Salinity Processes in the Upper Ocean Regional Study (SPURS)

EN533 Cruise Report

R/V Endeavor

Ponta Delgada, Azores – Woods Hole, MA
16 September 2013 – 13 October 2013

Contents

(1) Objectives

EN533 was the third of three cruises associated with the NASA-sponsored Salinity Processes in the Upper Ocean Regional Study (SPURS) program in the tropical Atlantic. The main objective of this voyage was to recover moored, drifting, and autonomous platforms deployed on the two previous SPURS cruises (KN209-1 in September, 2012 and EN522 in March, 2012). This equipment included:

- One Surface Flux mooring (WHOI)
- Two Pico moorings with T/S-measuring Prawler (NOAA/PMEL)
- One Seaglider (APL/University of Washington)
- Three Liquid Robotics Wave Gliders (WHOI)
- One Lagrangian Mixed Layer Float (MLF; University of Washington)

Secondary objectives included a swap-out of a temperature/humidity sensor on the PIRATA mooring at 20N, 38W, and a coarse survey of the Atlantic salinity maximum region using underway (TSG) and profiling (CTD) systems.

(2) Participants

Science Party

Dr. Dave Fratantoni	Chief Scientist	WHOI
Dr. Ben Hodges	Scientist	WHOI
Jeff Lord	Scientist	WHOI
Jason Smith	Scientist	WHOI
Dave Rivera	Scientist	NOAA/PMEL

Crew

Rhett McMunn	Captain
Shanna Post-Maher	Chief Mate
Chris Armanetti	2^{nd} Mate
Patrick Quigley	Bosun
Kevin Walsh	AB
Oscar Sisson	AB
Tim Varney	Chief Engineer
George Maltby	Assistant Engineer
Nick Tosto	Assistant Engineer
Steve Sniezak	Chief Steward
Michael Brennan	Messman
Lynne Butler	Marine Technician

(3) Cruise Overview

R/V Endeavor departed Ponta Delgada on 19 September 2013 at approximately 1025Z and sailed southwestward towards the PIRATA mooring at 20N, 38W. Once we were outside the 200 nm EEZ surrounding the Azores we performed test casts to ascertain the performance of the CTD and the hydrographic winches. There were problems with both the #1 winch and a bad cable/connection on the CTD pump. These problems were resolved.

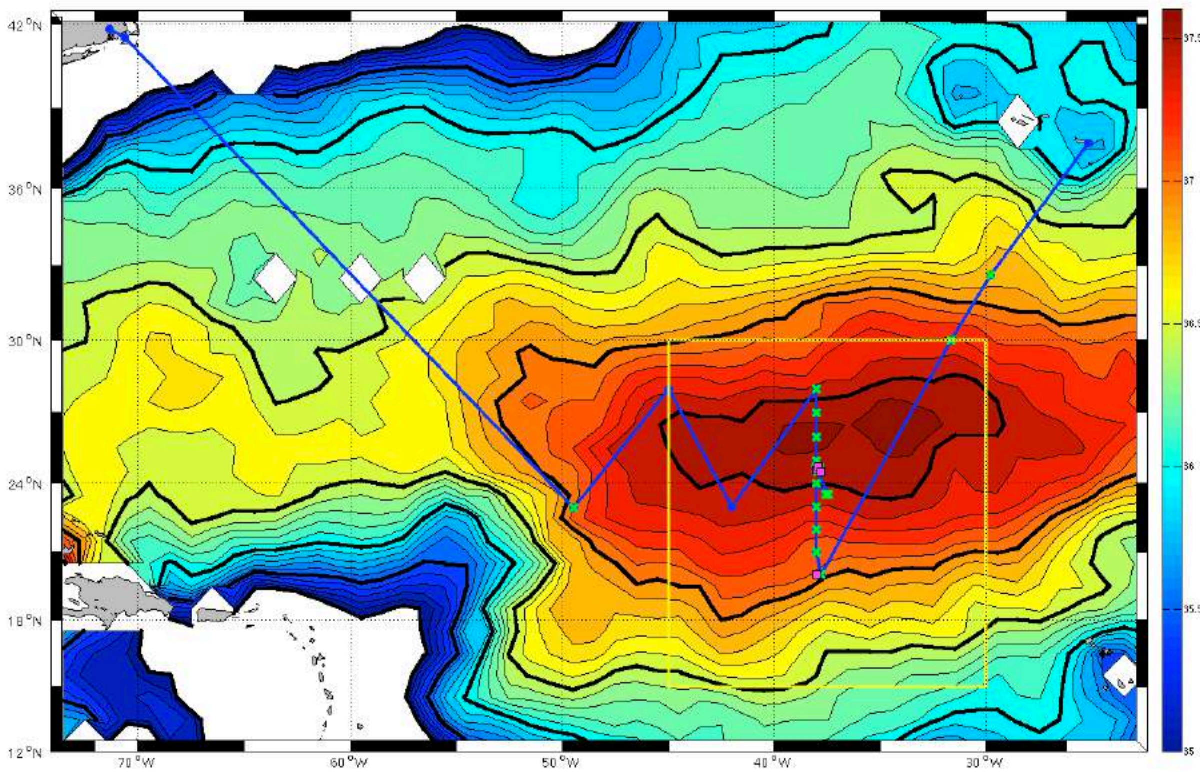


Figure 3.1: Overview of EN533 cruise track. Green crosses denote locations of over-the-side activity. Mooring sites are indicated by pink squares. Background is a composite September surface salinity as observed by Aquarius.

We successfully changed out a failed temperature/humidity sensor on the PIRATA mooring, then recovered Seaglider 122 on the way to the SPURS moored array near 24N, 38W. A low-resolution (60 nm spacing) CTD section was occupied along 38W. Once in the vicinity of the moored array we recovered the Mixed Layer Float. We were able to recover both the subsurface portion of the PICO-E mooring (which had lost its surface buoy 6 weeks earlier) and the entirety of the PICO-N mooring. All three Wave Gliders were recovered in one morning. Taking advantage of a good weather window, the recovery of the large WHOI flux mooring was spread over two days to increase safety. We spent several hours on three separate occasions searching (acoustically) for the missing Seaglider 160 but were unsuccessful in locating her.

We departed the SPURS area and performed a zig-zag survey across the western half of the salinity maximum region. The highest salinity of the trip (37.77) was noted near 26 29N, 46 32W on the final southwestward leg, in reasonable agreement with the JPL numerical model used for cruise guidance.

The PICO-E surface buoy was recovered after drifting westward more than 650 nm. Recovery was performed at night and without use of the small boat. We then sailed northwestward towards the WHOI dock. A waypoint was added to our return voyage to keep the ship's path in international waters as we passed to the east of Bermuda.

Weather during the cruise was generally excellent (see Figure 3.2, below). Only a couple of rain squalls were encountered and winds were generally less than 10 kts during the intensive period of mooring operations and instrument recovery.

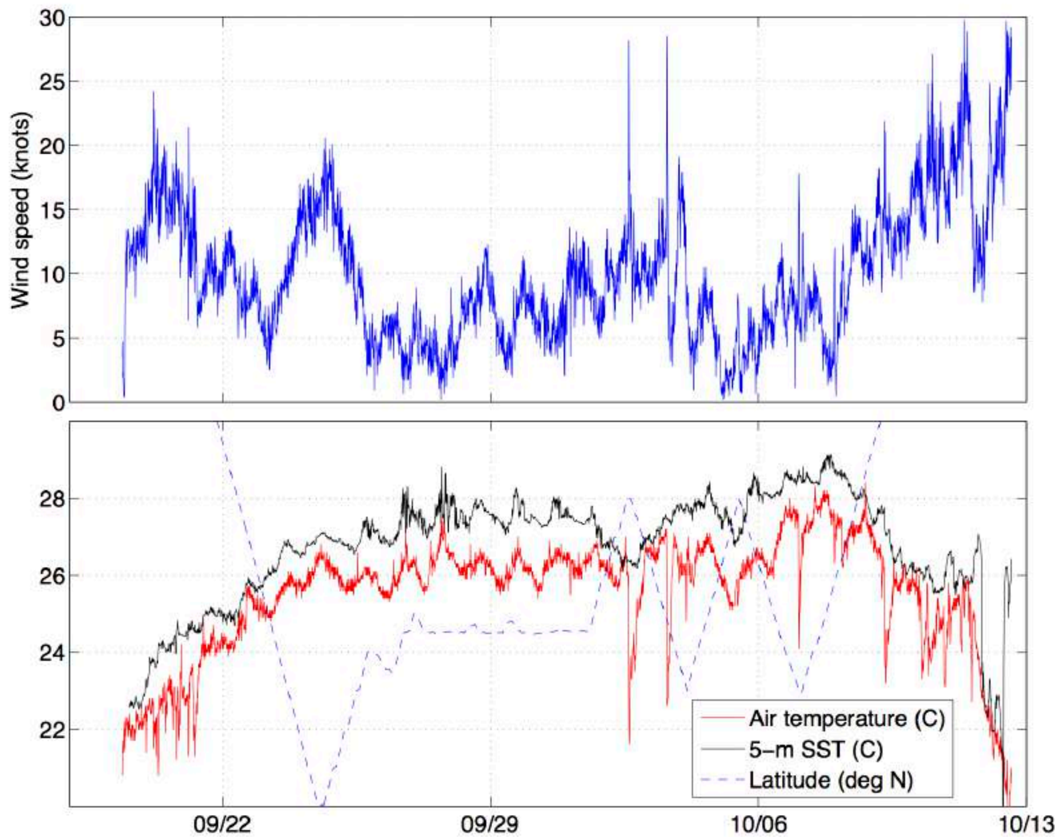


Figure 3.2: Recorded (top) wind speed and (bottom) air and sea surface temperature. Latitude it shown in the bottom panel for reference.

(4) Timeline

19 Sep

- Left dock 1025Z
- Installed and tested salinity snake on starboard side
- Safety briefings and boat drills
- Heading SW towards CTD #1 (test station)

20 Sep

- CTD ops briefing
- CTD #1 2120 – significant noise on all channels below 900 m, and then up to 500 m. No bottles sampled.
- CTD #2: Retried cast – noise again at 1000 m. 6 bottles tripped at 900 m. Winch #1 problems with 90 m out, significant delay in recovery.
- Deployed Argo float #7174

21 Sep

- Steaming 212/10.5 towards PIRATA mooring
- Snake sucking lots of air – trying different remedies and valve settings
- Switching to CTD winch #2 after wire jumped sheave on winch #1 last night
- Lynne Butler found CTD data problem was Sea-Bird pump cable
- CTD #3 to 2000 m went well 1830Z
- First a-Sphere test cast over stern. Worked well, but off side next time.
- Deployed Argo float #7176 2030Z

22 Sep

- Sent WG red to hold circle – slowest vehicle
- Vacuum-tested EMs
- Salinity increased rapidly over the past 24 hr / 250 km

23 Sep

- At 24N – flying fishes!
- Wind 209/11
- Fire drill
- Salinity 37.6 and falling rapidly. SST rising.

