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### Cruise Report AR11 Subduction 3

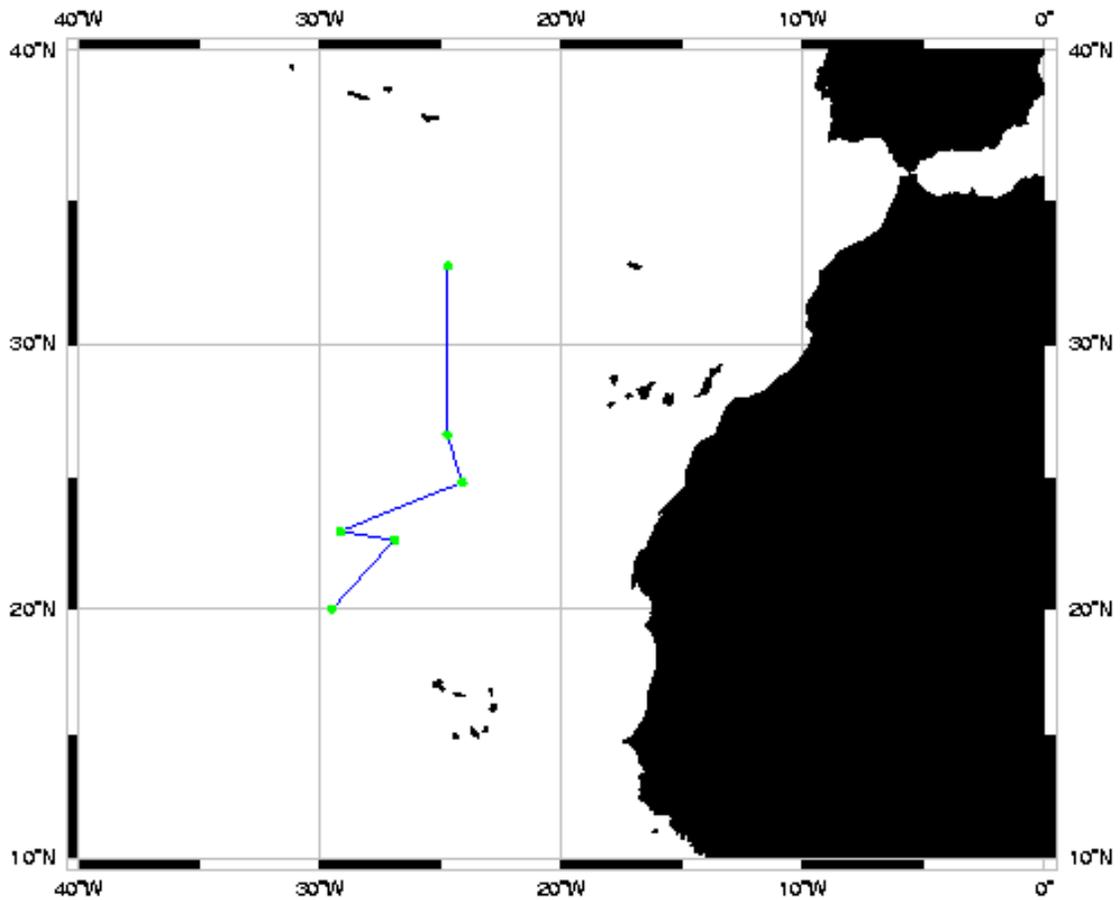
Chief Scientist: Terrence M. Joyce  
WHOIShip: R/V Oceanus OC254/4  
EXPOCODE: 32OC254\_4  
Ports of Call: Las Palmas to AzoresCruise  
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## Introduction

This was the third in a series of 4 cruises in the Subduction Experiment devoted to Seasoar sampling in the upper ocean. On the first cruise in May 1991, a total of 18 Bobber floats were released south of the Azores front in the general vicinity of 30° N, 23° W. These were put at three different depth intervals (shallow, medium, deep) defined by bounding isotherms between which to 'bob'. At the deployment sites, mesoscale-resolving spatial surveys were carried out by towing the Seasoar undulating CTD in a 'radiation pattern' between depths of 0 and 400m: spanning the depth range of the Bobbers. Tracer samples were collected from a conventional profiling CTD for tritium/helium-3 dating of the upper ocean. Some limited tracer and Seasoar sampling was also carried out near the Azores front. The second cruise in February 1992 focused on Seasoar and tracer studies of the Azores front; no measurements were made over the Bobbers. This third survey was planned to concentrate on the measurement of the mesoscale variability following the Bobbers in order to define the nature of the change since deployment. The fourth and final cruise is planned for summer 1993. All of these cruises were/are aboard the R/V Oceanus.

