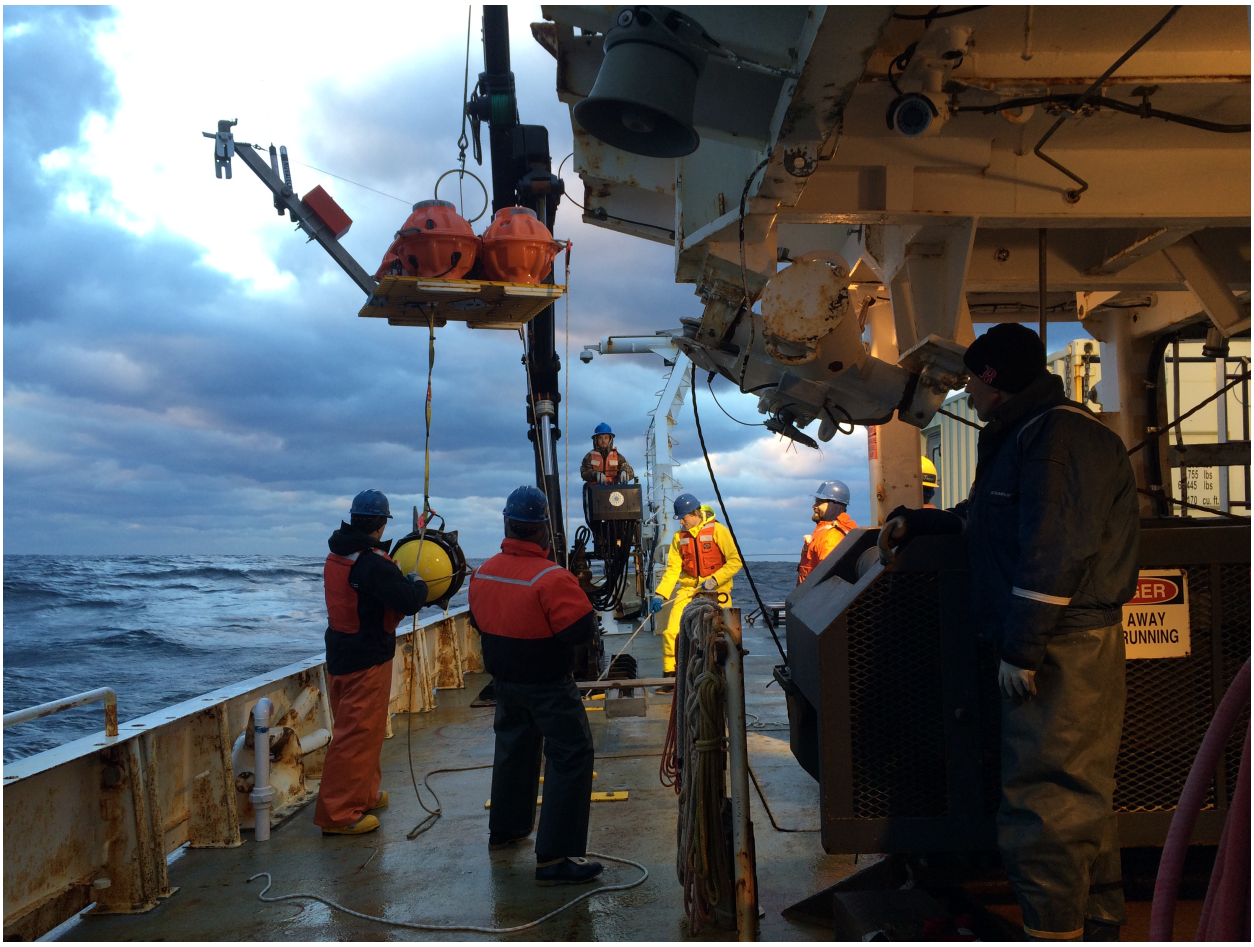
Cruise Report

Eastern North American Margin (ENAM) Community Seismic Experiment (CSE)

Cruise **EN-554**, *R/V Endeavor*
Broadband OBS recovery



Geodynamic Processes at Rifting and Subducting Margins
GeoPRISMS

North-Kingstown (RI)-North- Kingstown
March 27 – April 9, 2015

NSF

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Annexes :

1. Cruise Objective

The purpose of the ENAM community seismic experiment is to collect an open-access onshore/offshore, active/passive seismic dataset across the Mid-Atlantic continental margin that can be used by the community to tackle a broad range of the science questions stated in the NSF-GeoPRISMS Science and Implementation Plans regarding the formation and evolution of rifted margins. The ENAM Community Seismic Experiment (CSE) consists of different components that include on passive and active source seismology. The ENAM data will provide coverage across the shoreline, and over a range of length scales that are appropriate for investigations of shallow sedimentary features and crustal and mantle structure.

The passive-source seismic part of this program involves the one-year deployment of thirty broadband ocean bottom seismometers on the seafloor spanning a 400 x 500 km