24 Sep

- Dave Rivera and Jeff Lord took small boat to swap T/RH sensor on PIRATA Tflex mooring 20N,38W
- CTD #4 between Tflex and ATLAS moorings
- a-Sphere #2 1500Z
- CTD #5 (a-Sphere not working)
- CTD #6 (a-Sphere not working)

25 Sep

- CTD #7
- a-Sphere #3 1145Z
- CTD #8 1210Z
- Calmer winds (8 kts) with easy 6-8 ft swell
- Overnight test cast on winch #1 for engineers

26 Sep

- SG122 commanded by UW to drift on surface 0630Z
- Recovered SG22 0940Z with small boat
- CTD #9 to 1000 m at SG recovery site
- Bottle #3 was leaking from lower cap – Lynne will replace
- Visited WHOI mooring surface buoy for visual check
- Surface salinity near 37.65 – highest so far
- Visited PICO-E anchor location to confirm release health
- Visited SG160 last known position – no acoustic response
- CTD #10 2345Z. Bottle #11 leaked (not sampled)

27 Sep

- Moved Red, Yellow, Green to holds at 233,232,231 (on green circle)
- PICO-E anchor released 0700Z. Initial acoustic survey found range as small as 50 m, but subsequently appears to be down around 400 m. Identified position within about 100 m horizontal range. Best guess: 1155Z: [24 31.34N 37 48.23W]. rng=108/443 hor/slant (assuming depth = 400 m)
- MLF recovered 1345Z
- CTD #11 1430Z
- Acoustic search for PICO-E. Located around 1800Z. Single yellow hardhat sighted at acoustic range of 600+ m. Small boat used to attach additional flotation and lifting strap. Wound all rope and wire onto TSE winch. Prawler was found intact, but imploded! Orange wire had broken 1 foot above stop where repair on previous cruise noted damaged jacket. Mooring recovery complete at 2300Z
- Overnight spent near WHOI buoy.

28 Sep

- CTD #12 to 1000 m near PICO-N
- PICO-N mooring recovery completed 1400Z
- By 1600Z parked near WHOI buoy. Wind 045/8
- CTD #14 to 5000 m near WHOI buoy 2110Z

29 Sep

- red, green, yellow wave gliders recovered using small boat.
- red missing 3 tidbits
- all wave gliders disassembled and cleaned – fouling pretty light

30 Sep

- tag line attached to WHOI buoy and outboard instruments removed
- release fired at 1040Z
- WHOI mooring recovered to 35m, then buoy cast loose for overnight
- Cleaned recovered instruments
- Calm with minimal seas

1 Oct

- WHOI buoy recovered 1051z with top 35m of instruments
- Cleaned recovered instruments
- 8-10 kt winds, moderate swell coming from NW. TS Jerry?
- Revised remainder of cruise plan to expedite exit from area affected by Jerry
- Listened at SG160 site for one hour – no evidence of life.
- CTD #15 to 2000 m at 26N, 38W

2 Oct

- CTD #16 to 2000 m at 27N, 38W
- a-Sphere #4
- CTD #17 to 2000 m at 28N, 38W
- a-Sphere #5
- Argo float #7080 deployed 1537Z
- winds 180/15, but then big squall hit with winds to 35kts
- a-Sphere #6 1830Z

3 Oct

- Winds 220/10-15. A bit lumpier.
- Another squall this afternoon. Not as dramatic as yesterday.
- TS Karen forms in Gulf of Mexico

4 Oct

- a-Sphere casts at 1000Z, 1500Z, 2000Z

5 Oct

- very calm as we steam towards PICO-E buoy

6 Oct

- flaming embers shooting out of the stack before dawn. Boosted rpms to burn off junk in exhaust. Made over 13 kts for a little while. Fun.

7 Oct

- PICO-E surface buoy recovered 0050
- Test cast on winch #1 after breakfast
- Very large salinity gradient noted around 1800Z
- Deployed Argo float #7177 1705Z

8 Oct

- Wind 110/16, seas picking up a bit
- Endeavor holding 11.5+ kts
- Near 28N, 55W at 1400Z
- Deployed Argo float #7178 2041Z

9 Oct

- Deployed Argo float #7175 0430Z
- Wind 120/10, larger swells than yesterday.

10 Oct

- Wind 120/20+, raining, rolling.
- Square aluminum beam portion of salinity snake spar buckled at a drilled hole – recovered snake and all hardware 1215Z
- Deployed Argo float #7183 1428Z

11 Oct

- Seas 6-10 ft, winds 15-25 kts.
- Crossed Gulf Stream
- SST drop of around 6 deg C near 2100Z – north wall of GS

12 Oct

- Evidence of warm-core ring near continental slope. TSG warm and salty. NAVO GS analysis indicates WCR.
- Winds 25-30 kts, seas 9-12 ft.

13 Oct

- Entered Vineyard Sound about 0800Z
- Arrived at WHOI dock 1540Z

(5) WHOI Mooring and Recovery

The WHOI surface buoy used in the SPURS project is equipped with meteorological instrumentation for estimation of air-sea fluxes, including two Improved Meteorological (IMET) systems. The buoy also carries two atmospheric turbulence packages for measuring turbulent sensible and latent heat fluxes and wind stress. Each of these packages, known as Direct Covariance Flux Systems (DCFS), comprise fast-response infrared hygrometers (LiCor 7200 model), Gill 3-axis sonic anemometers, and a motion package. The mooring line also carries current meters, and conductivity and temperature recorders.

Figure 5.1: WHOI-SPURS buoy after deployment.

This mooring is of an inverse-catenary design utilizing wire rope, chain, and synthetic rope and has a scope of 1.25 (scope is defined as slack length/water depth). The buoy is a 2.8-meter diameter foam buoy with an aluminum tower and rigid steel bridle. The watch circle is 4.2 nm in diameter.

Surface Measurements
Wind speed
Wind direction
Air temperature
Sea surface temperature
Barometric pressure
Relative humidity
Incoming shortwave radiation
Incoming longwave radiation
Precipitation
Surface wave height and direction (buoy pitch, roll, heave, and yaw)
Turbulent fluctuations of humidity, temperature, and wind

Table 5.2: Surface Measurements collected on the WHOI-SPURS air-sea interaction surface mooring.

QTY	Description
2	Nortek Aquadopp Current Meter
7	Nortek Aquadopp High Resolution Current Meter
3	WHOI Vector Measuring Current Meter
2	Nortek Acoustic Doppler Current Profiler
3	RDI Acoustic Doppler Current Profiler
4	Sea-Bird SBE 39 Temperature Logger
4	Brancker TR 1060 Temperature Logger
5	Brancker XR420 Temperature/Conductivity
9	Sea-Bird SBE 16 Temperature/Conductivity
26	Sea-Bird SBE 37 Temperature/Conductivity
5	URI Passive Samplers

Table 5.3: Subsurface Measurements collected on the WHOI-SPURS air-sea interaction surface mooring.

Meteorological Intercomparisons

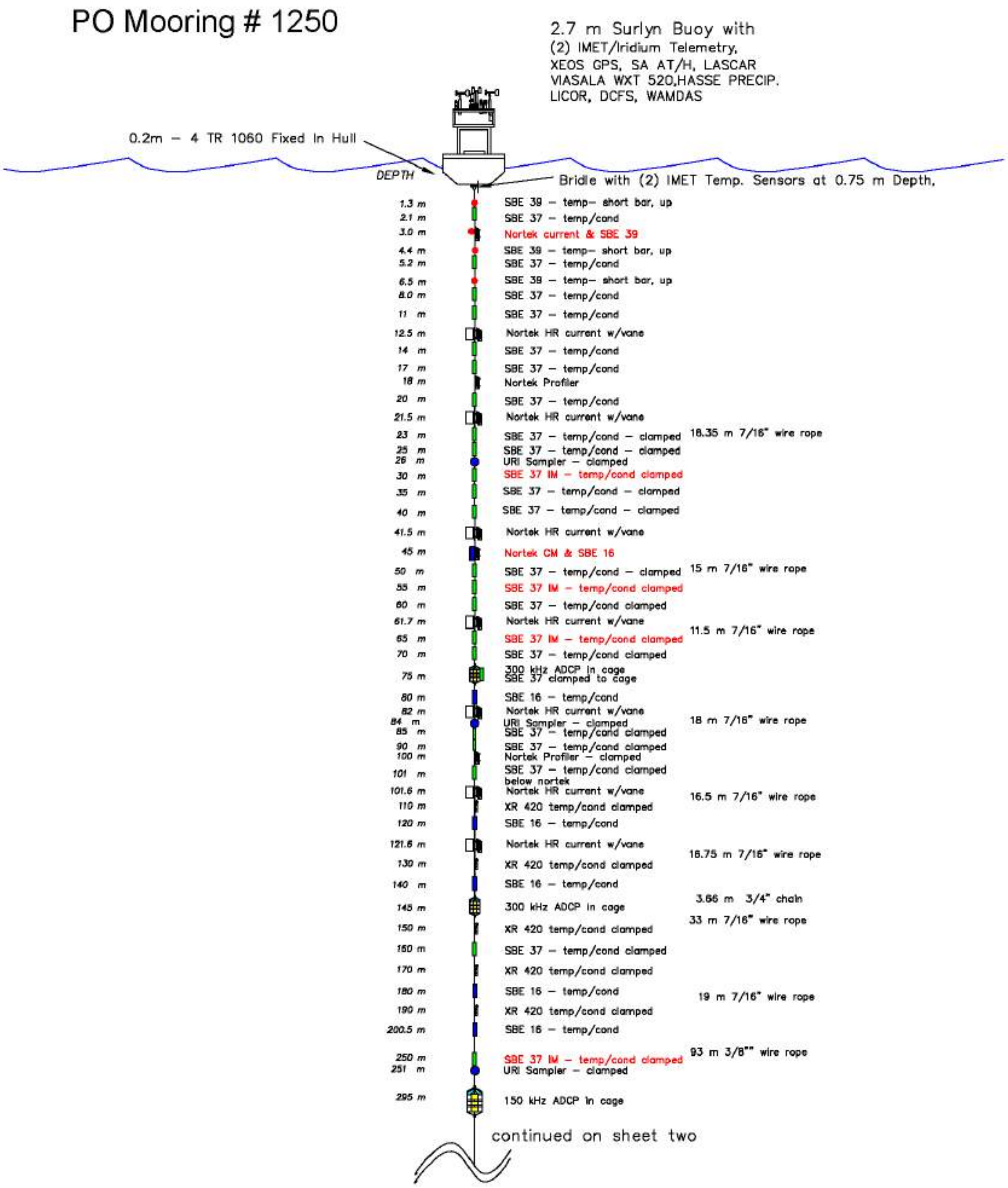
In order to assess the performance of the buoy meteorological systems, buoy vs. ship intercomparisons were made over several periods during September 27-29 2013. During these periods, the Endeavor established a position, with bow into the wind, approximately 0.5 nm downwind of the SPURS buoy. Data from ships meteorological sensors, as well as stand-alone units provided by WHOI will be used to analyze sensor accuracy and drift following one year in the field.

Recovery of WHOI Mooring

The mooring, WHOI PO mooring #1250, was deployed 14 September 2012, and recovered in two phases on September 30 and October 1.

Prior to the recovery, the workboat was deployed with technicians to remove some of the delicate meteorological instruments that could be damaged during the recovery. At that time a pickup sling and floating line were shackled to the buoy's lifting bale to make recovery easier.

Figure 5.2 Jeff Lord attaches pickup sling to WHOI buoy.



