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NOAA *Okeanos Explorer* Program

MAPPING DATA REPORT

CRUISE EX0907

Mapping Field Trials IV

Habitat Characterization

Cordell Bank & Gulf of the Farallones National Marine Sanctuaries Expansion Areas

July 14 23, 2009

Astoria, OR to San Francisco, CA

Report Contributors:

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1. Introduction

The *Okeanos Explorer* Program

Commissioned in August 2008, the NOAA Ship *Okeanos Explorer* is the nation's only federal vessel dedicated to ocean exploration. With 95% of the world's oceans left unexplored, the ship's combination of scientific and technological tools uniquely positions it to systematically explore new areas of our largely unknown ocean. These exploration cruises are explicitly designed to generate hypotheses and lead to further investigations by the wider scientific community.

Using a high-resolution multibeam sonar with water column capabilities, a deep water remotely operated vehicle, and telepresence technology, *Okeanos Explorer* provides NOAA the ability to foster scientific discoveries by identifying new targets in real time, diving on those targets shortly after initial detection, and then sending this information back to shore for immediate near-real-time collaboration with scientists and experts at Exploration Command Centers around the world. The subsequent transparent and rapid dissemination of information-rich products to the scientific community ensures that discoveries are immediately available to experts in relevant disciplines for research and analysis

Through the *Okeanos Explorer* Program, NOAA's Office of Ocean Exploration and Research (OER) provides the nation with unparalleled capacity to discover and investigate new oceanic regions and phenomena, conduct the basic research required to document discoveries, and seamlessly disseminate data and information-rich products to a multitude of users. The program strives to develop technological solutions and innovative applications to critical problems in undersea exploration and to provide resources for developing, testing, and transitioning solutions to meet these needs.

Okeanos Explorer Management – a unique partnership within NOAA

The *Okeanos Explorer* Program combines the capabilities of the NOAA Ship *Okeanos Explorer* with shore-based high speed networks and infrastructure for systematic telepresence-enabled exploration of the world ocean. The ship is operated, managed and maintained by NOAA's Office of Marine and Aviation Operations, which includes commissioned officers of the NOAA Corps and civilian wage mariners. OER owns and is responsible for operating and managing the cutting-edge ocean exploration systems on the vessel (ROV, mapping and telepresence) and ashore including Exploration Command Centers and terrestrial high speed networks. The ship and shore-based infrastructure combine to be the only federal program dedicated to systematic telepresence-enabled exploration of the planet's largely unknown ocean.

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2. Purpose

The purpose of this report is to briefly describe the mapping data collection and processing methods, and to report the results of the cruise. For a detailed description of the *Okeanos Explorer* mapping capabilities, see appendix C and the ship's readiness report, which can be obtained by contacting the ships operations officer (ops.explorer@noaa.gov).

3. Cruise Objectives

Cruise EX0907 had two separate objectives. The primary cruise objective was to test, troubleshoot, refine, and evaluate *Okeanos Explorer* mapping systems, sensors, protocols, and processes as they related to the systematic exploration mission of the ship. Specific goals pertaining to this objective were:

- Assessment of bottom backscatter data quality
- Resolution of interference between EM302, EA600, and Knudsen Sub-bottom sonars
- Continued refinement of data products, pipeline, documentation, and sensor integration

The secondary cruise objective was to continue preparation, personnel training, and evaluation of non-mapping *Okeanos Explorer* systems and sensors. Specific goals pertaining to this objective were:

- VSAT system trial
- Preparation for the 24 July public relations event
- CIMS trial

Both objectives were completed within the context of mapping in the vicinity of Cordell Bank and the Gulf of the Farallones, which are of national and regional interest.

4. Participating personnel

NAME	ROLE	AFFILIATION
CDR Joseph Pica	Commanding Officer	NOAA Corps

Mashkoor Malik	Cruise Coordinator/Mapping Team Lead	NOAA OER
LTJG Kyle Byers	Acting Field Operations Officer	NOAA Corps
Colleen Peters	Senior Survey Technician	NOAA OMAO
Lorraine Anglin	ONMS Representative	ONMS
Andrea LeBarge	Mapping Watchstander	NOAA OER Intern
Christopher Paul	Mapping Watchstander	NOAA OER Intern
Elena Crete	Mapping Watchstander	NOAA OER Intern
Gregory Beadle	Mapping Watchstander	NOAA OER Intern
Samuel Baldwin	Mapping Watchstander	NOAA OER Intern
Denise Gordon	NCDDC CIMS team	NCDDC
McKinley Freeman	NCDDC CIMS team	NCDDC

5. Cruise Statistics

Dates	JD197 to JD203
Weather delays	0 days
Total non-mapping days	0 days
Total survey mapping days	7 days
Total transit mapping days	2.5 days
Line kilometers of survey	2477 km
Beginning draft	4.34 m (bow) 4.42 m (stern)
Average ship speed for survey	7.9 kts

6. Mapping sonar setup

NOAA *Okeanos Explorer* (EX) is equipped with a 30 kHz Kongsberg EM 302 multibeam sonar and a 3.5 kHz Knudsen sub-bottom profiler (SBP 3260). During this cruise EM 302 bottom bathymetric / backscatter along with water column data were collected. The Knudsen Sub-bottom profiler was only operated for the purposes of testing interference between EM 302 and Knudsen on 15-16 July 2009 up to depth of ~ 2000 m and was found to work satisfactorily at the same time with the EM 302 with no interference observed in EM 302.