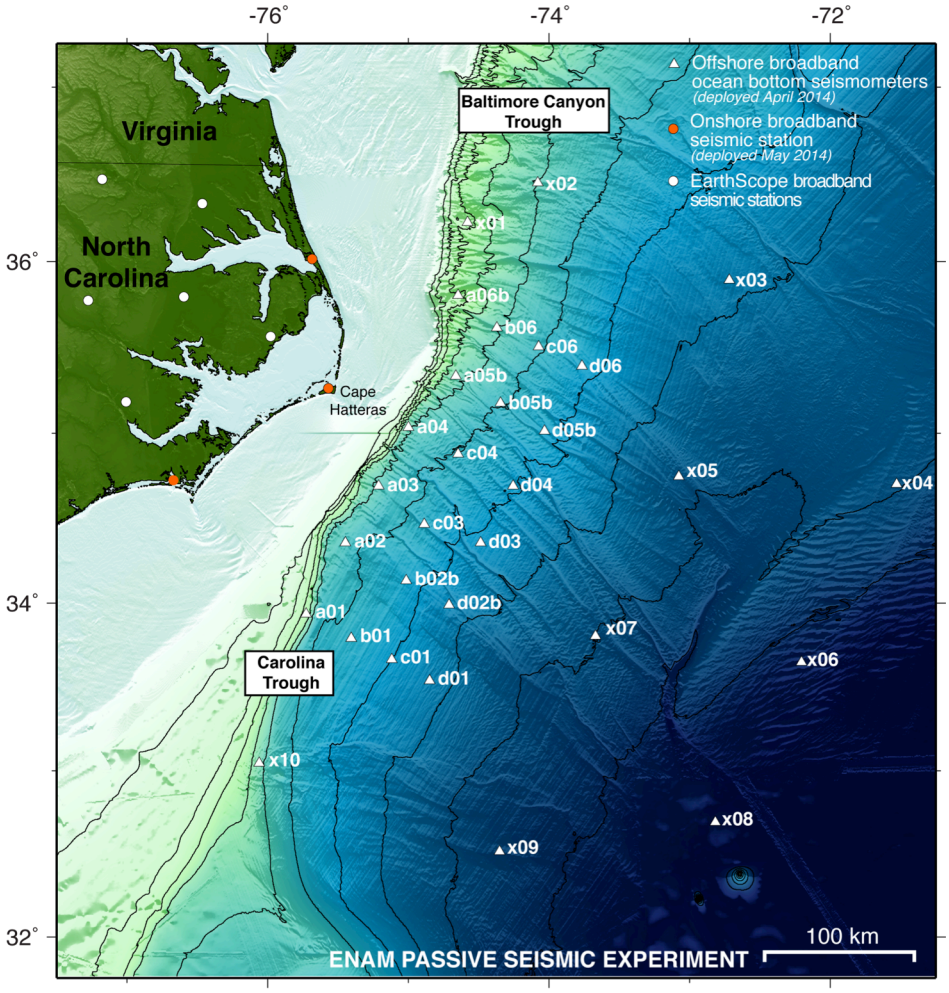

Figure 1: *ENAM Broadband seismic component. White triangles represent the thirty WHOI broadband OBS and the orange circles are the three onshore broadband seismometers installed on the outer banks.*

area offshore North Carolina. Three broadband seismometers were also installed onshore, on the Outer Banks, North Carolina for one year. The ENAM CSE broadband instruments operated contemporaneously with EarthScope USArray Transportable Array stations installed in the Carolinas and Virginia and thus complement the onshore TA deployment. The ENAM broadband data, in combination with USArray data, will thus provide continuous imaging of the North American lithosphere across the shoreline (Fig. 1).

The objective of this cruise is the recovery of the thirty offshore broadband OBS, which were deployed in April 2014 on the *R/V Endeavor*.

The science targets of the marine passive-source program are focused on the structure and evolution of the lithosphere across the transition from continental to oceanic lithosphere at the ENAM passive margin. Tectonic and magmatic processes associated with rifting (and post-rift evolution) almost certainly have distinct expressions in the lithospheric mantle. Images of the lithosphere beneath the ENAM CSE region can be compared and contrasted with information about crustal structure obtained via the active-source component of the experiment, allowing for an integrated portrait of crustal and mantle lithosphere.

The broadband seismometers will have recorded distant earthquakes for one year, allowing for a suite of imaging techniques to be applied (body and surface wave tomography, ambient noise tomography). Depending on the quality of the horizontal component data, receiver function analysis and SKS splitting analysis may also be feasible. The broadband seismometers have also recorded the offshore airgun shots of the R/V Marcus G. Langseth in September-October 2014 for the MCS and refraction profiling; these data can be combined with data from the short-period OBS deployment to perform combined 3D tomographic imaging of crust and upper mantle structures.

2. ENAM community seismic experiment

The research expedition offshore North Carolina aboard the R/V *Endeavor* is a part of a major effort by the NSF-GeoPRISMS program to understand the breakup of continents to form new oceans and active processes at the edges of continents that define their structure and evolution. The program is inherently broad, with the goal of providing and integrating a diverse range of datasets for a broad spectrum of the Earth Science community. The US scientific community chose Eastern North America (ENAM) as an ideal place to study continental breakup and continued active processes on rifted margins. The selection of this region and the design of the seismic study were guided by input from the US scientific community through workshops and online forums.

ENAM components

Marine active-source seismic data: 2D Marine seismic reflection and refraction data offshore North Carolina and Virginia along more than 5000 km of profiles were acquired in September/October 2014 onboard the R/V Marcus G. Langseth and the R/V Endeavor. This component of the ENAM CSE was a carefully designed two-ship experiment. The seismic reflection data were acquired with a 8-km long streamer and the 6600 cu.in airgun source array from the Langseth. Langseth also provided the shots for the wide-angle reflection/refraction data. The R/V Endeavor deployed and recovered short period ocean bottom seismometers at 94 locations along four profiles (Figure 2).

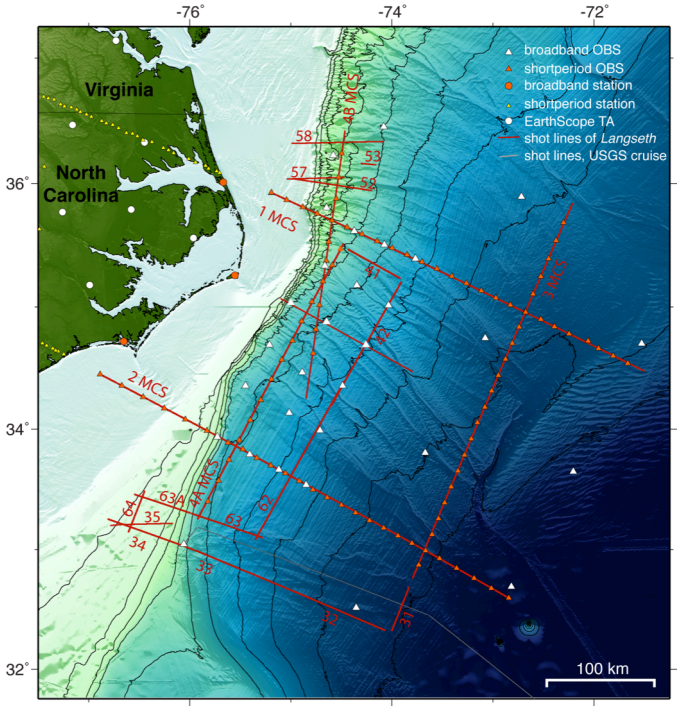

Figure 2: *Active and passive components of the ENAM experiment*

Onshore active-source seismic refraction data: A temporary array of 80 seismometers, which were onshore in North Carolina and Virginia in September and October 2014, recorded airgun shots from the R/V *Marcus Langseth*. In June 2015, we also plan to acquire active-source seismic refraction data onshore along two ~200km long profiles from the piedmont to the coast in North Carolina. Along each of these lines, there will be 7 explosive shots recorded by ~700 seismographs. Data from these two efforts will provide an onshore continuation of the marine active-source seismic profiles, which can provide information on the structure of the crust before it stretched and of rifting structures onshore.

Deployment of broadband seismometers: Broadband seismometers were deployed in April 2014 and are recovered during this cruise. Both the recovery and deployment took place on the R/V Endeavor. The three seismometers that were deployed onshore in May 2014 on the Outer Banks, North Carolina were recovered in May 2015.

