:26:41	25 37.250	122 36.000	306
54U1	08-9-2009	04:35:24	25 37.270	122 35.990	306
55D1	08-9-2009	07:49:55	25 31.890	122 39.480	959
55U1	08-9-2009	08:12:01	25 31.830	122 39.700	959
59D1	11-9-2009	03:48:59	25 42.100	122 29.920	127
70U1	11-9-2009	15:03:02	26 0.080	121 59.940	104
71D1	11-9-2009	18:00:50	25 36.110	121 47.940	122
71U1	11-9-2009	18:05:07	25 36.230	121 47.900	122
72D1	11-9-2009	20:26:29	25 18.010	121 45.200	165
72U1	11-9-2009	20:30:31	25 18.040	121 45.310	165
7BD1	05-9-2009	11:24:57	25 40.210	122 27.060	121
7BU1	05-9-2009	11:30:32	25 40.120	122 27.010	121
7CD1	05-9-2009	13:58:37	25 39.350	122 25.610	117
7CD2	05-9-2009	14:58:22	25 38.000	122 24.170	116
7CD3	05-9-2009	17:24:48	25 38.200	122 24.840	117
7CD4	05-9-2009	17:58:35	25 36.660	122 24.350	182
7CD5	05-9-2009	19:02:59	25 34.170	122 22.850	119
7CD6	05-9-2009	20:44:36	25 31.270	122 21.920	253
7CU1	05-9-2009	14:01:59	25 39.280	122 25.520	117
7CU2	05-9-2009	15:01:41	25 37.900	122 24.110	116
7CU3	05-9-2009	17:28:35	25 38.030	122 24.800	117
7CU4	05-9-2009	18:04:53	25 36.380	122 24.240	182
7CU5	05-9-2009	19:06:50	25 34.050	122 22.740	119
7CU6	05-9-2009	20:51:45	25 31.400	122 21.650	253
9CD1	06-9-2009	13:02:58	25 38.990	122 29.100	142
9CD2	06-9-2009	13:57:01	25 38.500	122 28.130	141
9CD3	06-9-2009	14:56:43	25 37.550	122 27.170	273
9CU1	06-9-2009	13:06:49	25 39.000	122 29.020	142
9CU2	06-9-2009	14:01:12	25 38.450	122 28.050	141
9CU3	06-9-2009	15:02:06	25 37.460	122 27.090	273
AAD1	05-9-2009	22:47:03	25 41.600	122 17.830	117
AAU1	05-9-2009	22:50:19	25 41.630	122 17.800	117
ADCPD1	09-9-2009	09:01:52	25 59.060	122 31.560	111
ADCPU1	09-9-2009	09:06:10	25 59.070	122 31.550	111
B-ENV-1D1	04-9-2009	10:53:59	25 42.500	122 36.930	133
B-ENV-1U1	04-9-2009	10:58:12	25 42.440	122 36.820	133
C1D1	06-9-2009	17:07:56	25 37.870	122 28.080	184
C1U1	06-9-2009	17:13:08	25 37.690	122 28.100	184
C2D1	06-9-2009	17:50:57	25 35.880	122 32.060	604
C2U1	06-9-2009	18:09:34	25 35.160	122 32.250	604
C3D1	06-9-2009	18:57:49	25 33.910	122 35.900	893
C3U1	06-9-2009	19:18:21	25 33.390	122 35.600	893
C4D1	06-9-2009	20:33:06	25 30.970	122 42.030	1090
C4U1	06-9-2009	20:56:53	25 30.980	122 42.000	1090
CTD2D1	08-9-2009	06:22:56	25 33.630	122 38.280	1008
CTD2U1	08-9-2009	06:50:37	25 33.660	122 38.320	1008
CTD3D1	08-9-2009	09:14:54	25 33.260	122 39.470	972
CTD3U1	08-9-2009	09:38:52	25 33.330	122 39.620	972
CFD-D1	08-9-2009	05:18:36	25 35.410	122 37.180	750
CFD-U1	08-9-2009	05:36:44	25 35.400	122 37.160	750
MHC1D1	10-9-2009	20:02:51	25 29.980	122 13.060	159

Table 21: R/V OR1 CTD stations from Leg2					
59U1	11-9-2009	03:52:50	25 42.210	122 29.870	127
60D1	11-9-2009	04:38:15	25 48.180	122 29.940	113
60U1	11-9-2009	04:41:35	25 48.250	122 29.900	113
61D1	11-9-2009	05:28:04	25 54.120	122 29.960	120
61U1	11-9-2009	05:31:53	25 54.180	122 29.920	120
62D1	11-9-2009	06:21:18	26 0.050	122 29.970	111
62U1	11-9-2009	06:24:44	26 0.090	122 29.920	111
63D1	11-9-2009	08:02:14	25 59.990	122 15.010	103
63U1	11-9-2009	08:05:05	26 0.000	122 15.010	103
MHC1U1	10-9-2009	20:07:15	25 29.970	122 13.070	159
MHC2D1	10-9-2009	21:08:36	25 26.990	122 16.070	615
MHC2U1	10-9-2009	21:24:19	25 26.980	122 16.020	615
MHC3D1	10-9-2009	22:25:22	25 22.020	122 19.030	729
MHC3U1	10-9-2009	22:43:43	25 22.010	122 18.990	729
MHC4D1	10-9-2009	23:48:10	25 17.960	122 22.990	713
MHC4U1	11-9-2009	00:05:41	25 17.980	122 23.000	713

Figure 3.7 displays locations of the CTD casts performed during Leg 2 as the OR1 heads down the Mien-Hua Canyon. Figure 3.8 also shows those casts, but in the Leg2 area only. Temperature for those casts are shown in Figure 3.9 and the temperature/salinity relationship is shown in Figure 3.10.

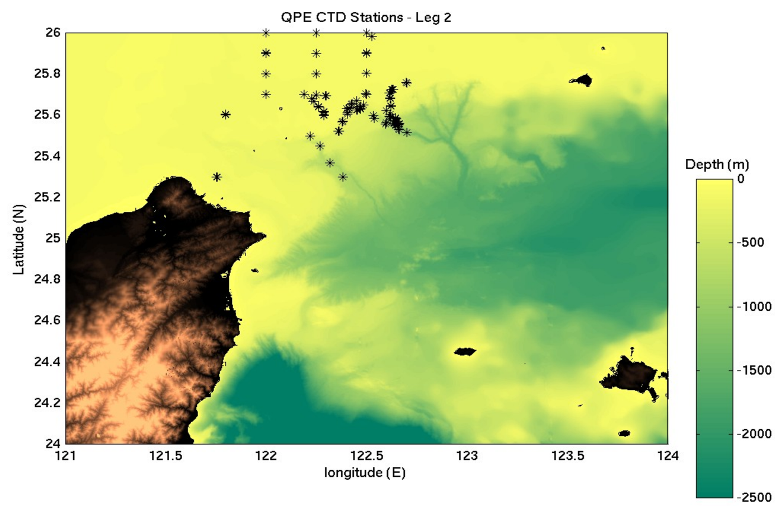


Figure 3.7. CTD casts performed during OR1 Leg 2.

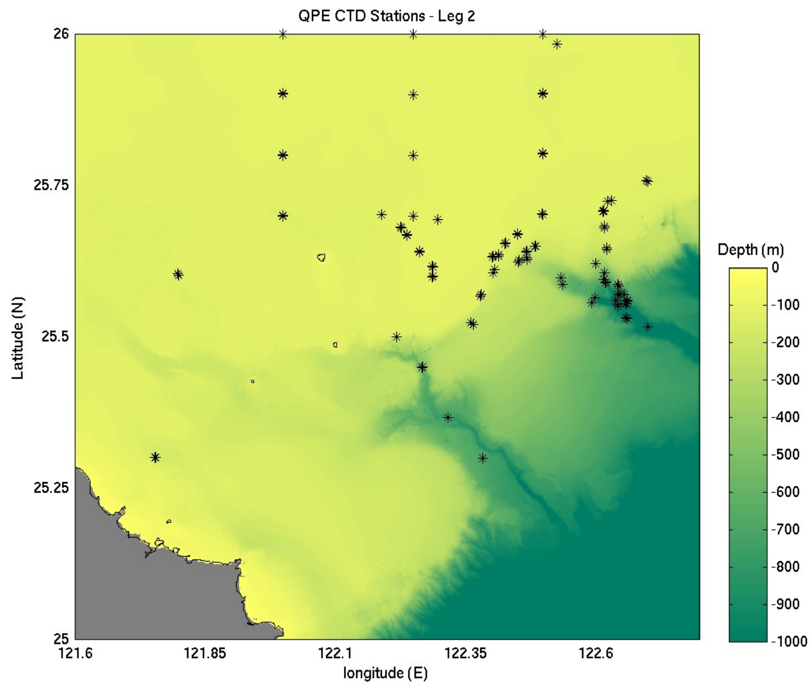


Figure 3.8. Zoomed version of the CTD casts performed during OR1 Leg 2.

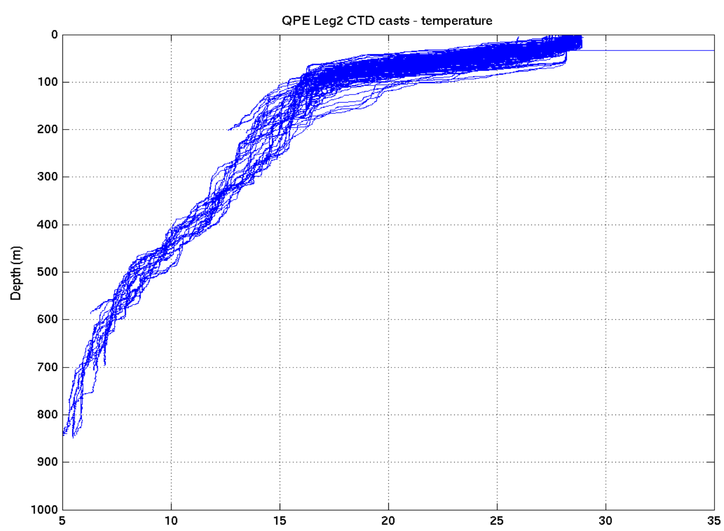


Figure 3.9. All casts from OR1 Leg 2 CTD showing temperature.

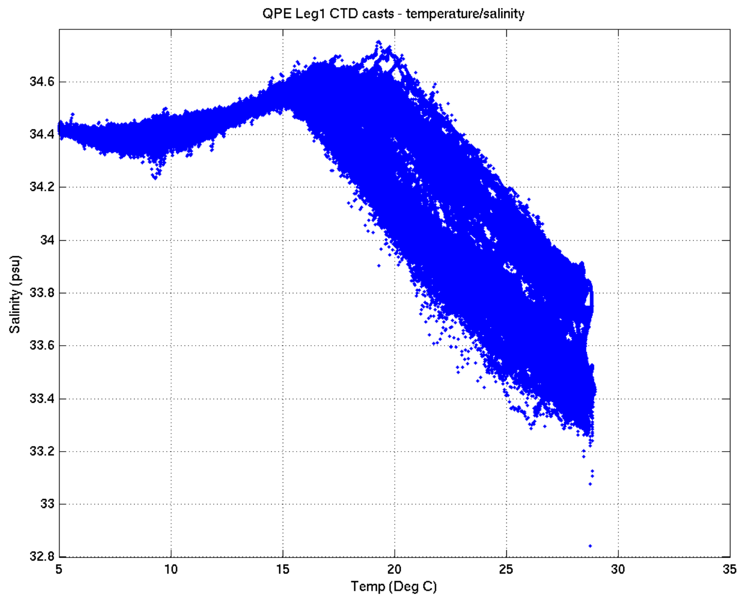


Figure 3.10. S/T plot for OR1 Leg 2.

3.2.3 Shipboard Radar (OR1)

The R/V OR1 was equipped with a horizontally looking radar to inspect the ocean surface for internal wave signatures. Figure 3.11 shows one image taken on Aug. 24th at 10:00 (UTC), while at location 25° 44.214' N and 122° 37.2588' E. This image clearly shows the directional complexity of the internal waves propagating through our research area. During Leg 1 from 8/24/2009 at 16:30 (*local time*) to 8/31/2009 at 19:15 (*local time*), one image every 5 minutes was saved. One image every 1 minute was saved during Leg 2 which started at 9/04/2009 at 10:21 (*local time*) and finished at 9/12/2009 at 05:38 (*local time*). The data filenames containing the radar images are time stamped with the date and time they were taken in local time. UTC time is local time minus 8 hours.

The range of ORI radar images is set to 3 nautical miles, and the grid interval as shown in the radar gif image (see Figure 3.11) is 1000m. For the raw binary radar data, i.e. the r-theta data, the pixel resolution is 15m and there are 380 pixels along each scan line. 2050 radar images were saved during leg 1 and 5740 images were saved during leg 2 (Table 22).

Table 22: Times during available surface expression radar images from R/V OR1

	Start Time (LOCAL)	***End Time (LOCAL)***	***Number of images***
Leg 1	8/24/2009 at 16:30	8/31/2009 at 19:15	2050
Leg 2	9/04/2009 at 10:21	9/12/2009 at 05:38	5740

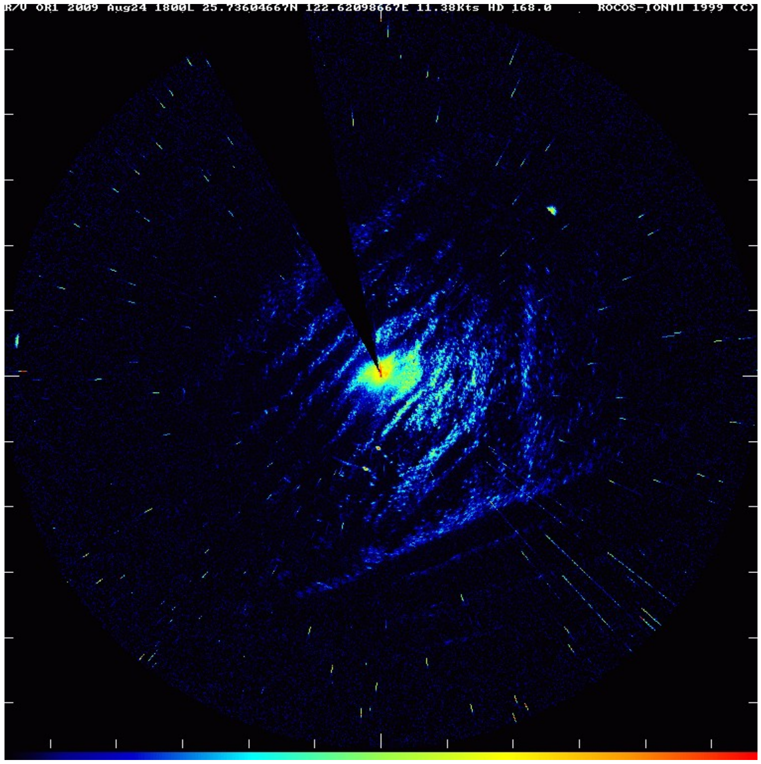


Figure 3.11. Radar image from R/V OR1 of the sea surface clearly showing multiple internal wave coming from different directions. Each tick mark on the image axis is equal to 1km.

3.2.4 Simrad EK500 (OR1)

All Ocean Researcher vessels were equipped with a EK500 echosounder, but only the data from R/V OR1 is discussed here. The EK500 echosounder provides ship over ground bathymetry as well as backscatter from any density variations due to fish and/or microstructure. Figure 3.12 shows the density differences caused by internal waves on Aug. 25th. Files were saved approximately every 20 minutes and filenames were timestamped with their acquisition time in UTC. Images are available simultaneously from two EK500 settings: 180 meter depth and 500 meter depth.

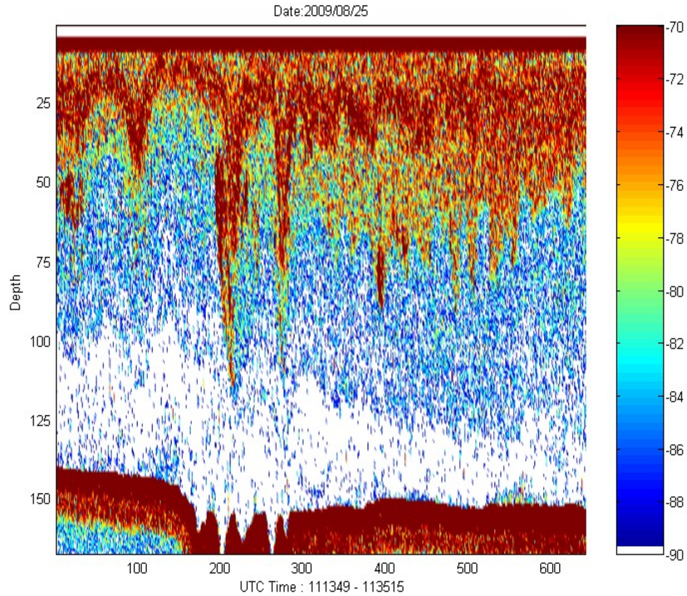


Figure 3.12. Image from the OR1 EK500 set to 180m for 11:13:49 on Aug 25th.

3.3 Environmental moorings

Well instrumented environmental (ENV) moorings were deployed in a triangular configuration to address internal wave magnitudes and direction. But due to time and weather considerations, all three moorings were only deployed in this configuration at Site B for both OR1 Leg1 and Leg2. Only one environmental mooring was used at Site A for leg 1, but no moorings were deployed at Site A for Leg 2 due to foul weather. These moorings were instrumented with fast-sampling temperature sensors (see Table 23) to obtain a complete, high resolution sampling of the oceanography for acoustics purposes. Each mooring had a temperature sensor attached to the high-flyer buoy floating at the surface (as a marker) as well as temperature and some conductivity (salinity) sensors 5 meters apart spanning the entire mooring. See Section 5 for exact mooring diagrams and Tables 16 and 17 for sensor placement. Multiple Seamon tpods were attached to measure temperature. Additionally, Seabird SBE37 sensors were also attached to each mooring to record pressure for determining the actual depths of all the sensors and any motion of the mooring. A temperature sensor was also placed on the release to make surface to bottom monitoring complete.

During Leg 1, three environmental moorings were deployed and named A(alpha), B(bravo), and C(charlie). Alpha and bravo were damaged due to fishing activity so were reconfigured and renamed AB(alpha-bravo) and BB(bravo-bravo) for leg 2. Mooring C was redeployed during leg 2. The site locations and mooring configurations follow in the next sections.

Table 23: Environmental Sensor Sampling

Sensor	***Sampling***
Starmon Mini temperature – leg1	1 minute
Starmon Mini temperature – leg 2	15 seconds
Seabird SBE39 T/P (legs 1 and 2)	10 seconds
Seabird SBE37 T/C (legs 1 and 2)	30 seconds

3.3.1 Leg1 (OR1 911)

Table 24: Env Moorings for leg1

Site / Mooring	***Deployed Location / Time(UTC) Date***	***Recovered Time(UTC) Date***	***Depth (m)***
Site A ENV#1 (AB)	25 59.059 122 31.574 10:56 8/29/09	21:33 8/30/09	112.5
Site B ENV#1 (A)	25 42.549 122 36.866 12:46 8/24/09	05:48 8/28/09	131.8
Site B ENV#2 (B)	25 42.505 122 37.454 13:37 8/24/09	02:57 8/28/09	134.4 (moved)
Site B ENV#3 (C)	25 42.051 122 37.117 12:45 8/24/09	00:50 8/28/09	139.7 (moved)

3.3.1.1 Leg 1 (OR1 911), Site A

The work at Site A began after work at Site B finished. Only one ENV mooring (AB) was deployed at Site A due to time constraints. Since the mesoscale oceanography is historically very homogeneous in this area, one mooring was deemed adequate. Table 25 show the placement of the sensors and Figure 3.13 displays a time series of the sensor data at that site. Since Site A was chosen for its shallow depth, the mooring was configured for 112 meters (Figure 5.1).

Table 25: Sensor serial numbers and placement for ENV moorings for Site A.

