

**CCGS HUDSON SPRING CRUISE 2013, HUD 2013-004**  
**REPORT ON THE RECOVERY AND DEPLOYMENT OF**  
**RAPID-WAVE MOORINGS IN THE SCOTIAN SLOPE-RISE**  
**4 APRIL-12 APRIL 2013**

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## INTRODUCTION

This is the first leg of the annual CCGS Hudson Spring cruise, which combines work for the Canadian AZMP (Atlantic Zone Monitoring Program) and the UK funded Western Atlantic Variability Experiment (WAVE), a component of the UK Natural Environment Research Council's RAPID-WATCH<sup>1</sup> Program. The objectives of this cruise are, first, to recover 7 moorings deployed in September 2011 (see cruise report HUD2011043) and, second, to deploy a set of 6 replacement moorings for a period of 18 months (April 2013-September 2014). The moorings record bottom pressure, currents, temperature, and conductivity (from which salinity is calculated) at various depths. The scientific purpose of these moorings is to measure bottom pressure changes in the western Atlantic and, from these changes, infer the variability of the Atlantic meridional overturning circulation, which, to leading order, is governed by pressure variability on the western ocean boundary.

In RAPID-WAVE missions prior to 2011, moorings were deployed for one year only. HUD201143 was the first time that the mooring line was deployed for 18 months. Successful recovery of these moorings in the present cruise will indicate that 1 ½-year deployments can be done without compromising the safety of the equipment. Being able to deploy the array for longer periods of time will significantly reduce the costs of maintaining the line.

## NARRATIVE

**Wednesday 03-04-2013.** Jeff Pugh and I arrived in BIO at ~0900 local time (ADT, or Atlantic Daylight Time, which is 3 hours behind GMT). We spent the morning and part of the afternoon testing and readying 6 Bottom Pressure Recorders for deployment. The BPRs were programmed to record for a period of ~24 hr in conjunction with a high-accuracy barometer. These data will allow us to accurately determine the pressure offset of each BPR. I had a discussion with John Loder and Dave Hebert (PSO) at ~0300 about the location of the moorings sites. There will be an attempt at dragging for the moorings lost at RS5 (2<sup>nd</sup> deployment, 2009) and RS6 (3<sup>th</sup> deployment, 2010) during the AZMP 2013 Fall cruise on the Hudson. It is therefore imperative that the new moorings deployed at RS5 and RS6 during the Spring cruise are sufficiently separated from the lost moorings to minimize the risk of accidentally hitting the wrong mooring during the dragging operations in the fall.

**Thursday 04-04-2013.** Jeff Pugh and I embarked on the Hudson at ~0830 ADT. The ship left the quay at ~1030 ADT. Departure was initially planned for 0900 ADT but a number of problems with the lifeboats (new parts for the launching mechanism of the boats had to be ordered and installed, as some of the old ones had been found faulty during routine ship tests two days earlier). This is the first cruise of the year for the Hudson. Quite a few members of the crew and officers are new to the ship and also to mooring work. It will take some time for them to familiarise themselves with the mooring techniques involved. Fortunately, the BIO technician in charge of mooring operations, Jay Barthelotte, has many years of experience in the field and has been involved with the RAPID-WAVE project since 2008. The ship will be on ADT for the duration of the cruise. After departure, we headed for the Bedford Basin to run a series of tests on the ship and on some of the scientific equipment before leaving for the Scotian Shelf and Slope. The weather forecast for the East Scotian Slope is for wind to pick up through Friday, with strong southerlies (40 kn) but easing toward Sunday and Monday. A boat drill was carried out in the basin at ~1100. All tests were completed at ~1440 ADT, at which time the Hudson left the Bedford Basin. Ship familiarisation for scientific

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<sup>1</sup> WATCH stands for "Will the Atlantic Thermohaline Circulation Halt?"

personnel took place from ~1600 ADT to ~1700 ADT. From 1815 ADT to 2030 ADT, Jeff and I downloaded the data from the 24 hour BPR and barometer tests that we had started on Wednesday. The BPRs were then reset to start logging on 04-04-2013 at 2355 GMT ready for deployment.

**Friday 05-04-2013.** We have been recovering moorings in succession since about 1000 ADT. The moorings at RS1 to RS5 have been recovered without problems. The plan is to recover the two remaining moorings at RS6 on Saturday 06-04-2013. The weather is expected to deteriorate in the evening of Friday but them progressively improve throughout Saturday.

**Saturday 06-04-2013.** Bad weather. Westerly winds (35 kn) and waves 4-6 m high. The plan is to sit at RS6 while the gale passes and, in the mean time, do the calibration dips for new and old instruments. A calibration dip was started at ~0930 ADT at or near station HL9 (close to RS6). All available 3500 m rated microCATs were calibrated there. The cast ended at ~1400 ADT. The ship then proceeded to the HL11 site to carry out a second calibration dip for all the 7000 m rated microCATs that are available (i.e., all except those still deployed at RS6). At around 1630 ADT, half way to HL11, it was decided to turn around and head for CTD station HL8 instead. The reason for this change was that it was realised that the gale would have not weakened sufficiently upon our arrival in HL11 to permit a safe deployment of the CTD rosette. The ETA at HL8 was midnight of Saturday. According to the weather forecast, the worst of the gale should have passed by this time.

**Sunday 07-04-2013.** An AZMP CTD cast took place at HL8. This included dipping the remaining RAPID microCATs for calibration. The only microCATs left that need calibration are those still deployed at RS6. The plan for today is to recover RS6 and start re-deploying as many moorings as possible starting at RS6 and working our way up the RS Line. The Canadian Weather Office forecast for today is: “wind northwest 25 knots diminishing to north 10 to 15 this morning and to light this afternoon. Wind increasing to southwest 10 to 15 Monday morning and to southwest 15 to 20 Monday afternoon”. Waves diminishing 3-4 m to 1 m near midnight. The long mooring at RS6 was recovered in the morning, followed by the short mooring containing only a SBE53. The new mooring at RS6 was deployed by about 0430 ADT very close to the position of the RS6 mooring of 2011, as agreed in our discussion with John Loder and Dave Hebert on 03-04-2013.

**Monday 08-04-2013.** CTD casts at HL9 and HL7 were done over night. At HL7, the remaining microCATs from the RAPID moorings were dipped for calibration. The expectation was that we might be able to deploy at least four moorings, perhaps all five, today. In practice, only three moorings were deployed, namely, RS5, RS4 and RS3. An informal bathymetric survey was carried out around the target deployment position at RS5 to make sure that the sea floor in the deployment area is not too rugged. The chosen deployment site was located about a mile south eastwards of the location initially considered in the meeting with Loder and Dave Hebert on 03-04-2013. This position is about 2.5 miles to the east of our best position for the RS5 lost mooring. Although the mooring at RS4 was deployed very close to the position used in 2011, there was a discrepancy in the M-Cal-derived depths for the “old” mooring (~2780 m) and the “new” mooring (~2730 m). Part of the discrepancy is explained by the fact that the speed of sound used is not quite the same (1500 m/s in 2011 vs 1489 m/s in the present cruise), but the largest part of the disparity remains unexplained.

**Tuesday 09-04-2013.** Deployments at RS1 and RS2 took place in the morning. Poor visibility because of fog but otherwise fair weather conditions. Jeff and I run a test on SBE53-45 as per instructions from Gary Morast, from SBE, to verify the integrity of the reference crystal. The test consisted on typing the command “tsx” and record the instrument output. The instrument produces a line of “esoteric” data every two minutes. Fourteen of these lines were sent to Gary via e-mail for inspection. The RAPID component of the cruise has come to an end.

## RS ARRAY RECOVERY

The moorings at RS1 to RS5 were recovered without incidents on 5<sup>th</sup> April 2013. Visibility was good, with weak winds and low wave field.

A calibration dip for 8 microCATs recovered at RS1 to RS5, 8 of the microCATs to be deployed and a spare microCAT (SN 1696) were carried out in the morning of the 6<sup>th</sup> April while waiting for the weather to improve sufficiently to permit us to recover RS6. The microCATs were clamped to the CTD rosette and submerged to 3500 m. As the rosette was being brought up to the surface, three 25-minute stops were made to allow the microCATs to record at reasonably constant and uniform conditions. The microCAT sampling rate was set to 10 seconds for this calibration dip, thus affording about 150 samples per rosette stop. The nominal sampling depths were: 3500 m, 2500 m, and 1500 m. Results from these calibration casts will be used, in combination with dips done on the previous cruise, HUD2011043, to correct raw temperature, conductivity and pressure data from the microCATs. Yuri Geshelin and John Loder, from BIO, will lead the calibration and quality control of the microCAT and ADCP data recovered. The ADCP data, which is typically more difficult to calibrate than CTD or BPR data, will be calibrated first. After this, a preliminary calibration of the microCAT data will be performed using the raw CTD cast data as truth. Subsequently, once the CTD data has been calibrated itself using the bottle samples, a final slope and offset correction will be applied to the SBE37 microCAT measurements.

The following four tables summarise relevant information for all recoveries.

SITE	LATITUDE (N)	LONGITUDE (W)	DATE RECOVERED	DEPTH (m)	MOORING TYPE
RS1	42 51.1523	61 38.1068	05/04/13	1106	Short
RS2	42 44.3020	61 34.4829	05/04/13	1718	Short
RS3	42 39.3558	61 27.3860	05/04/13	2325	Short
RS4	42 33.4337	61 22.2630	05/04/13	2783	Short
RS5	42 23.3777	61 16.8417	05/04/13	3428	Short
RS6	42 10.8283	61 00.3925	07/04/13	3836	Long
RS6A	42 12.3469	61 09.1772	07/04/13	3873	Short

Note. Positions were calculated from M-Cal triangulations (see SEANAV's website <http://www.seanav.com/>). Echo sounder depths with assumed sound velocity of 1500 m/s.

Table 1: Moorings recovered.

	RS1	RS2	RS3	RS4	RS5	RS6
Casabel Irid. beacon	300034012204210					RS6: 300034012152420
Sable Irid. beacon		300034012021780	300034012298970	300034012484560	300034012615490	RS6A: 300034012153420
SBE37 microCAT	6437					
SBE37 microCAT	3682					4614
SBE37 microCAT		3709				6435
SBE37 microCAT			6434			
SBE37 microCAT			3681			4617
SBE37 microCAT				3710		6432
SBE37 microCAT					2165	
SBE37 microCAT					3713	3675
SBE37 microCAT						3680
SBE37 microCAT						3714
WHADCP	11432	11433	13153	12455	11089	16405
Aanderaa RCM11 <sup>1</sup>	595					
Benthos 865-A acoustic release	47462 13.0 kHz; R:D/E:G	40082 8.75 kHz; R:G	53468 8.5 kHz; R:B	47464 14.0 kHz; R:A/E:F	51819 14.5 kHz; R:H/E:A/D:G  40080 8.25 kHz; R:C/E:B	RS6: 805 11.25 kHz; R:D/E:E  889 9.25 kHz; R:C/E:A  RS6A: 47463 13.5 kHz; R:G
SBE53 BPR	24	52	73	47	23	25