Community Outreach

We broadly advertised the opportunity to participate in all of the science cruises for the ENAM Community Seismic Experiment and worked together to select science staff from the community for each cruise based on their interest and desire to utilize ENAM data. We particularly sought to engage early-career scientists and graduate students in all cruises. Through this opportunity, we hope to expand the pool of scientists familiar with geophysical data-collection techniques. For this EN-554 cruise, we selected 5 highly motivated participants from diverse set of institutions to join the cruise (*see participant feedback section*). In total, more than 25 participants have already gain experienced in seismic data acquisition through this program.

Two training workshops will be host at LDEO and UTIG for students and early-career scientists who want to gain experience with the multi-channel processing and marine seismic refraction data analysis, respectively. The 5-day seismic refraction workshop will take place May 18-22 and the 7-day seismic reflection workshop will take place June 22-29, 2015. We encourage as broad a participation in these workshops as possible. We advertised those two workshops through the NSF-Geo-PRISMS, IRIS and UNOLS mailing list. Following the two training workshops, we will hold a workshop in summer 2015 to encourage close collaboration between the onshore and offshore, passive and active seismic research communities and to facilitate partnerships for post-cruise analysis.

Data distribution/Data access

All the data from this project are open to public access. The offshore and onshore broadband seismic data, as well as any continuous short-period data, will be distributed through the IRIS Data Management Center (www.iris.edu/ds/nodes/dmc), using network code YO for years 2014-2015. The marine seismic reflection and refraction data will be distributed through the marine seismic data portals at Lamont-Doherty Earth Observatory (LDEO) (www.marine-geo.org/portals/seismic) and the University of Texas Institute for Geophysics (UTIG) (www.ig.utexas.edu/sdc). The raw and onboard processed marine seismic reflection data and underway geophysical data are already available for download:

http://www.marine-geo.org/tools/search/DataSets.php?seismic=MGL1408 (raw),
http://www.ig.utexas.edu/sdc/cruise.php?cruiseIn=mgl1408 (processed),
http://www.rvdata.us/catalog/MGL1408 (underway data),

Links with more information on community workshops, input, field work can be found at : http://geoprisms.org/initiatives-sites/rie/enam/

3. Cruise Summary

The objective of this cruise is the recovery of thirty broadband ocean bottom seismometers of the ENAM experiment. The instruments were deployed in April 2014 from the R/V Endeavor. The instruments are seismometers from the U.S. Ocean bottom Seismometer Instrument Pool (OBSIP). All these instruments were supplied by the OBSIP instrument center at Woods Hole Oceanographic Institution (WHOI).

The thirty WHOI OBSIP instrument are four component instruments. The broadband ocean bottom seismographs carry Guralp 3T broadband seismometers and Differential Pressure Gauges (DPG). Data are recorded by Quanterra Q330s and logged on Quanterra Baler 14s. Three-component seismometers recorded at 100 Hz sampling while the differential pressure gauge recorded at 20 Hz sampling.

Twenty of the instruments are deployed in a dense grid with nominal station spacing of 30-40 km, spanning the base of the continental slope. These instruments site astride the East Coast Magnetic Anomaly, and are aimed at imaging variations in magmatic processes associated with continental breakup (Figure 3). The remaining 10 instruments are deployed in a wider backbone array with nominal spacing of 125-175 km, and they will be useful for placing the detailed margin structure into the context of the surrounding continental and oceanic lithosphere, as well as correlating segmentation on the margin to subsequent segmentation of the oceanic lithosphere. Of these 10, the location of one (station x01) is specifically on the Currituck submarine landslide block, with the goal of using compliance and other techniques to better understand slide structure (Figure 4). All sites

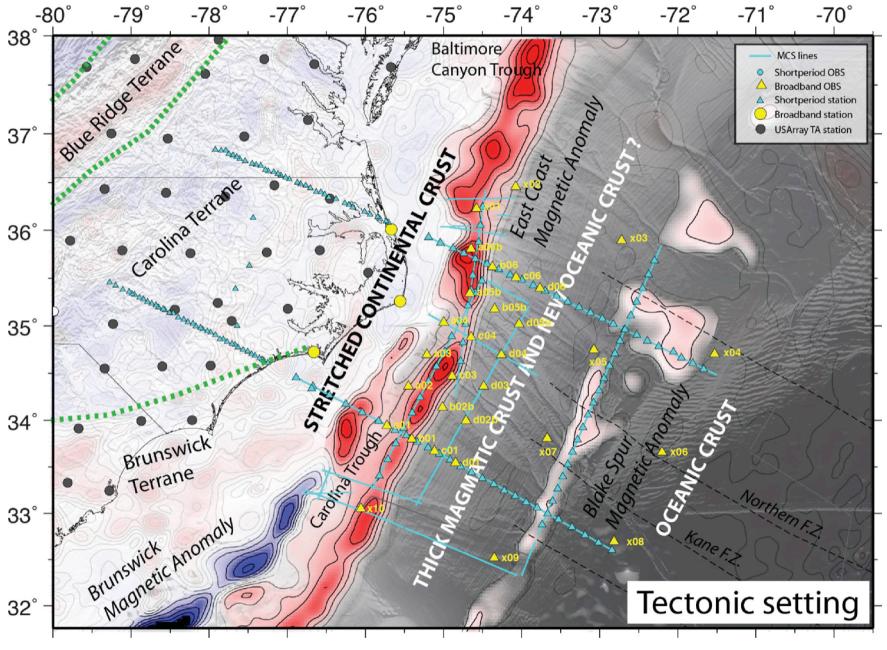

Figure 3: *Broadband ocean bottom locations (yellow triangles) with respect to the magnetic anomalies*

are in deep water (>1300 m) due to expected high noise levels at shallow depth.

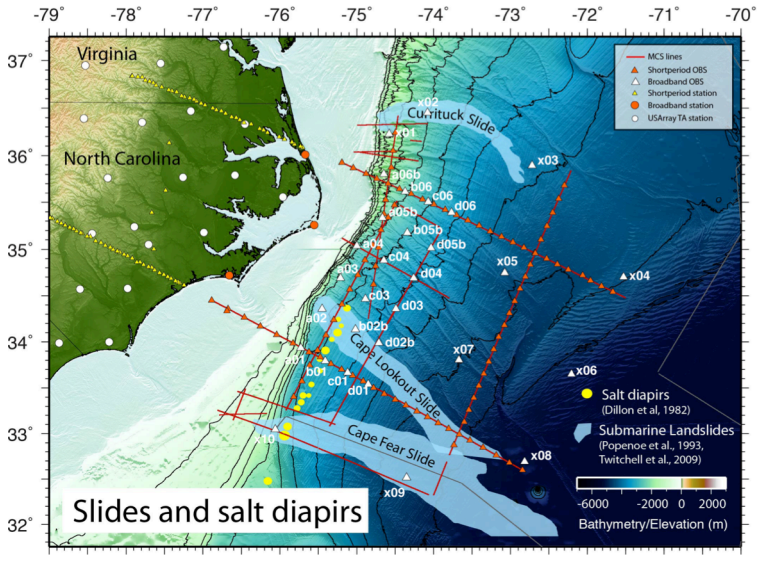

Figure 4: *Map showing the location of the broadband OBS (white triangles) with respect to the slides.*

The EN-554 science party included four WHOI technicians (Alan Gardner, Daniel Kot, Jimmy Elsenbeck and Tim Kane), four co-chief scientists (Anne Bécel, Maggie Benoit, Maureen Long, Lara Wagner), five watchstanders selected from an open participation process (Gillean Arnoux, Sampath Rathnayaka, Sumant Jha, Colton Lynner, Terry Cheiffetz) and the Endeavor Research technician Jason Agnich. This was the first experience on a research cruise for six members of the science party. To allow the WHOI team to design a reasonable work and sleep schedule around the OBS operations, we grouped the closely spaced OBS sites in sets of five or six instruments followed by longer transits.