The ship used a POS-MV ver. 4 to record and correct the multibeam data for any motion. C-NAV GPS system provided DGPS correctors with position accuracy expected to be better than 2.0 m.

All the corrections (motion, sound speed profile, sound speed at sonar head, draft, sensor offsets) are applied during real time data acquisition in SIS ver. 1.04. XBT casts (Deep Blue, max depth 760 m) were taken every 6 hours (0000, 0600, 1200 and 1800 local time). XBT cast data were converted to a SIS compliant format using NOAA Velocwin ver. 8.92 Plus.

7. Data acquisition plan

The data were collected during transit from Astoria, OR, to working grounds (15-16 July) in the vicinity of Cordell bank National Marine Sanctuary. Active data acquisition in the working grounds was carried out 16 – 22 July.

Due to large depth variations, the lines were planned to run parallel to the contour lines and the whole area was divided into four sub areas with line spacing of 750 m, 1500 m, 3000 m and 6000 m respectively.

Most of the shallow water areas (with depths < 400 m) demanded line spacing of 750 m. Throughout the survey, the EM 302 data provided 3-5 times water depth coverage.
The weather got worse on 18 July with 7-12 ft swells from the north and remained rough until the end of the survey. As the northbound lines caused the ship to pitch heavily, a lot of bubble sweep down episodes were observed in the northbound lines, which caused the sonar to loose bottom track. During heavy weather the sonar also suffered from decreased swath coverage and therefore a lot of additional lines were run to fill in the data holidays.

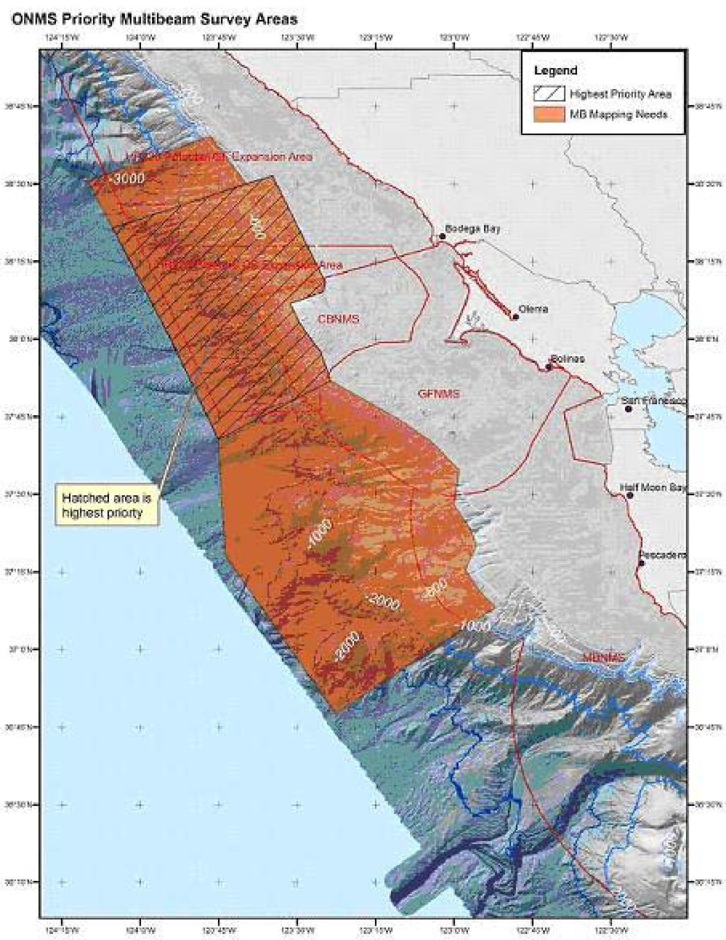

Figure 1. Survey areas showing priorities.