SPURS MOORING

Sheet 1 of 2

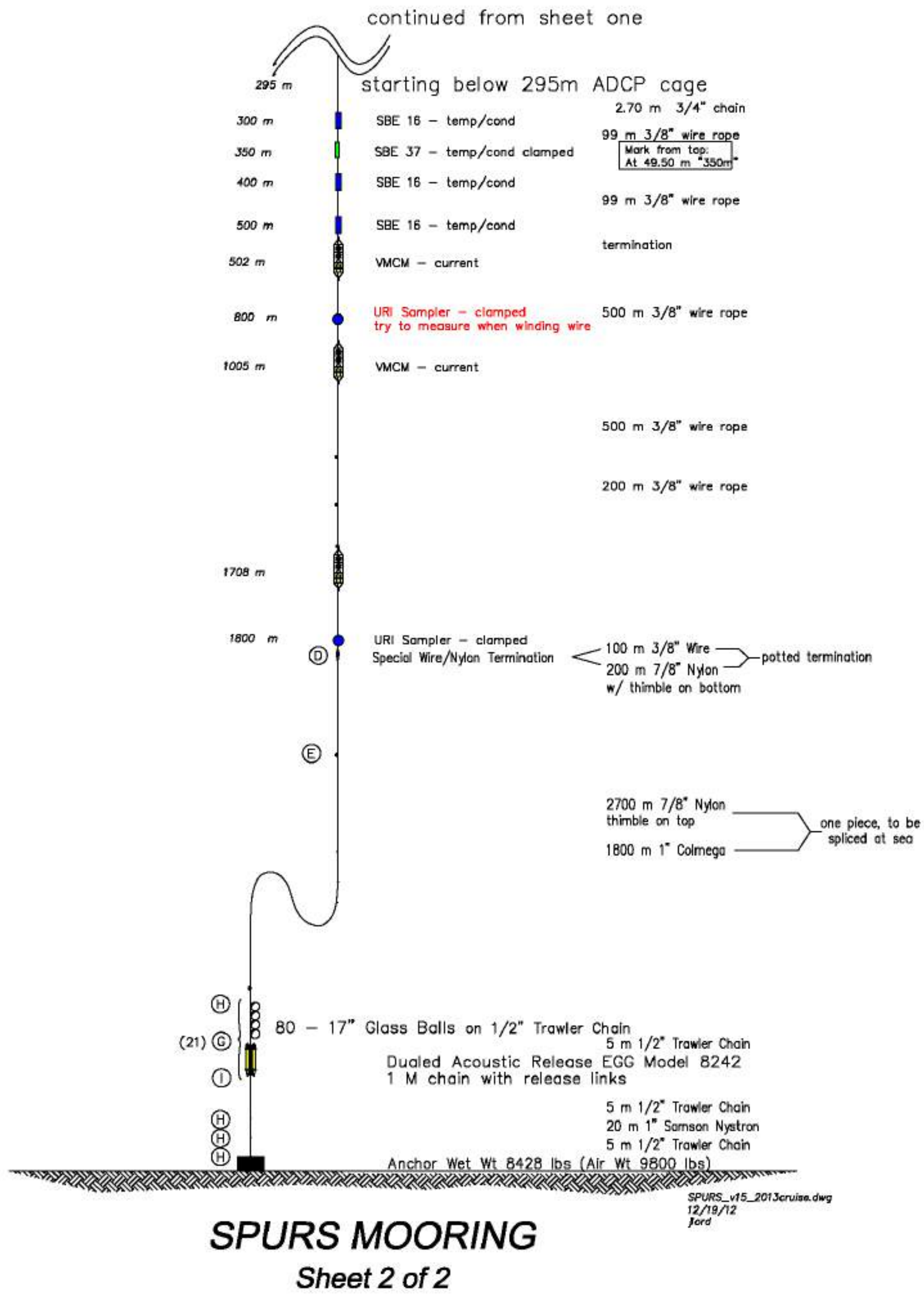


Figure 5.3 (continued from previous page): Diagram of WHOI-SPURS mooring, showing mooring design and subsurface instrumentation.

At 0840 UTC on September 30, the command was sent to the acoustic release to decouple the mooring from the anchor. Fifty minutes later, the large cluster of glass balls that serve as backup recovery were spotted on the surface. The ship approached the glass ball cluster to begin the recovery process.

A grapnel was thrown into the cluster of glass balls, and they were brought through the a-frame using the ship's mooring winch.

Once the glass balls were safely on deck, and the mooring line leading back to the buoy was secured, all hands assisted with breaking down the twisted cluster of balls and chain and getting them stowed.

As soon as the deck was clear, the recovery continued by hauling up the 4700 meters of synthetic line (rope) using an electric capstan. The line was stowed in wire baskets.

Once most of the line was recovered, the mooring line/load was transferred to the mooring winch for the remainder of the recovery.

As the wire rope was pulled in, instruments clamped to the wire were removed. Instruments in cages or on titanium load bars were removed by transferring the tension of the mooring to “stopper lines” just below the instrument to be removed. Once the instrument was removed, the wire rope segments were shackled back together and the winch continued hauling in. This procedure was repeated until all the instruments, wire, and chain up to 40 meters below the buoy were removed.

At this point, the buoy and remaining mooring line were set adrift for the night while the crew cleaned up the deck and recovered instruments.

On the morning of October 1, the ship approached the buoy from the port side. A grapnel was tossed over the line that had been attached to the buoy the previous day. This line was hauled in slowly, and when the buoy was close enough, the pickup sling was transferred to the hook on the ship's crane.

The crane lifted the buoy out of the water and brought it to rest against the side of the ship. Lines from three air tuggers were attached to points on the buoy to control the swinging of the 5,000-pound buoy as it was lifted on board.

Once the buoy was on deck and secured, the remaining mooring was stopped off and detached from the buoy. The crane was used to pull 8-meter segments of the mooring with instruments straight out of the water for recovery. Each segment was stopped off at the deck, and as the crane lowered the segment down, it was disconnected and moved away from the buoy. The last part of the mooring to be recovered was an 18.5-meter segment of wire rope that was pulled up by hand.

As soon as the buoy and remaining instruments were on deck and secured the cleaning commenced. All instruments that had biofouling needed to be cleaned before they were brought into the lab for data recovery.

(6) PMEL Moorings and Recovery

NOAA supplied two moorings, PICO #1000 and PICO #3000, for the SPURS project. These moorings were deployed by PMEL technicians, John Shanley and Andrew Meyer, from the R/V Knorr in September of 2012. Both PICO moorings were then recovered and redeployed by Jeff Lord on the R/V Endeavor in March and April of 2013.

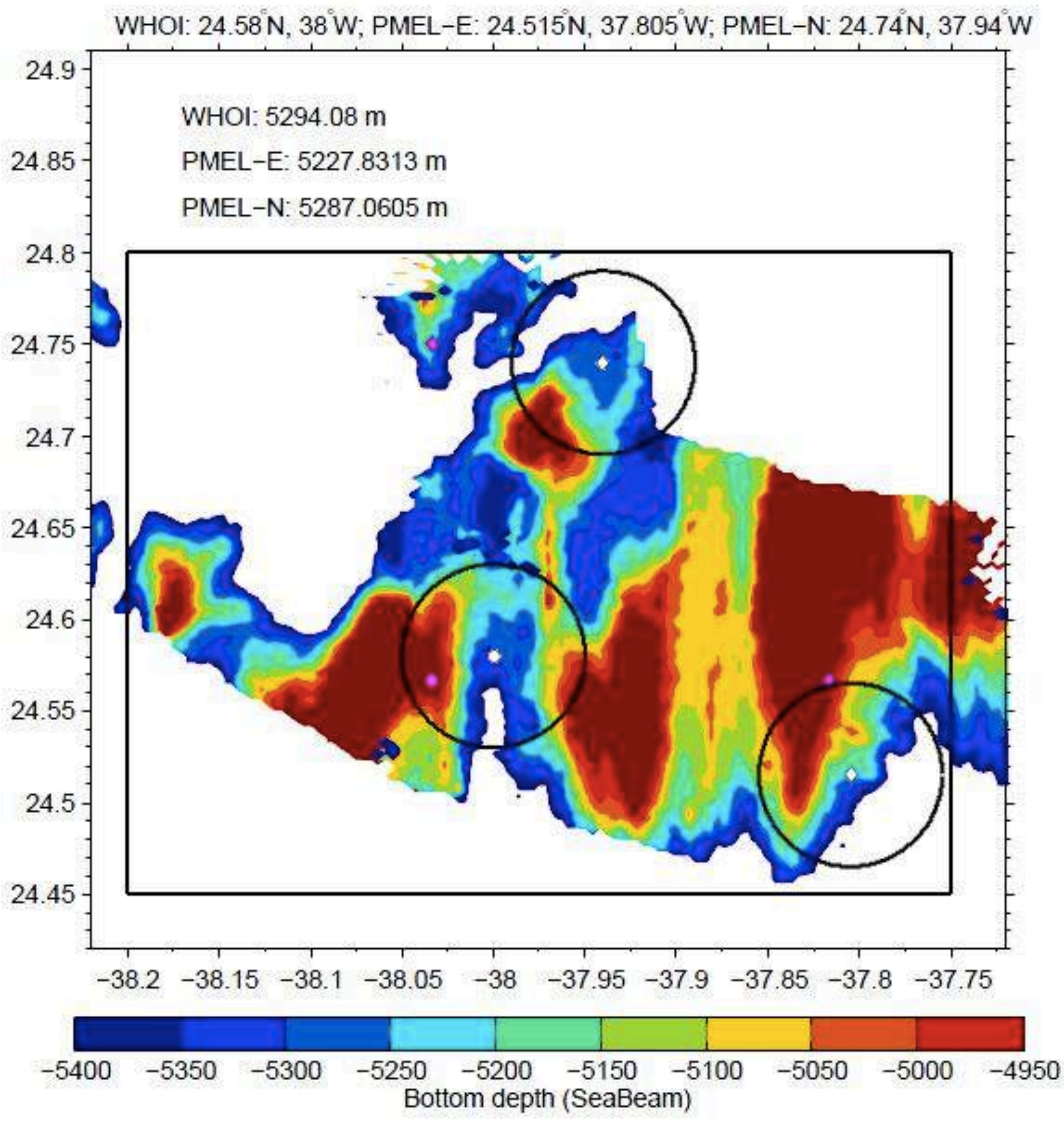


Figure 6.1: Original anchor positions for WHOI and PICO moorings.

The two NOAA PICO moorings were equipped with experimental subsurface instruments known as Prawlers- "Profiling Crawlers." The Prawler, which utilizes a CTD package, inductive modem, and microprocessor with a ratchet mechanism, operates by conducting a

CTD profile as it descends down the mooring line; thus, eliminating the need to mount multiple subsurface instruments. After reaching a prescribed depth of 500m, the microprocessor activates the ratcheting mechanism, and the instrument ascends the line via wave action. The Prawler averages a rate of approximately twenty profiles per day with range of five to thirty profiles. All data collected by the Prawler is then sent via inductive modem to the surface buoy, and ultimately transmitted back to PMEL.

Figure 6.2.b. (right) PICO surface buoy

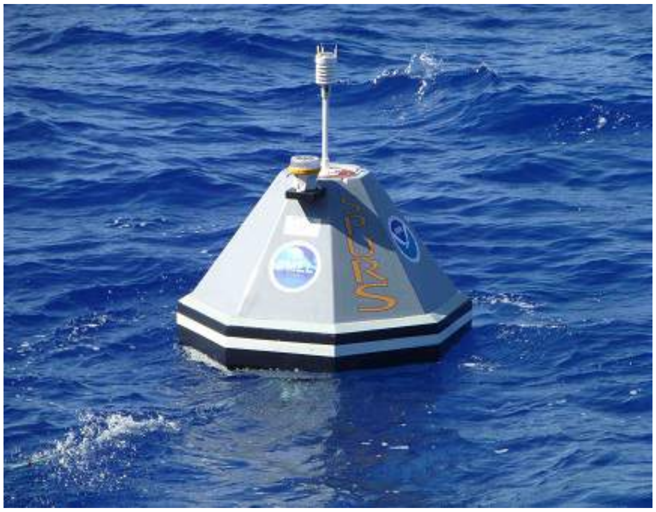


Figure 6.2.a. (left) Prawler unit on wire rope.

