

APPENDIX 1 - Science Party and Ship's Crew

Science party

Suzanne Carbotte (LDEO), Chief Scientist
Matthias Delescluse ENS Professor
Berta Biescas (Dalhousie) Post-Doc
Louise Watremez (Dalhousie), Post-Doc
Guillermo Bornstein (Consejo Superior de Investigaciones Cientificas (BCSI-CSIC), Barcelona, Student
Laurel Childress (Northwestern University), Student
Aaron Farkas (Dalhousie), Student
James Gibson (LDEO), Student
Shuoshuo Han (LDEO), Student
Greg Horning (WHOI), Student
Helen Janiszewski (LDEO), Student
Milena Marjanovic (LDEO), Student
Beatrice Parker (MIT), Student

Shipboard Technical Staff

Steinhaus, Robert J., Chief Science Officer
Johnstone, Jay D., Science Officer
Martinson, David, Acquisition/navigation - Chief
Martello, Michael C., Acquisition/navigation
Gutierrez, Carlos D., Chief Gunner
Tatro, Michael P., Gunner
Groves, Weston B., Gunner
Ingram, Heidi E., Protected Species Observer - Chief
Allen, Jami M. PSO
Douglas, Katherine M., PSO
Ellis, Emily M., PSO
Moreno, Tatiana A., PSO

Ships' Officers and Crew

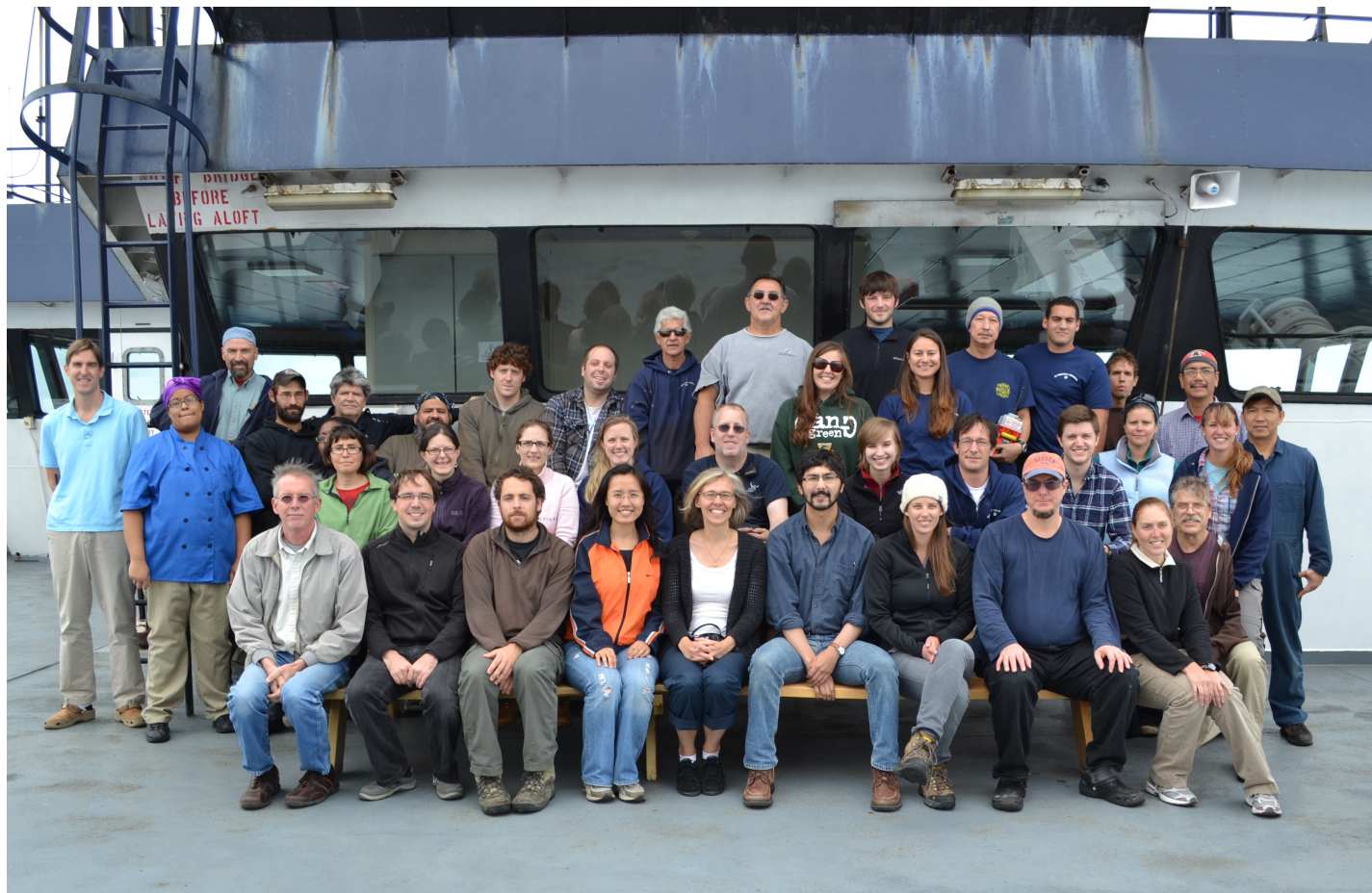
Landow, Mark C., Master
Fischer, Robert V., Chief Mate
Wolford, David H., 2nd Mate
Lemite, Zachary D., 3rd Mate
Woronowicz, Jason J., Bosun
Rimando, Inocencio B, AB
Cereno, George G., AB
James, Glenice, AB
Webster, Jeromiel J., OS
Jordan, Lakia M., OS

Karlyn, Albert D., Chief Engr.
 Vetting, Ryan P., 2nd Engr.
 Guilas, Chrisse A., 3rd Engr.
 Neis, Philip D., Electrician
 Billings, Jack C., Oiler
 Florendo, Rodolfo A., Oiler
 Uribe, Guillermo F.
 McCoy, Michael G., Steward
 Rios, Ricardo, Cook

MGL1211 Watch Schedule

Shift Times	People	Watch
6 am-12 pm	James and Beatrice	Science
12 pm to 6 pm	Helen and Greg	Science
6 pm to 12 am	Shuoshuo and Louise	Science
12 am to 6 am	Aaron and Laurel	Science
	Berta/ Guillermo	XBT
	Matthias and Milena	Seismic QC
8am – 10 pm	Suzanne	Science

APPENDIX 2 – Cruise Photo



Science Party and Ship's Crew for MGL1211.



- | | | | |
|-----|---------------------|-----|----------------------|
| 1. | Mark Landow | 21. | Milena Marjanovic |
| 2. | Lakia Jordan | 22. | Louse Watremez |
| 3. | David Martinson | 23. | Berta Biescas Gorriz |
| 4. | Matthias Delescluse | 24. | Glenice James |
| 5. | Guillermo Bornstein | 25. | Jason Woronowicz |
| 6. | Shuoshuo Han | 26. | Phillip Neis |
| 7. | Suzanne Carbotte | 27. | Guillermo Uribe |
| 8. | Aaron Farkas | 28. | Ricardo Rios |
| 9. | Heidi Ingram | 29. | Michael Tatro |
| 10. | Michael McCoy | 30. | Jay Johnstone |
| 11. | Jami Allen | 31. | Carlos Gutierrez |
| 12. | Robert Fischer | 32. | Michael Martello |
| 13. | Laurel Childress | 33. | Emily ellis |
| 14. | Rodolfo Florendo | 34. | Weston Groves |
| 15. | Katherine Douglas | 35. | Tatiana Moreno |
| 16. | Gregory Horning | 36. | George Cereno |
| 17. | James Gibson | 37. | Zachary Lemite |
| 18. | Helen Janiszewski | 38. | Cameron Ruth |
| 19. | Robert Steinhaus | 39. | Inocencio Rimando |
| 20. | Beatrice Parker | | |

APPENDIX 3 – Summary Track Maps

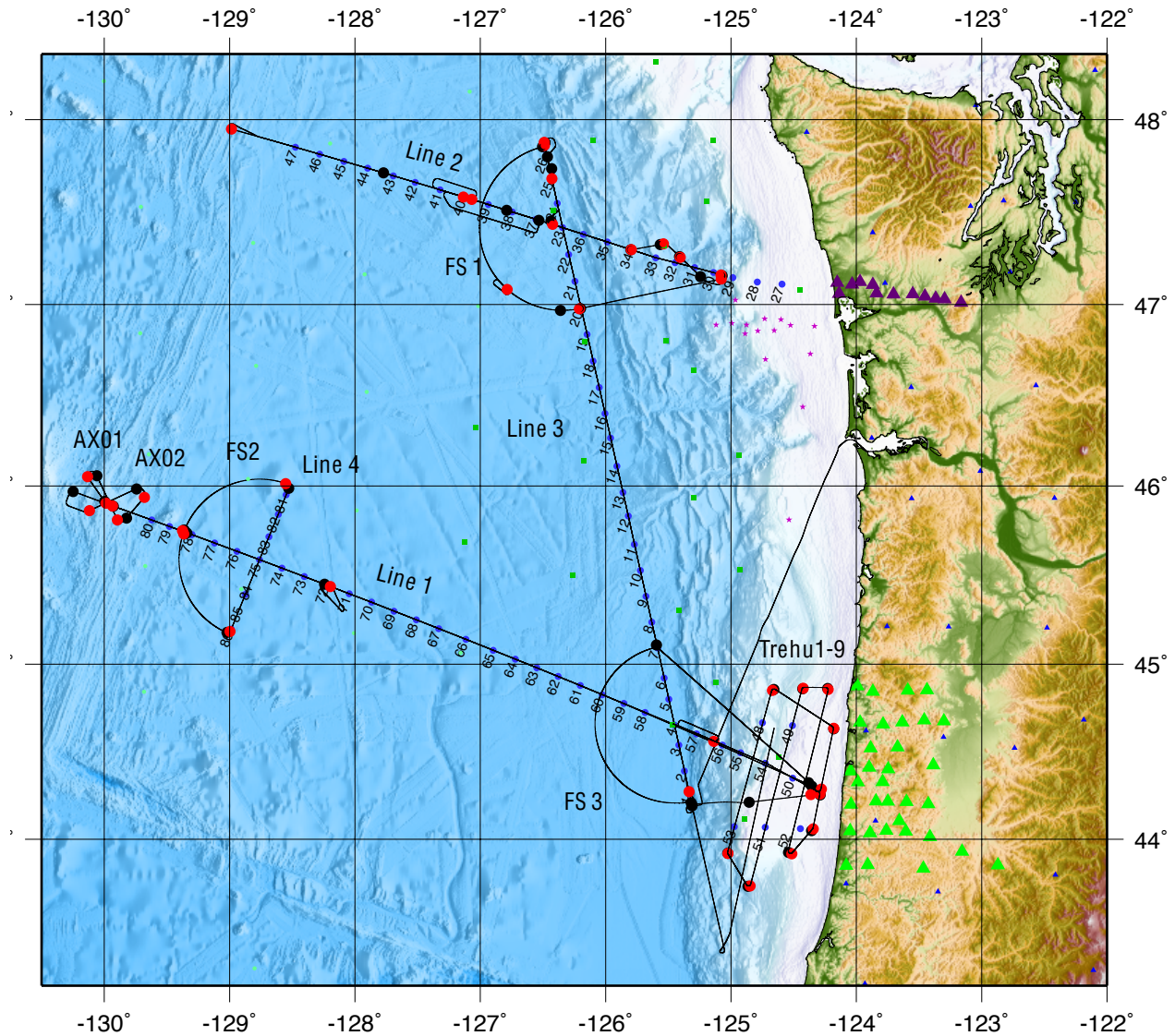


Figure 3a. Track map for seismic survey with primary lines labeled. Black/red dots show line start/end locations respectively. Numbered blue dots indicate OBS locations.

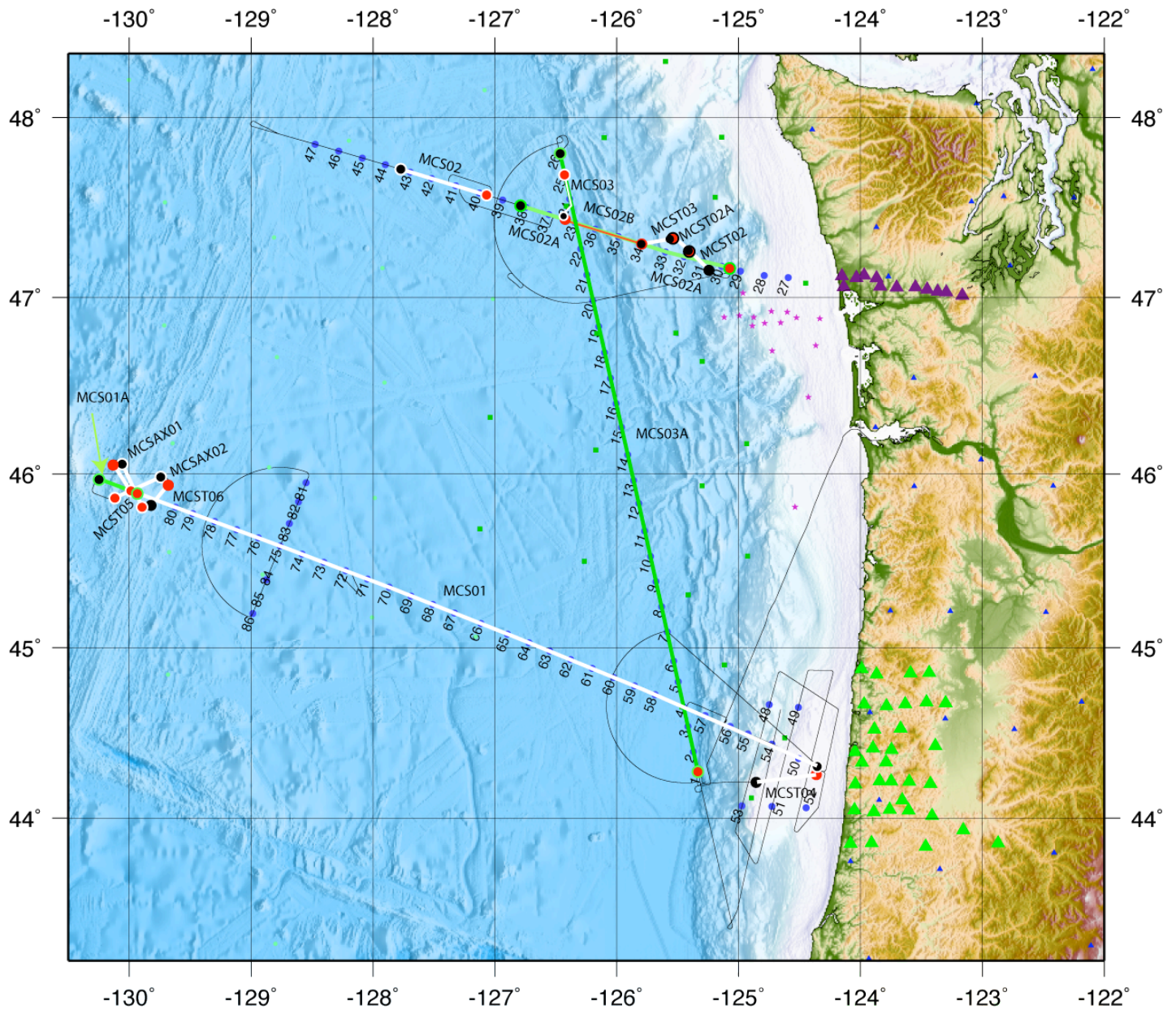


Figure 3c. Track map for MCS survey showing coverage acquired with line names indicated. Track map for OBS survey. Primary lines shot in multiple segments are shown with different colored line for each segment (white-green-red). Black/red dots show line start/end locations respectively. Numbered blue dots indicate OBS locations.

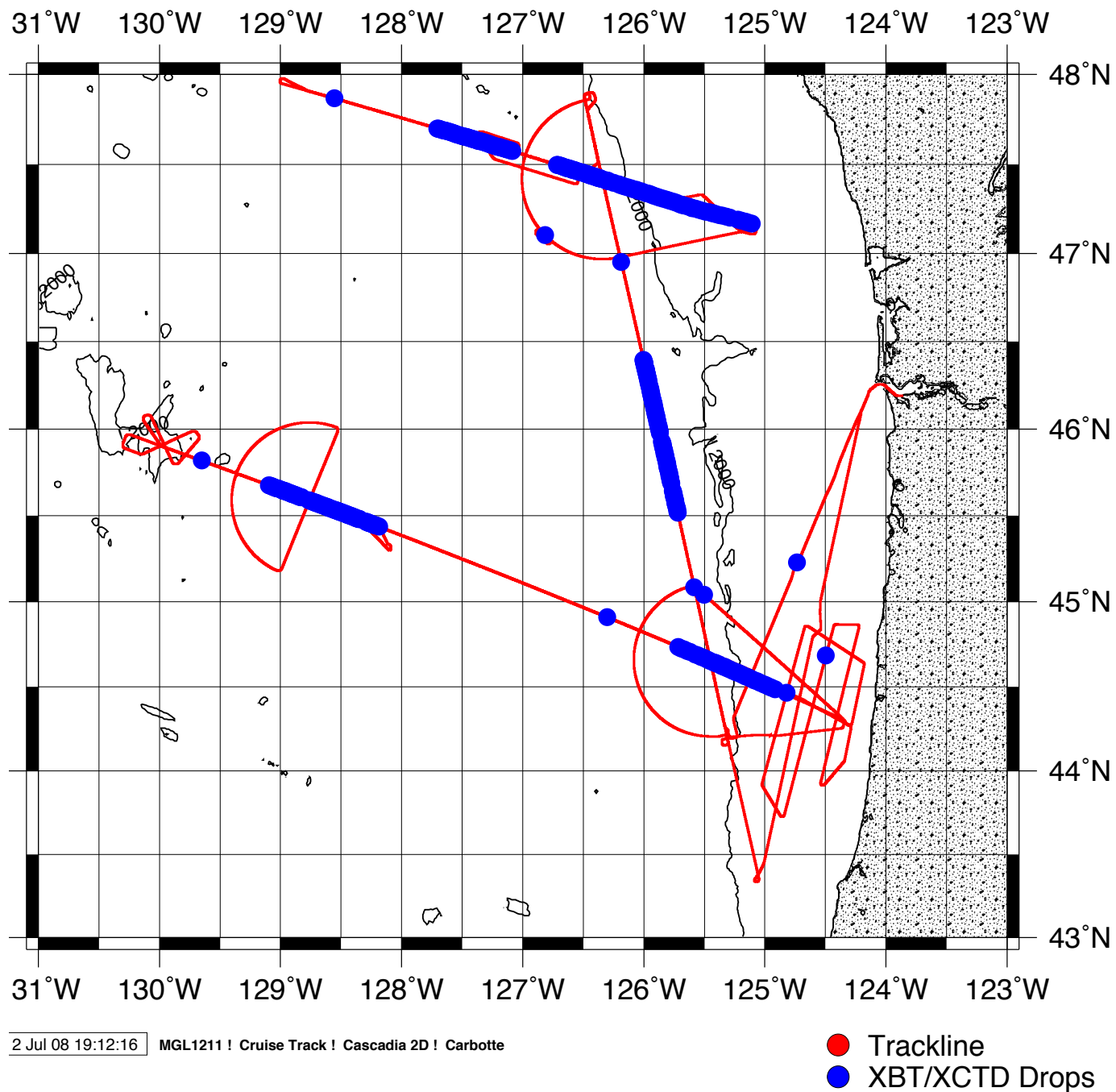


Figure 3d. Track map showing XBT/XSV coverage. Probes dropped included both daily XBTs to determine sound velocity for multibeam acquisition as well as densely spaced XBT/XSVs for the seismic oceanography program.

APPENDIX 4 – Shot Coverage Summa

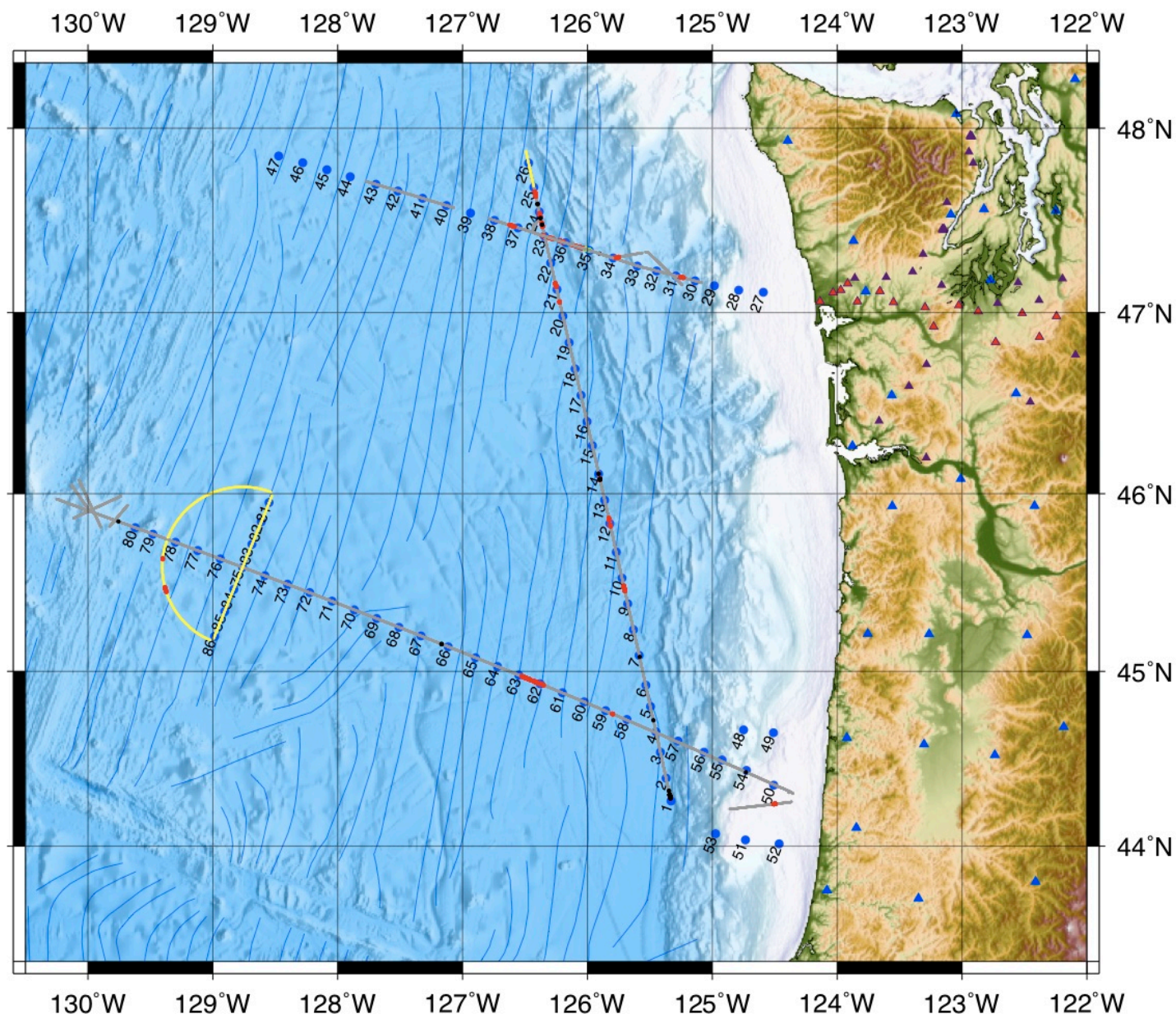


Figure A4a. Track map for MCS survey showing coverage acquired and missing/rampup/dead shots. Grey lines show MCS coverage acquired at 37.5 m shot interval, yellow indicates 150 m shot interval. Red indicates mitigation gun only, green- ramp up shots, black- dead shots (due to NCC failure or missed file record). Numbered blue dots indicate OBS locations.

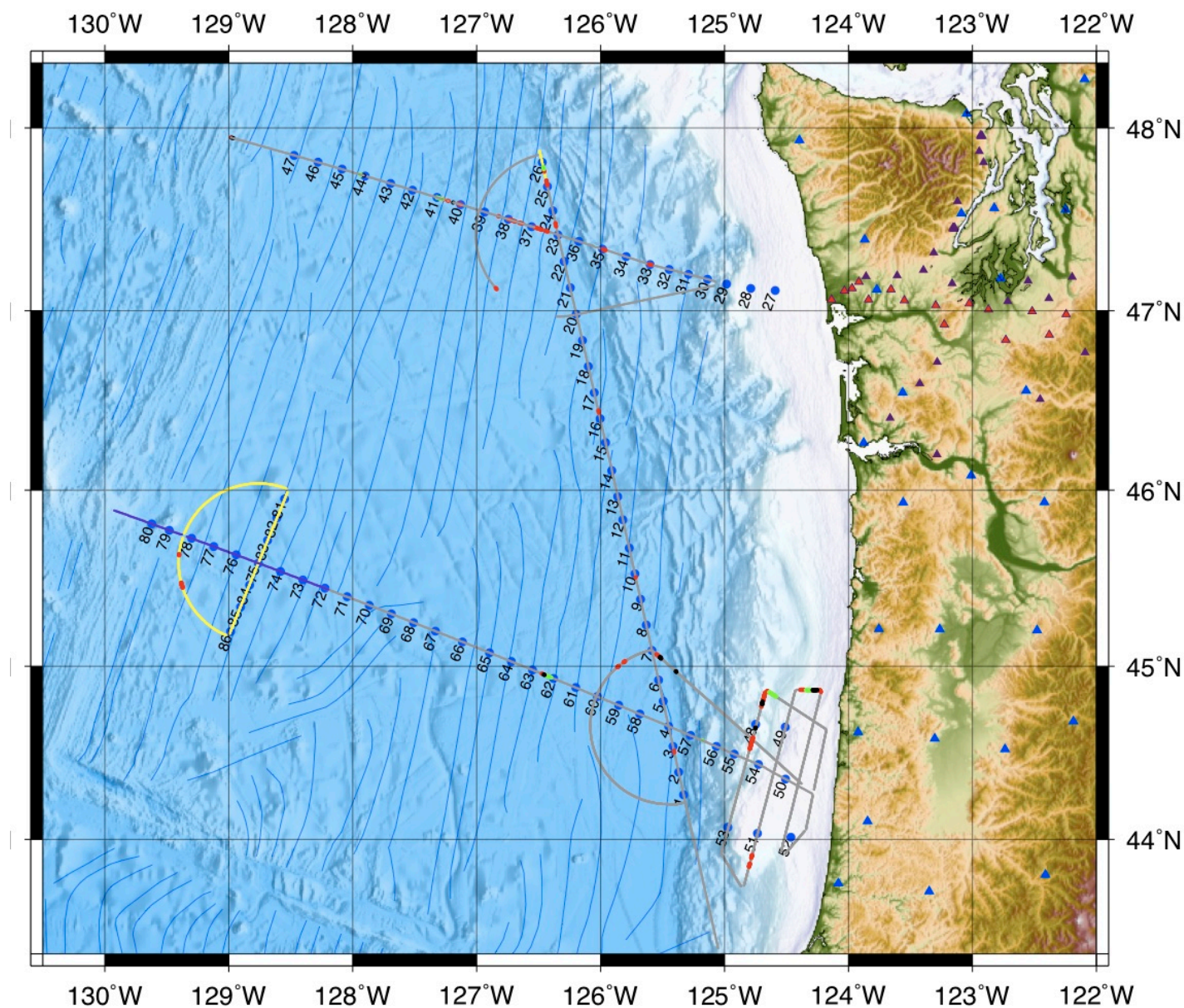


Figure A4b. Track map for OBS survey showing coverage acquired and missing/rampup/dead shots. Grey lines show MCS coverage acquired at 37.5 m shot interval, yellow indicates 150 m shot interval. Purple: shallow source OBS (we towed the guns at 9 m depth, but shot spacing was still 500 m). Red indicates mitigation gun only, green- ramp up shots, black- dead shots (due to NCC failure or missed file record). Numbered blue dots indicate OBS locations.

Table A4 -1. Summary for each line of shots fired with mitigation gun only, ramp-up and dead shots.

Line Name	Seq #	S Of Line	E of Line	S of Miti	E of Miti	S of Ramp	E of Ramp	S of Dead	E of Dead
MGL1211OBS03	1	995	1831	1066	1069	1811	1815	1507	1507
				1295	1295			1799	1808
				1506	1506			1819	1819
				1508	1509				
				1741	1745				
				1791	1798				
				1809	1810				
MGL1211OBSFS01	2	1845	2062	2049	2051				
MGL1211OBSFS01A	3	2133	2156						
MGL1211OBST01	4	2159	2333						
MGL1211OBS02	5	3124	3450	3206	3209			3345	3345
				3265	3268			3399	3400
				3339	3342				
				3346	3357				
				3371	3375				
				3380	3383				
				3385	3389				
				3401	3402				
MGL1211OBS02A	6	3555	3939	3649	3653	3672	3680	3659	3664
				3665	3666	3773	3777	3667	3670
				3671	3671			3769	3772
				3939	3939			3936	3938
MGL1211MCS02	7	6657	8132						
MGL1211MCS02A	8	8716	12316	9070	9076	10347	10438	9155	9155
				9092	9095			9660	9660
				9101	9154			10112	10119
				9609	9659			10134	10184
				9913	9963			10196	10243
				9977	9998			10591	10591
				10120	10133			11926	11953
				10185	10195				
				10244	10346				
				11954	12008				
MGL1211MCST02	9	15083	15534						
MGL1211MCST02A	10	15547	15877						
MGL1211MCST03	11	15930	16401	16311	16379				
MGL1211MCS02B	12	16502	17825	17515	17592				
MGL1211MCS03	13	18139	18799						
MGL1211OBS03B	14	19004	19149					19077	19077
								19091	19091
MGL1211MCS03A	15	20167	30879	20601	20685			20600	20600
				20957	21018			20686	20686
				21120	21144			20807	20809
				21147	21183			20952	20956
				22111	22172			21019	21019
				22417	22433			21038	21039
				25384	25393			21119	21119
				25405	25409			21145	21146
				26055	26098			21184	21184
				26177	26199			21522	21527
				27209	27304			22173	22173
				30810	30812			22434	22435
				30814	30814			23077	23080
				30816	30817			25306	25307
				30829	30840			25382	25383
								25394	25404
								25410	25410
								26054	26054

								26099	26099
								26176	26176
								26200	26200
								27208	27208
								27305	27305
								28432	28436
								29523	29523
								29566	29591
								30750	30751
								30809	30809
								30813	30813
								30815	30815
								30818	30828
								30841	30879
MGL1211MCST04	16	31333	32391	32082	32121			32081	32081
								32122	32122
MGL1211MCS01	17	32467	45199	35810	35826			33047	33054
				37076	37266			33347	33348
				37318	37477			35807	35809
								35827	35827
								37317	37317
								38927	38929
								44696	44696
MGL1211MCST05	18	46011	46506						
MGL1211MCSAX1	19	46845	47704						
MGL1211MCST06	20	47851	48317						
MGL1211MCSAX2	21	48886	49754						
MGL1211MCS01A	22	50101	50794					50209	50211
MGL1211OBS01	23	51032	51123						
MGL1211OBSFS02A	24	51207	51725					51494	51494
								51603	51603
MGL1211OBS04	25	52013	52656						
MGL1211OBSFS02B	26	52711	53206	52992	53015				
				53130	53135				
MGL1211OBS01A	27	53429	53620						
MGL1211OBS01B	28	54312	54840	54611	54613	54616	54624	54614	54615
				54826	54826	54827	54833	54794	54825
MGL1211OBS01C	29	55792	55991						
TREHUOBS01	30	56006	56138						
TREHUOBS02	31	56207	56322						
TREHUOBS03	32	56433	57059	57058	57059				
TREHUOBS04	33	58005	58096	58005	58012	58042	58059	58018	58034
				58016	58017			58065	58065
				58035	58041				
				58066	58080				
TREHUOBS05	34	59003	59768	59648	59659				
				59681	59694				
TREHUOBS06	35	60015	60160						
TREHUOBS07	36	61001	61633	61413	61458			61412	61412
				61578	61586			61457	61457
				61598	61633			61493	61496
								61587	61597
TREHUOBS08	37	62006	62271	62006	62014	62015	62046		
TREHUOBS09	38	62303	62533						
MGL1211OBS02	39	62659	63412	63376	63391			63292	63294
								63368	63374
MGL1211OBSFS03	40	64003	64920	64110	64118			64608	64609
				64140	64147				
MGL1211OBS03A	41	65002	65196						

APPENDIX 5: Seismic line Log and Acquisition Parameters

Table A5.1 Seismic Line Log with Acquisition Parameters (next page)

Line #	Seq #	Date	Time (UTC)	Latitude	Longitude	Date	Time (UTC)	Latitude	Longitude	Start Shot#	File#	Stop Shot#	File#	Tape#	Shot Interval (m)	AcquisitionP arm	Gun Depth	Source Volume
MGL1211OBS03	001	2012-06-14	20:22	44.19155	-125.30962	2012-06-16	22:56	47.86166	-126.48765	995	na	1831	na	na	500		12	6600
MGL1211OBSFS01	002	2012-06-17	0:44	47.85412	-126.50200	2012-06-17	13:58	47.08286	-126.78500	1845	na	2062	na	na	500		12	6600
MGL1211OBSFS01	003	2012-06-17	22:12	46.9683	-126.35964	2012-06-17	23:35	46.97727	-126.20944	2133	na	2156	na	na	500		12	6600
MGL1211OBS01	004	2012-06-17	23:41	46.97861	-126.19902	2012-06-18	9:17	47.13951	-125.07799	2159	na	2333	na	na	500		12	6600
MGL1211OBS02	005	2012-06-18	9:34	47.15679	-125.07038	2012-06-19	5:43	47.58417	-127.13433	3124	na	3450	na	na	500		12	6600
MGL1211OBS02A	006	2012-06-19	14:49	47.45756	-126.53195	2012-06-20	14:06	47.94897	-128.98454	3555	na	3939	na	na	500		12	6600
MGL1211OBS02	007	2012-06-21	4:26	47.71388	-127.77320	2012-06-21	10:55	47.57120	-127.06709	6657	1	8132	1475	1-3	37.5	1	9	6600
MGL1211MCS02A	008	2012-06-21	21:45	47.51242	-126.78943	2012-06-22	14:25	47.16140	-125.08009	8716	1	12316	3600	4-9	37.5	1	9	6600
MGL1211MCS02	009	2012-06-22	17:09	47.15248	-125.24293	2012-06-22	19:20	47.25731	-125.40374	15083	1	15534	451	10	37.5	1	9	6600
MGL1211MCS02A	010	2012-06-22	19:23	47.26111	-125.40955	2012-06-22	20:54	47.33050	-125.53836	15547	1	15877	331	11	37.5	1	9	6600
MGL1211MCS03	011	2012-06-22	21:09	47.32619	-125.56382	2012-06-22	23:09	47.29882	-125.79444	15930	1	16401	471	12	37.5	1	9	6600
MGL1211MCS02B	012	2012-06-22	23:10	47.29920	-125.79877	2012-06-23	5:06	47.43654	-126.42374	16502	1	17825	1323	13-15	37.5	1	9	6600
MGL1211MCS03	013	2012-06-23	5:27	47.45441	-126.43575	2012-06-23	9:11	47.68332	-126.42900	18139	1	18799	661	16-17	37.5	1	9	6600
MGL1211OBS03B	014	2012-06-23	9:14	47.73726	-126.43026	2012-06-23	11:37	47.87871	-126.48995	19004	1	19149	144	18	150		9	6600
MGL1211MCS03A	015	2012-06-23	14:20	47.80063	-126.46387	2012-06-25	13:35	44.27333	-125.33391	20167	1	30879	10639	19-35	37.5	1	9	6600
MGL1211MCS04	016	2012-06-25	19:40	44.21272	-124.85564	2012-06-26	0:41	44.25651	-124.36231	31333	1	32391	1059	36-37	37.5	2	9	6600
MGL1211MCS01	017	2012-06-26	1:29	44.30412	-124.35526	2012-06-28	12:43	45.90408	-129.98667	32467	1	45199	12716	38-57	37.5	2	9	6600
MGL1211MCS05	018	2012-06-28	12:55	45.91430	-129.99754	2012-06-28	15:47	46.06209	-130.13327	46011	1	46506	496	58	37.5	2	9	6600
MGL1211MCSAX1	019	2012-06-28	16:43	46.05686	-130.05865	2012-06-28	20:28	45.81122	-129.89495	46845	1	47704	856	59-60	37.5	2	9	6600
MGL1211MCS06	020	2012-06-28	21:08	45.82172	-129.82178	2012-06-28	23:45	45.93719	-129.67989	47851	1	48317	463	61	37.5	2	9	6600
MGL1211MCSAX2	021	2012-06-29	1:04	45.98383	-129.74223	2012-06-29	5:15	45.86216	-130.11858	48886	1	49754	868	62-63	37.5	2	9	3300
MGL1211MCS01A	022	2012-06-29	8:45	45.96899	-130.24869	2012-06-29	12:03	45.88894	-129.93382	50101	1	50794	691	64-65	37.5	2	9	6600
MGL1211OBS01	023	2012-06-29	12:03	45.88748	-129.92804	2012-06-29	17:55	45.75122	-129.37592	51032	1	51123	92	66	500		9	6600
MGL1211OBSFS02	024	2012-06-29	18:06	45.75536	-129.36253	2012-06-30	4:04	46.01317	-128.55179	51207	1	51725	517	67	150		9	6600
MGL1211OBS04	025	2012-06-30	4:22	45.98792	-128.52733	2012-06-30	15:37	45.18527	-128.98724	52013	1	52656	644	68-69	150		9	6600
MGL1211OBSFS02	026	2012-06-30	15:53	45.17955	-129.02069	2012-07-01	1:14	45.73347	-129.36525	52711	1	53206	496	70	150		9	6600
MGL1211OBS01A	027	2012-07-01	1:31	45.73852	-129.34149	2012-07-01	13:06	45.43800	-128.19497	53429	1	53620	192	71	500		9	6600
MGL1211OBS01B	028	2012-07-01	20:36	45.45087	-128.24274	2012-07-03	5:03	44.56169	-125.13723	54312	na	54840	na	na	500		12	6600
MGL1211OBS01C	029	2012-07-03	8:47	44.79247	-125.41524	2012-07-03	21:02	44.26027	-124.28904	55792	na	55991	na	na	50		12	6600
TREHU0BS01	030	2012-07-03	8:47	44.25437	-124.28874	2012-07-03	23:18	44.05944	-124.34356	56006	na	56138	na	na	170		12	6600
TREHU0BS02	031	2012-07-03	23:19	44.04920	-124.35615	2012-07-04	1:22	43.91599	-124.51402	56207	na	56322	na	na	170		12	6600
TREHU0BS03	032	2012-07-04	1:39	43.92407	-124.54047	2012-07-04	12:59	44.85732	-124.22416	56433	na	57059	na	na	170		12	6600
TREHU0BS04	033	2012-07-04	13:03	44.86158	-124.22870	2012-07-04	15:31	44.86358	-124.42440	58005	na	58096	na	na	170		12	6600
TREHU0BS05	034	2012-07-04	15:34	44.86124	-124.42783	2012-07-05	4:23	43.73017	-124.84665	59003	na	59768	na	na	170		12	6600
TREHU0BS06	035	2012-07-05	4:35	43.72840	-124.86463	2012-07-05	7:07	43.91761	-125.02464	60015	na	60160	na	na	170		12	6600
TREHU0BS07	036	2012-07-05	7:08	43.91925	-125.02483	2012-07-05	18:05	44.85198	-124.66941	61001	na	61633	na	na	170		12	6600
TREHU0BS08	037	2012-07-05	18:13	44.85678	-124.65718	2012-07-05	22:41	44.63574	-124.18033	62006	na	62271	na	na	170		12	6600
TREHU0BS09	038	2012-07-05	22:43	44.63285	-124.17943	2012-07-06	2:35	44.28830	-124.27908	62303	na	62533	na	na	170		12	6600
MGL1211OBS02	039	2012-07-06	3:45	44.32466	-124.38016	2012-07-06	16:36	45.09150	-125.58849	62659	na	63412	na	na	170		12	6600
MGL1211OBSFS03	040	2012-07-06	16:39	45.10850	-125.59333	2012-07-06	16:39	44.21281	-125.32662	64003	na	64920	na	na	170		12	6600
MGL1211OBS3C	041	2012-07-07	8:18	44.20902	-125.3177	2012-07-07	19:51	43.35775	-125.05026	65002	na	65196	na	na	500		12	6600

Table A5.2 MCS Summary Acquisition Parameters

AcquisitionParameterID	MGL1211_ACQ01	MGL1211_ACQ02 (From line MCST04 to OBSFS02B)
Acquisition System Name	Syntron Syntrack 960	
Seismic_Nav_System	C-Nav 3050 primary	
Survey_datum	WGS84	
Navigation Reference Point (NRP)	GPS Antennae	
NRP_to_Antennae	0 m	
NRP to source	232	
Antenna_to_Source	232m	
Source_to_Near_Channel	172m	272 m
Number_of_channels_recorded	636	
Number_of_cables	1	
Number_of_channels_each_cable	636	
Channel_length	12.5 m	
Cable_length	7950 m active (8100 m)	
Cable_spacing	NA	
Near_Channel_Number	636	
Cable_depth	9 m	9 m
Number_source_arrays	1 (four strings)	
Alternate_Shooting	NA	
Source_array_separation	NA	
Source_volume	6600 cu in	6600 cu in/3300 cu in
Source_pressure	2000 psi nominal	
Source_make,model	Bolt	
Source_number	40 (10 guns per string)	40 (10 guns per string)
Source_depth	9	9
Shot_control	Distance	
Shot_Interval	37.5/150m	37.5m/150m/500m
Sample_interval	2 ms	
Record_length	12.228 sec	
Compass_birds	Yes	
Tail_buoy_Positioning	Yes	

APPENDIX 6: MCS Data QC and Onboard Processing

Raw data directory and naming structure:

Raw MCS data are organized in tapes. Each tape generally includes 644 files but this quantity may vary so that the memory space of a tape is below 10GB. When a new line is starting, the acquisition system increments the tape number even if only a few files are written in the current tape. Tape numbers are sequential. The RAW file names include the FFID number (ex: R000002_1310774253.RAW, 0002 is the FFID number, 1310774253 is a time in seconds). The FFID number can be reset and has no strict correlation to the shot point (SP) number, although each file only contains one shot gather.

