IFM-GEOMAR REPORT

IFM-GEOMAR

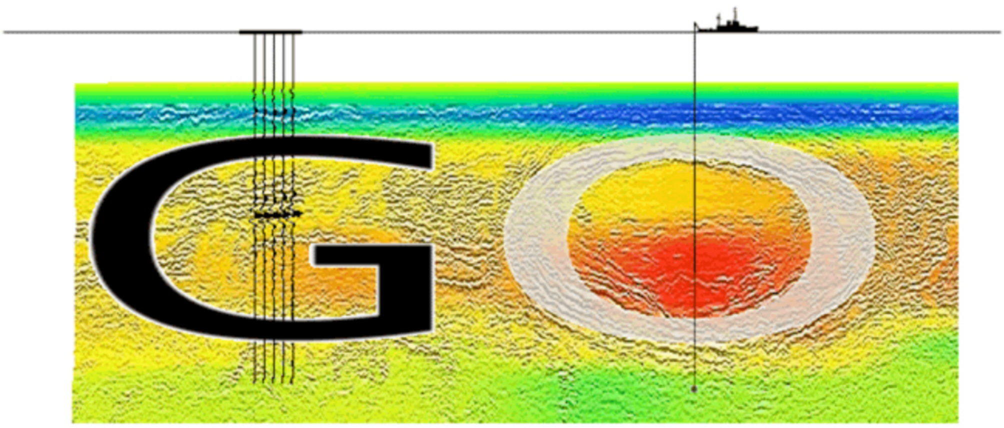
Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

RV POSEIDON
Fahrtbericht / Cruise Report
P350

Internal wave and mixing processes studied by
contemporaneous hydrographic, current, and seismic measurements

Funchal - Lissabon

26.04.-10.05.2007



Berichte aus dem Leibniz-Institut
für Meereswissenschaften an der
Christian-Albrechts-Universität zu Kiel

Nr. 26
Februar 2009

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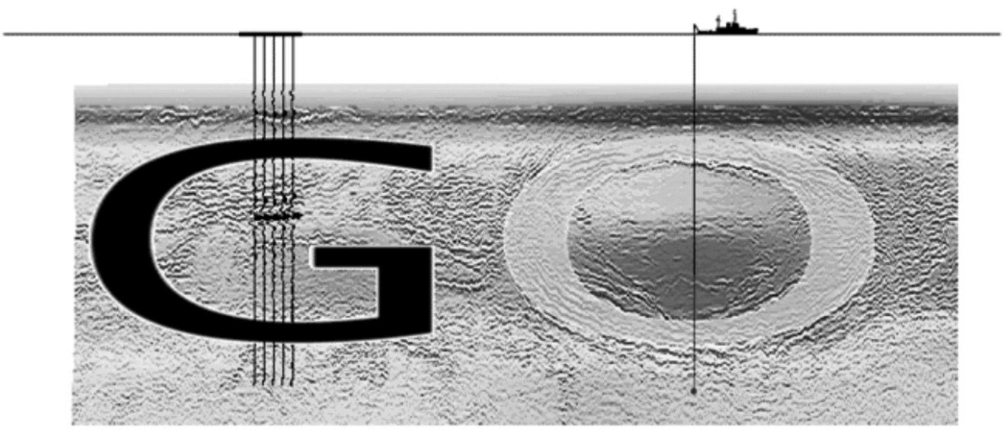

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Cruise Report

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R/V Poseidon Cruise No.: 350

Cruise Schedule: 26 April – 10 May 2007

Research Topics: Physical Oceanography, Marine Seismics

Oceanic Region: Gulf of Cadiz

Ports of Call: Funchal (Madeira, Portugal), Lisbon (Portugal)

Institute: IFM-GEOMAR. Kiel, Germany

Chief Scientist: Dr. Gerd Krahmann, IFM-GEOMAR, Kiel, Germany

Number of Participants: 9 Scientists/Technicians

Projects: Internal wave and mixing processes studied by contemporaneous hydrographic, current, and seismic measurements (DFG), Geophysical Oceanography (EU)

Contents

1 Scientific team

1.1 Participating institutions

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Dr. Anne Krabbenhöft	Scientist	IFM-GEOMAR
Uwe Koy	Technician	IFM-GEOMAR
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1.3 National and international collaboration

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2 Research program

2.1 Research objectives

The goal of this project was to obtain accurate and well resolved hydrographic and ocean current data and to combine these with seismic measurements acquired by the EU project *GO* to study the internal wave field and mixing processes in the Gulf of Cadiz. New methods to underpin the developing research field of seismic oceanography will be evaluated and improved on the basis of this data set. CTD/LADCP data were collected contemporaneously and at very close distance to marine seismic reflection measurements. The combination of the seismic data with its very high horizontal resolution of down to a few meters together with the more accurate hydrographic and current measurements will yield new understanding and insights into water mass mixing processes and will significantly further the new tool of seismic oceanography. In particular the combined data set will be used to investigate the mixing processes connected to meddies (subsurface eddies with water of Mediterranean origin), which result in structures highly visible in seismic data.

As described above, hydrographic and current data were measured with standard and state of the art physical oceanography tools on FS Poseidon. A good part of the cruise this was done following RRS Discovery which was underway doing seismic oceanography measurements for the EU project GO.