1. This current meter is BIO's and not part of the RAPID-WAVE project.

Table 2: Summary of equipment recovered

Instrument	Site	Sampling (ensemble) interval (seconds)	Averaging interval	Number of bins/bin size (m)	Time of first record (Z)	Time of last record (Z)
SBE37-SM 2165 CTD/3500 m	RS5	1800	Note 1	-	26/09/2011 14:00:01	05/04/2013 20:00:01
SBE37-SMP 3675 CT/7000 m	RS6	1800	Note 1	-	28/09/2011 13:00:01	07/04/2013 20:00:01
SBE37-SMP 3680 CT/7000 m	RS6	1800	Note 1	-	28/09/2011 13:00:01	07/04/2013 19:00:04
SBE37-SMP 3681 CTD/7000 m	RS3	1800	Note 1	-	29/09/2011 16:00:01	05/04/2013 16:00:02
SBE37-SMP 3682 CTD/7000 m	RS1	1800	Note 1	-	29/09/2011 11:00:01	05/04/2013 12:30:01
SBE37-SMP 3709 CTD/7000 m	RS2	1800	Note 1	-	29/09/2011 13:00:01	05/04/2013 14:00:03
SBE37-SMP 3710 CTD/7000 m	RS4	1800	Note 1	-	26/09/2011 18:00:01	05/04/2013 17:30:02
SBE37-SMP 3713 CTD/7000 m	RS5	1800	Note 1	-	26/09/2011 14:00:01	05/04/2013 20:00:02
SBE37-SMP 3714 CTD/7000 m	RS6	1800	Note 1	-	28/09/2011 13:00:01	07/04/2013 19:00:03
SBE37-SM 4614 CTD/3500 m	RS6	1800	Note 1	-	28/09/2011 13:00:01	07/04/2013 13:30:01
SBE37-SM 4617 CTD/3500 m	RS6	1800	Note 1	-	28/09/2011 13:00:01	07/04/2013 14:30:00
SBE37-SM 6432 CTD/3500 m	RS6	1800	Note 1	-	28/09/2011 13:00:01	07/04/2013 15:00:01
SBE37-SM 6434 CTD/3500 m	RS3	1800	Note 1	-	29/09/2011 16:00:01	05/04/2013 16:00:01
SBE37-SM 6435 CTD/3500 m	RS6	1800	Note 1	-	28/09/2011 13:00:01	07/04/2013 14:30:01
SBE37-SM 6437 CTD/3500 m	RS1	1800	Note 1	-	29/09/2011 11:00:01	05/04/2013 12:30:01
WHADP Sentinel 11089	RS5	3600	50 pings/ensemble 1 ping/36 s	30/4/50	26/09/2011 14:00:00	13/04/2006 14:18:45
WHADP Sentinel 11432	RS1	3600	50 pings/ensemble 1 ping/36 s	30/4/50	29/09/2011 10:00:00	13/04/2006 14:56:10
WHADP Sentinel 11433	RS2	3600	50 pings/ensemble 1 ping/36 s	30/4/50	29/09/2011 13:00:00	-
WHADP Sentinel 12455	RS4	3600	50 pings/ensemble 1 ping/36 s	30/4/50	26/09/2011 19:00:00	13/04/2006 08:45:54
WHADP Sentinel 13153	RS3	3600	50 pings/ensemble 1 ping/36 s	30/4/50	29/09/2011 16:00:00	13/04/2006 09:36:03
WHADP Sentinel 16405	RS6	3600	50 pings/ensemble 1 ping/36 s	30/4/50	28/09/2011 12:00:00	13/04/2008 09:33:47
SBE53 23	RS5	1200	300 s <sup>2</sup>	-	23/09/2011 17:50:00	04/09/2013 19:45:00
SBE53 24	RS1	1200	300 s <sup>2</sup>	-	23/09/2011 17:20:00	04/09/2013 21:05:00
SBE53 25	RS6	1200	300 s <sup>2</sup>	-	23/09/2011 21:20:00	04/09/2013 19:45:00
SBE53 47	RS4	1200	300 s <sup>2</sup>	-	23/09/2011 20:00:00	04/09/2013 19:05:00
SBE53 52	RS2	1200	300 s <sup>2</sup>	-	23/09/2011 20:00:00	04/09/2013 21:25:00
SBE53 73	RS3	1200	300 s <sup>2</sup>	-	23/09/2011 21:40:00	04/09/2013 19:05:00

1. The most recent SBE73s no longer have a tunable averaging option: each sample is calculated as the average of 4 consecutive measurements (because of this, the fastest possible sampling rate is about 15 seconds).
2. Sensor warming up period was set to 300 seconds too. The time stamp for SBE53 samples correspond to the beginning of each 300- second averaging interval. The reference frequency measurement was set to once per week. With these settings, and taking into account that all SBE53s were fitted with alkaline batteries, the estimated maximum battery endurance should be 805.6 days.

**Table 4: Summary of instrument set up.**

SBE37 serial number	Date of calibration cast	Sensors	Pump	Depth rating (m)	Notes
1696	06/04/13	CTD	No	7000	Good
2165	06/04/13	CTD	No	3500	Good. Recovered from RS5
3675	08/04/13	CT	Yes	7000	Good. Recovered from RS6
3680	08/04/13	CT	Yes	7000	Good. Recovered from RS6
3681	06/04/13	CTD	Yes	7000	Good. Recovered from RS3
3682	06/04/13	CTD	Yes	7000	Good. Recovered from RS1
3709	06/04/13	CTD	Yes	7000	Good. Recovered from RS2
3710	06/04/13	CTD	Yes	7000	Good. Recovered from RS4
3713	06/04/13	CTD	Yes	7000	Good. Recovered from RS5
3714	08/04/13	CTD	Yes	7000	Good. Recovered from RS6
4614	08/04/13	CTD	No	3500	Good. Recovered from RS6
4617	08/04/13	CTD	No	3500	Good. Recovered from RS6
6432	08/04/13	CTD	No	3500	Good. Recovered from RS6
6433	06/04/13	CTD	Yes	3500	Good
6434	06/04/13	CTD	No	3500	Good. Recovered from RS3
6435	08/04/13	CTD	No	3500	Good. Recovered from RS6
6436	06/04/13	CTD	No	3500	Good
6437	06/04/13	CTD	No	3500	Good. Recovered from RS1
8110	06/04/13	CTD	Yes	7000	Good
8111	06/04/13	CTD	Yes	7000	Good
8263	06/04/13	CTD	Yes	3500	Good
8264	06/04/13	CTD	Yes	3500	Good
8265	06/04/13	CTD	Yes	3500	Good
9021	06/04/13	CTD-DO	Yes	3500	Good
1784	07/04/13	CTD	No	7000	Good
6467	07/04/13	CTD	Yes	7000	Good
7647	07/04/13	CTD	Yes	7000	Good
8109	07/04/13	CTD	Yes	7000	Good
8110	07/04/13	CTD	Yes	7000	Good
8111	07/04/13	CTD	Yes	7000	Good
9410	07/04/13	CTD-DO	Yes	7000	Good
9411	07/04/13	CTD-DO	Yes	7000	Good

Table 3: Summary of calibration dips. Note: three 25-minute stops were made at ~3500, ~2500 and ~1500 m..

## *Notes on recovered instruments*

### **1. Bottom pressure recorders**

**SBE53s.** All 6 BPRs deployed in 2011 were recovered. Overall, their performance was quite good, as we have become accustomed to. However, there are a few concerns, which are as follows. Firstly, the crates in which the BPRs SBE53 23, 24, 25, 47 and 52 had been transported to BIO after recertification at Sea Bird showed clear evidence that they had been subject to severe shock, and some of the crates were very badly damaged. Examination of the BPRs at BIO by Rick Boyce and Adam Hartling in September 2011 did not indicate, however, that the instruments had been badly



affected. Another serious problem with these BPRs is that all of them were reset at Sea Bird as having an internal temperature sensor, while, in reality, they use all five an external temperature sensor. As a result, the calibration coefficients are likely to be significantly off the mark for all these instruments. Subsequently, Jeff Pugh and I carried out an experiment in which all these BPRs and, in addition, the new BPR SBE53 73, were kept running for 24 hours in the geochemical laboratory on board the Hudson. All six instruments performed reasonably well, providing reassurance as to the integrity of the sensors in spite of the problems that likely took place during shipping from Sea Bird to BIO.

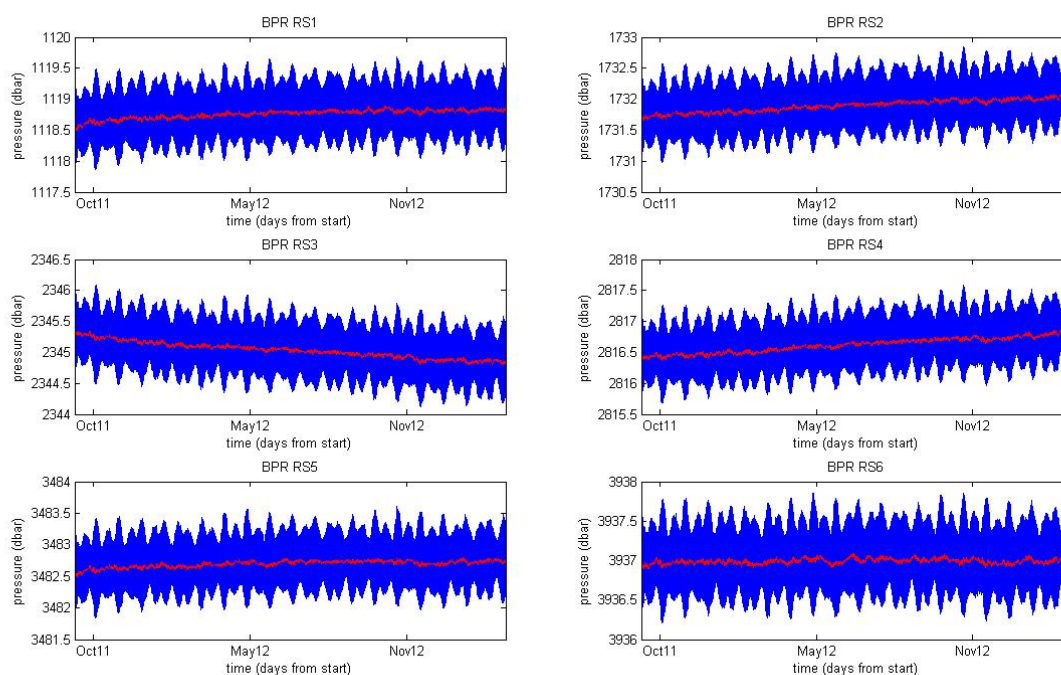


Figure 1: Time series of bottom pressures from recovered SBE53s. The blue line traces the raw data and the red line depicts a moving averaged version of the data calculated with a 1 day and 20 minutes averaging window.

A small problem was encountered when downloading the data from SBE53 73. The file .hex was corrupted and it was almost two times as large as the .hex files from the other BPRs. The problem was solved by uploading the data from this BPRs at a smaller baud rate (9600) than the one used for the other BPRs (115200). An additional and more serious problem is that all the reference frequencies measured during the deployment appear to be zero. Whether this is a problem with the sampling of these frequencies or only with their recording is unclear. We have run tests on the performance of the ovenized crystal oscillators after recovery of the BPR units using the Seaterm command 'tsx'. These tests seem to give reasonable oscillator frequencies and so I wonder whether the problem is with the recording or downloading of these frequencies. Sea Bird will be alerted to this problem.

Pressure ranges in all 5 recovered sites were approximately 1.5 decibars, with trends over the period of measurement that can be as large as 0.2 decibars per year, significantly larger than in the previous year when the trends were on the order of  $\sim 0.1$  decibars per year. This poorer performance might in part be explained by the various problems referred to above. The BPRs will be returned to Sea Bird for refit and calibration.

After recovery, the BPRs were kept running for several days inside the geochemical lab of the

Hudson in order to obtain a dry calibration against a high accuracy Digiquartz barometer. Figure 2 shows the time series of BPR and barometer pressures (left panel) and BPR temperatures (right panel) between 07-04-2013 at ~18:12:06 and 09-04-2013 at ~18:47:16. This is the period during which all BPRs were placed in the geochemical lab. BPRs 23, 24, 47, 52 and 73 were recovered on 05-04-2013. Dry-calibration data for all of these five moorings was collected between the 05-04-2013 and 07-04-2013, but is not shown here. It is clear from the figure that SBE53 25 takes about one day to adapt to laboratory temperature, which suggests that the temperature recorded is an internal one. During the last day of calibration, all BPRs as well as the barometer evolve in consonance, exhibiting very similar variability but separated from one another by a nearly constant offset. Taking the barometer pressure as truth, the pressure error can be as high as 0.8 decibars.