Raw data file structure:

The MCS data are acquired with a 500Hz sample-rate and a trace length of 12.288s. Shots are triggered every 37.5m. A SEGD .RAW file contains data from the 636 receivers of the 8 km-long streamer. Receiver 636 is the closest to the guns. 636 traces are recorded with 6144 (12.288/ 0.002s) samples each. Every sample is written with 4 bytes, which lead to a file size of 14.90MB + the size of the headers.

Each SEGD .RAW file starts with an ASCII header. This header includes many informations, some of particular interest like the SP number, the corresponding vessel and guns LAT/LON positions, the time of the shot, the seafloor depth. The following combination of Unix commands allow the display of the header: “strings FILE.RAW | head”

Checking for acquisition errors:

SP positions are prepared in advance in the ship's navigation system. When the ship reaches the next SP coordinates, the shot is triggered and the pre-defined shot number and location is written in the SEGD file header. All kinds of possible errors can however occur:

- The shot is triggered but without any file being written
- A .RAW file can be written but with a bad header, which does not allow a proper identification of the seismic data.
- A shot can be triggered at an undefined location
- A shot can fail being triggered with or without being recorded
- SP numbers can be used several times for different locations

All these errors can produce two kinds of problems to read the data correctly:

- A crash of the program reading the SEGD file (i.e. Focus trying to read a bad header)
- A collection of shot gathers with non-sequential SP numbers, for example in the case of a missing file or

shot.

This second problem can be minor, but it is important for further processing to know which shot gathers are missing. Finding all these errors is a very tedious process and is practically impossible to do manually because of the huge number of RAW files. Many errors are also not reported in the watch-keeper's logs because they can hardly be detected during the acquisition. To perform this task, a bash script was written to prepare the lists of files to be read for each line. The script also outputs a list of errors based on several criteria like the sequential increment of SPs and FFIDs, the correctness of headers...

Appendix6-2 Reading the SEGD raw data

Preparing lists of SEGD files to read for each line

The first step to do in the Check directory is to create a “MCSLINEALL” directory and run the init.sh script. This script has to be edited with the TAPE_MIN variable. The script will create symbolic links of the tapes directories into the MCSLINEALL directory. As new tapes are written, the init.sh script has to be run to update the

MCSLINEALL directory with the new tape files.

For reasons explained in the previous section, a careful selection of SEG-D files has to be carried out in order to read the data correctly and merge them in a unique file for each line. Using the script `check_seg.sh` (`./check_seg.sh TAPEMIN TAPEMAX XX ALL > lineXX.log`), we produce two kind of files (in addition to the screen output log):

- `list_lineXXmcs`: This is the list of SEG-D files to be read in Focus software for line XX.
- `lineXXmcs_errorlist`: These contain the missing shots, missing files, bad headers for each line. They have been reformatted into .xls files. A description of the errorlist files follows:

Column 1 :	FFID
Column 2 :	TAPE
Column 3 :	SHOT
Column 4 :	BAD HEADER if marked "1". In this case, the SHOT column indicates the last valid SP
Column 5 :	MISSING FILE if marked "1". The FFID and SHOT columns are then the next valid file FFID and SHOT.
Column 6 :	MISSING SHOT. If marked "1", this error leads to one or several missing shots.
Column 7 :	NUMBER OF MISSING SHOTS. Note that after BAD HEADER lines, the next line is usually accounting for the skipped shots. This is why Column 7 is empty (0) for BAD HEADER lines, to avoid counting them twice.
Column 8 :	Comments

The control line calculates the number of files read with the formula $(\text{SHOTMAX} - \text{SHOTMIN}) + 1 - \text{SUM OF COLUMN 7}$. This has to correspond to the number of lines in the focus list, otherwise, it means that there might be several identical SPs in the SEG-D files.

Preparing a stack and a migration section for each line

To prepare a stack and a migrated profile, we need to move into the stack directory. There, another `init.sh` has to be edited with the new line name. This script will prepare the correct list of files to be read by `sioseis` using the `list_lineXXmcs` file created in the Check directory.

Once the latest `listXX` file is created, one can run the `./sioseis_brute_JDFplate_list_mute.csh` script (after editing: the line name must be given). A SEG-Y file is created in the SEG-Y directory. A migration script (`sioseis_mig.sh`) can also be used. It reads the SEG-Y stack, transform the data to FK domain, performs an FK migration with a 1550 m/s velocity and writes a time domain SEG-Y in the SEG-Y directory.

Reading SEG-D files with Focus software

Our final goal onboard is to merge the geometry of the streamers with the RAW seismic data. A first step is then to write a temporary file with the raw data for each line. The raw data for each line will be stored in the Focus database and will eventually be deleted once the final merged product is obtained. All the focus jobs can be found in the geometry directory.

The first part of the job is to load the raw format information, for every seismic line of the Focus project. The SEG-D format, as SEG-Y, has different "flavors". The `00_get_segformat.dat` will read any .RAW SEG-D file and extract the SEG-D format, and store it in the database. The SEG-D file to read in that job is always a file with a 12.288s trace length and 636 receivers, so this job can always read the same RAW file. The important thing is that the SEG-D format is present in the Focus project line database.

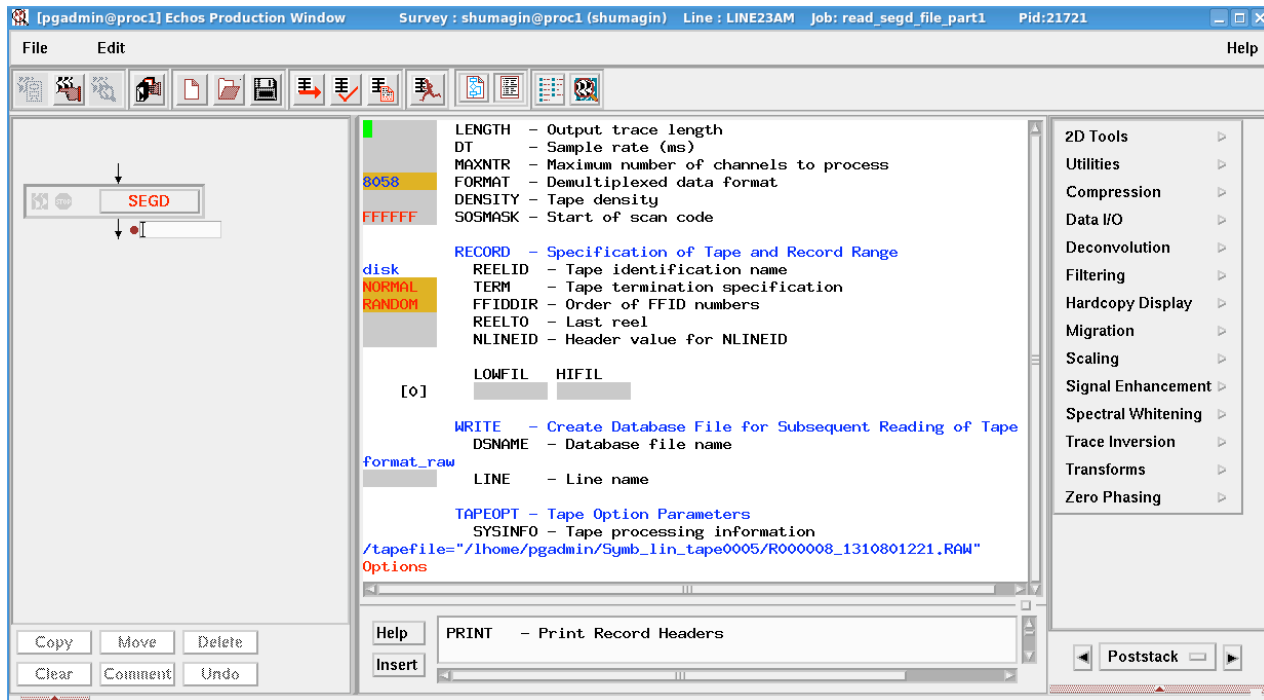


Figure 1: 00_get_segdfORMAT.dat. Read the SEG-D format from a SEG-D file

```
User File:: LINE12F.SEGD.FORMAT_RAW Date: 1-AUG-2011 01:22:21.00
/data/seismic/shumagin/Echos/SeisDataDB/tmp000083
```

1	SEG-D database file version 2.1		
2	Maximum number of channels is :	1272	
3	Maximum record length in seconds is:	22.5280	
4	Block size limit in bytes is :	131072	
5	Additional blocks in Gen Header is :	2	
6	Extended header in blocks is :	260	
7	External header in blocks is :	35	
8	The size of header in bytes is :	9600	
9	The SEG-D revision level is :	1	0
10	The format number is :	8058	
11	The format description is :	(Demultiplexed)	
12	32-bytes general header extensions :	2	
13	The manufacturers code is :	34	
14	Number of bytes/scan is :	0	
15	Number of scan types/record is :	1	
16	Record length in seconds is :	22.5280	
17	Base scan interval in ms. is :	2.0000	
18	Number of scans/block is :	0	
19	Number of channel sets per scan type	2	
20	Skew block count is :	0	
21	General trailer block count is :	0	
22	Trace trailer length in samps is :	1	
23	***** Scan type number :	1	
24	The total number of seismic channels	1272	
25		Channel Set 1	Channel Set 2
26	Number of channels	636	636
27	Channel set type	Seismic	Seismic
28	Sample interval in msec	2.00	2.00
29	Start time in msec	0	0
30	End time in msec	22528	22528
31	Descale multiplier	0.1250000E+00	0.1250000E+00
32	Channel gain type	IFP gain control	IFP gain control
33	Extended trace header blks	1	1
34	Physical record length	45080	45080

Figure 2: format_raw SEG-D format in the SeisDB application

Once the format_raw information is loaded in the database, the job 01_read_segD_lineXX.dat can be run. In

this job, the user has to provide the path to the list file prepared in the previous subsection (Check) as well as the first line and last line of the file (not the FFIDs, as we can miss or repeat some). An output name to be used in the Focus database (it won't be a file) has to be given too. The SEGDFORMAT saved in step 00_get_segdfmt also has to be provided.

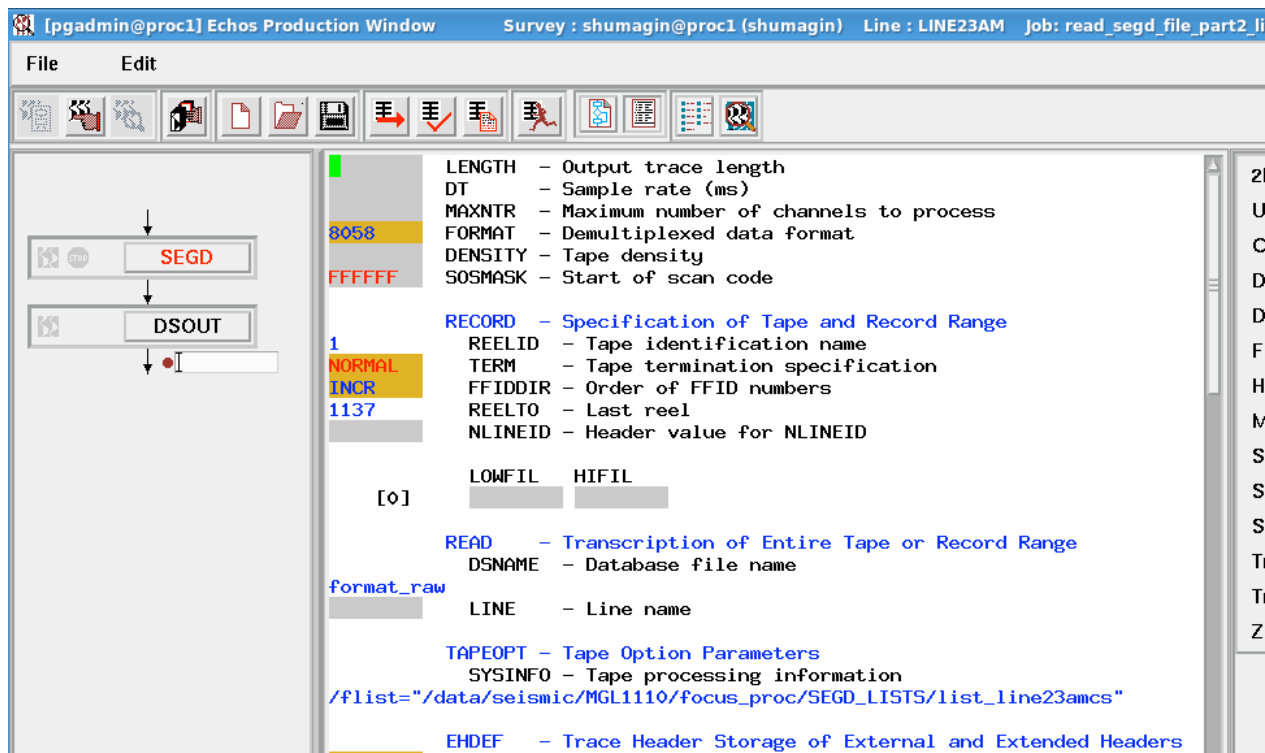


Figure 3: 01_read_segdfmt_lineXX.dat. Reading a list of SEGDFORMAT files with the format_raw SEGDFORMAT format

This job also reads character strings in the SEGDFORMAT headers to report them in the Focus trace headers (SP LAT/LON, TIME, Julian Day, SP...). There is almost no change to make from line to line in this part of the job as the header informations are always at the same place in the SEGDFORMAT ASCII headers.

The job 01_read_segdfmt_lineXX_5digits.dat has to be used if the shot number in the line is 5 digits. This is because Focus cannot recognize the string 09000 as being 9000, so different jobs have to be used in function of the SP digits. If a line includes the transition from 4 to 5 digits, it has to be separated in two parts. It is then possible to merge the two parts in Focus.

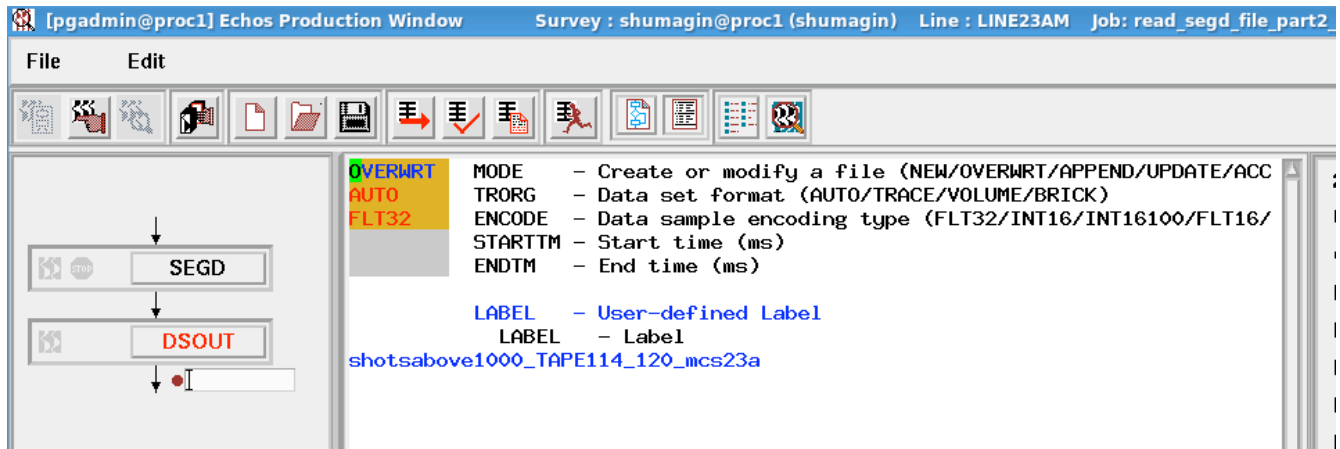


Figure 4: DSOUT database output of the shots read from the SEG D files

What can be improved with more time and efforts

Regarding the bad header files, some additional verifications were not performed onboard but could be useful in the future. Some lines include a large number of consecutive bad header files that were not read onboard. Although it is not sure that this data can be used, there is a possibility to avoid losing such a significant number of shots by rebuilding the header from the p190 navigation files. In some cases, there might however be a doubt on the association of the file to a navigation SP number.

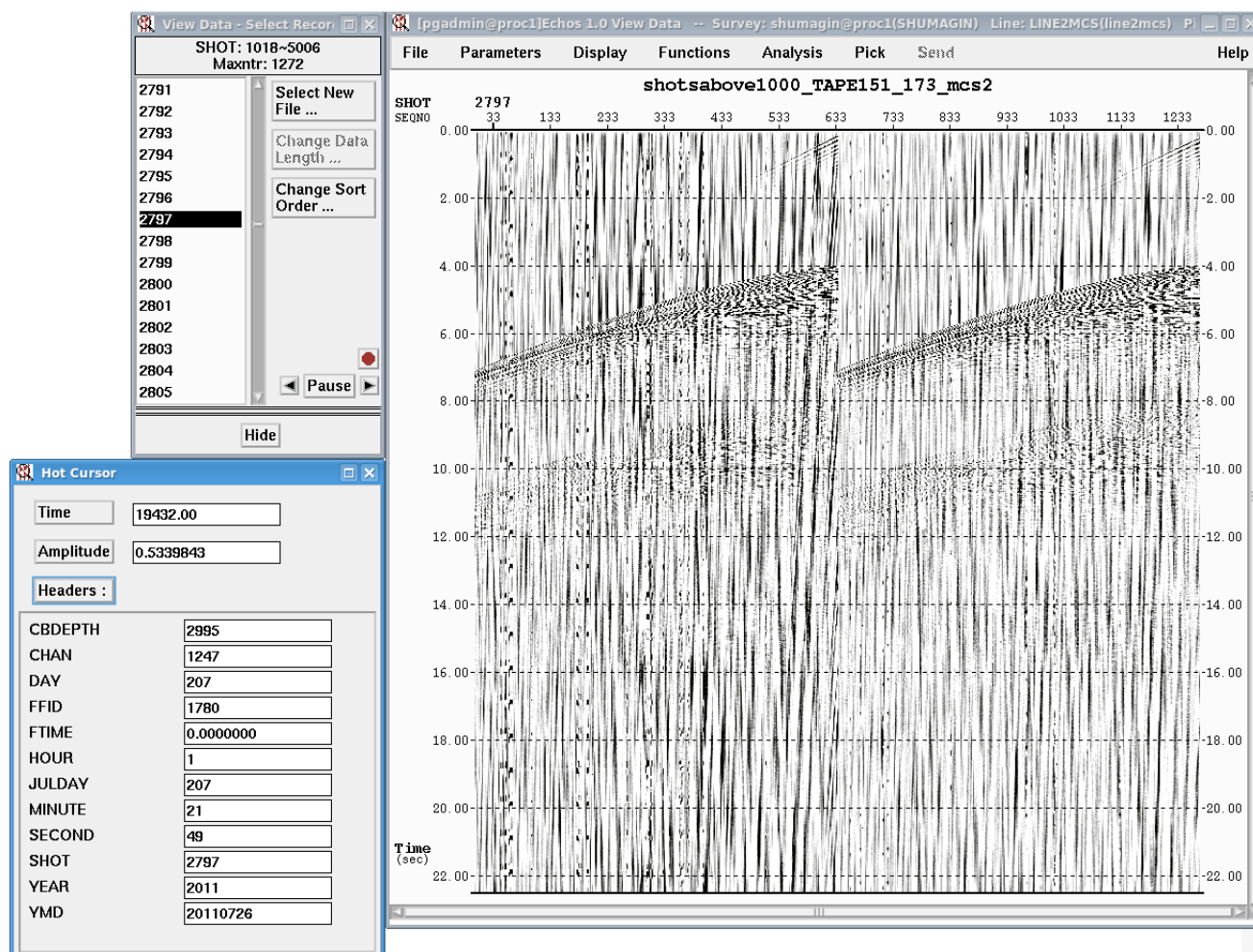


Figure 5: Trace headers extracted from SEG-D for a shot gather. This is a two streamers example.

Appendix6-3 Importing and checking the .p190 navigation files

Using acoustics and compasses attached to the streamers, David Martinson computed UKO0A90 formatted .p190 navigation files for us. These files describe for every shot the projected XY position of all the receivers. .p190 files are in the P190 directory. Some of them have to be edited when the line contains more than 9999 shots (the maximum number of shots that can be processed with Focus in the PROTAPE module, see last step). In this case, they are modified in the P190w directory. Below is a part of a .p190 ASCII file:

```

V MGL1110MCS03 1 1110561747.94N1580021.87W-179528.56293664.8 232.5202071207
S MGL1110MCS03 11 1110561754.17N1580028.34W-179608.06293874.0 232.5202071207
C MGL1110MCS03 111 1110561757.05N1580032.72W-179668.56293974.6 232.5202071207
C MGL1110MCS03 112 1110561759.41N1580026.68W-179553.76294030.4 232.5202071207
R0636-179729.36294075.4 9.40635-179736.46294085.6 9.40634-179743.76294095.8 9.41
R0633-179751.06294105.9 9.40632-179758.46294116.0 9.40631-179765.96294126.0 9.41
R0630-179772.86294135.1 9.40629-179780.46294145.1 9.30628-179788.16294154.9 9.31
R0627-179795.96294164.7 9.30626-179803.76294174.4 9.30625-179811.66294184.1 9.31
R0624-179819.66294193.7 9.30623-179827.66294203.3 9.20622-179835.76294212.8 9.21
R0621-179843.96294222.3 9.20620-179852.26294231.6 9.20619-179860.56294241.0 9.21

```

The first four lines describe the latitude and longitude of the vessel, of the gun array, and the positions of the first two CMPs (one for each streamer, but these two lines are optional). The SP number is highlighted in light blue. After the shot information, the receivers (numbers in pink) of the streamer are listed with their positions (three per line). The next shot is then appended with the same format.

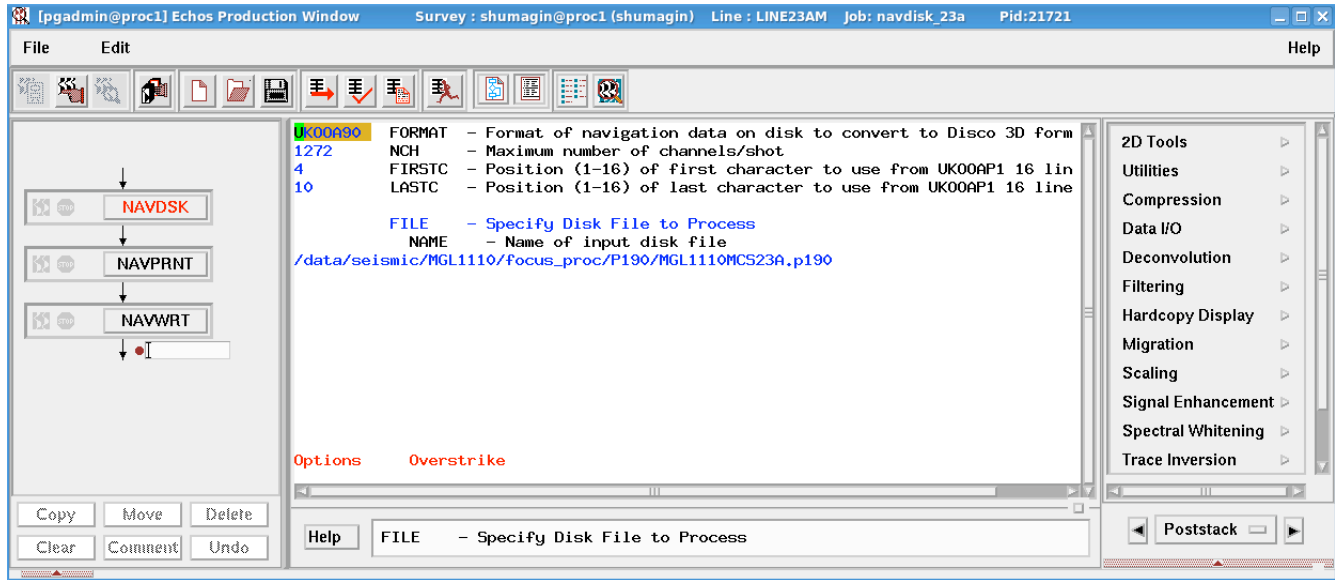


Figure 6: Reading the .p190 navigation file with 02_navdisk_lineXX.dat

The next step is to load this .p190 file into Focus to build the proprietary .fmt file. The job 02_navdisk_lineXX.dat will do that.

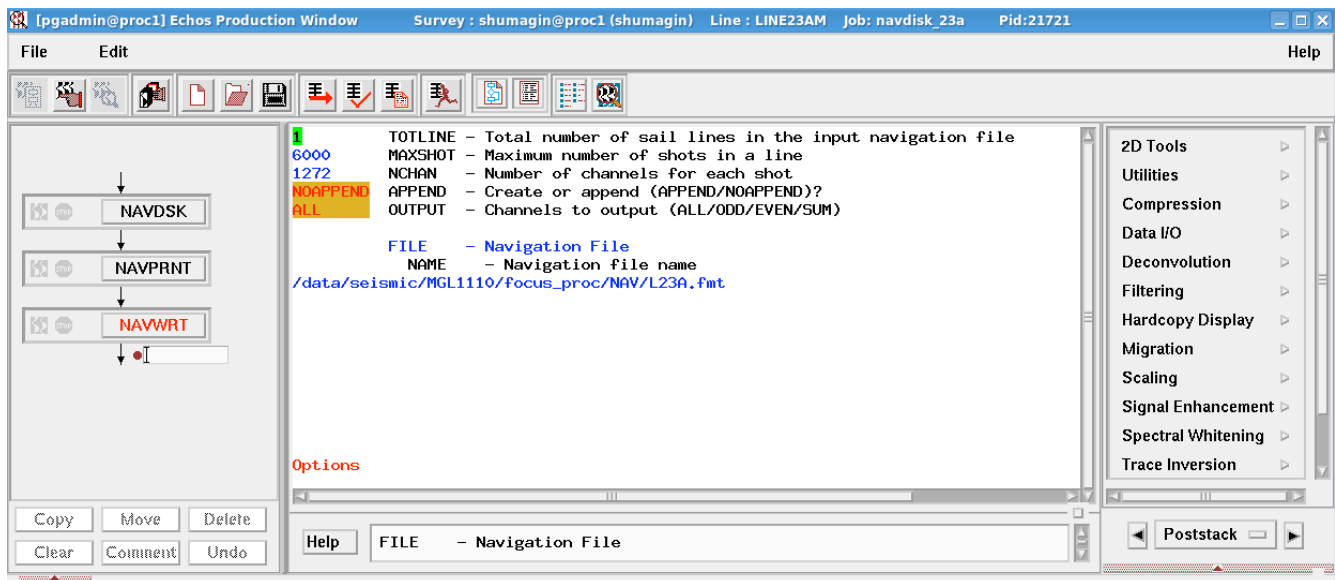


Figure 7: Writing the .fmt navigation file with 02_navdisk_lineXX.dat

This very simple job only needs input and output files and the number of channels per shots (636, 1272 is for two streamers).

Once the .fmt geometry file is prepared, it can be loaded into the 3D geometry application in Focus. QC mode has to be selected, then the .fmt file has to be opened. 1 cables/Shot is needed, in single cable mode. Clicking “marine display” will open a new window with a list of SP numbers. The apply button will display the receivers and guns positions (see Figure). The range of SPs can slightly differ from those read in the SEG2 as turns are not always available.

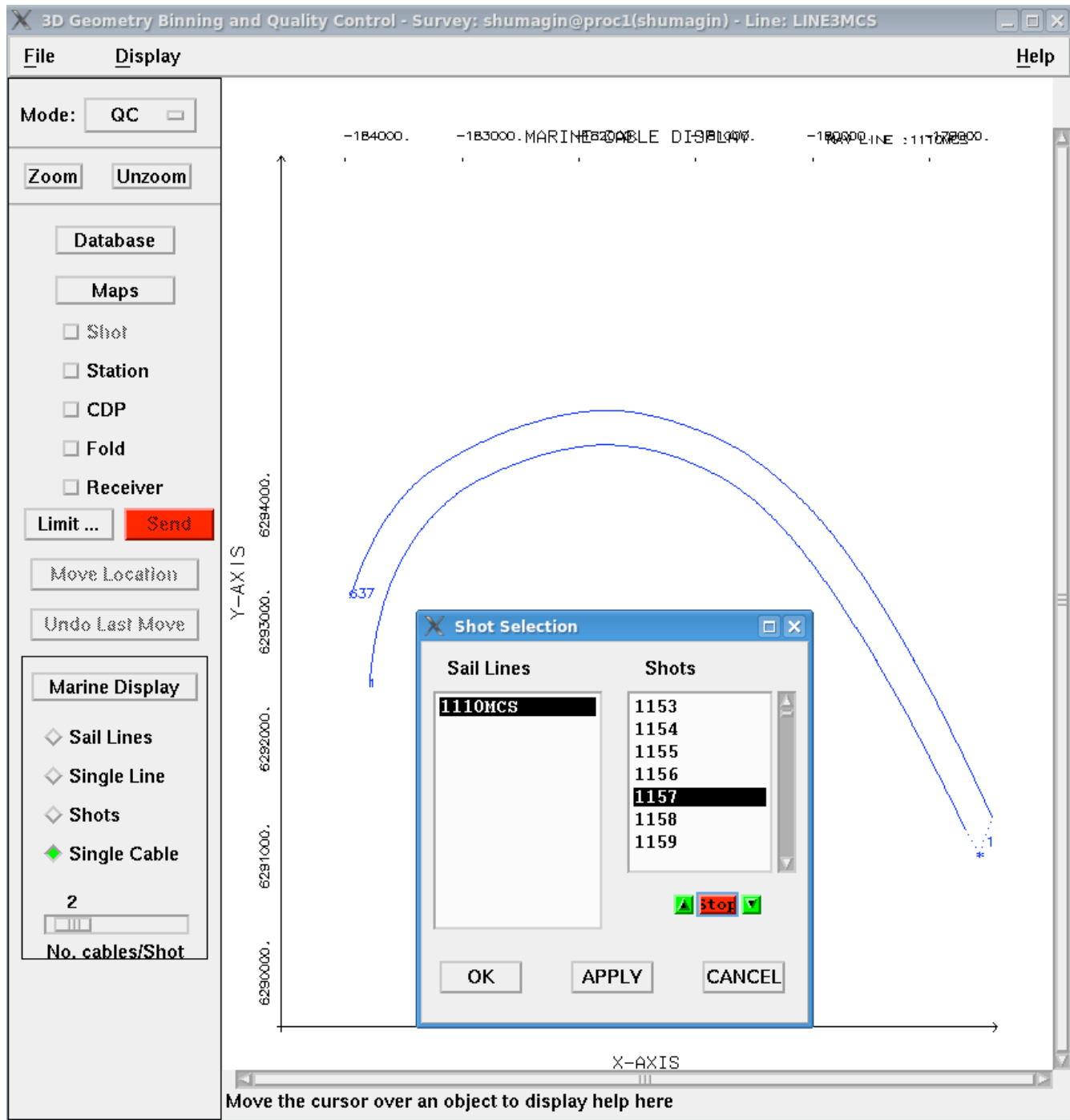


Figure 8: 3D geometry application: streamer geometry QC (for a 2 streamers configuration)

The green arrow button can make the streamer move on the screen. The apply button has to be activated to

re-frame the display from times to times. The geometry has been checked shot by shot for potential problems in the geometry of the streamer. Below is an example of a bad compass value creating an artifact in the streamer geometry.

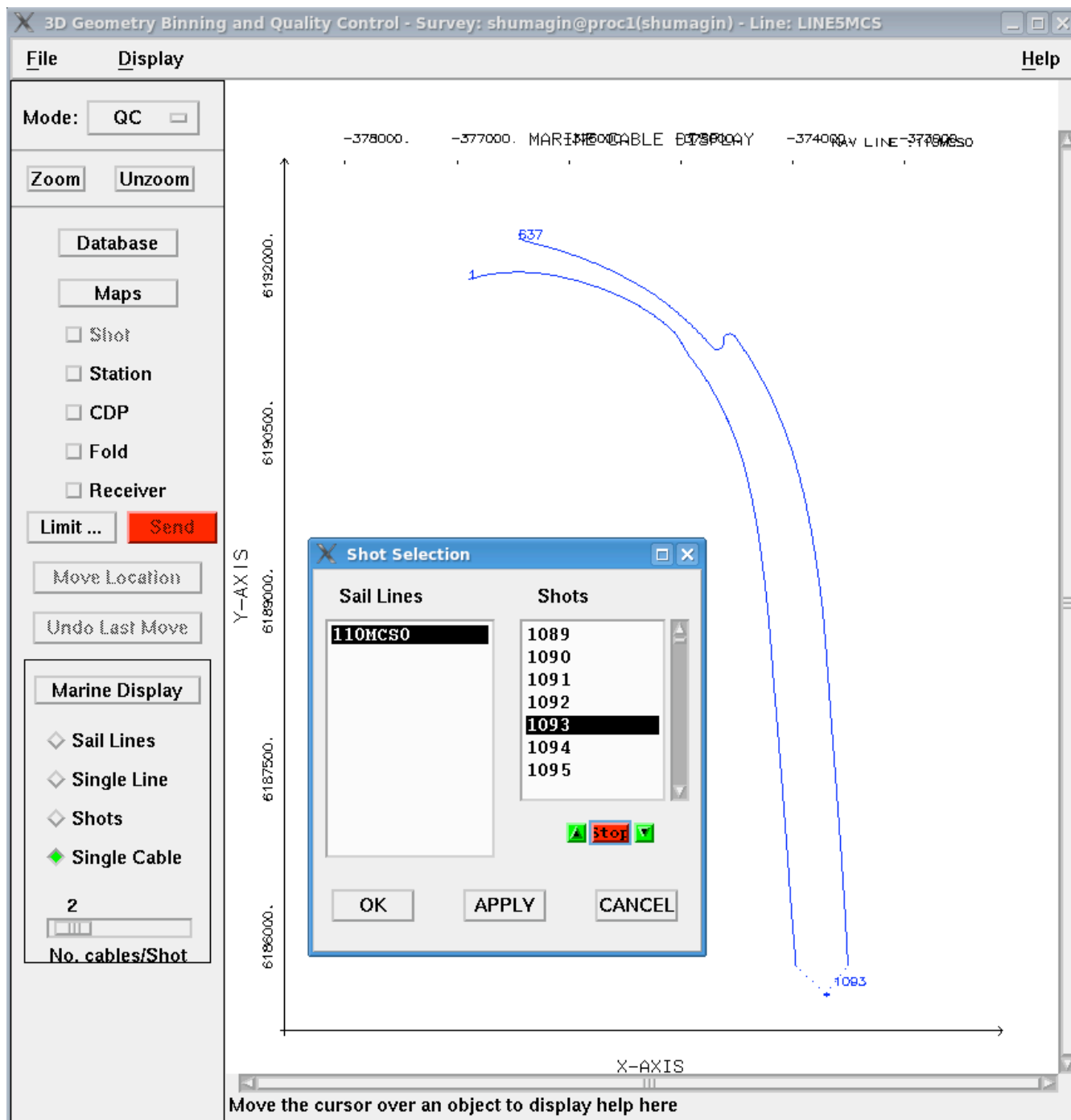


Figure 9: An example of bad geometry of the streamers

(

Appendix6-4 Pseudo-3D binning of the Mid-points scatter.

Once the geometry file is validated, the next step is to prepare the CDP-binning to allow the ultimate Focus

merging job to attribute CDP numbers to traces.

In the 3D geometry application, the Binning Mode displays the mid-points (by clicking on “CDP”, even if it is already selected). It clearly appears, as one would expect, that the mid-points do not form a straight line, especially at the ends of the line. CDP bins have to be defined. The nominal 6.25m DXLINE value is chosen as well as a large enough DSLINE value (for example 5000m).

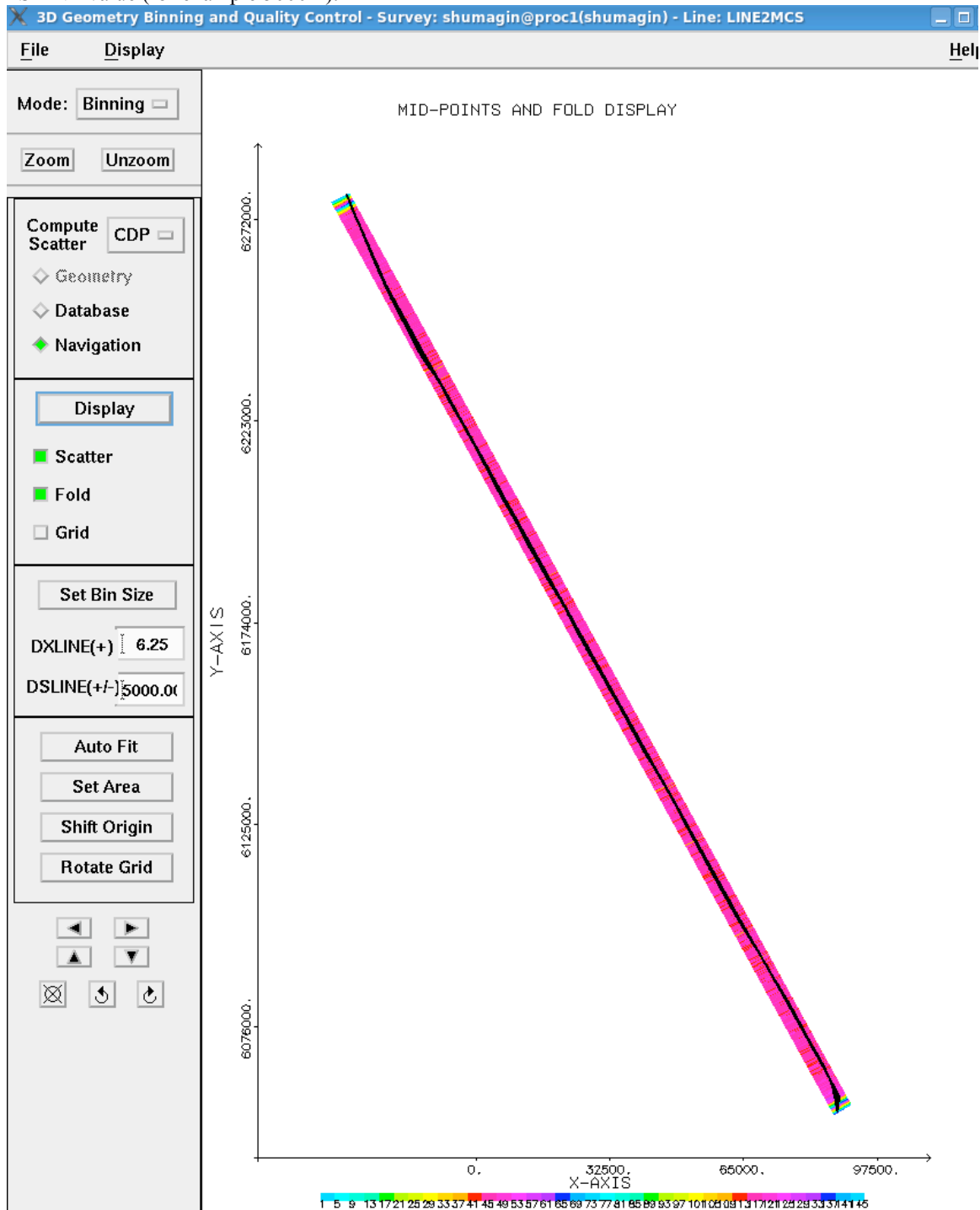


Figure 10: mid-points scatter (black) in binning mode

After clicking on “set bin size”, the “Auto Fit” Button can be activated. With the mouse, it is then possible to point the start of the line, and then to right click on the other end of the line. A rectangular box composed of many 6.25x5000m rectangles is created. The DSLINE width has to be sufficient enough so that no mid points fall outside of the box.