Marker / meters above bottom (mab)	*sensor*	***Alpha Bravo 112.5 m depth***
Hi-flyer / 1 m depth	tpod	n/a
Top of sphere / 94.75 mab	tpod	2040
1m from termination / 93.0 mab	SBE37 (t/c/p)	1770
20 / 91.2 mab	tpod	2063
25 / 86.2 mab	tpod	267
30 / 81.2 mab	tpod	271
35 / 76.2 mab	tpod	257
40 / 71.2 mab	tpod	209
45 / 66.2 mab	SBE39	3124
50 / 61.2 mab	tpod	212

Marker / meters above bottom (mab)	*sensor*	***Alpha Bravo 112.5 m depth***
55 / 56.2 mab	tpod	219
60 / 51.2 mab	tpod	217
65 / 46.2 mab	n/a	n/a
70 / 41.2 mab	tpod	2098
75 / 36.2 mab	tpod	2097
80 / 31.2 mab	tpod	2068
85 / 26.2 mab	SBE39	3128
90 / 21.2 mab	tpod	2094
95 / 16.2 mab	tpod	2076
5m wire / 7.0 mab	SBE37 (t/c/p)	1141
Release / 3.5 mab	tpod	2045

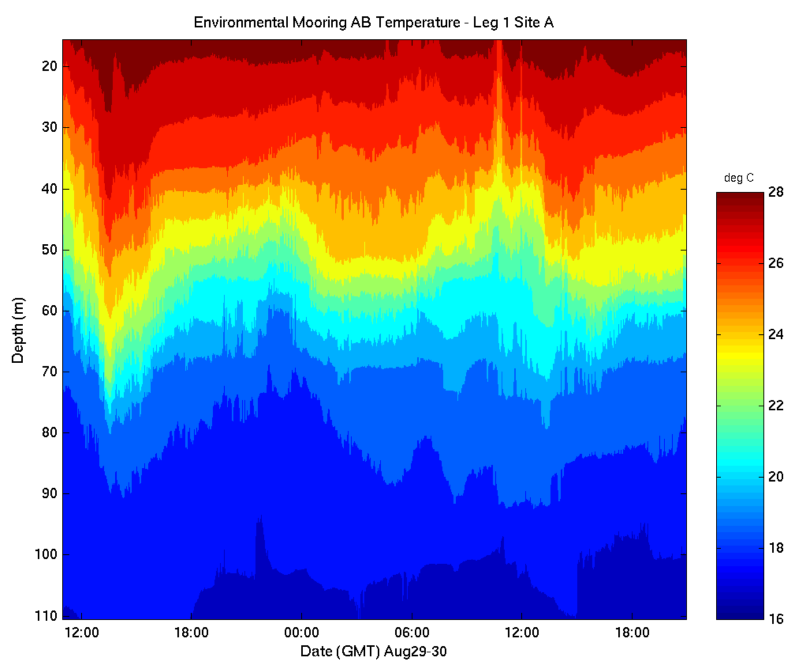


Figure 3.13. Temperature from AB mooring at Site A, OR1 Leg 1.

3.3.1.2 Leg 1 (OR1 911), Site B

Alpha mooring was dragged from Aug 24 21:37:00 to Aug 25 01:09 (3.5 hrs). Bravo mooring was also dragged. See Figure 2.2 for chart of deployment/recovery positions. Due to the slightly greater depth at Site B, all three moorings deployed there were configured for 125 meter depth.

Table 26: Sensor serial numbers and placement for ENV moorings for Site B.

Marker / meters above bottom (mab)	*sensor*	***Alpha* *131.8 m depth***	***Bravo* *134.4 m depth***	***Charlie* *139.7 m depth***
Hi-flyer / 1m depth	tpod	1994 **lost**	2005 **lost**	2046
Top of sphere / 107.75mab	tpod	2010	1996	2045
1m from termination / 106.0 mab	SBE37 with press	4284 **damaged**	4079 **damaged**	1770 (t/c/p)
20 / 104.2 mab	tpod	2038 **lost**	2004	2047
25 / 99.2 mab	tpod	2037 **lost**	1993	2084
30 / 94.2 mab	tpod	2036 **lost**	2003 **lost**	2048
35 / 89.2 mab	tpod	2035 **lost**	2007 **lost**	2051
40 / 84.2 mab	tpod	2034 **lost**	2008 **lost**	2052
45 / 79.2 mab	tpod	2033 **lost**	327 (sbe39 t/p)	321 (sbe39 t/c)
50 / 74.2 mab	tpod	2032 **lost**	2011 **lost**	2053
55 / 69.2 mab	tpod	2031 **lost**	2016 **lost**	2061
60 / 64.2 mab	tpod	2030 **lost**	2017 **lost**	2062
65 / 59.2 mab	SBE37 (t/c)	4104 **lost**	1140	1141
70 / 54.2 mab	tpod	2028 **lost**	2018 **lost**	2064
75 / 49.2 mab	tpod	2028 **lost**	2019 **lost**	2065
80 / 44.2 mab	tpod	2027 **lost**	2020	2080
85 / 39.2 mab	tpod	2026 **lost**	2021	2081
90 / 34.2 mab	tpod	2092 **lost**	2022	2085
95 / 29.2 mab	SBE39	324 (t/p)	322 (t/p)	311 (t/c)
100 / 24.2 mab	tpod	2041 **lost**	2023 **lost**	2086
105 / 19.2 mab	tpod	2042	2024 **lost**	2087
110 / 14.2 mab	tpod	2043	2040	2066
End / 12.0 mab	tpod	2044	2039	2088
5m wire	SBE37 (t/c/p)	1137	1132 **damaged**	1138
Release / 3.5 mab	tpod	2012 **lost**	2013	2015

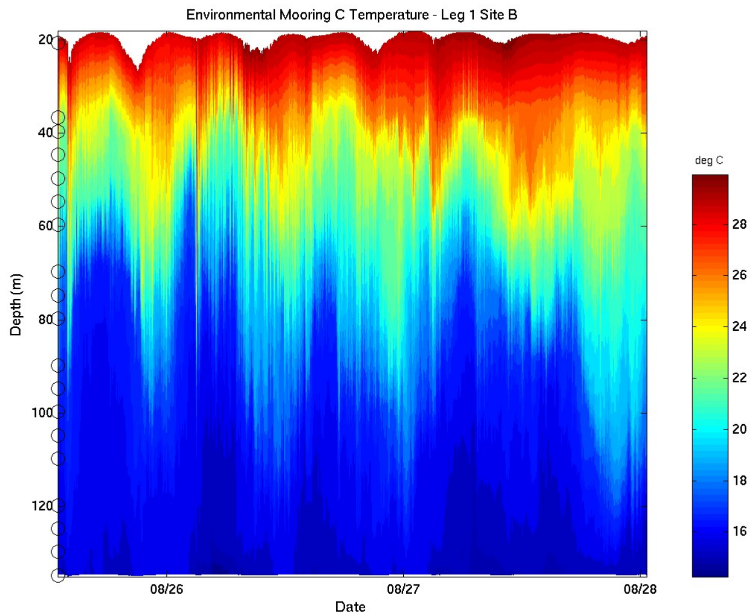


Figure 3.14. Temperature for env mooring C at Site B, OR1 Leg 1.

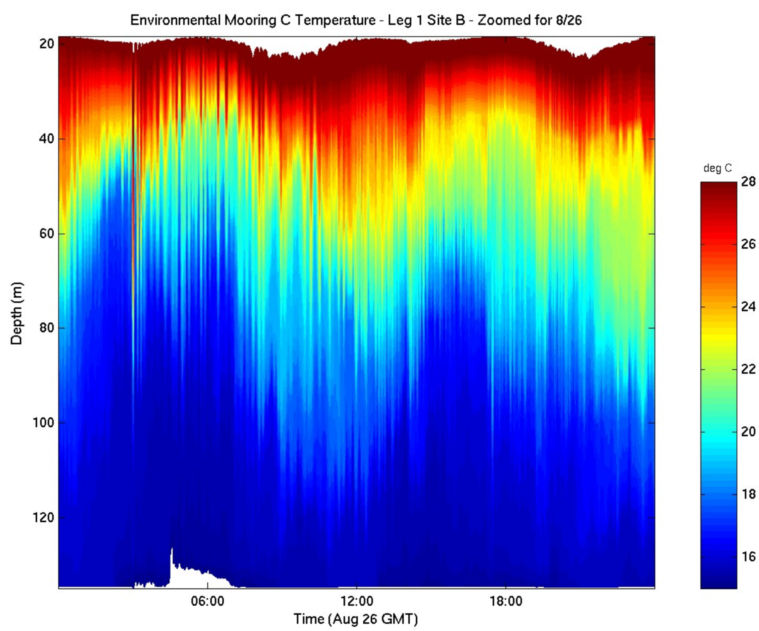


Figure 3.15. Temperature for Aug 28th at env mooring C, Site B, OR1 Leg 1.

3.3.2 Leg 2 (OR1 912)

Table 27: Environmental Moorings for OR1 Leg 2. No Environmental moorings were deployed at Site A.

Site / Mooring	***Deployed Location / Time(UTC) Date***	***Recovered Time(UTC) Date***	***Depth (m)***
Site B ENV#1 (AB)	25 42.541 122 36.842 10:34 9/04/09	23:43 9/08/09	129.0
Site B ENV#2 (BB)	25 42.519 122 37.444 11:40 9/04/09	23:15 9/08/09	133.0
Site B ENV#3 (C)	25 42.049 122 37.104 12:20 9/04/09	22:04 9/08/09	139.0

3.3.2.1 Leg 2 (OR1 912), Site B

Tpods 209, 212, 217, 219 did not start because of a software glitch with the older seamon temperature sensors. Alpha-Bravo and Bravo-Bravo moorings were configured for 112 meter depths (figure 5.1) with an additional 10 meter shot added to the bottom. Mooring Charlie was configured with the standard 125 meter configuration (Figure 5.2). Some SBEs and tpods were reused during this leg, so there will be multiple data files with the same instrument serial number.

Table 28: Sensor placement for ENV moorings Alpha-Bravo and Bravo-Bravo for Site B, OR1 Leg 2.

Marker / meters above bottom (mab)	***sensor***	***Alpha-Bravo 129.0 m depth***	***Bravo-Bravo 133.0 m depth***
Hi-flyer / 1m depth	tpod	x	x
Top of sphere / 105.75mab	tpod	2022	1992
1m from termination / 103.0 mab	SBE37 (t/c/p)	4079	1770
20 / 101.2 mab	tpod	2063	2073
25 / 96.2 mab	tpod	2045	2071
30 / 91.2 mab	tpod	x	2096
35 / 86.2 mab	tpod	257	221 n/d
40 / 81.2 mab	tpod	209 n/d	263 n/d
45 / 76.2 mab	SBE39 t/p	2024	326
50 / 71.2 mab	tpod	212 n/d	2099
55 / 66.2 mab	tpod	219 n/d	275 n/d
60 / 61.2 mab	tpod	217 n/d	145 n/d
65 / 56.2 mab	SBE37 t/c	1140	1133
70 / 51.2 mab	tpod	2098	274 n/d
75 / 46.2 mab	tpod	2097	256 n/d
80 / 41.2 mab	tpod	2068	279 n/d
85 / 36.2 mab	SBE39 t/p	3128	324

Marker / meters above bottom (mab)	***sensor***	***Alpha-Bravo 129.0 m depth***	***Bravo-Bravo 133.0 m depth***
90 / 31.2 mab	tpod	2094	2095
95 / 26.2 mab	tpod	2076	2100
2m from top 10m / 20.0 mab	tpod	1996	2001
2m from bottom of 10m / 14.0 mab	tpod	2044	2020
Bottom of 5m wire / 7.0 mab	SBE37 (t/c/p)	1141	1138
Release / 3.5 mab	tpod	2090	2014

Table 29: Sensor serial numbers and placement for ENV mooring Charlie for Site B, OR1 Leg 2.

Marker / meters above bottom (mab)	***sensor***	***Charlie 139.0 m depth***
Hi-flyer / 1m depth	tpod	x
Top of sphere / 107.75mab	tpod	2021
1m from termination / 106.0 mab	SBE37 with press	321(t/c/p)
20 / 104.2 mab	tpod	2047
25 / 99.2 mab	tpod	2084
30 / 94.2 mab	tpod	2049
35 / 89.2 mab	tpod	2051
40 / 84.2 mab	tpod	2052
45 / 79.2 mab	tpod	322 (sbe39 t/c)
50 / 74.2 mab	tpod	2053
55 / 69.2 mab	tpod	2061
60 / 64.2 mab	tpod	2062
65 / 59.2 mab	SBE37 (t/c)	1134
70 / 54.2 mab	tpod	2064
75 / 49.2 mab	tpod	2065
80 / 44.2 mab	tpod	2080
85 / 39.2 mab	tpod	2081
90 / 34.2 mab	tpod	2085
95 / 29.2 mab	SBE39	323 (t/c)
100 / 24.2 mab	tpod	2086
105 / 19.2 mab	tpod	2087
110 / 14.2 mab	tpod	2066
End / 12.0 mab	tpod	2088
5m wire	SBE37 (t/c/p)	1137
Release / 3.5 mab	tpod	2040

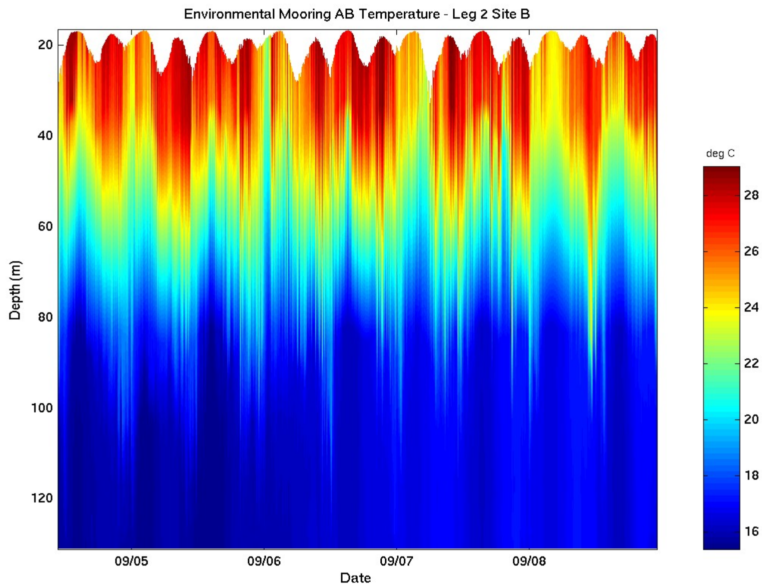


Figure 3.16. Temperature for ENV mooring AB at Site B, OR1 Leg 2.

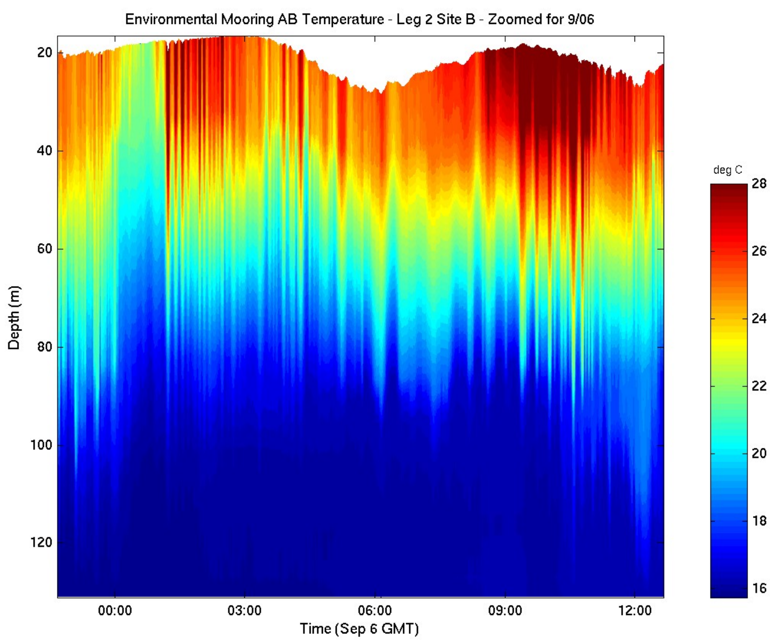


Figure 3.17. Temperature for Sept 6th at ENV mooring AB at Site B, OR1 Leg 2.

3.4 SHRU

A number of Several Hydrophone Receiving Units (SHRU) were used to record acoustic signals used during the QPE exercise. Each of these listening devices were equipped with 4 hydrophones that were attached to the mooring cable away from the electronics package at different depths (see Table 30) to create a vertical line array (VLA).

SHRU data records have a 1024 byte header followed by 16 bit data. The header structure for the SHRU is described below. A SHRU data record is 64 seconds of data at a 9765.625 Hz sample rate. This system was set up for 4 channels (labeled ch0-3). The data is saved one channel at at time starting with channel 0. There are 524288 samples per channel in each record for a total of 4194304 data bytes per record for all 4 channels. Each record will then, including the header, be comprised of 4195328 bytes. A full, single SHRU data file consists of 128 records and is therefore 537,001,984 (128 * 4195328) bytes in size. The flat passband is .453 times the sample rate (4424 Hz) and the -3dB point is .49 times the sample rate.

SHRU data was acquired using a Persistor, model CF2 which employs a Motorola 32 bit processor and therefore, stores data big endian, i.e. the higher order byte of a 2-byte sample value occurs first in ascending memory space. The SHRU data set has a fixed gain of 26 dB (or a fixed gain of 20 in linear scale). Therefore when normalizing SHRU data to volts at the sensor output, a fixed gain of 20 should be used.

If the data was recorded from one day to the next past midnight, the day did not not get incremented until the next new file was created. The day rollover increment will have to be incorporated into the software that reads the DRH. This has not been done to date.

The 1024 byte structure below is written as a Data Record Header (DRH) by the SHRU.

```
struct data_rec_h                                  // 1024 bytes total        (DRH bytes)
{
        unsigned char   rhkey[4];                  // header key, "DATA"    (0-3)
        unsigned int    date[2];                   // date[0]=year, date[1]=Year-day#   (4-7)
        unsigned int    time[2];                   // time[0] = (hours*60 + minutes)     (8-11)
                                                   // time[1] = (seconds*1000 + milliseconds)
        unsigned int    microsec;                  // microseconds, (12-13)
        unsigned int    rec;                       // this record #      (14-15)

        int             ch;                        // # channels   <4>    (16-17)
        char            unused1[2];                // (18-19)
        long            npts;                      // # sample periods per record, 524288 for SHRU4  (20-23)
        float           rhfs;                      // sample rate in Hz <9765.625> ,  19531.25 B/s     (24-27)
        long            rectime;                   // record time in microsec <53687091>      (28-31)
                                                   // 128 recs* 4195328 B/rec  =  537,001,984bytes per file
        char            rhlat[16];                 // long, ascii DDD MM SS.T N or S,  for SW06 N/A   (32-47)
        char            rhlng[16];                 // long, ascii DDD MM SS.T E or W,  for SW06 N/A    (48-63)

        unsigned long   nav120[7][4];              // N/A
        unsigned long   nav115[7][4];              // N/A
        unsigned long   nav110[7][4];              // N/A

        char            POS[128];                  // N/A for SHRU   (400-527)
        char            unused2[208];              //  (528-735)

        int             nav_day;                   // N/A for SHRU
        int             nav_hour;                  //  (738-739)
        int             nav_min;                   //  (740-741)
        int             nav_sec;                   //  (742-743)
        int             lblnav_flag;               //  (744-745)
        char            unused3[2];                //  (746-747)
        long            record_length;             // record length in bytes; 1,251,024    (748-751)
```

```
        int         acq_day;              // N/A for SHRU
        int         acq_hour;             //  (754-755)           "
        int         acq_min;              //  (756-757)           "
        int         acq_sec;              //  (758-759)           "
        int         acq_recnum            // (760-761)            "
        int         ADC_tagbyte           // (762-763)            "
        int         glitch_code;          // (764-765)            "
        int         boot_flag             // (766-767)            "

        char        internal_temp[16];    //  temp for SHRU   (768-783)
        char        bat_voltage[16];      //  Vmain for SHRU   (784-799)
        char        bat_current[16];      //  (800-815)
        char        status[16];           //  (816-831)
        char        proj[16];             // project name <QPE>,   (832-847)
        char        aexp[16];             //    (848-863)
        char        vla[16];              // <PHONE SENS  -170>     (864-879)
        char        hla[16];              // same as above  < -170 >      (880-895)
        char        fname[32];            // ascii file name     (896-927)
        char        record[16];           // ascii representation of  rec #, REC ####   (926-943)
        char        adate[16];            // ascii representation of  date, mo/da/yr   (944-959)
        char        atime[16];            // ascii rep of  rec time, hr:mn:ss.mmmmmm    (960-975)

        long        file_length;          // 128 record file len, SHRU,  53,7001,984 bytes   (976-979)
        long        total_records         // total # records to date    (980-983)
        char        unused4[2];           //  (984-985)
        int         adc_mode;             // 0 =fixed point, 1 = 24 bit, <2 = pfp>   (986-987)
        int         adc_clk_code;         // ADC clock timebase divider, SHRU=1  (988-989)
        char        unused5[2];           //   (990-991)

        long        timebase;             // 5 MHz  Austron     (992-995)
        char        unused6[12];          //   (996-1007)

        char        unused7[12];          //   (1008-1019)
        char        rhkeyl[4];            // end of rec header key "ADAT"    (1020-1023)
} ;
```

Data were stored as unsigned short int (2 bytes), with the upper byte occurring first followed by the lower byte.