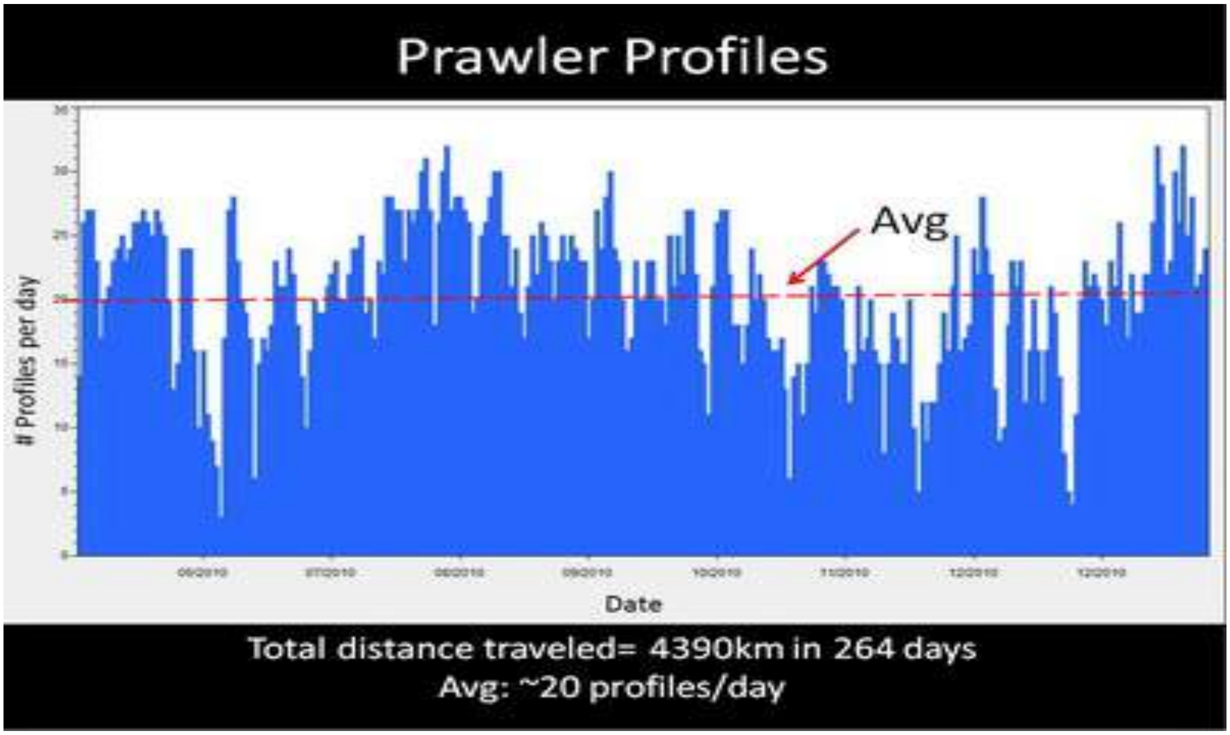


Figure 6.3: Prawler profiling chart

The mooring itself is a reverse-catenary design, or “slack” mooring, with a scope of 1.3:1 and is made up of wire rope, three variations of synthetic Yalex rope, buoyant copolymer rope, and chain.

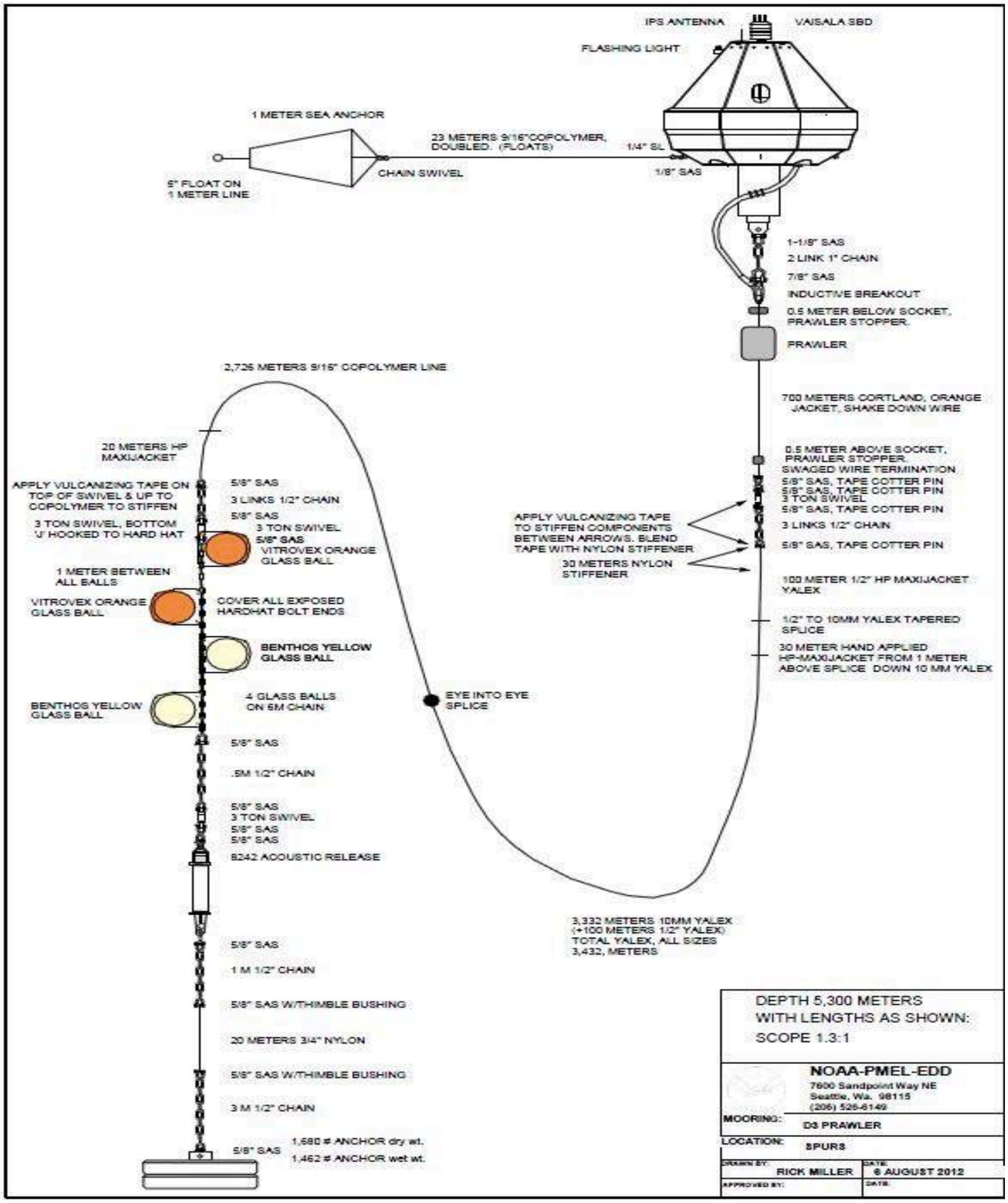


Figure 6.4: PICO mooring diagram

The PICO #3000 mooring eventually failed after redeployment, and the buoy parted from the mooring line approximately 2 meters from the surface. All evidence suggests that corrosion to the wire rope was the cause of the break as the jacketing that protects it was damaged earlier this spring. As a result, the entire mooring line along with the Prawler sank to the bottom while the buoy itself was set a drift.

Figure 6.5: The damage to the wire rope jacketing indicates that corrosion was the leading cause for the mooring to fail.

On the morning of September 27th, the R/V Endeavor released the broken mooring line from the anchor, and after spending most of the day acoustically tracking it in the water column, was able to recover it. The surface buoy was not recovered until the night of October 7th, and had drifted more than 650 nm from the mooring position.

The ship recovered PICO #1000 mooring on September 28th. Both moorings were recovered using the R/V Endeavor's TSE winch.

Unfortunately due to the current federal government shutdown, there is no Prawler data available on the NOAA server to include in this report at this time.

(7) Mixed Layer Float Recovery

On September 27, the small boat was used to attach a hoisting line on a University of Washington Mixed Layer Float (MLF) #5984. This float, deployed in March 2013, spent the previous six months drifting about the SPURS domain. It was recovered in the center of the SPURS moored array and found to have relatively little biofouling with only a few small gooseneck barnacles. The ablative antifoul paint was worn through in several large areas of the hull. No external damage was evident.

(8) Seaglider Recovery

Seaglider 122 was located on the surface on the morning of September 26. The vehicle was lifted into the small boat, then the small boat was lifted aboard Endeavor. A CTD cast (#9) to 1000 m was conducted at the site of the SG122 recovery. The vehicle was covered with a light greenish brown slime with very few barnacles. There were several places on the hull that were free of fouling, suggesting possible contact with marine life.

We attempted to acoustically range on SG160 on September 26, 28, and October 1 in the vicinity of her last commanded station-keeping position. No responses were heard.

Figure 8.1: Seaglider 122 just prior to recovery.

Figure 8.2: Seaglider 122 in the small boat prior to transfer to R/V Endeavor

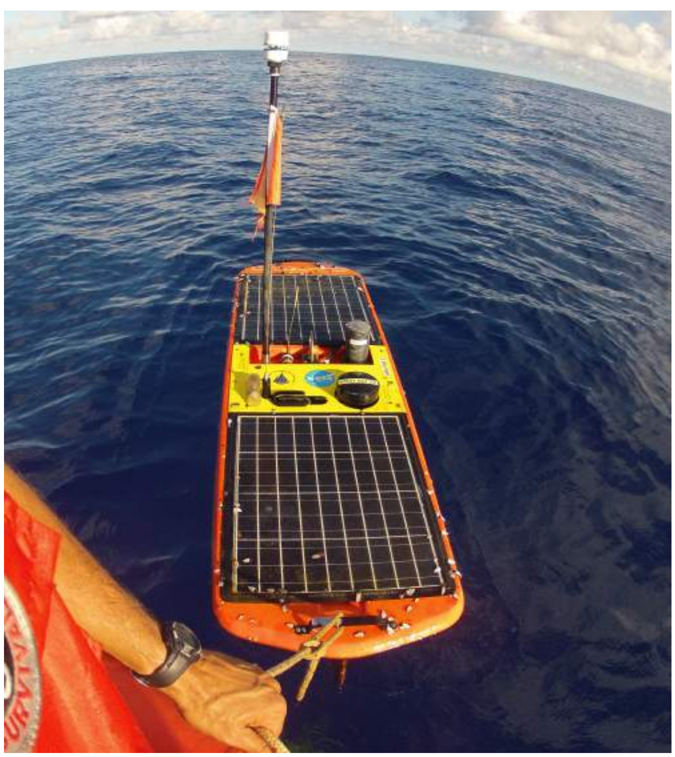
(9) Wave Glider Recovery

Three Liquid Robotics, Inc. Wave Gliders were deployed from R/V Knorr on September 15 and 16 during the fall 2012 SPURS cruise (KN209-1). Each Wave Glider (WG) was equipped with two Sea-Bird GPCTDs, with intakes at roughly 30 cm and 6.5 m depth. Additionally, each WG carried an Airmar PB200 Weather Station on a one-meter mast, and an Airmar CS4500 ultrasonic water speed sensor. The wave gliders were recovered, serviced, repainted and redeployed during the March 2013 SPURS cruise (EN522).