The research program carried out during Poseidon cruise P350 focused on

- Collaboration with the EU project GO's cruise on RRS Discovery,
- Collecting high quality CTD data contemporaneously with RRS Discovery's seismic data,
- Investigating new methods for seismic data collection with the goal to derive oceanographic information.

2.2 Measurement program

The target area of the measurement program was the Gulf of Cadiz. Work was concentrated on two sections near Cape St. Vincent (Fig. 1). The intended measurement program consisted of nine components:

(i) continuous shipboard measurements of multiple oceanic and atmospheric variables,
(ii) CTD measurements performed during ship stations that included water samples for salinity calibration collected by the CTD rosette system,
(iii) lowered ADCP (attached to the CTD rosette) and vessel-mounted ADCP ocean current measurements,
(iv) XBT measurements to fill the gaps between CTD stations,
(v) CTD yoyo stations,
(vi) deployment and recovery of several Ocean Bottom Hydrophones (OBH) to record the seismic signals transmitted by RRS Discovery,
(vii) Vertical Seismic Profiler stations during which a vertical array of OBHs, suspended on the CTD wire from FS Poseidon, recorded the seismic signals from RRS Discovery,
(viii) microstructure profiler casts,
(ix) and two autonomous gliders to measure CTD data independently of the ship.

Continuously sampled variables included upper ocean velocity (20-600m) from a shipboard acoustic Doppler current profiler (ADCP), sea surface temperature and salinity from a thermosalinograph, water depth, and atmospheric parameters such as wind speed and direction, air temperature, air pressure, and humidity.

On stations, conductivity-temperature-depth (CTD) profiles were collected. The CTD system was mounted on a rosette frame with nominally12 bottles (only 10 bottles were attached to create space for the lowered ADCP system). Water samples were collected only on a limited number of stations. The water samples were later analyzed at IFM-GEOMAR for salinity.

Two 11 and 12 hour long Yoyo CTD stations were performed during which the CTD was repeatedly lowered and raised between 500 and 2000m (500 and 1700m for the 2nd Yoyo). During the first Yoyo station RRS Discovery deployed the multichannel streamer system (MCS) so that no contemporaneous seismic data exists, while during the second Yoyo station seismic data was collected on 5 parallel seismic sections in very close proximity to FS Poseidon.

During two 18 hour long experimental vertical profiler station FS Poseidon remained on station with 15 sound recording devices (modified Ocean Bottom Hydrophones, OBH) attached to the heavy-load wire. RRS Discovery continued seismic shooting in a star-shaped pattern around FS Poseidon. The intention is to examine whether this data can be used to create a three dimensional image of reflecting layers underneath FS Poseidon.

Three OBH systems were deployed and recovered from FS Poseidon at different locations to record the source signal of the seismic system on RRS Discovery. Later seven OBH systems were deployed and recovered along the south-western end of section A-B to investigate the use of OBH for seismic oceanography and to study sub-seafloor properties near the location of a recent earthquake.

Initially it was planned to do a larger number of microstructure profiler casts to estimate mixing parameters. After three casts at a single location and because of fairly rough conditions it was decided to skip this in favour of higher horizontal CTD resolution.

For the cruise the deployment of two autonomous glider systems was planned. Both gliders were to observe temperature and salinity in parallel to the two ships but with a much higher horizontal resolution of about one profile per 3 nautical miles. Both gliders malfunctioned due to problems with their acoustic pinger system and were not used during the cruise.

3 Narrative of cruise

FS Poseidon left Funchal, Madeira as scheduled at 9:00 on April 26, 2007 for the transit towards the experiment area in the Gulf of Cadiz. A test station was performed on April 27 at 17:00 UTC about halfway from Funchal to the experiment area at 34° 40.5'N 12° 34.5'W. The station included testing of the CTD rosette and lowered ADCP systems. Apart from the lowered ADCP system, the computer part of which had not yet been properly set up, everything worked fine. A test XBT was also deployed at the same location and showed a functional setup.