The "C" coded method of normalizing the stored 16 bit integer SHRU data to a value of volts from the hydrophone is:

```
exp =  val[i] & 0x0003
gain = 10^(26/20) * 2^(exp*3)
voltage (at hydrophone output) = (((val[i] >> 2) / 8192) * 2.5v) / gain
```

A method used when data are brought into Matlab (tm) for processing is to read the data as 16 bit shorts. Data will become doubles in Matlab. SHRU data are stored big endian so Matlab has to be instructed to read it accordingly. The gain normalizing algorithm shown below accommodates the SHRU ADC linear fixed gain of 20 (~26 dB).

```
fixed_gain = 20;           % linear - fixed gain is 20(~26dB) for shru.
ADC_halfscale = 2.5;       % ADC half scale volts (+/- half scale is ADC i/p range)
ADC_maxvalue = 8192; % ADC max halfscale o/p value, half the 2's complement range
norm_factor = ADC_halfscale/ADC_maxvalue/fixed_gain;

data = data/4;                  % clip off the last two bits as a gain (actually an exponent)
mantissa=floor(data);      % "floor" is required due to the nature of negative binary numbers
gain=4*(data-mantissa);
gain=(2*(ones(1,BLKSIZE))).^(3*gain);   % one channel,  BLKSIZE (npts) = 524288
voltage=(2.5)*((data)./gain)/8192/20;
```

Peak to peak voltage at the output of a phone is 1Vpp. (Vpp = -9 dBv). Since the SHRU hydrophone sensitivity is 170 dB re 1 μPa per 1 volt, to convert the data time series, after normalizing as described above, from volts to microPascals (μPa) is:

$$\mu Pa = voltage * 10^{(170/20)}$$

Standard processing procedures can be performed in either microPascals or volts. The conversion of dB levels from volts to microPascals is:

$$dB\ re\ 1\ \mu Pa = dB\ re\ 1\ volt + 170$$

A sample spectrogram of the SHRU acoustics data is shown in Figure 3.21 which shows OMAS LFM and CW signals from 500Hz to 1000Hz. Figure 3.22 shows the pulse compressed travel times from the OMAS to a SHRU located neat the mouth of the canyon on 9/08. One can see the mobile source getting closer to the receiver then veering away.

All SHRU data files are named using the date and time from the first record in the file. The filename convention is

MMDDhhmm.D09

where MM is the month, DD is the day, hh is the hour, and mm is the minute of the first record in that file. All data between records are seamless without any time delay.

The four hydrophones (shallowest ch0 and deepest ch3) were attached to the mooring cable starting at 7.2 meters above the bottom. Distances from the mooring bottom are shown in Table 30.

Table 30: SHRU configuration OR1 Leg1 Site B. Phones/sensors at other locations also were attached to the cable as described below.

Distance (meters from the mooring bottom)	*sensor*	***Array 1***	***Array 2***
18.5	SBE39	326	323
18.0	**Ch0 phone**	238067	238058
15.8	tpod	1991	n/a
13.6	**Ch1 phone**	238053	238065
11.5	tpod	2006	1992
9.3	**Ch2 phone**	238071	238064
7.2	tpod	n/a	2014
5.0	**Ch3 phone**	238046	238068
3.5 (release)	tpod	2002	2001

3.4.1 Leg1 (OR1 911)

3.4.1.1 Leg 1 (OR1 911), Site A

Table 31: Deployment positions, depths and times for SHRU Site A moorings, OR1 leg 911

Mooring	***Deployed Position (latitude N longitude E)***	***Deployed Time / Date (UTC)***	***Recovered Time / Date (UTC)***	***Depth (m)***
SHRU#1 (s/n 06 array 2)	25 59.290 122 31.889	11:14 8/29/09	22:00 8/30/09	114.0

SHRU s/n 06 had same tpod #2001 as for site B earlier.

3.4.1.2 Leg 1 (OR1 911), Site B

Table 32: Deployment positions, depths and times for SHRU Site B moorings, OR1 leg 911

Mooring	***Deployed Position (latitude N longitude E)***	***Deployed Time / Date (UTC)***	***Recovered Time / Date (UTC)***	***Depth (m)***
SHRU#1 (s/n 08 array 1)	25 42.866 122 36.759	11:55 8/24/09	08:48 8/28/09	126
SHRU#2 (s/n 07 array 2)	25 38.993 122 36.014	11:52 8/25/09	09:38 8/28/09	208.4

The SHRUs had a single temperature sensor attached to the release 1 meter above bottom. For Leg 1, Site B, tpod temperature sensor #2002 was attached to Array 1 (SHRU s/n 08) and tpod sensor #2001 was attached to Array 2 (SHRU s/n 07).

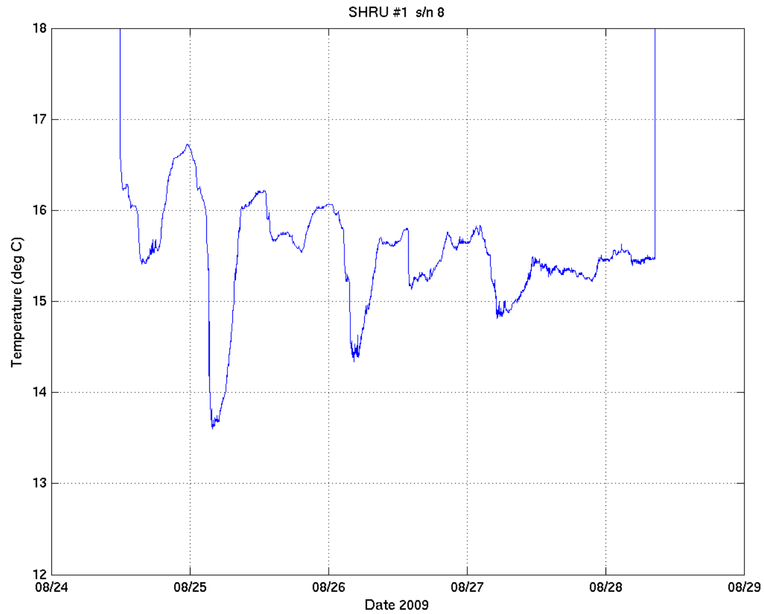


Figure 3.18. Temperature for SHRU #1, OR1 Leg1, Site B at 126m depth.

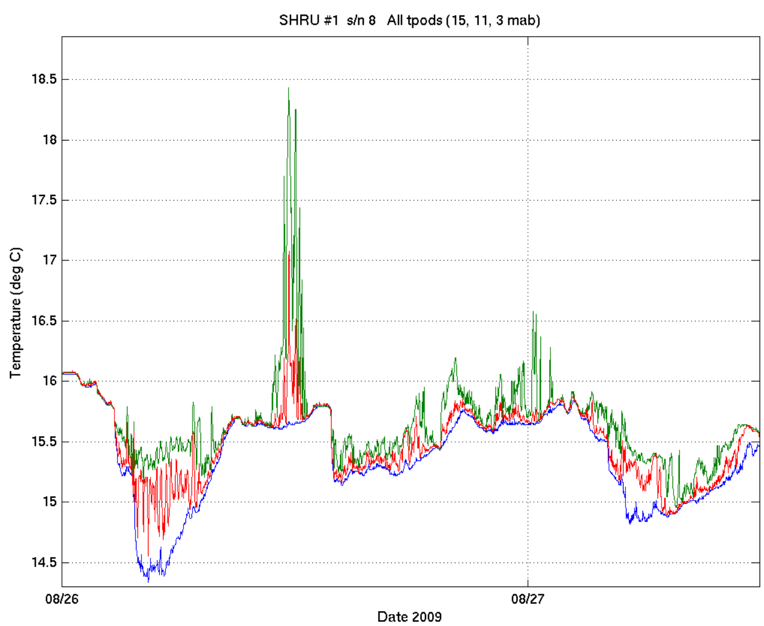


Figure 3.19. Difference among the 3 tpods on SHRU #1, Site B, OR1 Leg1.

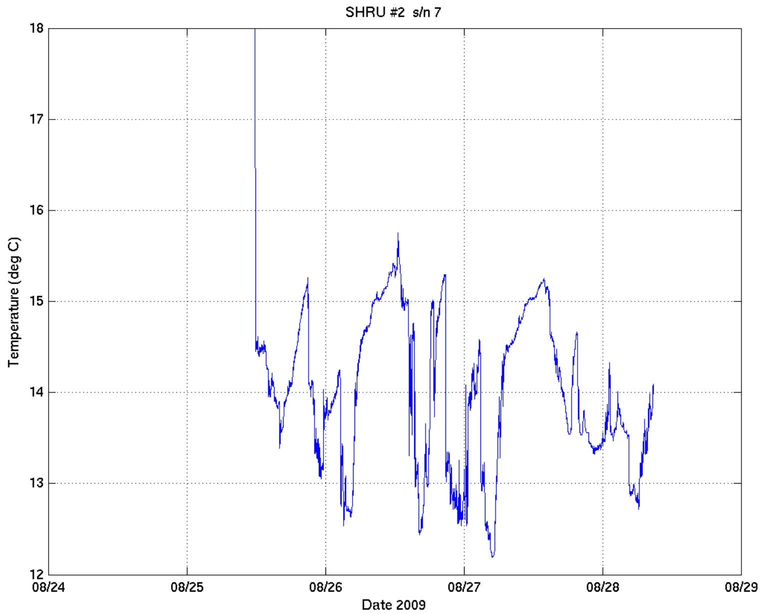


Figure 3.20. Temperature for SHRU #2, OR1 Leg1, Site B at 208m depth.

3.4.2 Leg2 (OR1 912)

3.4.2.1 Leg 2 (OR1 912), Site B

Table 33: Deployment positions, depths and times for SHRU Site B moorings, OR1 leg 912

Mooring	***Deployed Position (latitude N longitude E)***	***Deployed Time / Date (UTC)***	***Recovered Time / Date (UTC)***	***Depth (m)***
SHRU#1 (s/n 07 array 2)	25 42.841 122 36.724	13:03 9/04/09	00:15 9/09/09	126
SHRU#2 (s/n 08 array 1)	25 37.563 122 35.924	13:58 9/04/09	03:25 9/09/09	337

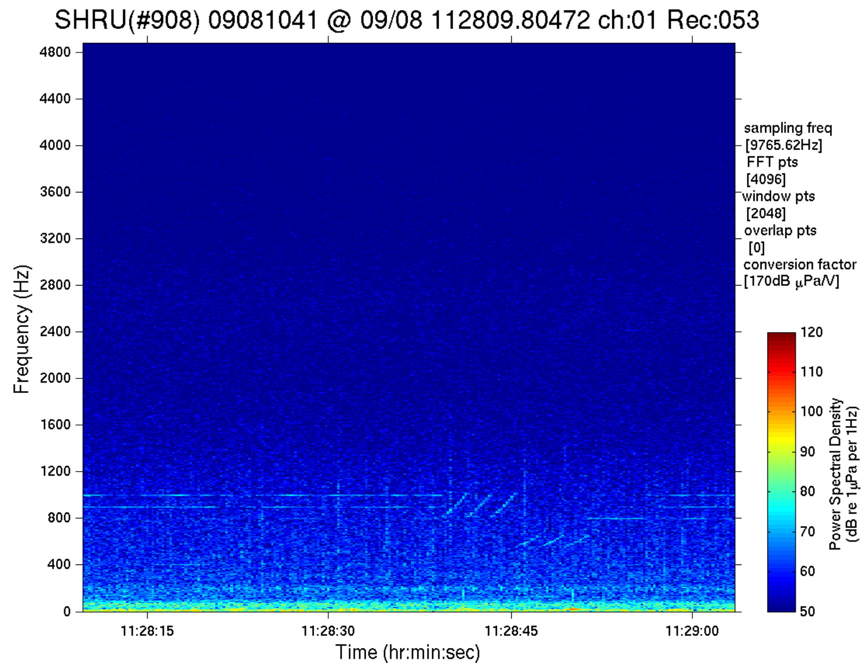


Figure 3.21. SHRU spectrogram showing OMAS signal.

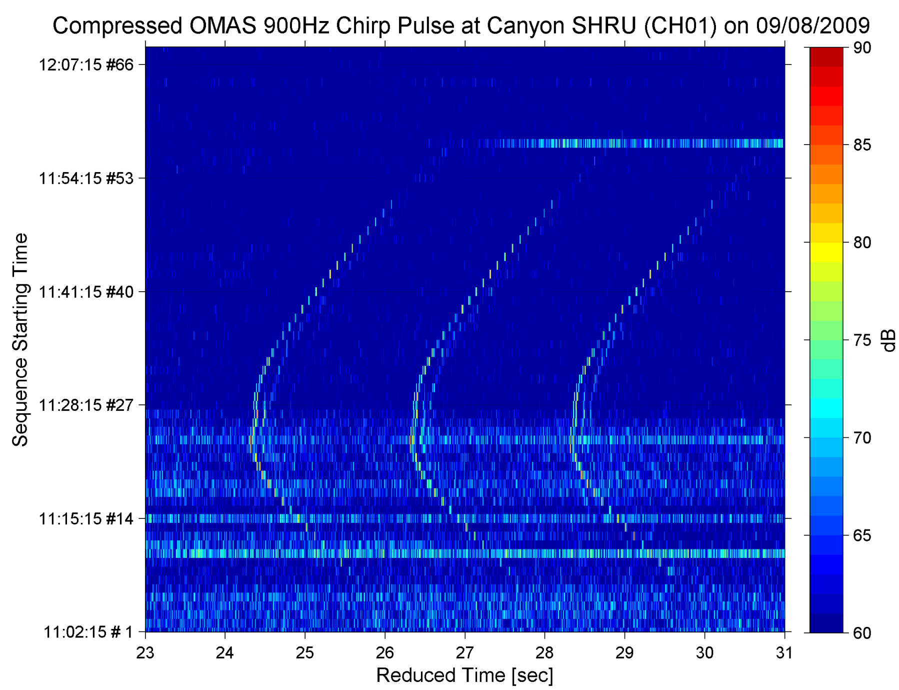


Figure 3.22. Pulse compressed OMAS signal tracked over time.

3.4.3 NSYSU SHRU

A SHRU was also deployed by National Sun Yat-Sen University (NSYSU) from the R/V OR2 (cruise #1656) about a month before the WHOI SHRUs and recovered by the OR1 at the end of the intensive operations period. This SHRU was deployed at Site B earlier during the QPE experiment on Aug 2nd for a long-term ambient noise study for the area but was also available during QPE acoustics work at Site B. Figure 3.22 shows receptions from the mobile source deployed at the end of OR1 Leg 1, as does Figure 3.23 but at a different time. The position of the NSYSU SHRU compared to the WHOI SHRUs can be seen in Figure 3.25.

The NSYSU only employed a single hydrophone which was positioned 6.5 meters above the bottom. The sampling rate was the same as the WHOI SHRU at 9765.653 Hz as is the data storage format. However, the fixed gain was set to be 6dB instead of 26dB used by WHOI. Moreover, the time stored by the NSYSU SHRU was recorded in local time, so 8 hours should be deducted to get UTC.

A thermistor was attached to the mooring just below the hydrophone at ~128.5 meters depth and sampled every 30 seconds from Aug 2nd through to Sept 4th when sampling stopped. Figure 3.24 shows the temperature measured at the NSYSU SHRU.

Table 34: Deployment position, depth and times for NSYSU SHRU

Mooring	***Deployed Position (latitude N longitude E)***	***Deployed Time/Date (UTC)***	***Sampling finished (UTC)***	***Recovered Time/Date (UTC)***	***Depth (m)***
SHRU - NSYSU	25 41.910 122 38.944	00:30 08/01/09	17:30 9/4/09	20:00 9/9/09	143 (water) 134 (phone)

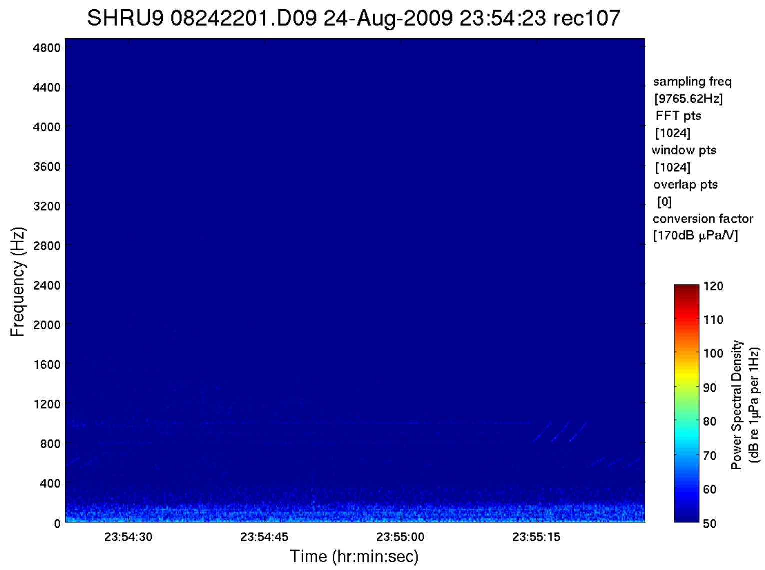


Figure 3.23. Spectrogram from NSYSU SHRU showing receptions at 900Hz from an OMAS. The date/time here is local time (UTC - 8).

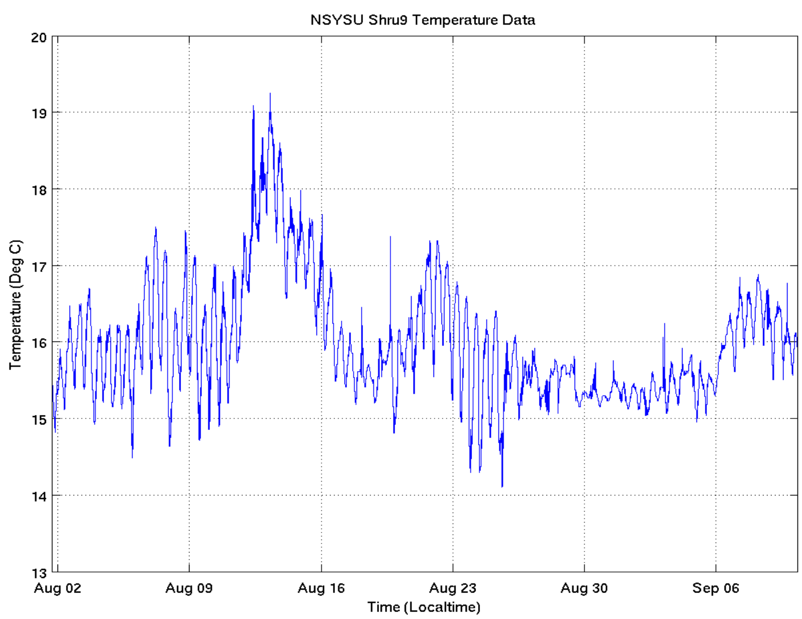


Figure 3.24. Long term temperature data from the NSYSU shru which was located at ~128.5m depth .