Of critical importance to goals of this cruise was the location of Bobber positions. The main array of Autonomous Listening Stations (ALSs) deployed for Bobber float tracking is still in the water and the data are (hopefully) safely still in the instruments. In order to discover float locations for the cruise, several 'real time' tracking options were available. The first of these was a Drifting Sofar Receiver (DSR) consisting of a surface float, 500 m of cable and hydrophones at the bottom. Telemetry signals received from the Bobbers were processed by the DSR and relayed via satellite (ARGOS) to shore. We deployed (and later recovered) one of these drifters on the cruise (it did not work). The second mode was an ALFOS float: a modified ALACE float built by D. Webb (with much input and support from R. Davis) and modified at WHOI to carry a small hydrophone (like a RAFOS) and signal detector. It was normally floating at a depth of 1000m (???), but every 10 days would come to the surface, and transfer its Bobber telemetry data and its position to shore via ARGOS. One of these worked prior to and during our cruise: two others did not. The third and last resort for tracking was by heaving to and lowering a hydrophone array over the side of the ship to a depth of 1200m (sound channel axis) and 'listening'. A total of 4 listening stations were necessary to 'locate' the shallow Bobbers selected for tracking.

## Station locations for AR11 OAKY



In addition to the above work, deep CTD stations were made over Bobbers to collect water samples for calibration of both CTD and Seasoar sensors (all SeaBird), and to fill in gaps in a large-scale tracer survey of tritium/helium-3 in the region made in October 1992 aboard the R/V Charles Darwin.

## Cruise Narrative

The Oceanus left Las Palmas, Canaries, at 0910Z on 24 November and steamed to the southwest for approximately 1 day before deployment of the DSR (serial #02), an initial listening station (LS#1), and test CTD station (CTD#1). The time window for Subduction Bobber telemetry was 0-600Z and 12-1800Z every day. Just prior to LS#1 it was discovered that the hydrophone array was 'dead' with no signal at all. We deployed the backup cable, but our LS results showed very low signal levels at telemetry times and thus did not provide hard evidence for Bobber locations. It was later discovered that the penetrator pin was bad on the main array-this was subsequently fixed and used for the remainder of the listening stations. The main problem with the backup array was a broken wire in the cable which cut off 3 of the 6 hydrophones and thus limited the signal gain of the array. The DSR launch went well, but the first CTD station showed a lot of unbelievable vertical structure in the salinity and oxygen profiles. Water samples were collected at the bottom (4500m) of the cast and at the oxygen minimum layer (app. 900m). The test station was quite useful in teaching us the importance in 'turning on' the SeaBird CTD system after it is in the water to properly 'prime' the pump and associated plumbing, and to identify 3 bad (leaky) bottles out of the 24 place 1.2 liter General Oceanic rosette.