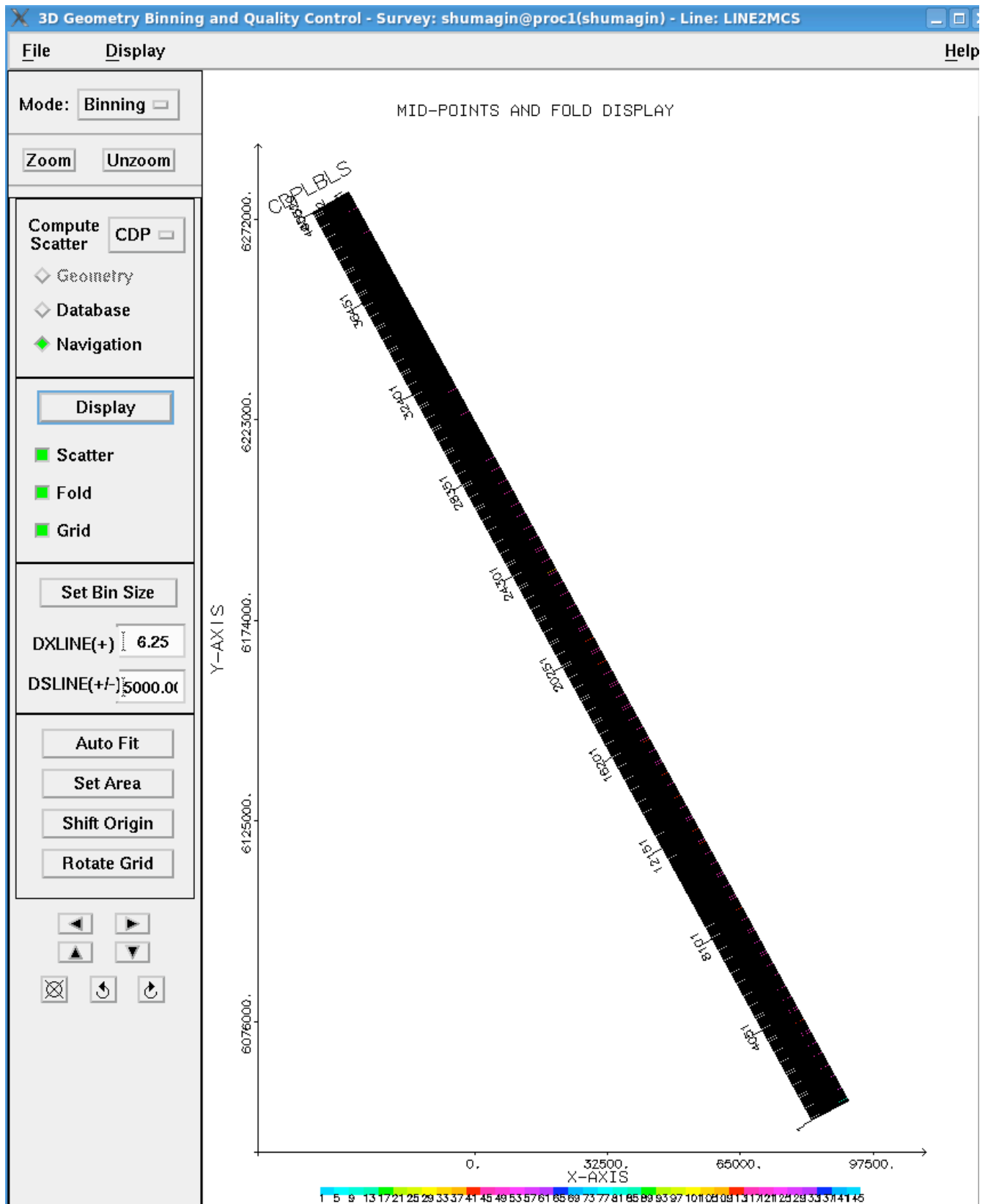


Figure 11: CDP grid after Auto Fit

The shift and rotate buttons can adjust the grid on the line. Zooming on the edges is usefull to check the good fit of the grid.

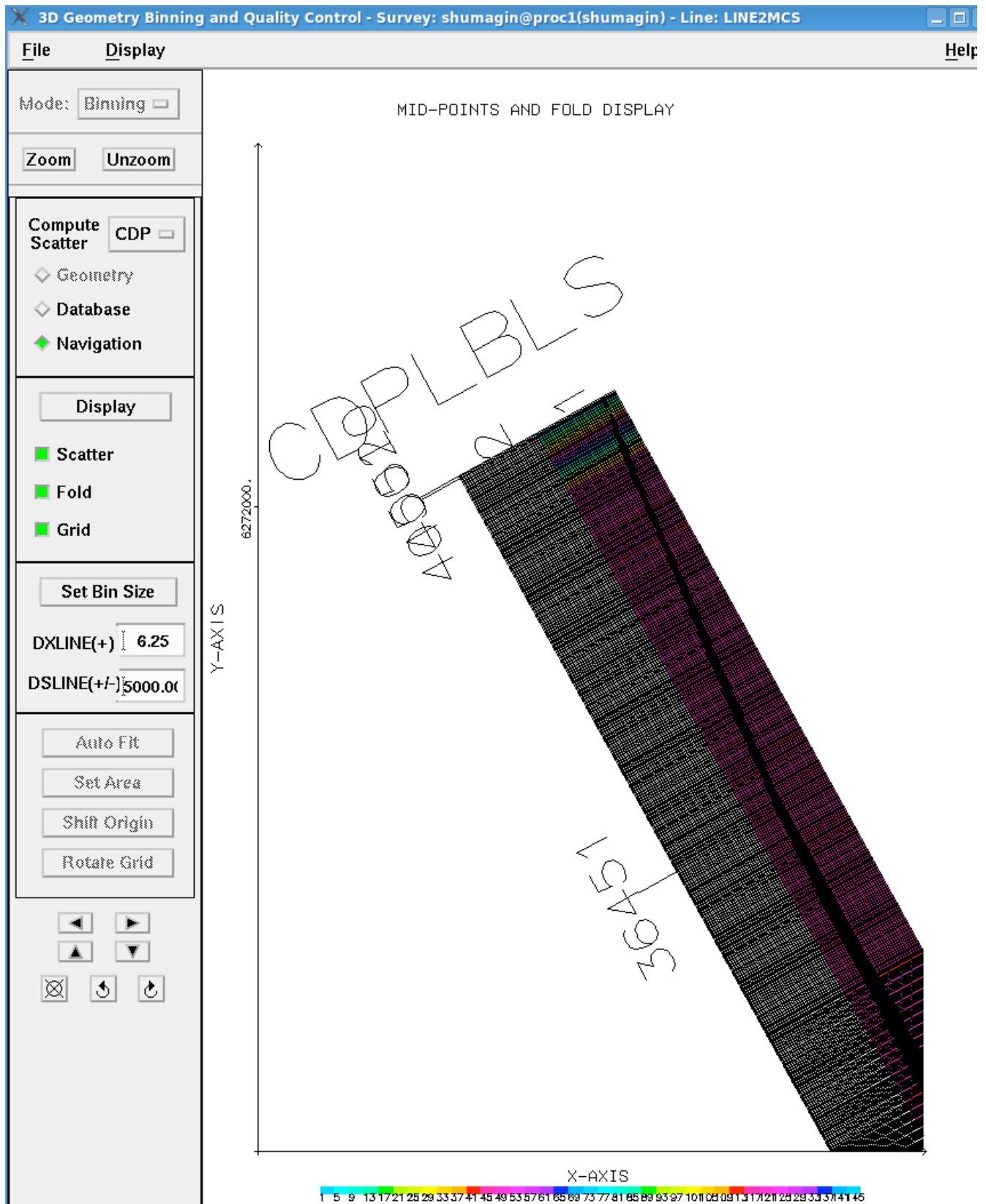


Figure 12: zoom on one edge of the line. No mid-point is out of the first CDP line

The best grid will not include empty bin on the edges, but will also not miss any mid-point. The goal is to minimize the number of CDPs. Because we will use a 3D job to merge the geometry with the seismic data in the next section, we have to define a pseudo-3D geometry. It consists in a second line juxtaposed to the first one. No mid-point must be in this line, it must remain empty and it is present only for the purpose of mimicking a 3D situation although we are in 2D. Once the grid is correct, save the CDP model, the fold and the scatter in the “File” menu.

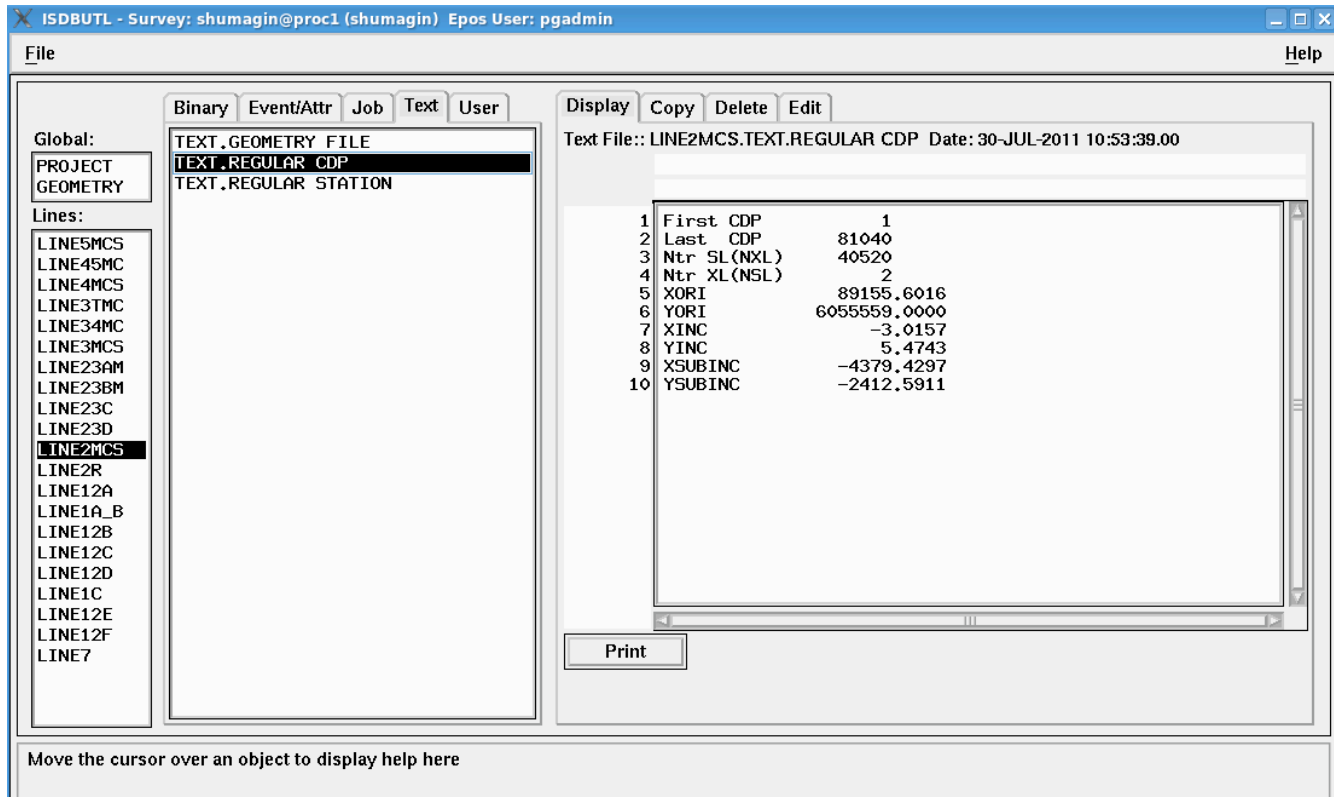


Figure 13: The CDP model in the SeisDataDB application

In the SeisDataDB application, the TEXT.REGULAR CDP entry must be present. Duplicate it into REGULAR.TEXT STATION. Without the stations, the geometry merging job will not run.

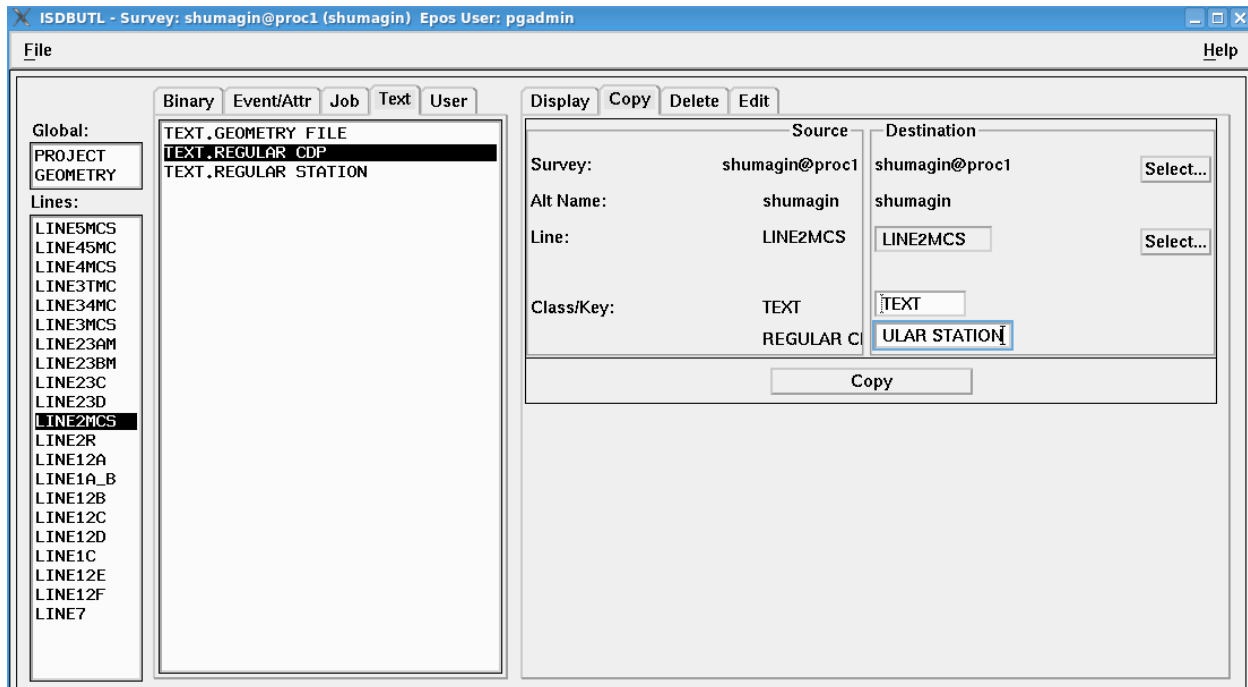


Figure 14: Duplicating the CDP model into a STATION model

Appendix6-5 Merging the seismic data with the navigation geometry

In the production window, load the 03_merge_lineXX.dat job. With the 4th button from the left just below the file menu, select the file created at section D5-2. Do not include any shot with a smaller number than the first shot in the p190 navigation file. If a shot is missing in the middle of the P190 file and is present in the SEG D files, the geometry will be interpolated.

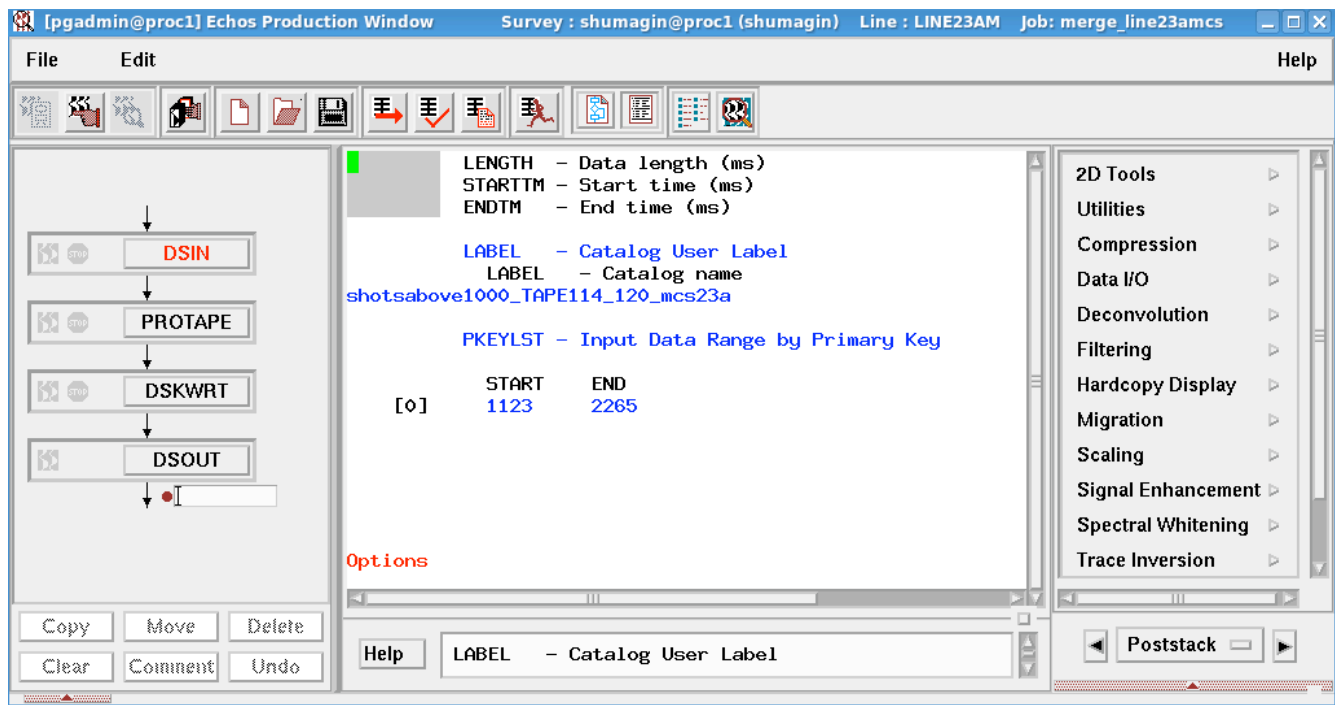


Figure 15: Input of the 03_merge_lineXX.dat job

The PROTAPE module is the main module associating traces with positioning of receivers and CDPs. The TEXT.REGULAR CDP and TEXT.REGULAR STATION entries in the database are mandatory, although there is no mention of these in the module itself. The .fmt file path is also needed.

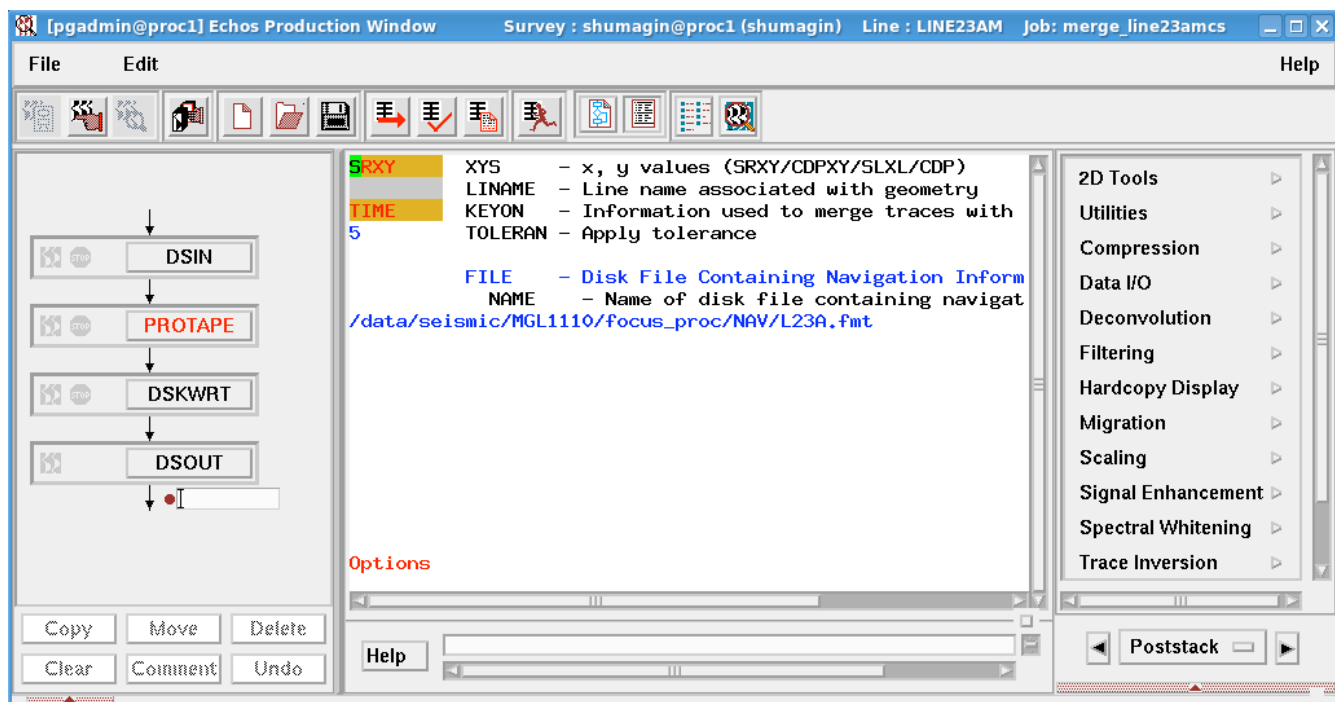


Figure 16: PROTAPE module. Associates geometry in .fmt file with seismic data using CDP and STATION models

The PROTAPE module will associate traces to the receiver and CDP position based on the shot time with a 5s tolerance. This makes sure that there is no mismatch in case of different shot number in the geometry file when compared to the SEG-D shot numbers. It also works correctly in the case of different shot gathers recorded with the same SP number (This did not happen during this cruise).

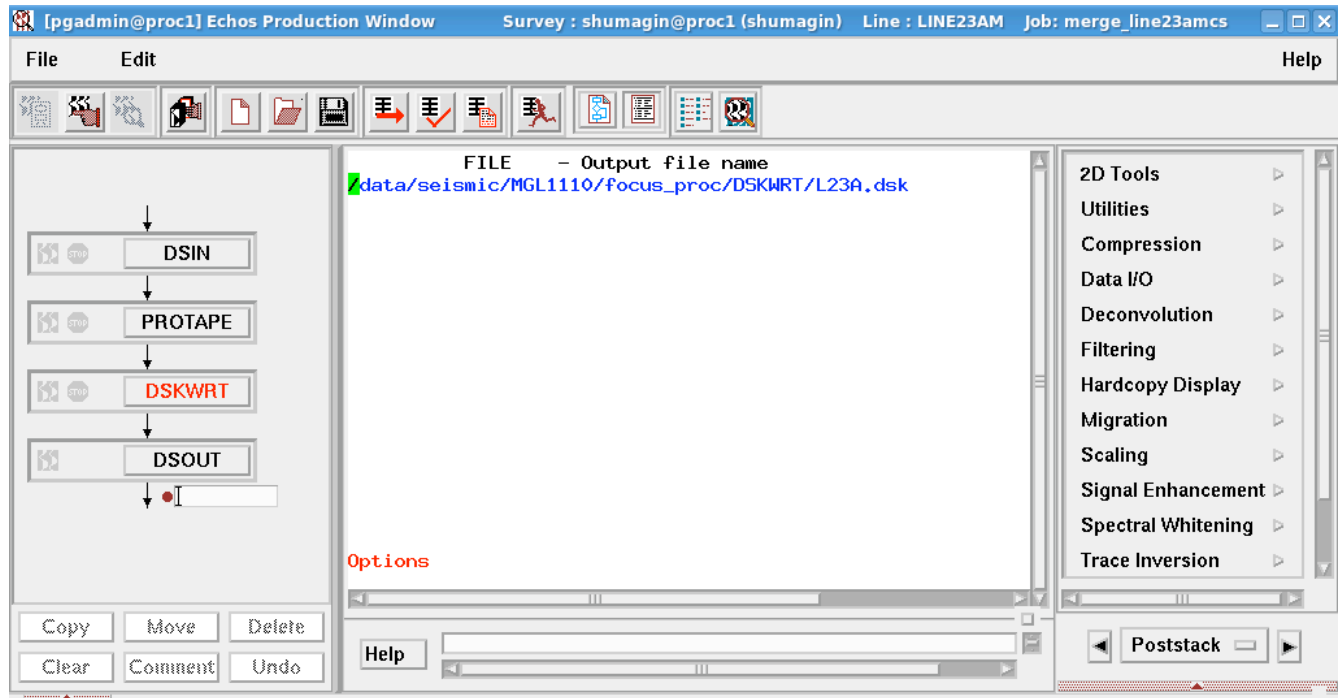


Figure 17: .DSK output file to export merged data

The output file is a .dsk file that can be exported in another computer where Focus is installed. This file is the final product of the onboard processing. A database file is also written with the DSOUT module for the sole purpose of checking if the DSK file is correct. If it is, then the database file is deleted to save some disk space.

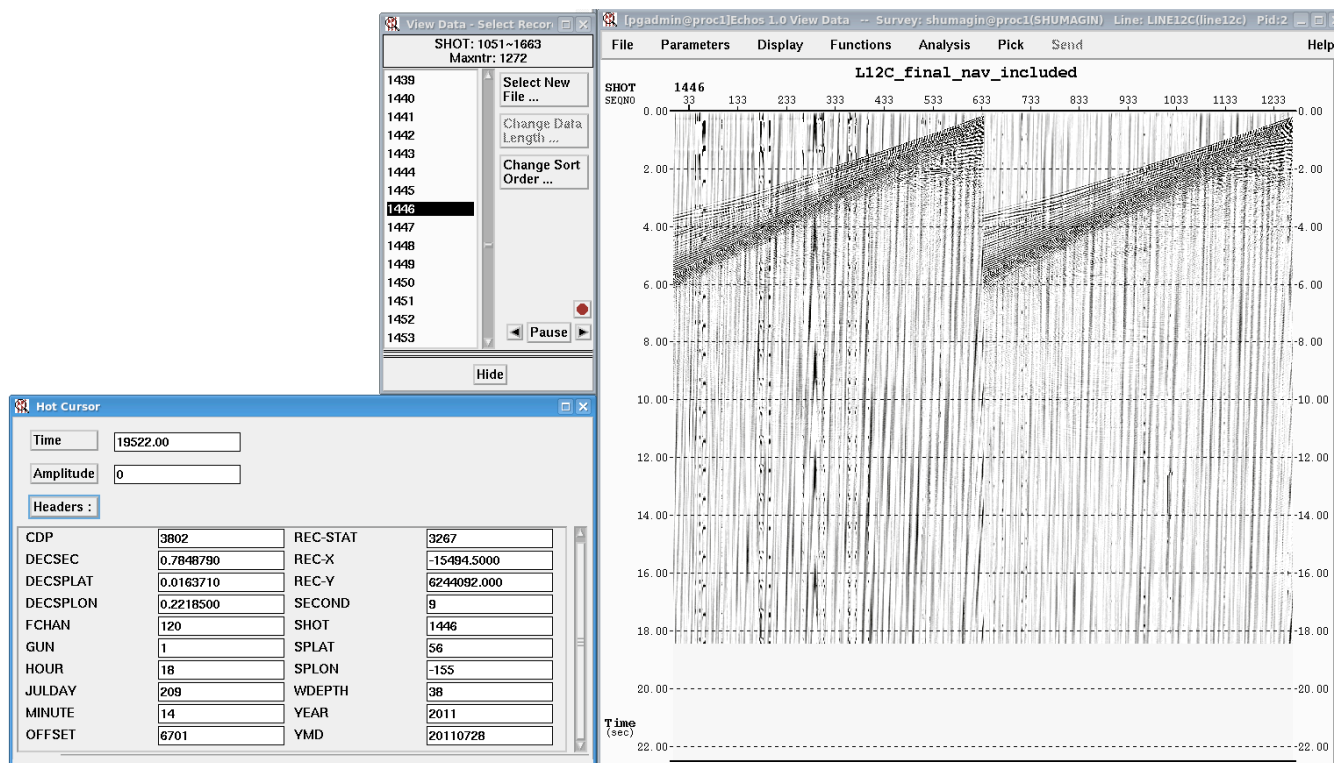


Figure 18: Example of merged data with offset, CDP, REC-X and REC-Y header words.

Check_segd.sh:

```
#!/bin/bash

i1=${1}
i2=${2}

rm 'line'${3}'mcs_errorlist'
touch 'line'${3}'mcs_errorlist'
rm 'list_line'${3}'mcs'
touch 'list_line'${3}'mcs'

k=0
kcont=0
kex=0
```



```

kmiss=0

sumsm=0

LINEDIR='MCSLINE'${4}

echo $LINEDIR

for (( i=$i1; i<= $i2; i++ ))
do
    logic=0
    if (( $i < 10000 )); then ti=$i; fi
    if (( $i < 1000 )); then ti='0'$i; fi
    if (( $i < 100 )); then ti='00'$i; fi
    if (( $i < 10 )); then ti='000'$i; fi
    echo 'Checking TAPE'$ti
    nfiles=`ls -l $LINEDIR'/TAPE'$ti'.REEL/R'*'.RAW' | wc |awk '{print
$1}'`
    echo $nfiles' RAW SEGD files in TAPE'$ti
    echo 'Now checking SEGD headers...'
    for (( j=1;j<($nfiles+1);j++ ))
    do
        oldshotnum=$shotnum
        knoshot=0
        k=`expr $k + 1`
        kcont=`expr $kcont + 1`
#in case of FFID reset ...
        if (( $i > $i1 )); then if [ -e
$LINEDIR'/TAPE'$ti'.REEL/R000001_*.RAW' ]; then if (( $logic == 0
)); then k=0; echo 'FFID RESET TAPE'$i; fi fi fi

        if (( $k < 100000 )); then kt=$k; fi

```

```

if (( $k < 10000 )); then kt='0'$k; fi
if (( $k < 1000 )); then kt='00'$k; fi
if (( $k < 100 )); then kt='000'$k; fi
if (( $k < 10 )); then kt='0000'$k; fi

while [ ! -e $LINEDIR'/TAPE'$ti'.REEL/R0'$kt'_'*'.RAW' ]
do
    k=`expr $k + 1`
    kcont=`expr $kcont + 1`
    knoshot=`expr $knoshot + 1`
    if (( $k < 100000 )); then kt=$k; fi
    if (( $k < 10000 )); then kt='0'$k; fi
    if (( $k < 1000 )); then kt='00'$k; fi
    if (( $k < 100 )); then kt='000'$k; fi
    if (( $k < 10 )); then kt='0000'$k; fi
done

ip=`expr $i - 1`

    if (( $knoshot > 0 )); then kmiss=`expr $kmiss +
$knoshot`;echo '' ;echo $knoshot' shots are missing in TABLE
'$ip;echo''; echo $k" "$i" "$shotnum" 0 1 1 "$knoshot-1 >>
'line'${3}'mcs_errorlist'; fi

    error=`strings $LINEDIR'/TAPE'$ti'.REEL/R0'$kt'_'*'.RAW' |
head | grep '>>>' |wc | awk '{print $1}'`

    if (( $error > 0 )); then echo ' ';echo 'SEGD ERROR';echo 'No
SEGD header in FFID'$k', TAPE'$i'. Skipping file in list';kex=`expr
$kex + 1`; echo $k" "$i" "$shotnum" 1 0 1 " >>
'line'${3}'mcs_errorlist';

    else

        kw=`expr $kcont - $kex - $kmiss `

        shotnum=`strings $LINEDIR'/TAPE'$ti'.REEL/R0'$kt'_'*'.RAW'
|head -n30 |grep UTC0 | awk ' {printf("%4d\n",substr($1,38,5))}'`

        echo $shotnum

```

```

        if (( $shotnum == 1000 )); then echo "shot 1000 at FFID "$k",
TAPE "$i", index "$kw; fi

        ls $LINEDIR'/TAPE'$ti'.REEL/R0'$kt'_'*.RAW' | awk '{print
'$kw', $0}' >> 'list_line'${3}'mcs'

        fi

        syntshot=`expr $shotnum - $oldshotnum`

        if (( $syntshot > 1 )); then sumsm=`expr $sumsm +
$syntshot`;echo $k" "$i" "$shotnum" 0 0 1 "$syntshot-1 >>
'line'${3}'mcs_errorlist'; else

        if (( $syntshot < 1 )); then echo $shotnum" WARNING
"$oldshotnum; fi

        fi

#        if (( $syntshot == 0 )); then echo $shotnum" written several
times"; fi

        logic=1

    done

done

echo 'A total of '$kw' files are listed, '$kex' have header problems,
'$kmiss' files are missing, '$sumsm' shots are skipped between files'

```

APPENDIX 7: SIOSEIS Scripts for Onboard MCS data processing

Appendix 7A: Brute Stack

```
#!/bin/csh -f

set LINENO = bs01a
set DIR = ltr
set LATEST = "latest.list"$LINENO
set OUTDIR = "SEGYP"

#ls -al ../raw_data/${LINENO}/TAPE*.REEL/R*RAW | awk '{print $9}' >! list

#/export/home/phenkart/bin/sioseis << eof
#/opt/sioseis/bin/sioseis << eof
#/export/home/mgl1109/sioseis << eof
/home/pgadmin/sioseis/sioseis-2011.2.20/sioseis << eof
procs segddin prout geom wbt gather nmo stack avenor filter gains diskoa avenor filter plot end
#procs segddin prout geom wbt gather nmo stack diskoa end
#
segddin
  ftr 486 ltr 636
  fcset 1 lcset 1
  secs 12
  listpath $LATEST
# stack $LATEST
  logpath ./${LINENO}-stack.log
  end
end

prout
  fno 0 lno 9999999 ftr 1 ltr 1 noinc 10 end
end

geom
  type 1 # Fixed marine geometry
  fs 1 ls 999999 # all shot have the same parameters (preset)
  gxp 636 -250 # RESET the closest group only.
  ggx -12.5 # Used to extrapolate gxp!
  dfls 37.5 # ignored with type 9
  dbrps 6.25 mindfls 60 maxdfls 65
  rpadd 1000 end
end

mute
```

```
fno 1 lno 999999
addwb yes xtp 200 -.1 1000 -.1 1500 1 end
end
```

```
wbt
  vel 1500 track .1 end
end
```

```
gather
  maxtrs 53 maxrps 318 END
end
```

```
nmo
# real time nmo, replace interpolation by RP to WB depth in Meters.
# If water depth changes by > 500 m, use previous value. Water-depth
# velocity functions derived from ESP5, interpolation by iso-velocity layering
vtrkwb 500 stretc 1
vintpl 1
```

```
fno 1000 lno 1000
vtp 1500 1.33
1580 1.88
1700 2.58
1900 4.33
2400 5.4
3600 6.58
4000 7.33
5000 9.5
5400 12 end
```

```
fno 1700 lno 1700
vtp 1500 2.25
1580 2.8
1700 3.5
1900 5.25
2400 6.3
3600 7.5
4000 8.2
5000 10.5
5400 12 end
```

```
fno 2000 lno 2000
vtp 1500 2.75
1580 3.5
1700 4.0
2400 5.8
```

3600 7.0
4000 8.2
5000 10.5
5400 12 end

fno 2900 lno 2900
vtp 1500 3.85
1580 4.2
1700 4.65
2400 5.45
3600 6.65
4000 7.85
5000 9.15
5400 12 end

fno 3300 lno 3300
vtp 1500 4.4
1580 4.9
1700 5.65
#2400 7.4
3800 7.4
4000 9.8
5000 12 end

fno 5300 lno 5300
vtp 1500 7.3
1800 8
3500 10
4500 11.8
5600 16
5800 18 end

end

diskoa # Write out disk file
opath \$OUTDIR/\$LINENO-stack.segy
end end

diskob # Write out disk file
opath \$OUTDIR/\$LINENO-nmo.segy
end end

avenor
hold 300
addwb yes sets 0 1 2 5 6 8 10 12 end

end

filter

pass 3 60 ftype 0 dbdrop 48 minpha yes end
end

gains

type 3 alpha 1.25 end
end

plot

dir \$DIR
scalar -1 tlines 0.5 1 nibs 7225 ann gmtint anninc 5 ann2 shotno
def 0.04 trpin 125 wiggle 0
vscale 1.25 clip .03
opath \$OUTDIR/\$LINENO-stack.atlantek srpath \$OUTDIR/\$LINENO-stack.sunfil
end
end

end

eof

Appendix 7B: FK Migration

#!/bin/csh -f

set LINENO = ax2
set LINENOUT = ax2
set DIR = ltr
set LATEST = "latest.list"\$LINENO
set OUTDIR = "SEG Y"

/lhome/pgadmin/sioseis/sioseis-2011.2.20/sioseis << eof
procs disk in tx2fk fkmigr fk2tx disk oa end

disk in

fno 294400 lno 299503
ipath \$OUTDIR/\$LINENO-stack.segy end
end

```

tx2fk
    nxpad 2000
    PATH1 ./dummy
    PATH2 ./dummy2 end
end

fkmigr
    vel 1550
    deltax 6.25
    deltat .002 end
end

#fdmigr
#   dx 6.25
#   vtp 1520 12 end
#   epad 100
#   bpad 100
#   path ./tempfile end

#end

fk2tx
    PATH1 ./dummy3
    PATH2 ./dummy4 end
end

diskoa # Write out disk file
    opath $OUTDIR/$LINENOUT-mig.segy
end end

end
eof

```


APPENDIX 8: Multibeam Bathymetry Data

Appendix 8a: Summary Report

R/V Langseth is equipped with a 1°x1° Kongsberg EM122 multibeam swath sonar system. The multibeam system uses a frequency of 12 kHz with angular coverage up to 150 degrees, and up to 288 beams (432 Soundings) per ping cycle. On smooth seafloor, the achievable swath width was observed to be approximately 3.5 times the water depth. Therefore, in our working water depths of ~60-2900m, the system acquired a useable swath width of between 200m and 10km.

During operations data were acquired using a 65° take off angle port/starboard. After a brief comparison of ping modes for achievable swath width and ping Hz, the Medium ping mode was determined to be most suitable for the range of depths encountered during our survey > 500m. In “Medium” ping mode the relatively short pulse length of 5ms combined with Dynamic dual swath mode allows for a higher sounding density across the survey then can be achieved using Auto ping mode. When above 500m the ping mode was manually toggled to Shallow as that is standard practice on the Langseth.

Using MB-system, multibeam data were converted from the raw .all files to format .mb59 , cleaned, manually ping edited, and binned at 50m on a daily basis. Due to a shorter pulse length the data were predicted to be noisy in the near nadir region of the respective swaths. This was confirmed, and the cleaning parameters were adjusted accordingly.

```
mbclean -I$grid -F-1 -M1 -C50/2 -D0.01/0.20 -G0.80/1.20 -V
```

Differencing of two 30 minute files acquired in opposite directions revealed a roll bias, deeper to the starboard side. At ~2000m water depths it results in a +/- 20m range across the swath over flat seafloor (Fig. 1, 2). Using MB-system, a roll bias calculation was performed (report attached) and a bias, preferential to the starboard side at an angle of 0.022 deg was obtained (starboard preference results in increasingly shallower data values on the port side as a function of distance from nadir). However, a roll bias calculation done for another set of coincident but opposite direction swaths along line 1 resulted in a different bias value, which is not expected for a true roll bias. This roll bias issue will require further investigation and correction of the MB dataset post-cruise.

During the cruise Expendable Bathythermographs (XBT's) were launched on a ~daily basis. These data provide measurements of seawater temperature as a function of depth, and when calculated with salinity values collected from the Thermosalinograph (TSG) provide sound velocity (Fig. 3). The TSG is factory calibrated and was installed in early December 2012 by the Langseth technical group. Once accepted by the operator, the sound velocity profile is then used by the multibeam RX array for the beam forming process.

Overall the bathymetry and sidescan data collected were very good. At an average depth of 2000m and using minimal interpolation, the bathymetry data can be binned at 15m and the sidescan at a 5m grid cell size with resolving improvement in sharpness of features (Fig. 4, 5). These high quality of the data are attributed to the mode selection, diligent ping editing, and a relatively calm sea state for the duration of the cruise.

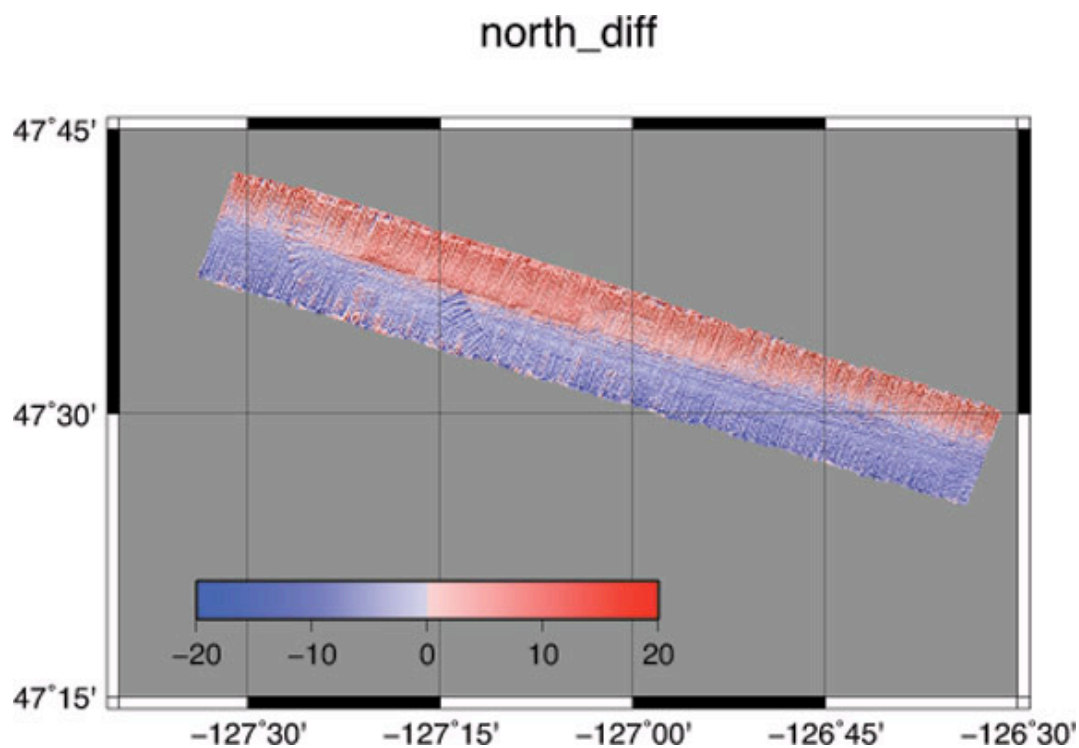


Figure A8-1. Data residuals calculated from differencing MB data collected along coincident $\sim 180^\circ$ ship tracks along Line 3.