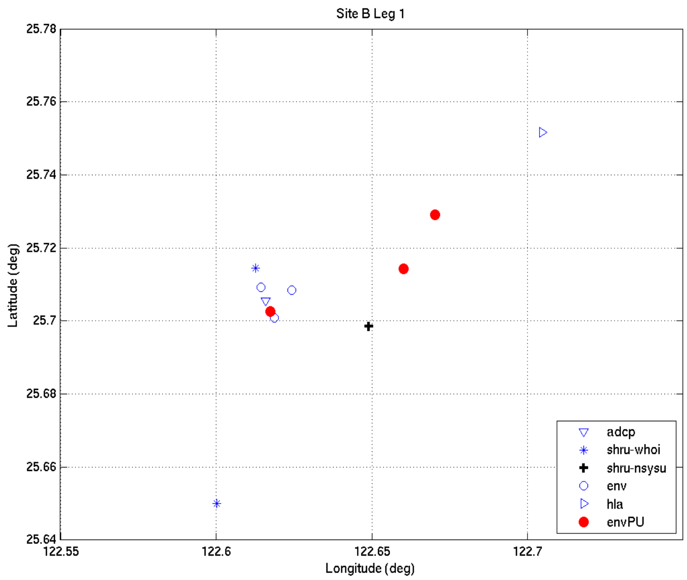


Figure 3.25. NSYSU SHRU deployment position in relation to the other moorings in Site B, OR1 Leg1. Solid colored dots in this plot are recovery positions for the environment moorings that were dragged by fishing activity.

3.5 Webb horizontal and vertical line arrays (WHOI HLA and NTU VLA)

An 8 element, hydrophone line array designed at Webb Research Corporation (WRC) was deployed multiple times by R/V OR1 on the ocean bottom to be used as a Horizontal Line Array (HLA). A similar vertical line array (VLA), also designed at WRC and has similar specifications, was deployed by National Taiwan University from the R/V OR2. The NTU VLA is described in more detail in Section 3.5.3.

Hydrophones along the WHOI HLA were separated by 7.92 meters (26 ft) and their distances from the sled can be seen in Table 35. Hydrophone channel 1 was 2.08 meters from the eye that attaches the array to the sled, and the chain wrapped in tygon tube attached to the end of the array for drag was 2 meters from hydrophone channel 8. Since this array was assembled at the last minute, no diagram is available. Two temperature sensors were attached to each end of the mooring. Figure 3.27 displays a time series of the temperature data from one of the temperature sensors on the Webb array.

WHOI HLA data sampling is set to 8000 Hz. Sampling is stopped 20 seconds short of 8 hours to write data to disk. File size (for 8 hours) should be 8000*16*86400/3 = 3,686,400,000 bytes but the actual file size is 3683840016 bytes adjusting for the minus 20 seconds of data for writing. All data files began exactly on the 8 hour mark. The clock was synced to GPS time before deployment and checked for drift at recovery (Tables 35 and 36). WHOI HLA data are stored as 16 bit integer values from 0 to 5 volts which corresponds to -2.5 to 2.5 volts rms.

The hydrophones used with the WHOI HLA are model HTI-90-U from High-Tech Inc. Specifications for the received signals follow:

Hydrophone sensitivity is -186 dB re 1V/uPa.
Hydrophone amplifier gain is 28 dB.
Recorder gain is 28 dB.
Relationship of full range voltage to 16 bit data: 5V -> 2^{16}

To transform array data, x_i, from the 16 bit raw data stored by the array to sound pressure level (SPL) in dB re 1 uPa, the following expression can be used.

$$SPL = 20*\log10((x_i/\text{sqrt}(2)*5/(2^{16})) - 35 - 28 + 186$$

Data is saved channel by channel starting at channel 8 (ch1-8) which is *furthest* from the sled housing the electronics pressure case. Data is stored continuously as unsigned integer (16bits) without any time information. Hydrophones were spaced 8 meters apart. At this time, orientation and exact locations of the hydrophones have not been calculated. Sample Matlab code for reading the Webb array data follows:

```
phone = 1;                          % Phone number to extract
nelts = 8;                          % 8 hydrophones
fsamp = 8000;                       % sampling at 8kHz
Npts_total   = fsamp * 60*60 *8;    % 8 hrs of sampling at
Npts = Npts_total/480;              % cut up into 1 min sections to analyze

fid=fopen(File,'r','ieee-be');
A=fread(fid,nelts*Npts,'uint16');
B=reshape(A,nelts,Npts);            % line them up
mn=mean(B')';                       % average for each elt.
D=B-mn*ones(1,Npts);                % demean

ich = 9-phone;                      % data stored in reverse channel order (8->1)
D(ich,:);                           %  Data for hydrophone (phone) for Npts
```

To sample temperature at the site, tpod #2089 was attached 1meter from yale grip on one end and tpod #2090 was attached 1meter from thimble at the tail end for all deployments.

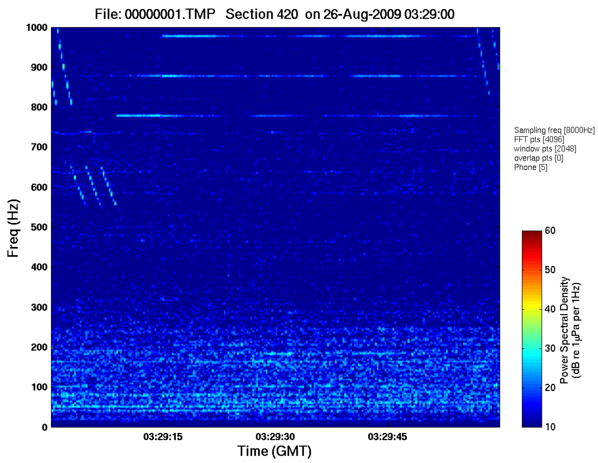


Figure 3.26. OMAS signal on single hydrophone from the WHOI HLA.

3.5.1 WHOI HLA Leg1 (911)

The WHOI HLA was only deployed at Site B for both legs. The HLA has a more complicated deployment than a single environment mooring since it has to be carefully lain on the ocean bottom. Time and weather conditions made it impossible to deploy at Site A for either leg. Figure 3.26 shows a spectrogram of OMAS reception on the WHOI HLA.

3.5.1.1 Leg 1 (OR1 911), Site B

Table 35: WHOI hydrophone array deployment positions, depths and time for Site B, OR1 Leg 1 (911).

WHOI Hydrophone Array, OR1 Leg 1, Site B	
Deployment location	25 45.097 N 122 42.285 E
Deployment Date/Time (UTC)	8/25/09 10:40
Recovered Date/Time (UTC)	8/28/09 07:38
Depth	133.1
Cutoff filters	50 Hz, 1000 Hz
Array start date (jday:hr:min:sec)	**237:12:30:00**
Sampling frequency	8000 Hz
Data file size	~3.6 GB
Number of hydrophones	8
Hydrophone #1 (distance (m) from sled)	2.08
Hydrophone #2 (distance (m) from sled)	10.00
Hydrophone #3 (distance (m) from sled)	17.92
Hydrophone #4 (distance (m) from sled)	25.84

WHOI Hydrophone Array, OR1 Leg 1, Site B	
Hydrophone #5 (distance (m) from sled)	33.76
Hydrophone #6 (distance (m) from sled)	41.68
Hydrophone #7 (distance (m) from sled)	49.60
Hydrophone #8 (distance (m) from sled)	59.52

Table 36: Clock checks for WHOI VLA Site B mooring, OR1 Leg 1 (911)

	Time day:hr:min:sec	***Date***
Webb time before deployment	237:05:34:14	8/25/09
GPS time after deployment	237:05:34:14	8/25/09
Webb time at recovery	241:12:21:32	8/29/09
GPS time at recovery	241:12:22:02	8/29/09

WHOI HLA lagged GPS by 30 seconds at the last time check, 4 days 6 hours 53 minutes and 18 secs from initial time check when starting.

Table 37 displays the position of the ship during different times during deployment in order to understand the direction the array was oriented.

Table 37: Locations during deployment for calculating array orientation, Site B moorings, OR1 Leg 1 (911)

Deployment	***Position***
sled on bottom	25 45.097 122 42.285
after 4 mins	25 45.102 122 42.290
Hi flyer in	25 45.116 122 42.272

3.5.1.2 Temperature at WHOI HLA – leg 1 (OR1 911), Site B

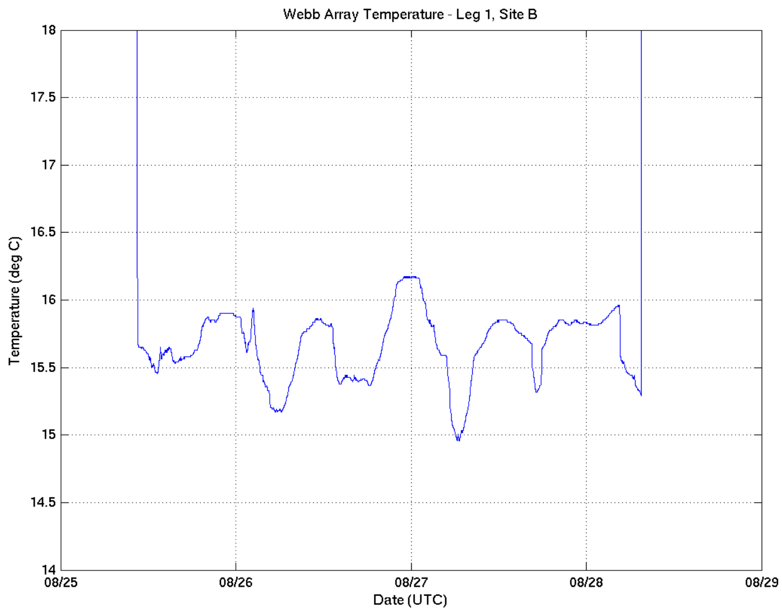


Figure 3.27. Temperature at WHOI Array for OR1 Leg 1, Site B.

3.5.1.3 Light bulbs – Leg 1 (OR1 911), Site B

Common household light bulbs were imploded at 10 meters depth to create a broadband pulse to survey the hydrophone positions of the WHOI Horizontal Line Array. Due to having to rush to catch slack tide for mooring recovery operations, only two stations were executed, each with two bulbs imploded at each station.

Table 38: Light bulb positions and times for Webb Array hydrophones, Site B moorings, OR1 leg 911

Bulb Number	***Position***	***Time (UTC) date***
Bulb #1	25 45.038 122 42.227	06:59:29 8/28/09
Bulb #2	25 45.038 122 42.227	07:02:50 8/28/09
Bulb #3	25 45.059 122 42.366	07:10:00 8/28/09
Bulb #4	25 45.067 122 42.366	07:11:20 8/28/09

3.5.2 Leg2 (OR1 912)

3.5.2.1 Leg 2 (OR1 912), Site B

WHOI HLA data sampling ended sooner than expected. Files were not written for the entire deployment and stopped unexpectedly after 24 hours of sampling. This also affected the localization using light bulbs that was performed just before recovery so no localization information is available. Array orientation has not been determined so OR1 GPS locations will have to be examined during the deployment to calculate the HLA orientation and probable HLA hydrophone placement.

Table 39: Deployment positions, depths and times for WHOI HLA Site B moorings, OR1 leg 912

Deployed Position (latitude N longitude E)	***Time sampling started***	***Deployed Time / Date (UTC)***	***Recovered Time / Date (UTC)***	***Depth (m)***
25 45.429 122 42.019	248:01:00:00	22:32 9/04/09	05:10 9/09/09	133.7

Clock drift for WHOI array, OR1 Leg 2, site B. Clock drifted +4:20:54, over 4 hours, since starting! This might be a cause for concern the next time we deploy. The WHOI array set to start sampling on day 248 at 0100 Z and prematurely stopped sampling exactly 24 hours later on day 249 at 0100Z.

Table 40: Clock drift for Webb HLA, Site B mooring, leg 912

	Time day:hr:min:sec	***Date***
Webb time when started	247:14:07:30	9/04/09
GPS time when started	247:14:07:30	9/04/09
Webb time at recovery	252:06:03:56	9/09/09
GPS time at recovery	252:10:24:50	9/09/09

3.5.2.2 Temperature – Leg 2 (OR1 912), Site B

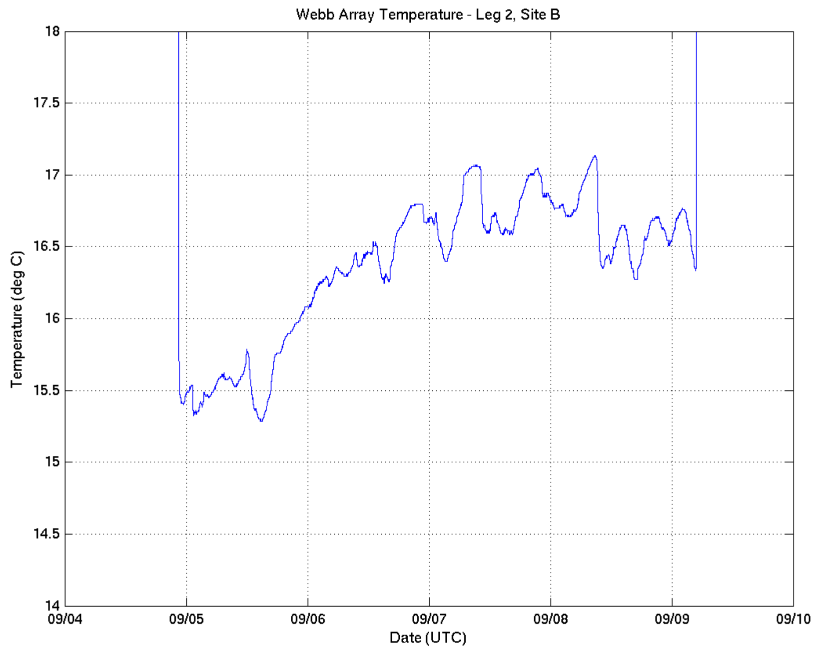


Figure 3.28. Temperature for WHOI Array on bottom for OR1 Leg 2, Site B.

3.5.2.3 Light bulbs – Leg 2 (OR1 912), Site B

Common household light bulbs were popped at 10 meters depth to create a broadband pulse to survey the hydrophone positions of the WHOI horizontal Line array. Three stations were performed. Since the HLA stopped sampling early, no hydrophone localization can be performed, but this information is being kept here for completeness.

Table 41: Light bulb positions and times for WHOI HLA hydrophones, Site B mooring, OR1 leg 912

Bulb Number	***Position***	***Time (UTC) date***	***Slant Range***	***2-way time***
Bulb #1	25 45.373 122 41.910	06:23:00 8/08/09	274	.366
Bulb #2	25 45.507 122 42.026	06:35:00 8/08/09	158	.211
Bulb #3	25 45.366 122 42.145	06:45:00 8/08/09	389	.519

3.5.3 National Taiwan University Vertical Line Array (VLA)

National Taiwan University deployed an 8 channel vertical hydrophone array (VLA) in the Site B area concurrently with other WHOI and NSYSU moorings (see Figure 3.29) and recorded continuously at a 2 kHz sample rate for a period of 4 days from Sept. 5th to Sept. 9th when it was picked up by the OR1 during Leg 2 (cruise number 912). The VLA hydrophone array has 16 channels and is 80 meters in length, however, due to physical, internal constraints only 8 channels (channels 2,4,6,8,10,12,14,16) were set for recording. Unfortunately, the top four channels malfunctioned, so only data from channels 10, 12, 14 and 16 are available. Channel 16 was the deepest (at bottom of the VLA) hydrophone. The sensitivity of each channel is calibrated to about -170dB ref 1V/microPa and hydrophone spacing is 3.75 meters. See Table 43 for the depths of the hydrophones used during this deployment and Figure 3.30 for a spectrogram of a subset of the data.

The data format for the NTU VLA is similar to the WHOI HLA, described in section 3.5 except that the length (time) of the data file was shorter at 5 hours per file. Each file is separated exactly at 5 hours and each file is 20 seconds short of total 5 hour sampling period to make time for moving data to hard disk. Each data file size is 575360000 bytes (8 elts * 2000 samples/sec * 5 hrs * 2 samples/byte minus the 20 seconds to store data). Each data file contains 287680000 samples ((8elts * 2000sampes/sec * 5hr * 60min/hr * 60sec/min) – (8elts*2000samples/sec*20sec)).

Three types of temperature-pressure sensors were also attached to the VLA. They were SBE39s, Star-ODIs and T-bits. The SBE39s and Star-ODIs have both pressure and temperature data. T-bits have only temperature data. Sampling rate of all sensors were set to 30 seconds. A list of the sensors attached to the VLA is shown in Table 38 and a plot of the temperature at the VLA is shown in Figure 3.31.

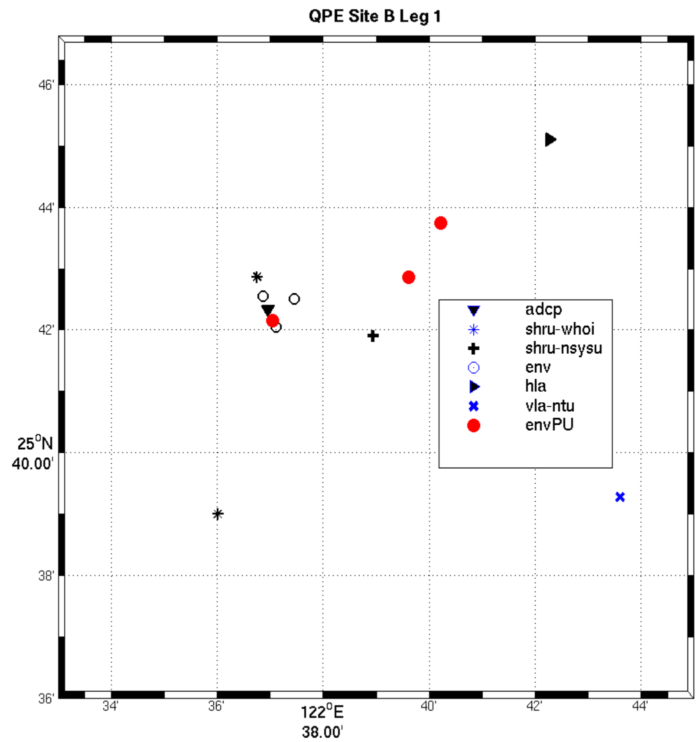


Figure 3.29. NTU vertical line array position in relation to other moorings deployed at Site B. The NTU VLA is located in deeper water to the SE of the WHOI moorings.

Table 42: Deployment position, depth and times for NTU VLA, Site B mooring

Deployed position (lat N, Long E)	25 39.277 122 43.598
Time sampling started	9/3/09 19:00
Deployed date/time (Local Time)	9/5/09 20:40
Recording finished date/time (Local Time)	9/9/09 00:00
Retrieval date/time (Local Time)	9/9/09 10:00
Retrieval position (approximate)	25 39.630 122 42.270
Depth (m) deployed	240.9

Table 43: VLA hydrophone and sensor depths calculated at deployment.

Channel Number (hydrophone)	Additional Sensor	Deployment Depth (m)
Ch1 (not used)	1622-SBE	164.8140
Ch2	Tibits-6462	175.3008
Ch3 (not used)	X	
Ch4	2329-STAR-ODI-002	187.5205
Ch5 (not used)	2009- Tibits	189.7476
Ch6	2008- Tibits	192.4736
Ch7 (not used)	6464- Tibits	195.7451
Ch8	SBE-1848	190.6080
Ch9 (not used)	5452- Tibits	199.9138
Ch10	2720-STAR--ODI -002	202.2442
Ch11 (not used)	5453- Tibits	203.1167
Ch12	2005- Tibits	207.2238
Ch13 (not used)	2007- Tibits	211.0353
Ch14	2330-STAR--ODI -002	215.5643
Ch15 (not used)	6463- Tibits	218.0341
Ch16	SBE	219.6640

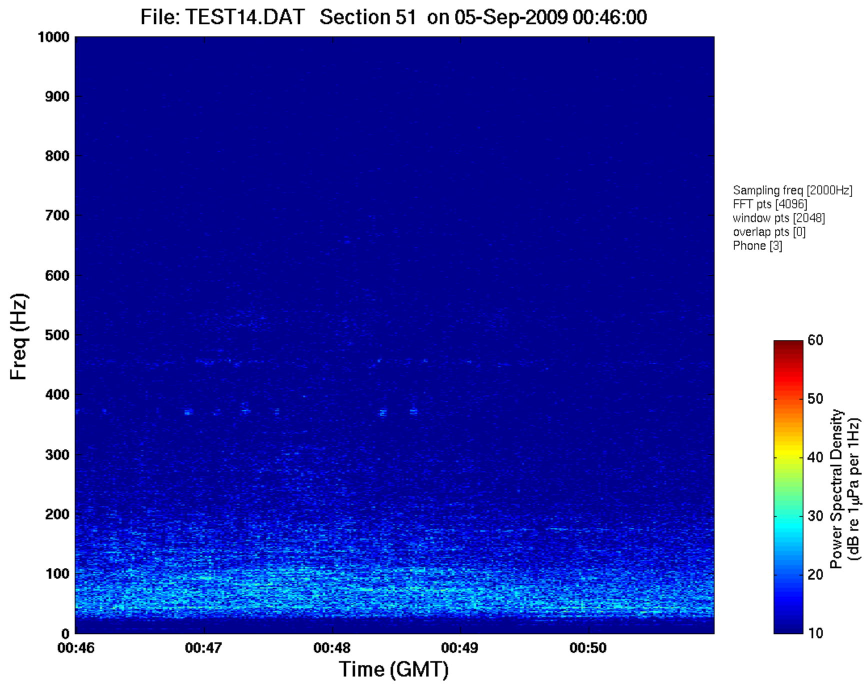


Figure 3.30. A spectrogram from the NTU VLA receiving a 375Hz signal.