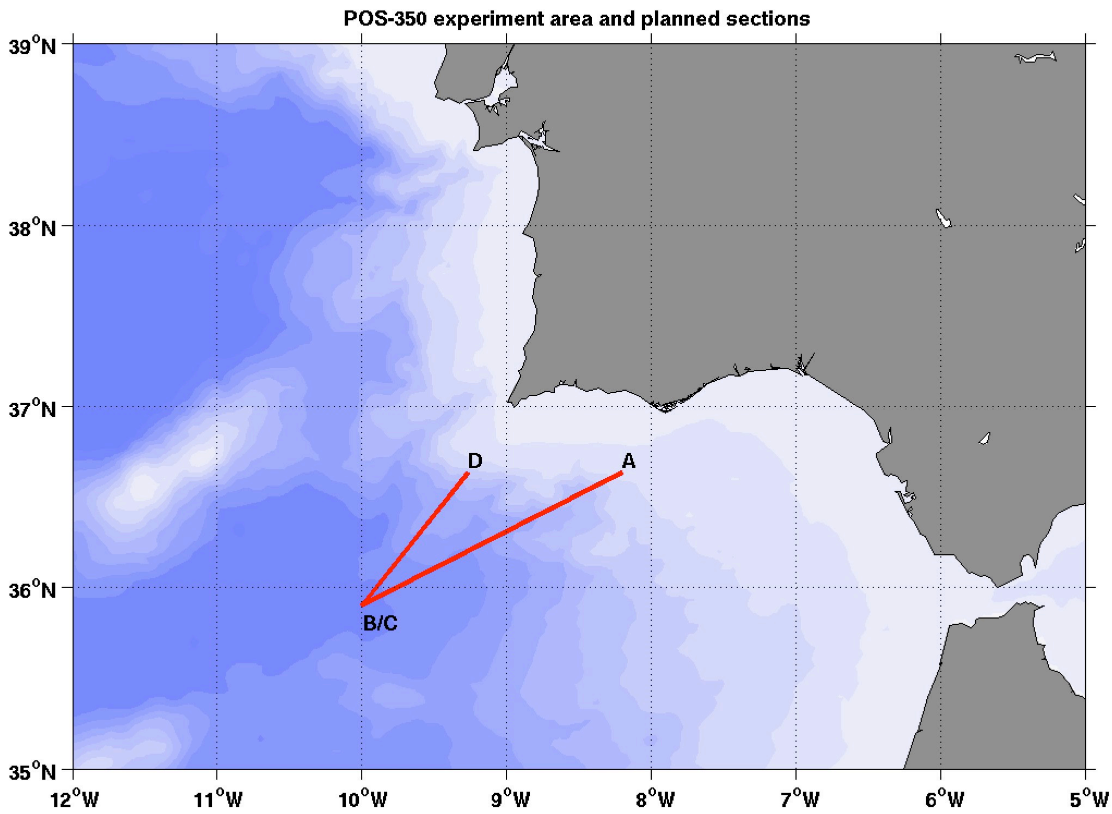


Figure 1: Experiment area and planned sections for P350.

After arrival in the experiment area on April 28, 2007 an autonomous glider was deployed at 35° 53.2'N 10° 1.0'W (near location B/C in Figure 1) with the help of a inflatable boat. Unfortunately we had to recover the glider a few hours later after it became clear that the steering mechanism did not work (see also below).

We continued with CTD and XBT station work in northeasterly direction along section B-A until on April 29, 2007 when we reached the location of two Ocean Bottom Hydrophones (OBH) previously deployed by RRS Discovery to record their seismic source signal. Both OBH were recovered without problems. Later that day we rendezvoused with RRS Discovery and established radio communication as well a as line-of-sight wireless data transmission connection which allowed us to transfer data files up to a distance of about 12 nautical miles.

Directly after the rendezvous we started the first of two Vertical Seismic Profiler (VSP) stations on which OBH systems were attached to a wire and lowered from the ship to create a vertical hydrophone array. RRS Discovery deployed the seismic sound sources and steamed for several hours in various patterns and distances around the stationary FS

Poseidon. At the end of the VSP station RRS deployed its Multi-Channel Streamer (MCS) system and on FS Poseidon we recovered the OBH systems. We then started an 11 hour long CTD yoyo station during which the CTD was repeatedly lowered to 2000 m depth and then raised to 500 m. During this time RRS Discovery steamed in patterns around the again stationary FS Poseidon and collected seismic data in close proximity to our CTD data. This operation ended on May 1, 2007 in the morning hours.

After the stationary work, FS Poseidon moved to a central position along A-B and deployed an OBH system again to record the seismic sound source of RRS Discovery. RRS Discovery meanwhile moved to a position near location B and started a seismic section towards location A. After RRS Discovery had passed FS Poseidon we took up the chase and started CTD and XBT work right behind RRS Discovery. The time needed to do a CTD cast down to 2000 m and the speeds of the two ships allowed for a station distance of about 10 nautical miles between CTDs and an additional XBT between the CTD stations.

Near location A the weather worsened on May 2, 2007 and it was decided to interrupt work with both ships and temporarily seek shelter near the Portuguese coast.

Work resumed May 3, 2007 in the morning hours and at location A a star shaped pattern of seismic measurements by RRS Discovery and CTD stations by FS Poseidon was accomplished. At this location RRS Discovery had previously deployed 3 current meter and thermistor chain moorings to measure the deep outflow of Mediterranean water that follows the shelf break at this location. Additionally FS Poseidon deployed two more OBH systems and we tried Micro-Structure Profiler (MSP) measurements while RRS Discovery was busy deploying the MCS. Because of the still rough sea state and because the available system can only sample the upper 400 m we decided to quit the MSP measurements for this cruise and concentrate our efforts on a denser CTD sampling.

On May 4, 2007 we recovered the two OBH systems and then followed RRS Discovery on section A-B continuing our CTD and XBT station work. Along the way we recovered the single OBH deployed a few days earlier.

On May 5, 2007 both ships extended the section A-B beyond location B and we deployed a set of seven OBH. The intention was to use the opportunity to do deep seismic measurements at the location of a recent seaquake and compare them to pre-quake observations. After the deployment RRS Discovery turned around and passed over all seven OBH which subsequently were recovered by FS Poseidon.