After one or two days, the science party developed a standard routine to recover the OBS. In the main lab, when we were approaching the OBS site (1-1.5 nm away), we first turned off the echo-sounder profiler then started communicating with the instrument using the acoustic deck box, sent the release and burn commands and estimated the time the instrument would reach the surface using a rising time of ~40m/min. After the release of the instrument, the co-chief scientist on duty estimated the new expected locations at the surface using the ADCP (acoustic dopler current profiler) data and communicated those new coordinates and OBS ETA at the surface to the bridge. Twenty minutes before the estimated time at the surface, the WHOI team would prepare the deck for the recovery. Ten minutes before the ETA, the watchstanders and co-PI would help chasing the OBS at the surface. During night shifts, watchstander would also help the bridge with the light. The WHOI team carried out the all deck operations during recovery with the assistance of other members of the crew of the R/V *Endeavor*. Once the recovery done, the co-chief scientist would confirm the next site location and the Endeavor research tech would confirm to the bridge that we could leave the site after the OBS on deck was secured and some data uploaded. During the recovery, the co-chief on duty or watchanstander filled out the WHOI check sheet with all the key data (time the OBS was

seen at the surface, time the OBS was on deck, whether or not the radio and flash light were working, etc.) and the tables in Annexes. In table 1 we list the surveyed locations and water depth of OBS, the transit time between stations, time arrival on site, time departure from site. In table 2, we list for few cases the current rates in the North and East direction from the ADCP and the new OBS locations after drift correction.

WHOI team downloaded raw data after instrument recovery. Then, they provided SEG-Y/miniSEED data to a member from Leidos, a navy's contractor, who was on board to screen the data and additionally create a low pass filter data set containing all data below 3 Hz. All of the instruments were designated for screening. The navy representative provided the low pass filtered data to the science party at the end of the cruise. The Navy agrees to ensure all screening is complete within 90 days of the recovery vessel's return to port. Low pass filtered data will be first available to the IRIS DMC database and will be replaced by the screened data within the next three months.

Although we have had a slow start to due unfavorable weather conditions during the transit from North Kingstown to the first OBS site and during the following days, all the instruments were successfully recovered. All of the recoveries went smoothly and we finally came back to days earlier than originally planned. One factor that we considered during OBS recovery was the Gulf Stream current, which could drift instruments up to 1.0 km from the surveyed site to their locations at the surface after ascent. In some areas, the surface currents exceeded 1m/s both in the North and East direction within the first kilometer of the water column. We thus used the ADCP data to estimate the location of the instrument when it would reach the surface. ADCDP corrections very useful since we often recovered the OBS near the location predicted after taking into account the current. The more seaward instruments were not affected by the Gulf Stream.

Underway data consisted of ADCP and 3.5 kHz and 12 kHz subbottom profiles, although data is generally discontinuous because all acoustic equipment would be turned off during OBS acoustic operations. All underway data will be provided through the MGDS.

4. Daily Narrative

All times listed here are local time. Narrative by Bécel (0000-0800 local), Wagner (0800-1600 local) and Long (1600-0000 local).

March 25 (JD 84) : Half of the science party of cruise EN-554 arrived during the day of March 25 and stay for the night in a hotel, the Marriot Townplace Suites, located two miles from the Senesco Repair Yard where the Endeavor was berthed.

March 26 (JD 85) :
By September 26 at 11 :00am, the science team was almost complete. Soon after lunch, around 12:30pm, 8 of the 9 members of the science party went to the Senesco Repair yard. We moved our personal effects into staterooms and met with the WHOI team and Endeavor members and crew. The WHOI team was installing their portable van on deck. We left the ship at 2pm. Maggie Benoit and Anne Bécel came back at 3pm to have a meeting with the WHOI team and John Collins to discuss in more details the OBS recovery procedure. By 5pm, the science party was complete. We all went for last dinner onshore and came back to the ship. Weather forecasts were not optimistic for the next day and most of the science party started to take seasickness medicines.

March 27 (JD 86) :
At 7:00am, Maggie, Maureen and Sampath went to GSO to park their cars and came back with the 7:30am shuttle bus from GSO to the Senesco shipyard. Before leaving the yard, we had a briefly ship safety meeting given by Chris Armanetti in the main lab. At 9 :00am, we left the Senesco dock in North Kingstown and transit south. The weather was bad with high wind (30-40knots) and high seas (up to 12 ft). After lunch, we had a longer ship safety drill, we first watched a video, went to the upper deck in life vest and some of the participants who has not been at sea before had the chance to try on the immersion suits. During this long transit (~615km), all the science party adjusted to the strong ship motion.

March 28 (JD 87):
The day of March 28, we were still in transit to the first OBS recovery site. At 1pm, Alan Gardner gave us an introduction to the different steps used for the release of the instrument and how to fill out the OBS recovery checksheet. We made ~8.30 knots on average on way down. It took us 40 hours to reach the first OBS site, more than we expected.

March 29 (JD 88):
We arrive to the first site (***OBS x02***) during the night, at 1am. Since it was the first time that the Endeavor crew was doing broadband OBS recovery and that the crew and the WHOI team are not used to work together, the Captain was more confortable to do the first recovery during daylight. We waited 5:42am (local time) to start to enable acoustics

and send the release commands. The estimated liftoff time was 05:54 (9:54 UTC), the estimated surface time was then 06:51 (10:51 UTC) using a rise rate of 45m/min. OBS was seen at the surface at 06:57 (10:57 UTC) and was on deck at 07:05 (11:05 UTC). It took less than 10 min between the time the OBS was seen at the surface and the time the instrument was onboard. It was a very successful start. The radio was not working on the first OBS, so it was good that we saw it quickly. We departed from the site at 7:35, after the WHOI team had time to secure the OBS on deck and have a quick look at the data. Most of the science party woke up to see the first OBS recovery. By this time, we were about 12 hours behind our regular schedule, but still on track to arrive a full day early (4am on April 8).