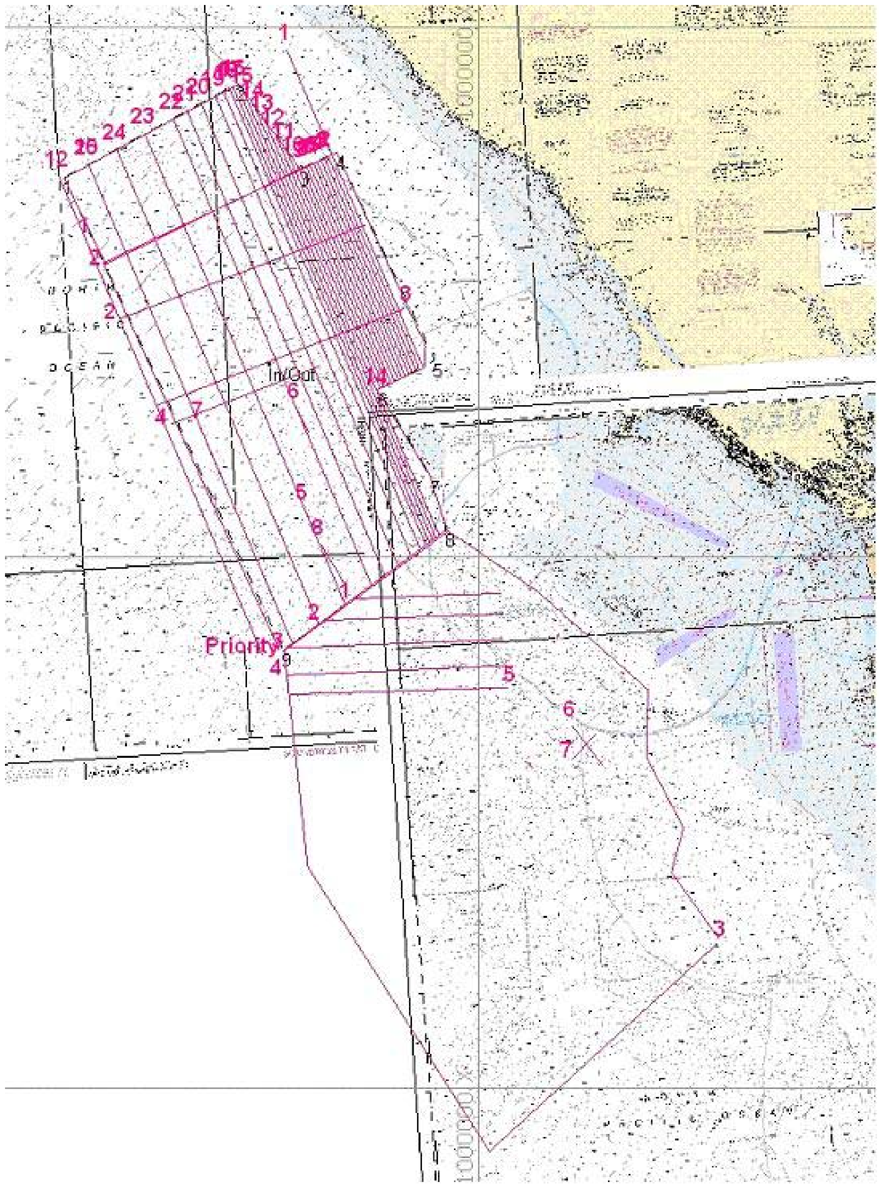

Figure 2. Screen shot of HYPACK showing different lines run during the survey. Image credit: NOAA.

8. Multibeam Data Quality Assessment and Data Processing

Onboard processing of bathymetric data was done in CARIS HIPS ver. 6.1 during which the data were cleaned in 'Swath Editor' and 'Subset Editor'. No tidal corrections were applied during post processing; however, no appreciable differences were observed between different lines by not applying tidal corrections.

The cross lines yielded a favorable comparison between main scheme lines and cross lines.

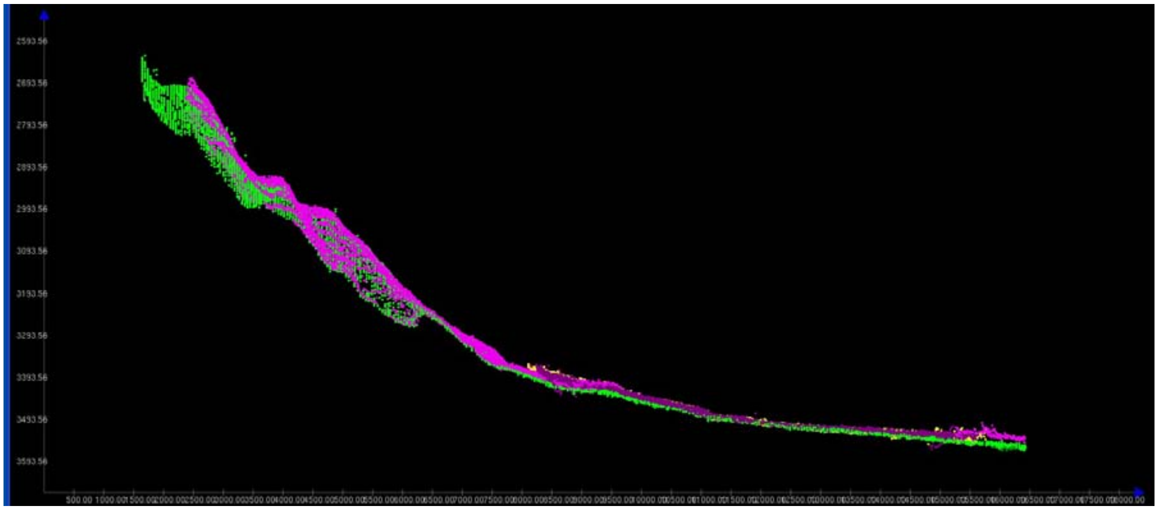

Figure 3. Screen grab of subset editor in CARIS HIPS showing agreement of cross lines (pink) with main scheme lines. Image credit: NOAA.