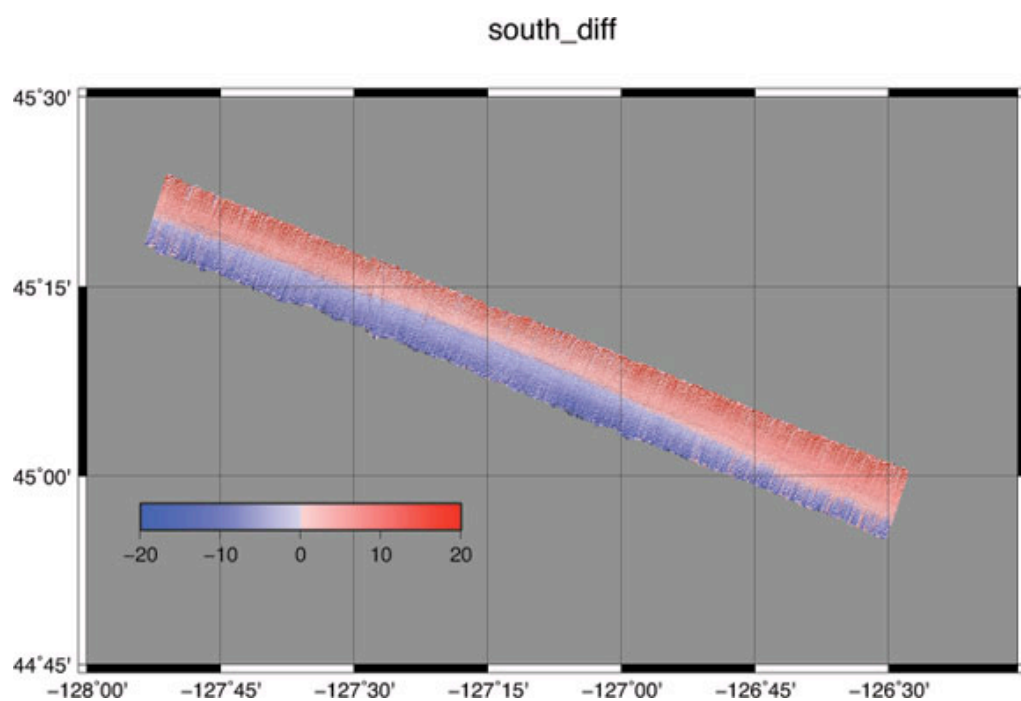


Figure A8-2 Data residuals calculated from differencing MB data collected along coincident $\sim 180^\circ$ ship tracks along Line 1.

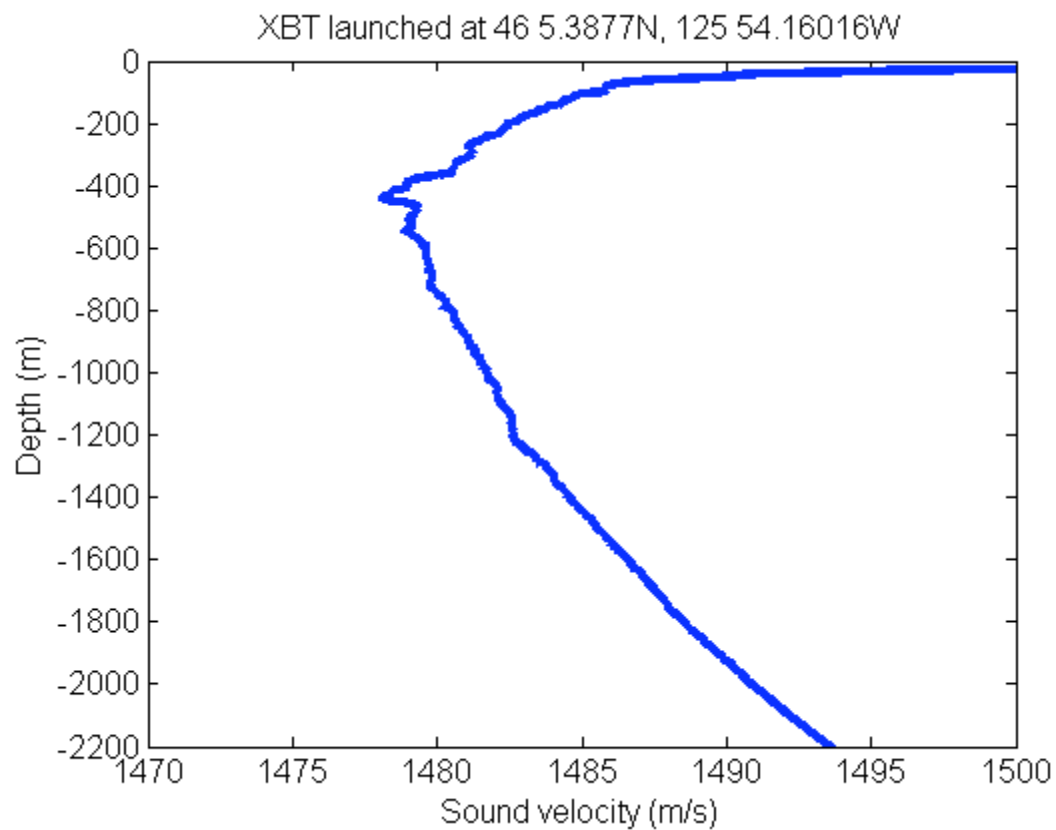


Figure A8-3 Example sound velocity profile derived from XBT and TSG data at average survey depth.

20120626p_15

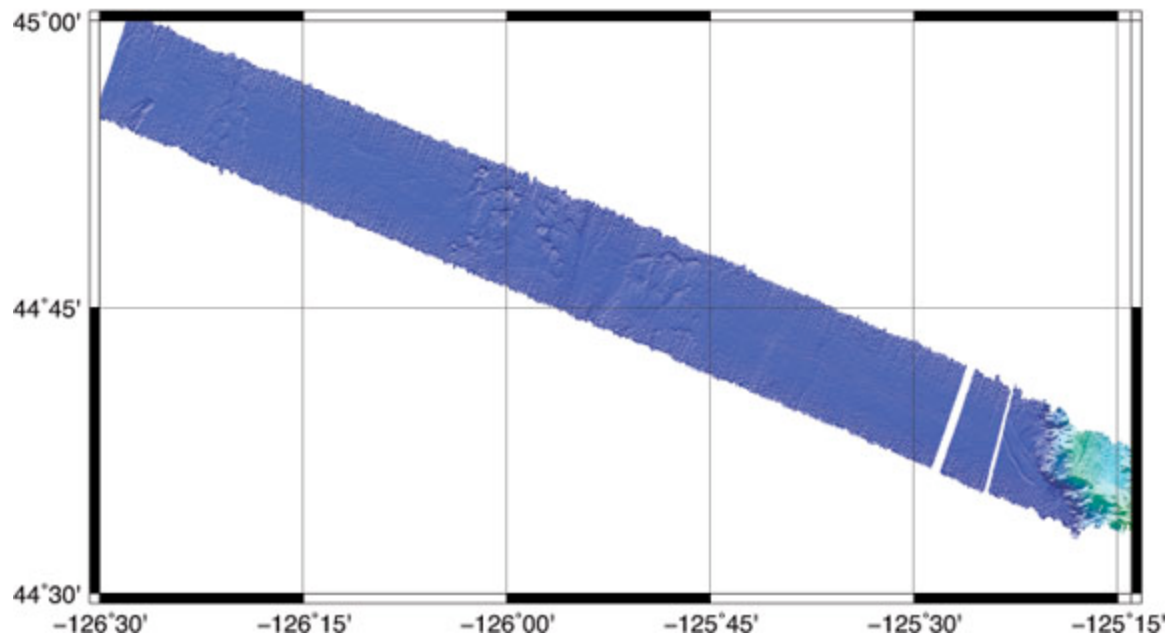


Figure A8-4 showing 15m achievable bathymetry data.

20120626p.5.ss

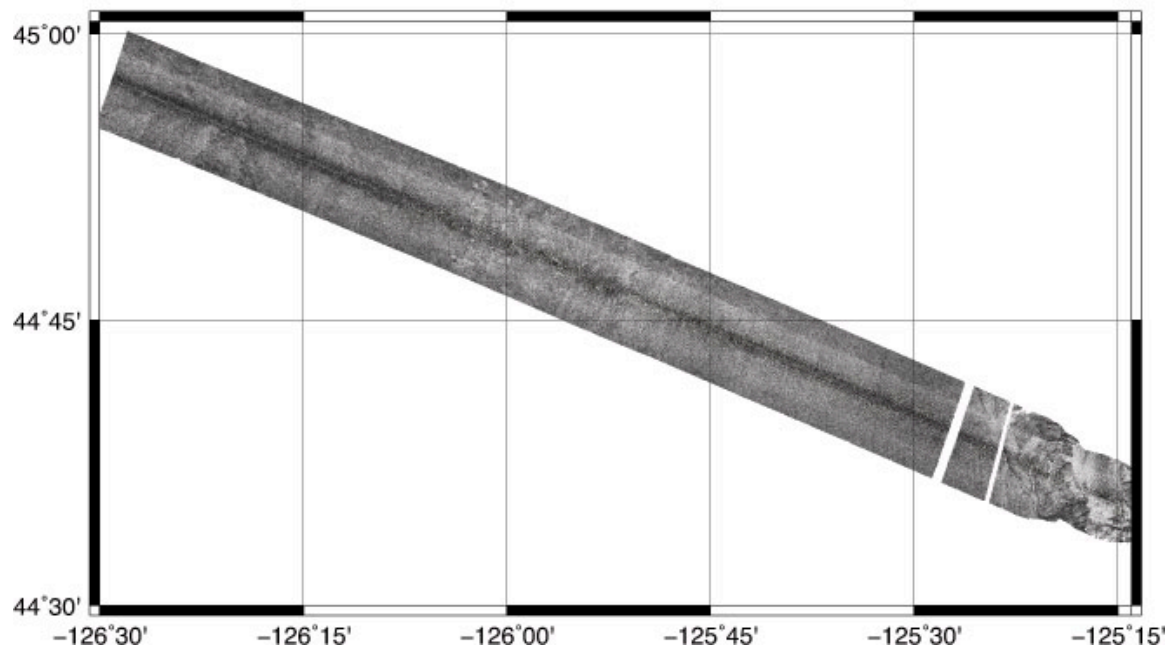


Figure A8-5 showing 5m achievable sidescan data.

Appendix 8b: Multibeam Processing Scripts

```
#!/bin/csh
#set date=`date +%m-%d_%H-%M`
#set gmtpath="/opt/gmt/bin"
#set mbpath="/opt/mbsystem/bin"
#set path=($path $mbpath)
#set path=($path $gmtpath)
set datapath="../fast_files"
set datapath2="../gmt_grids"
set datapath3="../ss_grids"
set grid="MGL1211_North"
set illum="$grid.I"
set cell="1.75i"
set cpt="$grid"
set ll="-129:15/-124:00/46:50/48:05"
#set ll="-128/-126:15:30/44:45/45:30"
#set ll="-126:30/-125:14/44:30/45:00"
goto next
cd $datapath
set latlon_info=`mbinfo -F-1 -I $grid -G | grep 'Minimum Longitude'`
set lon_info = `echo $latlon_info | sed "s/Minimum Longitude: //"`
set lon_info2 = `echo $lon_info | sed "s/ Maximum Longitude: /\//"`
set latlon_info=`mbinfo -F-1 -I $grid -G | grep 'Minimum Latitude'`
set lat_info = `echo $latlon_info | sed "s/Minimum Latitude: //"`
set lat_info2 = `echo $lat_info | sed "s/ Maximum Latitude: /\//"`
set ll="$lon_info2/$lat_info2"
echo $ll

goto next
next:
#goto clean
#goto filter
#goto process
goto grid_plot
#goto ss_grid_plot
#goto get_svp
#goto roll_bias

clean:
cd $datapath
mbclean -I$grid -F-1 -M1 -C50/2 -D0.01/0.20 -G0.80/1.20 -V
end
cd ../scripts
stop
```

filter:

```
cd $datapath
set tmp_file = `cat $grid`
foreach i ($tmp_file)
  echo Filtering .... $i
  mbfilter -F59 -I$i -D1/3/10/1/10000 -S4/3/3/5 -C1/5/5/1 -V
end
cd ../scripts
stop
```

process:

```
cd $datapath
mbprocess -F-1 -I$grid
end
cd ../scripts
stop
```

grid_plot:

```
cd $datapath
mbgrid -I$grid -A2 -C3/2 -E50/0m! -F5 -G3 -N -R$ll -S1 -O$grid
mbm_grd2arc -I$grid.grd -O$grid.asc -V
makecpt -Crainbow -T-2700/-725/50 -Z -V > $cpt.cpt;
gmtset COLOR_NAN white
gmtset HEADER_FONT_SIZE 20
#gmtset PAPER_MEDIA letter
gmtset PLOT_DEGREE_FORMAT ddd:mm
grdgradient $grid.grd -G$illum.grd -A0/350 -V -Ne0.75
grdimage $grid.grd -Jm$cell -R$ll -I$illum.grd -C$cpt.cpt -K -V -P >$grid.ps;
psbasemap -R$ll -Jm$cell -B0.5g0.25:."$grid":WeSn -O -K -V -P >>$grid.ps
end
cd ../scripts
stop
```

ss_grid_plot:

```
cd $datapath
mbmosaic -I$grid -F -A4 -E20/0m! -C3/2 -R$ll -S1 -Y3 -V -O$grid.ss
mbm_grd2arc -I$grid.ss.grd -O$grid.ss.asc -V
gmtset COLOR_NAN white
gmtset HEADER_FONT_SIZE 20
gmtset PAPER_MEDIA Custom_792x612
gmtset PLOT_DEGREE_FORMAT ddd:mm
grdimage $grid.ss.grd -Jm$cell -R$ll -CEM122_HR.ss.cpt -K -V -P > $grid.ss.ps
psbasemap -R$ll -Jm$cell -B0.25g0.25:."$grid.ss":WeSn -O -K -V -P >> $grid.ss.ps
end
cd ../scripts
stop
```

```

get_svp:
cd $datapath
mbsvplist -F-1 -I$grid -V -O
end
cd ../scripts
stop

roll_bias:
cd $datapath
set first=""
set second=""
mbrollbias -R$I -D1/1 -F59/59 -I$first -J$second -V
end
cd ../scripts
stop

```

Appendix 8c: Roll Bias Calculation from MB data along Line 3

```

Program MBROLLBIAS
Version $Id: mbrollbias.c 1917 2012-01-10 19:25:33Z caress $
MB-system Version 5.3.1917

MBROLLBIAS Parameters:
Input file 1: 0385_20120621_221148_Langsethp.mb59
Input file 2: 0277_20120619_161713_Langsethp.mb59
Region grid bounds:
  Longitude: -126.7500 -126.7083
  Latitude: 47.3750 47.5000
Region grid dimensions: 1 1
Longitude interval: 0.041667 degrees or 3.143038 km
Latitude interval: 0.125000 degrees or 13.897417 km
Longitude flipping: 0

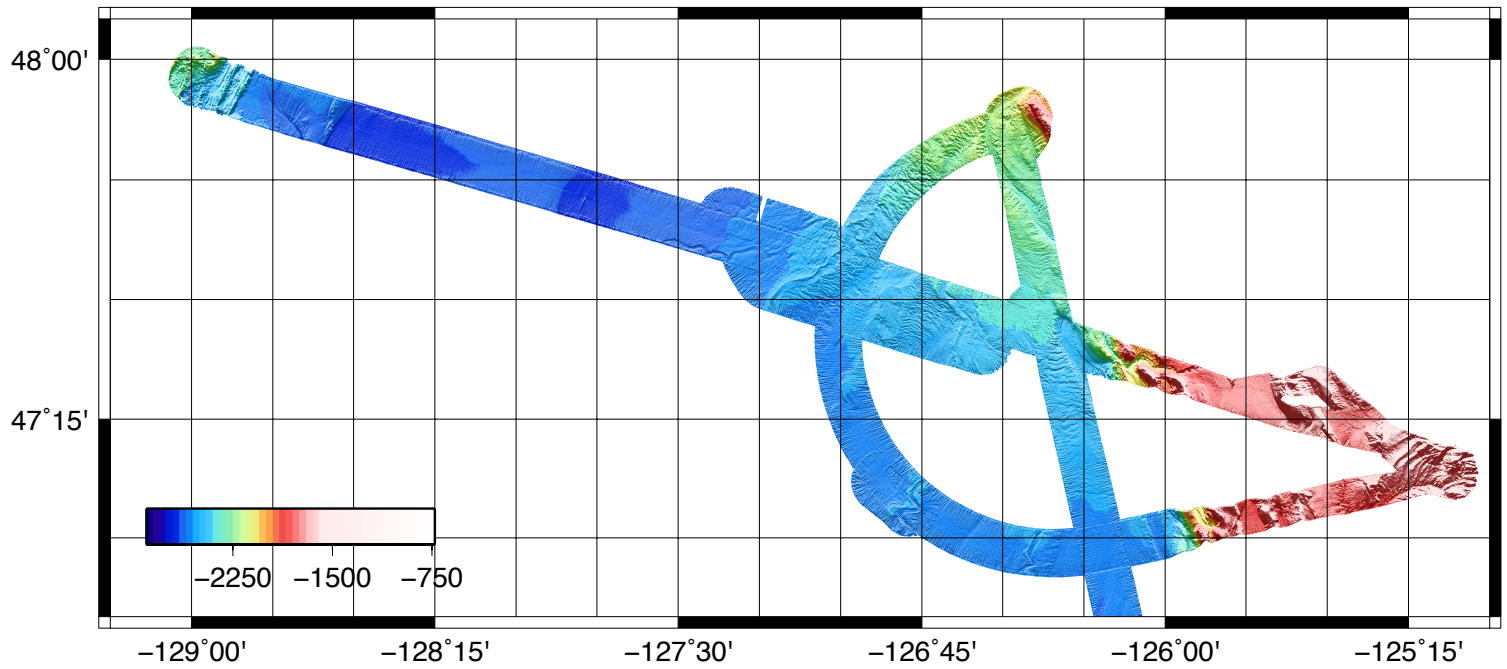
32664 depth points counted in 0385_20120621_221148_Langsethp.mb59
31007 depth points counted in 0277_20120619_161713_Langsethp.mb59
32664 depth points read from 0385_20120621_221148_Langsethp.mb59
31007 depth points read from 0277_20120619_161713_Langsethp.mb59

Region 0 (0 0) bounds:
  Longitude: -126.7500 -126.7083
  Latitude: 47.3750 47.5000
First data file: 0385_20120621_221148_Langsethp.mb59
  Number of data: 32664
  Mean heading: 108.331593
  Plane fit: 2.567821 0.000423 -0.008429
Second data file: 0277_20120619_161713_Langsethp.mb59
  Number of data: 31007
  Mean heading: 289.017945
  Plane fit: 2.553210 0.000948 -0.007709
Roll bias: 0.000380 (0.021769 degrees)
Roll bias is positive to starboard, negative to port.
A positive roll bias means the vertical reference used by
  the swath system is biased to starboard,
  giving rise to shallow bathymetry to port and
  deep bathymetry to starboard.

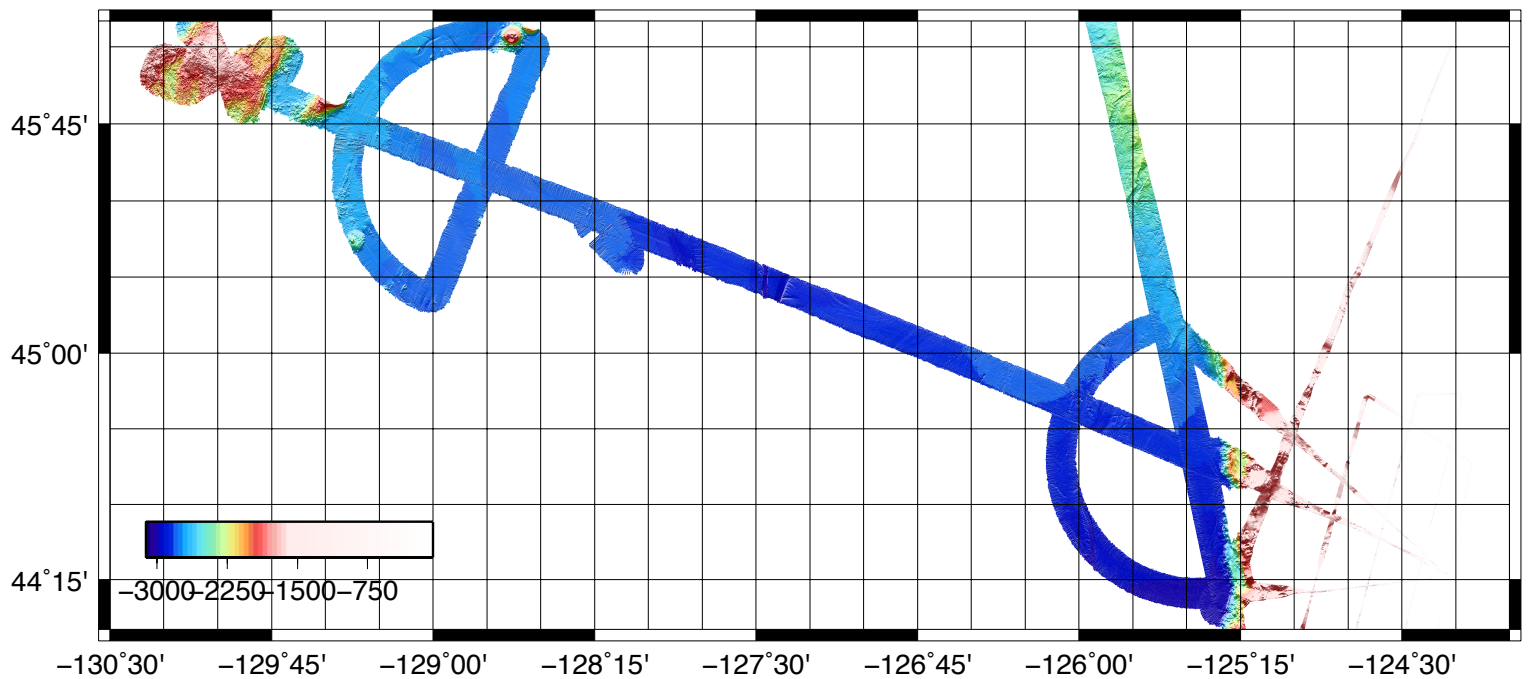
```

Appendix 9: Final Gridded Multibeam Bathymetry Data

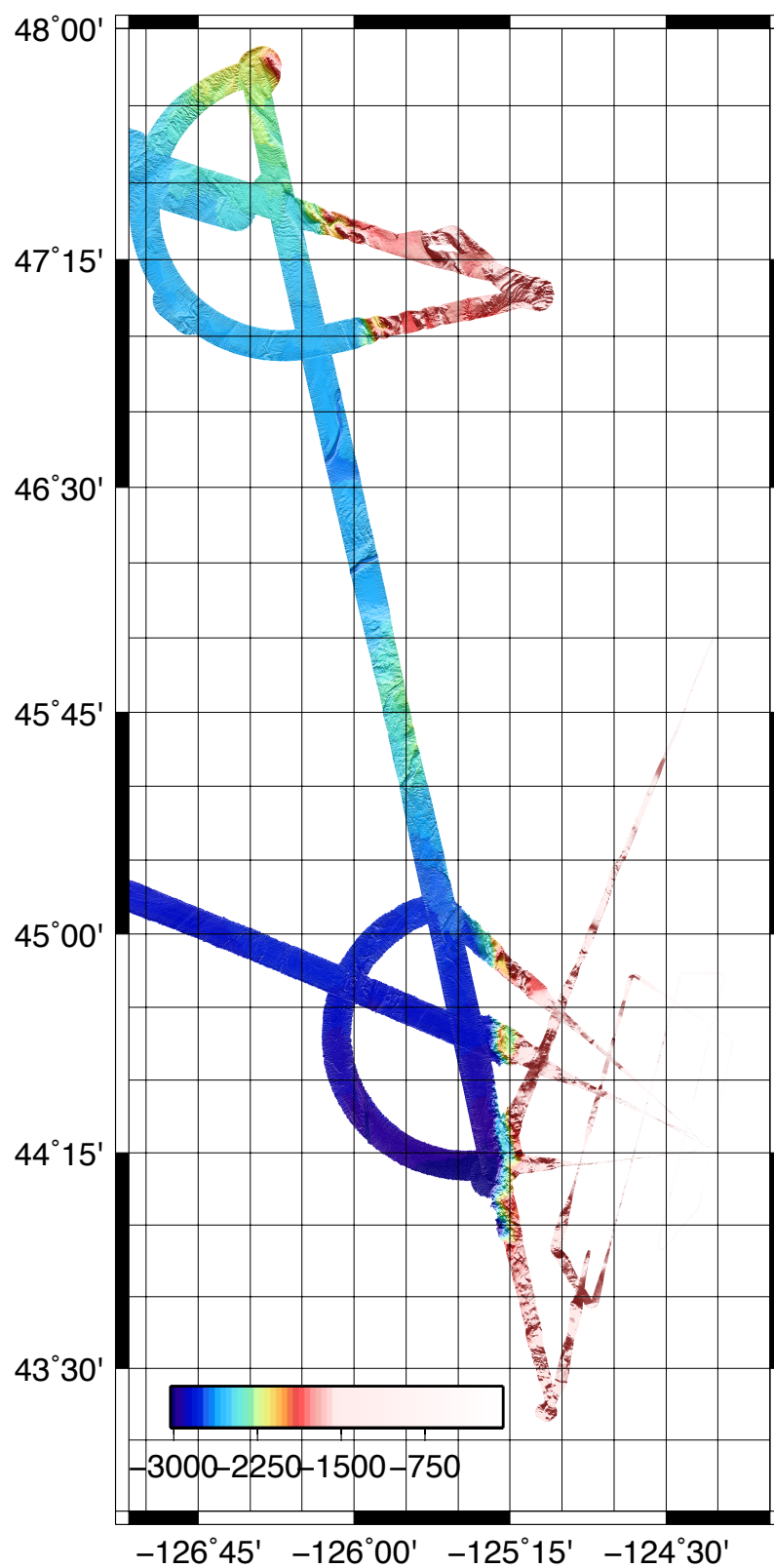
MGL1211_North



MGL1211_South



MGL1211_East



APPENDIX 10: Seismic Oceanography Program

SEISMIC OCEANOGRAPHY IN THE "JUAN DE FUCA RIDGE TO TRENCH" SURVEY

B. Biescas, G. Bornstein, J.F. Mujica and A. Bartlett

July 5, 2012

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Motivation

Seismic oceanography(SO) is a discipline that studies physical properties of the oceanic water from multichannel seismic reflection data (Holbrook et al., 2003). Multichannel seismic reflection data can be used to image mesoscale structures in the ocean like fronts, eddies (Biescas et al., 2008) and currents (Buffett et al., 2009). These data reveal the lateral coherence of thermohaline oceanic structures as well as the interactions with the topography. This discipline uses the same instrumentation and software for data acquisition and processing that marine geophysics, but it uses the first 5-6 seconds of the seismic records, which travel through the water column. Therefore, it can be a complementary study to the one done by marine geophysicists.

The "Juan de Fuca Ridge to Trench" survey has been carried out in the Cascadia Basin (Figure 1). The water column above Cascadia Basin is affected by several currents that influence regional patterns. As the North Pacific Current approaches North America from the central Pacific, it splits into the north flowing Alaskan Current and the south directed California Current (Figure 2). Different water masses can be identified in the water column: the California Current up to 500 m; the Subarctic Intermediate Water, between 900 m and 1900 m deep and the Cascadia Basin Bottom Water and the Cascadia Deep Water below 2000 m. These water masses have different properties of temperature and salinity. It was expected that these thermohaline contrasts were going to generate reflectivity, allowing seismic oceanography to image the oceanic currents. In fact, a similar geological survey was carried out 10 years ago in the same area and the data shows strong reflectivity above 1000 m (Figure 3).

In the present time, one of the main efforts in SO is focused on inversion techniques. Inversion methods

provide temperature and salinity maps from seismic amplitudes (Papenberg et al., 2010). The gap of low frequencies existing in the seismic data is provided by oceanographic data acquired with expendable probes like xbt, xsv and xctd. These complementary data needs to be recorded simultaneously to the seismic acquisition and it is also used for the calibration of the inversion results. Synthetic full waveform inversion has been applied with success to seismic oceanographic data (Kormann et al., 2011) and the improvement in the understanding of this method is also a benefit for the geophysics community.

The "JuandeFucaRidge to Trench" survey has been done on board on the RV Marcus Langseth, which is the most advanced seismic vessel available in the academic community worldwide and provides seismic data of excellent quality. We have also had the opportunity of acquiring XBTs and XSVs simultaneously to the seismic acquisition and apply these data for seismic inversion. Besides, the RV Oceanus, which has carried out the deployment of the OBS for the geological survey, offered to us the opportunity of doing CTD space-coincident casts (not in time) of the seismic acquisition, in order to detect the thermohaline structure with better resolution than with the expendable probes and to have an accurate temperature-salinity relationship of the area.

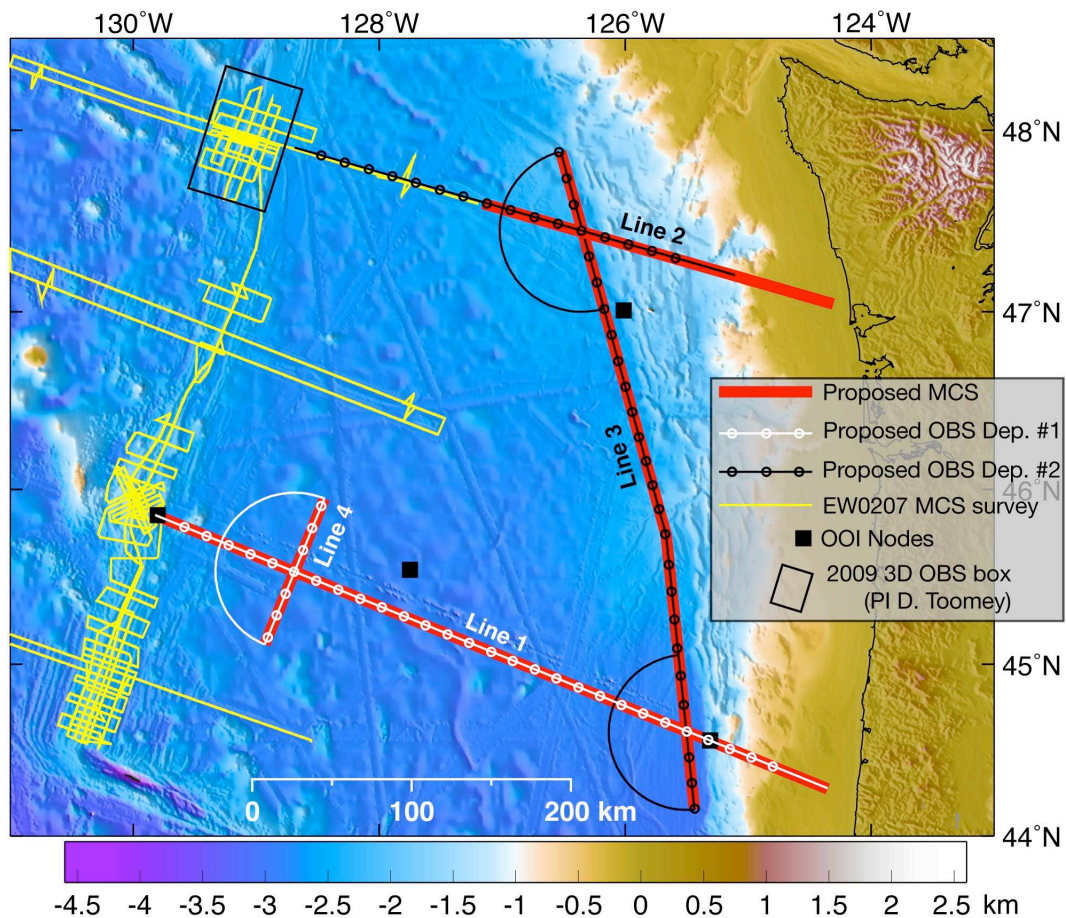


Figure 1: Location of the MCS lines (red) acquired during the Juan de Fuca Ridge to Trench Survey in June-July 2012.

Ocean Currents of the North Pacific

© 2005 State of the Salmon, a joint program of Wild Salmon Center and Ecotrust

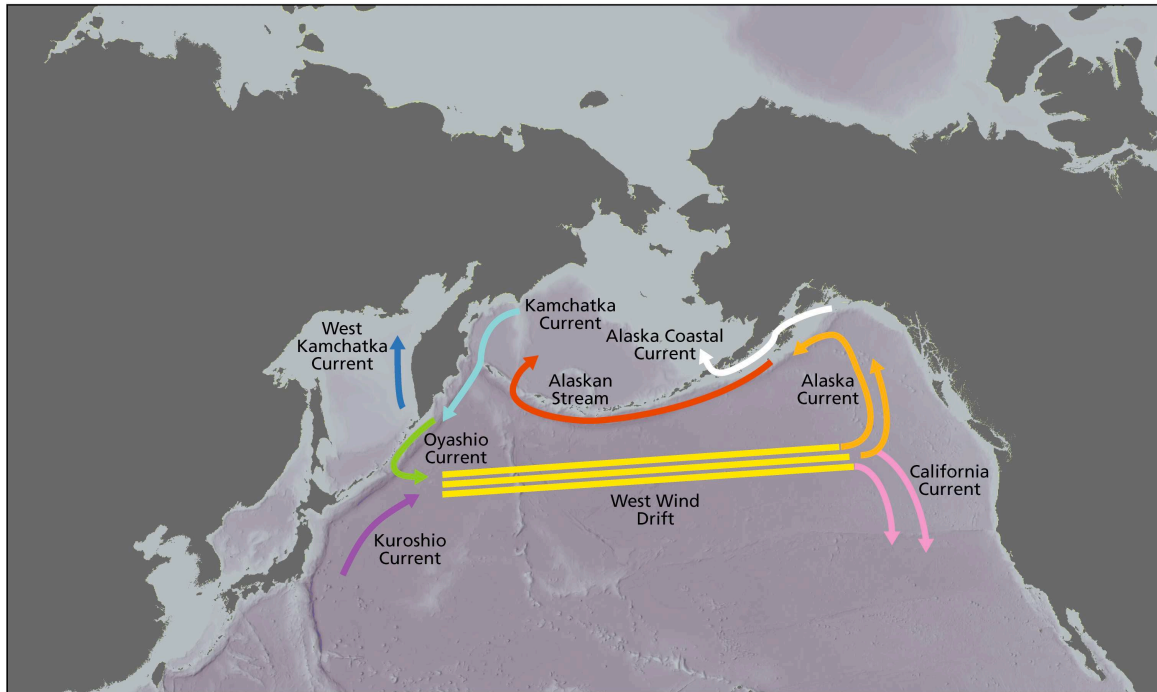


Figure2: NorthPacific current systemprovidedby theAtlas ofPacificSalmon: TheFirstMap-basedStatus Assessment of Salmon in the North Pacific.

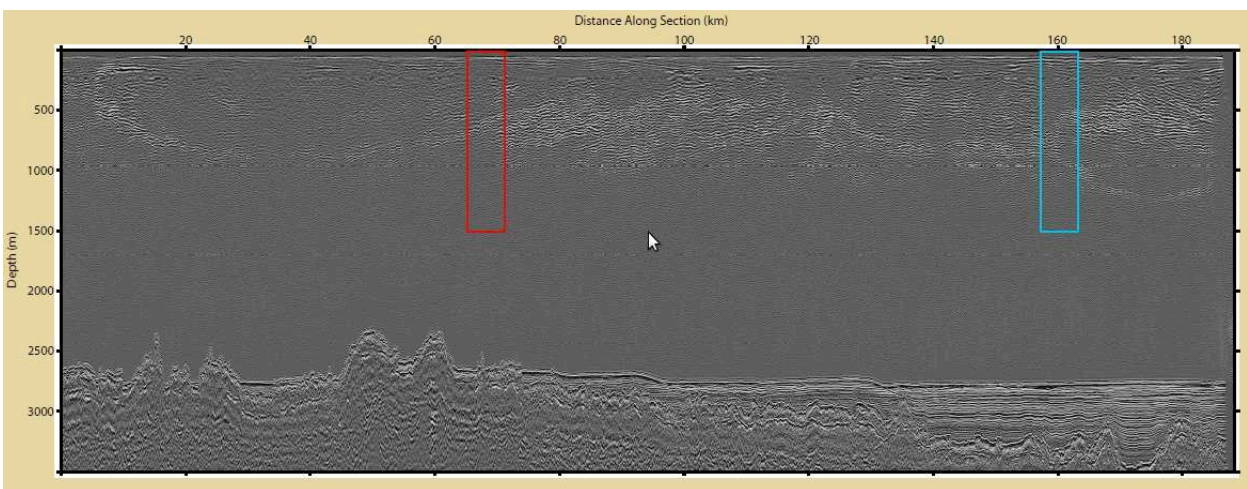


Figure 3: Seismic oceanography data across Juan de Fuca ridge system. Survey carried out by Mladen Nedimovic in the Cascadia Basin in 2002.

Physical oceanography at the Cascadia Basin [44-49N, 124-131W] Northeastern Pacific Ocean

The physical oceanography within the Cascadia Basin is dominated by the California Current System (CCS). The CCS extends, in the north, from the Transition Zone ($\sim 50^{\circ}$ N, separating the North Pacific and Alaska gyres), where the east-flowing North Pacific Current approaches North America, south to the subtropical waters off Baja California, Mexico ($\sim 15^{\circ}$ – 25° N). To the west is the North Pacific Gyre, and to the east are Canada, the United States of America and Mexico (Checkley and Barth, 2009).

The main physical and processes patterns of the CCS include wind-driven upwelling, downwelling, the geostrophically balanced California Current (CC), the coastal jet California Undercurrent (CU) and the formation of eddies. The CC is the equatorward fresh and cool flow within about 1000 km of the west coast of North America. The CC exists year-around, occupies the upper 500 m, is the surface intensified, and carries about 10 Sv. The CC is fed in the north by the North Pacific Current (NPC) and is part of the North Pacific Gyre. Intense equatorward jets are embedded within the region of slower southward flow. The intense jets have widths of 50–75 km, speeds excess of 0.5 m s^{-1} and comprises up to half of the total CC transport (Checkley and Barth, 2009). The CU is a narrow coastal jet that flows between 100 and 400 m deep. It extends up to 100 km far away from the coast and flows poleward carrying warm, salty and oxygen-poor water. Summer time equatorward winds drive flow offshore in a surface Ekman layer, leading to upwelling of deep, cold, salty and nutrient-rich water near the coast (Checkley and Barth, 2009), while winter is defined as periods of persistent northward wind stress and onshore Ekman transport with downwelling conditions.

Summer and fall are the most active seasons for undercurrent eddy generation while there is less seasonal variation at surface. Most of the eddies have radii in the range of 25–100 km, sea level anomaly amplitudes of 1–4 cm and vorticity normalized by f amplitudes of 0.025–0.2. Many of the eddies formed near the coast travel considerable distance westward with speeds about 2 km/day. Anticyclones and cyclones show equatorward and poleward displacements, respectively. Eddies containing CC and CU can be found. The subsurface CU generates more long-lived anticyclones than cyclones through instabilities and topographic/coastline effects. In contrast, surface eddies and subsurface cyclones have much more widely distributed birth sites. Eddies extend to 800–1500 m depth and have distinctive vertical structures for cyclones and anticyclones. Eddies show high nonlinearity (rotation speed higher than propagation speed) and hence can be efficient in transporting materials offshore (Kurian et al., 2011).

The plume from the Columbia River is one of the dominant hydrographic features of the California Current System, traceable as a coherent, low salinity, tongue at least as far south as 38°N in summer. The plume region in the vicinity of the river mouth plays a key role in local shelf physical, biogeochemical and ecological functioning, carrying a mixture of fine silts, clays and dissolved organic matter into the coastal zone (Thomas and Weatherbee, 2006).