RRS Discovery on May 6, 2007 reached location B/C and turned onto section C-D. After encountering what appeared to be the signature of a Meddy (a subsurface eddy formed by Mediterranean outflow) it was decided to do another CTD yoyo station with surrounding seismic measurements. During the 12 hour long yoyo station RRS Discovery passed FS Poseidon 4 times at a distance of less than 2 nautical miles (see Figure4 for an example of the CTD data).

After finishing this station both ships resumed the regular seismic and CTD section along C-D and later turned westward. With the MCS system in tow both ships could not reach location D as it was located in the nautical traffic separation zone off Cape St. Vincent where extremely heavy ship traffic is found. The section in westerly direction was followed for some 20 nautical miles and on May 8, 2007 we turned southeast to pass again over the location of the yoyo station.

At this same location we started a second 12 hour long VSP station that lasted into the early hours of May 9, 2007. FS Poseidon then raised the equipment and after a short last meeting with RRS Discovery turned onto the home stretch towards Lisbon. FS Poseidon reached Lisbon on May 10, 2007.

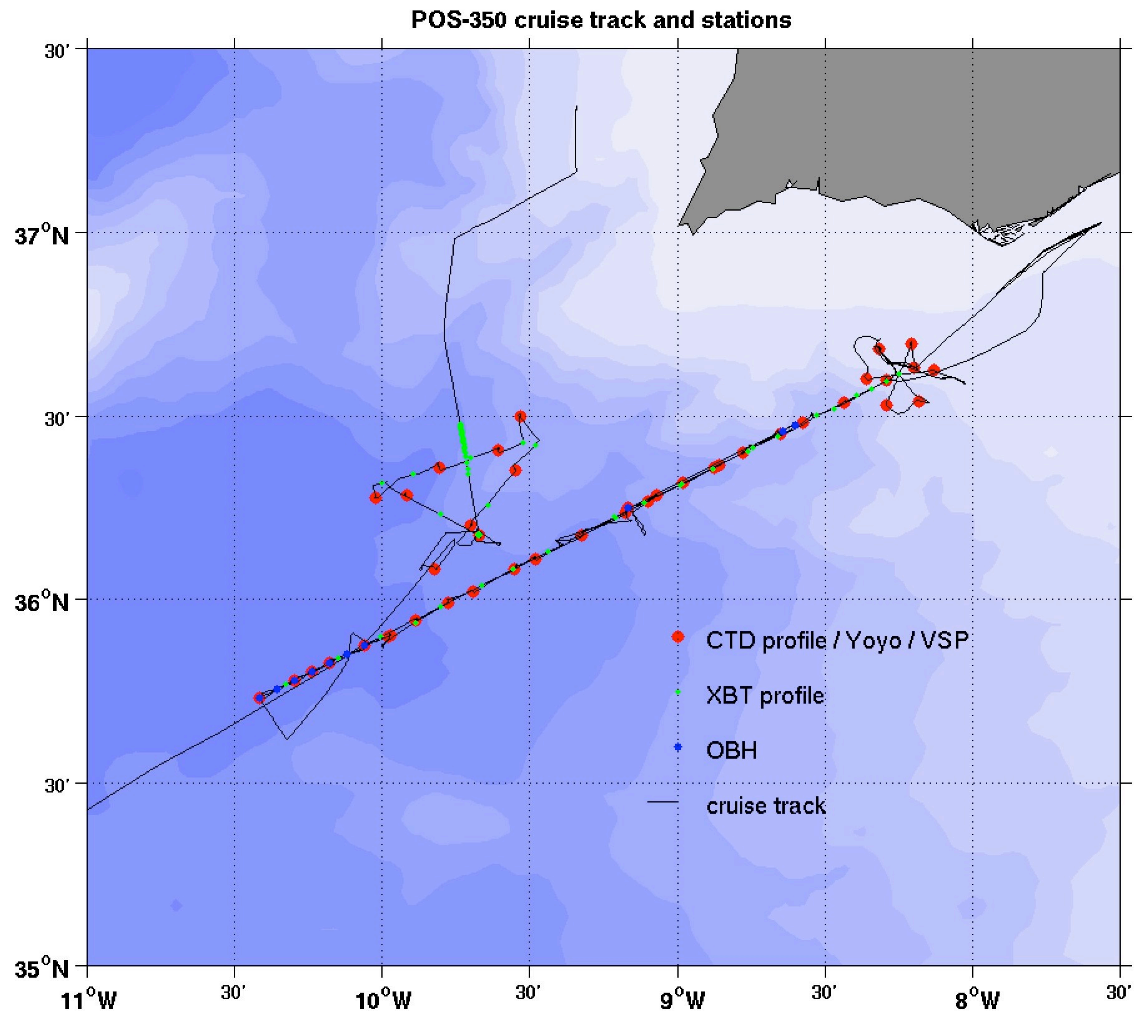


Figure 2: Cruise track of P350 in the experiment area and location of various stations.

4 Technical aspects and preliminary results

4.1 CTD measurements

The main measurement tool on this cruise was one of IFM-GEOMAR's CTD systems. The intention was to collect high quality CTD data for the comparison and evaluation of the seismic data collected on RRS Discovery and for developing insight into the mixing processes between Mediterranean and Atlantic water masses.

a) Technical aspects

A SeaBird SBE 9plus CTD (IFM-GEOMAR system SBE-3) was used together with a 12 10-liter bottle rosette. Ten bottles were installed. Two had been removed to make room for the lowered ADCP systems. Though the bottles were installed on all profiles only during one profile per day water samples for calibration of the conductivity sensor were taken. In all 45 water samples were collected and sent back to the institute for measurement with an Autosal salinometer.