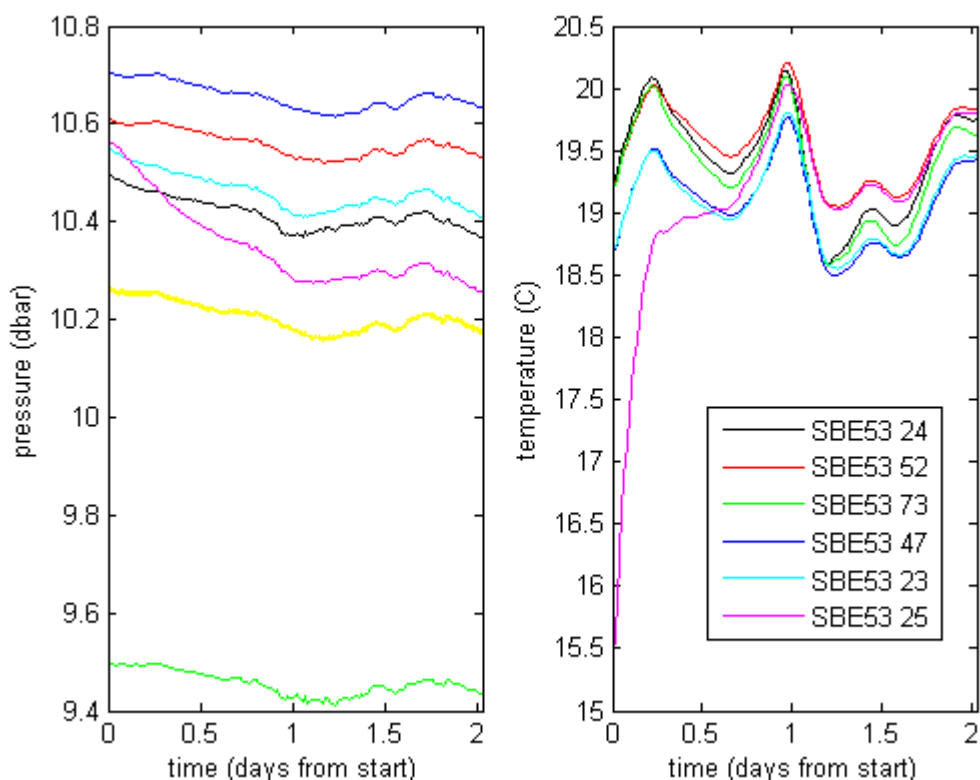


Figure 2: Time series of pressure (left) and temperature from the 6 BPRs that were recovered during the cruise and dry-calibrated in the geochemical laboratory. The yellow curve on the left panel is the one for the DQ 765 barometer time series.

In 2011 similar dry tests were carried out on these BPRs before deployment although no barometer was available for their calibration. It is interesting to note that the sign of the pressure difference between any two BPR time series remains the same as in the dry tests of 2011 (see cruise report for HUD11043). The SBE53 23 needs to be excluded from this inter-comparison because it was placed upside down during the tests carried out in 2011 and, as a result, its recorded pressure at the time was more than 2 dbar lower than the pressure of any of the other BPRs.

## 2. RDI Workhorse ADCPs

All ADCPs were recovered, although the ADCP at RS2 seems to have malfunctioned. No data was recorded by this instrument. All other ADCPs provided fairly good data, and none of them run out of batteries prematurely. The effective ADCP range decreases with depth, presumably as a result of the decreasing number of scatterers in the water column as depth increases. The mooring length was increased compared to previous years in order to avoid contamination of the ADCP bins in the

range >50 m by the presence of the mooring's top float. Only detailed analysis of these data back at BIO will allow us to determine whether this change of mooring architecture worked, but a preliminary examination seems to show an improvement. In all sites, the measured velocities are very coherent in the vertical (see figure below). At all sites, the vertical profile of the current appears to be somewhat distorted at a range of ~50 m. This is due to the presence of a microCAT at that depth.

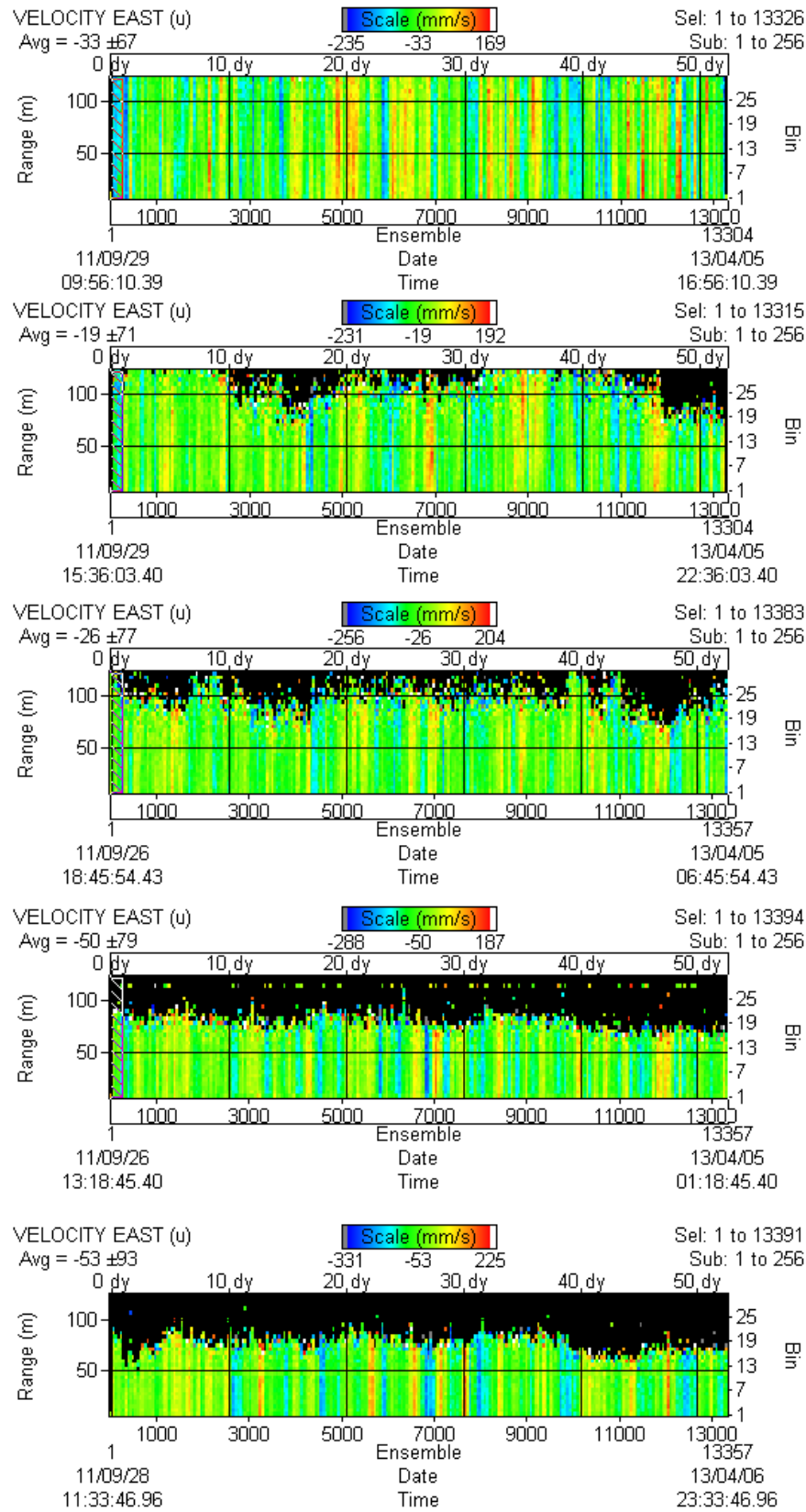


Figure 3: Time series of zonal velocity from ADCPs at, from top to bottom, RS1, RS3, RS4, RS5 and RS6. As a results of battery malfunction the ADCP at RS2 recorded no data.

### **3. SBE37 microCATs**

The mooring microCAT data was summarily examined soon after recovery. All data seemed of acceptable quality. Drift of the pressure gauges amounted to  $\pm 0.2$  decibars or less in all instruments. When drift existed, it was predominantly negative. Only the bottom microCAT at RS5 (SBE37 1806) shows a gentle drift of  $\sim 0.5$  dbar. microCATs with drifts larger than 2 decibars are SBE37 1809 (-10 dbar) and SBE37 1808 (-17 dbar). The microCAT SBE37 6434 (top microCAT at RS3) has not evident drift, but the pressure time series shows a jump of -4 dbar that occurred toward the end of 2012. There is no indication of a similar jump in the data from SBE37 3681, which was located about 50 m below 6434, and this suggests that the pressure jump displayed by SBE37 6434 is spurious.

### **4. CTD data**

CTD casts were made adjacent to all six RS mooring sites. BIO are currently performing quality control and calibration of these CTD data.

## RS LINE ARRAY REDEPLOYMENT

### *Preparation of BPRs for deployment*

Six BPRs are available for deployment during the cruise, although we will consider the possibility of turning around one or more of the BPRs recovered. The BPRs are

Part #	Serial #	Batteries	Notes
5340415	5340415-0045	New alkaline batteries	Poorly secured in crate. The amount of foam in the crate is not enough to ensure that the BPR is conveniently padded and does not move during transportation (see Figure 2). Transportation problems are likely to have been at the root of problems experienced with the high accuracy reference oscillator glass metal seals which were discovered to be broken upon examination of the BPR at SBE. All BPRs sent for recertification to SBE (serial numbers 45, 48, 49, 50, 66) seemed to have this problem. Previously deployed at RS2 in HUD2010049.
5340415	5340415-0048	New alkaline batteries	Poorly secured in crate (see comments for SBE53-0048 above). Previously deployed at RS3 in HUD2010049.
5340415	5340415-0049	New alkaline batteries	Poorly secured in crate (see comments for SBE53-0048 above). Previously deployed at RS5 in HUD2010049.
5340415	5340415-0050	New alkaline batteries	Poorly secured in crate (see comments for SBE53-0048 above). Previously deployed at RS1 in HUD2010049.
5357555	5357555-0065	New alkaline batteries	Newly bought BPR (2013). This BPR was bought directly by NOC and shipped to BIO ahead of the cruise. It is the only BPR with an internal temperature sensor. All other BPRs are equipped with high accuracy external temperature sensors. Never deployed.
5353201A	5353201-0066	New alkaline batteries	Poorly secured in crate (see comments for SBE53-0048 above). Previously deployed at RS4 in HUD2010049.

Table 4: Summary of SBE53 BPRs that were made ready for deployment.

The six BPRs were set up for dry calibration. The dry calibration consists in having a BPR running out of the water in the vertical position (i.e., with the cable connectors pointing upwards) concurrently with a very high accuracy barometer, so that the pressures recorded by both systems can be compared and the BPR's pressure corrected accordingly. All BPRs were configured to use the same settings as in a normal deployment (so that the accuracy and precision of the measurements are exactly the same as during a deployment) and then left to run for about 24 hours. The only differences in the BPRs configuration were as to the start times. Two of them (SNs 50 and 48) were set to start at 1655 GMT, while the rest (SNs 66, 65, 49 and 45) were set for 1855 GMT. The reason for this discrepancy is simply a fortuitous delay that prevented us from having all BPRs set up before the intended initial start time (i.e., 1655 GMT). Another difference between these BPRs is that SN 65 has an internal temperature sensor while all others are equipped with a more accurate external temperature sensor. The barometer (a Paroscientific Model 765-15A Pressure Standard, SN 24004, with a range of 0-15 psi) was set to start recording pressure at ~1910 GMT. The sampling rate was set to 1 second. The barometer records internally every single sample. The barometer data can subsequently be downloaded to a computer using Digiquartz data download software. A quirk of either the recording or data download software of the Digiquartz barometer seems to be that an 'hour:minute:second' time stamp is not written when the time is 00:00:00 (i.e., midnight). For example, this is how the output file looked like near midnight on the 3<sup>rd</sup> April 2013:

16685,03/04/2013 23:59:59,1006.8977,hPa,N  
16686,04/04/2013,1006.8977,hPa,N  
16687,04/04/2013 00:00:01,1006.8992,hPa,N

The time component of the date-time stamp is gone. This causes problems when reading the output file with Matlab. The “faulty” line was manually corrected by adding the right time to it. Figure 1 shows the time series of pressure and temperatures from all BPRs and high-accuracy barometer between approximately 1909 GMT on 03-04-2013 and 2100 on 04-04-2013. Note that each BPR sample consist in a 5-minute averaged pressure taken every 20 minutes. In contrast the barometer samples are point measurements taken every second.