Arrived at ***OBS X01*** site at about 11:15 am… nice but windy sunshine – some confusion about lat/lon conversion for decimals to minutes so we had to double back. We made a list of all station locations for the bridge in degrees and minutes. The station here locked with no problems (Alan worked the box with Colton watching). Release command sent at about 11:40 local time. The station surfaced at about 12:17. It was brought onboard at 12:26. Left for next site at 1:07pm.

Arrived close to **OBS a06b** at ~3:35 pm. Water temperature was really high (25 C) so we must be in the gulfstream. No current to speak of below 100 m, so we're not worried about a correction. Successful first release command at 3:44 pm local. Visual at 4:19 local time. On deck by 4:32 pm. Bridge heard no radio transmissions while sensor was in the water. However, after it was on deck, they turned it off /on and then it worked.

Maureen's team took over from Lara and Maggie's team at 17:00. We have hit the Gulf Stream – water much warmer and steam coming off the ocean! Maureen is starting to feel better but Gillean is sick. We arrived at station **OBS b06** at approximately 19:27 and locked masses. Rise began at 19:34. Instrument successfully recovered, quite a bit of drifting due to current though. Instrument on deck at 20:51, started transit to next station at 21:22.

Because this OBS drifted a lot with respect to the surveyed longitude and latitude due to the strong currents associated to the Gulf stream, we've decided to use the ADCP/current data available on board to estimate the drift of the instrument and the new coordinates of the OBS after drift correction. The new coordinates will be transmitted to the bridge after the instrument is released for future recoveries.

Arrived at station **OBS c06** at 23:00. Once we arrived ~1-1.5nm from the survey location, we started to send release and burn commands. Masses did not lock on first try. Tried several more but masses did not lock. Rise began at 23:20. For this OBS, we used the current data from the ADCP to estimate its new location after taking into account the current drift. Expected at surface at 00:33. Handed things off to Anne's team at midnight.

March 30 (JD 89):

The OBS was first seen at the surface at 12 :30am (4 :30 UTC) and was onboard at 1am. The ship missed it a first time, we had to make a maneuver. OBS was on deck at 1am (5:00 UTC).

Recovery of **OBS d06** went quickly. We arrived on site at 3:09 (7:09 UTC) and start to send the release and burn commands. OBS was seen 2 min before the estimated time arrival of the OBS at the surface using a rise rate of 40m/min meaning that the actual rise time was higher.

Lara took over at 8am. Long haul to **OBS x04**, but at a faster clip than on previous days. Station masses locked on first try by 4 pm. Released at 4:01. Visual at 5:55pm local time. On deck at 6:17pm. There was a pretty strong current, so we corrected the search location by about 700 m. Seems like we under-corrected.. not surprising as we only had good current info for the upper 600 m. The adjustment was calculated by using findmehere.pl with -0.2 m/s North and 0.7m/s East.

Maureen's team took over from Lara and Maggie's team at 16:00 but both groups stuck around for the recovery of **OBS x04**. Very choppy seas but recovery went well. We used Lara's program to predict station location taking into account currents in the top ~600m or so and it worked like a charm. Seas got very choppy after that – 14' swells - and everyone settled down for another long transit.

March 31 (JD90):
The transit from **OBS x04** to **x05** took us more time than expected because of the rough sea. We made 6.7 knots in average. The night was really rough (40 knot winds + 12 to 13' waves)… a number of us had a hard time sleeping because of seasickness. Chief mate said we were almost catching air going over some of these waves. On site, though, the seas were pretty calm. Station **x05** locked at 5:46 am local, released at 6 am local, not sure what time radio signal was picked up, but then visual site at 7:56 am local, on board by 8:01 am local.

Apparently the station drifted really far… so even with the station correction for currents, it was still a good ways off from where we expected. The radio was working, though, so we were able to find it that way. Deep site, so long rise time.
After 2-days, the coordination between the bridge, OBS team and science lab quickly became a familiar routine.

Next stop, **OBS d05b**… made a station correction that actually went pretty spot on. Station was spotted right away and brought on deck… water is now smooth enough that we started our approach to the next station before everything was put away on deck (as per recommendation of the WHOI techs).

We arrived at **OBS b05b site** at about 4:30 pm local time. Still lovely weather…warm, perfect blue water. Sent the release command at 4:44… surfaced at 6 pm and was immediately caught. Left this site at about 6:15 pm.

Maureen's team took over from Lara and Maggie's team at 16:00 but both groups stuck around for the recovery of **OBS b05b**. Arrived at station around 16:30 or so, OBS spotted at 17:58 and on deck at 18:07. Absolutely gorgeous weather, sunny and calm. Left to transit to **OBS a05b** at 18:20. Arrived at **OBS a05b** site at approximately 20:20. Chirp from instrument indicated that Guralp is not functioning properly. Sent a command to lock the masses just in case. Seems as though batteries may be dead. Instrument spotted at 21:20 very close to predicted surface point. Took a while to get it onto the deck, pretty windy with 30 knot winds. Instrument on deck at 21:41. Started transit to **a04** at 22:05. Transit going slow due to high winds and choppy seas. Handed things off to Anne's team at midnight.

April, 1st (JD 91) :
The day started with strong winds, waves and currents that made our ride very choppy. The transit from **OBS a05b** to **a04** was also slower than expected; this time, we made 4.79 knots in average. We arrived on site at 3:11am and started to communicate with the instrument. We have corrected the surveyed coordinates from the strong currents in this area (>1m/s at the surface in the East and North direction). The estimated surface time was 4 :25am. The first visual site was at 4:28am. It took us more time to recover the instrument than in general because of the strong currents. It also didn't help that a school of mermaids kept nudging the station just beyond the reach of the WHOI guys hooking poles. The instrument was quickly drifting, there were two attempts and the second one was the good one.

By the time Lara took over at ~8am, we were one full station behind… e.g. we were at **OBS c04** instead of **OBS d04**. Strong currents at c04 so put in over 1km of corrections due NE… worked well. Departed site at 9:06 am.

We've checked with everyone, including the captain, chief mate, 2nd mate, the whole WHOI team and all 4 science PIs, and we've agreed that we should change the order of stations to pick up time. The revised schedule will save us ~12 hours which at this point, given how we've been hemorrhaging time sounds like a good idea. The only downside is that it includes a stretch of 10 stations where the crew has only two short (6 hr and 5.5 hr) transit rests. They're willing to give it a shot, and promised to let us know if they needed a break. We can always slow down between sites to give them more rest time. The new station order, starting from the next site is: d04, x06, x08, x09, x10, a01, b01, c01, d01, x07, d02b, b02b, a02, a03, c03, d03, and x03.