Because we knew before the cruise that the Bobbers were all to the south of the working ALFOS (because they had been tracked by an equatorial ALS array recovered in September 1992!), data from the DSR or the LS was needed to determine float position. Unfortunately the LS#1 was not successful and the first data back from the DSR were not good either. For this reason, we steamed south and made LS#2 on 27 November. Data return from this station was much better and gave us tentative locations for a few of the Bobbers. One of these was Bobber 26, which was the furthest south of the lot. We went to this location and made a CTD station #2 followed by listening station #3 and our first 'radiation pattern' mesoscale survey with the Seasoar, which lasted approximately 27 hrs. towing the Seasoar at 7.5 kts. Because we experienced problems getting the servo controls to properly fly the Seasoar at first, we repeated legs 1 and 2 of the pattern before departing the region. The problem with the control of the servo was quickly fixed and did not re-occur for the remainder of the cruise. The LS#3 did not give good signals for Bobber 25, the next one to the north. For this reason, we towed the Seasoar over the suspected location and then headed for one of the two possible locations for Bobber 15 which were both possible based on the data from ALFOS and LS#3. During this run the main acquisition computer (a hybrid SUN workstation) for the Seasoar crashed and could not be re-booted once a bad fuse was replaced. Some quick shuffling put the data acquisition back on a PC with the navigation data logged to a laptop as backup (ADCP data were collected for the entire cruise including navigation data at 5 min intervals). A total of about 5 hrs. of data were lost due to the crash. Fortunately, the Seasoar deck unit and command system was unaffected and the fish continued to fly and collect engineering data on pitch, roll, tension, etc., during the CTD data loss.

Following a second mesoscale pattern (referred to as 'star' in the log), CTD #3 was made on 28 November. This was the first station where tritium/helium-3 samples were collected (from all water samples - subsequently samples were collected only from the 12 surface-

most bottles). We then re-deployed the Seasoar and towed it to the site of Bobber 19 where star #3 was made and thence to the second possible site for Bobber 15 (we later determined that this was the most likely one) where star #4 and, after recovery of the Seasoar, CTD #4 were made. Our final listening station (#4) was then made at the site of the CTD station and we steamed to Bobber 21 with the Seasoar deployed. We reached this site on 8 December and carried out star # 5, followed by CTD #5.

As at this point of the cruise it was clear that the DSR was not working and we were at our closest point to its position (ARGOS positions were OK and relayed out to the ship by fax), we steamed to the DSR and recovered it on 10 December. After steaming back over Bobber 20, we did CTD #6, deployed Seasoar, and made our last mesoscale survey (star #6). We then began a two day steam to the north, ending just to the west of the sites where the Bobbers were set in May 1991. Seasoar was then recovered, and a final CTD (#7) was made to the south of the Azores front, after which we steamed for Ponta Delgada, Azores where we arrived on 16 December.

### **Instrumentation Notes**

The Seasoar, manufactured by Chelsea Instruments, Ltd., is a towed fish equipped with a propeller-forced wing that can be adjusted to fly the fish. A winch with 750m of faired cable is used with a multi-conductor cable. The fish was loaded with a pair of Seabird temperature and conductivity sensors and pressure and dissolved oxygen probes, all of which telemeter data up the cable at 24 hz. In addition, engineering sensors measured pitch, roll, propellor rotations, pressure, wing angle; and tension on deck; they are sampled at 2.5 hz and the data displayed and stored on a separate computer on board the vessel. Just prior to the final recovery of the Seasoar, the fish became 'stuck' at the surface for extended periods of time; this was due to the wings sticking in the up position - possibly due to loss of hydraulic pressure in the Seasoar. On the profiling CTD, pairs of temperature and conductivity sensors and a single oxygen probe have water pumped through tubing. During the course of the cruise, the secondary sensors on each instrument were exchanged, as well as the Seasoar oxygen probe on the final CTD station. Problems were encountered with the oxygen probe on station 2, which led us to change sensors. When the problem recurred on station 3 (an abrupt shift in the oxygen current at a pressure of 2500 dbar on the down trace), we were able to isolate and correct the problem, which was with a faulty cable connection.

## Preliminary Results

Various results have been tabulated at the end of this report. Table 1 is a complete event log of the cruise, while Table 2 extracts locations of CTD, listening, and DSR 'stations'. Table 3 gives the estimated positions of the Bobbers tracked on the cruise along with the sources for the estimate. The cruise track is shown in Figure 1 with station locations indicated.