Geothermal heating at the Cascadia Basin seafloor produces a characteristic bottom-intensified temperature anomaly and plays an important role in the conversion of cold bottom water to lighter density within the CBBW. Although covering only about 0.05% of the global seafloor, the combined effects of bottom heat flux and diapycnal mixing within Cascadia Basin provide about 2 – 3% of the total required global input to the upward branch of the global thermohaline circulation (Hautala et al., 2005).

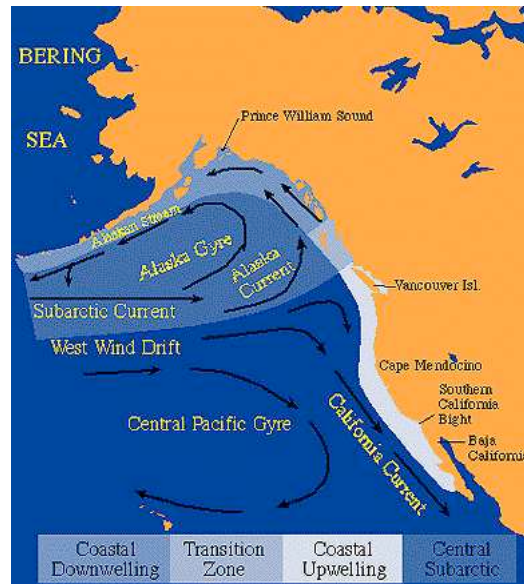


Figure4: CaliforniaCurrentSystem's image provided by the GLOBEC Northeast Pacific Program Mapping of Physical and Biological Fields in the Northern California Current.

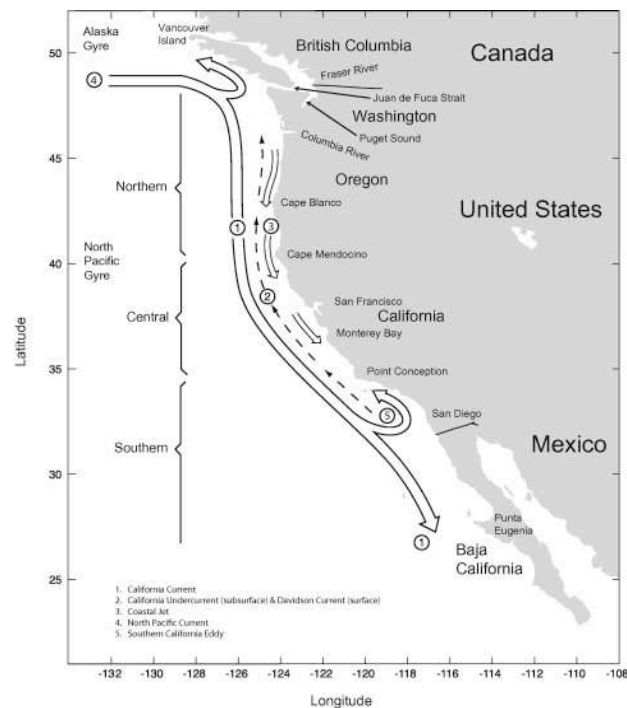


Figure5: Checkley andBarth(2009).

5 of 14

MCS data and expendable oceanographic probes at the RV Marcus Langseth

378 oceanographic probes were deployed simultaneously to the seismic data acquisition (1 box = 12 probes):

- 1 237 XBT-T5, 10 boxes bought by Dalhousie University, 5 by the Spanish Scientific Research Council (CSIC) and 6 by the MARCOM/ Canada National Defence.
- 2 120 XSV-02 from the MARCOM/ Canada National Defence.
- 3 21 XBT-T7, 1 box from the MARCOM/ Canada National Defence and 9 XBT-T7 provided from the RV Langseth storage.

The XBTs launched along Line 2 had ~ 1 km spacing in the deepest section and ~ 3 km spacing in the section over the continental slope. Along Line 1 and Line 3 the probes were deployed alternating XBTs with XSVs, with ~ 1 km spacing. Two plastic plumes were used for the deployment of the oceanographic probes to launch them as far away as possible from the ship, with the purpose of avoiding the wire of the expendable probe to get stacked in the air guns or the streamer array (Figure 7). This system does not have 100% of efficiency and ~ 10% of the wires of the probes were broken, however without the plumes, all the probes would have failed. All the successful probes were deployed using the port plume because it was longer and put the wire more separated from the seismic arrays.

A preliminary processing was applied, on board, to the seismic data coincident with the oceanographic profiles. The two seismic structures that show the most significant oceanic structures and their corresponding temperature and velocity profiles are shown in Figures 10, 13, 8, 9, 11 and 12. Both structures are high temperature and high sound speed anomalies that develop between the surface and 600 m depth and could be eddies, similar to the ones described by Kurian et al. (2011). Further work must be done in order to get concluding results. These oceanographic profiles will be used as starting models for the seismic inversion, as well as for the calibration of the inversions.

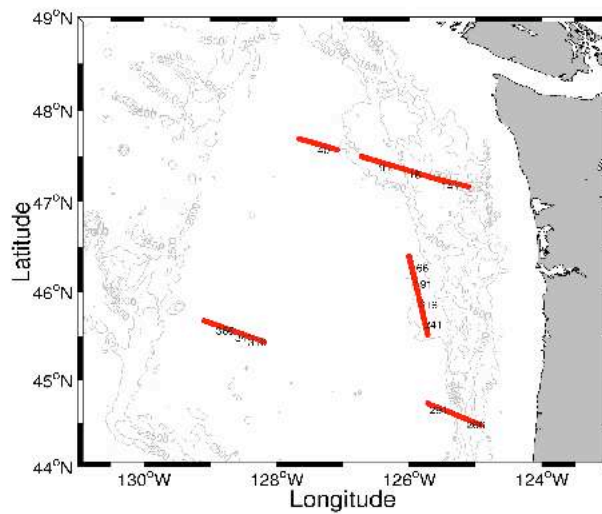


Figure6:Expendablebathythermograph and velocimeterprobeslaunchedduring theMCSdata acquisition of the "Juan de Fuca Ridge to Trench" survey.

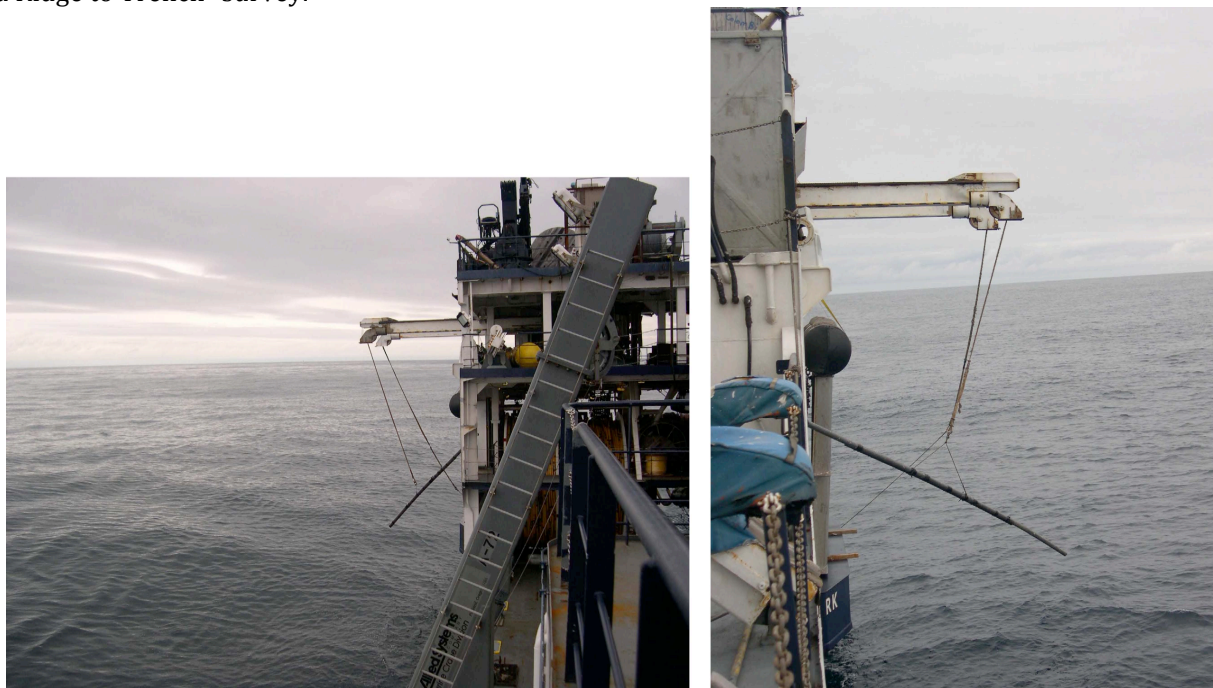


Figure7: Port(right) and starboard(left) plumesinstalledin theRVMarcusLangsethfor thelaunching of oceanographic probes.

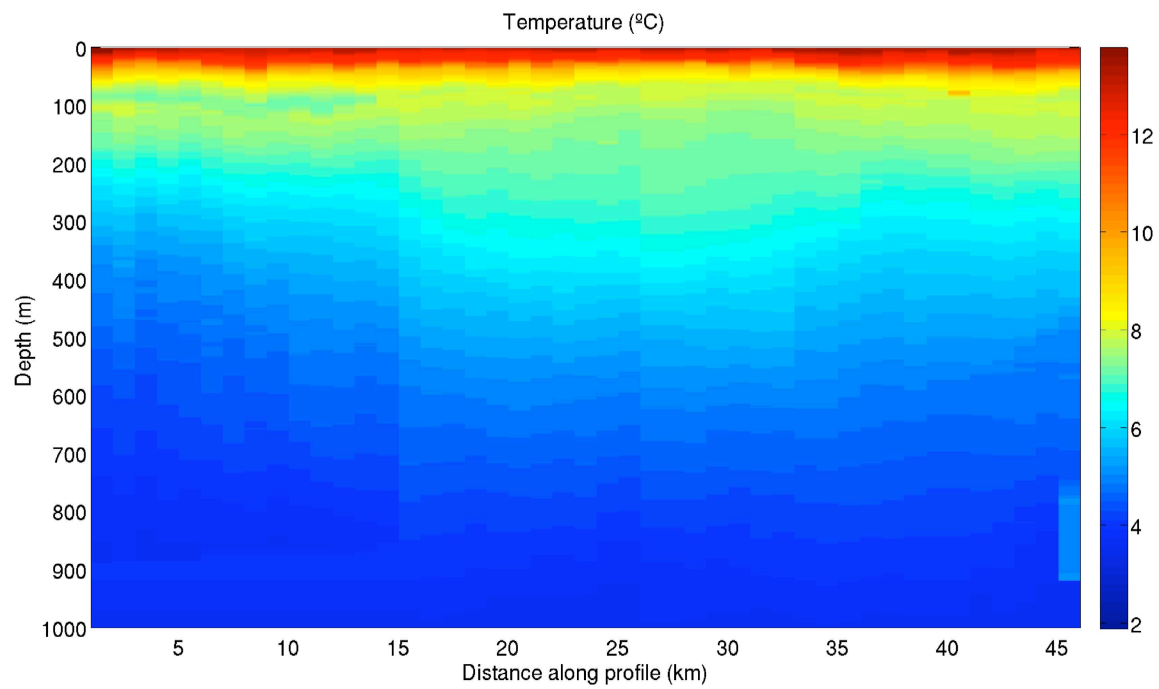


Figure 8: Temperature profile acquired along Line 1 with XBTs.

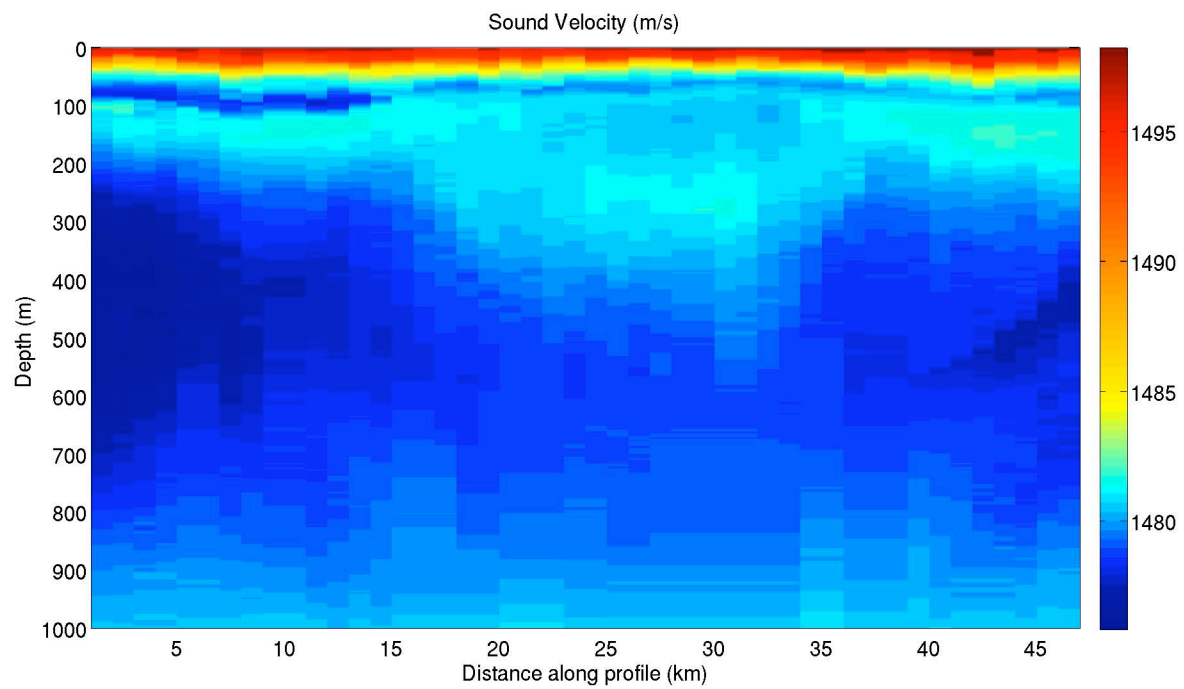
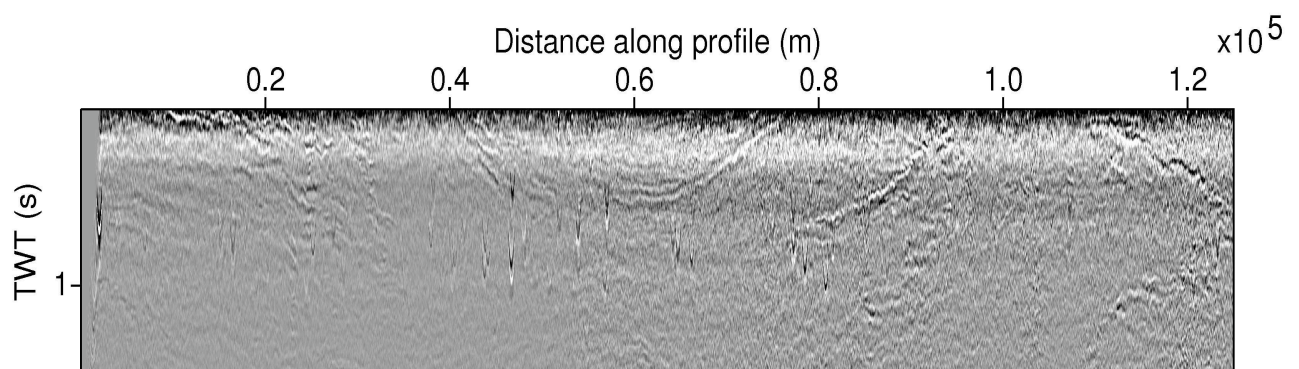


Figure 9: Sound speed profile acquired along Line 1 with XSVs.



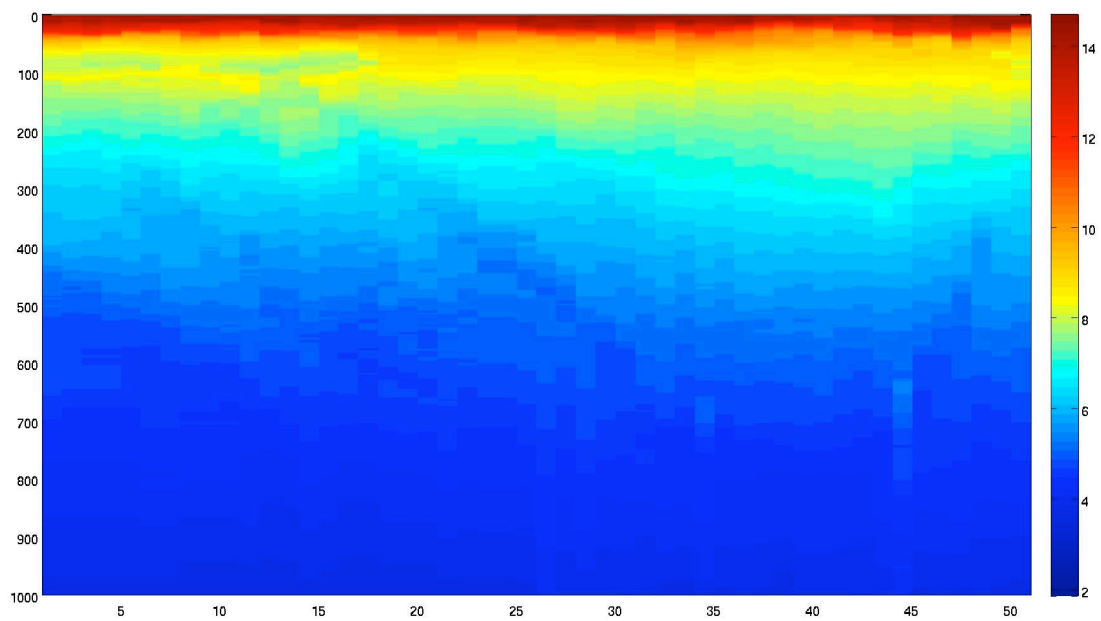


Figure 11: Temperature profile acquired along Line 3 with XBTs.

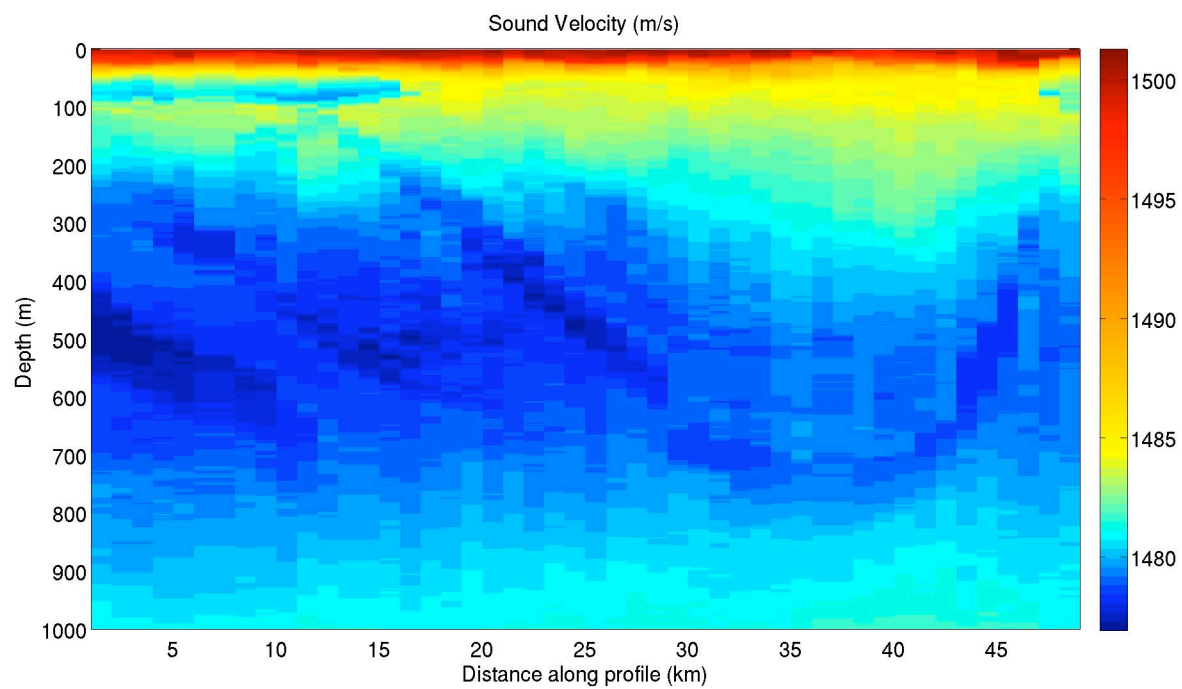
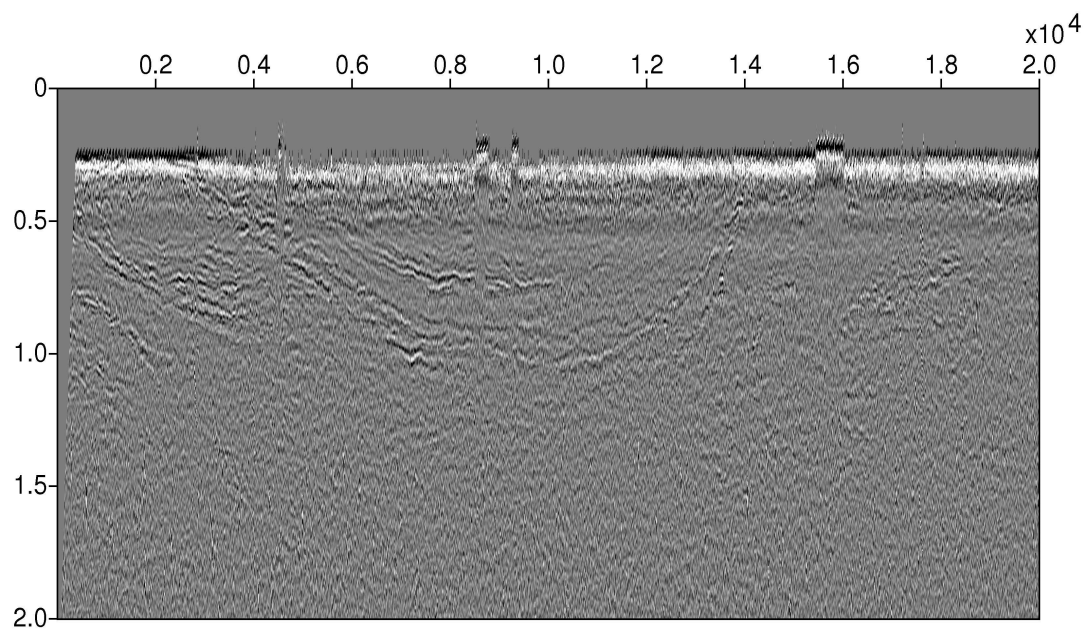


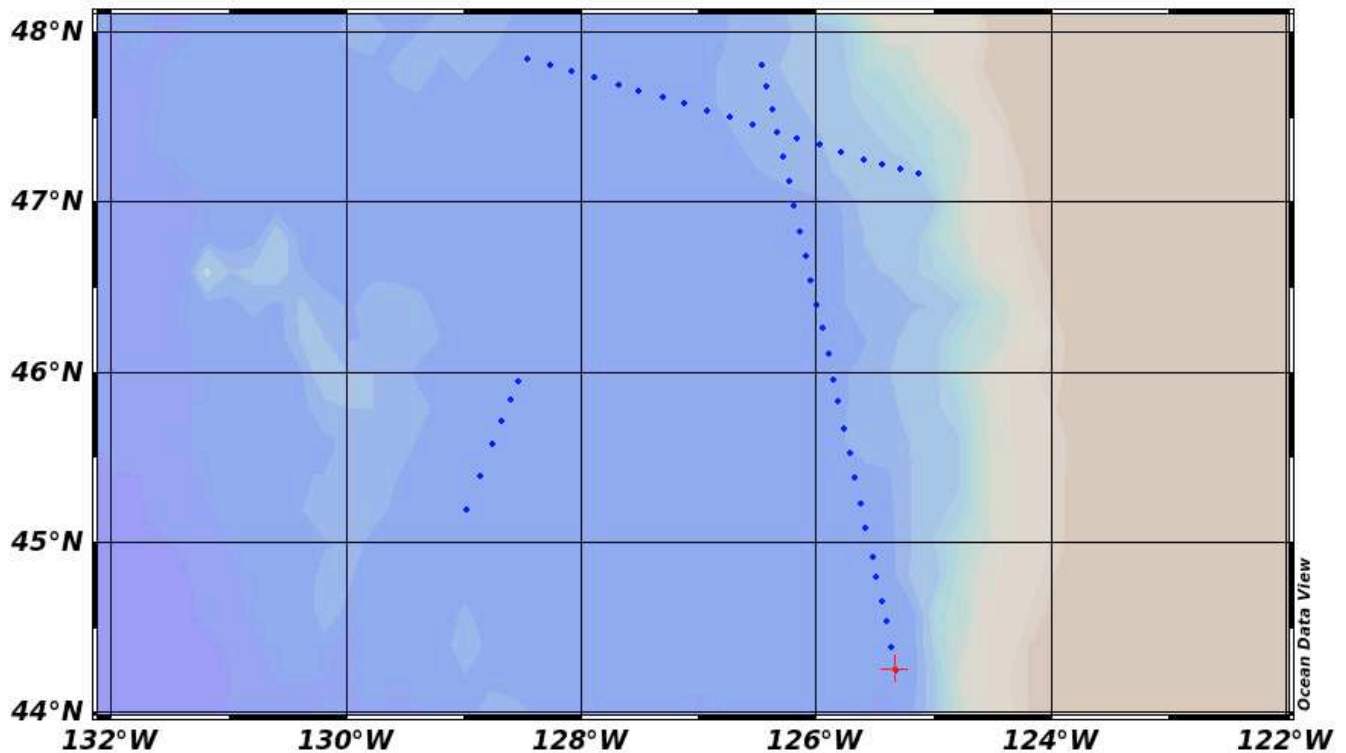
Figure 12: Sound speed profile acquired along Line 3 with XSVs.

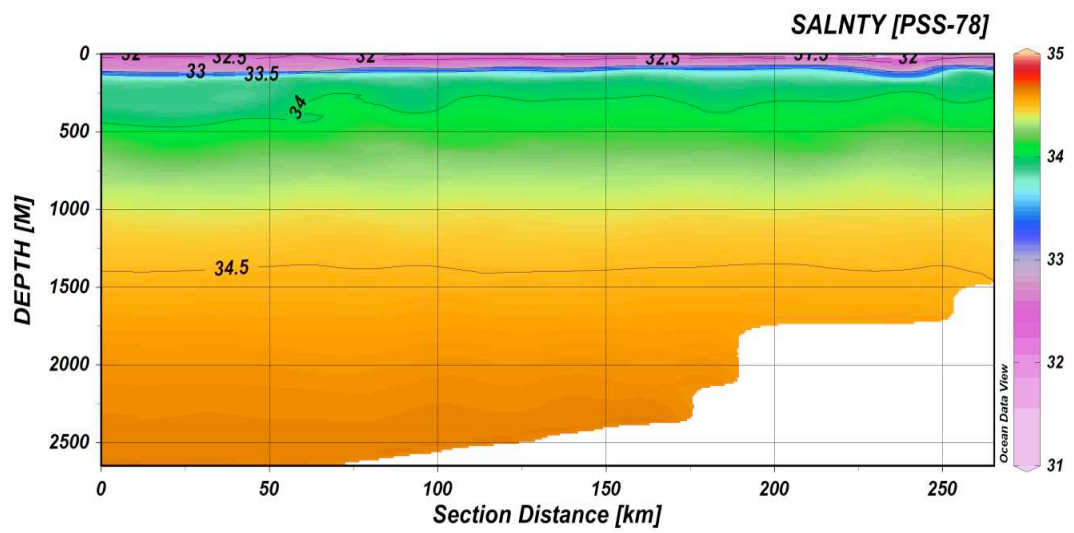
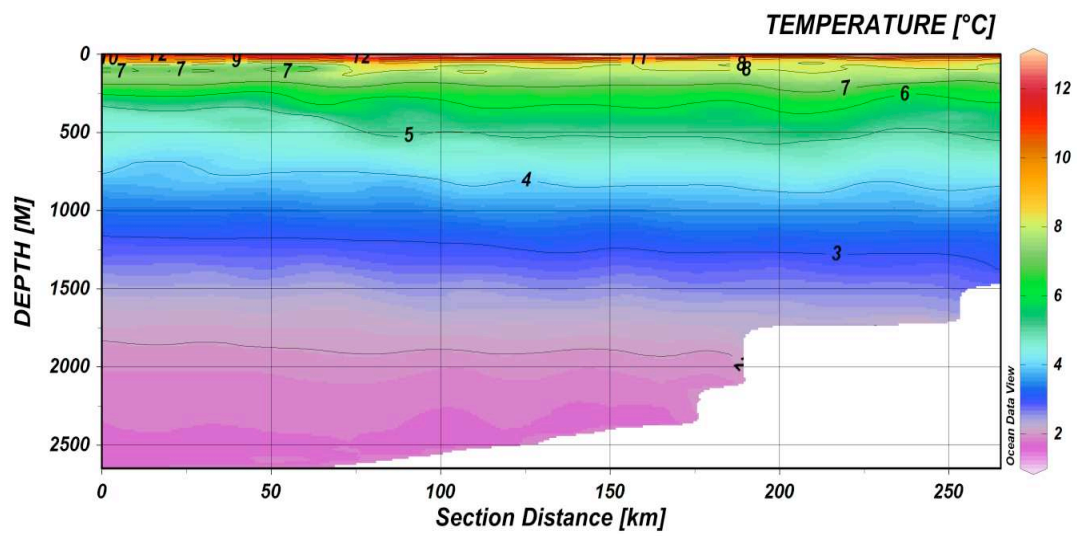


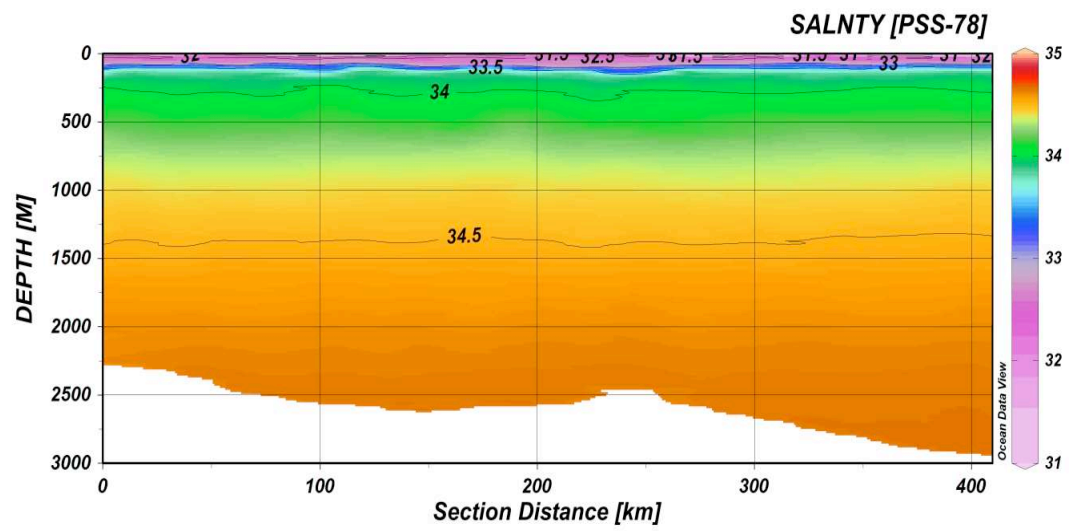
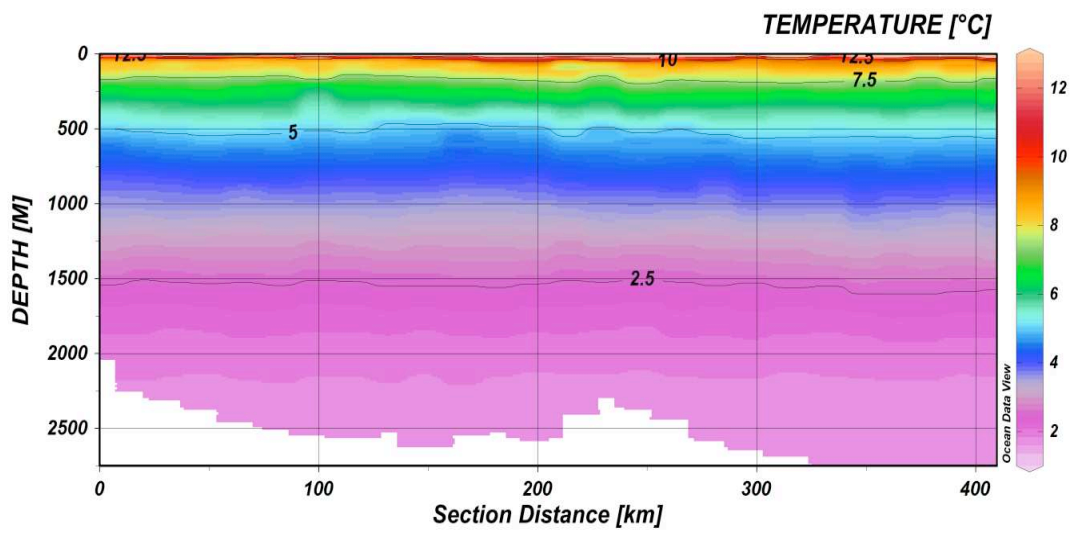
CTD data at the RV Oceanus

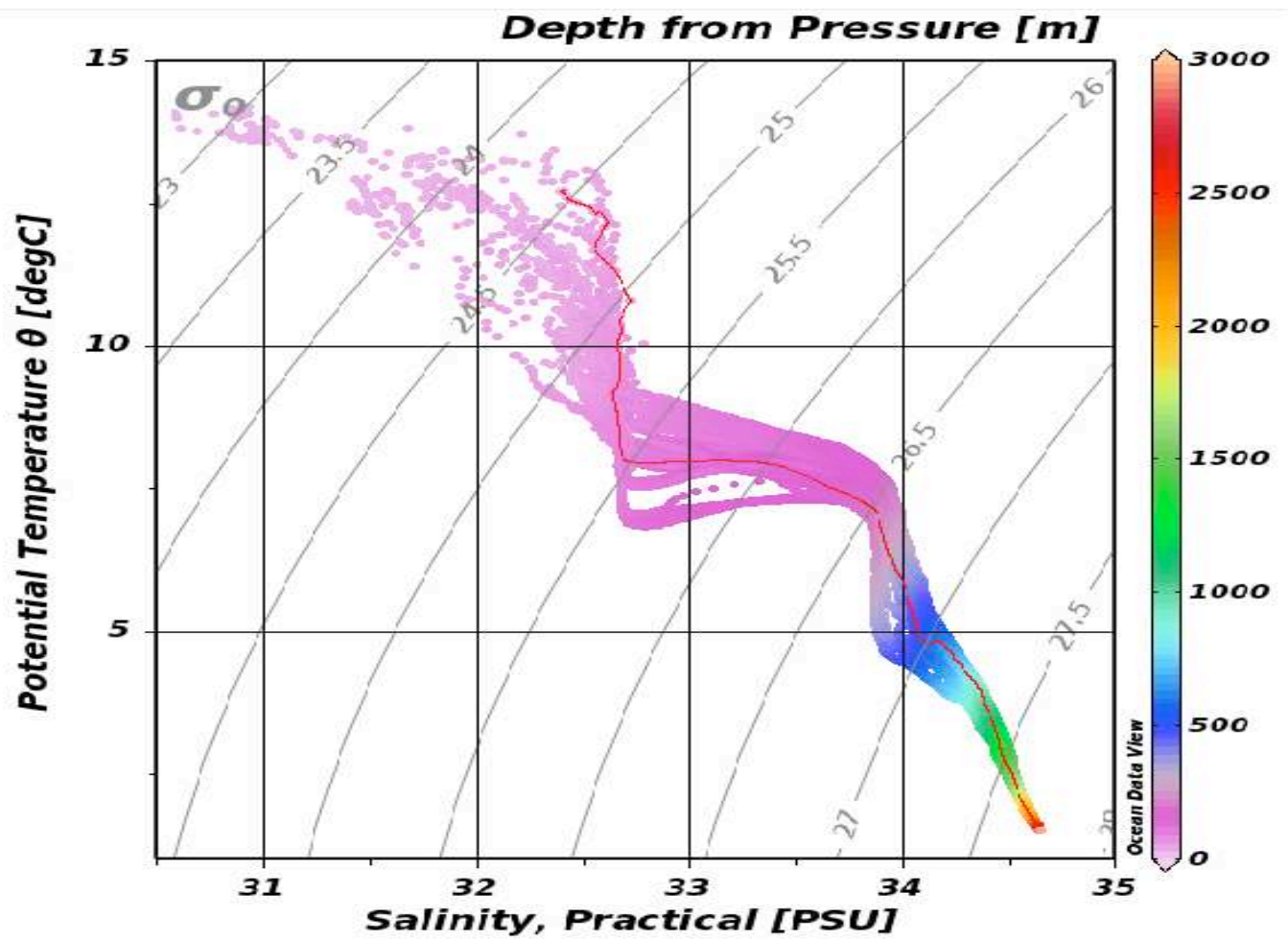
55 CTD casts were done onboard of the RV Oceanus, spatially coincident to the MCS data (Figure 14). It was used a SeaBird 911plus instrument and casts were taken on three separate lines with an approximate spacing of 15 km. The CTD acquired data from the surface until 20 m before bottom depth on all casts. The collected data was processed using SBEDataProcessing software, following standard procedures for the program.

Temperature and salinity profiles of Line 2 and Line 3 are shown in Figures 15, 16, 17 and 18. Finally the TS diagram plotted from the CTD data is displayed in Figure 19. The different water masses in the Cascadia Basin can be identified on the TS diagram. The surface water is displayed at the top of the diagram with salinity between 31-32.8 and below that there is a steep halocline from 32.8-33.9 at a depth interval of 8515 m to 20050 m. The water below the halocline monotonically increases with salinity and temperature. Below 1900 m there is very little change in the water column. This transition is between intermediate water and the Cascadia Bottom Deep Water, roughly marked at a potential density of 27.6. The TS data will be used to infer a T-S relationship for the area through Neural Networks (Kormann et al., 2011), this T-S relationship is needed for the derivation of temperature and salinity profiles from the inverted sound speed data.









Bibliography

- Biescas, B., Sallarès, V., Pelegrí, J., Machín, F., Carbonell, R., Buffett, G., Dañobeitia, J., Calahorrano, A., 2008. Imaging meddy finestructure using multichannel seismic reflection data. *Geophysical Research Letters* 35, L11609.
- Buffett, G., Biescas, B., Pelegrí, J., Machín, F., Sallarès, V., Carbonell, R., Klaeschen, D., Hobbs, R., 2009. Seismic reflection along the path of the Mediterranean Undercurrent. *Continental Shelf Research* 29, 1848–1860.
- Checkley, D. M., Barth, J. A., 2009. Patterns and processes in the California current system. *Progress in Oceanography* 83, 49–64.
- Hautala, S., Johnson, H., Bjorklund, T., 2005. Geothermal heating and the properties of bottom water in Cascadia basin. *Geophysical Research Letters* 32, L06608.
- Holbrook, W., Páramo, P., Pearce, S., Schmitt, W., 2003. Thermohaline fine structure in an oceanographic front from seismic reflection profiling. *Science* 301, 821–824.
- Kormann, J., Biescas, B., Korta, N., de la Puente, J., Sallarès, V., 2011. Application of acoustic full wave from inversion to retrieve high-resolution temperature and salinity profiles from synthetic seismic data. *Journal of Geophysical Research* 116, C11039.
- Kurian, J., Colas, F., Capet, X., McWilliams, C., Chelton, D. B., 2011. Eddy properties in the "California current system". *Journal of Geophysical Research* 116, C08027.
- Papenberg, C., Klaeschen, D., Krahmann, G., Hobbs, R., 2010. Ocean temperature and salinity inverted from combined hydrographic and seismic data. *Geophys. Res. Lett.* 37, L04601.
- Thomas, A., Weatherbee, R., 2006. Satellite-measured temporal variability of the "Columbia River" plume. *Remote Sensing of Environment* 100, 167–178.