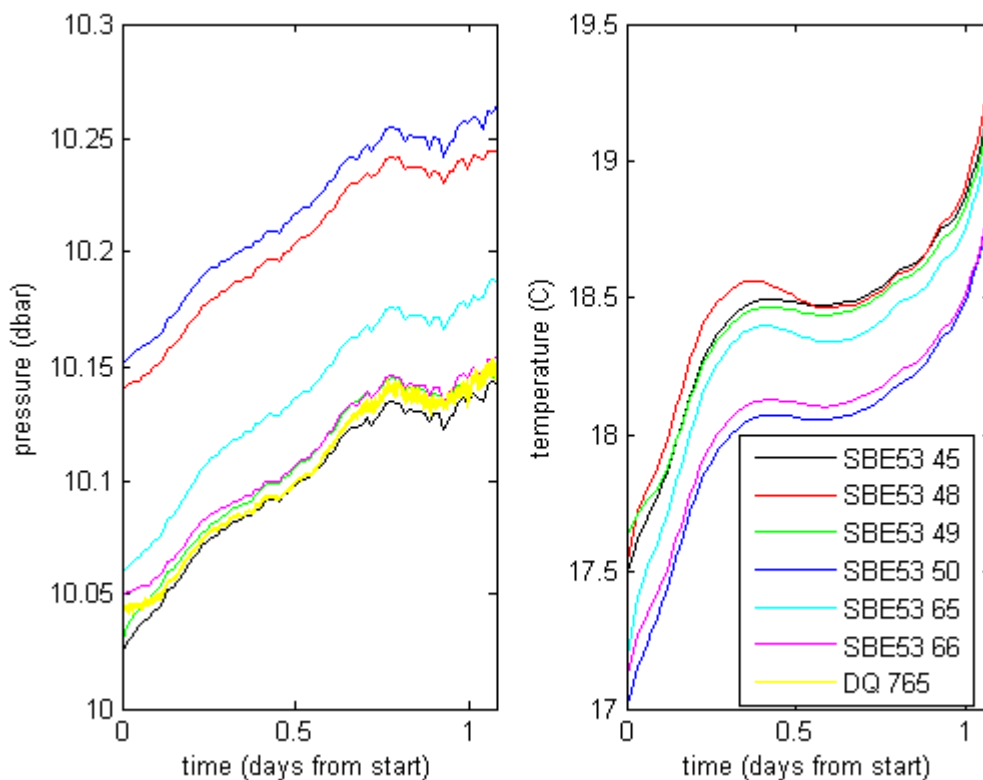


Figure 4: Time series of pressure (left) and temperature from the 6 BPRs that were set up ready for deployment.

We note the maximum pressure difference between the different sensors is on the order of 0.1 dbar, which is significantly smaller than the nominal quoted accuracy for these instruments of  $\sim 0.7$  dbar (0.01% of the full scale, which is 10000 psi, or  $\sim 6895$  dbar). Compared to the Digiquartz barometer, whose nominal accuracy is 0.008% of the range (i.e., 0.0008 dbar) and is used here as a reference, the SBE53 perform fairly well in following pressure variations on the order of 1 cm or so. In contrast, the accuracy of the temperature sensor is puzzlingly low. The nominal accuracy quoted by SBE for their high-accuracy temperature sensors is 0.002 °C. However the maximum temperature difference between sensors is of about 0.5 °C. Clearly, something is not quite right. SBE will have to be consulted about this problem. When these BPRs are recovered in 18 month's time, the same procedure will be followed in order to obtain an end-point calibration.



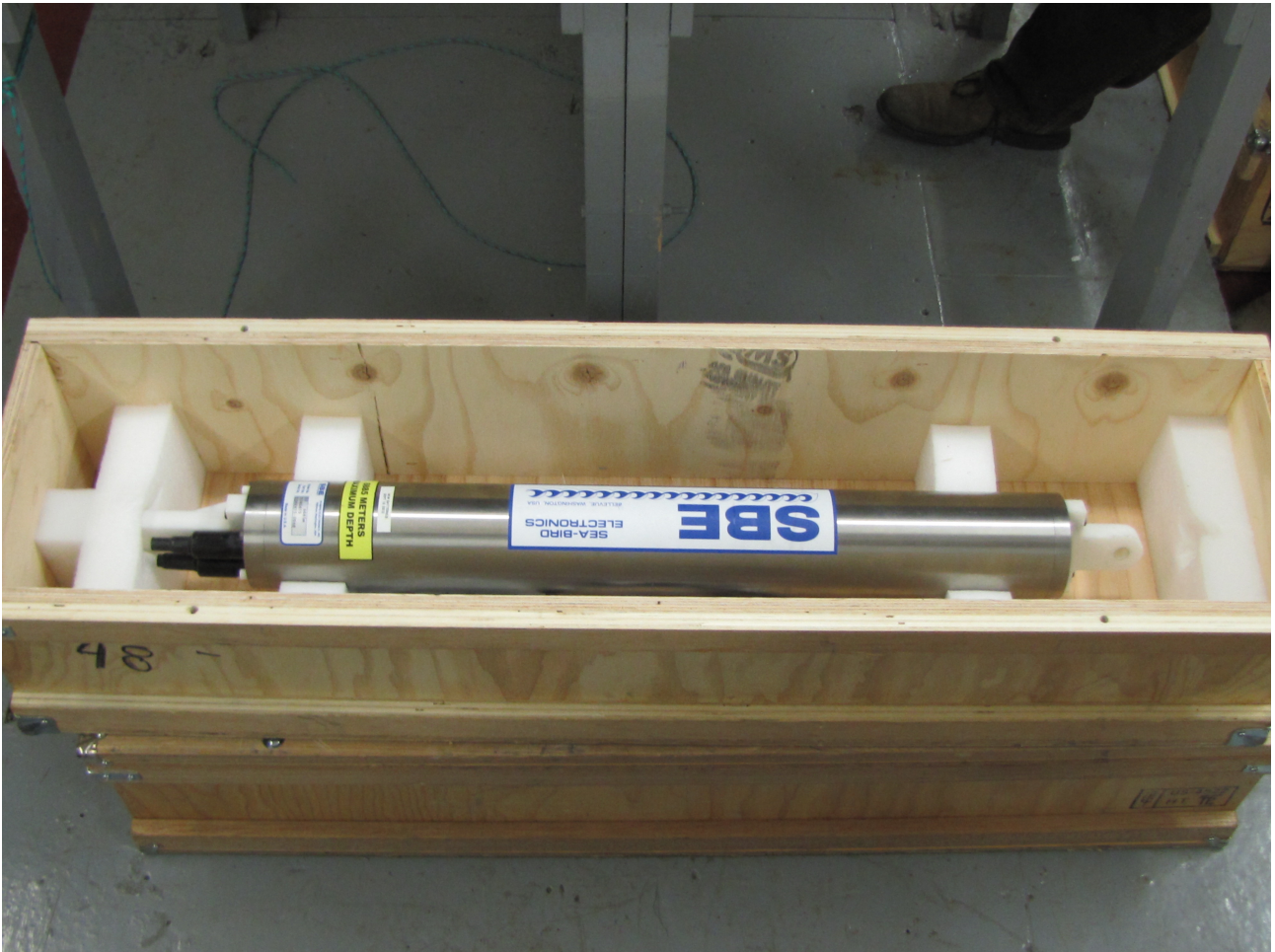


Figure 5: An example of the way in which the recertified SBE53s were shipped to BIO. Note how the top (left) white plastic bar has deformed the protective foam in the crate and is partly embedded in it. At the same time, there is a large gap between the bottom (right) white bar and the piece of foam glued to the crate on the right end. Clearly, the BPR can easily slip up and down (left to right) inside the crate. There is evidence that such slippage has occurred, as the foams on both ends of the crate have been markedly reshaped through contact with the white end plastic bars of the BPR. The protection against shocks and abrupt motion afforded by this way of packing the BPRs is obviously inadequate.

Joel Reiter from SeaBird advised on a test that is useful to run in order to verify the performance of the SBE53 reference crystals that are used to correct the pressure oscillator. The test consists in typing 'tsx' in the command line while connected to a BPR, which produces the following kind of output (from SBE53 45 in this case, just a couple of hours before it was deployed):

```
4000033.3607 20883 0.19 09 Apr 2013 11:20:51
4000033.6804 20767 -0.01 09 Apr 2013 11:22:55
4000032.9874 20597 -0.01 09 Apr 2013 11:25:00
4000032.2940 20430 -0.01 09 Apr 2013 11:27:04
4000031.6540 20278 -0.01 09 Apr 2013 11:29:09
4000031.0940 20143 -0.01 09 Apr 2013 11:31:13
4000030.5604 20021 -0.01 09 Apr 2013 11:33:18
4000030.0806 19909 -0.00 09 Apr 2013 11:35:22
4000029.6273 19804 -0.00 09 Apr 2013 11:37:26
4000029.2003 19706 -0.00 09 Apr 2013 11:39:31
4000028.8006 19611 -0.01 09 Apr 2013 11:41:35
4000028.4006 19521 -0.01 09 Apr 2013 11:43:40
```



4000028.0006 19433 -0.00 09 Apr 2013 11:45:44  
4000027.6272 19342 -0.01 09 Apr 2013 11:47:49  
4000027.4561 19292 -0.02 09 Apr 2013 11:49:53

A dozen lines or so are apparently needed to carry out a proper evaluation. This output can then be compared with similar data that SeaBird engineers produce during recertification tests. The key comparison is in the first two columns. The first column is the low power oscillator as measured against the reference and the second is the temperature frequency.

### *Preparation of microCATs for deployment (calibration dips)*

Prior to their deployment, calibration dips were carried out for all microCATs. Some of these dips included both fresh microCATs, ready for deployment, and microCATs just recovered. The microCATs were clamped to the CTD rosette and dipped to ~3500 m. On its ascent, the rosette was stopped for 25 minutes at ~3500 m, 2500 m and 1500 m. The microCAT sampling interval was 10 seconds. The objective of a calibration dip is to obtain simultaneous conductivity, temperature and pressure data from both the microCATs and the CTD system. The CTD system is frequently calibrated against temperature, salinity and pressure standards and, therefore, its data is of high accuracy and precision. The CTD data are used to calibrate the microCAT measurements. Combining a pre-deployment calibration dip, such as the one described here, with a post-deployment dip, it is possible to calibrate the microCAT data to an accuracy comparable to that of the ship's CTD system. A summary of the calibration dips carried out can be found in Table 3.

The agreement in temperature between microCATs is very good, with a temperature spread that is not larger than 0.005 °C at any depth. The spread in conductivity is 0.001 S/m, and that in pressure is 40 dbar. In the second calibration dip, only fresh microCAT were deployed. Their spread in pressure was of only 10 dbar, compared to the 40-dbar spread of the first calibration dip, which combined fresh and recovered microCATs. It is the recovered microCATs that contribute the most to the spread in pressure, bringing it up to the quoted 40 dbar (see Figures 6,7 and 8). The existence of this relative large differences in pressure illustrates why it is so important to carry out this type of calibration, specially on recovered microCATs. However, note that the pressure spread observed in the fresh microCATs, while consistent with the manufacturer's specification, is still quite large. The calibration will help to reduce such spread by, nominally, an order of magnitude.

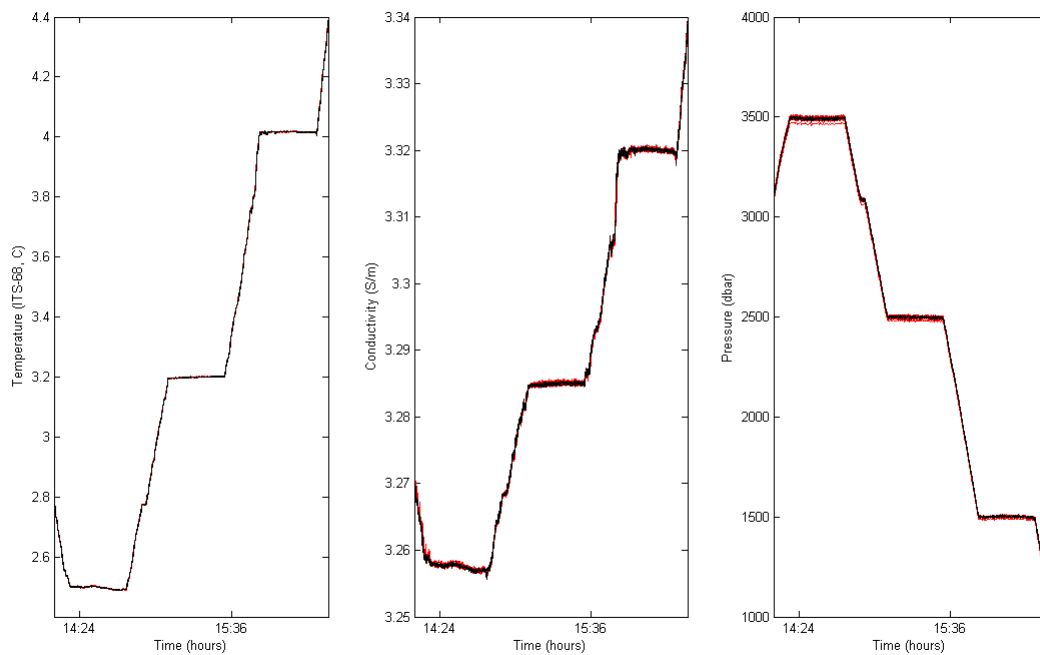


Figure 6: Results from the calibration dip done on the 6<sup>th</sup> April 2013. Each panel includes data from all the microCATs (left: temperature; centre: conductivity; right: pressure). The red curves correspond to microCATs recovered at RS1 to RS5. The black curves are for fresh microCATs (see Table 3).