When the Bobbers were initially deployed in May 1992, they were in or slightly deeper than winter mode water of the Madeira type. Our preliminary findings show that none of these winter modes remain in the water tagged by the Bobbers; they have been replaced by and embedded within a smooth pycnocline. At the time of deployment, the Bobbers were grouped in two regions and Seasoar mapping was carried out with 'radiator patterns' with diameters of approximately 120 km. It was discovered subsequently that the mesoscale variability had scales of order 10 km, leaving large areas with the pattern that were poorly mapped. For this reason the diameter of the pattern was reduced to 80 km for this cruise. This was fortuitous because the smaller pattern could be carried out in 1 day as opposed to 2 days, thus permitting more patterns over the now dispersed Bobbers to be done. Data from the first pattern or star will be shown for illustration of our results. This pattern is chosen not because it is typical, but because the loss of the main acquisition computer and switch over to the backup required a change in data format and loss of the ability to provide the same advanced level of processed data at sea.

The Seasoar sensors data at 24 hz. was edited and averaged into a 3 second time series as the instrument 'flew' between the mixed layer and a depth of about 400 dbar. Data were interpolated onto a uniform grid in depth/distance along track using a Gaussian filter with vertical and horizontal scales of 5 dbar and 4 km, respectively. One of the long legs of star 1 (leg 6) is shown in figure 2. The mixed layer had a temperature and salinity of 24.5 oC and 37.1 psu respectively. A subsurface salinity maximum in excess of 37.2 can be seen below the base of the mixed layer over most of the section. The density structure shows no deeper mode below the mixed layer. The locations of the interpolated data from the entire survey (figure 3) show the spatial mapping pattern. Data were then mapped onto density surfaces (figure 4) at intervals of 0.05 sigma theta. The thickness of each density surface is the difference between pressures at bounding density surfaces. Below the mixed layer, thickness monotonically increases with depth. The 'thin' layers of the pycnocline show a large degree of potential temperature variation over the survey. Two density levels have been selected and objectively mapped using a spatial correlation scale of 10 km in figures 5, 6. The T/S variability can be seen to have short spatial scales of 10-20 km in the north-south and 40 km east-west which are 'coherent' in the vertical. Thicker layers tend to be warmer (and saltier). The error map assumes a noise to signal ratio of 50 (0.5) and shows the ability of the array to 'map' the variability, which is much improved over the larger patterns of the first cruise. We have not examined the variability scales for the entire cruise yet, but these data suggest a much smoother and somewhat larger scale than the deployment cruise with a clear relationship between the thickness and the potential temperature of the layers. The oxygen data appear rather good and once the probe data are 'calibrated' should yield oxygen maps as well. The pair of conductivity

sensors on the Seasoar appeared stable over the cruise and the preliminary salinity data shown in the figures should be correct to at least 0.01.

Seasoar conductivity, temperature and oxygen sensors were exchanged with those on the cable-lowered CTD and we should eventually be able to calibrate the conductivity and oxygen sensors used on the cruise by reconciling the results with the bottle data. Sampling depths for the bottle data were at 500 dbar increments from the bottom of the stations (4000 to 5000 dbar) up to 1500 dbar. Intervals were reduced to 50 dbar between 400 dbar and the surface. Sampling for tritium/helium-3 was done for the shallowest 12 bottles (700 dbar to the surface) on all stations after #2, except for station 3, where all levels were sampled with the copper tube 'clangers'. Deep CTDs were done near Bobber locations except for the last station (#7) which was done to the west of the original deployment sites for the Bobbers and south of the Azores front in order to 'fill in' sampling gaps from the Darwin mooring and tracer cruise of Weller and Jenkins in October 1992. The front itself was crossed on 15 December, as can be seen from the ADCP temperature sensor (figure 7) and the ADCP velocities (contoured vs. latitude, figure 8a,b).

In total, approximately 4100 km of Seasoar profiling was obtained during the cruise.

### **Personnel and Acknowledgments**

Six members of the scientific party carried out all of the work and are listed below together with general areas of responsibility; all except Szelag, who is from URI, are from WHOI.

Terrence Joyce	Chief scientist, oxygen analyses
Julie Pallant	Seasoar, CTDs
Frank Bahr	Seasoar, ADCP
Jerry Dean	Float tracking, Seasoar
Paul Fucile	Float tracking, electronics troubleshooting
Jan Szelag	CTDs, salinity analyses

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Terrence M. Joyce 15 December 1992