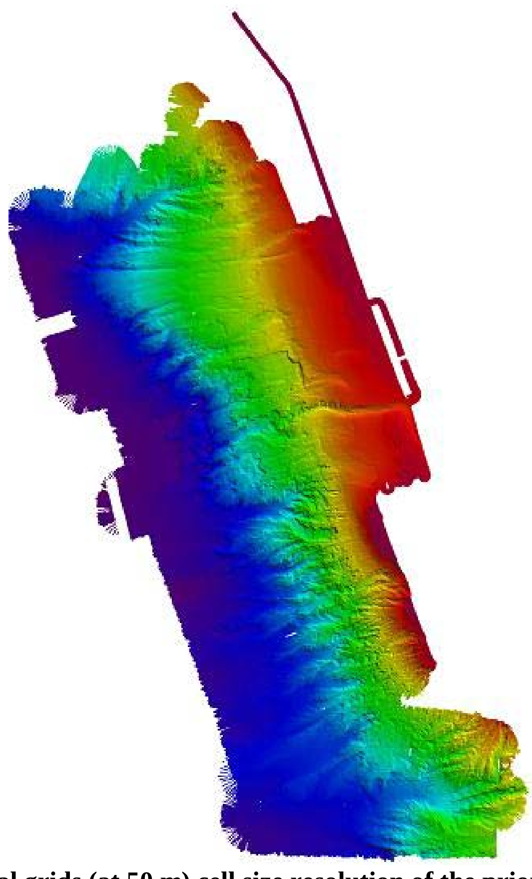

Figure 4. Images of the final grids (at 50 m) cell size resolution of the priority area 1 and 2. Image created in CARIS HIPS 6.1.

Onboard processing of water column data remained minimal due to the difficulty in discerning biological targets from noise in the water column data. Water column data from the survey have been provided with the cruise data.

Onboard processing of bottom backscatter data were conducted using the University of New Hampshire research tool ‘Geocoder’. The results obtained during fair weather are encouraging but during the days when the weather was choppy, a lot of bubble sweep down issues degraded bottom backscatter data quality severely. At the time of filing of this report, we are not sure whether they weather effects can be taken care of during post processing. The ship is also expected to contact Kongsberg, Inc. regarding these backscatter artifacts.

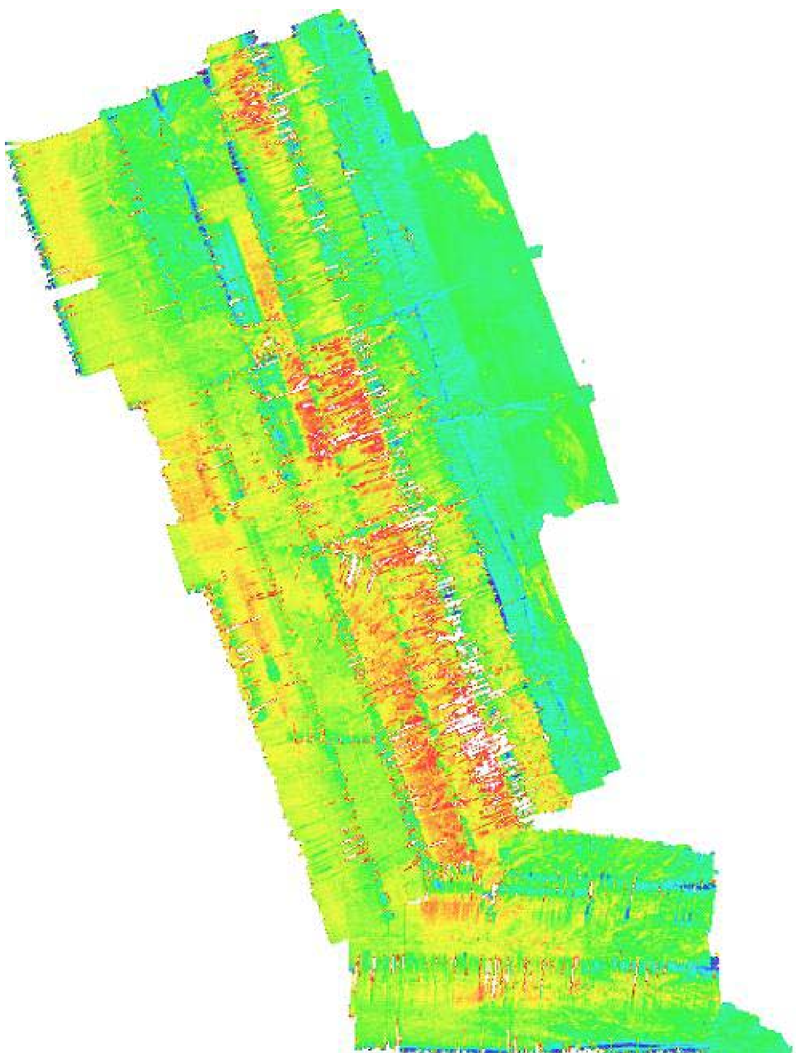

Figure 5. Backscatter mosaic results with 40 m grid cell size. Severe degradation of backscatter data due to bubble sweep down is clearly visible in the central region of the survey.

The latest patch test for the EM 302 was performed in May 2009 which showed only a pitch bias of 0.7 degrees. These patch test values were used during data acquisition throughout this cruise.

9. Cruise Calendar

July 2009						
Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
13 Mission party onboard the ship except Baldwin and Crete	14 Baldwin and Crete arrived 1030. Left Astoria, OR 1230	15 In transit to the working grounds.	16 Arrived at working grounds ~ 1400	17 Mapping in Priority 1 and 2 of expansion areas	18 Weather getting worse with very little useable data in north bound line	19 Weather still preventing data collection northbound
20 Mapping in ONMS areas wrapping up. Running cross lines	21 Mapping in ONMS areas wrapping up	22 Mapping in Dump site. USS Independence investigation	23 Return to San Francisco	24	25	27

10. Daily cruise log

(ALL TIMES LOCAL PACIFIC DAYLIGHT TIME)

July 14, 2009

Ship sailed at 1230. Original sailing at 0900 was delayed due to flight cancellation of Baldwin and Crete who spent ~ 36 hrs traveling from Durham, NH, to Astoria, OR. Mission party met with Peters and Malik to discuss briefly cruise objectives and introductions. Lt Byers also welcomed the mission party and briefed about essential safety issues. Initial orientation with mission control room and mapping operations along with XBT operations was provided by Peters.