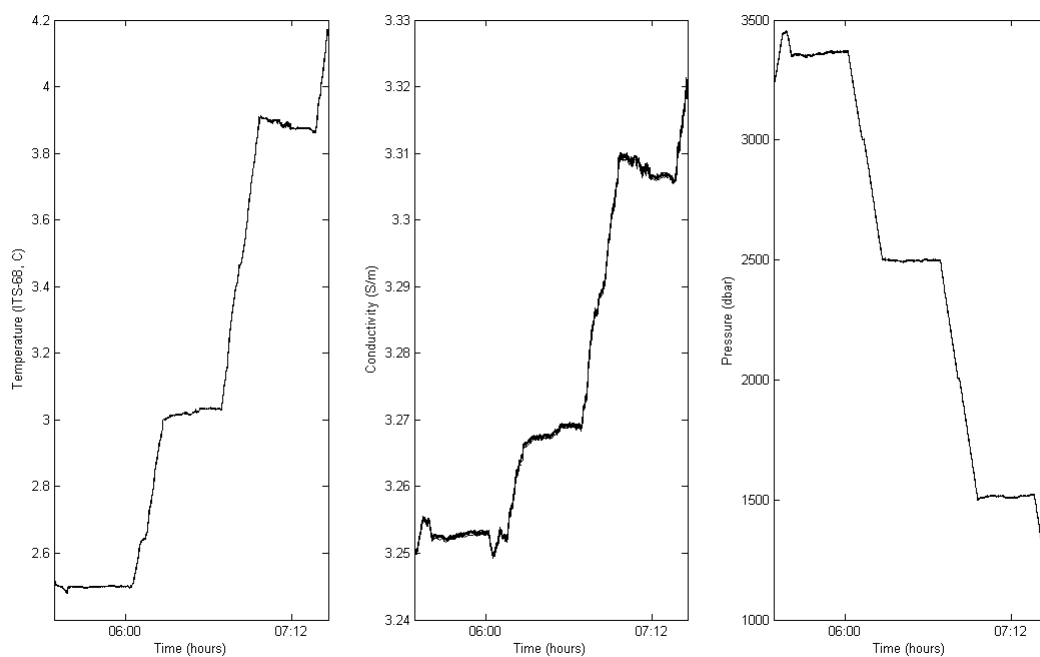


Figure 7: Results from the calibration dip done on the 7th April 2013. Each panel includes data from all the microCATs (left: temperature; centre: conductivity; right: pressure). See Table 3.

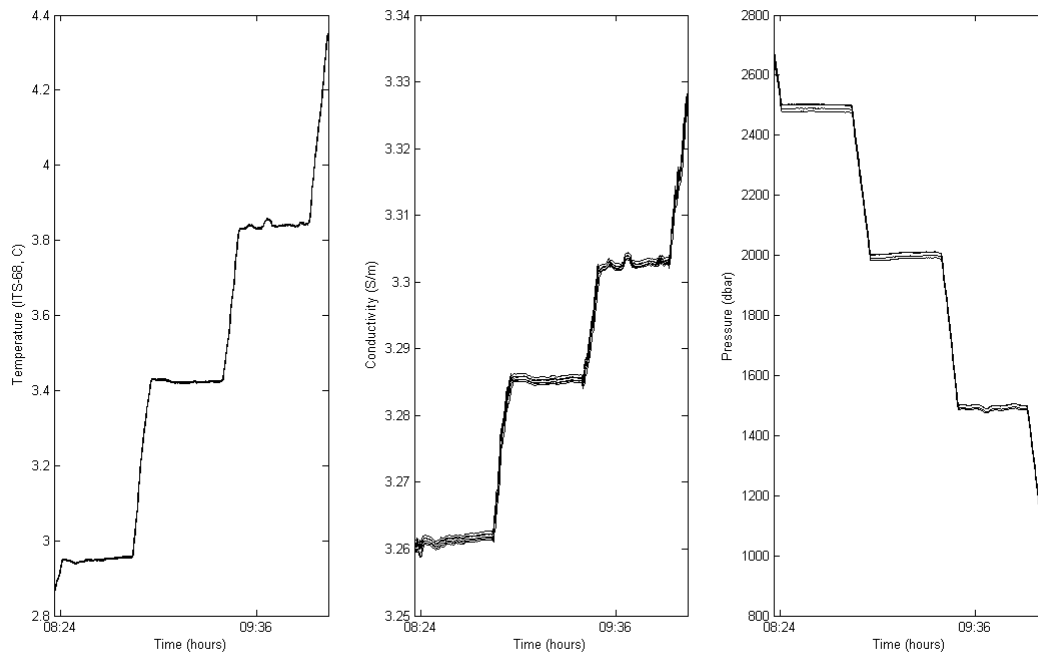


Figure 8: Results from the calibration dip done on the 8th April 2013. Each panel includes data from all the microCATs (lef: temperature; centre: conductivity; right: pressure). The microCATs calibrated here are those recovered from the RS6 mooring. See Table 3.

SITE	LATITUDE (N)	LONGITUDE (W)	DATE & TIME AT BOTTOM	DEPTH (m) SV=1489 m/s	MOORING TYPE
RS1	42 51.1240	61 38.0330	09-04-2013, 11:29 Z	1081	Short
RS2	42 44.3112	61 34.4219	09-04-2013, 14:14 Z	1698	Short
RS3	42 39.3633	61 27.4953	08-04-2013, 22:28 Z	2280	Short
RS4	42 33.3927	61 22.4997	08-04-2013, 18:55 Z	2724	Short
RS5	42 23.8300	61 13.3595	08-04-2013, 15:34 Z	3440	Short
RS6	42 10.8822	61 00.2514	07-04-2013, 20:15 Z	3812	Short

Note. Positions were calculated from M-Cal triangulations (see SEANAV's website <http://www.seanav.com/>). All times record the moment when the mooring anchor hit bottom. Echo sounder depths with assumed sound velocity of 1489 m/s.

Table 5: Moorings deployed.

The following table includes the serial number of all the instruments, beacons and releases deployed in the line. Mooring schematics can be found in the Appendix.

	RS1	RS2	RS3	RS4	RS5	RS6
Casabel Irid. beacon	300034012722800	300034012126050	300034012204160			
Sable Irid. beacon				300034012482560	300234060527560	300234060522560
SBE37 microCAT	9021	9410	9411	6436	8110	6467
SBE37 microCAT	6433	8263	8264	8265	8109	8111
WHADCP	13983	19080	13873	10941	13874	13592
Benthos 865-A acoustic release	59519 40083	59437 40081	54935 44302	47459 59434	59518 40047	59433 51801
SBE53 BPR	50	45	48	66	49	65

Table 6: Summary of equipment deployed

Instrument	Site	Sampling (ensemble) interval (seconds)	Averaging interval	Number of bins/ bin size (m)	Time of first record (Z)	Time of last record (Z)
SBE37-SMP 9021 CTD-DO/3500 m	RS1	3600	Note 1	-	09/04/13 10:00	
SBE37-SMP 6433 CTD/3500 m	RS1	1800	Note 1	-	09/04/13 10:00	
SBE37-SMP 9410 CTD-DO/7000 m	RS2	3600	Note 1	-	09/04/13 13:00	
SBE37-SMP 8263 CTD/3500 m	RS2	1800	Note 1	-	09/04/13 13:00	
SBE37-SMP 9411 CTD-DO/7000 m	RS3	3600	Note 1	-	08/04/13 20:00	
SBE37-SMP 8264 CTD/7000 m	RS3	1800	Note 1	-	08/04/13 20:00	
SBE37-SM 6436 CTD/3500 m	RS4	1800	Note 1	-	08/04/13 16:00	
SBE37-SMP 8265 CTD/3500 m	RS4	1800	Note 1	-	08/04/13 16:00	
SBE37-SMP 8110 CTD/7000 m	RS5	1800	Note 1	-	08/04/13 11:00	
SBE37-SMP 8109 CTD/7000 m	RS5	1800	Note 1	-	08/04/13 11:00	
SBE37-SMP 6467 CTD/7000 m	RS6	1800	Note 1	-	07/04/13 17:00	
SBE37-SMP 8111 CTD/7000 m	RS6	1800	Note 1	-	07/04/13 17:00	
WHADP Sentinel 13983	RS1	3600	50 pings/ensemble 1 ping/36 s	30/4/50	09/04/13 11:00	
WHADP Sentinel 19080	RS2	3600	50 pings/ensemble 1 ping/36 s	30/4/50	09/04/13 12:00	
WHADP Sentinel 13873	RS3	3600	50 pings/ensemble 1 ping/36 s	30/4/50	12:00:00	
WHADP Sentinel 10941	RS4	3600	50 pings/ensemble 1 ping/36 s	30/4/50	08/04/13 17:00	
WHADP Sentinel 13874	RS5	3600	50 pings/ensemble 1 ping/36 s	30/4/50	08/04/13 12:00	
WHADP Sentinel 13592	RS6	3600	50 pings/ensemble 1 ping/36 s	30/4/50	07/04/13 18:00	
SBE53 50	RS1	1200	300 s <sup>2</sup>	-	04/04/13 23:55	
SBE53 45	RS2	1200	300 s <sup>2</sup>	-	09/04/13 11:55 <sup>3</sup>	
SBE53 48	RS3	1200	300 s <sup>2</sup>	-	04/04/13 23:55	
SBE53 66	RS4	1200	300 s <sup>2</sup>	-	04/04/13 23:55	
SBE53 49	RS5	1200	300 s <sup>2</sup>	-	04/04/13 23:55	
SBE53 65	RS6	1200	300 s <sup>2</sup>	-	04/04/13 23:55	

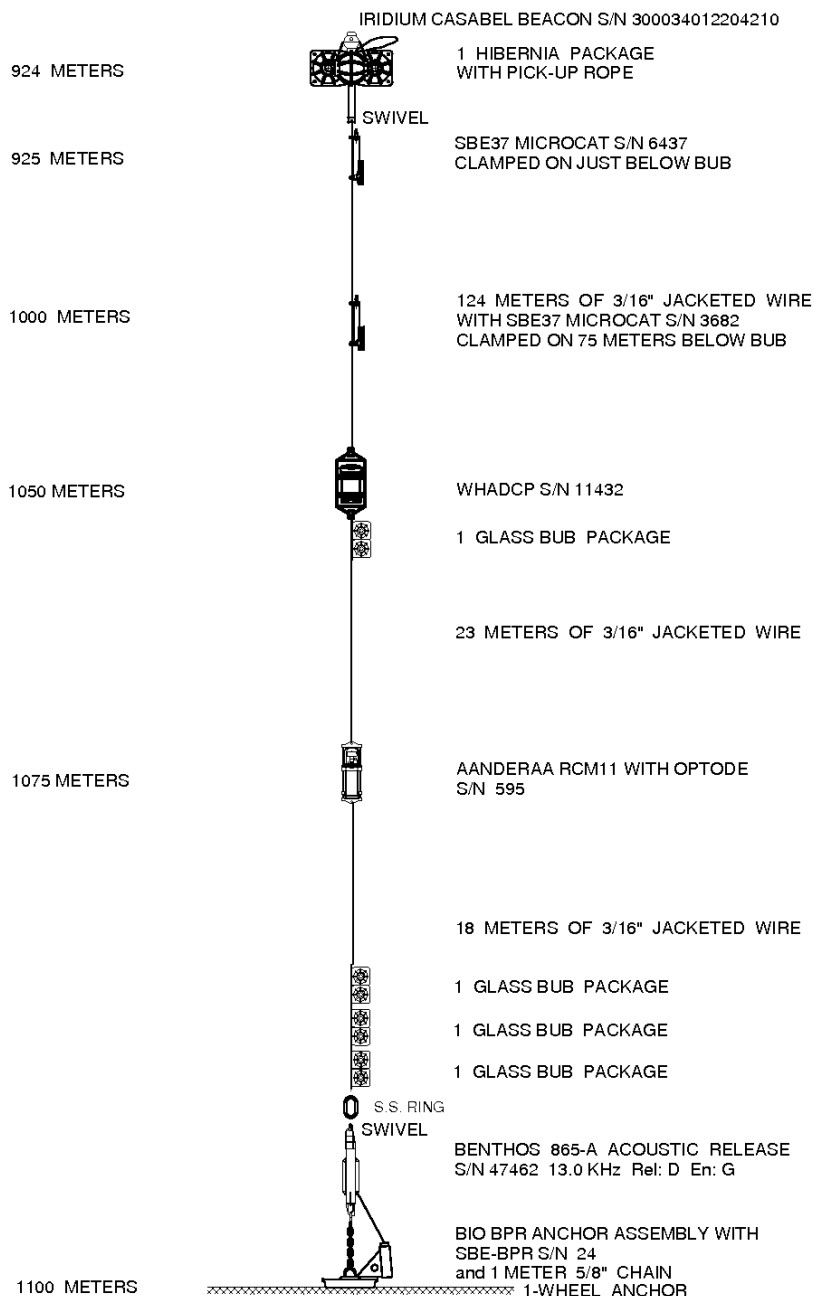
- .1. The most recent SBE73s no longer have a tunable averaging option: each sample is calculated as the average of 4 consecutive measurements (because of this, the fastest possible sampling rate is about 15 seconds).
- .2. Sensor warming up period was set to 300 seconds too. The time stamp for SBE53 samples correspond to the beginning of each 300- second averaging interval. The reference frequency measurement was set to once per week. With these settings, and taking into account that all SBE53s were fitted with alkaline batteries, the estimated maximum battery endurance should be 805.6 days.
- .3. This BPR was set to start later because it was used on the 9<sup>th</sup> April to run a test of its crystal oscillator, which required to stop the BPR and then restart it again after the test was completed.