During the cruise a total of 43 CTD profiles as well as two CTD yoyo stations were collected. CTD casts were taken down to 2000m or the bottom, whichever was shallower. The Seabird bottle release unit used with the rosette worked well throughout the cruise.

Different methodologies were used for the calibration of the CTD sensors. While the CTD temperature and pressure sensors were calibrated in the calibration laboratory of IFM-GEOMAR before the cruise, the conductivity sensors were calibrated using water samples collected during the cruise that were analyzed for salinity content. The salinity analysis was carried out using a Guildline Autosal salinometer at IFM-GEOMAR after the ship and the samples had returned to Germany directly after the cruise. The calibration back in Kiel has been chosen over an on-board calibration because of the need of a well air conditioned room and a very reliable power supply. Past experiences have shown that this is not readily available on FS Poseidon.

Altogether, 45 salinity values from the water samples were available. Conductivity sensor calibration was performed using a multi linear fit of temperature, conductivity, and pressure. For the fit, the third of the laboratory values deviating most from the CTD data were discarded as possibly unreliable (Fig. 3). Tests using quadratic fits in some or all of the dependencies did not improve the overall quality in a significant manner. The downcast was chosen as final dataset mainly because of the incoming flow not being perturbed by turbulence generated by the CTD-rosette. For the downcast conductivity, we got a root mean square (rms) difference between lab and CTD values of 0.00040 S/m corresponding to a rms salinity error of 0.0034 PSU (Fig. 3).

The CTD data were recorded and directly post-processed using Seabird Seasave V7.12 software. Calibration and further post-processing was done using the newly developed IFM-GEOMAR CTD processing package version 0.9.

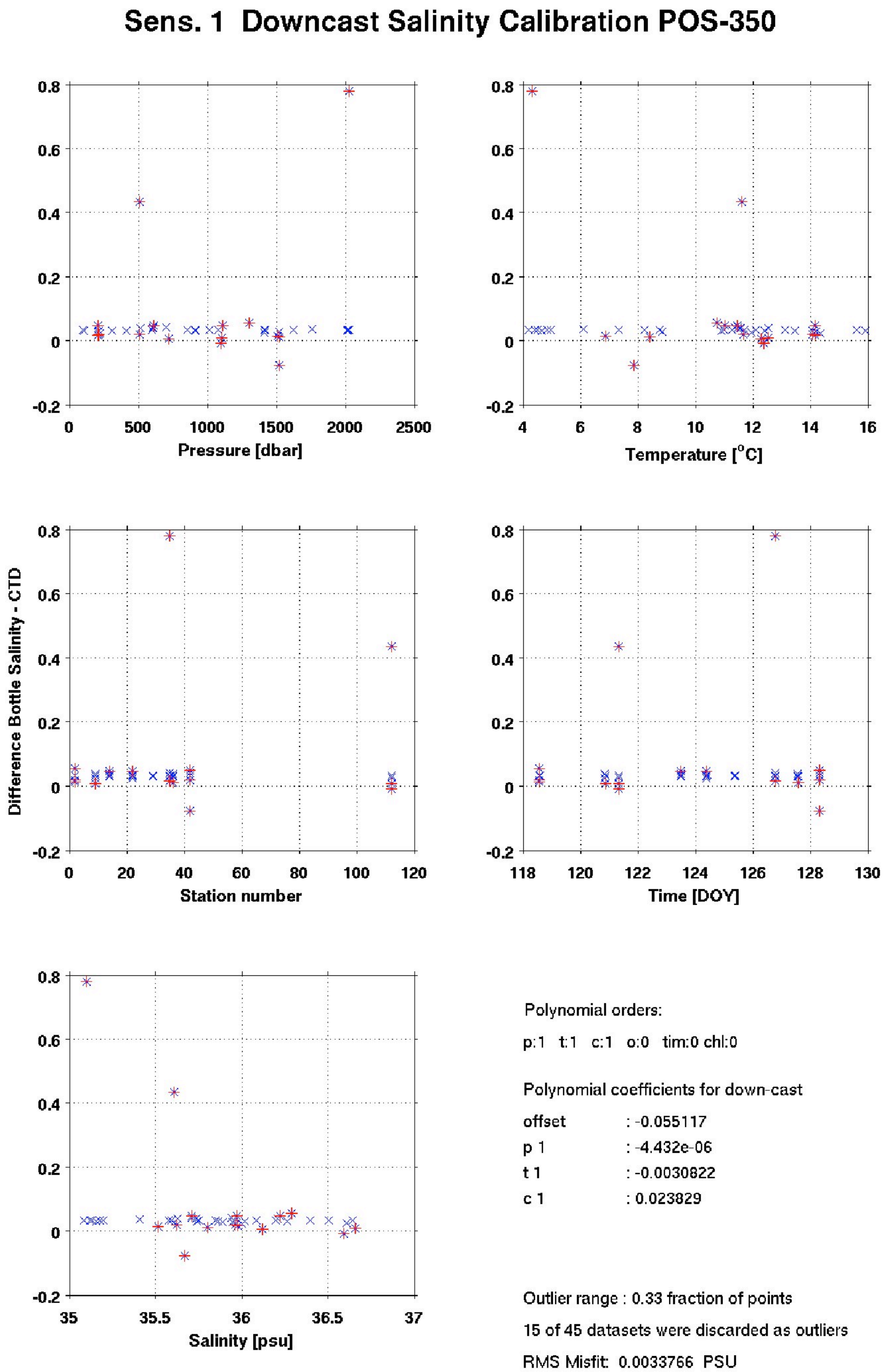


Figure 3: Salinity calibration results. Shown are the differences between laboratory measurements of salinity and the CTD measurements as function of various parameters.