All three WGs were located and recovered for the final time without difficulty on the morning of September 29, 2013. Approximately 72 hours prior to recovery the vehicles were instructed to transit to and maintain position in the northeastern quadrant of the SPURS domain to await pickup. This allowed all vehicles to be recovered quickly. The small boat was used to attach a lifting strap to each WG. Endeavor then maneuvered next to the boat and lifted each WG onto the deck using the small crane. The entire recovery process for 3 vehicles took less than 2 hours.

There was moderate gooseneck barnacle growth on all three vehicles, especially above the waterline along the edges of the solar panels (see Figure 9-1). Fouling below the waterline was mostly hairy slime.

One pin was corroded on the speed sensor cable of WG Red – pin remains lodged in the female plug on the C&C drybox. WG Red had shown intermittent bad speed data in the weeks prior to recovery.



One WG (Red; WHOI-ASL22) was outfitted with 15 HOBO Tidbit v2 water temperature data loggers. The loggers were programmed to sample at 10-minute intervals, allowing for 300 days of data storage. Ten were attached to the umbilical with zip ties and electrical tape, to provide a temperature profile spanning the upper 6 m. The remaining five loggers were bolted to the float and the sub (see Table 9-1).

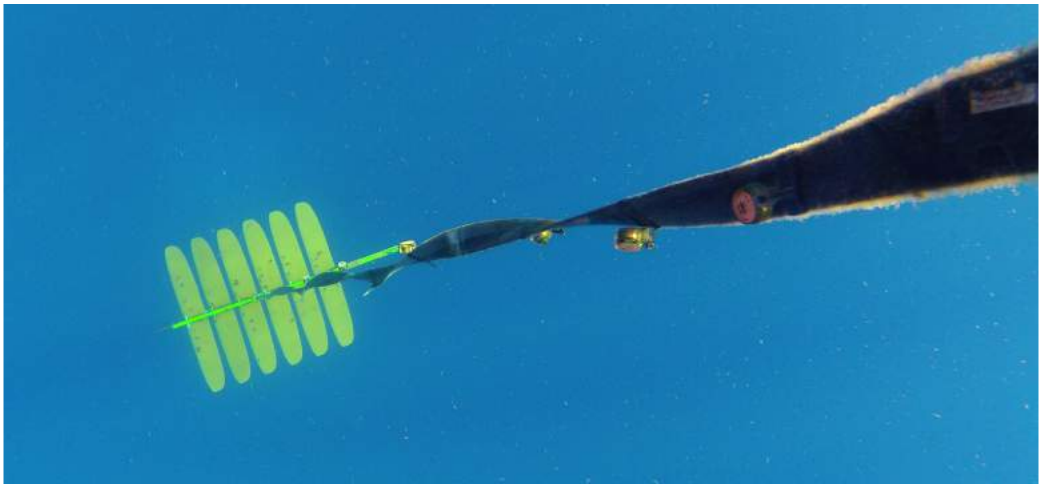


Table 9-1: WHOI-ASL22 Tidbit Mounting Locations and Status

S/N	*Location*	*Estimated depth (cm)*	*Status*
53	Float	5	OK
52	Float	10	OK
71	Float CTD	25	OK
58	Umbilical	50	OK
59	Umbilical	75	OK
60	Umbilical	100	OK
61	Umbilical	150	OK
63	Umbilical	200	Lost: broken zip tie
64	Umbilical	250	OK
65	Umbilical	300	OK
66	Umbilical	400	Lost: broken zip tie
67	Umbilical	500	Lost: unwrapped tape
68	Umbilical	600	OK
69	Rudder module	620	OK
70	Sub CTD	650	OK

Red recovered @ 1015Z 9/29/13
Tidbit loggers → ice bath @ 1308Z 9/29/13
Tidbit loggers → bucket at output of TSG @ 1321Z 9/29/13
Tidbit loggers → removed from bath @ 2138Z 9/29/13

(10) Argo Float Deployment

Eight SOLO-II profiling floats were shipped from WHOI to the Endeavor in Ponta Delgada. Seven were deployed during the cruise, and one, which failed to start up properly, was carried back to WHOI for diagnosis. The first three float deployment locations were chosen to match, as closely as possible, sites chosen ahead of time by Pelle Robbins based on the planned cruise track. On October 3, the latest position of active Argo floats were transmitted to Endeavor, and subsequent deployment sites were picked to try to fill gaps in the array.

S/N	Startup date (2013)	Startup time (UTC)	Deploy date (2013)	Deploy time (UTC)	Deploy latitude (N)	Deploy longitude (W)	IMEI (last 6 digits)	Notes
7174	Sep 20	12:05	Sep 21	00:51	32° 37.4’	29° 46.0’	159364	
7176	Sep 18	22:25	Sep 21	20:28	29° 59.7’	31° 38.8’	034036	
7080	Oct 1	15:38	Oct 2	15:37	27° 59.2’	37° 59.2’	046648	
7177	Oct 6	21:30	Oct 7	17:05	24° 50.5’	52° 13.6’	034634	
7178	Oct 6	21:53	Oct 8	20:41	28° 54.4’	55° 54.8’	034535	
7175	Oct 7	14:12	Oct 9	04:30	30° 0.6’	56° 58.7’	034834	Second attempt at startup
7183	Oct 8	21:28	Oct 10	14:28	35° 2.5’	61° 44.2’	034236	
7060							034036	Failed to startup properly

The floats were shipped equipped with bridles and water-releases. Each float was carried to the fantail and started up with a magnet swipe at least several hours prior to deployment. A stethoscope was used to listen for the sound of the buoyancy pump, and the external bladders were checked to ensure that they inflated and then deflated properly. After receipt of an automated email indicating a successful self-test, the plastic bag and stretch-wrap were removed from the float box, and it was lowered off the fantail into the water and supported until the water release activated. Ship speed at the time of deployment never exceeded 5 knots. The seven floats deployed all sent launch notification emails indicating that they had completed their cycle-0 dive.

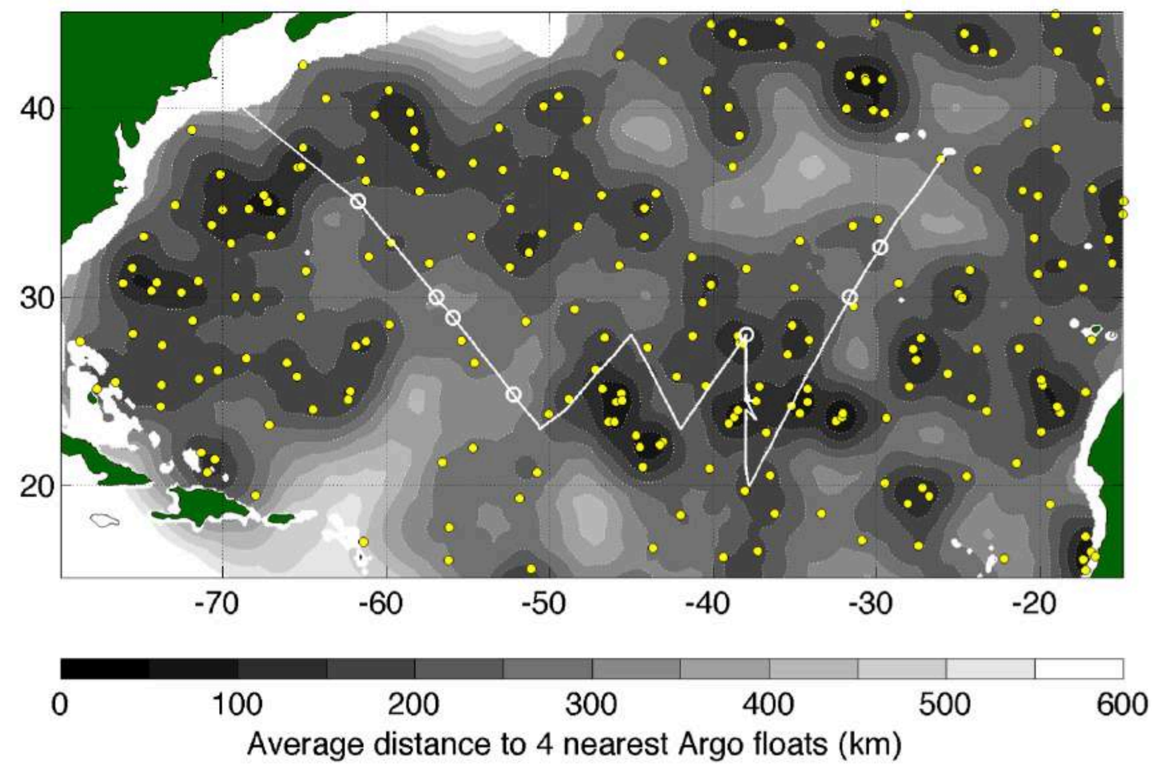


Figure 10.1: Argo float deployment locations (white rings) the cruise track (white line). Yellow circles mark the latest positions of other active Argo floats. Shading indicates the spatial density of floats (average distance to the nearest 4), not including the floats deployed on this cruise.

(11) Underway Salinity Observations

Introduction

In addition to the two thermosalinographs (TSGs) aboard the R/V Endeavor, a "sea snake" was deployed for the entire cruise, with the exception of the first few hours, the final two days, and short periods during recovery work that required its retraction. The snake is a 1" vacuum-rated hose connected to a pump and de-bubbling system that was used to measure sea surface salinity (SSS) every 10 seconds. The objective of the snake was to identify near-surface vertical structure in salinity by sampling within centimeters of the surface and in an area undisturbed by the ship's wake, and comparing with simultaneous measurements by the Endeavor's TSGs.

TSG Overview

The R/V Endeavor is equipped a SBE-21 unit, which sampled at 6-second intervals, and a SBE-45 MicroTSG unit, which sampled at 2-second intervals. Both units are supplied with de-bubbled water from the hull intake at 5m depth, located along the center line of the ship in the mid-ship section. In the headers of shipboard data file (e.g. "Data60Sec_001.elg"), the SBE-21 is signified by "Tsal" and the SBE-45 by "MicroTSG"; "Tsal-SST" refers to the temperature measured at the 5-m intake to the system; temperatures measured at the TSGs are typically higher, as the water warms during transit through the plumbing. The SBE-21 has a faster response rate than the SBE-45 MicroTSG, but the overall accuracy and stability is claimed to be higher for the SBE-45. Moreover, during periods with near-surface temperature stratification, when the sensors are subjected to large and rapid temperature fluctuations, the unprocessed salinity data output by the SBE-21 is quite noisy. Processing the raw C and T data to compensate for lags due to thermal mass, spatial separation, and sensor response time might eliminate much of this noise. TSG data logging commenced at approximately 1400Z on 19 September, and ran continuously for the duration of the cruise except for the period between 0000 and 0600 on 25 September when the flow through the SBE-45 was interrupted. Salinity recorded by the shipboard SBE-45 is shown in Figure 11.1. This large-scale survey of the surface salinity maximum was one of the primary scientific objectives of the cruise.