Table 7: Summary of instrument set up.

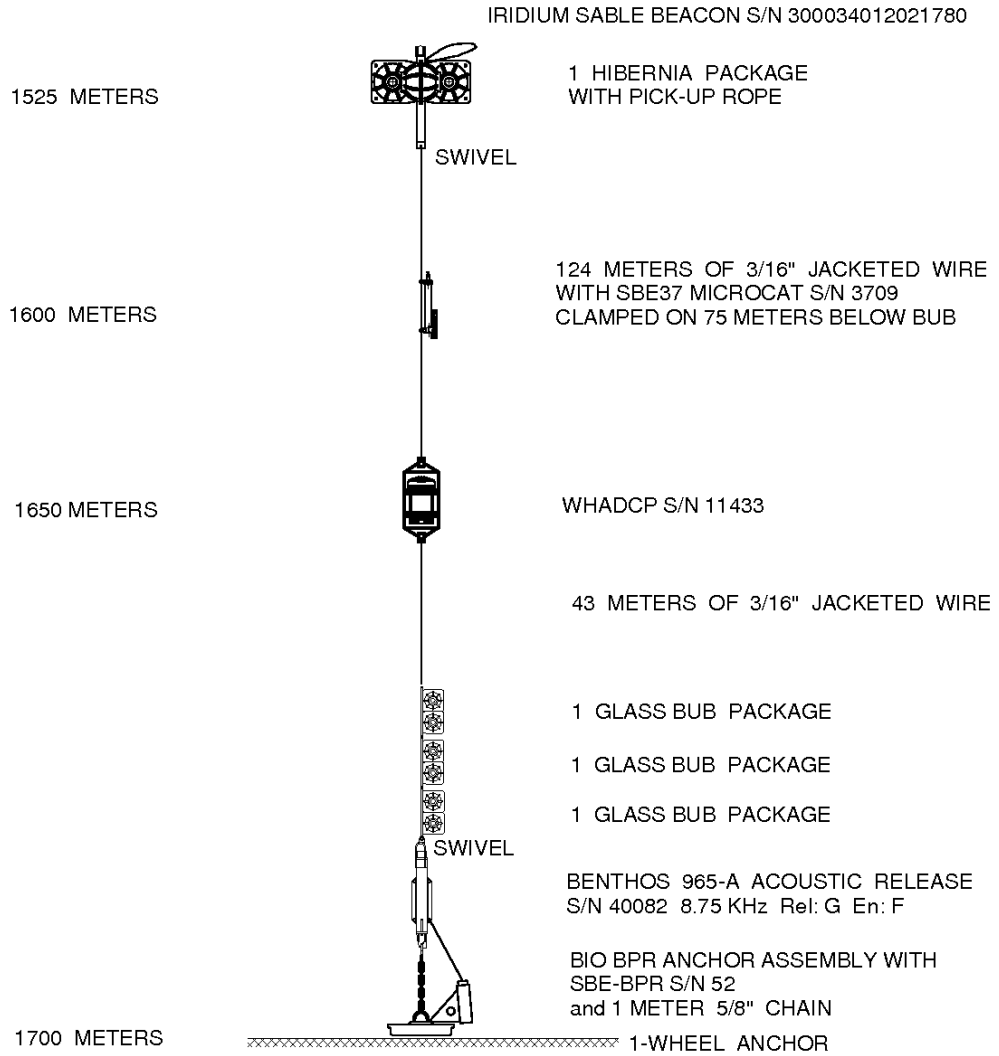
# APPENDIX. MOORING DIAGRAMS

## *Deployments 2011*

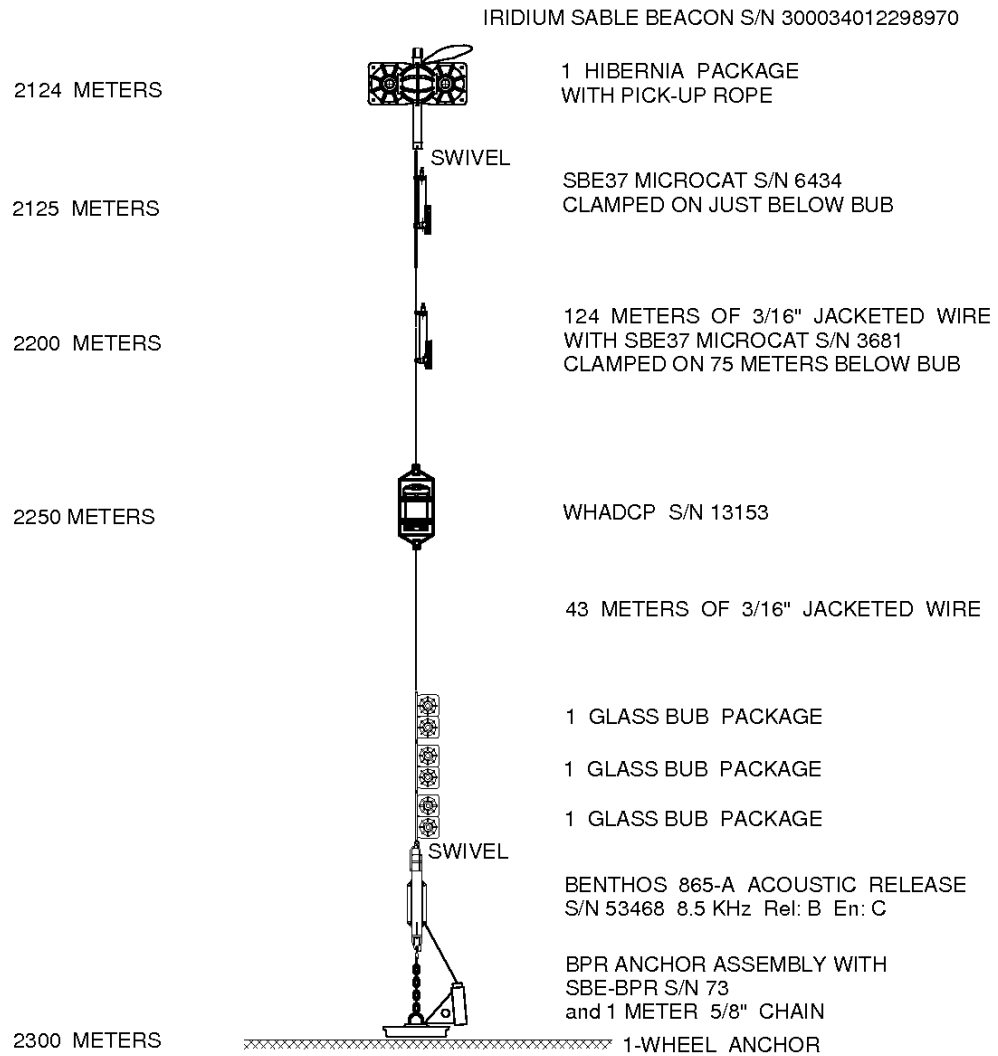
### MOORING # 1804 RS1 LODER/POL SCOTIAN SLOPE OCT 2011