July 15, 2009

Ship is in transit to working grounds off the coast of CA.

July 16, 2009

Ship passed over several plume sites during 15/16 night. The ship was directed to make another pass and resulted in finding more than 3 plume sites in addition to the one detected in the May 2009 mapping field trial cruise. Arrived at working grounds and started mapping.

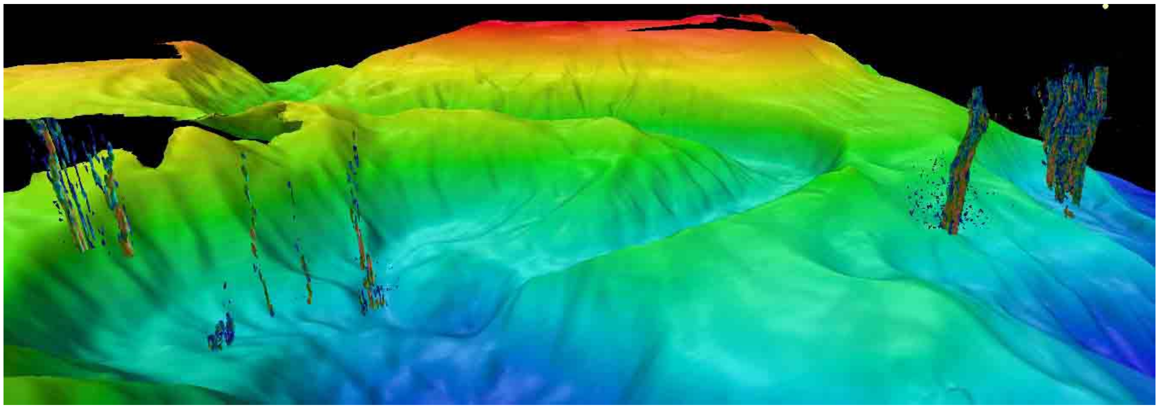
Figure 6. At least five plume sites visible with multibeam—50 m grid, compiled in Fledermaus.

July 17, 2009

Ship continued to work in the sanctuary expansion areas priority 1 and 2.

July 18, 2009

The weather has been progressively getting worst. Large swells (~ 5-10 ft) are causing ship to pitch and the bubble sweep down is causing EM 302 to loose bottom track. Reducing survey speed to 5 kts helped little bit but still the data quality during north bound lines is degraded severely. Discussions are in progress to rerun these north bound lines at the end of the survey.

July 19, 2009

The weather is still bad for the north bound lines and north bound lines have to be run again to make useable data. The survey was broken off to fill in few holidays left in the shallow part of the survey. Resumed main scheme lines.

July 20, 2009

Mapping in the area with lot of bubble sweep down episodes.

July 21, 2009

Finished with running main scheme lines. Now running lines to fill in the holidays. Over night the ship transited to the ammunition dump site and started mapping in the dump site, located in priority 3 area. No noticeable items were detected in the dump site. The backscatter data were processed but due to bad weather did not provide any useful information about the type of the material.

July 22, 2009

After finishing dump site, the ship made few passes over reported wreck of USS Independence and located an object which seemed to be a wreck of a ship ~ 190 m long.

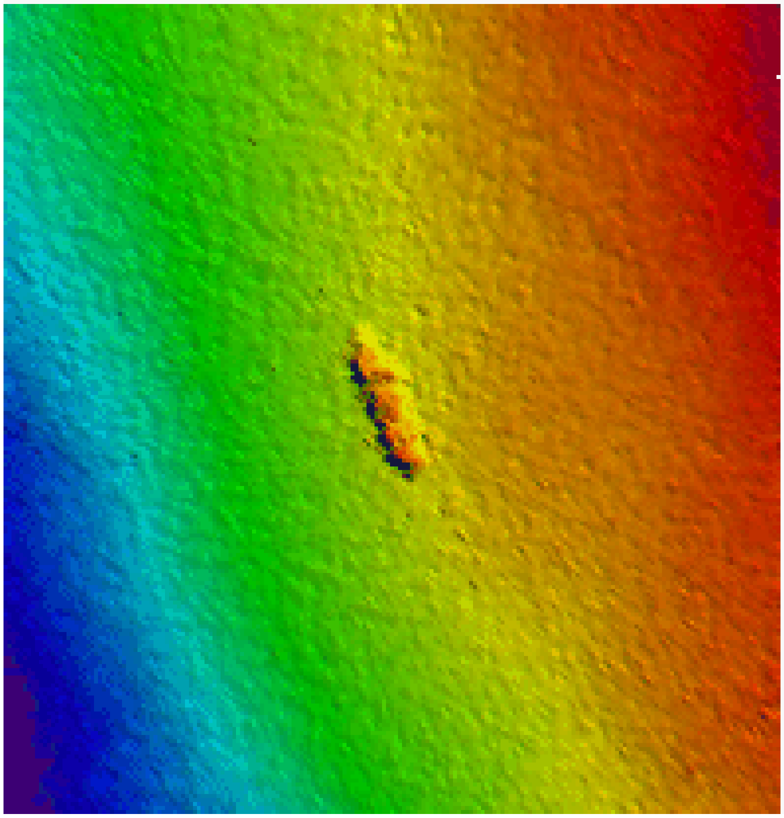

Figure 7. A plan view of USS Independence located in position 123.1346 W, 37.4779 N, compiled in Fledermaus.