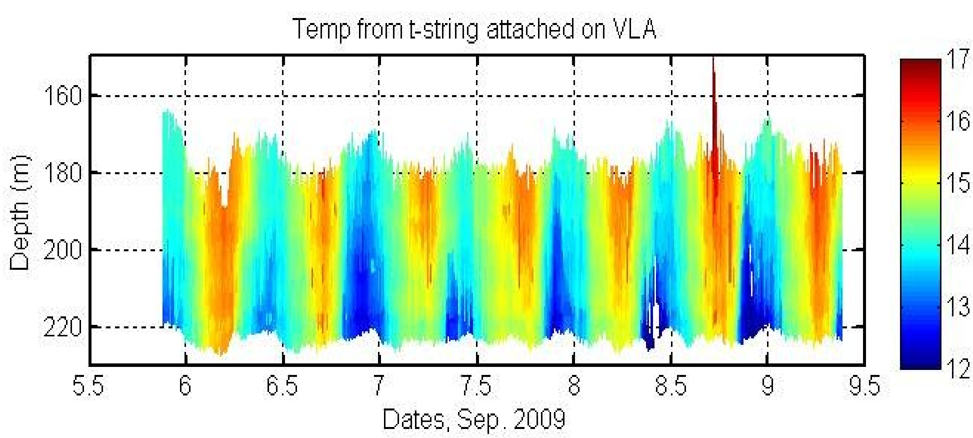


Figure 3.31: Temperature along the VLA mooring.

3.6 Moored ADCP

Two bottom mounted Acoustic Doppler Current Profilers (ADCP) were deployed at Site B and one bottom mounted ADCP was deployed at Site A. All were deployed during OR1 Leg 1 and remained throughout the entire experiment for both legs. One of the ADCPs at Site B belonged to the National Taiwan University (NTU) who will be working with that data.

Table 44: Deployment and recovery positions, depths and times for Site A moorings, OR1 leg 911

Mooring	***Deployed Position***	***Deployment Time (UTC) date***	***Recovery Time (UTC) date***	***Depth (m)***
ADCP 'A'	25 59.323 122 31.525	10:20 8/29/09	08:37 09/09/09	113
ADCP 'B'	25 42.334 122 36.961	10:54 8/24/09	11:15 09/09/09	130
ADCP (NTU)	25 40.340 122 35.240	n/a	11:59 09/09/09	186

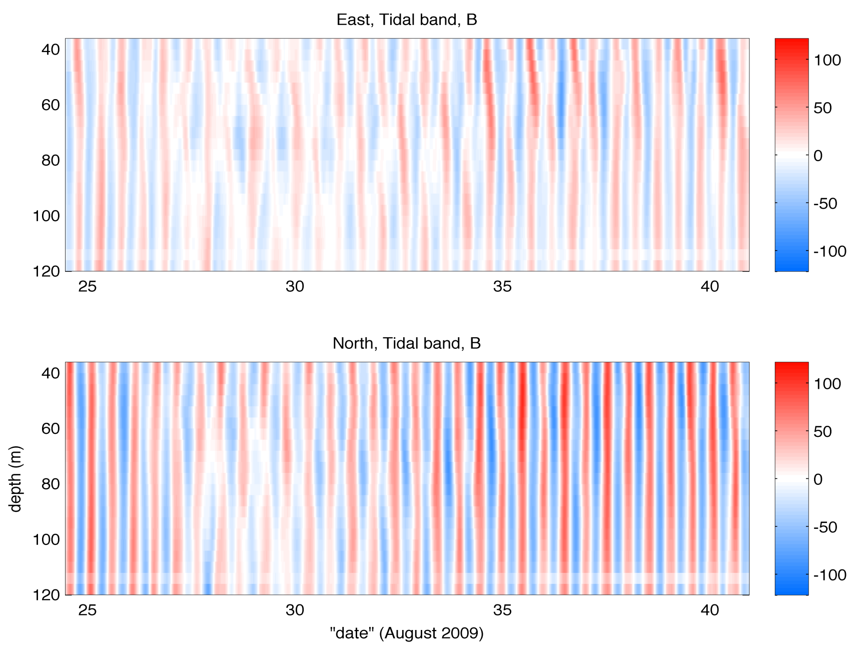


Figure 3.32. ADCP 'B' record of currents in the tidal frequency band.

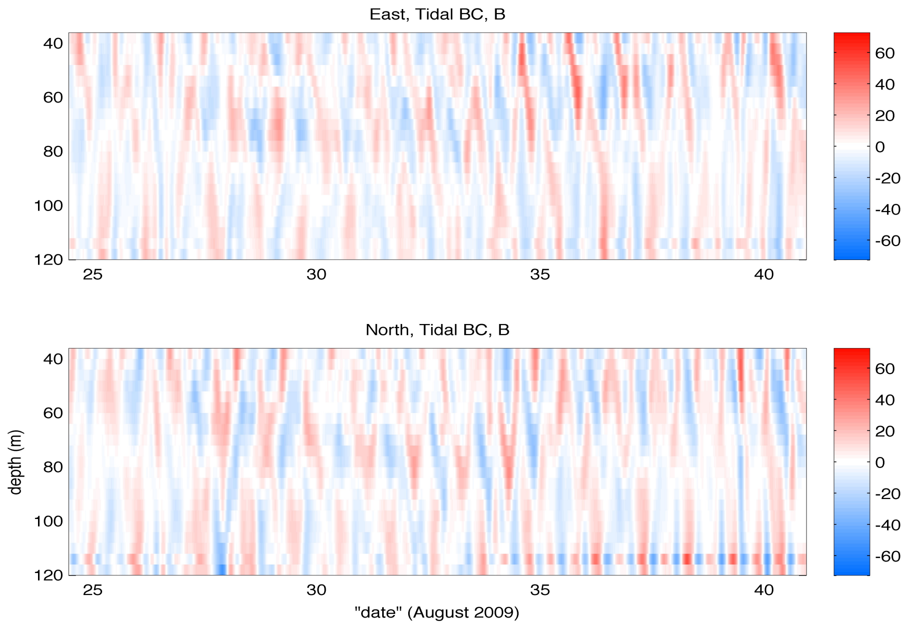


Figure 3.33. ADCP record of the baroclinic tide estimate. This figure show the result after the barotropic tide estimate (depth-mean) is removed from the ADCP current profiles.

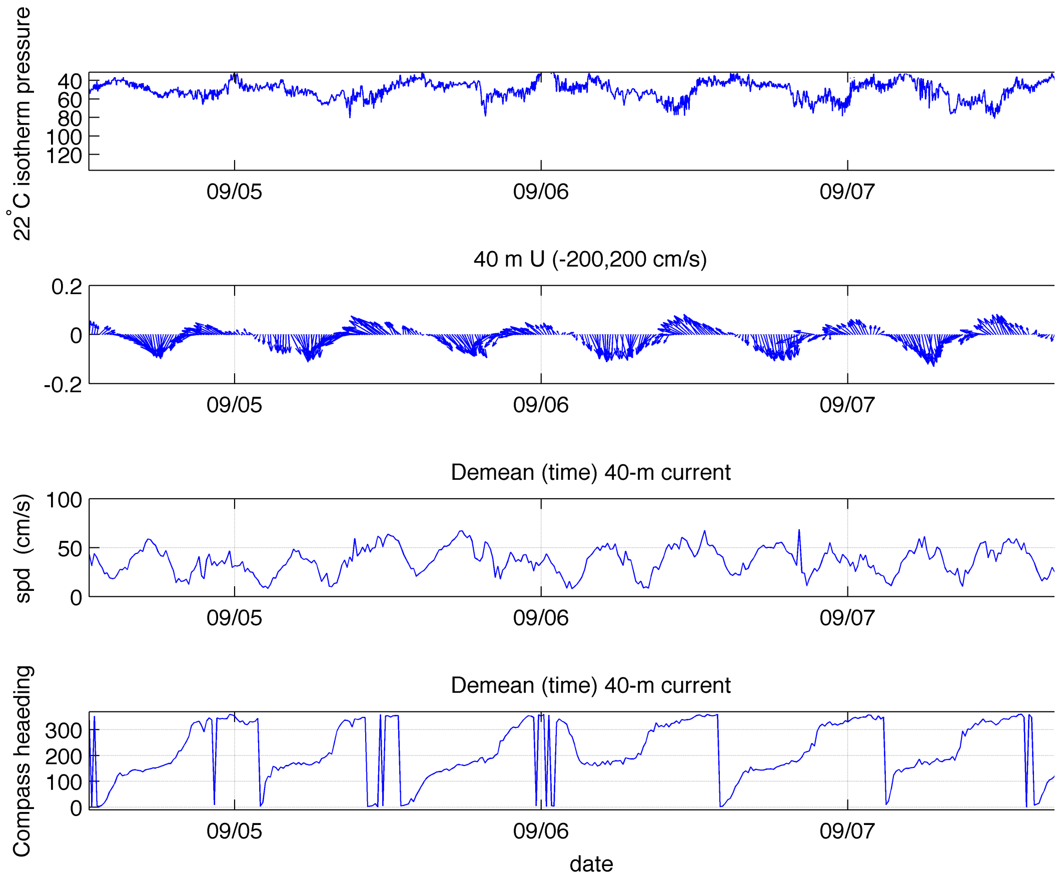
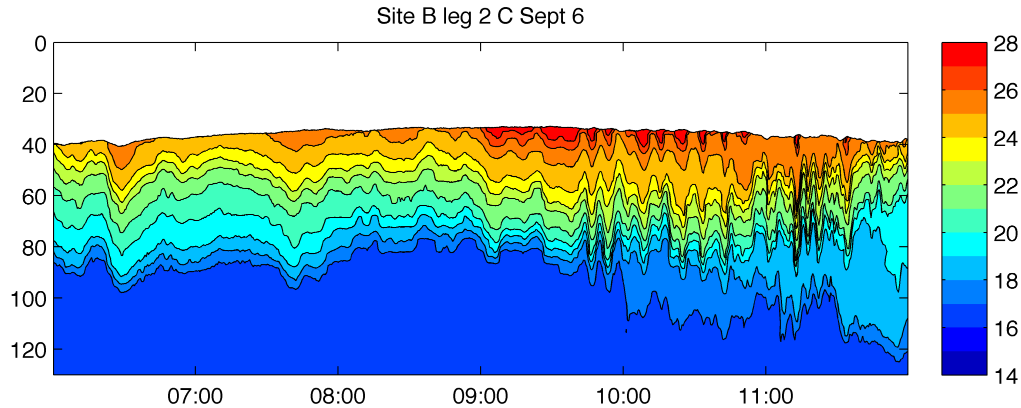


Figure 3.34. Top panel tracks the depth of the 22 degree C isotherm. Second panel arrows show phase and magnitude of the U current component at 40 meters. Bottom two panels show de-meaned speed and direction, respectively, for the current at 40 meters.



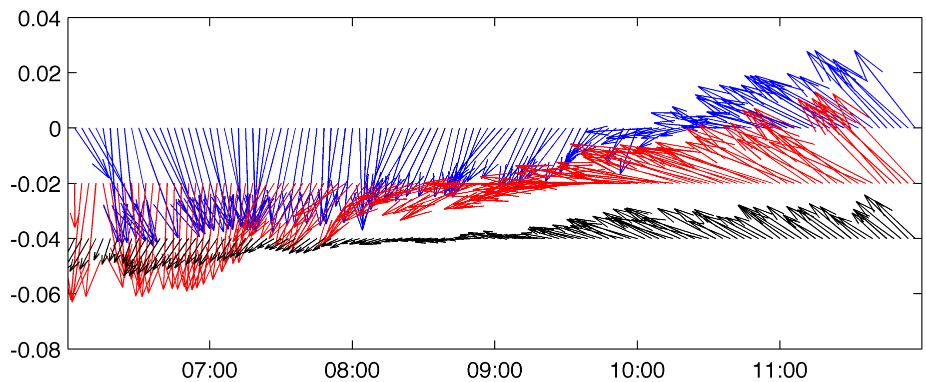


Figure 3.35. Top panel shows the temperature from Mooring C at Site B on Sept 6th. Bottom panel arrows show the direction and magnitude of the current a depths (blue: shallowest, red; mid-water, black deepest) for the same times. Notice internal wave activity starting around 10:00 and current magnitude change at both the shallow and mid-water depths.

3.7 SeaSoar

Hydrographic data was collected using a towed undulating SeaSoar vehicle for a total of 10 surveys over the two cruise legs. The tracks were designed to allow for both along-shelf and cross-shelf sampling (Fig 3.36). On the shelf, SeaSoar profiled to within ~10m of the bottom. To allow for safer and quicker change between shallow, bottom avoidance flight mode and deep water mode in the steep canyons (several hundred meters water depth), maximum deep water profiling depth was restricted to to 200m.

The SeaSoar was equipped with a Seabird 911+ CTD system with pumped temperature and conductivity sensors. In addition, chlorophyll fluorescence and light transmission data were collected with Chelsea Instruments optical sensors.

The original 24Hz data were averaged in time to generate hourly files of 1-second data along the flight path. For easier, quick data manipulation, the 1-second data were vertically binned and time-averaged over a SeaSoar dive cycle to generate average profiles. SeaSoar operation was conducted under NTU lead by Wang Bee. All surveys were performed during the day starting at 00:00 (UTC) or 08:00 (localtime).

As an example of the collected SeaSoar data at the 130 meter isobath (Figure 3.37), a temperature and salinity section collected on the shelf is shown in Figure 3.38, indicating the presence of a dramatic internal bore at that time. All the individual survey maps are shown in Figures 3.39 (OR1-Leg1) and 3.40 (OR1-Leg2). More information can be found at http://science.whoi.edu/users/seasoar/qpe09_cruisecd

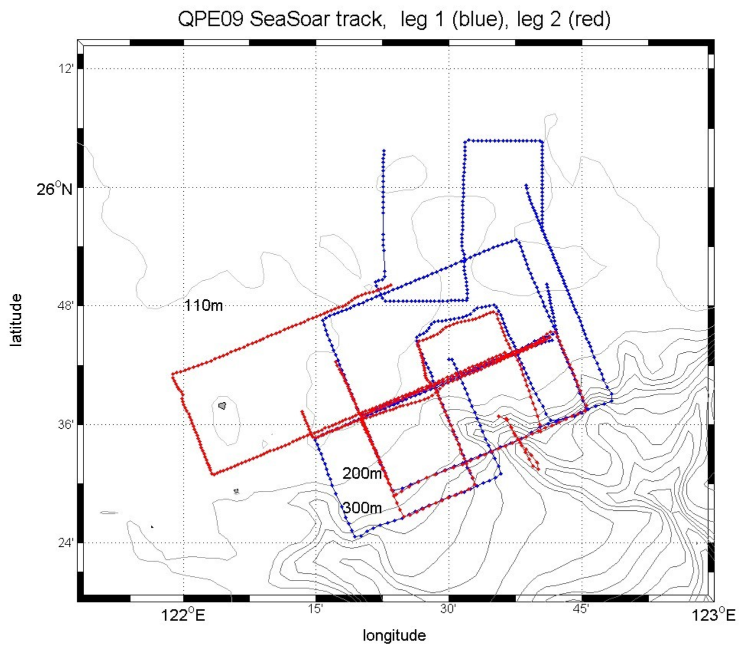


Figure 3.36. SeaSoar surveys during Leg 1 (blue) and Leg 2 (red). Dots indicate the positions of "average profiles" defined in the text.

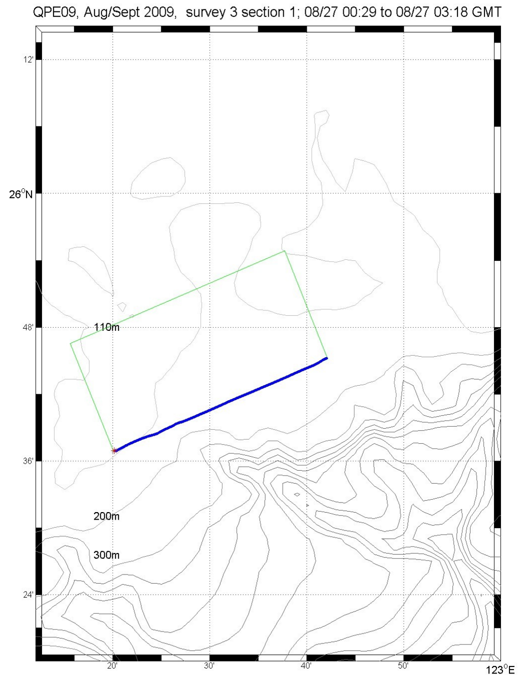


Figure 3.37. Survey 3 section 1 track at the along shelf 130m isobath.

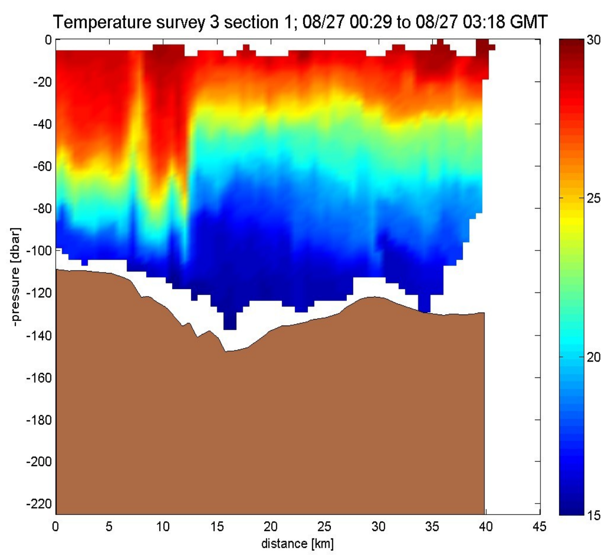


Figure 3.38. SeaSoar temperature along the 130m isobath showing presence of internal bore.