Reached **OBS d04** ahead of schedule.. onsite at 11am. There's a ship about 4 nm to the northeast, which is also the direction the current is moving. However, the current isn't that strong (0.5 m/s) so we'll likely have a correction on the order of a few hundred

meters. The other ship is also moving fast, so he'll pass us by in the time it takes the OBS to rise. Checked w. Cap'n… he agrees we're good to go. Current correction is only ~450 m to the northeast. Station released at 11:18 ish am. Surface time (radio) was about 12:45 and visual at 12:52. There was a sharp change in current direction from east to west… station ended up significantly further west than anticipated. But radio was working, so we're good. Onboard by 12:57pm. Seas too rough to start heading to next site right away. Actual departure time: 1:22 pm.

Very slow shift for Maureen's team – we were in transit the entire time! Maureen's team did not have any recoveries today.

April, 2nd (JD 92) :
We continued to make good progress with OBS recoveries. We arrived at site **x06** at 1:47am (4 :47 UTC time) and started to communicate and send the release commands. There was no need for drift correction this time, the currents were almost non-existent in both the W-E and N-S directions, we are far enough offshore, out of the Gulf stream. This OBS was located in deep water at 5153m depth, the expected time at the surface was 8 :05 using a rise rate of 40m/min. The OBS was seen at the surface at 8 :02am meaning that the rise rate was higher than 40. OBS was on deck at 8 :16am. We depart site at 5:38am. The sea is calm and there is almost no wind.

First and only station for Lara's shift was **OBS x08**. Arrived onsite at about 10:30 am… ahead of schedule. Deepest site (~5200 m), so took a long time to rise. Used a small current correction that showed things moving to the southeast… but when the station surfaced at 12:46, it was to the southwest. No idea why. Anyway, the radio was working so had no trouble finding it… had a visual within minutes. Took a bit of ship adjusting to pull up along side it, but still had it on board by 1:05 pm. Beautiful day out! Supposed to stay this way until tomorrow (Friday) night. By then we should have most of our long transits done. Fingers crossed.

Maureen's team took over from Lara and Maggie's team at 16:00, in the middle of another long transit. ETA at site is 21:15. Nice weather and very calm seas. We arrived on site for **x09** at about 20:45, instrument expected at surface at 22:47. Instrument spotted at 22:46, on deck at 22:58. Uneventful recovery. Departed for next site (**x10**) at 23:20. Handed things off to Anne's team.

April, 3rd (JD 93):
The weather was great that night. No OBS pick up between 0am and 8am.

Lara's shift : got to **OBS x10 site** at a little after 7:30 am. Very very calm seas made for a great night's sleep. Pretty solid current… may have undercorrected.. looks to be headed due NE. Station lock and burn went well. Station came up pretty close to where expected. Beautiful day, picture perfect recovery. Why can't they all be like this one? Bad weather due to hit tonight and tomorrow. I'm torn between wanting to be outside to

enjoy the nice weather and wanting to get some work done before I have to crawl back into my bunk because of the 6 – 11 ft seas and 30 knot winds. Maybe a bit of both? Departing for a01 at 9:30am.

Arrived at **OBS a01** site early at 1:55 pm. Amazing what happens when you combine quiet seas with the gulf stream (working for you for a change). Surface time at 2:35 pm ish. For a bit it seemed like it wasn't rising… but then it surfaced within 5 minutes of expected time… and pretty much where our current correction said it should be… about 1 km NE of the surveyed location. No problem getting it onboard. Departed site by 3:15 pm. Handed things off to Maureen.

Arrived at **OBS b01** site at 17:00. Instrument was released and expected at surface at 18:20. Picked up radio signal at 18:28. Instrument on deck at 18:39. Got underway moving towards **c01** at 18:55. Arrived at **c01** and started pinging instrument at 20:40. Appears as though Guralp might be dead (hopefully already locked) – only got 7 pings back. Rise started at 20:50; expected time at surface 22:19. Visual contact at 22:20 – came up very close to the ship! Lara got some good pics of the nighttime recovery. On deck at 22:37. Left for station **d01** at 22:55.

April, 4rth (JD94):
Just after midnight, the sea state picked up and became choppy. However, the rougher sea did not interfere with deck operations. We successfully recovered **OBS d01**. We arrived at site **d01** at 00:16am and started to communicate with the instrument. OBS **d01** was seen at the surface at 2:02am, very close to the ship. 8min later, the instrument was on board. This means that the location after correction of the drift due to the current was in this case quite accurate.

Bad night for sleeping arrived somewhat delayed to **x07**. Locked at 9:30 am local time. Deep site, so it took a bit for it to surface. Due at 11:20 am. Got in a bit early… onboard by 11:29. Rough day overall.

Transit from **x07** to **d02b** went fairly slow. Pretty rough seas, some of the roughest we've had. Only going 6.5 knots over ground. Arrived at site at 19:30, expected time at surface 20:55. Sighted at 20:52, on deck at 21:03. Left **d02b** and started transit to **b02b** at 21:20. Started pinging b02b at 23:00, arrived at station at approximately 23:05. Guralp does not seem to be locking – but wait, locked on the second try! Woohoo! Expected surface time of 00:39.

April, 5th (JD 95):
* Easter day

Seas have been rough all night and day but seas calm down a little bit around midnight. The recovery of instrument **b02b** went smoothly. We've started to communicate with the

instrument at 11pm (JD94), we saw the OBS at the surface 2 minutes after the estimated time at the surface and recovered it in less than 13 minutes.

This was full moon. Recovery of instrument **a02** went also smoothly. We've arrived on site at 3:45 am and seen the instrument on the starboard side of the ship. It took us 12 minutes between the moment we've seen it and the moment the instrument was onboard despite the pretty strong currents: 1m/s in the North direction and 0.6m/s in the East direction. Graduate student participants really enjoy going to the bridge and help with the OBS chasing using the binocular and the light.

There was a full basket of painted Easter eggs with our names on it for breakfast. It was a beautiful day with calm seas, mild wind, and pleasant temperatures.

After a somewhat long-ish transit back to the grid after x07, had just arrived at **a03** when Lara's shift started. Beautiful weather and pretty calm seas, which is wonderful for a change. Scheduled to surface at 8:47 am. Pretty strong current. Yesterday, Cap'n commented on how well we were doing on predicting the location of the sensor when it surfaced. Hopefully our luck will hold for these last 4 stations! a03 onboard at 8:53 am after being immediately sighted at 8:44. Left for next station at 9:13 am.

Arrived at **OBS c03** at 11:20am. Picked up and on deck by 12:45 ish. Current correction of ~800 m NNE had us only about 100 m shy of where the station surfaced. Woohoo! Departed for **OBS d03** at 1:10 pm. Arrived at d03 at about 3pm. Station surfaced at 4:45 ish and was spotted immediately.. very close to the corrected location again.

Maureen's team took over at 16:00; they were in the middle of recovering **d03**. Instrument on deck at 16:50. Nice calm seas and sunny weather. Started transit for **x03** (LAST STATION!!) at 17:15. This is a long transit – around 12 hours expected – so not much to do for a while, except eat an awesome Easter dinner and have our group photo. Group photo of the science party was taken at 18 :00.