11. Appendices

Appendix A. Tables of data files collected

<u>XBT Locations:</u>

Date	Time (GMT)	XBT/CTD Filename	Lat	Long	Remarks
071409	21:54	TD_00001	46 5.28N	124 12.19W	
071509	18:04	T6_00002	42 38.31N	124 55.33W	
071609	04:07	TD_00003	40 54.43N	124 44.95W	
071609	20:48	T6_00004	38 45.17N	123 43.38W	
071709	01:22	T6_00005	38 10.94N	123 26.78W	
071709	07:28	T6_00006	3819.26N	123 31.69W	
071709	13:08	T6_00007	38 23.64 N	123 34.79 W	
071709	20:22	TD_00008	38 13.50N	123 31.77W	
071809	01:05	TD_00009	38 29.28N	123 41.20W	
071809	07:13	TD_00010	38 9.85N	123 33.38W	
071809	13:03	TD_00011	38 19.17N	123 38.75W	
071809	19:04	TD_00012	38 2.30N	123 33.91W	
071909	01:24	TD_00013	38 33.1N	123 47.89W	
071909	07:12	TD_00014	37 51.51N	123 31.21W	
071909	13:00	TD_00015	38 9.53N	123 41.54W	
072009	01:07	TD_00016	37 55.23N	123 29.21W	
072009	12:52	TD_00017	38 34.04N	123 53.85W	
072009	21:17	TD_00018	40 54.50N	124 44.95W	
072109	01:13	TD_00019	38 29.77N	124 01.68W	
072109	07:10	TD_00020	37 55.27 N	123 45.97W	
072109	12:57	TD_00021	37 55.27N	123 45.97W	
072109	21:22	T6_00022	38 13.63N	123 29.87W	
072209	01:30	TD_00024	38 7.48N	123 44.23W	
072209	08:07	TD_00025	37 45.03N	123 25.23W	
072209	13:01	TD_00026	37 40.36N	123 30.00W	
072209	20:37	TD_00027	37 31.19N	123 09.03W	

Multibeam files collected during the cruise:

Cruise DayNo.	Date	File Name	Location	Remarks
2	071509	0000_20090715_003242_EX	Transit	Transit
		0001_20090715_012502_EX		Transit
		0002_20090715_072501_EX		Transit
		0003_20090715_132502_EX		Transit
		0004_20090715_164528_EX		Transit
		0005_20090715_183657_EX		Transit
		0006_20090715_223507_EX	Plume site	Transit
3	071609	0007_20090716_034420_EX	Plume site	Transit
		0008_20090716_063022_EX	Plume site	Transit
		0009_20090716_064152_EX	Plume site	Transit
		0010_20090716_081122_EX	Plume site	Transit
		0011_20090716_081931_EX	Plume site	Transit
		0012_20090716_083615_EX	Plume site	Transit
		0013_20090716_085824_EX		Transit
		0000_20090716_202221_EX		Transit
		0001_20090716_211442_EX		Transit
		0002_20090716_222054_EX	Priority 1 & 2	Start of box
4	071709	0003_20090717_000030_EX	Bodega Canyon head	Start of new day (GMT)
		0004_20090717_004209_EX		End line, start turn
		0005_20090717_010429_EX		End turn, start line
		0006_20090717_033320_EX		End line, start turn
		0007_20090717_034453_EX		End turn, start line
		0008_20090717_060129_EX		End line, start turn
		0009_20090717_060513_EX		End turn, start line
		0010_20090717_084137_EX		End line, start turn
		0011_20090717_985053_EX		End turn, start line
		0012_20090717_110840_EX		End line, start turn
		0013_20090717_111704_EX		End turn, start line
		0014_20090717_134258_EX		End line, start turn
		0015_20090717_134952_EX		End turn, start line
		0016_20090717_160823_EX		End line, start turn
		0017_20090717_161358_EX		End turn, start line
		0018_20090717_183849_EX		End line, start turn
		0019_20090717_184336_EX		End turn, start line
		0020_20090717_210151_EX		End line, start turn
		0021_20090717_211503_EX		End turn, start line
5	071809	0022_20090718_000317_EX		End line, start turn
		0023_20090718_003452_EX		End turn, start line
		0024_20090718_032527_EX		Begin turn line
		0025_20090718_032911_EX		Begin main line Water column targets
		0026_20090718_045943_EX		End line, start turn
		0027_20090718_050646_EX		End turn, start line
		0028_20090718_103400_EX		End line, start turn
		0029_20090718_110310_EX		End turn, start line