b) Preliminary results

The CTD measurements as well as the XBTs thrown between CTDs showed the expected vertical and horizontal variability patterns. In the depth range from about 800 to 1400 m we found in all profiles waters that showed signs of Mediterranean origin (see Figure 4). Horizontally the strength of the Mediterranean signal varied to a very large degree. Mediterranean water was pronounced near the coastal Mediterranean Outflow Current that follows the shelf break and also in a feature that we believe to be a Meddy and that we purposely intersected several times. The second Yoyo station was chosen just at the outer edge of the Meddy. From previous observations we were able to estimate that the Meddy was moving largely in westerly direction and over the twelve hour long stationary Yoyo station we basically cut into the Meddy.

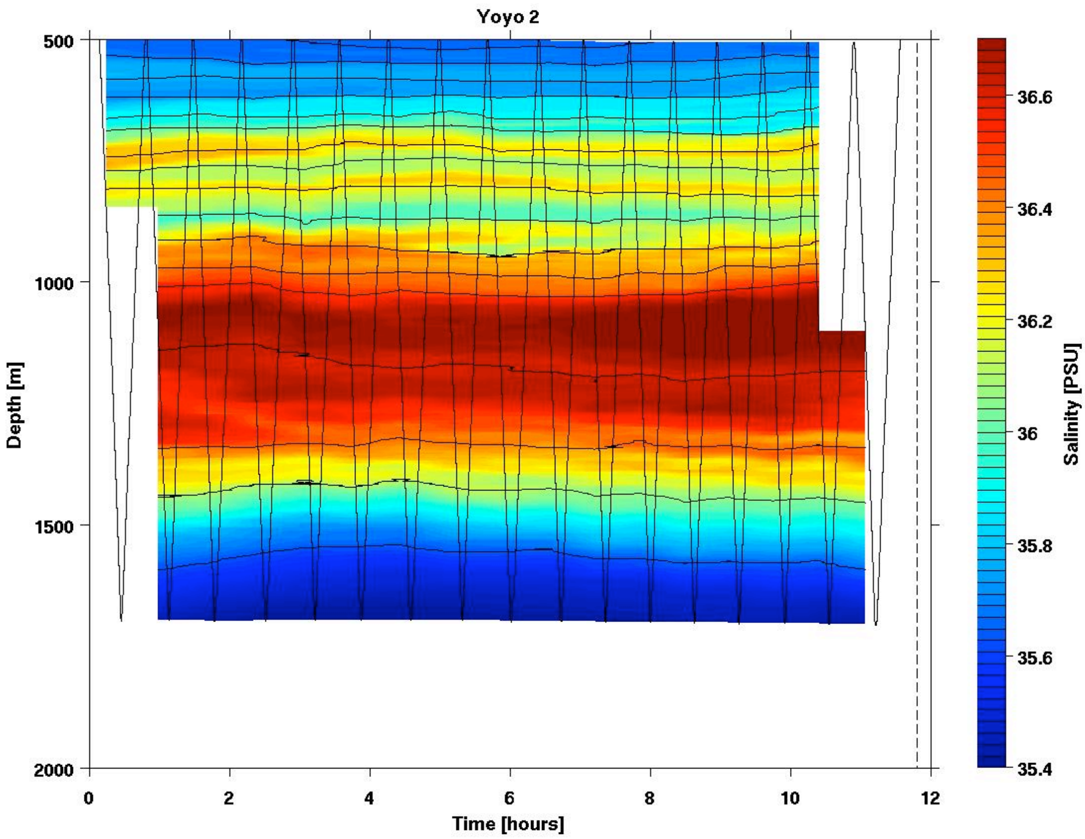


Figure 4: Salinity observed with the CTD during the second Yoyo station. Clearly visible is the salinity maximum of water with Mediterranean origin. A number of higher salinity layers are visible above. These layers are accompanied by temperature variations. Depth intervals with particularly high vertical gradients, such as between the layering, are reflective to the seismic sounds.

4.2 XBT measurements

a) Technical aspects

An XBT deck unit and recording computer was installed in the aft starboard lab of FS Poseidon. A long cable was laid to the starboard stern area from where the XBTs were deployed. This setup worked well in conditions with little winds from the starboard side. Under wind from starboard the XBT wire more often got into contact with the ship’s hull and caused spikes in the data. During future uses of XBTs one needs to ensure that the deployment can take place on either side of the ship depending on the wind conditions.

b) Preliminary results

Despite a number of XBT profiles having apparent problems, they have proven to be a worthwhile tool to complement the more accurate but much more labor-intensive CTD profiles. With their limited absolute accuracy in depth and temperature (see Figure 5) they are still sufficient to detect locations of high vertical temperature gradients that are the cause of the sound reflections seen in the seismic data.