April, 6th (JD 96):

Sea is calm, there is almost no wind and this is the last OBS recovery. Everything went smoothly with no incident. We arrived on site at 4:23am, earlier than planned, since we made 11.5 knots on average between **OBS d03** and **x03.** OBS was first seen at 10:05 at the aft of the ship, 400m away, it took 12 min to get it on the deck.

Just after the last OBS recovery, we started our 33 hr transit back to North Kingstown, RI.

5. Endeavor Crew and Science Party

Crew list

McMunn, Rhett	Capt.
Post-Maher, Shanna	Chief Mate
Armanetti, Chris	2nd Mate
Varney, Timothy	Chief Engineer
Rethron, Kurt	Asst. Eng.
Quigley, Pat	Asst. Eng.
Sisson, Oscar	AB/Deck
Bean, Charlie	AB/Deck
Irons, Ethan	AB/Deck
Walsh, Kevin	Boatswain
Duffy, Mike	Steward
Wright, Amanda	Mess. Att.
Agnich, Jason	Technical staff

Science Party

Bécel, Anne (LDEO)	Chief Scientist
Benoit, Maggie (TCNJ)	Co-Chief Scientist
Long, Maureen (Yale)	Co-Chief Scientist
Wagner, Lara (DTM-Carnegie)	Co-Chief Scientist
Arnoux, Gillean (U. Oregon)	Scientist
Rathnayaka, Sampath (U. Massachusetts)	Scientist
Jha, Sumant (Colorado State U.)	Scientist
Lynner, Colton (Yale)	Scientist
Cheiffetz, Terry (Cal Poly Pomona)	Scientist
Gardner, Alan	WHOI lead engineer
Kane, Tim	WHOI technician
Kot, Dan	WHOI technician
Elsenbeck, Jimmy	WHOI technician
Erika Cleary-Sprick	Leidos, Navy's Contractor

Science Party Shifts

Watch Leaders:

0 am – 8 am	Anne Bécel
8 am – 4 pm	Maggie Benoit and Lara Wagner
4 pm – 0 am	Maureen Long

Watch Standers:

12 am – 8 am	Sampath Rathnayaka, Terry Cheiffetz
8 am – 4 pm	Colton Lynner
4 pm – 12 am	Gillean Arnoux, Sumant Jha

Crew shifts

8-12 - 20-24	E. McMunn, T. Varney, S. Sisson
0-4 - 12-16	S. Post-Maher, K Rethorn, C. Bean
4-8 - 16-20	C. Armanetti, P. Quigley, E. Irons
8-12 - 12-16	K Walsh
7-12 - 12-15	M. Duffy, A. Wright

Contact information for the Science Party

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Rathnayaka, Sampath	sampath.rathnayaka.313@my.csun.edu
Wagner, Lara	lwagner@carnegiescience.edu

Science Party aboard the R/V Endeovor : *Back row, left to right :* Sampath Rathnayaka, Sumant Jha, Alan Gardner, Jason Agnish, Jimmy Elsenbeck, Terry Cheiffetz – *middle row, left to right :* Maggie Benoit, Anne Bécel, Erika Cleary-Sprick, Maureen Long, Lara Wagner, *front row, left to right:* Lynner Colton, Dan Kot, Tim Kane.

6. Performance of the R/V Endeavor

Overall, we found the *Endeavor* to be in great condition, and the technical staff and crew are professional and capable. This was the first broadband OBS recovery for the Endeavor crew. The crew of the *Endeavor* are a pleasure to work with. We found everyone to be professional and hard working. Jason, the research tech was very responsive to all our requests and needs although it was his first cruise on the *R/V Endeavor*. The captain was initially very cautious about doing recoveries in bad weather at night, especially for the first station. However, once he became acquainted with the routine, he was receptive to our proposed station order change, and made helpful suggestions on how to save time. The cooks did an excellent job of preparing food to satisfy everyone's dietary needs and tastes. Mike, the main chef, deserves a medal.

One complaint would be that the internet is very slow and we would suggest that alternatives are sought or upgrades are made to improve internet speed. The accommodation spaces, galley and other leisure spaces (e.g. library) were in great shape. One major comment on accommodation is that it would be great if there were a more efficient temperature control in some of the staterooms (12, 7….), because several people found the rooms very warm.

7. Participant Feedback

Student 1) That I would like to do more OBS work in the future

Student 2) The opportunity to participate in an OBS retrieval research cruise aboard the R/V Endeavor has proven to be quite the high seas adventure. Working in such close proximity to both the research scientists and the crew has provided a unique insight into the field work that is preformed on a daily basis aboard a research vessel. The experience on a ship has its fair share of ups and downs just like the rough seas surrounding us. What I took for granted on land, i.e. walking up stairs, taking a shower, sleeping in the top bunk, I most certainly now appreciate out at sea. What I have taken from this internship overall is that I have been able to narrow down my future academic ambitions and will be applying to PhD programs in related fields of study.

Student 3) What I got out of the experience: Participating in the ENAM OBS recovery cruise aboard the R/V Endeavor provided excellent insight into how such scientific expeditions are run. Prior to this experience, I knew very little about the at-sea operations carried out during such cruises. Getting this experience was invaluable, as I work with OBS data and will continue to do so in the future. Learning the organization, logistics, communication, etc. required to complete such an endeavor was truly enlightening and will undoubtedly help me in my future career.

Student 4) I got experiences on OBS recovery phase that including how to locate instrument position and where it will show up on the water based on wave direction (vertically and horizontally), and what technique is used to communicate recover instruments at the water surface.
I enjoyed tracking OBS's by using spot light during my night shift. Also I had nice time with tracking OBS's during day times. Not only that I had a chance to talk with cruise members about their sailing experiences and I got lot of information from them.

Student 5) I had expected to do some science aboard the cruise. However, lack of availability of data hampered that. I very much look forward to this data being available in public domain and work with it (hopefully with the participating mentors). Being a first time sailor, the cruise was a good experience for me to understand the life of a marine geologist/seismologist, which I am sure will help me a lot as I continue my career in geoscience. Moreover, this cruise was also an experiment of sorts for me, since I am hard of hearing. I had talked to others having similar issues and none had an experience of research cruise (for fear of not being able to capable enough). My long term goal in geosciences is to teach. I expect and hope to meet students who will be differently abled but still have strong enough interest in geosciences to consider it making it their career. This cruise affirmed my conviction that with supportive colleagues any such experience is rewarding and will allow us, the diversity candidates, to learn more than what we think we can do. I really appreciate the selecting committee to allow me to come on this cruise. Thank you !!