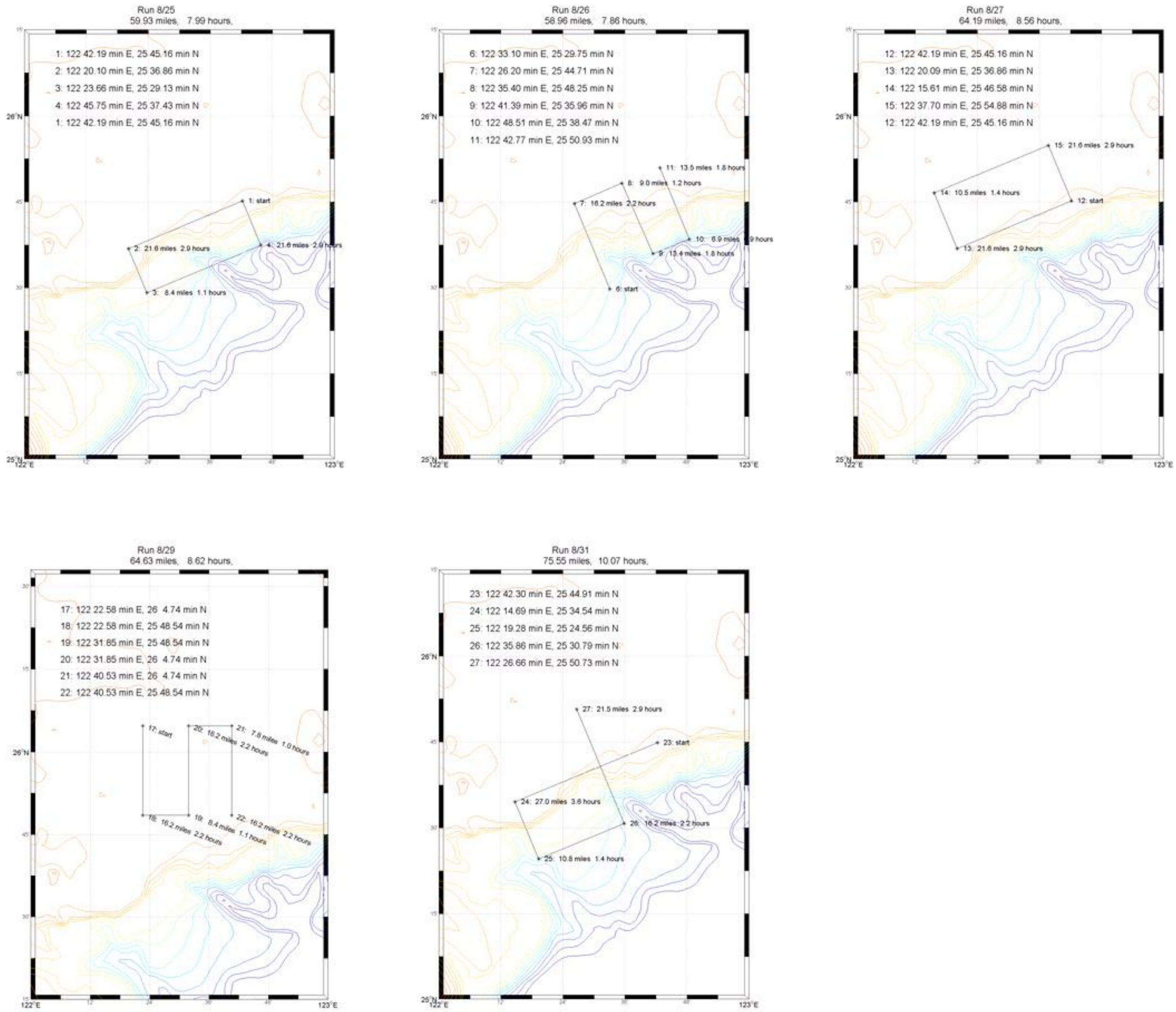


Figure 3.39. All surveys for SeaSoar, OR1-Leg 1

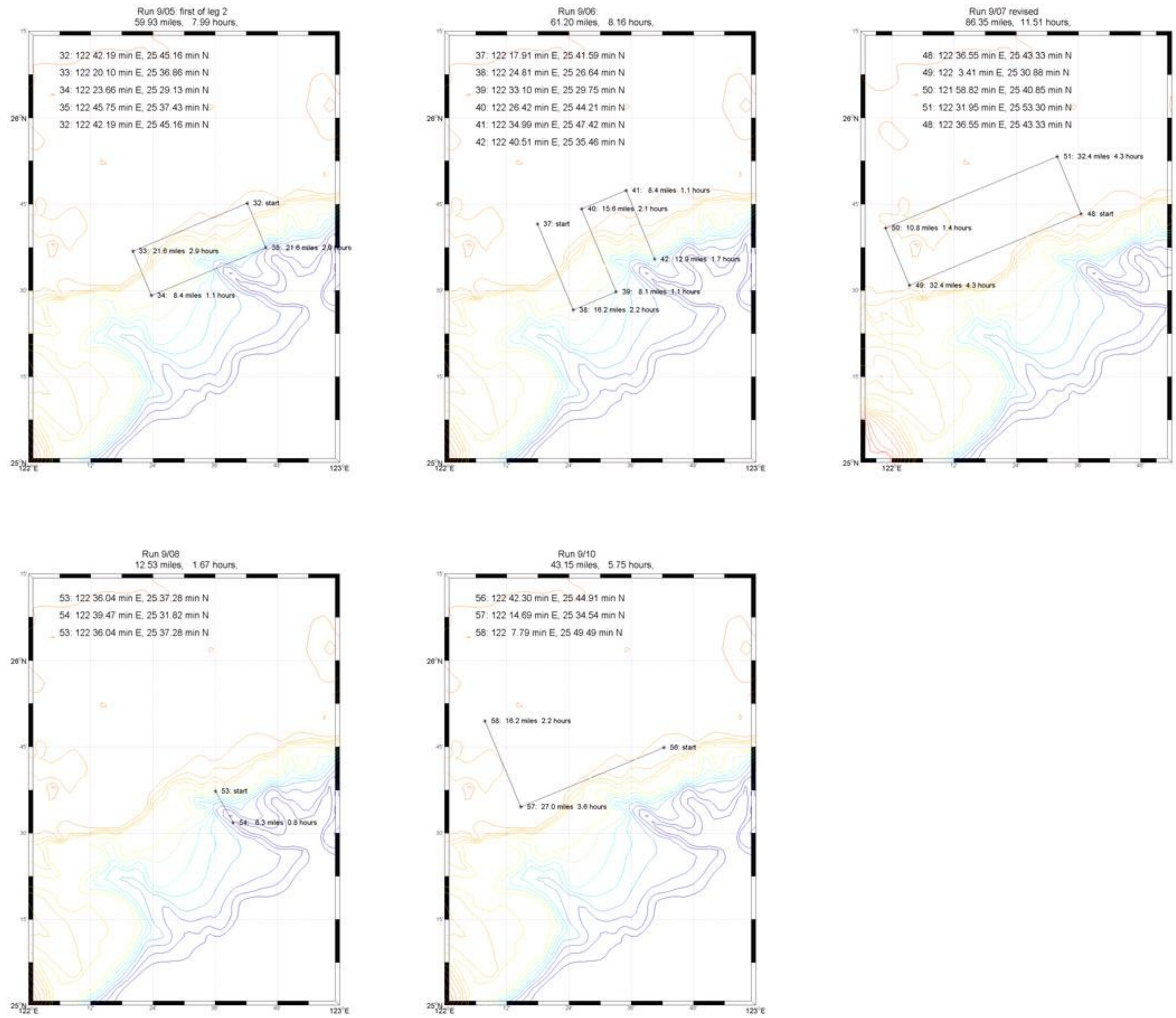


Figure 3.40. All surveys for SeaSoar, OR1-leg2

During the SeaSoar surveys in Legs 1 and 2, a primary goal was to determine the onshore transport of offshore waters both adjacent to the Kuroshio and from the Kuroshio to the continental shelf. Transects were repeated along the 130 m isobath as well as further offshore to determine the gradients across the shelfbreak. During the OR1 cruises, there were a number of significant oceanographic processes affecting the variability in the region. Figure 3.41 shows a curtain plot over bathymetry of transects from the 130 m and 500 m isobaths. On August 25 (Figure 3.42), there was a cooler surface layer which presumably reflects the impact of Typhoon Morakot on the region. The upper layer warms considerably by August 31 (Figure 3.43) and a strong thermocline with a warm upper layer is established. This is more typical of summer conditions in the region. On September 5, a cold slope eddy (note the alongshelf slope with isotherms descending to the northeast) appeared consistent with cold bottom water appearing on the shelf.

The salinity structure also indicates substantial small scale variability near the surface on August 25 (Figure 3.44). The pulse of fresh water appears in the main QPE study area on August 31 (Figure 3.45) with a decrease in salinity of 0.7 over the upper 60 m of the water column. Salinity returns to a more typical situation by September 5 (Figure 3.46) with alongslope salinity gradients at depth consistent with a fresher slope eddy than the ambient slope water. These SeaSoar sections are meant to give a brief introduction to the variability observed and further analysis is continuing on the ten SeaSoar surveys.

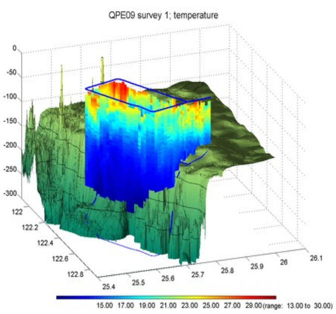


Figure 3.41 Survey 1 temperature.

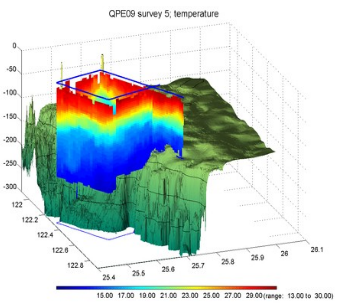


Figure 3.42 Survey 5 temperature.

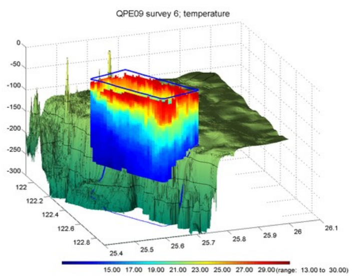


Figure 3.43 Survey 6 temperature.

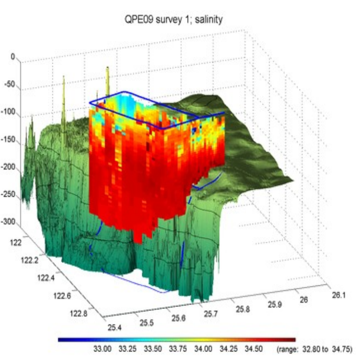


Figure 3.44 Survey 1 Salinity.

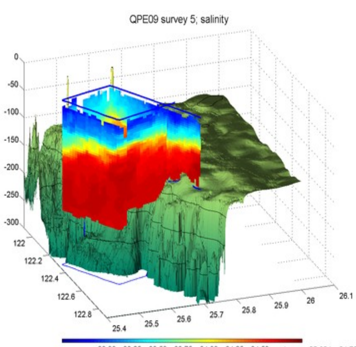


Figure 3.45 Survey 5 salinity.

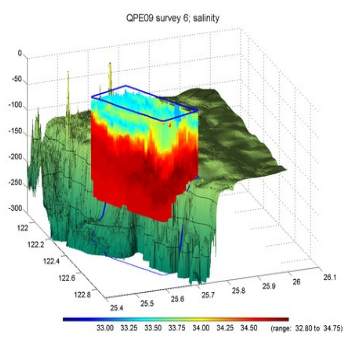


Figure 3.46 Survey 6 salinity.

3.8 Satellite images

Each time a satellite passed over the QPE site during the experiment, a synthetic aperture radar (SAR) image was saved. Figures 3.48 and 3.50 show the surface expressions in the area on Sept. 4th and Sept. 6th caused by the complicated paths of internal waves. Images were provided by M. Caruso and H. Graber of CSTARS, University of Miami.

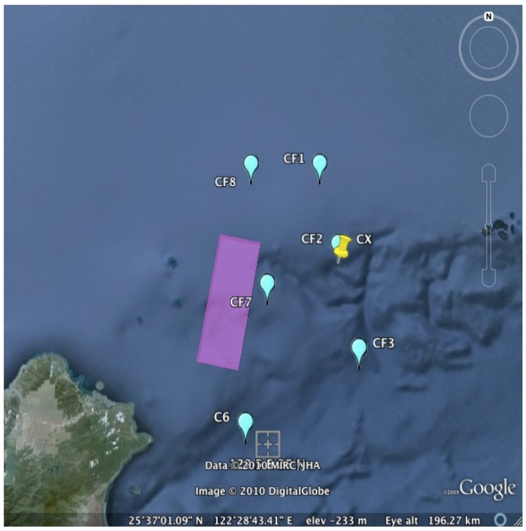


Figure 3.47. Area of satellite image from Figure 3.31on Sept 4th.

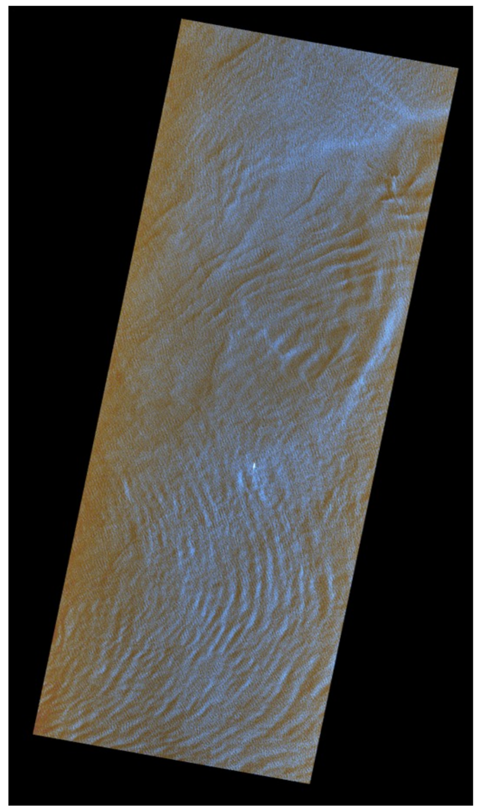


Figure 3.48. SAR satellite image for Sept 4th.

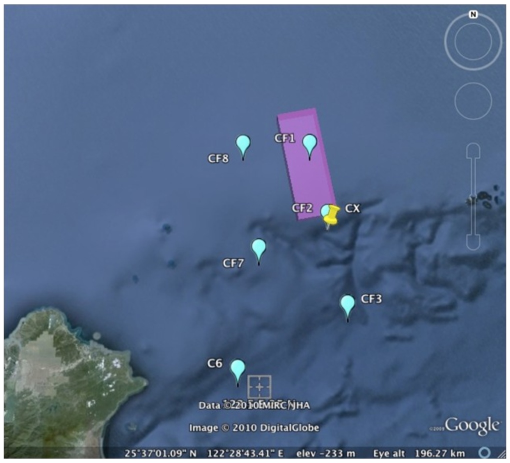


Figure 3.49. Area of satellite image from Figure 3.33 on Sept 6th.

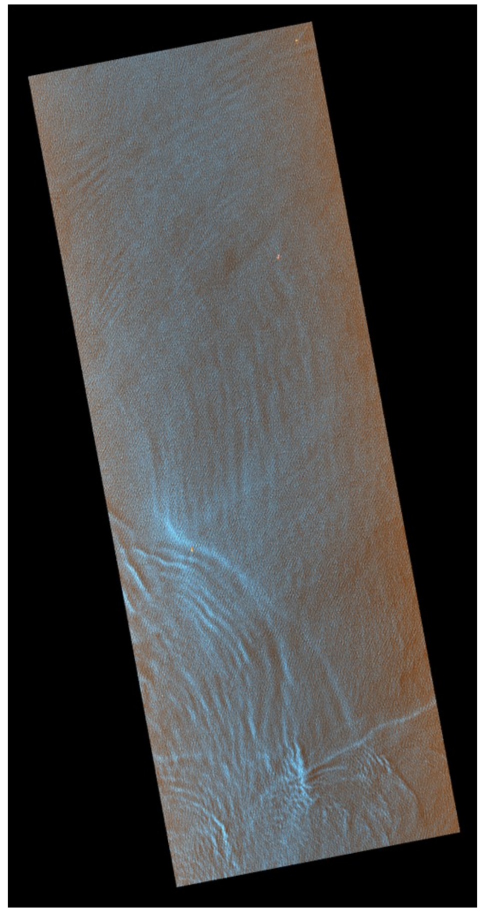


Figure 3.50. Satellite image for Sept 6th.

3.9 OASIS mobile acoustic sources (OMAS)

The acoustic oceanography conducted during Legs 1 and 2 of the QPE IOP utilized OMAS vehicles as the sound sources, and standard US Navy sonobuoys as the receivers. This section will briefly cover five of the twenty OMAS deployments, and includes plots of all reconstructed tracks and some selected measured transmission loss results. Details of each OMAS run are presented in tables in Figures 3.56 and 3.57.

Twenty OMAS were deployed over the course of the QPE experiment. Reconstructed tracks are shown for Leg 1 (Aug 24-29) in Figure 3.51 and for Leg 2 (Sept 5-10) in Figure 3.52. As can be seen in the figures, the track geometries were typically either circular, centered around a hydrophone receiver or linear, oriented either parallel or perpendicular to the isobaths. OMAS deployments were generally located close to either Site A or Site B, which are shown as yellow-filled circles in the figures, but there were also three runs in deeper water out over the canyon (Events 3A, 4 and 12) and two runs at a location 40 km WSW of Site B (Events 14A and B).

3.9.1 OMAS transmission loss (TL)

Transmission loss is calculated ping-by-ping in near-real-time during each OMAS deployment. TL is calculated as the difference between the OMAS source level and the peak of the matched-filtered output of the received signal at the sonobuoy hydrophone (A complete list of OMAS source levels, calibrated at NUWC's Dodge Pond facility, are given in t in table in Figure 3.58). TL data are then post-processed in a manner appropriate for the OMAS vehicle geometry. For circular OMAS tracks, the data are typically corrected to a common range and then plotted vs. bearing. This is useful for showing the isotropy or anisotropy of the acoustic field over the course of an individual OMAS run. In addition, comparing TL vs. bearing results from multiple circles separated by some distance also gives a measure of the translational invariance of the acoustic field. For linear tracks, TL is usually plotted vs. source to receiver range. Linear tracks are typically divided into separate legs in order to highlight any temporal or spatial variability in the data. Comparing TL vs. range results from multiple tracks separated by some distance gives a measure of the temporal and/or spatial variability of the acoustic field.

A good example of circular OMAS run geometries are those of Events 6A, B, and C, from August 29, the final day of Leg 1, which featured three back-to-back OMAS deployments in what has been designated "the 24-hour run." Each OMAS was programmed to transit 5km due north from its launch point and then proceed clockwise along a 5km-radius circular track. Each vehicle was able to complete two full circles before it expired and subsequently scuttled. The reconstructed tracks can be seen near Site A in Figure 3.52 (Note that the OMAS uses dead reckoning for navigation and the programmed circular tracks are distorted by drift as a result). The TL data from these events are first corrected to a common range of 5km via a 20log(R) correction and then plotted vs. bearing. The data are then aggregated into 15° bearing sectors and a mean is calculated for each sector. Figure 3.53 shows the range-corrected, 15° bearing sector average TL plotted vs. bearing for all six circles (two per vehicle). The figure shows that the data are fairly anisotropic with variations within an individual circle of up to 10 dB. Variations between circles can be seen of up to 15 dB. There also appears to be a time-dependence to the data, with the last two circles showing a marked increase in TL and a further reduction in isotropy.

Events 7 and 8 on September 5, the first day of Leg 2, are good examples of linear OMAS track geometries. The intention of these runs was to have two OMAS units simultaneously running parallel to the isobaths, with one running shallow (Event 7, ds = 30m) and one running deep (Event 8, ds = 90m). Figure 3.54 shows a close-up of the reconstructed OMAS tracks, with the deep OMAS shown in blue and the shallow OMAS shown in red. The figure shows four legs, with Leg 1 starting to the northeast and progressing to the southwest. Note that a strong southeasterly current caused significant drift over the course of the run and as a result, the four legs do not overlay on the map.

After calculating individual TL data points ping-by-ping in near-real-time, post-processing begins by plotting the individual TL data points vs. range for each leg. The data are then aggregated into 1/3 octave range bins and a mean is calculated for each bin. This process was applied to all four legs for both the deep and shallow vehicles. The resulting mean TL data are shown plotted vs. range in Figure 3.55. The figure shows the legs color-coded, with Leg 1 shown in blue, Leg 2 shown in red, Leg 3 shown in green and Leg 4 shown in light blue. The two vehicle depths can be differentiated by the data markers, with data from the shallow vehicle shown with circular markers and data from the deep vehicle shown with plusses. The plot allows for both a depth and leg to leg comparison. Comparing the two depths, the figure shows that for Legs 1, 2 and 4, with the possible exception of short range data from Leg 1, the deep source sees 3-8 dB more loss than the shallow source. In contrast, Leg 3 shows almost no difference between the two source depths. Comparing the results leg to leg, the plot shows that in both the deep and shallow cases, the first two legs (in red and blue) yielded similar results. Further into the run, Leg 3 (in green) shows a 5-10dB drop in the loss (with a greater reduction for the deep source). Leg 4 shows intermediate loss, greater than the first two legs, but less than Leg 3 (except for the high-range data from the shallow source). Similar analysis of the other 15 OMAS runs has been completed and will be provided in a separate report.