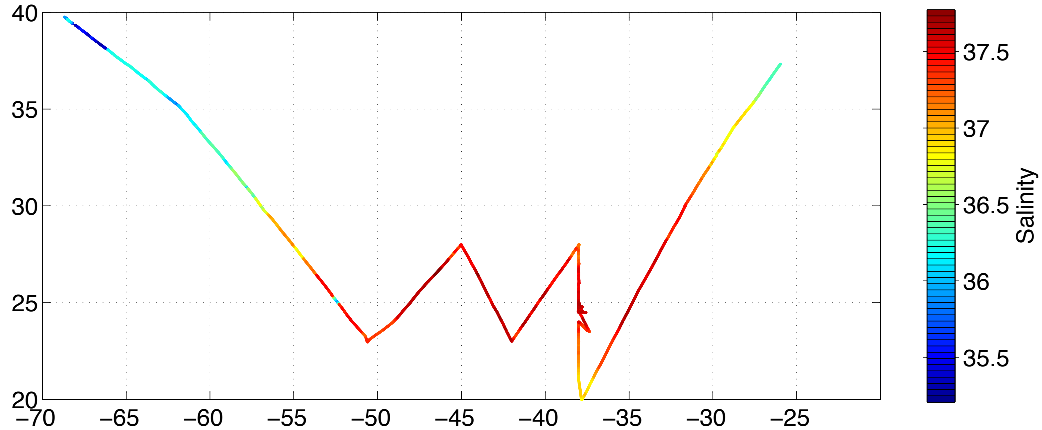


Figure 11.1: Salinity at 5-m depth recorded by the shipboard SBE-45 along Endeavor's cruise track.

<u>*Snake Overview*</u>

The sea snake was arranged in much the same configuration as was developed during its inaugural deployment on EN-522, the spring 2013 SPURS cruise aboard the Endeavor. The tuning process used to arrive at this configuration is described in some detail in the EN-522 cruise report. The snake was attached to a loop of line around a small block mounted on a boom that protruded approximately 6 m out from the starboard side of the vessel. The boom was mounted on the stairs leading from the 01 deck to the bow deck area. This setup allowed the snake to be quickly retracted as required for recovery operations on the starboard side, and is illustrated in Figure 11.2. The free end of the snake was plugged with an internal weight, and two 1-cm intake holes were drilled in the bottom of the hose approximately 50 cm from the end. Four 1 ¼" inner diameter zinc anodes were clamped to the hose at a height to ensure that the anodes remained out of the water for approximately 90% of the time in a moderate (2-3m) sea state.

Figure 11.2: The sea snake as seen looking aft from the starboard bow.

At approximately 12:15Z on October 10, in worsening weather, the inner section of the snake boom buckled, and the sea snake was secured for the remainder of the cruise.

A total of nearly 70 m of hose was connected to the intake, which was located in Endeavor's wet lab (Figure 11.3). The intake was set up to accept seawater from either the salinity snake hose or the vessel's saltwater supply for priming purposes. The pump is a self-priming Vanton Flex-I-Liner pump with a nominal flow rate of 5 gallons per minute (gpm) and was wired for 115 V.

Figure 11.3: The interior sea snake plumbing, showing valve positions during normal operation.

The majority of the time, the sea snake ran well, providing an adequate, bubble-free flow through the instrument. Under certain conditions, however, the pump struggled to pull enough water, and the flow was intermittent. A variety of factors combined to determine the severity of the problem, including sea state and ship speed, but the single most important factor seemed to be relative wind direction. With the wind coming from the port side, the snake ran well; wind from the starboard side often caused difficulties in maintaining flow, perhaps because the wind pushed the snake into the aerated bow wave. The symptom of intermittent flow in the data is spurious high-salinity spiking: for unknown reasons, when the flow through the SBE-45 stops, the measured salinity climbs rapidly. These artifacts should not be difficult to remove and so are not expected to result in large gaps in the processed dataset. In especially severe cases, the de-bubbler ran dry, feeding air to the SBE-45 and resulting in extreme low-salinity artifacts. These negative spikes will be easily filtered out in post-cruise processing. Snake data between 0600Z and 1400Z on October 2, and before 1341Z on October 5 should not be used, as the priming valve was accidentally left open. In addition, any time Endeavor's speed through the water dropped below about 3 knots, the snake began to sink and take in deeper water.

The snake SBE-45 was directly connected to a laptop running SeaSave V7 without an external interface unit. As a result, no GPS navigational data are recorded in these files. To ensure that the time-stamp logged with the data can be used to geolocate the data in post-processing, the laptop was continuously synchronized with GPS time in UTC by connecting to Endeavor's network time server using the software NMEAtime. Time-shifting the records will likely still be required in post-processing to account for the difference in travel time through the plumbing for the shipboard TSGs relative to the snake.

With the exception of the first few hours of sea snake operation, during which time a number of files were created in the process of getting the system working properly, all of the sea snake data is contained in the Sea-Bird file tsg19Sep2013c.hex. The same time period is covered by the ASCII file tsg19Sep2013c.txt, which contains time, salinity, temperature, and conductivity.

Calibration

Water samples were taken twice daily from both the snake and the shipboard underway system for post-calibration and validation purposes. Jason Smith measured the salinity of the samples with an Autosal 8400B salinometer. Preliminary analysis suggests that none of the sensors drifted substantially over the course of the cruise, and that the error of each sensor is approximately independent of the salinity (i.e. the accuracy of the data can be improved substantially by applying a constant offset, as opposed to a gain or a time-varying offset). The difference in salinity between the Autosal measurements of each bottle sample and the raw data recorded at the corresponding time by each sensor is shown below in Figure 11.4.

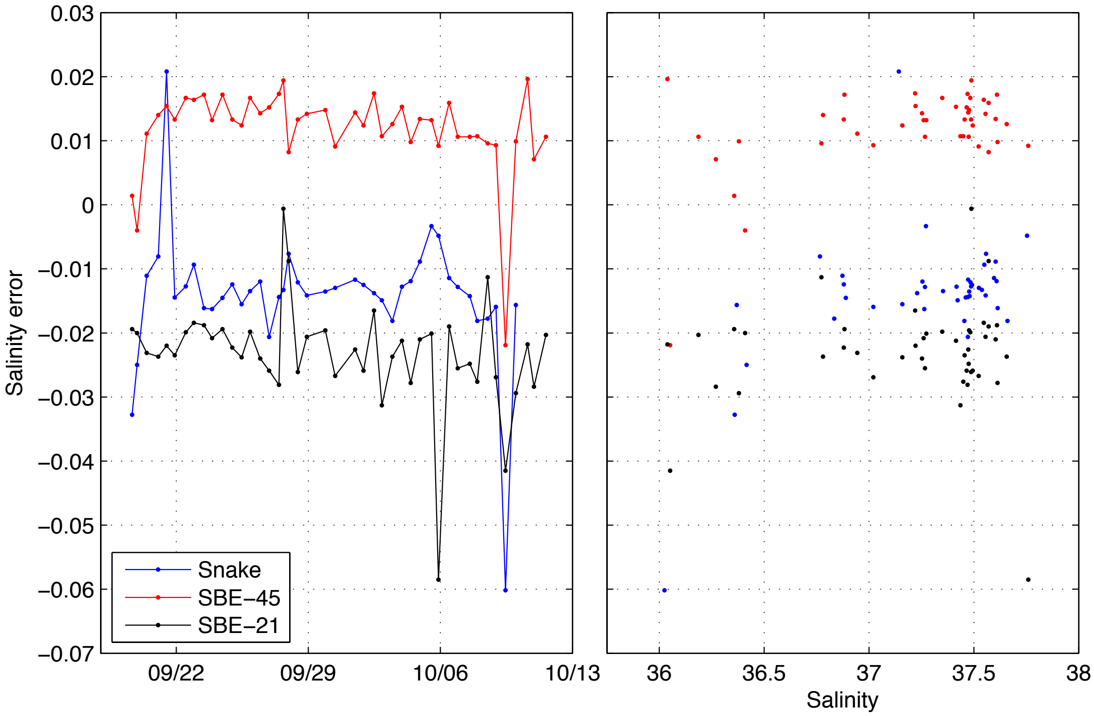


Figure 11.4: Salinity errors in unprocessed TSG and snake measurements.

The following table lists the date, time, and salinity of each bottle sample. The columns are: month, day, hour(Z), minute, snake salinity, tsg salinity. NaN's indicate no sample.

MM	DD	HH	MM	S-SNAKE	S-TSG
9	19	16	0	36.3598	36.3570
9	19	22	25	36.4158	36.4089
9	20	10	30	36.8732	NaN
9	20	10	34	NaN	36.9439
9	21	1	10	36.7663	36.7806
9	21	11	47	37.1423	37.2212
9	21	22	09	37.4607	37.4555
9	22	12	10	37.4872	37.4834
9	22	22	34	37.5505	37.5479
9	23	11	20	37.6136	37.6102
9	23	21	34	37.2636	37.2612
9	24	10	52	36.8895	36.8832
9	24	23	16	36.8794	36.8796
9	25	11	12	37.1590	37.1592
9	25	22	00	37.3529	37.3493
9	26	10	46	37.2550	37.2530
9	26	22	12	37.4719	37.4653
9	27	10	38	37.4711	37.4697
9	27	16	18	37.5387	37.4876
9	27	22	58	37.5584	37.5708
9	28	10	47	37.4846	37.4866
9	28	22	12	37.5564	37.5557
9	29	21	37	37.4780	37.4766
9	30	10	1	37.5248	37.5226
10	1	11	33	37.4728	37.4734
10	1	22	21	37.4912	37.4947
10	2	11	43	37.2296	37.2202
10	2	21	42	37.4221	37.4362
10	3	10	58	37.6598	37.6570
10	3	23	1	37.4169	37.4145
10	4	10	26	37.6086	37.6126
10	4	22	5	37.6042	37.6042
10	5	12	46	37.2715	37.2733
10	5	21	32	37.7542	37.7596
10	6	11	10	37.5955	37.5708
10	6	22	5	37.2672	37.2672
10	7	13	19	37.4800	37.4754
10	7	22	58	37.4543	37.4490
10	8	12	15	36.8341	36.7734
10	8	22	49	37.0208	37.0204
10	9	10	44	36.0244	36.0511
10	10	0	1	36.3693	36.3794
10	10	14	59	NaN	36.0386
10	10	22	56	NaN	36.2693
10	11	14	21	NaN	36.1866

Near-surface structure

In some instances, on calm days, a slight increase in salinity at the surface is detectable by comparing snake and TSG measurements. In one instance, at 1618Z on September 27, a measured salinity difference of 0.05 was validated by taking bottle samples from the outflows of the snake and TSGs. During the transit to WHOI, the snake captured some narrow low-salinity surface features. The four downward spikes shown in snake salinity in Figure 11.5 below are unlikely to be artifacts because they correspond to much less intense features recorded by the independently operating underway system. In one case the snake recorded a salinity fully 1.5 psu fresher than the shipboard TSGs. Also seen in the figure, at approximately 05:00 on Oct. 8, are the upward spikes in snake salinity characteristic of interrupted flow.

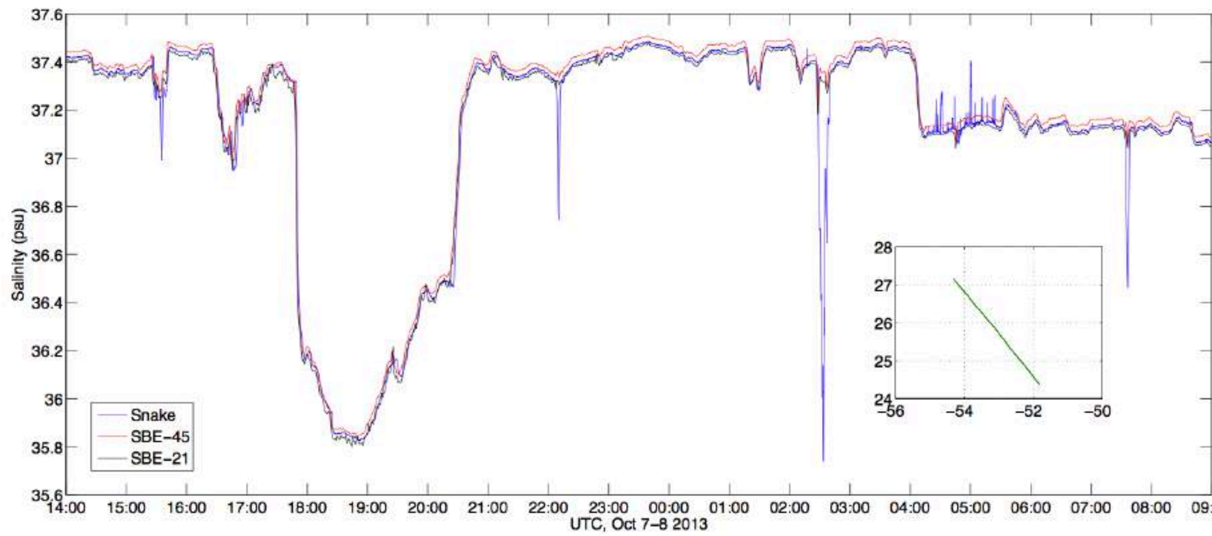


Figure 11.5: Nineteen hours of SSS data from the snake and both shipboard TSGs. The cruise track during this period is plotted as an inset, and was traversed from southeast to northwest.