APPENDIX 11: Summary of Logs Provided by Shipboard Technical Staff Documenting Operations

SSP_Carbotte_Rev6.docx: Science Support Plan prepared prior to cruise

MGL1211_DataReport.doc: Summary Data Report

MGL1211_Offsets (version 2).xls: Includes documentation of streamer/gun config and offsets for seismic operations

MGL1211 Seismic Configuration by Sequence Acquired

MGL1211_B15_line_log.xls: Summary Seismic line Log

MGL1211_Navlog-S00*.xls: Navigation Logs – One file per line

MGL1211_Obs_Log_s00*.xls: Observer Logs – One file per line

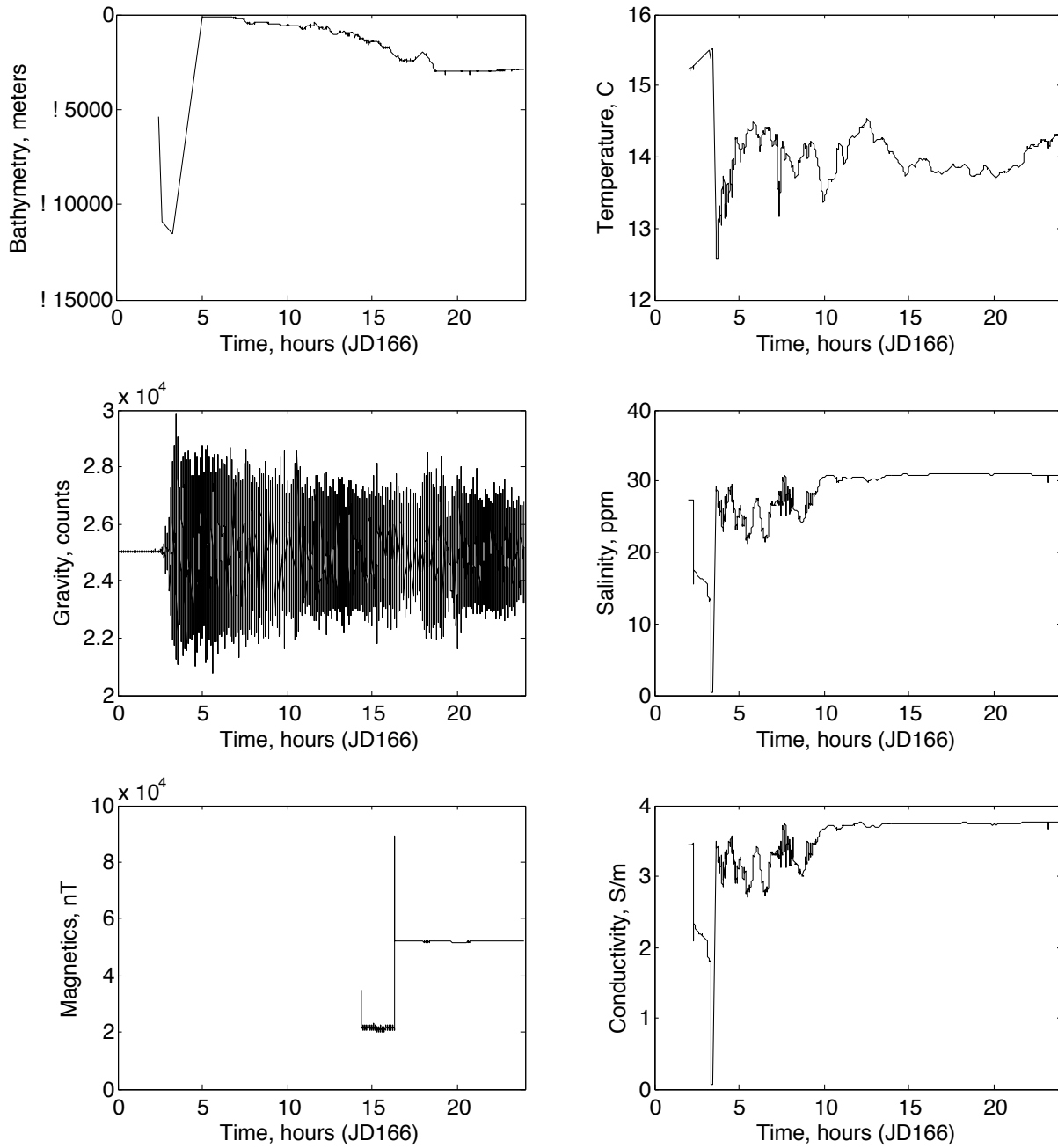
MGL1211_Production_book_V1.xlsx –Summary of Production Time, Equipment Maintenance, Mitigation etc for cruise

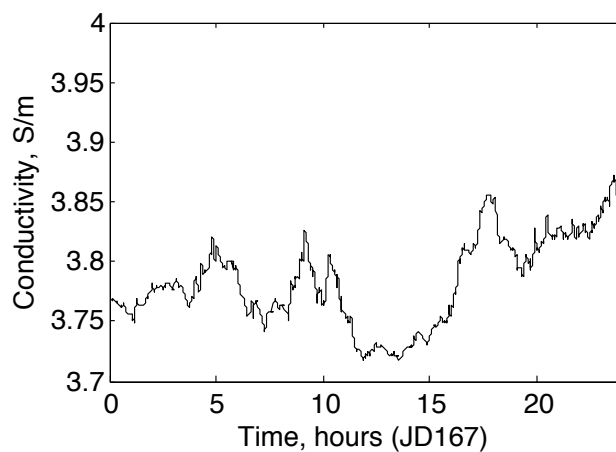
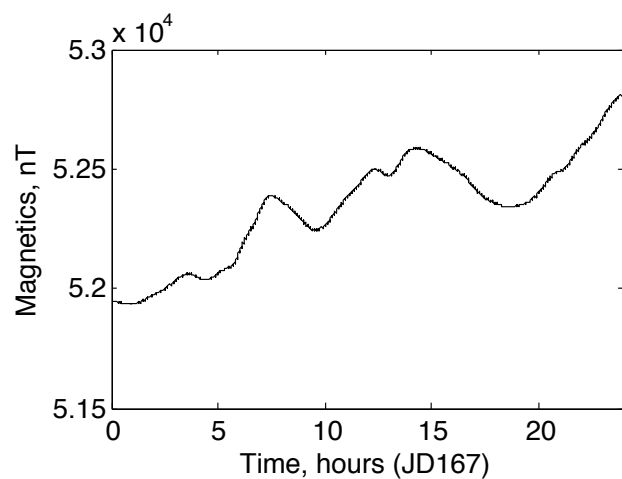
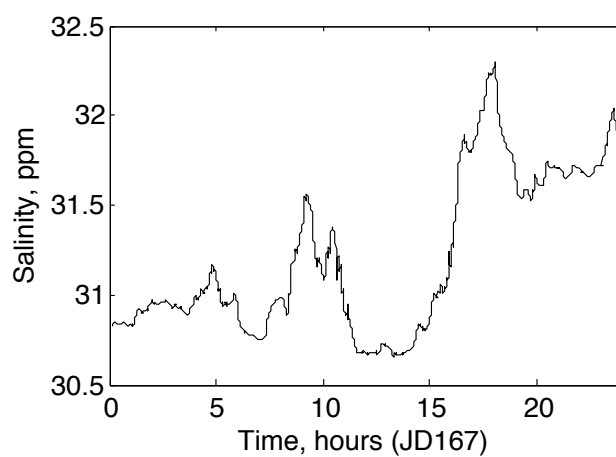
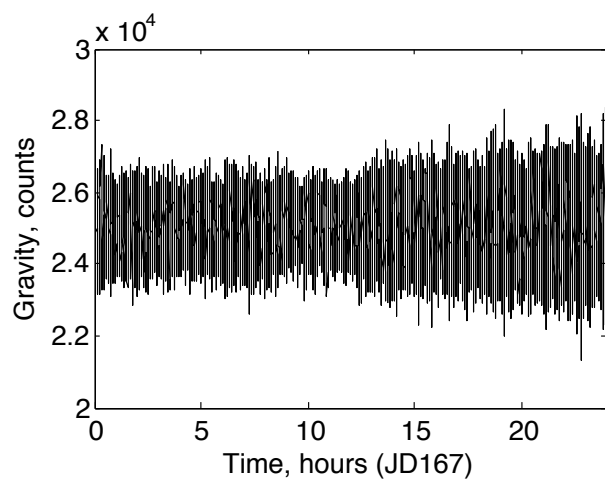
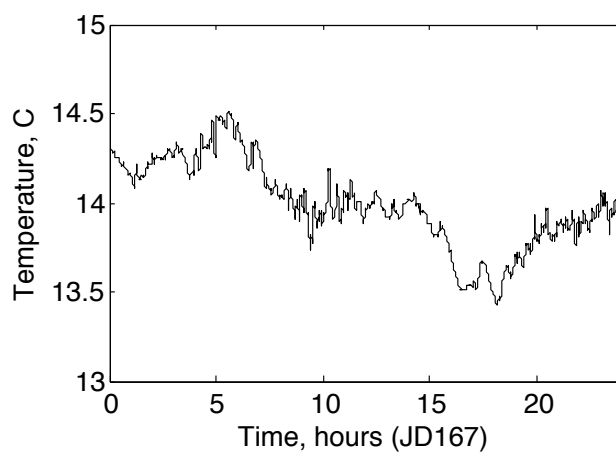
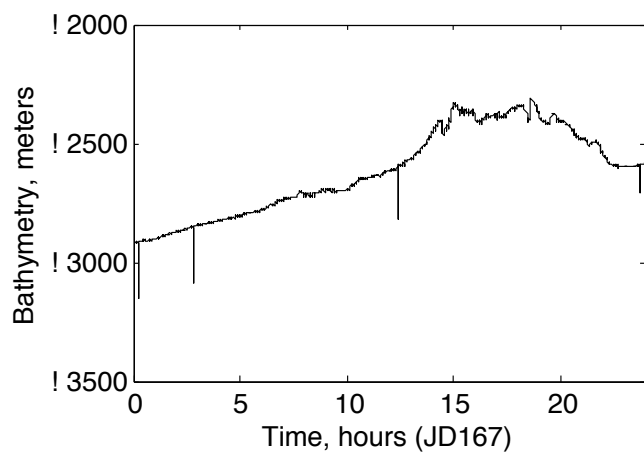
MGL1211_Expendable_Drops.xls: Summary of XBT casts

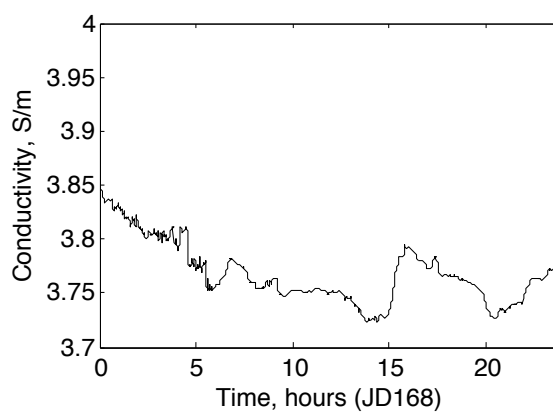
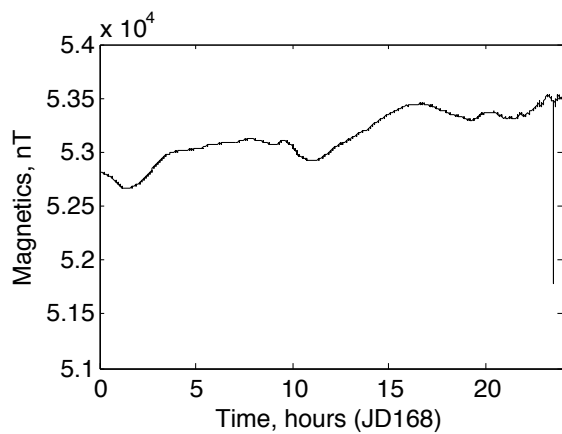
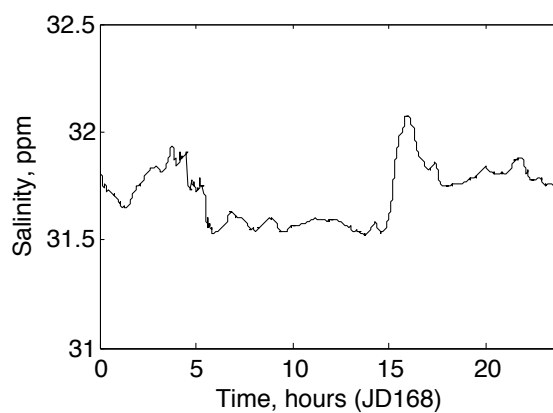
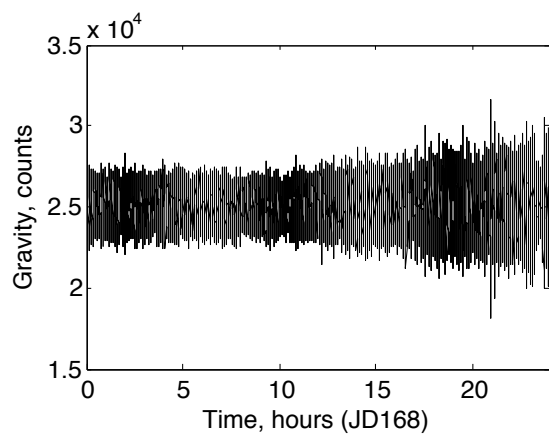
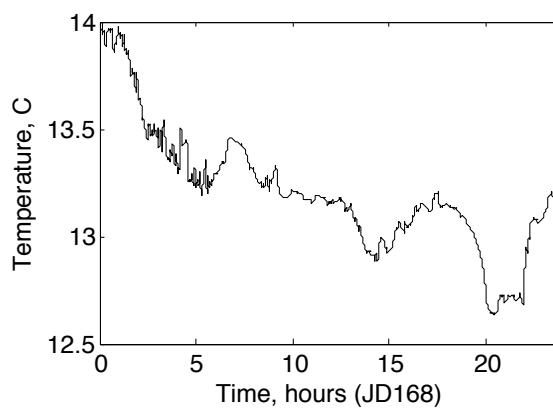
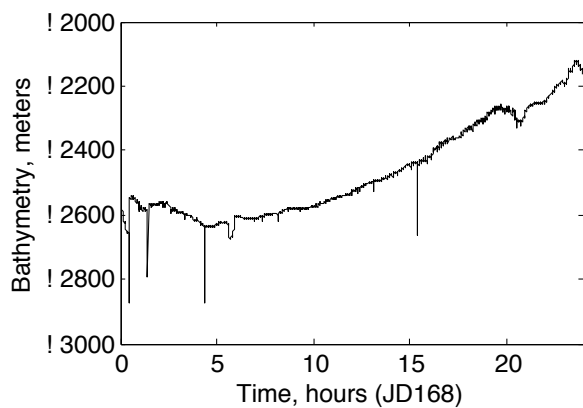
MGL1211_30min_Log.xls: 30 minute log for duration of cruise

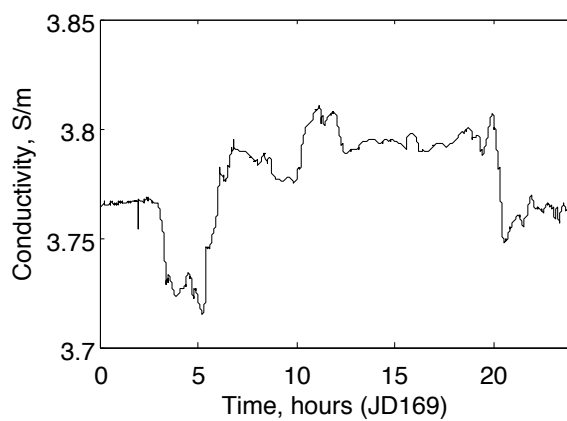
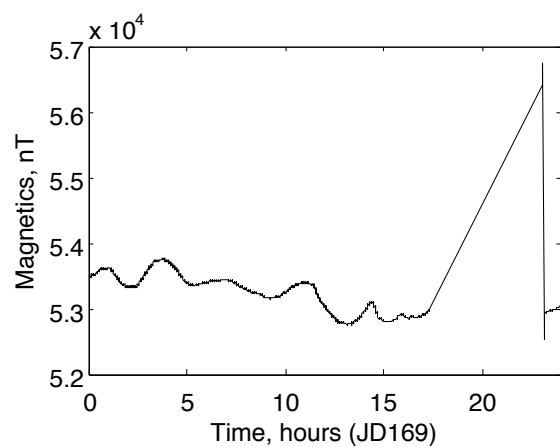
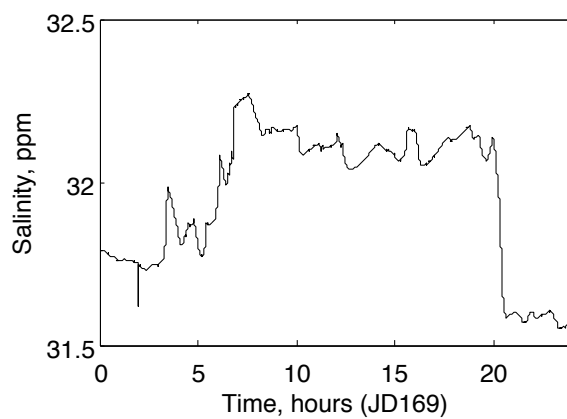
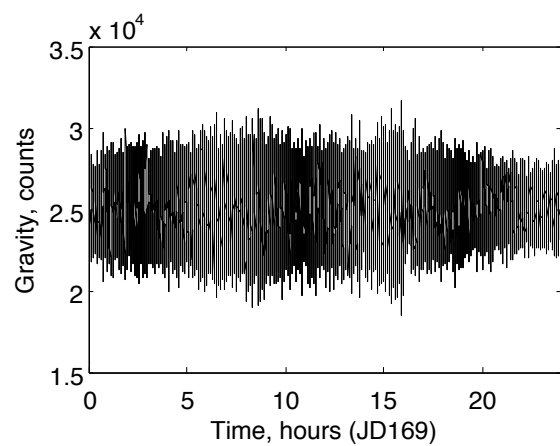
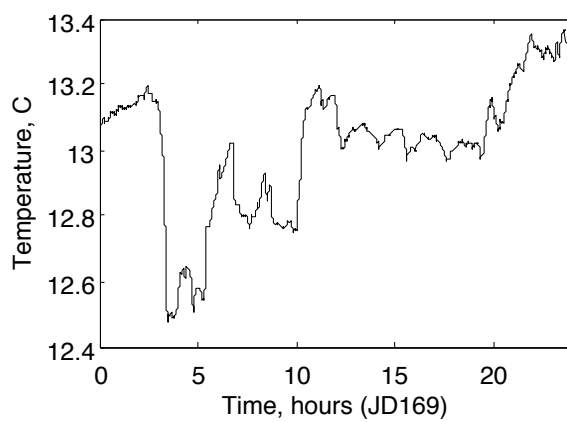
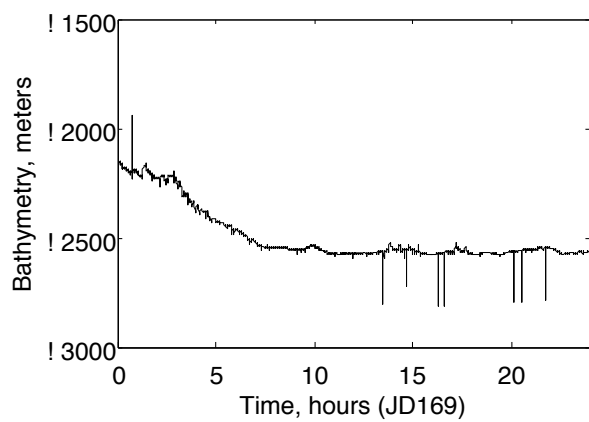
MGL1211_pre-cruise_Astoria.pdf: Gravity Tie conducted in Astoria prior to cruise

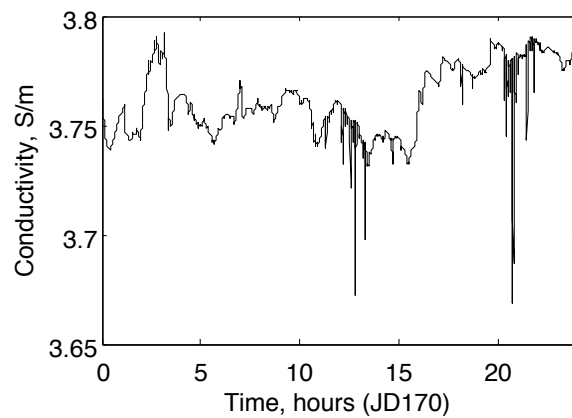
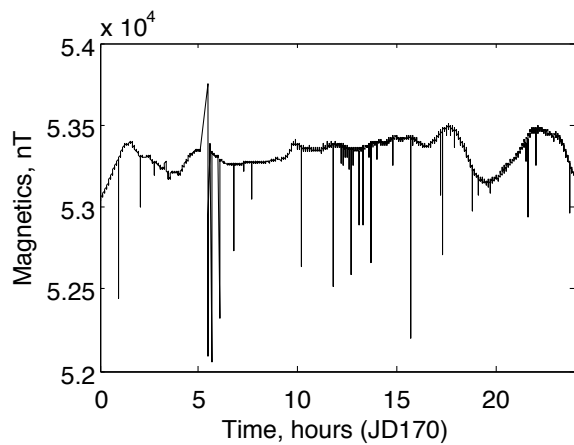
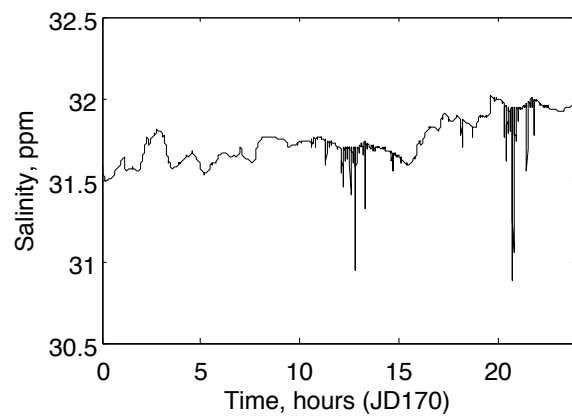
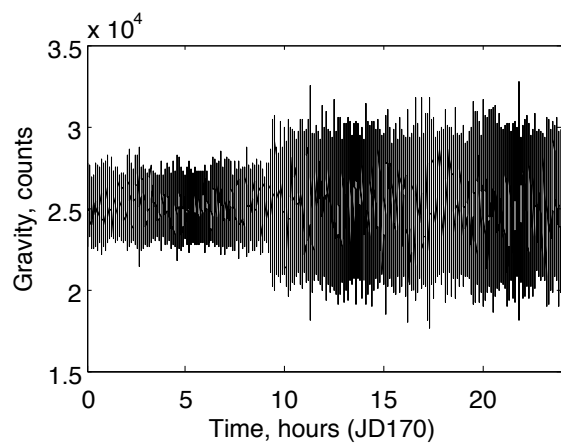
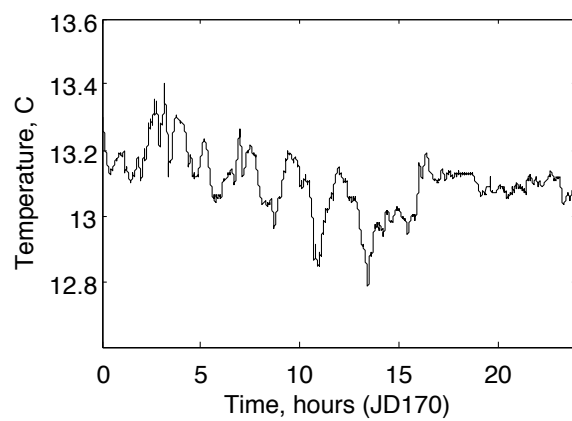
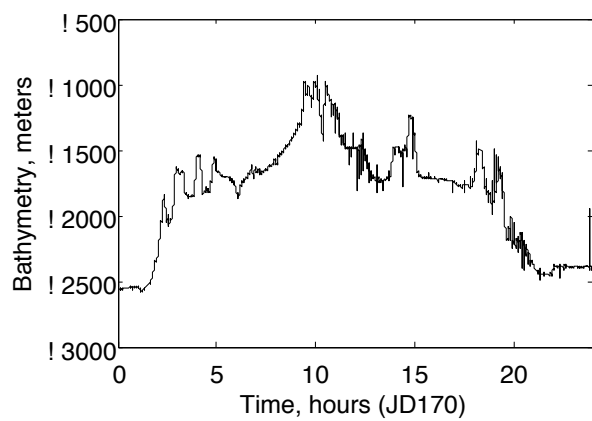
APPENDIX 12: Day Plots of Serial Data

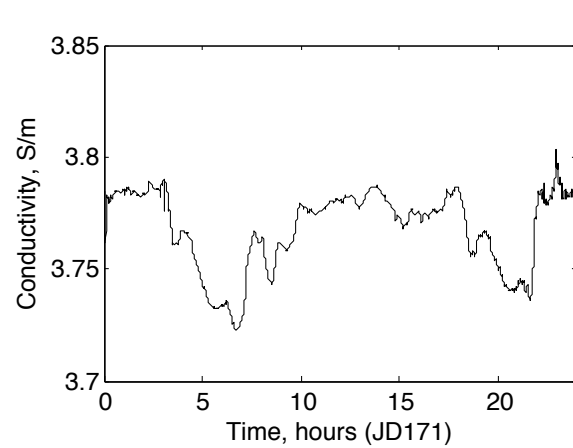
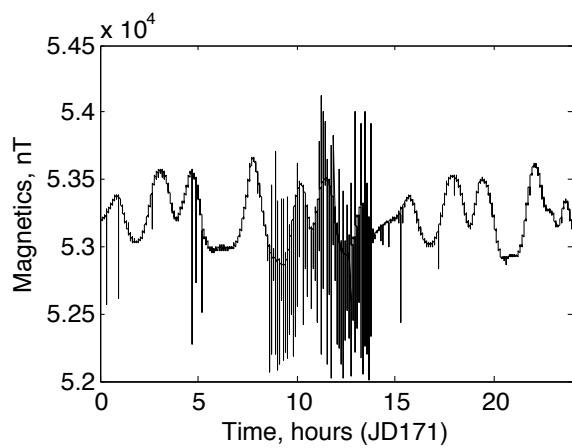
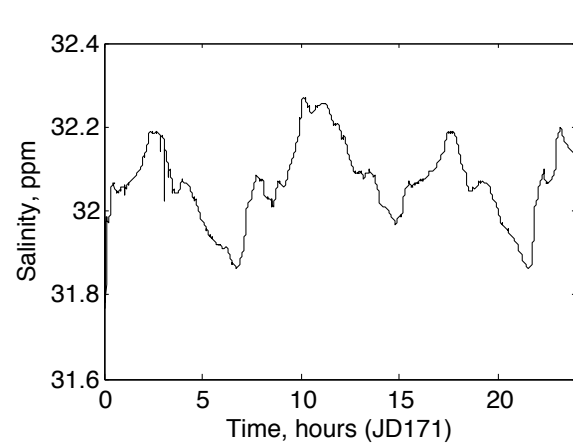
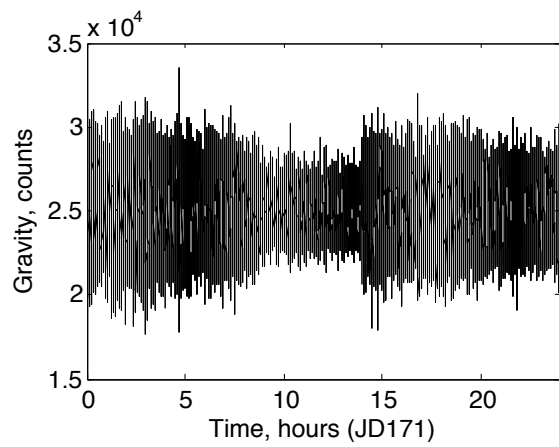
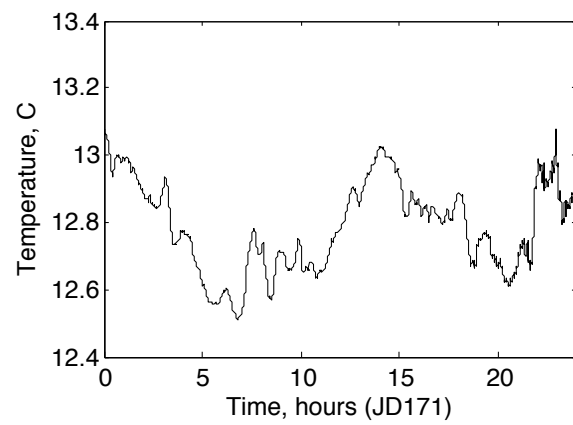
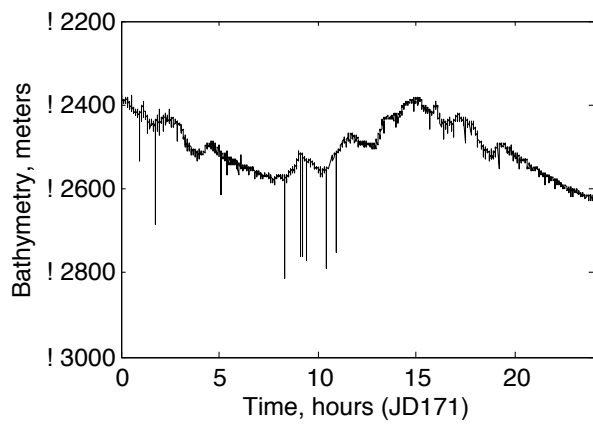


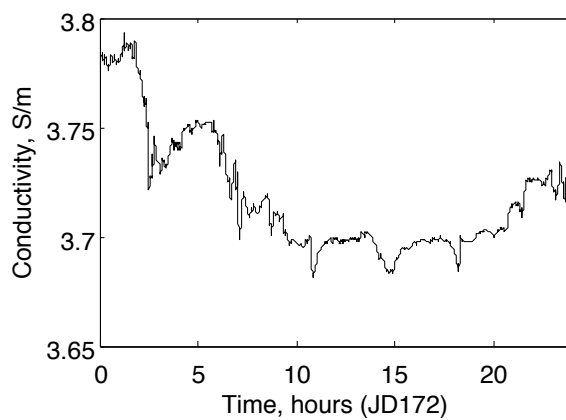
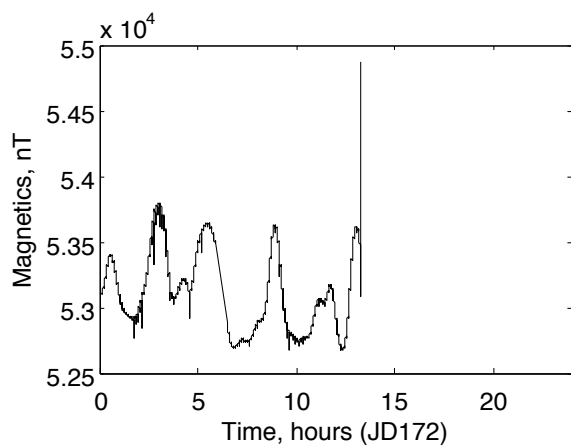
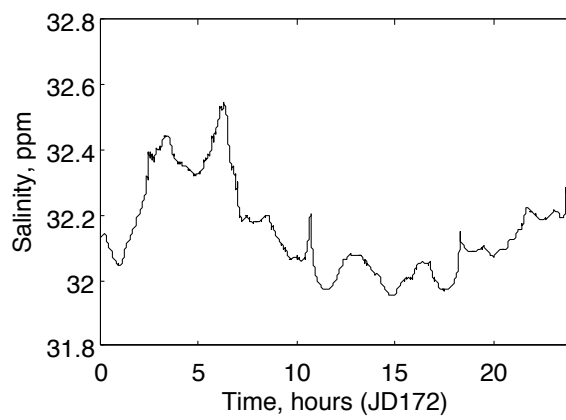
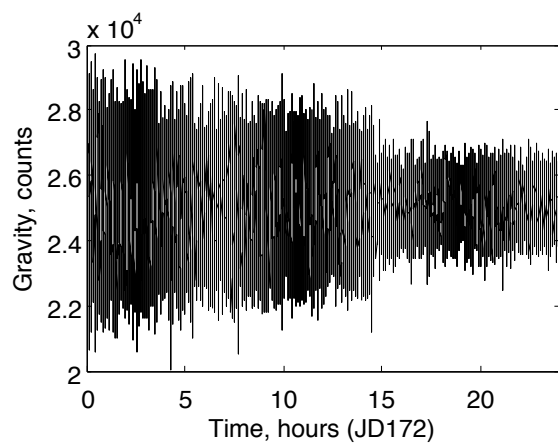
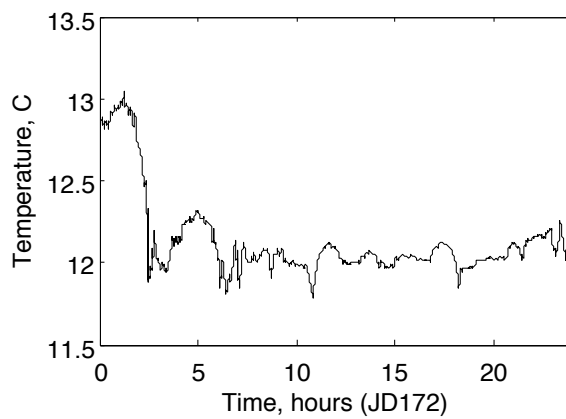
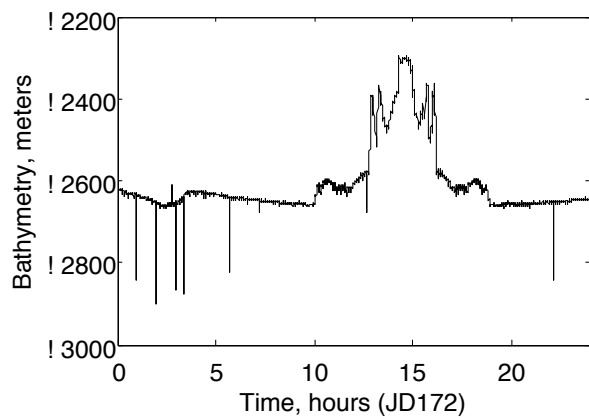


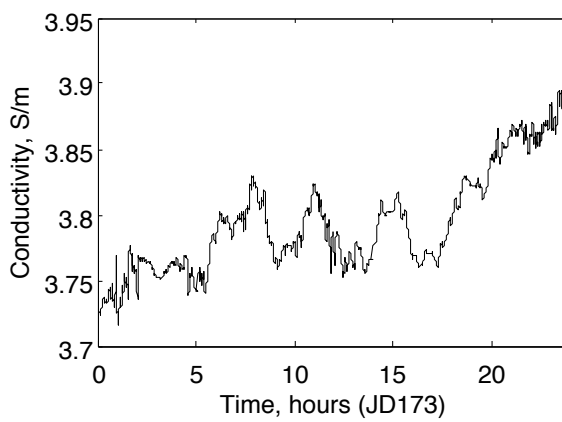
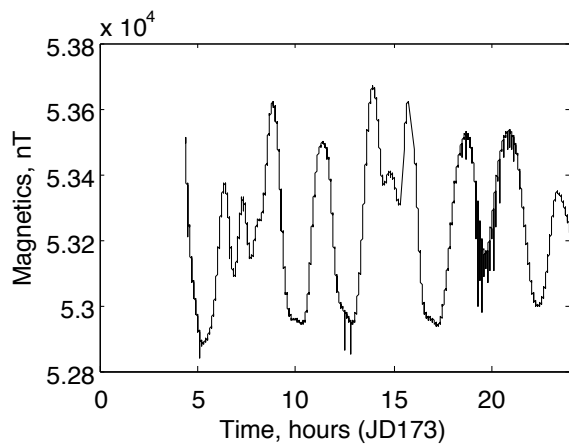
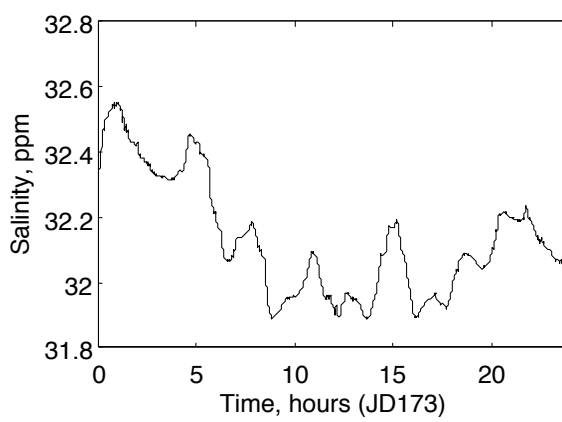
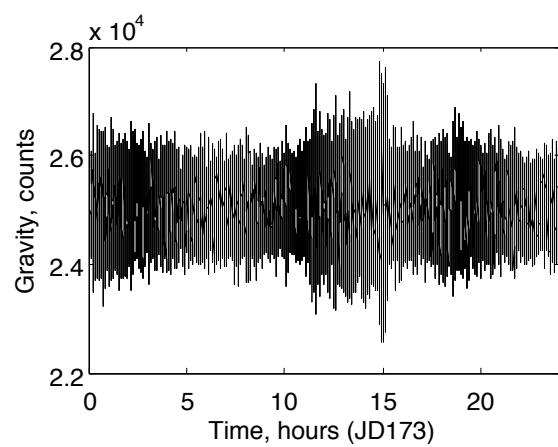
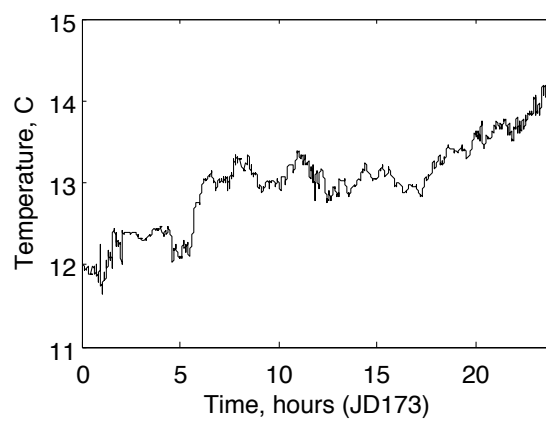
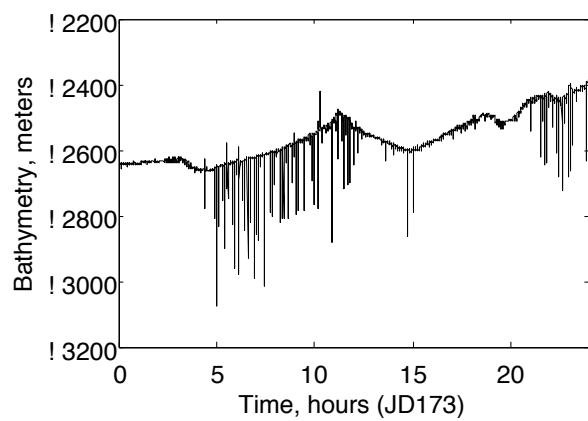


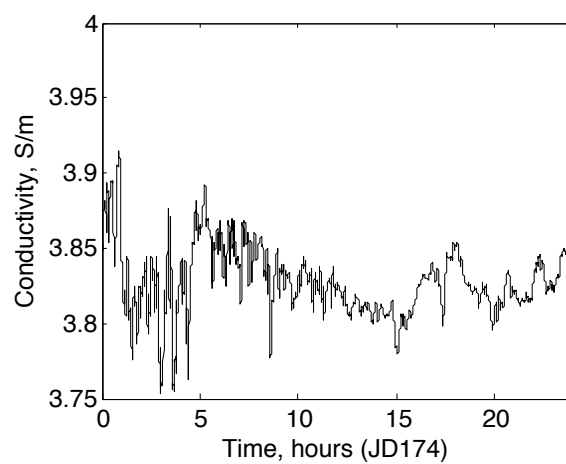
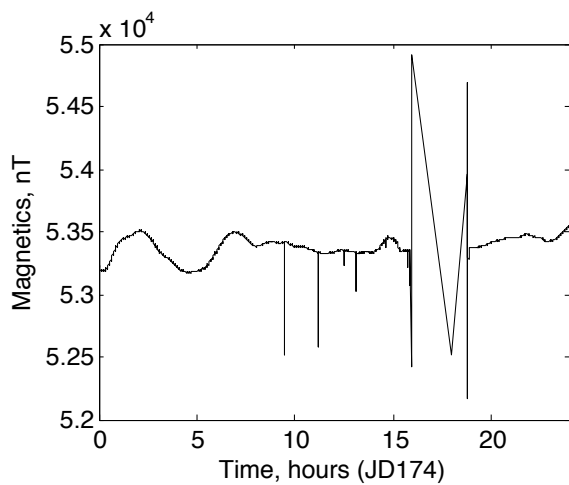
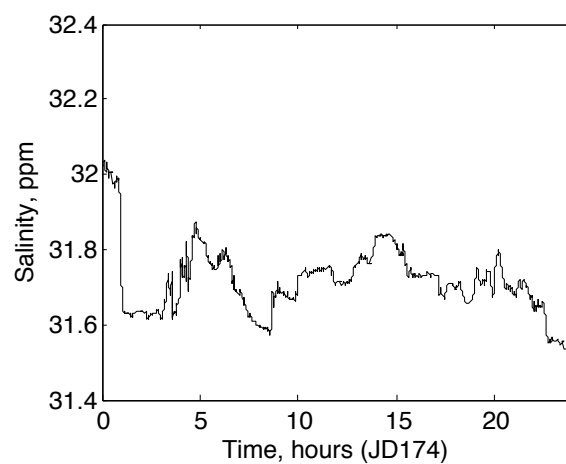
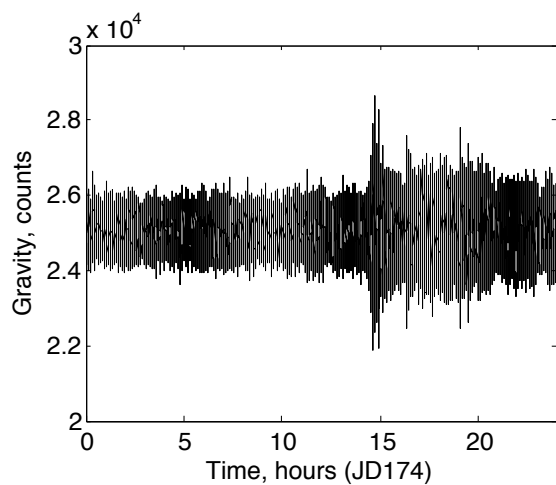
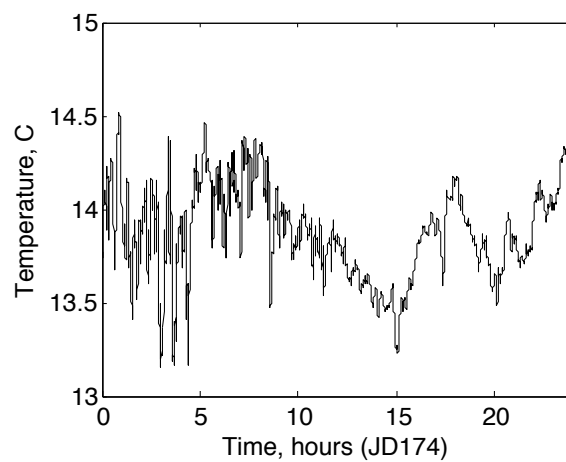
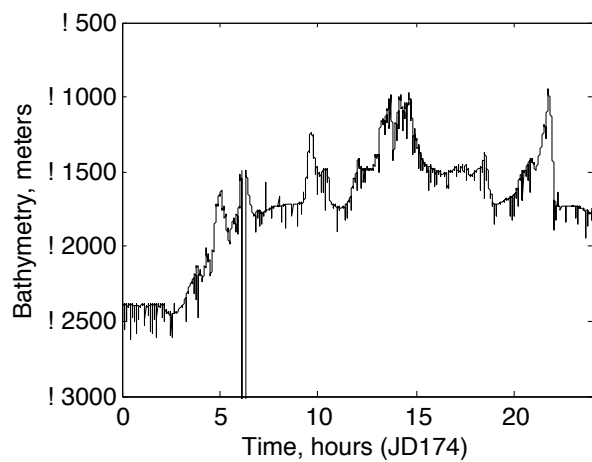