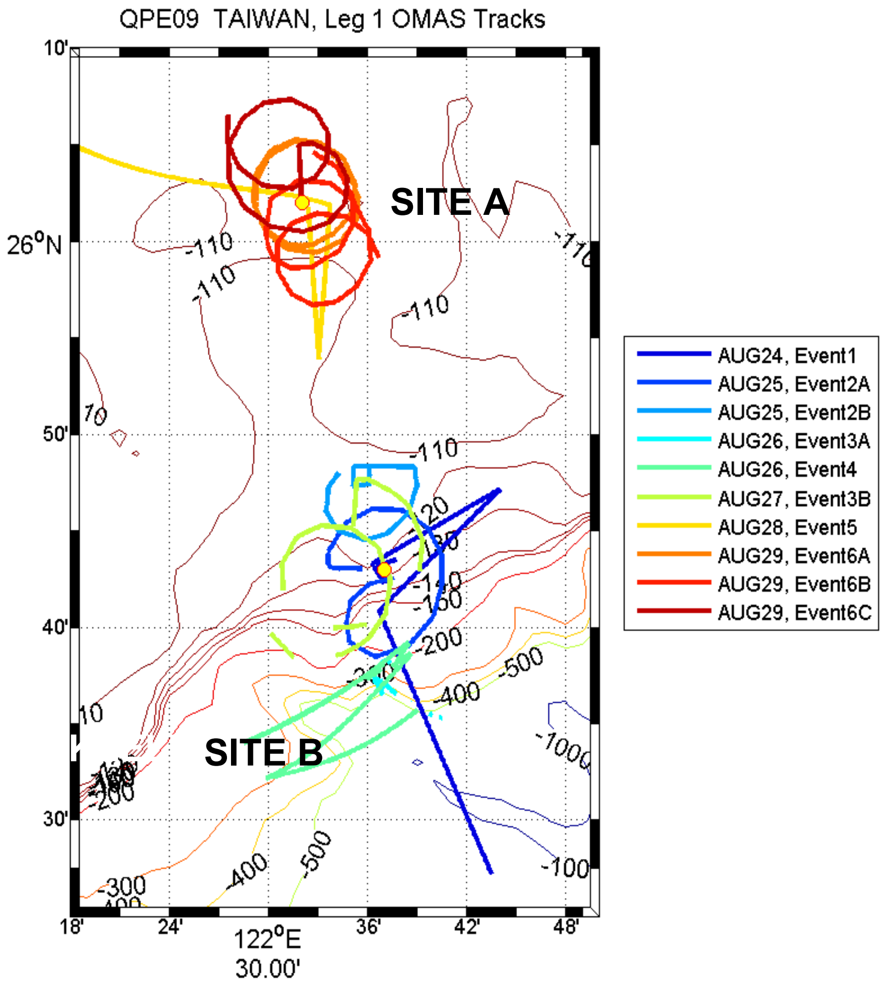


Figure 3.51. Reconstructed OMAS tracks from QPE OR1 Leg 1

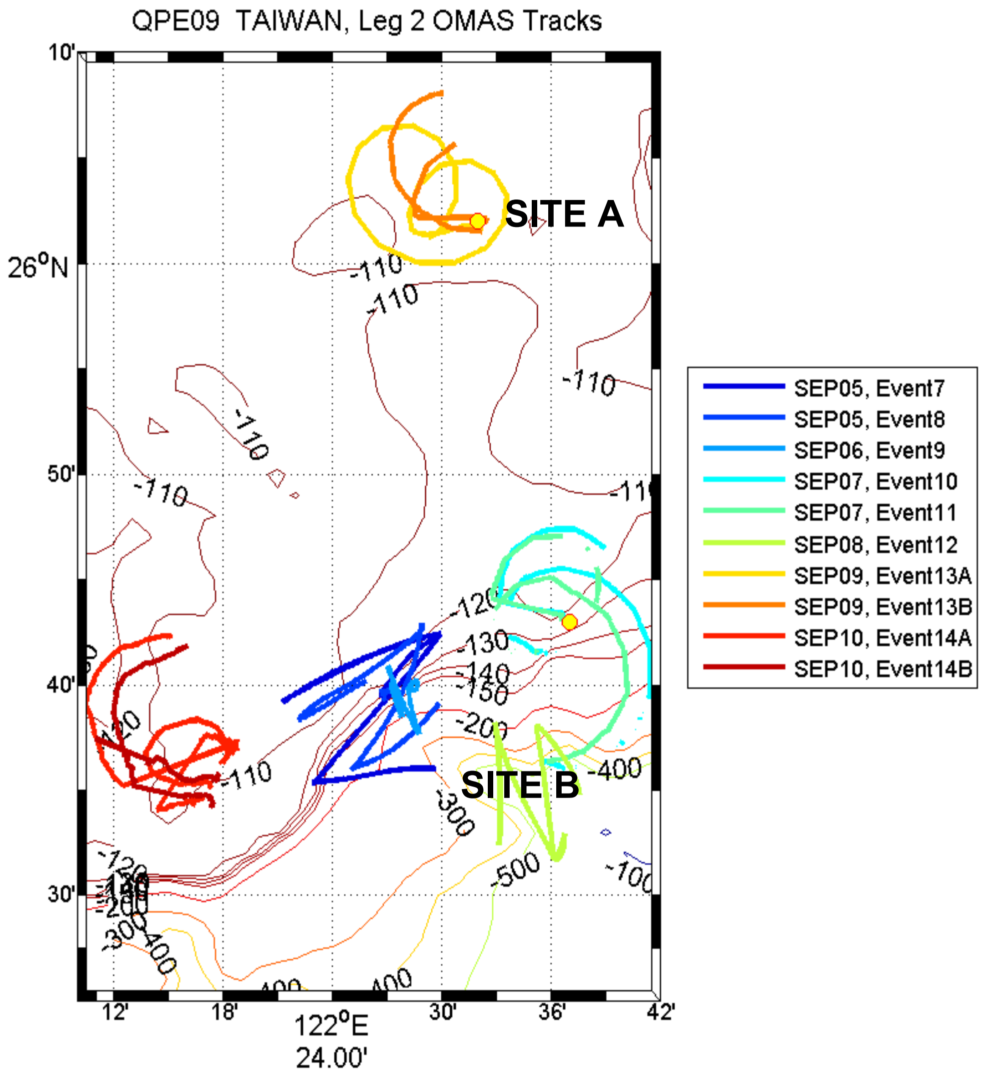


Figure 3.52. Reconstructed OMAS tracks from QPE OR1 Leg 2

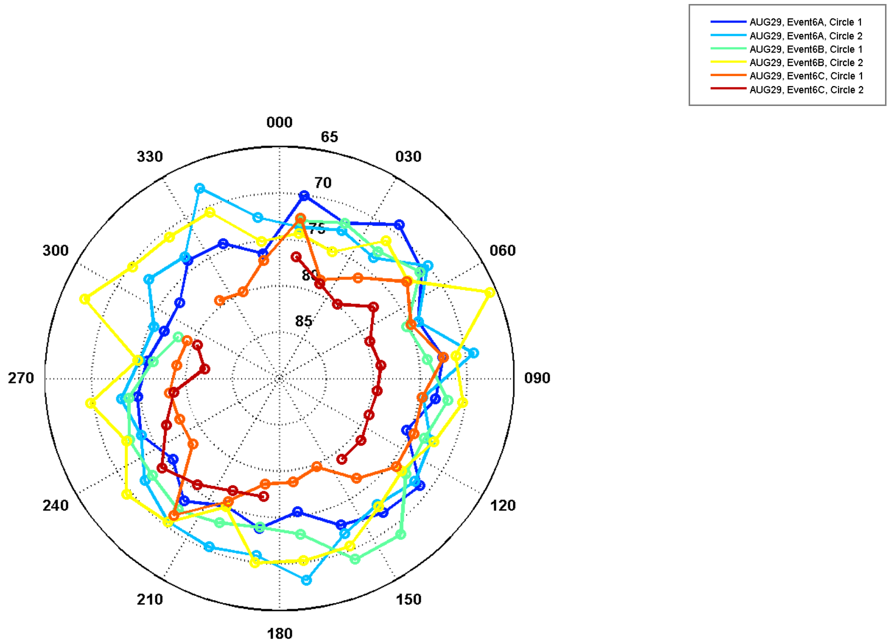


Figure 3.53. August 29, 15° bearing sector average comparison at DIFAR 1 for all three Event 6 vehicles. Event 6A, circle 1 is shown in dark blue, circle 2 is shown in light blue, Event 6B, circle 1 is shown in green-blue, circle 2 is shown in yellow, Event 6C, circle 1 is shown in orange, circle 2 is shown in Red.

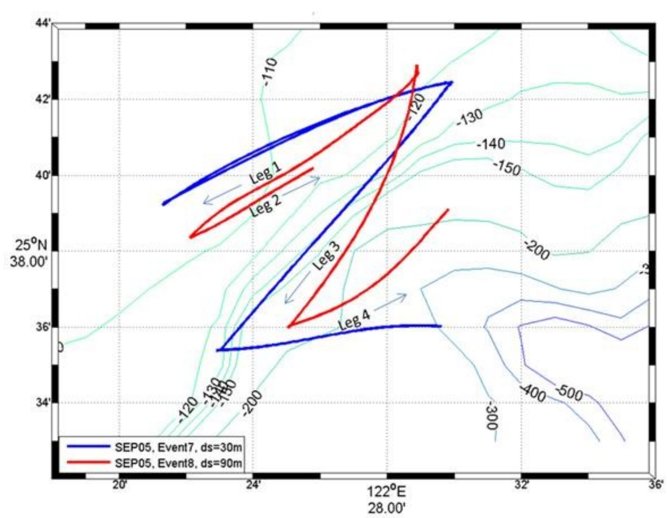


Figure 3.54: September 5, Reconstructed OMAS tracks for Events 7 (shallow source, in blue) and 8 (shallow source, in red). Note the four different legs defined in the figure.

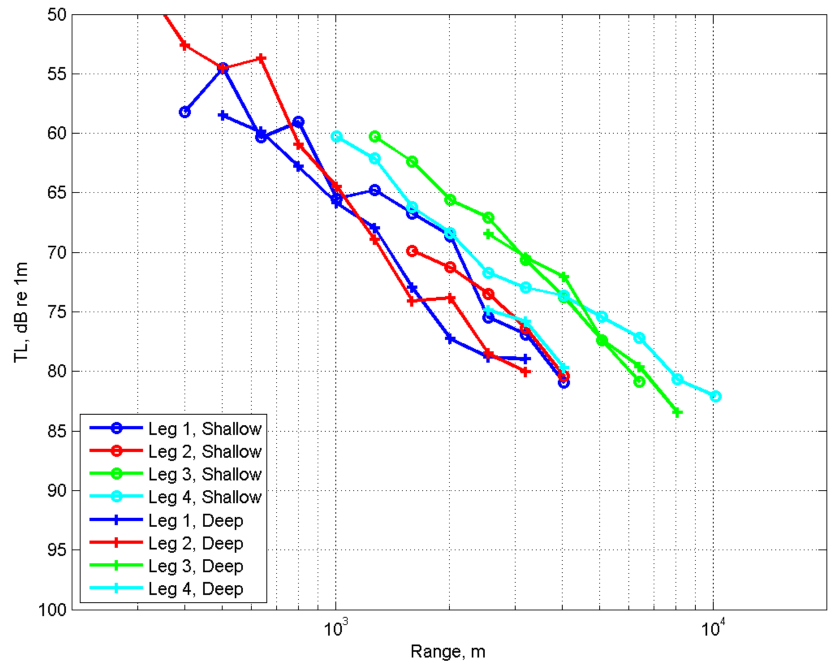


Figure 3.55. TL vs. Range Track and Depth Comparison for the Omni receiver, QPE Events 7 and 8, September 5, OMAS # 15308 (ds=90m, shown as +) and 15309 (ds=30m, shown as circles), dr = 61m. Track 1 is shown in blue. Track 2 is shown in red. Track 3 is shown in green. Track 4 is shown in light blue.

Date	Event	Unit S/N	Frequency, Hz 400	500	600	700	800	900	1000	1100	1200	1300
24-Aug-2009	1	15570	137.8	140.5	145.7	146.8	148.9	149.9	151.4	152	151.6	151.8
25-Aug-2009	2A	15562	139.7	142	145.5	147.3	149.5	151.1	151.5	152.3	151.9	152.4
	2B	15563	138.8	142.7	146	147.8	149.9	150.6	151.1	151.5	151.1	152.2
26-Aug-2009	3A	15558	138.7	142.6	145	147.8	149.7	150.4	151.3	151.8	151	152.2
	4	15560	138.8	142.8	145.5	147.7	149.5	150.6	151.4	151.5	151.4	151.2
27-Aug-2009	3B	15559	139	142.9	145.6	148	150	151.1	151.9	152.7	152.2	152.5
28-Aug-2009	5	15561	139.3	143	145.4	147.9	150.1	151.2	151.7	152.9	152.6	152.9
29-Aug-2009	6A	15557	139.2	143.1	145.4	148	150.2	151.5	152.2	152.5	150.9	149.3
	6B	15569	139.8	142.8	145.4	147.1	149.5	150.4	151.6	151.8	151.6	151.6
	6C	15567	139.4	142.7	146.4	147.7	150.3	150.8	151.3	152.3	152.6	152.6
5-Sep-2009	7	15309	See Below									
	8	15308	See Below									
6-Sep-2009	9	15568	137.8	139.9	143.9	147.3	148.5	149.7	151	150.4	150.5	151.2
7-Sep-2009	10	15312	See Below									
	11	15313	See Below									
8-Sep-2009	12	15310	See Below									
9-Sep-2009	13A	15566	139.6	142.6	145.7	147.3	150.4	151.1	151.3	151.4	151.2	151.5
	13B	15307	See Below									
10-Sep-2009	14A	15565	138.6	141.5	145.3	146.9	149.2	150.3	150.4	150.5	149.8	151.3
	14B	15564	139	142.4	145.8	148	149.6	150.6	151.1	152.4	152.8	152.8

		Unit S/N	Frequency, Hz 400	450	500	700	800	900	950	1000	1150	1300
5-Sep-2009	7	15309	139.0	140.9	143.4	148.8	150.9	151.3	150.6	150.2	150.5	150.7
	8	15308	138.6	140.4	142.5	147.4	149.3	150.5	151.1	151.2	151.4	150.6
7-Sep-2009	10	15312	138.6	140.4	142.5	148.3	149.6	150.5	150.7	150.7	141.5	140.7
	11	15313	139.4	140.7	142.4	147.6	149.7	150.7	150.9	151.1	141.2	140.6
8-Sep-2009	12	15310	140.1	141.7	143.7	148.3	149.4	150.0	150.2	150.5	150.8	151.1
9-Sep-2009	13B	15307	137.1	139.6	141.5	146.9	149.1	150.7	150.6	150.9	151.5	151.7

Figure 3.56: OMAS source levels.

Date	Event	OMAS S/N	OMAS LS @ 600,800,900, 1kHz	OMAS Speed	OMAS Depth	OMAS Signal	First Ping	Lost Contact	Comments	OMAS Launch Lat	OMAS Luanch Lon
August 24, 2009	1	15570	145.7, 148.9, 149.9, 151.4	5 kts	200ft	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	14:45 (Z)	20:35(Z)	Along/Across Shelf at 125m isobath	25° 42.969' N	122° 37.028' E
August 25, 2009	2A	15562	145.5, 149.5, 151.1, 151.5	5 kts	200ft	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	16:32 (Z)	22:52 (Z)	5 km circle over shelfbreak	25° 42.964' N	122° 36.975' E
	2B	15563	146.0, 149.9, 150.6, 151.1	5 kts	200ft	3x800-1000Hz HFM Down 3x550-650Hz HFM Down 780,880, 980Hz CW	16:35 (Z)	20:19 (Z)	5 km circle over shelf	25° 48.320' N	122° 35.008' E
August 26, 2009	3A	15558	145.0, 149.7, 150.4, 151.3	5 kts	50, 100, 175m	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	15:07 (Z)	19:58 (Z)	Offshore N/S Run Over Canyon Variable Depth	25° 37.990' N	122° 36.996' E
	4	15560	145.5, 149.5, 150.6, 151.4	5 kts	50, 100m	3x800-1000Hz HFM Down 3x550-650Hz HFM Down 780,880, 980Hz CW	15:02 (Z)	21:48 (Z)	Offshore NE/SW Run Over Canyon Variable Depth	25° 37.980' N	122° 37.006' E
August 27, 2009	3B	15559	145.6, 150, 151.1, 151.9	5 kts	200ft	2x1000-1200Hz HFM Up Alternating 550-650Hz and 800-1000Hz HFM Up, 20-	10:44 (Z)	16:56 (Z)	Coherence Run	25° 45.044' N	122° 35.089' E
August 28, 2009	5	15561	145.4, 150.1, 151.2, 151.7	5 kts	90 ft	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	13:17 (Z)	18:19 (Z)	110m Isobath Run Along/Across shelf	26° 01.996' N	122° 31.945' E
August 29, 2009	6A	15557	145.4, 150.2, 151.5, 152.2	5 kts	90 ft	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	12:07 (Z)	19:18 (Z)	First Vehicle of 24 Hr Coverage Run Buoys Lost, No GPS	26° 02.078' N	122° 32.062' E
	6B	15569	145.4, 149.5, 150.4, 151.6	5 kts	90 ft	3x800-1000Hz HFM Down 3x550-650Hz HFM Down 780,880, 980Hz CW	20:19 (Z)	03:54 (Z) (August 30)	Second Vehicle of 24 Hr Coverage Run	26° 02.051' N	122° 31.833' E
	6C	15567	146.4, 150.3, 150.8, 151.3	5 kts	90 ft	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	05:06 (Z) (August 30)	11:41 (Z) (August 30)	Third Vehicle of 24 Hr Coverage Run	26° 02.220' N	122° 32.032' E

Figure 3.57: Table of OMAS run summary, OR1 Leg 1.

Date	Event	OMAS S/N	OMAS LS @ 600,800,900, 1kHz	OMAS Speed	OMAS Depth	OMAS Signal	First Ping	Lost Contact	Comments	OMAS Launch Lat	OMAS Luanch Lon
September 5, 2009	7	15309	146.1, 150.9, 151.3, 150.2	5 kts	100 ft	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	12:06 (Z)	18:50(Z)	Along Shelf Run at 130m isobath, 30m depth	25° 39.21' N	122° 27.07' E
	8	15308	145.0, 149.3, 150.5, 151.2	5 kts	295 ft	3x800-1000Hz HFM Down 3x550-650Hz HFM Down 780,880, 980Hz CW	12:14 (Z)	18:00(Z)	Along Shelf Run at 130m isobath, 90m depth	25° 39.21' N	122° 27.07' E
September 6, 2009	9	15568	143.9, 148.5, 149.7, 151	5 kts	30, 60, 90, 120m	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	12:42 (Z)	14:50(Z)	Across Shelf Run at 130m isobath, 30, 60, 90, 120m depth	25° 39.64' N	122° 28.40' E
September 7, 2009	10	15312	145.4, 149.6, 150.5, 150.7	5 kts	30m	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	12:36 (Z)	19:30(Z)	Circle Track Across Shelf at 30m Depth	25° 45.32' N	122° 36.18' E
	11	15313	145.0, 149.7, 150.7, 151.1	5 kts	90m	3x800-1000Hz HFM Down 3x550-650Hz HFM Down 780,880, 980Hz CW	12:47 (Z)	19:30(Z)	Circle Track Across Shelf at 90m Depth	25° 45.525' N	122° 37.76' E
September 8, 2009	12	15310	145.9, 149.4, 149.9, 150.5	5 kts	100m	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	10:51 (Z)	15:20 (Z)	"Canyon Run" up caonyon over SHRU 2 at 100m depth	25° 34.61' N	122° 37.82' E
September 9, 2009	13A	15566	145.7, 150.4, 151.1, 151.3	5 kts	30m	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	10:26 (Z)	16:50 (Z)	Circle Track On Shelf at 30m Depth	26° 02.07' N	122° 32.05' E
	13B	15307	144.6, 149.1, 150.7, 150.9	5 kts	100m	3x800-1000Hz HFM Down 3x550-650Hz HFM Down 780,880, 980Hz CW	10:34 (Z)	15:45 (Z)	Circle Track On Shelf at 90m Depth	26° 02.15' N	122° 31.96' E
September 10, 2009	14A	15565	145.3, 149.2, 150.3, 150.4	5 kts	30m	3x800-1000Hz HFM Up 3x550-650Hz HFM Up 800,900, 1000Hz CW	11:29 (Z)	17:25 (Z)	Circle Track On Shelf at 30m Depth ~40km from	25° 35.59' N	122° 17.45' E
	14B	15564	145.8, 149.6, 150.6, 151.1	5 kts	100m	3x800-1000Hz HFM Down 3x550-650Hz HFM Down 780,880, 980Hz CW	11:37 (Z)	16:55 (Z)	Circle Track On Shelf at 90m Depth ~40km from previous	25° 35.60' N	122° 17.45' E

Figure 3.58: OMAS run summary, OR1 Leg2

3.10 Multidisciplinary Simulation, Estimation, and Assimilation Systems (MSEAS) model

MIT, running the Multidisciplinary Simulation, Estimation, and Assimilation Systems (MSEAS) model, assimilated data from leg1 and provided forecasts for Leg 2. The MSEAS team estimated fields, predicted uncertainties, assimilated ocean data and provided adaptive sampling suggestions daily in real-time. The MSEAS simulations can be found at http://mseas.mit.edu/Sea_exercises/QPE_IOP09/index_iop2009.html. Forecasts consisted of both ocean state variables (temperature, salinity, density, sound speed, velocity) as well as transmission loss along both an along-shelf line as well as a cross-shelf line. Forecasts were produced from 1 to 5 days in advance and produced at daily intervals. More detailed information is given below and all observed data sets and simulated data are listed in Table 45.