		0030_20090718_155921_EX		End line, start turn
		0031_20090718_162109_EX		End turn, start line
		0032_20090718_172547_EX		End line, start turn
		0033_20090718_173446_EX		End turn, start line
		0034_20090718_174629_EX		End line, start turn
		0035_20090718_234628_EX		End turn, start line
6	071909	0036_20090719_020554_EX		End line, start turn
		0037_20090719_023945_EX		End turn, start line
		0038_20090719_073214_EX		End line, start turn
		0039_20090719_075741_EX		End turn, start line
		0040_20090719_130932_EX		Preserve file size, same line as line 39
		0041_20090719_184643_EX		Turn to S/B to fill holiday
		0042_20090719_200343_EX		End turn, start line to fill holiday
		0043_20090719_214422_EX		
		0044_20090719_220557_EX		End south bound fill line.
7	072009	0045_20090720_014232_EX		Begin transit to next holiday.
		0046_20090720_023807_EX		Filling in holiday northward
		0047_20090720_030330_EX		Transit line.
		0048_20090720_033345_EX		Filling in holiday northward
		0049_20090720_040012_EX		Transit line.
		0050_20090720_043814_EX		Filling in holiday southward
		0051_20090720_051109_EX		Transit line.
		0052_20090720_053458_EX		Filling in holiday northward
		0053_20090720_061144_EX		Filling in random holidays while heading north to begin next full line
		0054_20090720_071947_EX		New line to preserve data file size.
		0055_20090720_131949_EX		Transit, 6 hours elapsed
		0056_20090720_133514_EX		End transit, new line south
		0057_20090720_133519_EX		End line, start turn
		0058_20090720_194029_EX		Northbound
8	072109	0059_20090721_014033_EX		Turn line
		0060_20090721_014240_EX		Turn line continued
		0061_20090721_022001_EX		New line southward
		0062_20090721_072105_EX		End line, start turn
		0063_20090721_082212_EX		End turn, start line
		0064_20090721_130342_EX		Line continued, incremented to conserve file size.
		0065_20090721_151048_EX		
		0066_20090721_153809_EX		POS malfunction- POSMV rebooted
		0067_20090721_163536_EX		End turn, start line
		0068_20090721_170928_EX		End line, start turn
		0069_20090721_171824_EX		End turn, start cross line; Water column data
		0070_20090721_200807_EX		End cross line, start turn-transit-turn
		0071_20090721_210251_EX		End turn, start cross line
9	072209	0072_20090722_000108_EX		start turn line
		0073_20090722_001537_EX		Start cross line eastward
		0074_20090722_015726_EX		Turn line
		0075_20090722_022727_EX		Survey line south
		0076_20090722_024527_EX		Transit line
		0077_20090722_040717_EX		Survey line south
		0078_20090722_045949_EX		Transit line

		0079_20090722_054732_EX		Survey line south
	072209	0000_20090722_065138_EX	Munitions Dump Site	Dump site line 0
		0001_20090722_072053_EX		Transit to dump site line 1
		0002_20090722_073000_EX		Beginning line 1
		0003_20090722_073009_EX		Dump site line 1
		0004_20090722_084538_EX		Turn from line 1 line 2
		0005_20090722_090147_EX		Dump site line 2
		0006_20090722_111113_EX		Transit from line 2 to line 3
		0007_20090722_114947_EX		Dump site line 3
		0008_20090722_140255_EX		Transit from line 3 to line 4
		0009_20090722_142455_EX		Dump site line 4
		0010_20090722_170333_EX		End line, start turn
		0011_20090722_171901_EX		End turn, start Dump site line 5
		0012_20090722_192918_EX		Transit to USS Independence
	072209	0000_20090722_200531_EX	USS Independence	Continue transit to USS Independence
		0001_20090722_203850_EX		1st Independence survey line
		0002_20090722_210542_EX		Broke line, continue line
		0003_20090722_211805_EX		Turn line
		0004_20090722_212738_EX		NW/b detect target
		0005_20090722_215904_EX		Turn line
		0006_20090722_221848_EX		SW/b line- bubble sweepdown- lost bottom
		0007_20070722_223056_EX		N/b detect target S/b detect target
		0008_20090722_225705_EX		

Appendix B: List of Acronyms

BIST – Built In System Test

CBNMS – Cordell Bank Marine National Sanctuary

CO – Commanding Officer

CIMS – Cruise Information Management System

CTD – conductivity temperature and depth

CW – continuous wave

dB – decibels

DGPS –Differential Global Positioning System

DTM – digital terrain model

ECS – Extended Continental Shelf

ET – Electronics Technician

EX – NOAA Ship *Okeanos Explorer*

FM – frequency modulation

FOO – Field Operations Officer

GFNMS – Gulf of the Farallones National Marine Sanctuary

kHz - kilohertz

Km – kilometers

KM – Kongsberg Maritime AS

Kt(s) – knots

Ma – megaannum

MBES – multibeam echosounder

NCDDC – National Coastal Data Development Center

NGDC – National Geophysical Data Center

NMS – National Marine Sanctuary

NOAA – National Oceanic and Atmospheric Administration

NODC – National Oceanographic Data Center

OER – Office of Ocean Exploration and Research

OMAO – Office of Marine and Aviation Operations

OCNMS – Olympic Coast National Marine Sanctuary

ROV – Remotely Operated Vehicle

SST – Senior Survey Technician

SV – sound velocity

TRU – transmit and receive unit

TSG - thermosalinograph

UNH-CCOM/JHC – University of New Hampshire Center for Coastal and Ocean Mapping / Joint Hydrographic Center

UPS – uninterruptable power supply

US EEZ – United States Exclusive Economic Zone

USBL – ultra-short base line

WD – water depth

XBT – expendable bathythermograph

Appendix C: EM302 description and operational specs

EM 302 : Ideal for Ocean Exploration

There are several features of the Okeanos Explorer's 30 kHz multibeam that make it an excellent tool for ocean exploration. The following is a brief description of these features.