Table 1 : Recovery plan chronology

Activity	Latitude1	Longitude1	Distance (km)	Depth (m)	Transit time	ETA On Site	ETA Complete	Speed (knts)	Time on site	Days
Senesco Repair yard in North Kingstown							3/27/15 9:00	0	0	
Transit to and recover x02	36.4526367	-74.078978	614.965	2547.8	40.00	3/29/15 1:00	3/29/15 7:35	8.30	395	1.94
Transit to and recover x01	36.2252117	-74.57926	51.518	1328.8	3.92	3/29/15 11:30	3/29/15 13:07	7.10	97	2.17
Transit to and recover a06b	35.80447	-74.648798	47.104	1324.6	2.47	3/29/15 15:35	3/29/15 17:10	10.31	95	2.34
Transit to and recover b06	35.6159417	-74.372158	32.623	2517.1	2.28	3/29/15 19:27	3/29/15 21:22	7.71	115	2.52
Transit to and recover c06	35.5061383	-74.072622	29.764	2933	1.63	3/29/15 23:00	3/30/15 1:35	9.84	155	2.69
Transit to and recover d06	35.392645	-73.765693	30.578	3351.5	1.65	3/30/15 3:14	3/30/15 5:20	10.01	126	2.85
Transit to and recover x04	34.7011067	-71.527502	218.133	4458.7	10.67	3/30/15 16:00	3/30/15 18:46	11.04	166	3.41
Transit to and recover x05	34.7457617	-73.075407	141.864	4388	10.98	3/31/15 5:45	3/31/15 8:46	6.97	181	3.99
Transit to and recover d05b	35.0138	-74.032735	92.433	3334.5	4.48	3/31/15 13:15	3/31/15 15:00	11.13	105	4.25
Transit to and recover b05b	35.1758933	-74.345073	33.682	2960.6	1.55	3/31/15 16:33	3/31/15 18:20	11.73	107	4.39
Transit to and recovery a05b	35.3357617	-74.66454	34.056	2230.5	2.00	3/31/15 20:20	3/31/15 22:05	9.19	105	4.55
Transit to and recover a04	35.0349033	-75.000365	45.274	2293.3	5.10	4/1/15 3:11	4/1/15 5:21	4.79	130	4.85
Transit to and recover c04	34.8797667	-74.64646	36.620	3023.3	1.77	4/1/15 7:07	4/1/15 9:07	11.19	120	5.00
Transit to and recover d04	34.6899533	-74.257887	41.331	3417.3	1.88	4/1/15 11:00	4/1/15 13:22	11.85	142	5.18
Transit to and recover x06	33.6507467	-72.205687	221.554	5153.6	12.42	4/2/15 1:47	4/2/15 4:40	9.63	173	5.82
Transit to and recover x08	32.69324	-72.816493	120.511	5271.1	5.83	4/2/15 10:30	4/2/15 13:20	11.15	170	6.18
Transit to and recover x09	32.5168567	-74.353618	145.604	4725.5	7.42	4/2/15 20:45	4/2/15 23:20	10.60	155	6.60
Transit to and recover x10	33.0475033	-76.059905	170.334	2242.8	8.33	4/3/15 7:40	4/3/15 9:30	11.04	110	7.02
Transit to and recover a01	33.9366483	-75.72658	103.368	1755.3	4.42	4/3/15 13:55	4/3/15 15:15	12.64	80	7.26
Transit to and recover b01	33.79279	-75.408135	33.509	3123.7	1.75	4/3/15 17:00	4/3/15 18:55	10.34	115	7.41
Transit to and recover c01	33.6659	-75.118102	30.341	3485.2	1.75	4/3/15 20:40	4/3/15 22:55	9.36	135	7.58
Transit to and recover d01	33.538965	-74.849532	28.628	3808.4	1.35	4/4/15 0:16	4/4/15 2:30	11.45	134	7.73
Transit to and recover x07	33.8035917	-73.670508	113.212	4476	7.00	4/4/15 9:30	4/4/15 12:10	8.73	178	8.14
Transit to and recover d02b	33.9905483	-74.712912	98.623	3759.9	7.04	4/4/15 19:30	4/4/15 21:20	7.57	110	8.51
Transit to and recover b02b	34.1346667	-75.015725	32.203	3338.4	1.67	4/4/15 23:00	4/5/15 1:12	10.43	132	8.68
Transit to and recover a02	34.3574883	-75.448818	46.932	2778.5	2.55	4/5/15 3:45	4/5/15 5:30	9.94	105	8.85
Transit to and recover a03	34.69108	-75.210958	42.969	2639.1	2.00	4/5/15 7:30	4/5/15 9:19	11.60	129	9.03
Transit to and recover c03	34.46493	-74.888763	38.773	3245.8	2.09	5/8/00 10:49	4/5/15 13:15	10.00	90	9.18
Transit to and recover d03	34.35591	-74.488703	38.718	3583.7	1.75	4/5/15 15:00	4/5/15 17:15	11.95	135	9.34
Transit to and recover x03	35.8933467	-72.719032	234.751	3889.5	11.08	4/6/15 4:20	4/6/15 6:35	11.44	135	9.90
Senesco Repair yard in North Kingstown	41.587446	-71.412146	642.213		34.68	4/7/15 17:15		10		11.34

Table 2 - OBS Locations after drift correction using the ADCP data

Station Name	surveyed latitude	surveyed longitude	North current rate (m/s)	East current rate (m/s)	depthrange (m)	drift (km)	drift corrected latitude (dec. deg.)	drift corrected longitude (dec. deg.)	drift corrected latitude (deg)	drift corrected latitude (min)	drift corrected longitude (deg)	drift corrected longitude (min)
B06	35.6159417	-74.372158	1	0.7	700	1.281	35.6255	-74.3689	35	30.654	-74	22.13399
C06	35.5061383	-74.072662	0.8	0.4	600	0.804	35.5126	-74.0688	35	30.755999	-74	4.12799
D06	35.392645	-73.765693	0.4	0.2	450	0.301	35.3951	-73.7642	35	23.706	-73	45.852
X05	34.7457617	-73.075407	0.5	0.05	500	0.526	34.7505	-73.075	34	45.03	-73	4.5
A04	35.0349033	-75.000365	0.6	0.6	600	0.763	35.0398	-74.9944	35	2.38799	-74	59.66399
X10	33.0475033	-76.059905	0.8	0.8	450	0.763	33.0524	-76.0541	33	3.14399	-76	3.246
D01	33.53897	-74.84953	0.2	0.2	500	0.212	33.5403	-74.8479	33	32.418	-74	50.873
A02	34.35749	-75.44882	1	0.4	350	0.565	34.3622	-75.4466	34	21.732	-75	26.796
X06	33.6507467	-72.205687	~0	~0	~0	*no corr*						
X03	35.89335	-72.71903	-0.5	0	100	0.075	35.8927	-72.719	35	53.5619	-72	43.1399