The model forecasts were used extensively in Leg 2 to provide guidance for positioning of the Mobile Acoustic Source tracks. The adaptive sampling was conducted based on examination of the previous night's SeaSoar run, the model forecasts for ocean state and transmission loss, and consideration of special cases, such as the day long experiment down the axis of the West Branch of North Mien-Hua Canyon. An important element of this interaction was the shipboard communication with parties at MIT, National Taiwan University, and WHOI. There were daily discussions via email of the evolving ocean state which included discussion of remotely-sensed Sea Surface Temperature. During Legs 1 and 2, data from the SeaSoar runs as well as glider data from the University of Washington were assimilated in the numerical model in order to produce forecasts of the ocean state and transmission loss. During the OR1 cruises, data from other QPE participants at Scripps Institute of Oceanography and the University of Washington were also reviewed to evaluate the present ocean conditions. We note that all shipboard communications occurred through a Fleet Broadband 500 satellite based communications system which provided reliable means of communications throughout the experiment.

To support the 18 Aug - 10 Sep real-time exercise, 10 simulations, on average, were run each day to optimize model parameters as well as initialization and assimilation methodologies. These simulations included both short runs to assimilate the most recent data and reanalysis runs that spanned the entire exercise to date. The initial and boundary fields were created using OR2/OR3 initialization surveys, SeaGlider data, SSH and SST analyses, and a background constructed from high resolution August WOA-05 climatology with deep Summer WOA-05 climatology profiles. The simulations were forced with a combination of COAMPS (wind stress) and NOGAPS (net heat flux, E-P) atmospheric fields along with barotropic tides fitted to both our topography and the Egbert global model. Temperature/salinity data from SeaGliders and SeaSoar as well as SST analyses from OceanWatch were assimilated into these simulations.

In addition to standard forecast products (temperature, salinity, velocity), uncertainty forecasts (in the form of ensemble standard deviations of temperature, salinity and velocity) were provided on selected days. These uncertainties were constructed using ensembles consisting of 20 to 50 simulations with perturbed initial conditions and an additive error model in the form of a simple white noise forcing added in the upper 500m to temperature and salinity. Uncertainty estimates were provided before and after data assimilation to show the impacts on uncertainties of data collected at sea.

During IOP proper, three different types of acoustic products were also provided on a routine basis:

- *Acoustics climate map modeling:* These forecasts showed the acoustic variability estimated using MSEAS predicted ocean estimates over the QPE Acoustic Area /OMAS Area. This acoustic modeling covered a 56x33 km rectangle area with a 31x31 grid resolution, using the parabolic equation Range-dependent Acoustic Model (RAM). Specifically, a source is placed at each grid point and sound is propagated to 15 km distance in N=8 different directions (at 45^{o} intervals). The overall result is an N-by-2D transmission loss (TL) that is a function of (latitude, longitude, bearing, depth, range) at each grid point.
- *Nx2D canyon acoustic modeling:* Several Nx2D canyon acoustic forecasts coupled with the MSEAS ocean modeling were run in real-time.
- *Fully 3-D canyon acoustic modeling:* Y.T. Lin of WHOI predicted 3-D canyon acoustic effects on sound propagation, and also the temporal variability of the sound field, for the Mien-Hua Canyon using MSEAS ocean forecasts.

Table 45 describes the QPE data assembled from numerous different providers input to the MSEAS model. In this table, the column "File Format" describes the format in which the data is available. "mods format" refers to an MSEAS ascii data format and indicates that the date files have been processed for use within MSEAS. "unprocessed" files are data files which have not been modified from their original format. The "I/A?" column indicates whether or not the data was used in real-time MSEAS initialization or assimilation and the "Plots?" column indicates whether or not plots of the data are available. All of these processed data are available upon request.

Table 46 describes the output from MSEAS which are available from http://mseas.mit.edu/Research/QPE/index.html

Table 45. Input to MSEAS

		Time Period	**Number/Notes**	**File Format**	**I/A?**	**Plots?**
CTD						
OR1	Leg 1	24-31 Aug	54 casts	mods format	Yes	Yes
	Leg 2	04-12 Sep	67 casts	mods format	No	Yes
OR2	Leg 1	13-16 Aug	40 casts	mods format	Yes	Yes
	Leg 2	27-30 Aug	42 casts	mods format	No	Yes
OR3	Leg 1	13-16 Aug	50 casts	mods format	Yes	Yes
	Leg 1	13-16 Aug	50 casts	mods format	No	Yes

	Leg 2	29 Aug – 01 Sep	37 casts	unprocessed	No	No
OR2/OR3	Leg 2	27 Aug – 01 Sep	73 casts	mods format	No	Yes
GTSPP		1-17 Aug 1-29 Aug 1-30 Sep	27 casts 73 casts 70 casts	mods format mods format mods format	No No No	Yes Yes Yes
SEASOAR						
OR1		25 Aug – 10 Sep	10 files	mods format ascii files matlab files	Yes No No	Yes No No
UNDERWAY						
OR1	Leg 1	23-31 Aug	1 file	ascii file	No	Yes
	Leg 2	04-12 Sep	1 file	ascii file	No	Yes
OR2	Leg 1	13-16 Aug				
	Leg 2	27-30 Aug		ascii file	No	Yes
OR3	Leg 1	13-16 Aug				
	Leg 2	29 Aug – 01 Sep	3 files	ascii file	No	No
ADCP						
OR1	Leg 1	23-31 Aug	1 file	matlab file	No	Yes
	Leg 2	04-11 Sep	1 file	matlab file	No	Yes
OR2	Leg 1	13-16 Aug				
	Leg 2	27-30 Aug		unprocessed	No	No
OR3	Leg 1	13-16 Aug	1 file	matlab file	No	Yes
	Leg 2	29 Aug – 01 Sep		unprocessed	No	No
Meteorology						
OR1	Leg 1	23-31 Aug	1 file	ascii file	No	Yes
	Leg 2	04-11 Sep	1 file	ascii file	No	Yes
OR2	Leg 1	13-16 Aug				
	Leg 2	27-30 Aug	4 files	ascii files	No	Yes
OR3	Leg 1	13-16 Aug				
	Leg 2	29 Aug – 01 Sep	5 files	ascii files	No	No
SeaGlider						
SG165		21 May – 09 Sep	615 casts	mods file	Yes	Yes
SG166		22 May – 07 Sep	614 casts	mods file	Yes	Yes
SG167		21 May – 10 Sep	670 casts	mods file	Yes	Yes
Drifters						
Centurioni	Drifter	18 Aug – 15 Sep	111 diff. drifters	plotted	No	Yes
	T-Chain	13 Aug – 15 Sep	5 drifters	unprocessed	No	No
Remotely Sensed						

SSH	Colorado	1 Aug – 14 Sep		imagery		Yes
	Ocean Watch	5 Aug – 13 Sep	7 day ave	imagery and NetCDF		Yes
	NOAA	9-20 Aug	Jason-2	unprocessed	No	No
	Aviso	31 May – 30 Sep	Envisat	NetCDF	No	Yes
		31 May – 30 Sep	Jason-1	NetCDF	No	Yes
		31 May – 30 Sep	Jason-2	NetCDF	No	Yes
SST	UKHO	9 Aug – 13 Sep	Global NetCDF	NetCDF		No
	Japan	1 Aug – 14 Sep		imagery		Yes
	Taiwan	1 Aug – 14 Sep		imagery		Yes
	JPL	1 Aug – 14 Sep		imagery		Yes
	Ocean Watch	5 Aug – 13 Sep	3 day ave	imagery and NetCDF		Yes
Atmospheric Forcing						
COAMPS	Real-time	7 Aug – 14 Sep		grib	Yes	Yes
	5km	25 Aug – 10 Sep		binary	No	Yes
	15km	25 Aug – 10 Sep		binary	No	Yes
	Archive	1 Aug – 15 Sep			No	Yes
NOGAPS	Real-time	7 Aug – 14 Sep		grib	Yes	Yes
	Archive	1 Aug – 15 Sep		grib	No	Yes
Numerical Model						
NCOM		1 Aug – 14 Sep		imagery	No	Yes
NLOM		1 Aug – 14 Sep		imagery	No	Yes

Table 46. Output from MSEAS

		Time Period	File Format	I/A?	Plots?
Gridded Air-Sea Fluxes					
COAMPS	Real-time	7 Aug – 14 Sep	netCDF	Yes	Yes
	Archive	1 Aug – 15 Sep	netCDF	No	Yes
NOGAPS	Real-time	7 Aug – 14 Sep	netCDF	Yes	Yes
	Archive	1 Aug – 15 Sep	netCDF	No	Yes
Numerical Ocean Simulations					
MSEAS		18 Aug – 12 Sep	netCDF	N/A	Yes

4 Acknowledgments

We would like to thank Dr. Ching-Sang Chiu, Dr. Douglas Marble, and Dr. Ben Reeder, our program sponsors from the Office of Naval Research, who made this part of the QPE experiment possible, and also to the National Science Council for their support. We would like to thank the captains and crews of the Taiwanese research vessels R/V OR1, R/V OR2, and R/V OR3 who supported the sea-going operations and contributed greatly to the success of this experiment. We also acknowledge the logistical support of National Taiwan Ocean University and the National Museum of Marine Science and Technology.

5 Appendix A - Mooring diagrams

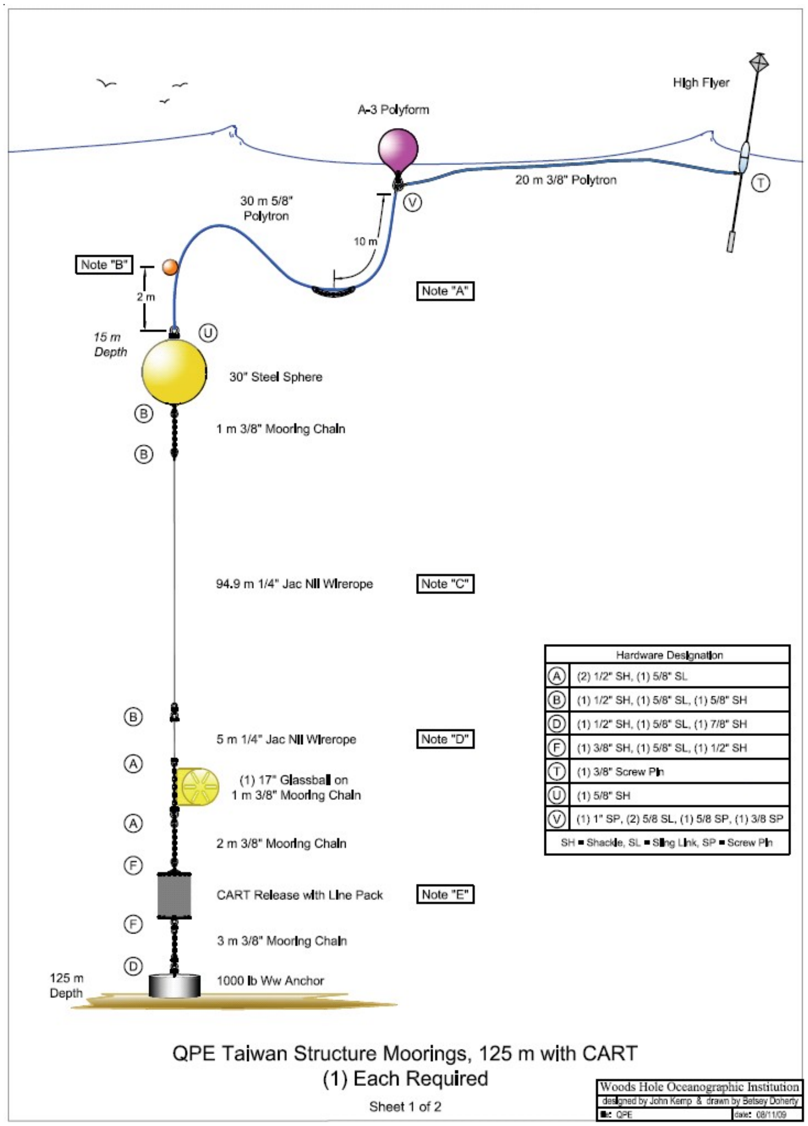


Figure 5.1. Mooring diagram for the 112m environment moorings. All environment moorings have same configuration, just cut for different depths.

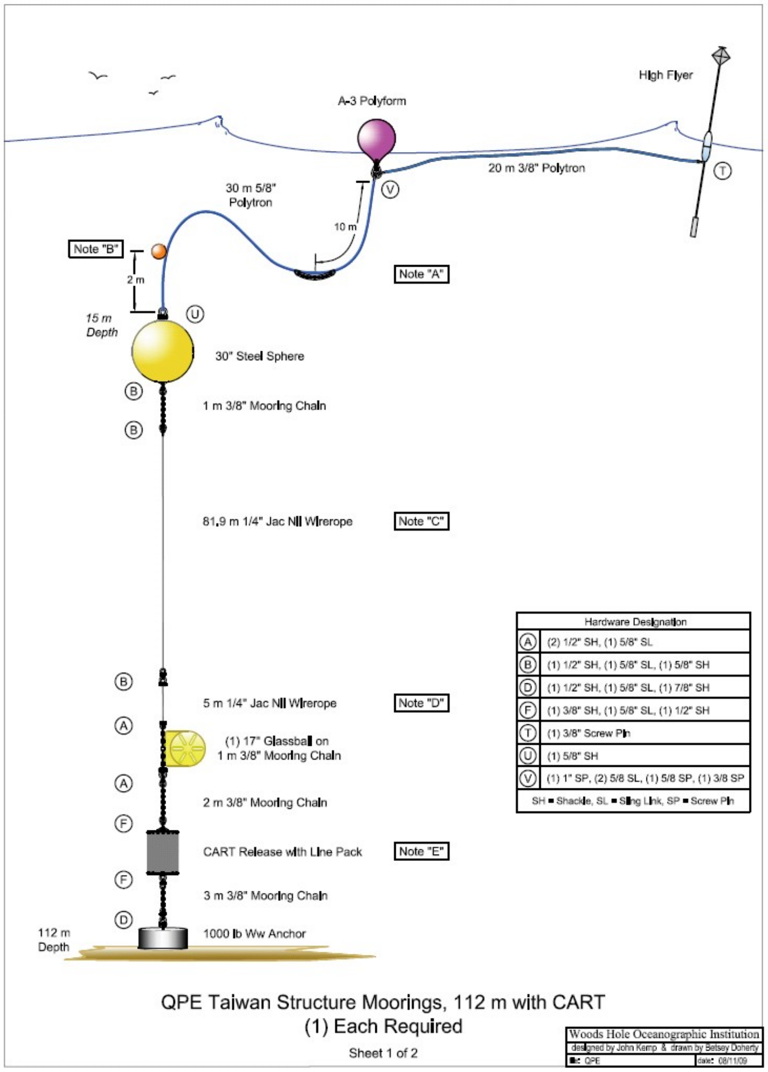


Figure 5.2. Mooring diagram for the 125 meter environment moorings. All environment moorings have same configuration, just cut for different depths.

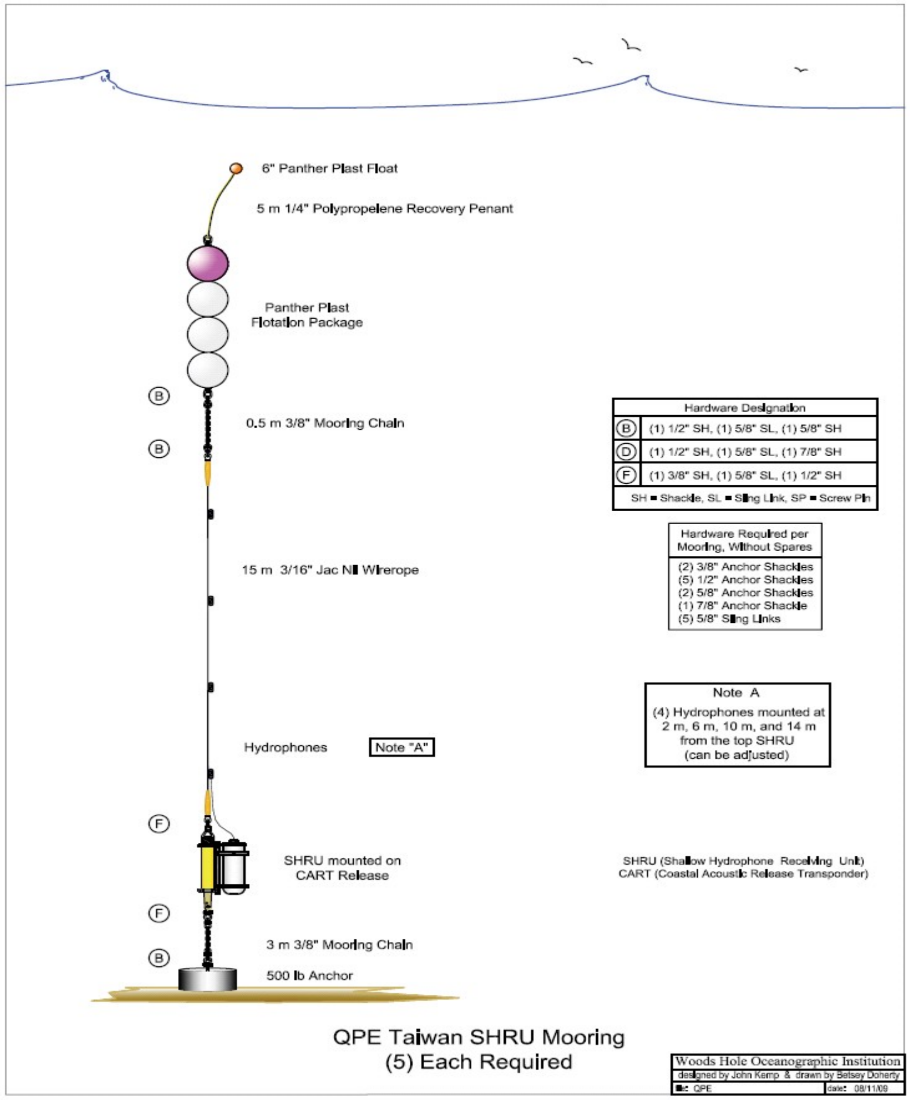


Figure 5.3. SHRU mooring diagram.

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4. Title and Subtitle Acoustics and Oceanographic Observations Collected During the QPE Experiment by Research Vessels OR1, OR2 and OR3 in the East China Sea in the Summer of 2009			5. Report Date August 2010 6.
7. Author(s) Arthur E. Newhall, et.al.			8. Performing Organization Rept. No.
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16. Abstract (Limit: 200 words)

This document describes data, sensors, and other useful information pertaining to the ONR sponsored QPE field program to quantify, predict and exploit uncertainty in observations and prediction of sound propagation. This experiment was a joint operation between Taiwanese and U.S. researchers to measure and assess uncertainty of predictions of acoustic transmission loss and ambient noise, and to observe the physical oceanography and geology that are necessary to improve their predictability. This work was performed over the continental shelf and slope northeast of Taiwan at two sites: one that was a relatively flat, homogeneous shelf region and a more complex geological site just shoreward of the shelfbreak that was influenced by the proximity of the Kuroshio Current. Environmental moorings and ADCP moorings were deployed and a shipboard SeaSoar vehicle was used to measure environmental spatial structure. In addition, multiple bottom moored receivers and a horizontal hy drophone array were deployed to sample transmission loss from a mobile source and ambient noise. The acoustic sensors, environmental sensors, shipboard resources, and experiment design, and their data, are presented and described in this technical report.

17. Document Analysis a. Descriptors

QPE experiment and mooring information
acoustic and oceanography data in the East China Sea
Quantifying, predicting and exploiting uncertainty initiative

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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