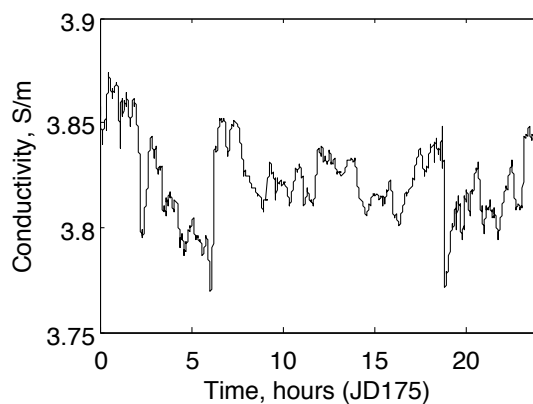
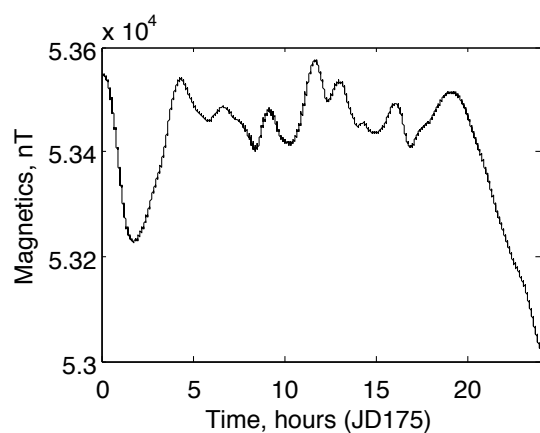
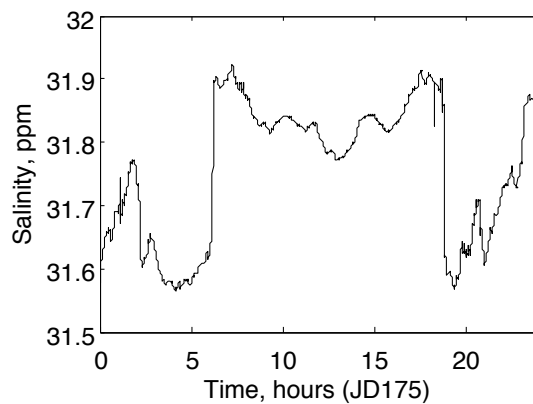
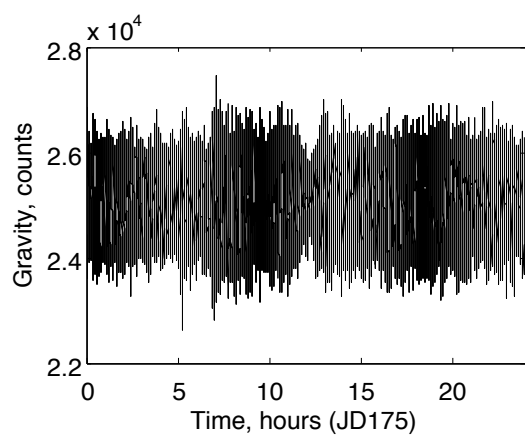
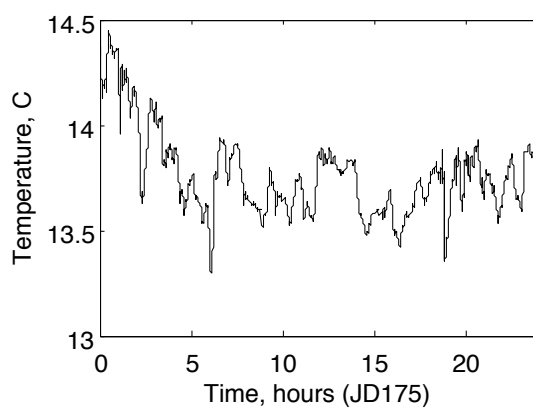
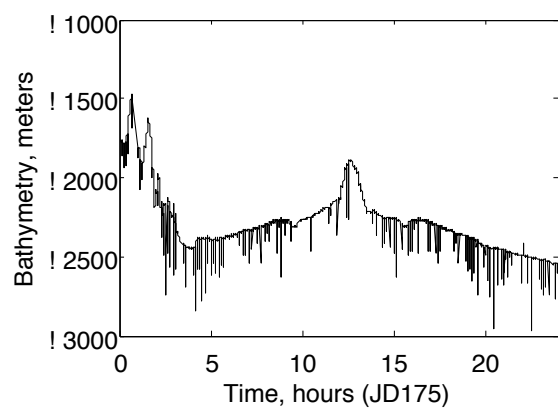


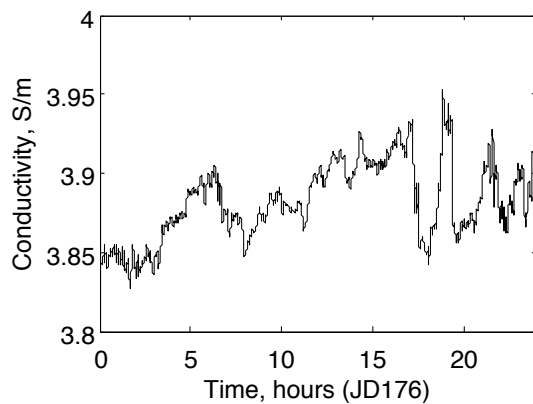
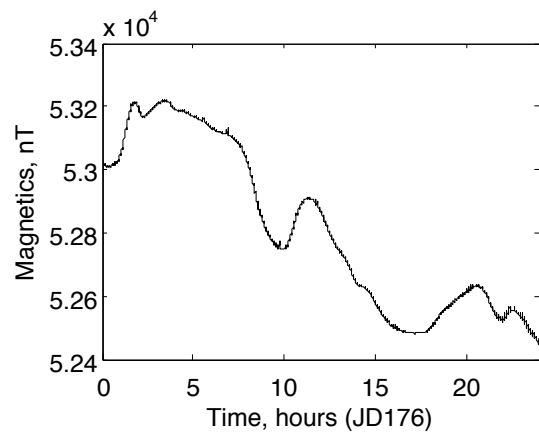
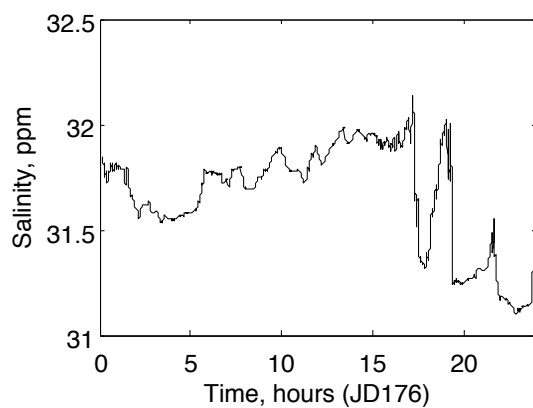
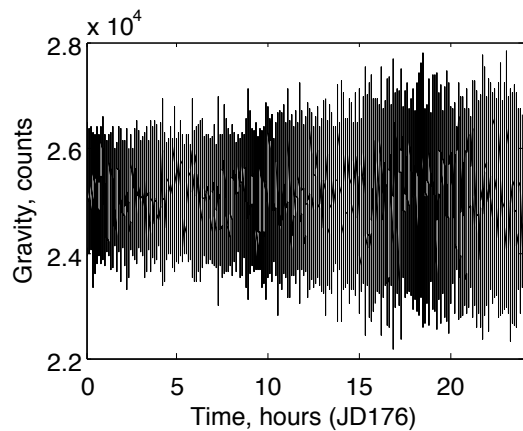
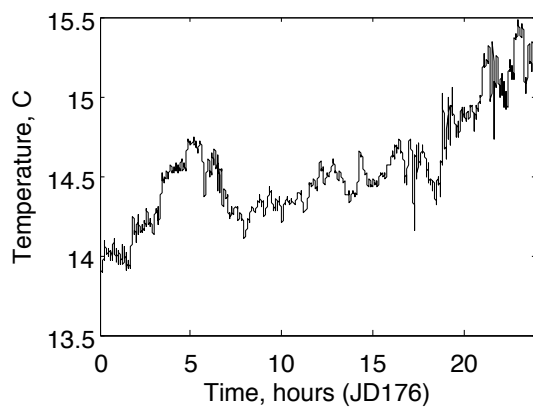
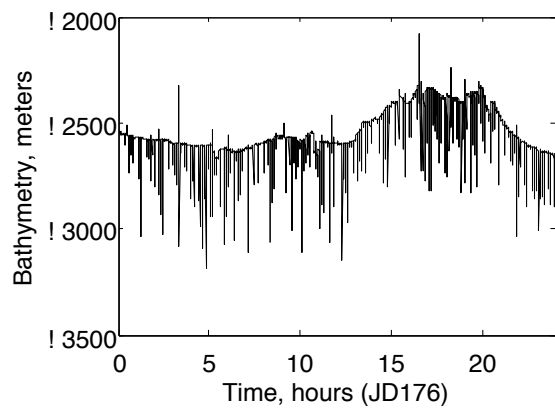


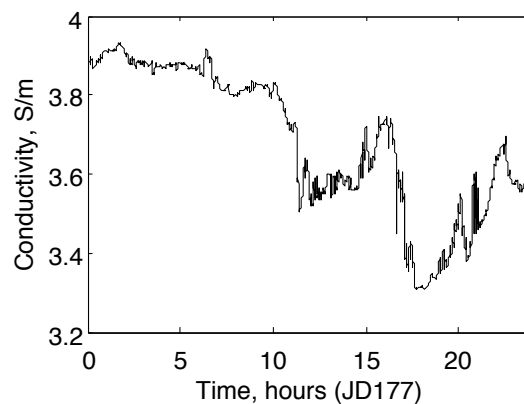
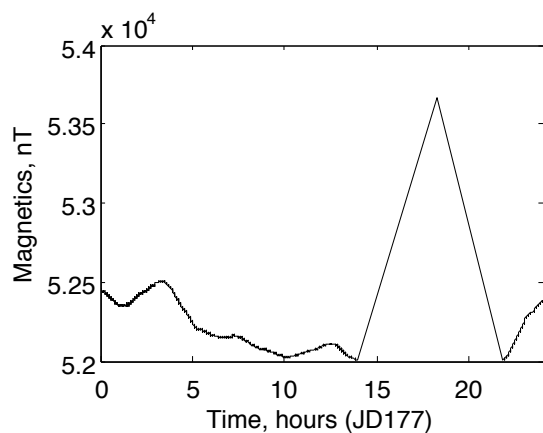
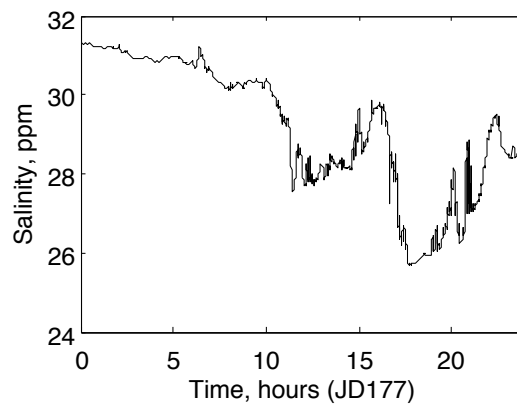
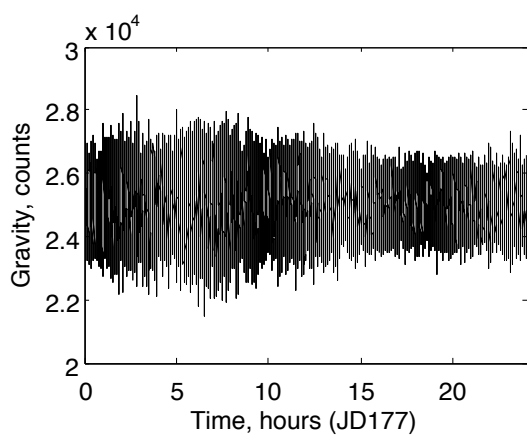
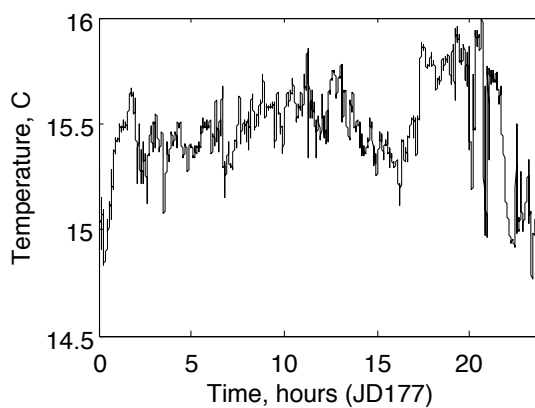
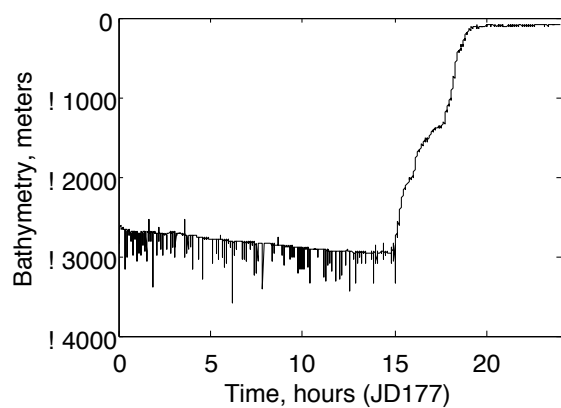


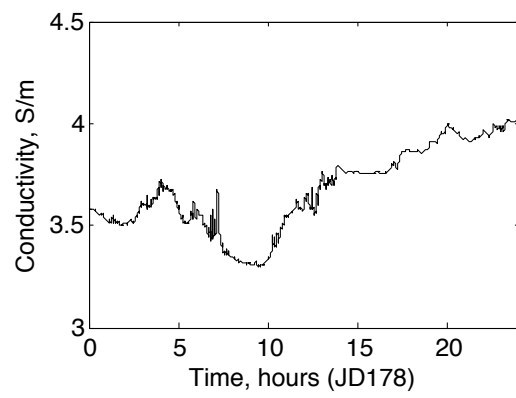
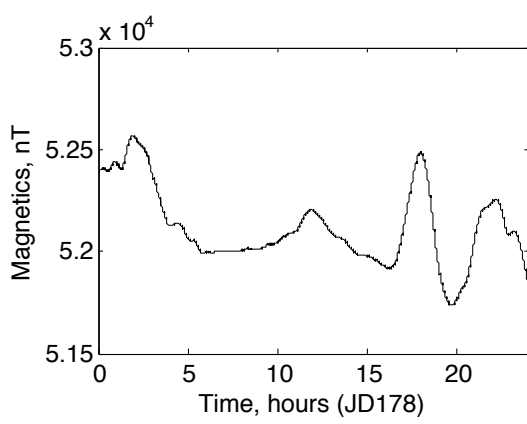
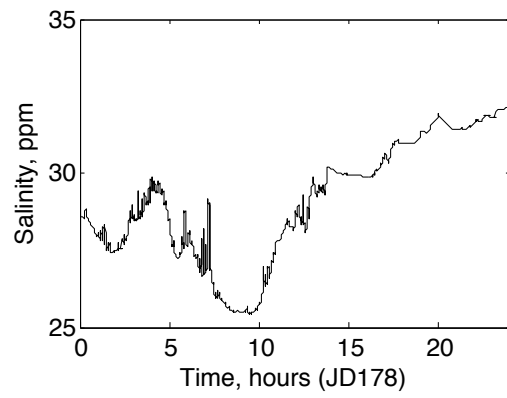
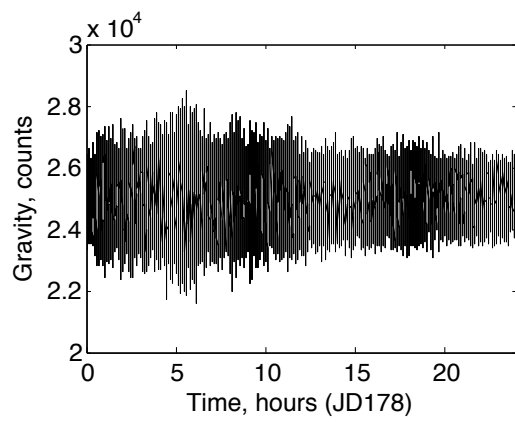
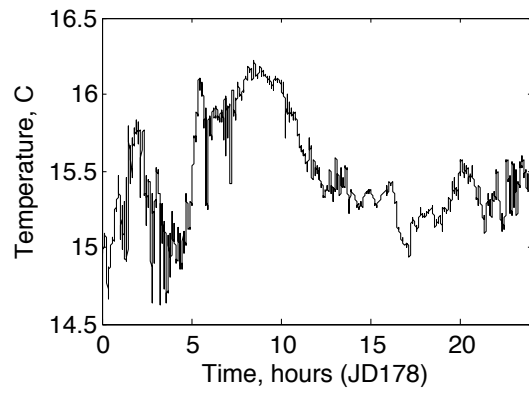
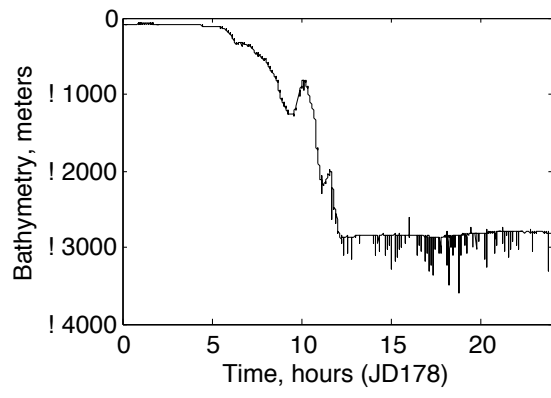


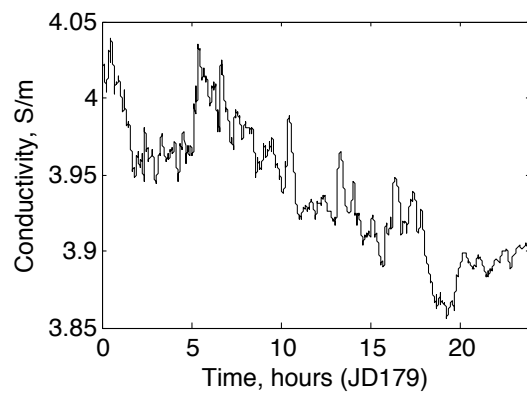
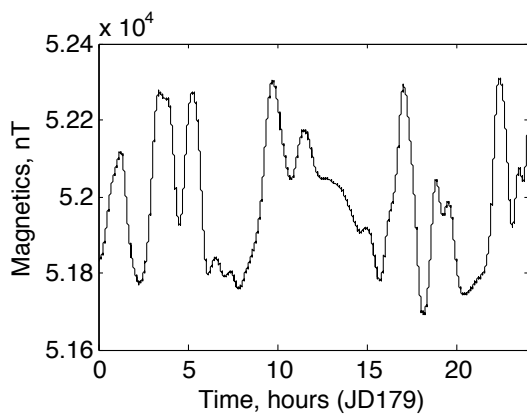
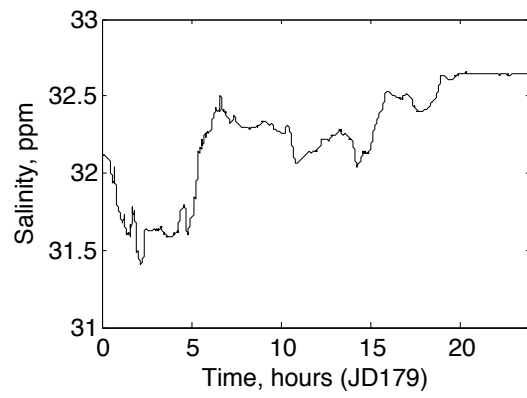
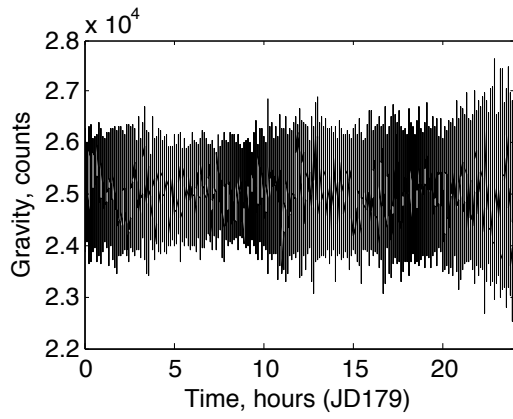
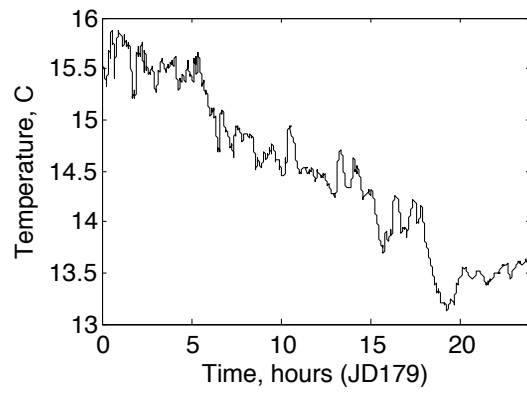
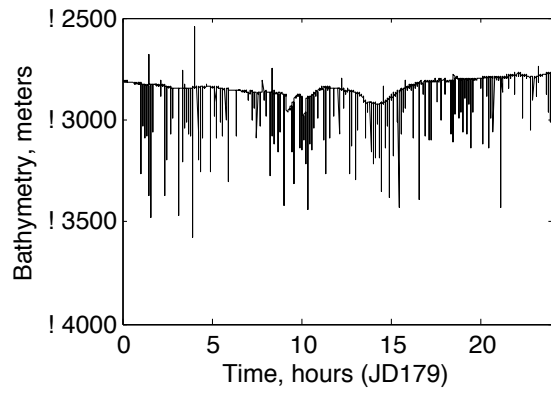


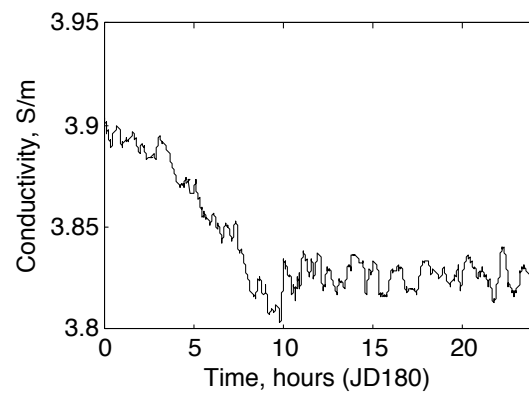
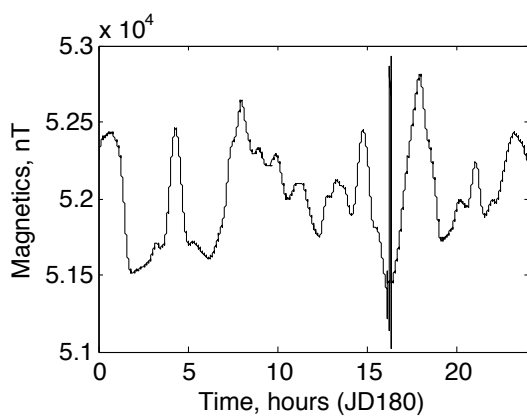
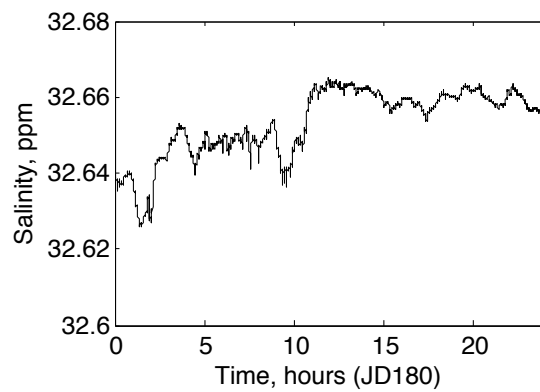
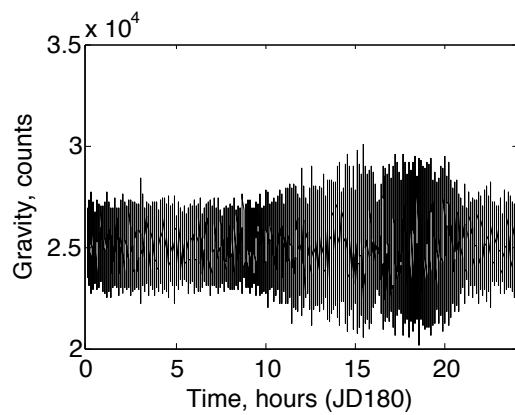
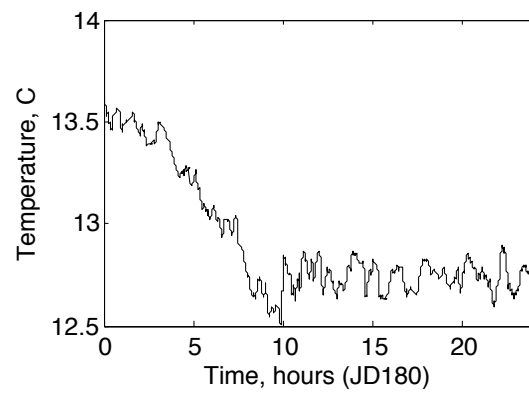
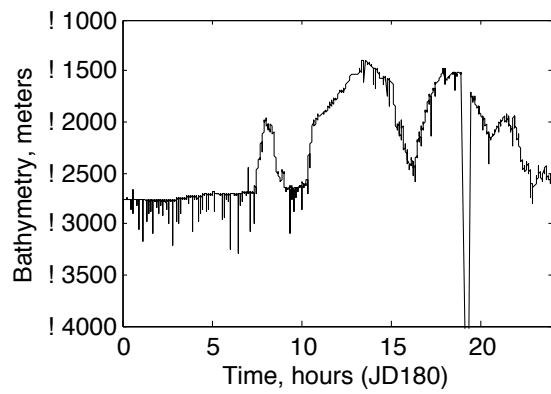


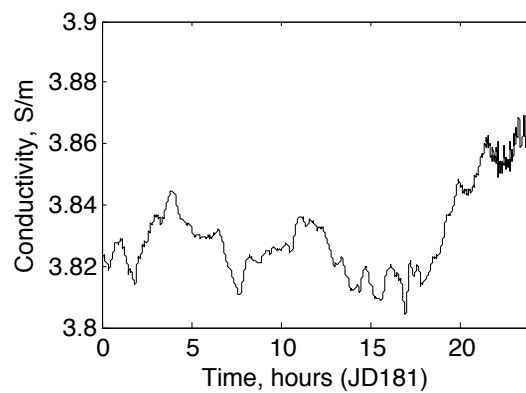
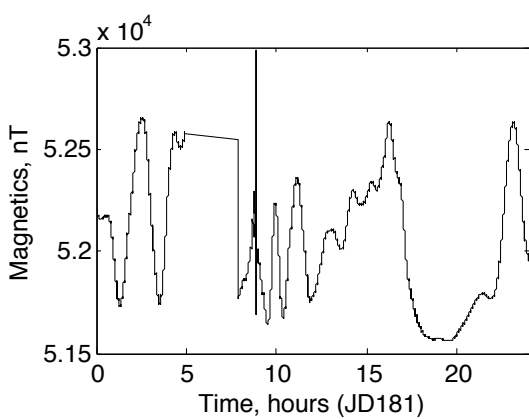
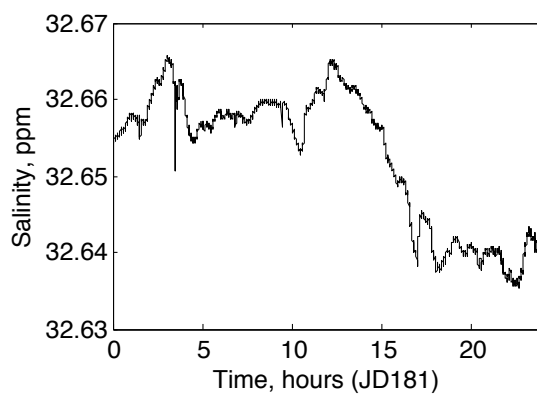
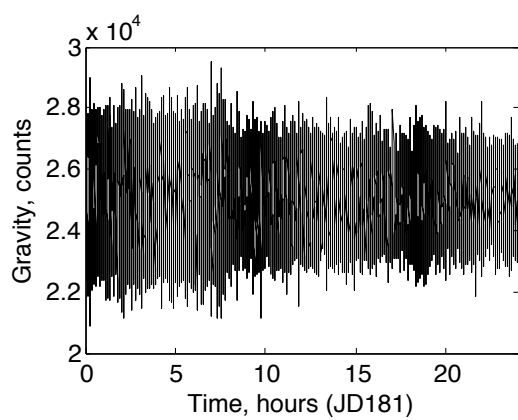
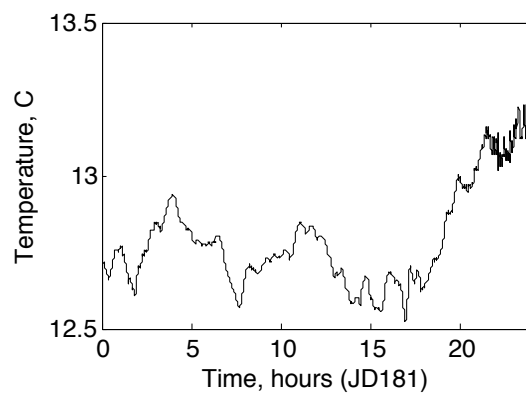
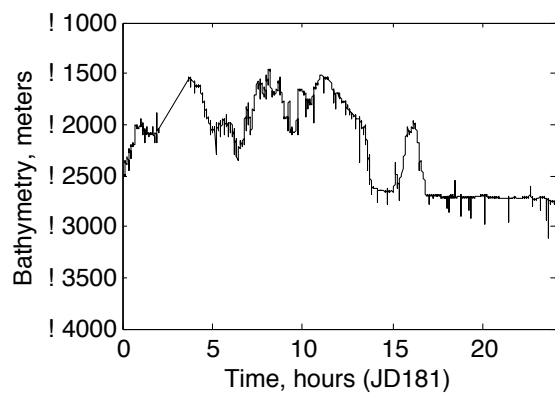


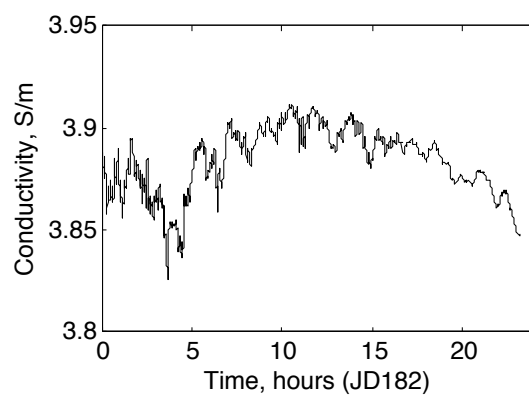
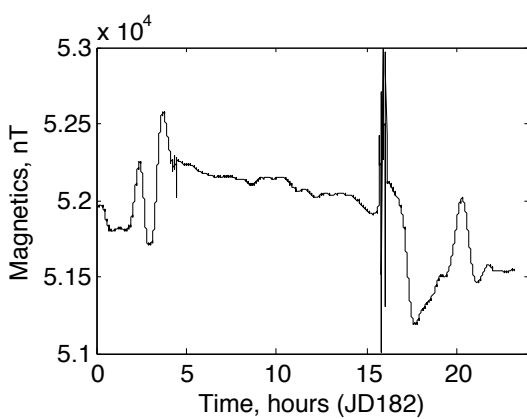
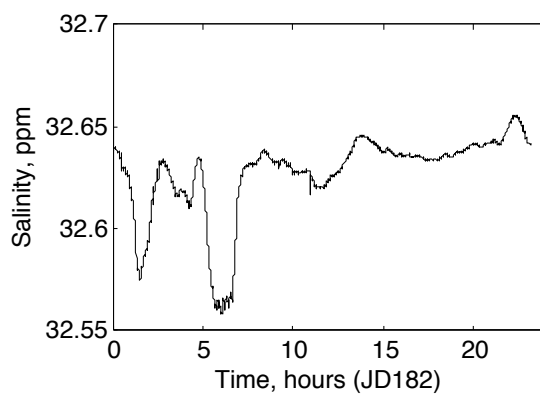
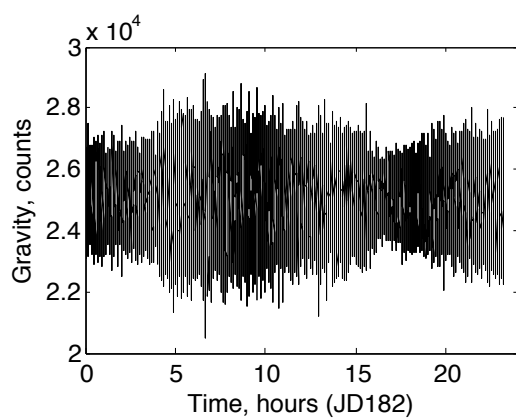
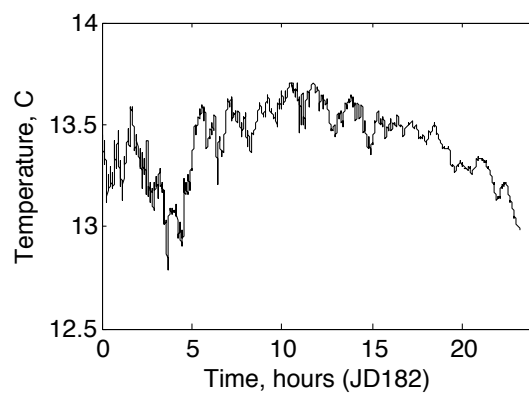
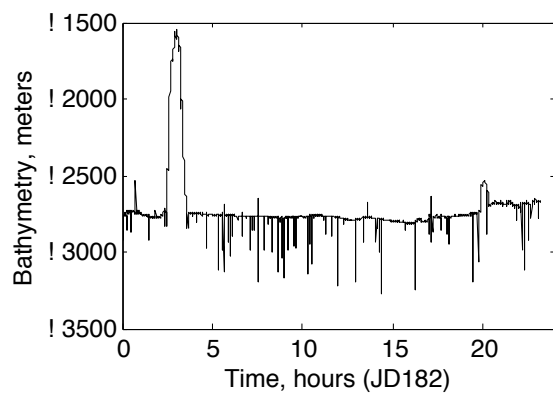


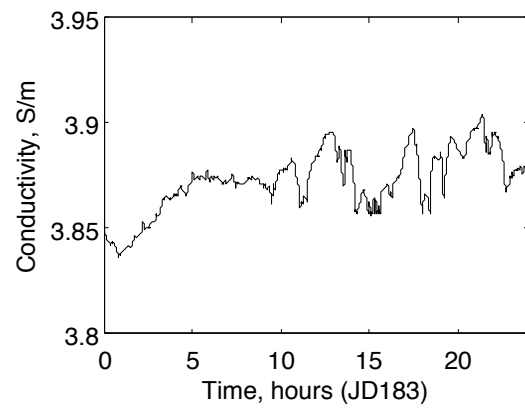
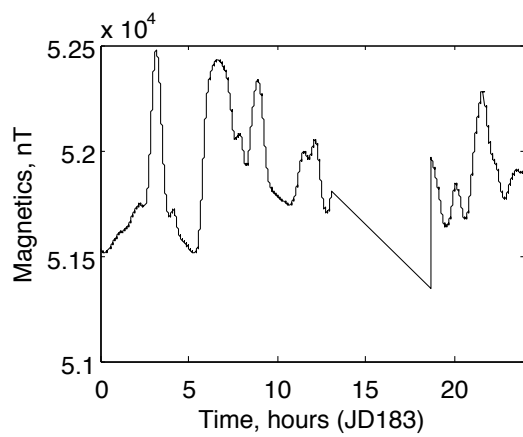
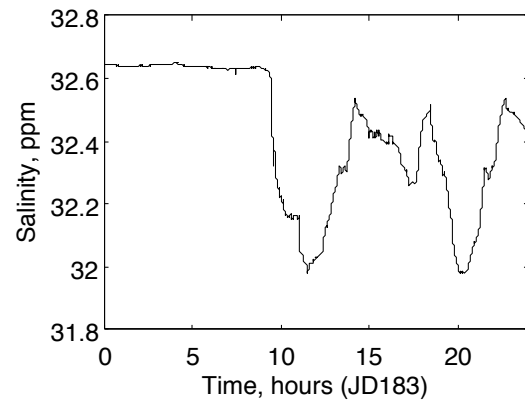
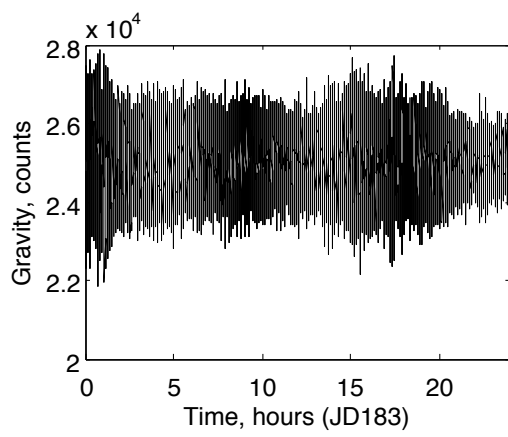
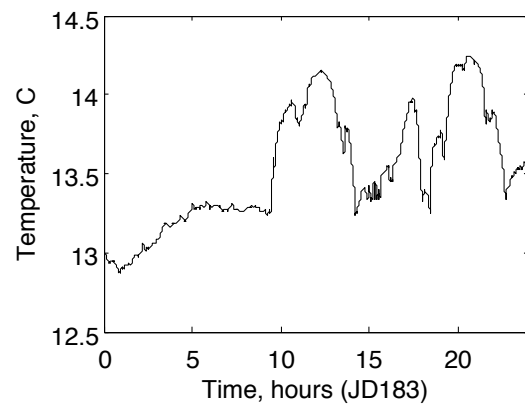
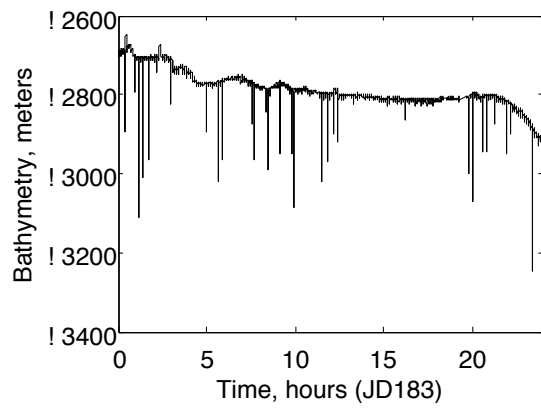