**MOORING # 1805 RS2 LODER/POL SCOTIAN SLOPE OCT 2011**

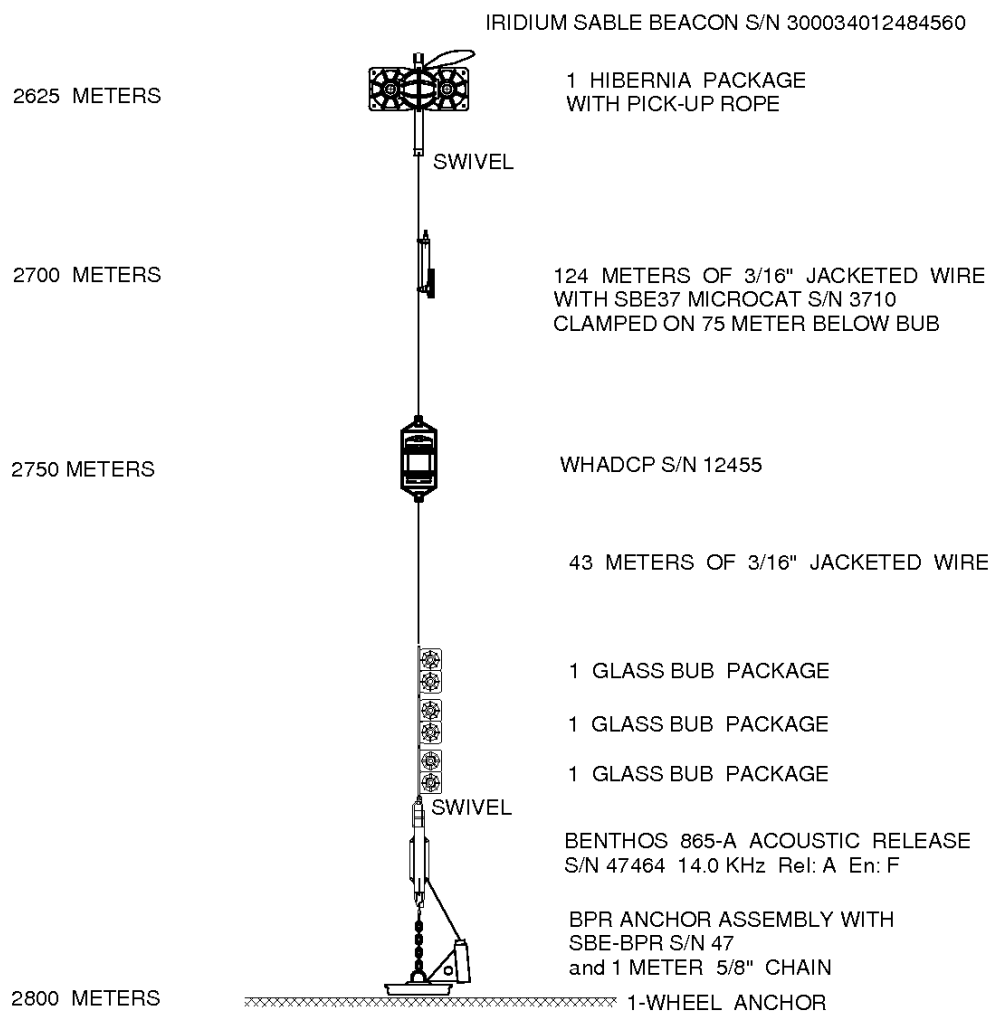


**MOORING # 1806 RS3 LODER/POL SCOTIAN SLOPE OCT 2011**

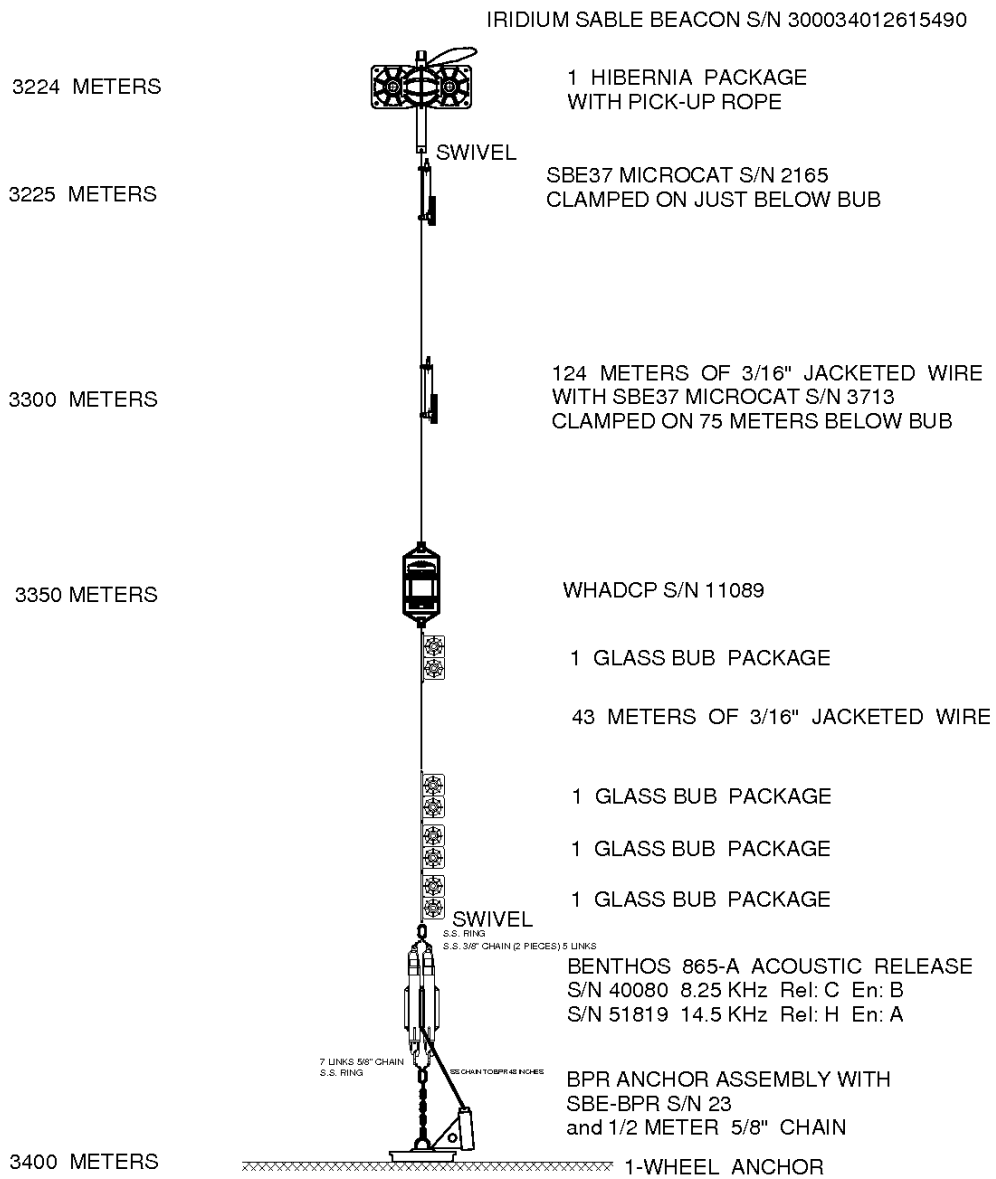




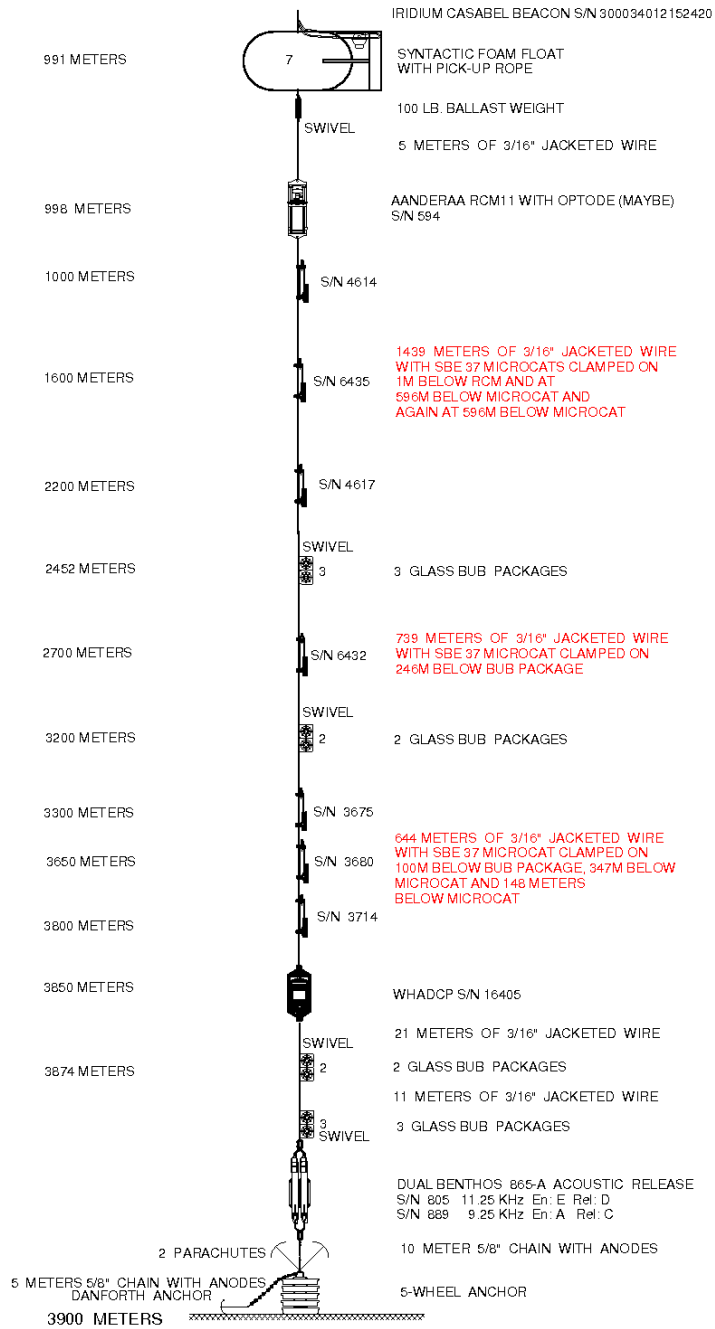
**MOORING # 1807 RS4 LODER/POL SCOTIAN SLOPE OCT 2011**



**MOORING # 1808 RS5 LODER/POL SCOTIAN SLOPE OCT 2011**

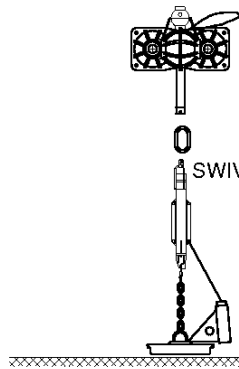


**MOORING # 1809 RS6 LODER/POL SCOTIAN SLOPE OCT 2011**



**MOORING # 1810 RS6A LODER/POL SCOTIAN SLOPE OCT 2011**

3900 METERS



IRIDIUM CASABEL BEACON S/N 30034012153420

1 HIBERNIA PACKAGE  
WITH PICK-UP ROPE

S.S. RING

SWIVEL

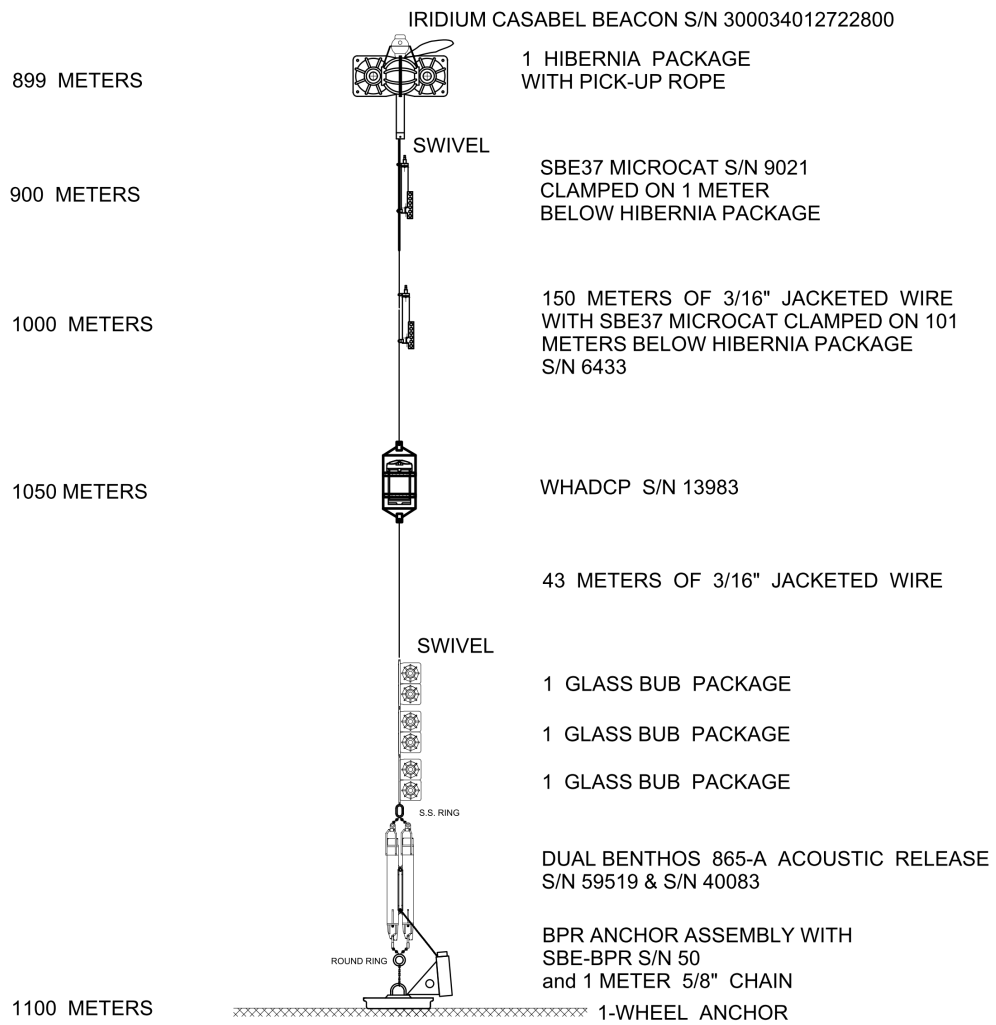