An ISAR sea surface temperature radiometer was mounted on the port-side rail of the flying bridge during most of the cruise. The primary objective of this deployment was testing of the instrument, but preliminary look at the data seems to identify periods of surface warming relative to the 5-m depth of the intake for the shipboard underway water sampling system, most notably on September 27 (Figure 11.6). Most of the time, the temperature measured by the ISAR is about 1 degree C cooler than that recorded at the ship's intake.

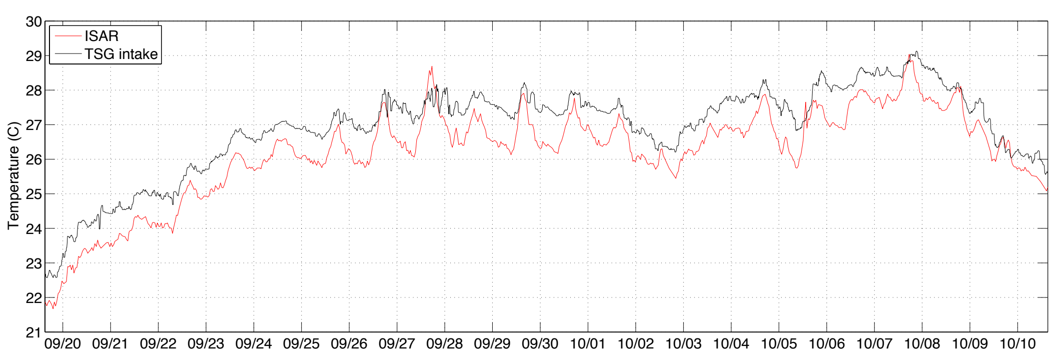


Figure 11.6: SST recorded by the ISAR (red) and in-situ at the inlet to the underway sampling system (black).

(12) CTD profiling

Seventeen CTD casts were completed during the cruise. The Endeavor's on-board SBE 9/11plus CTD carried dual T, C, and O2 sensors. A WET Labs ECO-AFL/FL chl-a fluorometer was included from Cast 7 onward. The rosette held 12 10-L Niskin bottles (of which six were used for salinity samples on most casts) and, for daytime casts, a Biospherical/Licor PAR sensor. Lynne Butler processed the data. Due to mechanical problems, we switched from Winch 1 to Winch 2 during Cast 3.

Casts 1 and 2 were back-to-back 1000-m test casts. The temperature profiles of both had serious artifacts below 500 m. Lynne Butler traced the problem to a faulty connector on the Sea-Bird pump, and after repair we completed a successful 2000-m test cast (Cast 3).

Cast 4 was located at the PIRATA mooring, which we visited to swap out a sensor. Though slightly east of 38W, this cast forms the southern end of a 2000-m section along that meridian extending from 20-28N at one-degree intervals. Casts 5-8, 10, and 15-17 complete this section.

Casts 9, 11, and 13 coincided with the recoveries of Seaglider 122, Mixed Layer Float 5984, and the Pico-N mooring, respectively, and were each to a depth of 1000 m. Cast 14 was a full-depth station located at the WHOI mooring site, and reached a depth of 5300 m. Cast 12 was an on-deck test cast and returned no useful data.

Station number	Latitude (N)	Longitude (W)	Date (2013)	Start (UTC)	Maximum depth (m)	Notes
1	32° 37.2'	29° 48.0'	Sep 20	21:31	992	test cast; bad data
2	32° 37.5'	29° 47.5'	Sep 20	22:33	1001	test cast; bad data
3	29° 59.9'	31° 39.6'	Sep 21	18:37	1978	test cast
4	20° 1.2'	37° 49.0'	Sep 24	13:06	2001	PIRATA mooring
5	21° 0.6'	38° 0.3'	Sep 24	21:26	2002	section
6	22° 0.5'	38° 0.1'	Sep 25	04:42	2001	section
7	23° 0.9'	38° 0.0'	Sep 25	12:11	2001	section
8	24° 0.0'	37° 59.6'	Sep 25	19:30	2002	section
9	23° 30.2'	37° 21.7'	Sep 26	10:26	1002	Seaglider 122
10	25° 0.0'	37° 59.9'	Sep 26	23:46	2001	section
11	24° 29.6'	37° 34.7'	Sep 27	14:33	1002	MLF
12						deck cast; no data
13	24° 40.3'	37° 56.6'	Sep 28	09:14	1001	Pico-N mooring
14	24° 30.1'	37° 58.2'	Sep 28	21:09	5302	WHOI mooring
15	26° 0.0'	37° 59.9'	Oct 1	22:26	2002	section
16	26° 59.9'	37° 59.8'	Oct 2	05:50	2002	section
17	27° 59.9'	37° 59.0'	Oct 2	13:57	2007	section

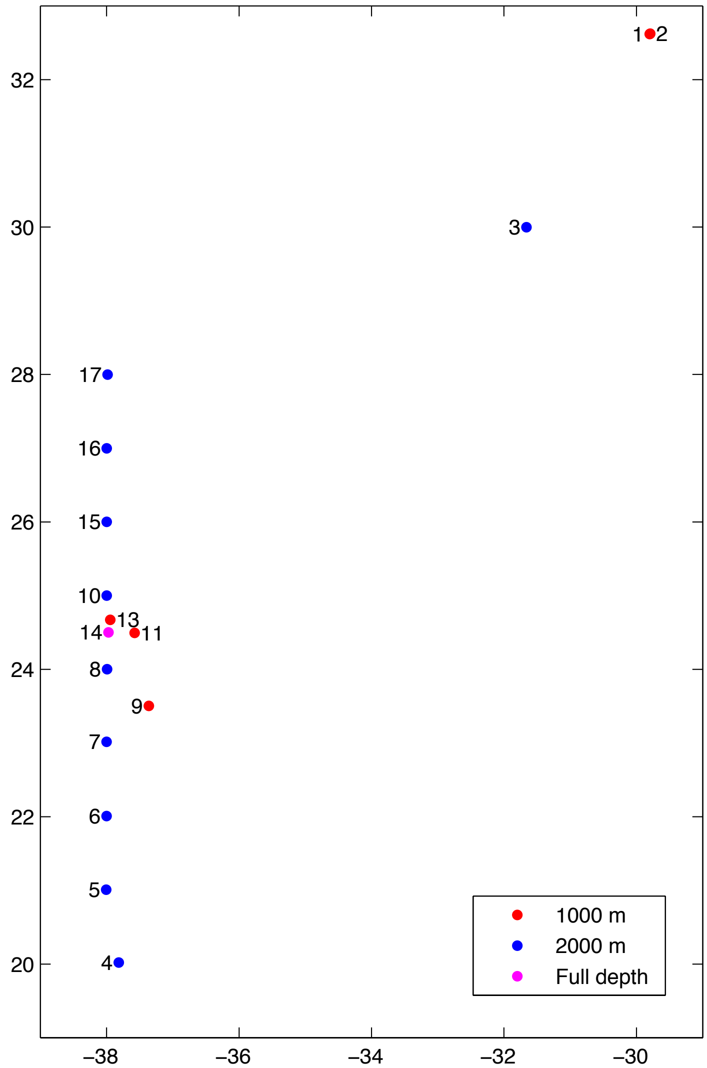


Figure 12-2: Map of CTD cast locations. Casts 1 and 2 were test casts. Cast 12 was a dummy deck cast and is not shown.

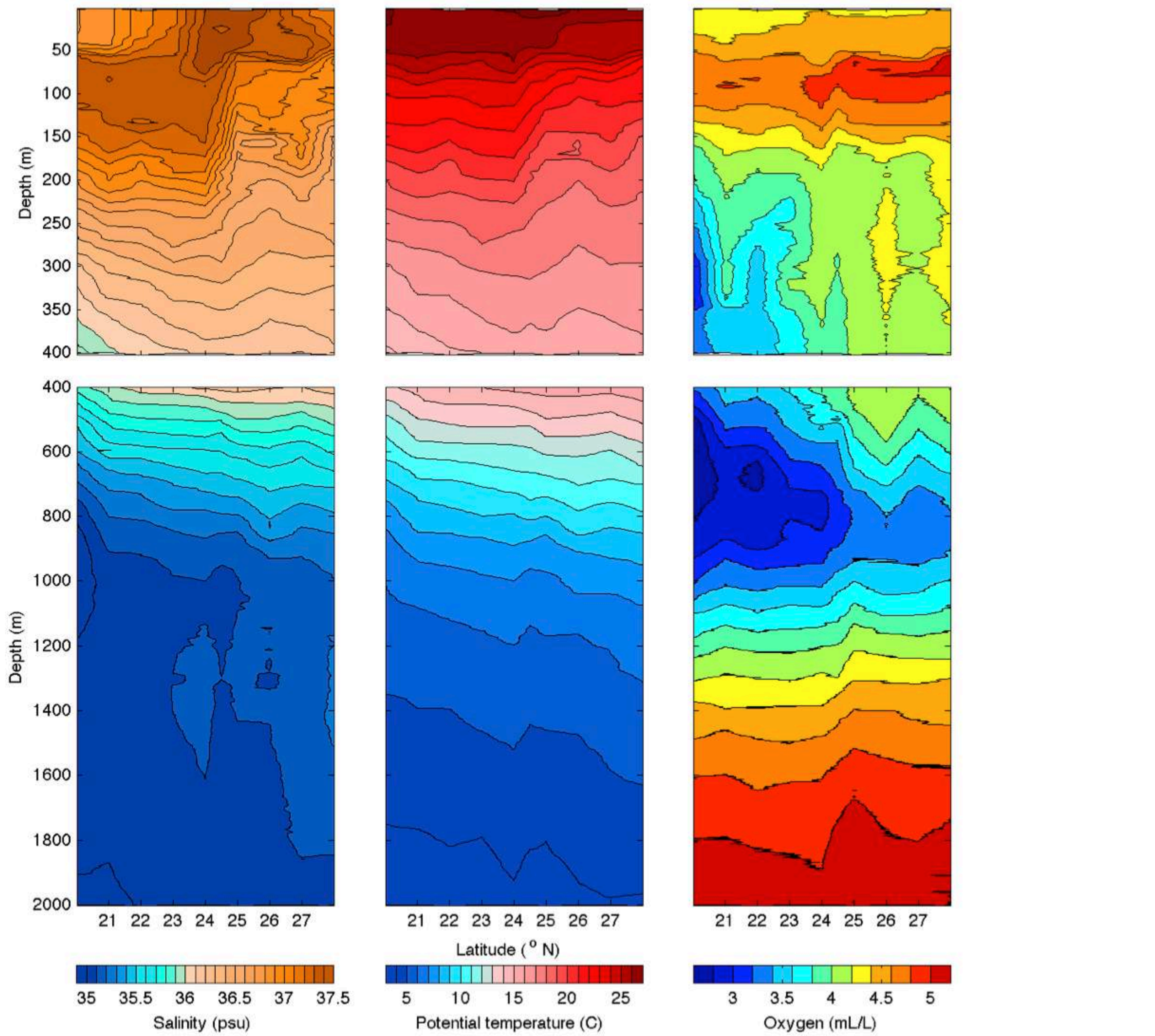


Figure 12-3: Sections along 38° W. Unfortunately, these were plotted by someone "trained" at Scripps, so the x-axes are backwards. Apologies.