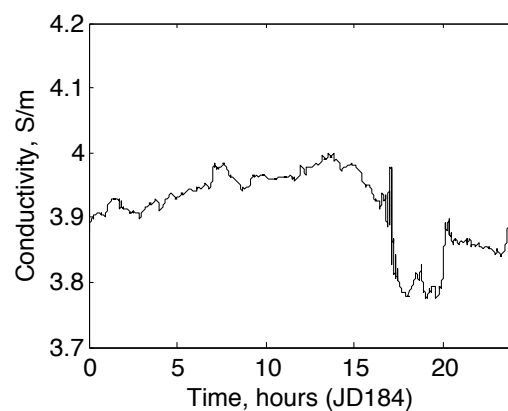
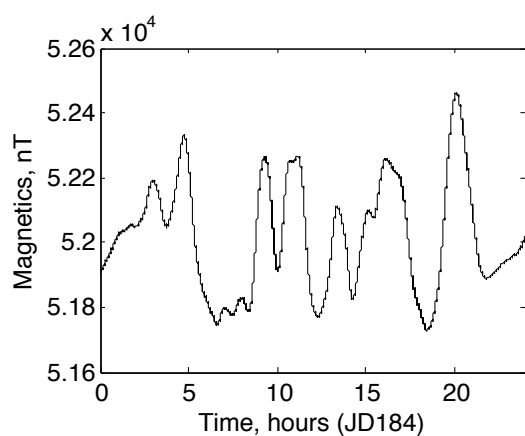
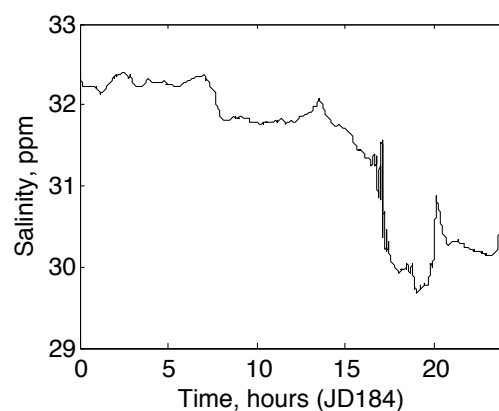
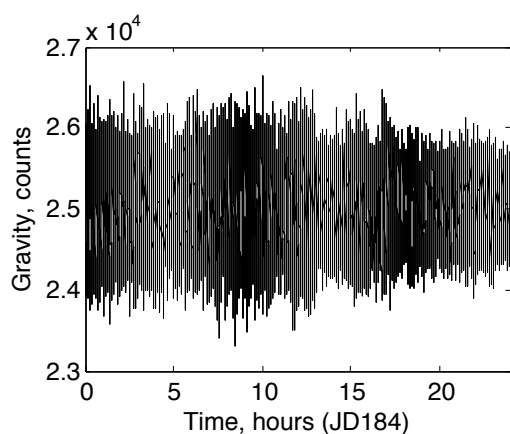
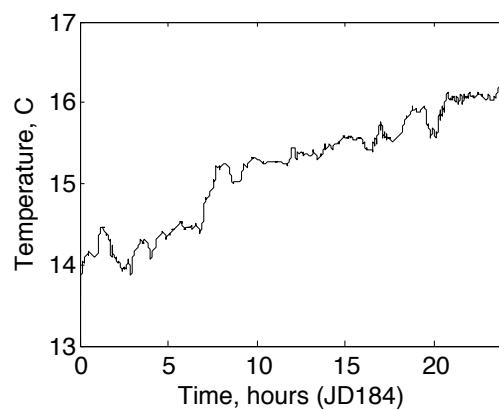
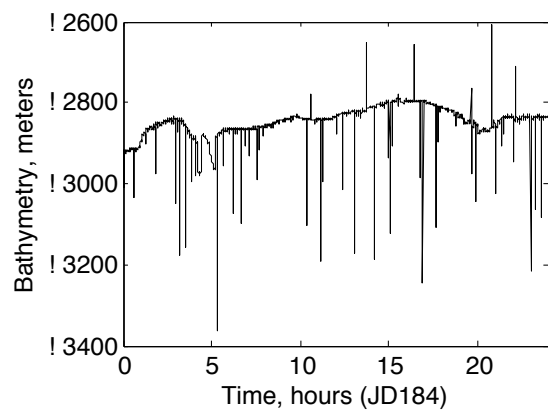


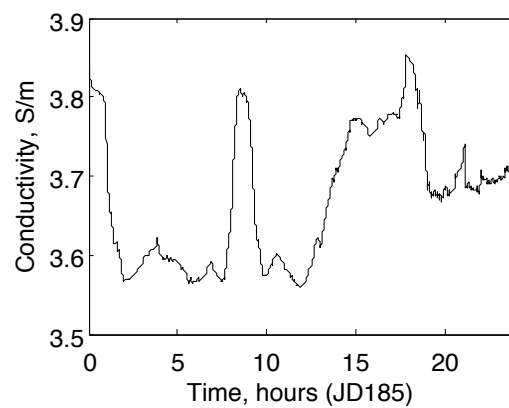
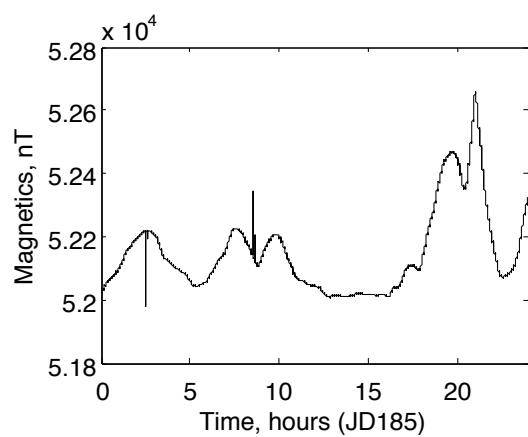
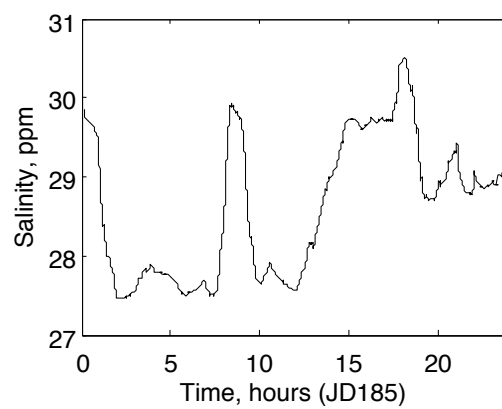
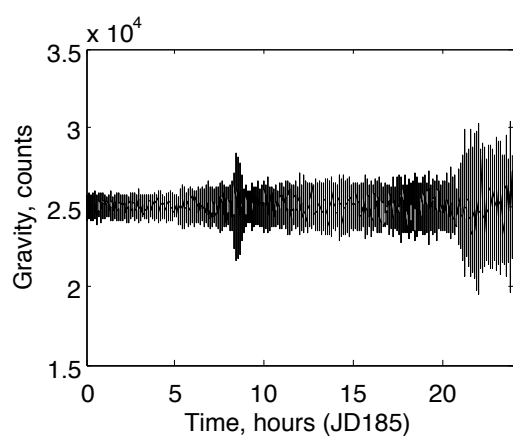
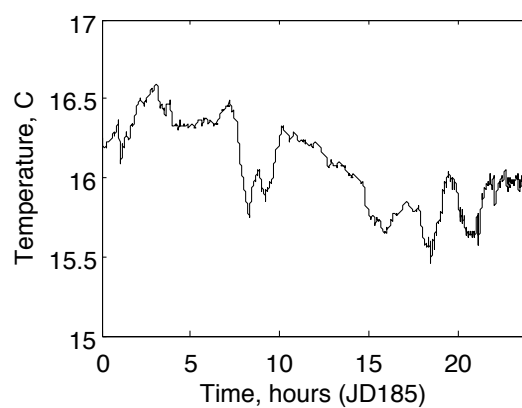
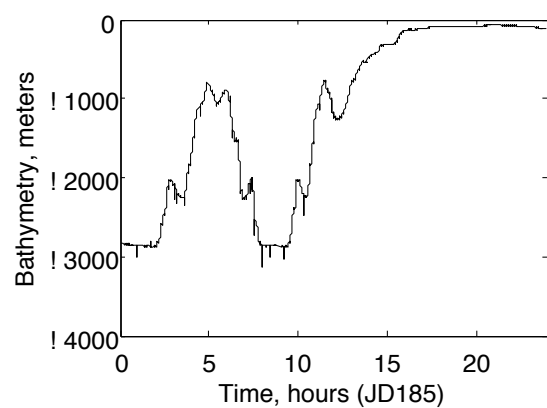


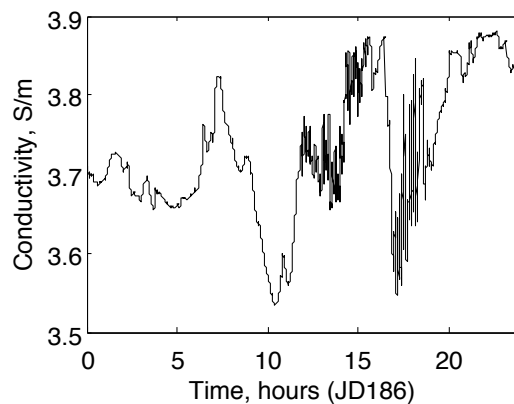
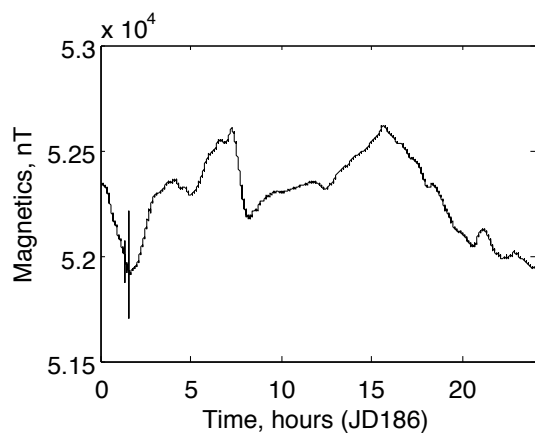
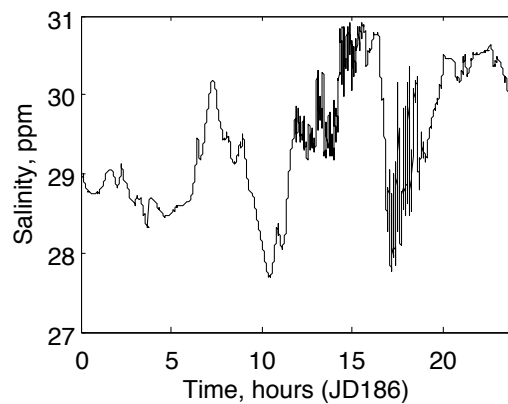
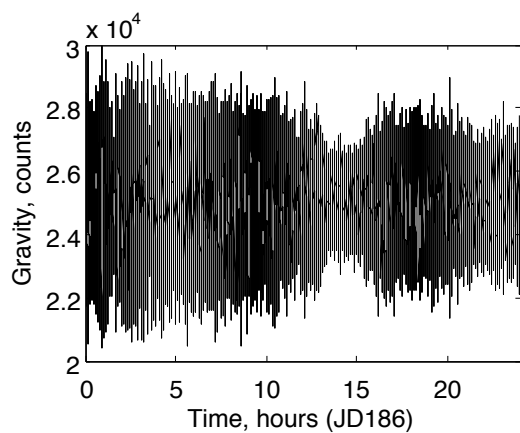
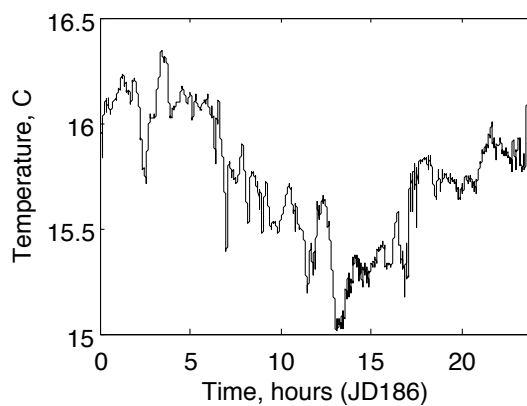
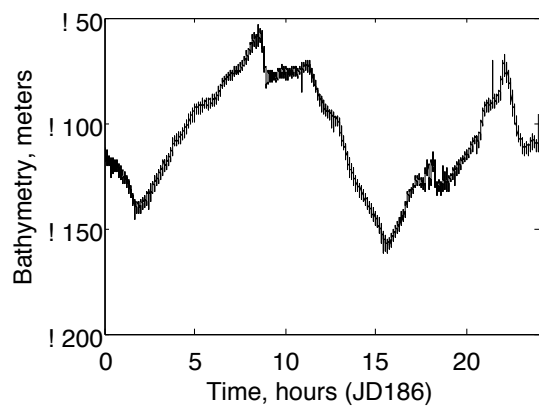


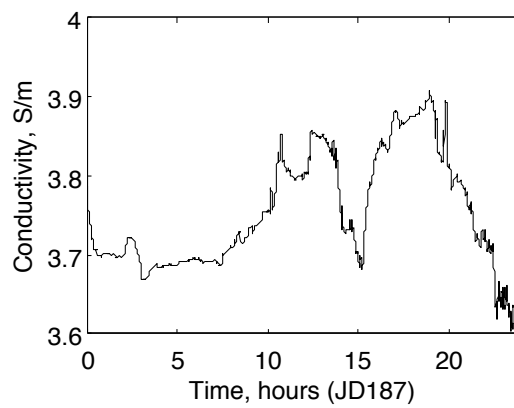
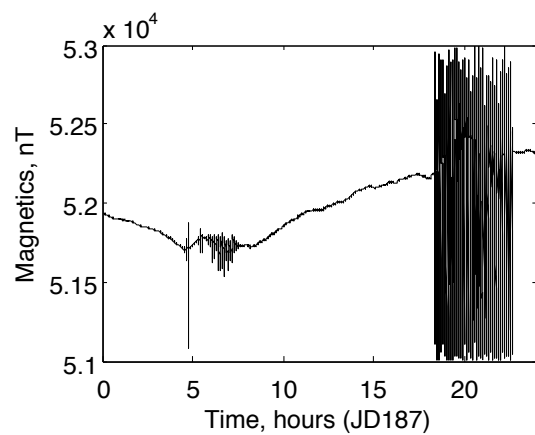
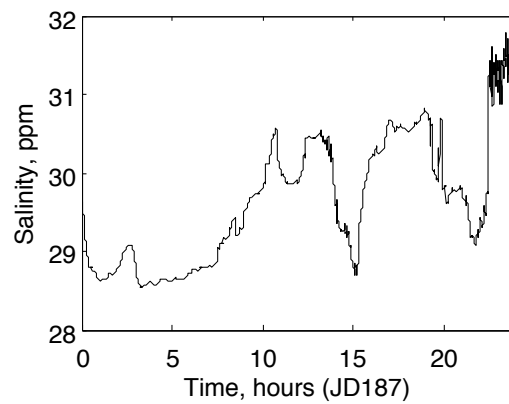
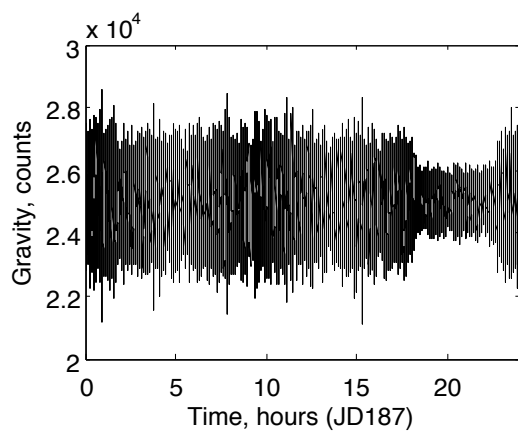
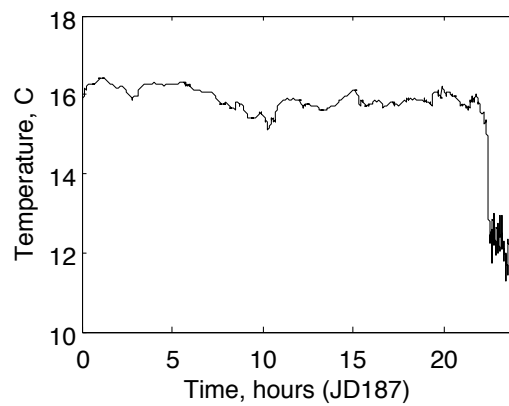
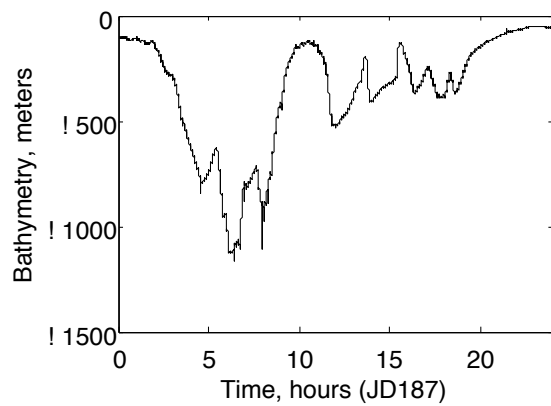


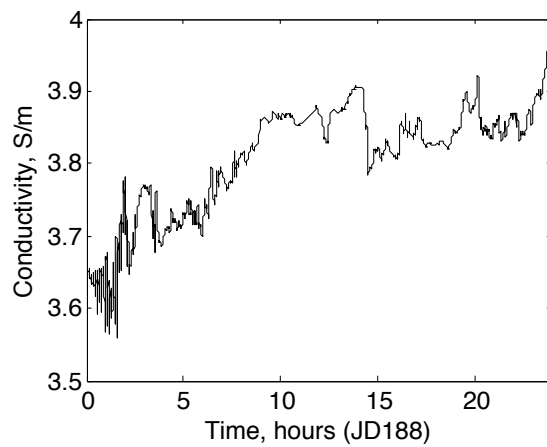
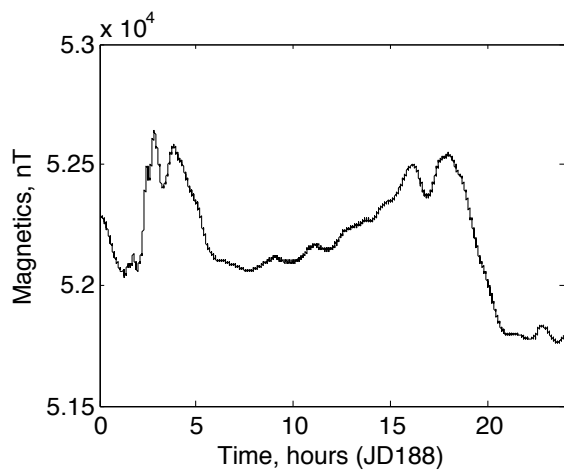
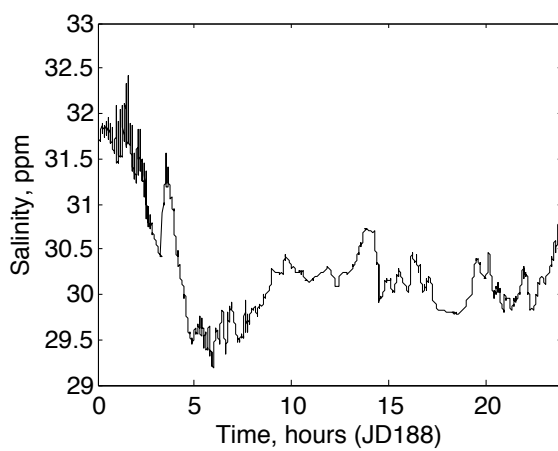
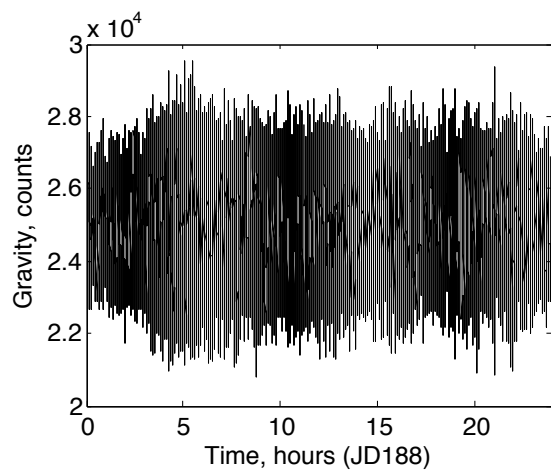
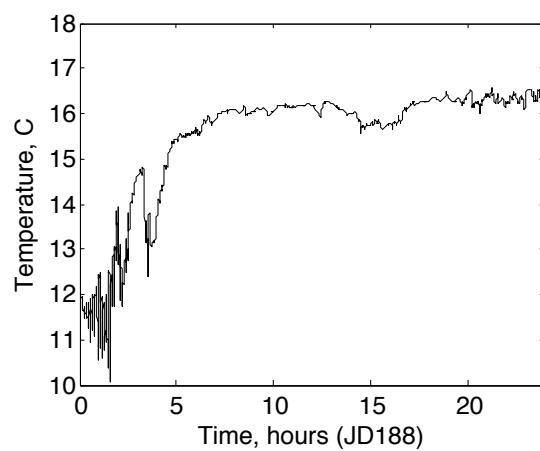
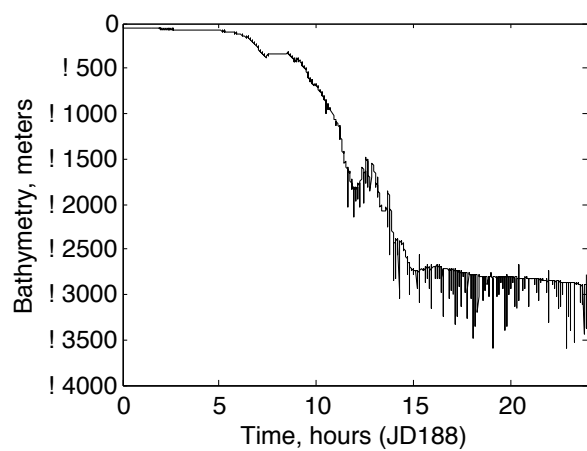












APPENDIX 13: IHA Permit



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

JUN 13 2012

Meagan J. Cummings
Marine Environmental & Safety Coordinator
Department of Marine Operations
Lamont-Doherty Earth Observatory
P.O. Box 1000
Palisades, New York, 10964-8000

Dear Ms. Cummings:

Enclosed is an Incidental Harassment Authorization (IHA) issued to the Lamont-Doherty Earth Observatory, under the authority of section 101(a)(5)(D) of the Marine Mammal Protection Act (16 U.S.C. 1361 *et seq.*), to harass small numbers of marine mammals, by Level B harassment, incidental to the R/V *Marcus G. Langseth's* marine geophysical survey in the northeastern Pacific Ocean during June to July, 2012.

You are required to comply with the conditions contained in the IHA which have also been included as Terms and Conditions for incidental take of endangered species in the Biological Opinion. In addition, you must submit a report to the National Marine Fisheries Service's (NMFS) Office of Protected Resources within 90 days of the completion of the cruise. The IHA requires monitoring of marine mammals by qualified individuals before, during, and after seismic activities and reporting of marine mammal observations, including species, numbers, and behavioral modifications potentially resulting from this activity.

If you have any questions concerning the IHA or its requirements, please contact Howard Goldstein, Jeannine Cody, or Jolie Harrison, Office of Protected Resources, NMFS, at 301-427-8401.

Sincerely,

Helen M. Golde
Acting Director
Office of Protected Resources

Enclosures





Incidental Harassment Authorization

We hereby authorize Lamont-Doherty Earth Observatory (L-DEO), P.O. Box 1000, Palisades, New York 10964-8000, under section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA) (16 U.S.C. 1371(a)(5)(D)), to harass small numbers of marine mammals incidental to a marine geophysical (seismic) survey conducted by the R/V *Marcus G. Langseth* (*Langseth*) in the northeastern Pacific Ocean, June to July, 2012:

1. This Authorization is valid from June 13 through July 25, 2012.
2. This Authorization is valid only for the *Langseth's* specified activities associated with seismic survey operations as specified in the Observatory's Incidental Harassment Authorization application and the National Science Foundation's (NSF) associated Environmental Assessment in the following specified geographic areas:

- (i) An area bounded by approximately 43 to 48 degrees (°) North by approximately 124 to 130° West.

3. Species Authorized and Level of Takes

- (a) This authorization limits the incidental taking of marine mammals, by Level B harassment only, to the following species in the waters of the northeastern Pacific Ocean:

- (i) Mysticetes – see Table 1 (attached) for authorized species and take numbers.
 - (ii) Odontocetes – see Table 1 (attached) for authorized species and take numbers.
 - (iii) Pinnipeds – see Table 1 (attached) for authorized species and take numbers.

- (iii) During the seismic activities, if the Holder of this Authorization encounters any marine mammal species under NMFS jurisdiction during seismic activities that are not listed in Table 1 (attached) for authorized taking and are likely to be exposed to sound pressure levels (SPLs) greater than or equal to 160 dB re 1 μ Pa (rms), then the Holder of this Authorization must alter speed or course, power-down, or shut-down the airguns to avoid take.

- (b) This Authorization prohibits the taking by injury (Level A harassment), serious injury, or death of any of the species listed in Condition 3(a) above or the taking of any kind of any other species of marine mammal thus, it may result in the modification, suspension or revocation of this Authorization.

4. This Authorization limits the methods authorized for taking by Level B harassment to the following acoustic sources without an amendment to this Authorization:

- (i) A 36 Bolt airgun array with a total capacity of 6,600 in³ (or smaller);
- (ii) A multi-beam echosounder;
- (iii) A sub-bottom profiler; and
- (iv) An acoustic release transponder used to communicate with ocean bottom seismometers (OBS).

5. The taking of any marine mammal in a manner prohibited under this Authorization must be reported immediately to the Office of Protected Resources, National Marine Fisheries Service (NMFS), at 301-427-8401.

6. Mitigation and Monitoring Requirements

The Holder of this Authorization is required to implement the following mitigation and monitoring requirements when conducting the specified activities to achieve the least practicable impact on affected marine mammal species or stocks:

- (a) Utilize two, NMFS-qualified, vessel-based Protected Species Visual Observers (PSVOs) (except during meal times and restroom breaks, when at least one PSVO shall be on watch) to visually watch for and monitor marine mammals near the seismic source vessel during daytime airgun operations (from nautical twilight-dawn to nautical twilight-dusk) and before and during start-ups of airguns day or night. The *Langseth's* vessel crew shall also assist in detecting marine mammals, when practicable. PSVOs shall have access to reticle binoculars (7 x 50 Fujinon), big-eye binoculars (25 x 150), laser range-finding binoculars, and thermal imaging cameras. PSVO shifts shall last no longer than 4 hours at a time. PSVOs shall also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior, when feasible.
- (b) PSVOs shall conduct monitoring while the airgun array and streamer(s) are being deployed or recovered from the water.
- (c) Record the following information when a marine mammal is sighted:
 - (i) Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to the airguns or vessel (e.g., none, avoidance, approach, paralleling, etc., and including responses to ramp-up), and behavioral pace; and

(ii) Time, location, heading, speed, activity of the vessel (including number of airguns operating and whether in state of ramp-up or power-down), Beaufort sea state and wind force, visibility, and sun glare; and

(iii) The data listed under Condition 6(c)(ii) shall also be recorded at the start and end of each observation watch and during a watch whenever there is a change in one or more of the variables.

(d) Utilize the passive acoustic monitoring (PAM) system, to the maximum extent practicable, to detect and allow some localization of marine mammals around the *Langseth* during all airgun operations and during most periods when airguns are not operating. One NMFS-qualified Protected Species Observer (PSO) and/or expert bioacoustician (i.e., Protected Species Acoustic Observer [PSAO]) shall monitor the PAM at all times in shifts no longer than 6 hours. An expert bioacoustician shall design and set up the PAM system and be present to operate or oversee PAM, and available when technical issues occur during the survey.

(e) Do and record the following when an animal is detected by the PAM:

(i) Notify the on-duty PSVO(s) immediately of the presence of a vocalizing marine mammal so a power-down or shut-down can be initiated, if required;

(ii) Enter the information regarding the vocalization into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position, and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The acoustic detection can also be recorded for further analysis.

(f) Visually observe the entire extent of the exclusion zone (EZ) (180 dB re 1 μ Pa [rms] for cetaceans and 190 dB re 1 μ Pa [rms] for pinnipeds; see Table 2 [attached] for distances) using NMFS-qualified PSVOs, for at least 30 minutes prior to starting the airgun array (day or night). If the PSVO finds a marine mammal within the EZ, L-DEO must delay the seismic survey until the marine mammal(s) has left the area. If the PSVO sees a marine mammal that surfaces, then dives below the surface, the PSVO shall wait 30 minutes. If the PSVO sees no marine mammals during that time, they should assume that the animal has moved beyond the EZ. If for any reason the entire radius cannot be seen for the entire 30 minutes (i.e., rough seas, fog, darkness), or if marine mammals are near, approaching, or in the EZ, the airguns may not be ramped-up. If one airgun is already running at a source level of at least 180 dB re 1 μ Pa (rms), L-DEO may start the second airgun without observing the entire EZ for 30 minutes prior, provided no marine mammals are known to be near the EZ (in accordance with Condition 6[h] below).

(g) Establish a 180 dB re 1 μ Pa (rms) and 190 dB re 1 μ Pa (rms) EZ for marine mammals before the 4-string airgun array (6,600 in³) is in operation; and a 180 dB re 1 μ Pa (rms) and 190 dB re 1 μ Pa (rms) EZ before a single airgun (40 in³) is in operation, respectively. See Table 2 (attached) for distances and EZs.

(h) Ramp-up procedures at the start of seismic operations or after a shut-down - Implement a "ramp-up" procedure when starting up at the beginning of seismic operations or anytime after the entire array has been shut-down for more than 8 minutes, which means start the smallest gun first and add airguns in a sequence such that the source level of the array shall increase in steps not exceeding approximately 6 dB per 5-minute period. During ramp-up, the PSVOs shall monitor the 180 dB EZ for cetaceans or the 190 dB EZ for pinnipeds, and if marine mammals are sighted within or about to enter the relevant EZ, a power-down, or shut-down shall be implemented as though the full array were operational. Therefore, initiation of ramp-up procedures from a shut-down or at the beginning of seismic operations requires that the PSVOs be able to view the full EZ as described in Condition 6(f).

(i) Alter speed or course during seismic operations if a marine mammal, based on its position and relative motion, appears likely to enter the relevant EZ. If speed or course alteration is not safe or practicable, or if after alteration the marine mammal still appears likely to enter the EZ, further mitigation measures, such as a power-down or shut-down, shall be taken.

(j) Power-down or shut-down the airgun(s) if a marine mammal is detected within, approaches, or enters the relevant EZ (as defined in Table 1, attached). A shut-down means all operating airguns are shut-down (i.e., turned off). A power-down means reducing the number of operating airguns to a single operating 40 in³ airgun, which reduces the EZ to the degree that the animal(s) is no longer in or about to enter it.

(k) Following a power-down, if the marine mammal approaches the smaller designated EZ, the airguns must then be completely shut-down. Airgun activity shall not resume until the PSVO has visually observed the marine mammal(s) exiting the EZ and is not likely to return, or has not been seen within the EZ for 15 minutes for species with shorter dive durations (small odontocetes and pinnipeds) or 30 minutes for species with longer dive durations (mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, killer, and beaked whales). Following a shut-down, the *Langseth* may resume airgun operations following ramp-up procedures described in Condition(h).

(l) Procedures after an extended power-down - Monitor the full 180 dB EZ for cetaceans and the full 190 dB EZ for pinnipeds. The *Langseth* may resume full power operations anytime after the entire array has been powered-down for more than 8 minutes. Resuming operations at full power after an extended power-down of more than 8 minutes requires that the PSVOs be able to view the full EZ as described in Condition 6(f). If the PSVO sees a marine mammal within or about to enter the relevant EZs, then the *Langseth* will implement a course/speed alteration or power-down.

(m) Marine seismic surveys may continue into night and low-light hours if such segment(s) of the survey is initiated when the entire relevant EZs are visible and can be effectively monitored.

(n) No initiation of airgun array operations is permitted from a shut-down position at night or during low-light hours (such as in dense fog or heavy rain) when the entire relevant EZ cannot be effectively monitored by the PSVO(s) on duty.

(o) If a North Pacific right whale (*Eubalaena japonica*) is visually sighted, the airgun array shall be shut-down regardless of the distance of the animal(s) to the sound source. The array shall not resume firing until 30 minutes after the last documented whale visual sighting.

(p) If killer whales (*Orcinus orca*) are visually sighted or detected acoustically, the airguns array shall be shut-down regardless of the distance of the animal(s) to the sound source. The array shall not resume firing until 30 minutes after the last documented whale visual sighting or acoustic detection.

(q) To the maximum extent practicable, communicate with NMFS Northwest Regional Office and/or Orca Network for near real-time reporting of the whereabouts of killer whales.

(r) To the maximum extent practicable, schedule seismic operations (i.e., shooting airguns) during daylight hours and OBS operations (i.e., deploy/retrieve) to nighttime hours.

(s) To the maximum extent practicable, plan to conduct seismic surveys (especially when near land) from the coast (inshore) and proceed towards the sea (offshore) in order to avoid trapping marine mammals in shallow water.

7. Reporting Requirements

The Holder of this Authorization is required to:

(a) Submit a draft report on all activities and monitoring results to the Office of Protected Resources, NMFS, within 90 days of the completion of the *Langseth*'s three cruises. This report must contain and summarize the following information:

(i) Dates, times, locations, heading, speed, weather, sea conditions (including Beaufort sea state and wind force), and associated activities during all seismic operations and marine mammal sightings;

(ii) Species, number, location, distance from the vessel, and behavior of any marine mammals, as well as associated seismic activity (number of power-downs and shut-downs), observed throughout all monitoring activities.

(iii) An estimate of the number (by species) of marine mammals that: (A) are known to have been exposed to the seismic activity (based on visual observation) at received levels greater than or equal to 160 dB re 1 μ Pa (rms) and/or 180 dB re 1 μ Pa (rms) for cetaceans and 190 dB re 1 μ Pa (rms) for pinnipeds with a discussion of any specific behaviors those individuals exhibited; and (B) may have been exposed (based on reported and corrected empirical values for the 36 airgun array and modeling measurements for the single airgun) to the seismic activity at received levels greater than or equal to 160 dB re 1 μ Pa (rms) and/or 180 dB re 1 μ Pa (rms) for cetaceans and 190 dB re 1 μ Pa (rms) for pinnipeds with a discussion of the nature of the probable consequences of that exposure on the individuals that have been exposed.

(iv) A description of the implementation and effectiveness of the: (A) terms and conditions of the Biological Opinion's Incidental Take Statement (ITS) (attached); and (B) mitigation measures of the Incidental Harassment Authorization. For the Biological Opinion, the report shall confirm the implementation of each Term and Condition, as well as any conservation recommendations, and describe their effectiveness, for minimizing the adverse effects of the action on Endangered Species Act-listed marine mammals.

(b) Submit a final report to the Chief, Permits and Conservation Division, Office of Protected Resources, NMFS, within 30 days after receiving comments from NMFS on the draft report. If NMFS decides that the draft report needs no comments, the draft report shall be considered to be the final report.

(c) In the unanticipated event that the specified activity clearly causes the take of a marine mammal in a manner prohibited by this Authorization, such as an injury (Level A harassment), serious injury or mortality (e.g., ship-strike, gear interaction, and/or entanglement), L-DEO shall immediately cease the specified activities and immediately report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, at 301-427-8401 and/or by email to Jolie.Harrison@noaa.gov, Jeannine.Cody@noaa.gov, and Howard.Goldstein@noaa.gov and the Northwest Regional Stranding Coordinator at 206-526-6550 (Brent.Norberg@noaa.gov). The report must include the following information:

(i) Time, date, and location (latitude/longitude) of the incident; the name and type of vessel involved; the vessel's speed during and leading up to the incident; description of the incident; status of all sound source use in the 24 hours preceding the incident; water depth; environmental conditions (e.g., wind speed and direction, Beaufort sea state, cloud cover, and visibility); description of marine mammal observations in the 24 hours preceding the incident; species identification or description of the animal(s) involved; the fate of the animal(s); and photographs or video footage of the animal (if equipment is available).

Activities shall not resume until NMFS is able to review the circumstances of the prohibited take. NMFS shall work with L-DEO to determine what is necessary to minimize the likelihood of further prohibited take and ensure MMPA compliance. L-DEO may not resume their activities until notified by NMFS via letter, email, or telephone.

In the event that L-DEO discovers an injured or dead marine mammal, and the lead PSO determines that the cause of the injury or death is unknown and the death is relatively recent (i.e., in less than a moderate state of decomposition as described in the next paragraph), L-DEO will immediately report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, at 301-427-8401, and/or by email to Jolie.Harrison@noaa.gov, Jeannine.Cody@noaa.gov, and Howard.Goldstein@noaa.gov, and the NMFS Northwest Regional Office (206-526-6550) and/or by email to the Northwest Regional Stranding Coordinator (Brent.Norberg@noaa.gov). The report must include the same information identified in Condition 7(c)(i) above. Activities may continue while NMFS reviews the circumstances of the incident. NMFS will work with L-DEO to determine whether modifications in the activities are appropriate.

In the event that L-DEO discovers an injured or dead marine mammal, and the lead PSO determines that the injury or death is not associated with or related to the activities authorized in Condition 2 of this Authorization (e.g., previously wounded animal, carcass with moderate to advanced decomposition, or scavenger damage), L-DEO shall report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, at 301-427-8401, and/or by email to Jolie.Harrison@noaa.gov, Jeannine.Cody@noaa.gov, and Howard.Goldstein@noaa.gov, and the NMFS Northwest Regional Office (206-526-6550) and/or by email to the Northwest Regional Stranding Coordinator (Brent.Norberg@noaa.gov) within 24 hours of the discovery. L-DEO shall provide photographs or video footage (if available) or other documentation of the stranded animal sighting to NMFS and the Marine Mammal Stranding Network. Activities may continue while NMFS reviews the circumstances of the incident.

9. L-DEO is required to comply with the Terms and Conditions of the ITS corresponding to NMFS's Biological Opinion issued to both NSF and NMFS's Office of Protected Resources (attached).

10. A copy of this Authorization and the ITS must be in the possession of all contractors and PSOs operating under the authority of this Incidental Harassment Authorization.



Helen M. Golde
Acting Director
Office of Protected Resources
National Marine Fisheries Service

JUN 13 2012

Date

Attachments

Attachment

Table 1. Authorized Take Numbers for Each Marine Mammal Species during the Juan de Fuca Plate Seismic Survey in the northeastern Pacific Ocean.

Species	Authorized Take in the Juan de Fuca Plate Study Area
Mysticetes	
North Pacific right whale (<i>Eubalaena japonica</i>)	0
Gray whale (<i>Eschrichtius robustus</i>)	10
Humpback whale (<i>Megaptera novaeangliae</i>)	19
Minke whale (<i>Balaenoptera acutorostrata</i>)	11
Sei whale (<i>Balaenoptera physalus</i>)	4
Fin whale (<i>Balaenoptera borealis</i>)	30
Blue whale (<i>Balaenoptera musculus</i>)	4
Odontocetes	
Sperm whale (<i>Physeter macrocephalus</i>)	24
Unidentified <i>Kogia</i> spp. Pygmy sperm whale (<i>Kogia breviceps</i>) and/or Dwarf sperm whale (<i>Kogia sima</i>)	16
Cuvier's beaked whale (<i>Ziphius cavirostris</i>)	10
Baird's beaked whale (<i>Berardius bairdii</i>)	27
Unidentified <i>Mesoplodon</i> beaked whale (<i>Mesoplodon</i> spp.)	40
Striped dolphin (<i>Stenella coeruleoalba</i>)	2
Short-beaked common dolphin (<i>Delphinus delphis</i>)	238
Pacific white-sided dolphin (<i>Lagenorhynchus obliquidens</i>)	806
Northern right whale dolphin	297

<i>(Lissodelphis borealis)</i>	
Risso's dolphin <i>(Grampus griseus)</i>	258
Killer whale <i>(Orcinus orca)</i>	0
Harbor porpoise <i>(Phocoena phocoena)</i>	2,153
Dall's porpoise <i>(Phocoenoides dalli)</i>	1,935
Pinnipeds	
Northern fur seal <i>(Callorhinus ursinus)</i>	1,931
California sea lion <i>(Zalophus californianus)</i>	0
Steller sea lion <i>(Eumetopias jubatus)</i>	303
Pacific harbor seal <i>(Phoca vitulina richardii)</i>	995
Northern elephant seal <i>(Mirounga angustirostris)</i>	1,058

Table 2. Exclusion Zone Radii for Triggering Mitigation.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted RMS Distances (m)		
			Shut-down EZ for Pinnipeds 190 dB	Shut-down EZ for Cetaceans 180 dB	Level-B Harassment Zone 160 dB
Single Bolt airgun 40 in ³	6 to 15	Shallow (<100)	150	296	1,050
		Intermediate (100 to 1,000)	18	60	578
		Deep (>1,000)	12	40	385

4 strings 36 airguns 6,600 in ³	9	Shallow (<100)	680	2,140	20,550
		Intermediate (100 to 1,000)	550	1,540	12,200
		Deep ($>1,000$)	400	940	3,850
4 strings 36 airguns 6,600 in ³	12	Shallow (<100)	770	2,250	23,470
		Intermediate (100 to 1,000)	615	1,810	13,935
		Deep ($>1,000$)	460	1,100	4,400
4 strings 36 airguns 6,600 in ³	15	Shallow (<100)	865	2,750	4,490
		Intermediate (100 to 1,000)	690	1,975	15,650
		Deep ($>1,000$)	520	1,200	26,350