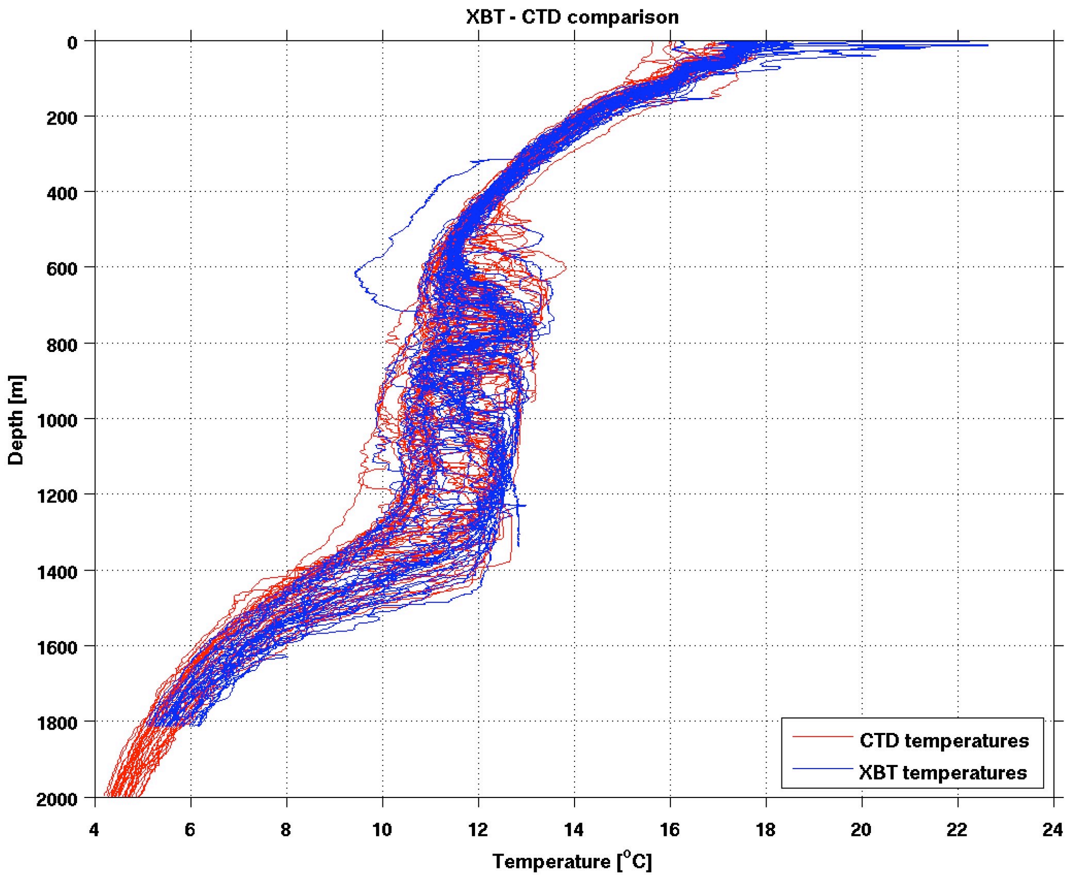


Figure 5: Comparison between XBT and CTD temperatures. In general the temperatures agree. A small but systematic difference appears at greater depth where possibly the depth model of the XBTs is not correct.

4.3 Vessel mounted ADCP measurements

During P350, continuous upper ocean velocity data were recorded by a vessel-mounted Ocean Surveyor that was installed in FS Poseidon's moon pool. The Ocean Surveyor (OS) is a newer generation shipboard acoustic Doppler current profiler (ADCP) which uses a phased array transducer consisting of 36 by 36 individual ceramic elements. In contrast to the older narrow band four transducer VMADCP, the OS produces sound pulses at all four beams during the same time and can be operated in either broadband or narrowband mode. R/V Poseidon is equipped with a 75kHz OS that allows to survey velocity in the upper 700 m of the water column. Unfortunately for the purposes of this cruise the range of the system was not sufficient to reach into the particularly interesting layers of Mediterranean outflow at about 1000 m depth.

a) Technical aspects

The system's configuration used during the cruise is briefly described as follows: The OS was controlled by RDI's vessel-mounted data acquisition system (VMDAS, version 1.3). Heading information from a gyrocompass was directly supplied to the electronic chassis via a synchro interface to convert the measured velocities from beam to earth coordinates, which were then recorded by the VMDAS as single ping data. In addition to the velocities, the VMDAS was supplied with real time heading from a 3-D Ashtech GPS receiver and GPS position via two serial interfaces. The VMDAS records these data in separate files ending on N1R and N2R. In post-processing, the erroneous heading from the gyrocompass needs to be corrected using the heading information from the Ashtech ADU2 system to ensure high data quality. The configuration of the 75kHz OS via the VMDAS was not altered during the cruise. We chose to record 100 bins at a sampling rate of about 2.4 s having a bin length of 8 m, a pulse length of 8 m and a blanking interval of 8 m. Considering that the Ocean Surveyor is mounted to the moon pool at 5 m water depth, the uppermost bin is located in a water depth of 21 m.The OS was set to record in narrow band mode, which is the preferable mode for open ocean current measurements.