BENTHOS 865-A ACOUSTIC RELEASE  
S/N

BPR ANCHOR ASSEMBLY WITH  
SBE-BPR S/N 25  
and 1 METER 5/8" CHAIN

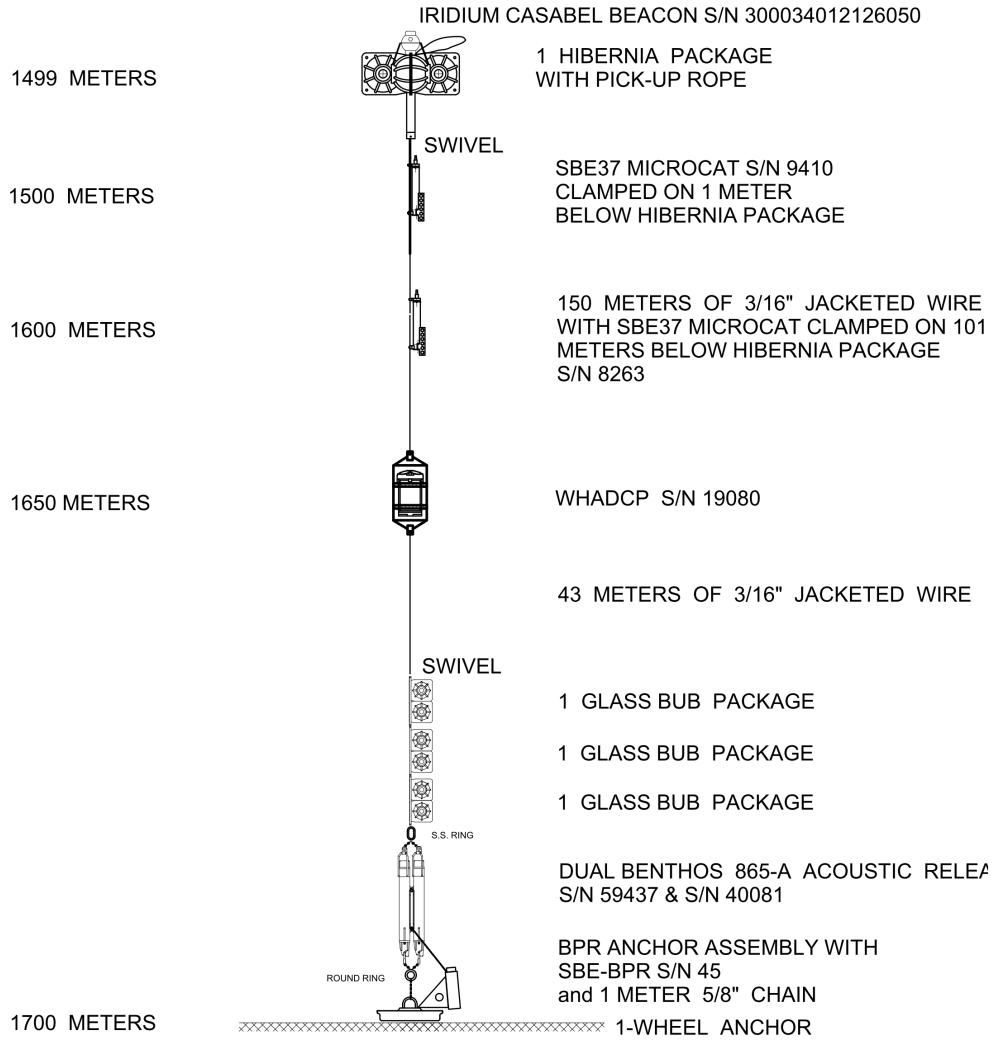
1-WHEEL ANCHOR

*Deployments 2013*

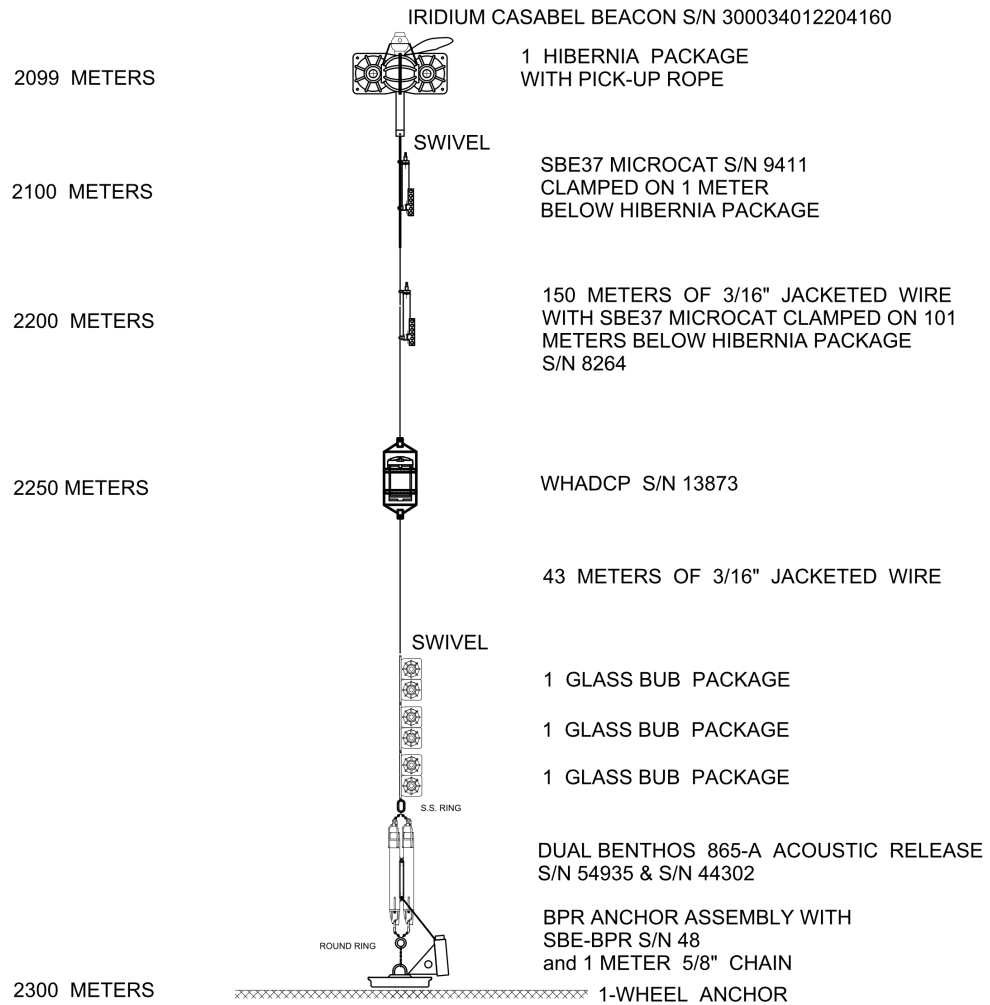
**MOORING # 1834 RS1 LODER/POL SCOTIAN SLOPE APRIL 2013**



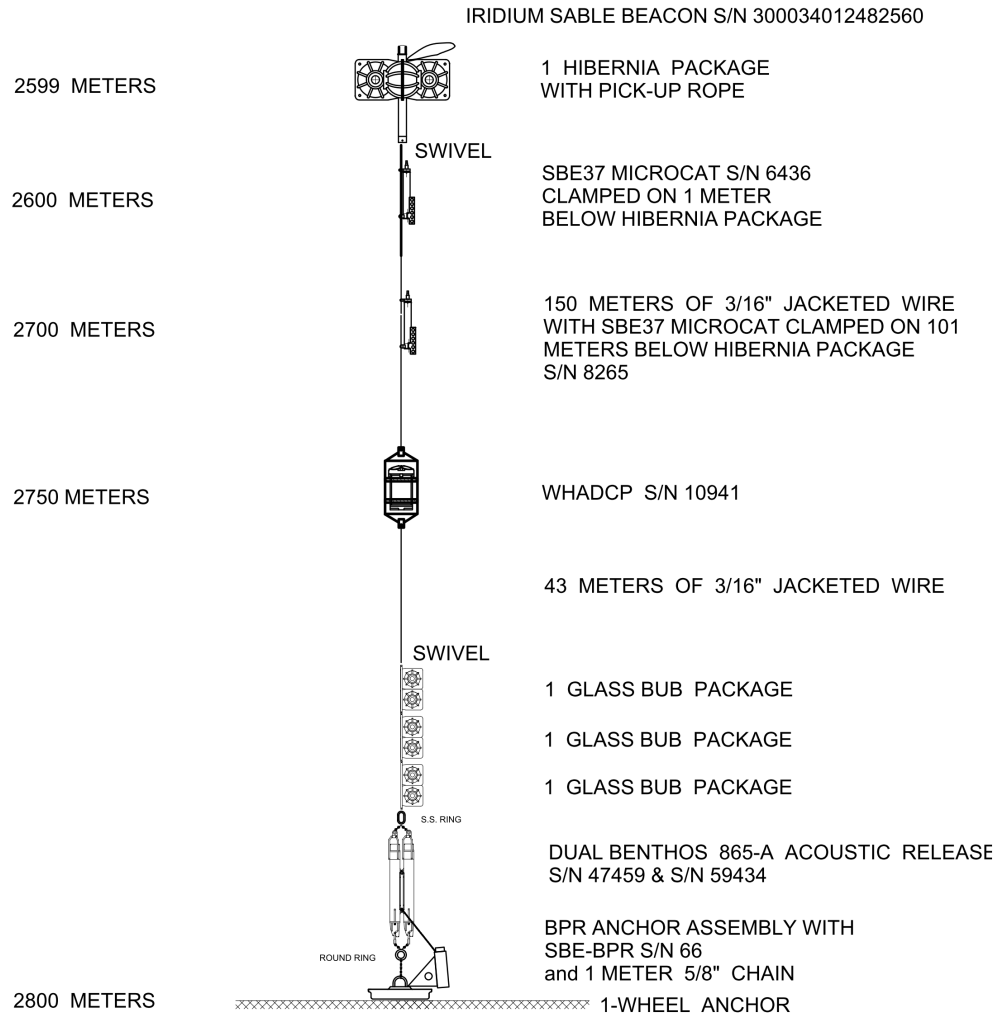
**MOORING # 1835 RS2 LODER/POL SCOTIAN SLOPE APRIL 2013**



**MOORING # 1836 RS3 LODER/POL SCOTIAN SLOPE APRIL 2013**

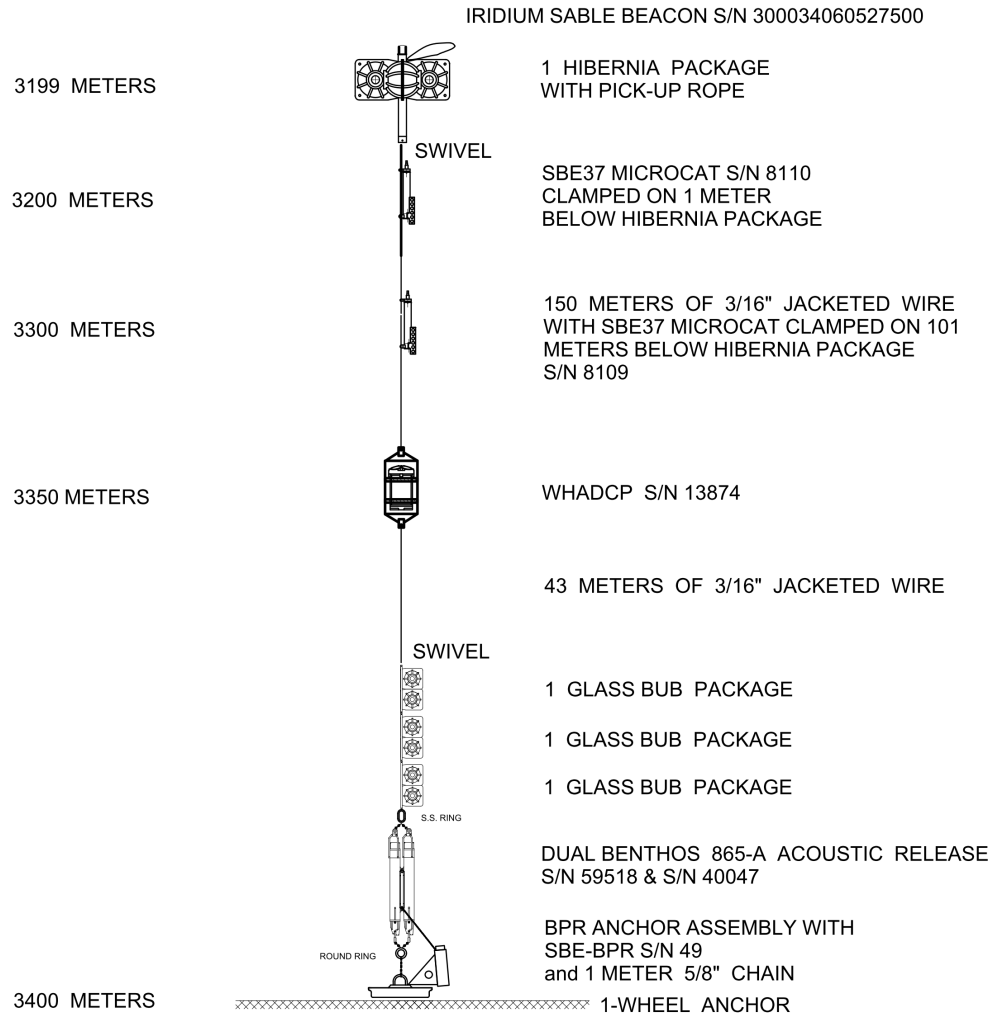


**MOORING # 1837 RS4 LODER/POL SCOTIAN SLOPE APRIL 2013**





**MOORING # 1838 RS5 LODER/POL SCOTIAN SLOPE APRIL 2013**



**MOORING # 1839 RS6 LODER/POL SCOTIAN SLOPE APRIL 2013**