Depth Range

The system is designed to map the seafloor in water depths of 10 to 7000 meters. This leaves only the deepest parts of the deeper ocean trenches out of the EM 302's reach. Moreover, operational experience on the *Okeanos Explorer* has shown consistent EM 302 bottom detection at depth ranges in excess of 8000m.

High Density Data

In multibeam data, the denser the data, the finer resolution maps you can produce. The system can operate in dual swath, or multiping mode, which results in increased along track data density. This is achieved by detecting two swaths per ping cycle, resulting in up to 864 beams per ping.

The Okeanos Explorer mapping team typically operates the multibeam in high density equidistant ping mode, which results in up to 864 soundings on the seafloor per ping.

Full Suite of Data Types Collected

The system collects seafloor backscatter data, which provides information about the character of the seafloor in terms of bottom type.

The system also collects water column backscatter data, which has the ability to detect gaseous plumes in the water column. The full value of this feature is still being realized.

FM chirp mode is utilized in water depths greater than 1000 meters, and allows for the detection of the bottom further out from nadir than with previous 30 kHz systems.

Multibeam Primer

The area of the seafloor covered, or ensonified, by a single beam within a pulse of sound, or ping, is called the beam footprint. This beam footprint is defined in terms of the across track and along track values. Both of these values are dependent on water depth and the beam width at which the sound pulse is transmitted and received. The across track beam width value is also dependent on the receive angle, or "listening" angle, of the system, and the angle from nadir which it is received from. The receive angle for the receive transducer on the Okeanos Explorer EM302 is 1°, which is the smallest possible angle currently available for the EM302 system. The further out from nadir a sounding occurs, the larger the footprint will be. For example, as seen in Table 1 below, in 2000 meters of water, a beam footprint will have a radius of 18 meters at nadir but 25 meters by the time it hits the seafloor at an angle 140 degrees out from nadir.

Calculated acrosstrack acoustic beam footprint for EM 302 (high density ping mode, 432 soundings/profile)				
Water depth (m)	**Angle from nadir**			
50	1 deg RX center	90 deg	120 deg	140 deg
100	1	0.5	1	1
200	2	1	2	3
400	4	2	3	5
1000	7	4	6	10
2000	18	9	16	25
4000	35	19	32	-

6000	70	37	-	-
7000	105	56	-	-

Table 1. Calculated across track EM 302 beam footprint. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 17.

Calculated acrosstrack sounding density for EM 302 (high density ping mode, 432 soundings/profile)			
Water depth (m)	**Swath Width**		
50	90 deg	120 deg	140 deg
100	0.2	0.4	0.9
200	0.5	0.8	1.7
400	0.9	1.6	3.5
1000	1.9	3.2	6.9
2000	4.6	8.1	17.4
4000	9.3	16.2	-

Table 2. Calculated across track EM 302 sounding density. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 17.

Acrosstrack sounding density describes the spacing between individual soundings on the seafloor in the acrosstrack direction. The maximum swath of the EM 302 is 150 degrees. At this swath, the sounding density will be the least dense, since the beams will be spread out over a larger horizontal distance over the seafloor. As the swath angle (width) is decreased, the sounding density will increase, as the same number of beams are now spread out over a smaller horizontal distance over the seafloor.

Calculated ping rate and alongtrack resolution for EM 302					
140 deg swath, one profile per ping					
			Alongtrack distance between profiles (m)		
Water depth (m)	**Swath Width (m)**	**Ping Rate (pings/second)**	**@4 kts**	**@8 kts**	**@12 kts**
50	275	3.2	0.7	1.2	1.9
100	550	1.8	1.1	2.2	3.3
200	1100	1	2.1	4.2	6.3
400	2200	0.5	4.1	8.2	12.2
1000	5500	0.2	10	20	30
2000	8000	0.1	15.2	30.5	45.7
4000	8000	0.06	19.2	38.5	57.7
6000	8000	0.04	24.5	49	73.4

Table 3. Calculated ping rate and along track EM 302 sounding density, one profile per ping. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 15.

Calculated ping rate and alongtrack resolution for EM 302					
140 deg swath, two profiles per ping					
Water depth (m)	**Swath Width (m)**	**Ping Rate**	**Alongtrack distance between profiles (m)**		
			@4 kts	**@8 kts**	**@12 kts**
50	275	3.2	0.3	0.6	0.9
100	550	1.8	0.6	1.1	1.7
200	1100	1	1.1	2.1	3.2
400	2200	0.5	2	4.1	6.1
1000	5500	0.2	5	10	15
2000	8000	0.1	7.6	15.2	22.8

Table 4. Calculated ping rate and along track EM 302 sounding density, two profiles per ping. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 15.

Reference: Kongsberg Product Description: EM 302 multibeam echosounder

Appendix D: Field products showing data results: Overview of Exploration Area

Okeanos Explorer Multibeam Survey with ONMS, July 2009