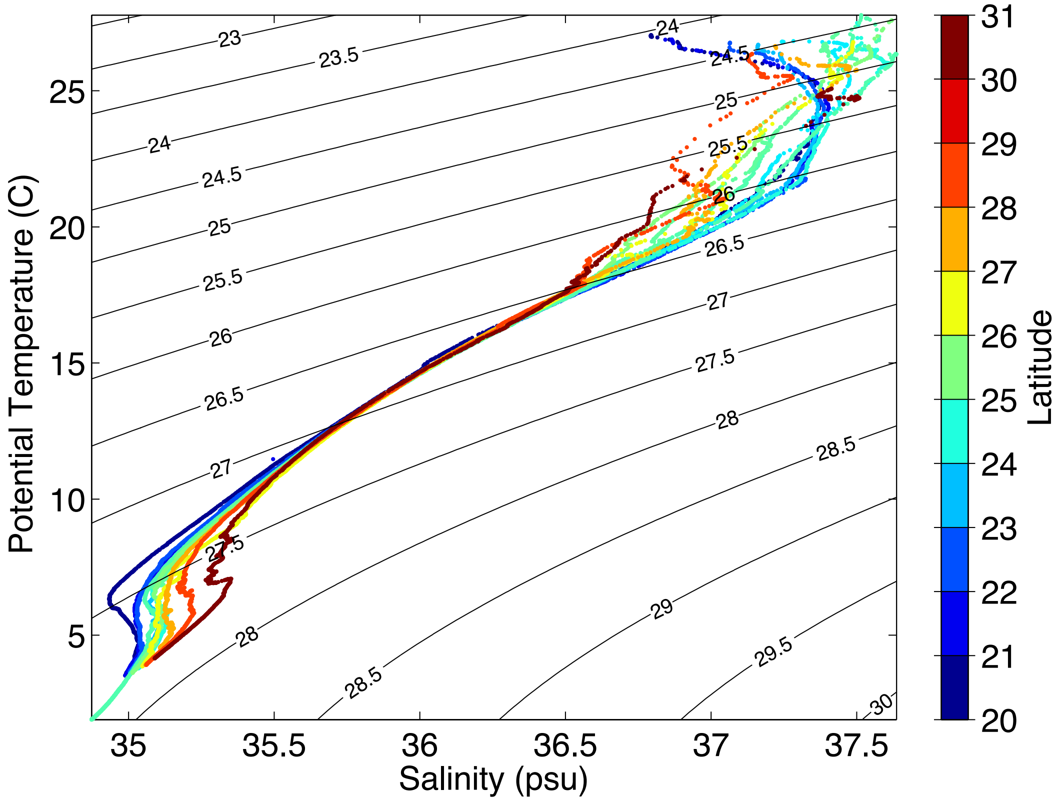


Figure 12-4: TS relationship for all casts with the exception of casts 1 and 2 (questionable data quality) and 12 (on-deck cast). Color indicates latitude. Labeled contours are sigma-theta.

(13) Salinometry

The salinometer used on the 2013 SPURS (EN533) cruise was an Autosal model 8400B (WHOI #11). It was set up in the Special Purpose Lab of the *R/V Endeavor*. This salinometer was also used on the 2012 SPURS Cruise (KN209) aboard the *R/V* Knorr.

As much care as possible was taken in setting up the salinometer. It was mounted securely in a room that had it's own temperature control in the event that special control was necessary. Extra consideration was given to ensuring that there was good ventilation behind the instrument and that the drain had a clear unobstructed path to the waste collection container. Once set up and allowed to stabilize for a day, the salinometer was standardized. OSIL IAPSO standard seawater, batch # P-153, was used for all standardizations. A few trial runs were then conducted to check the Autosal for stability, and then a few days later the salinometer was re-standardized prior to running the first batch of bottles.

The samples collected were analyzed every few days. Standard procedure was to allow the samples to sit at least overnight so that they were at room temperature at the time of testing. The Autosal was standardized prior to each run of bottles, and then again afterward to verify that there was no drift. All samples were gently mixed prior to analysis.

In all, 184 samples were analyzed. 99 were drawn from Niskin bottles on the CTD rosette following casts of various depths. 84 bottles were drawn from a special TSG system. This system utilized a snake suspended from the starboard side of R/V Endeavor that was attempting to skim water off the very surface of the ocean while underway.

(14) a-Sphere In-Situ Spectrophotometer Test casts

The Upper Ocean Processes Group at WHOI is interested in upper ocean variability. The absorption profile of the ocean becomes a primary factor in determining the temperature profile under low wind conditions.

The science party of the SPURS cruise was asked to bring a new a-Sphere In-Situ Spectrophotometer/Absorption Meter along to test in various conditions. The a-Sphere uses a spherical integrating cavity and an internal light source to provide information on optical absorption.

This instrument was mounted in a stainless steel cage with separate batteries so that it could be lowered into the water as a self-recording unit. After a short learning curve that provided questionable data files, a number of profiles were collected with the a-sphere.

The a-sphere was lowered into the water using the CTD winch and j-frame on the starboard side of the ship. A weight was added below the cage to keep the instrument vertical in the water. Twelve casts were taken. Most of them prior to, or just following a CTD cast.

This is a relatively new instrument, and we hope the information gained during these exercises will allow WHOI scientists to use it efficiently for future projects.

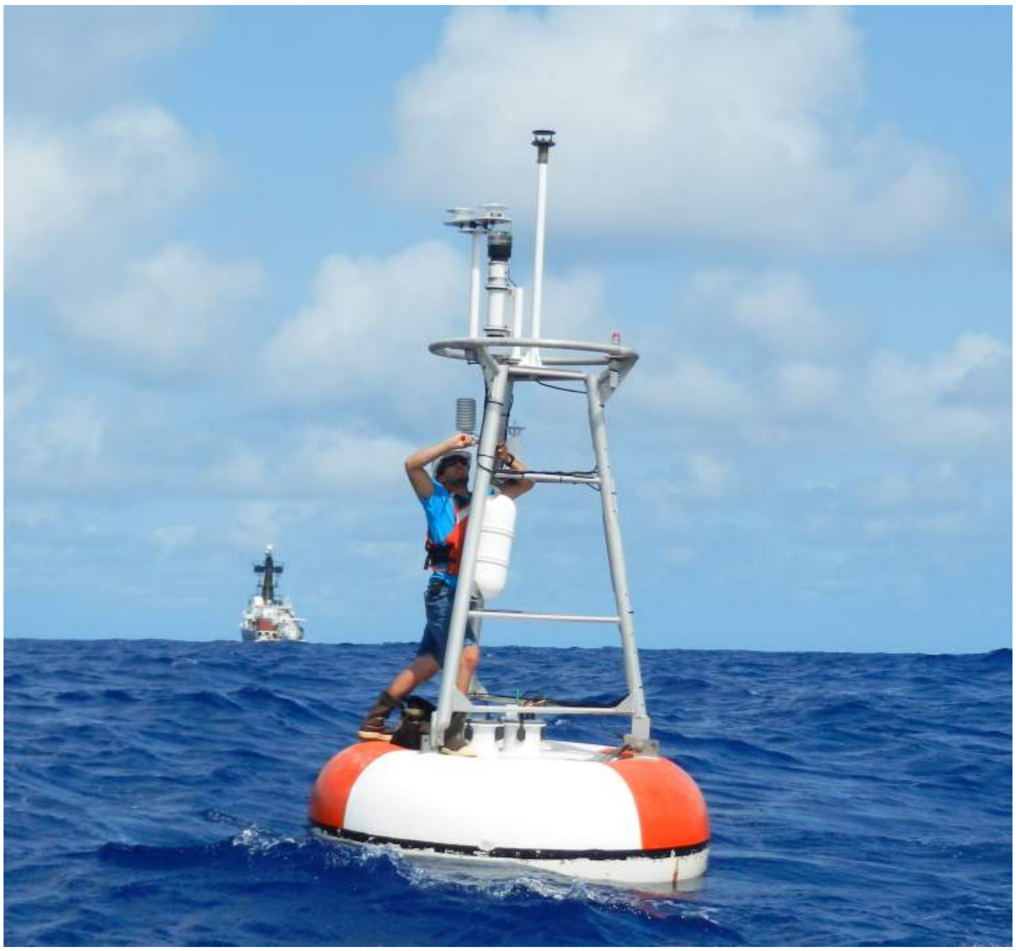
CAST #	DATE/TIME (UCT)	LATITUDE	LONGITUDE	FILE NAME	COMMENTS
1	9/21 2022	29° 59'	31° 39.27'	CST0006.BIN	First run ~ 50 m from fantail with tugger
2	9/24 1449	20° 00'	37° 50'	CST0007.BIN	CTD winch 20m/m down 30 m/m up 19.93VDC measure from cans y conn end 19.92
3	XXX	21°	38°		Never got a file. Power too low (19.92 volts)
4	9/25 1200	23° 00'	38° 00'	CST0016.BIN	Probably first good cast. Full charge, end 21.6 vdc. 20 m/m down 30 m/m up 200 m
5	9/25 1918	24° 00'	38° 00'	CST0017.BIN	Good 20 down 30 up. 21.44 vdc end
6	10/2 0748	27° 00'	38° 00'	CST0018.BIN	10 m/m stop for 10 sec at 25, 50, 75, 100m end 20.9. Charged batts - cloudy
7	10/2 1339	28° 00'	38° 00'	CST0019.BIN	10 m/m stop for 10 sec at 25, 50, 75, 100m end 21.99 vdc – cloudy, edge of storm
8	10/2 1937	27° 33'	38° 20'	CST0021.BIN	10 m/m stop for 10 sec at 25, 50, 75, 100m end 2nd try. Weight broke first try. 21.54 vdc - cloudy
9	10/4 1022	24° 07	42° 38	CST0022.BIN	Sunny – same 100m cast. 21.15
10	10/4 1524	24° 48	43° 05	CST0023.BIN	Sunny – same 100m cast. 21.15
11	10/4 2005	25° 32'	43° 30'	CST0024.BIN	Clear. End of day – GOPRO camera cast to 40 meters at 30mm – noted strumming in cable and noise from hardware
12	10/42037	25° 32'	43° 30'	CST0025.BIN	Clear. End of day – same 100m cast. 21.02

Charged batteries, cleaned sphere, ran calibration test, dumped data10/05/2013

Table 14.1 – a-Sphere log

(15) PIRATA Mooring Repair

On Tuesday September 24th, the R/V Endeavor launched the small boat in order for David Rivera to conduct buoy ride where he successfully swapped a faulty sensor on a mooring for another PMEL Seattle based division, the Tropical Atmosphere Ocean Project. With the help of Jeff Lord, David replaced an ATRH (air temperature and relative humidity) sensor, which is part of the meteorological instrument package on one of the international PIRATA (Prediction and Research Moored Array in the Atlantic) moorings at 20N, 38W.



the end