Both the OS and the ADU2 worked well throughout the cruise and a continuous upper ocean velocity data set was obtained. During post-processing, the misalignment angle between the axis of the ADCP and the axis of the ADU2 needs to be determined. This is done by evaluating the rotation of measured velocities during acceleration periods of the vessel. The so called water track calibration resulted in a misalignment angle of 3.44° with a standard deviation $\sigma = 0.616°$ and an amplitude factor of 0.99036 ($\sigma = 0.017$). A temporal dependency to the calibration coefficients was not applied. As indicated by the small standard deviations of the misalignment angle (Fig. 4), ocean surveyor velocity data in combination with the heading data from the Ashtech is of high quality.

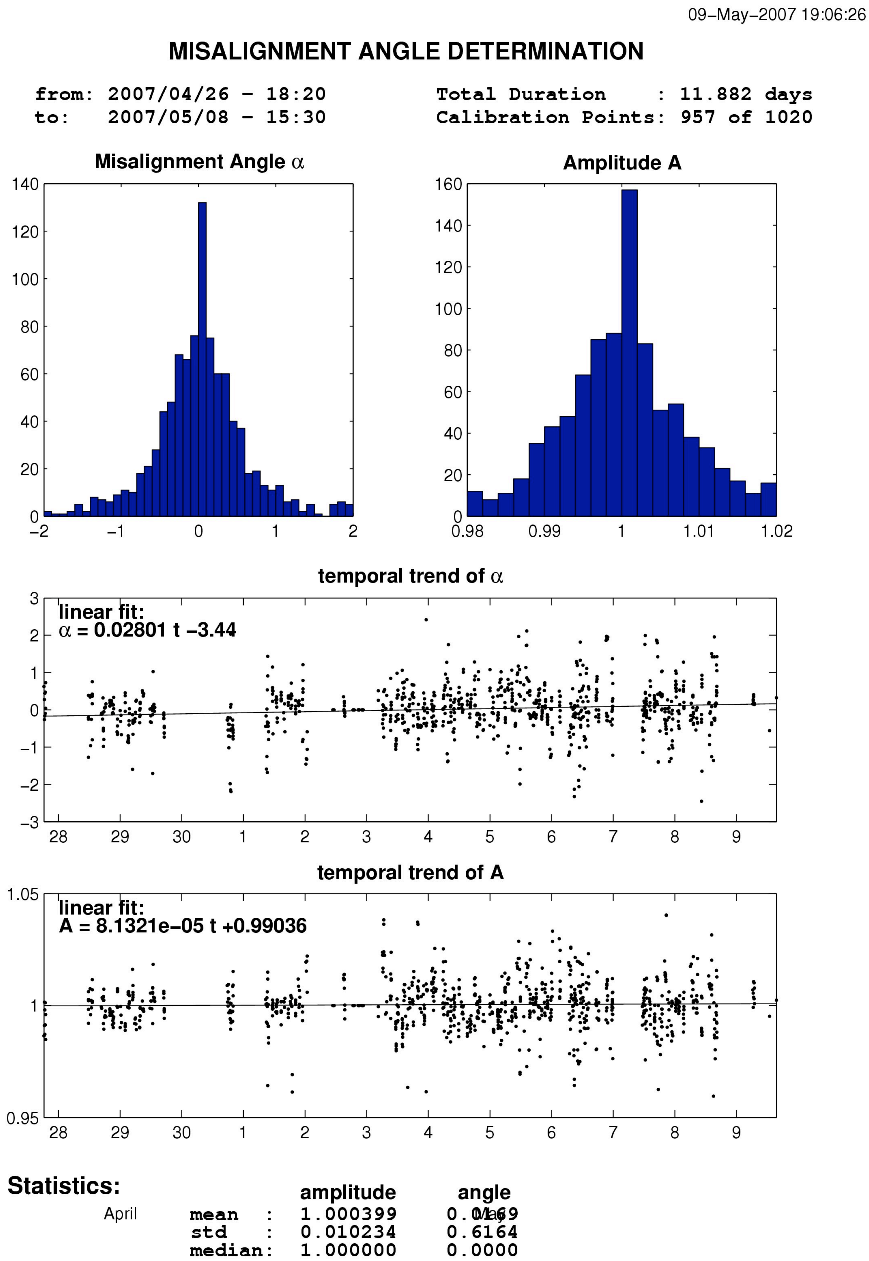


Figure 6: Water track calibration of misalignment angle and amplitude of the Ocean Surveyer velocity data after applying an angle α=3.44° and an amplitude factor of A=0.99036. Upper panels show the frequency distribution of calibration points, mid and lower panel show the temporal evolution of α and A.

b) Preliminary results

The current observations with the ship mounted ADCP are unfortunately of very little value to the experiment as the range of the instrument is not sufficient for observations of the Mediterranean outflow. We have looked into current signatures of a Meddy that was repeatedly intersected but were not able to detect any reliable signal. Such Meddies have sometimes current expressions up into the surface layers. Nevertheless the system functioned well during the cruise.

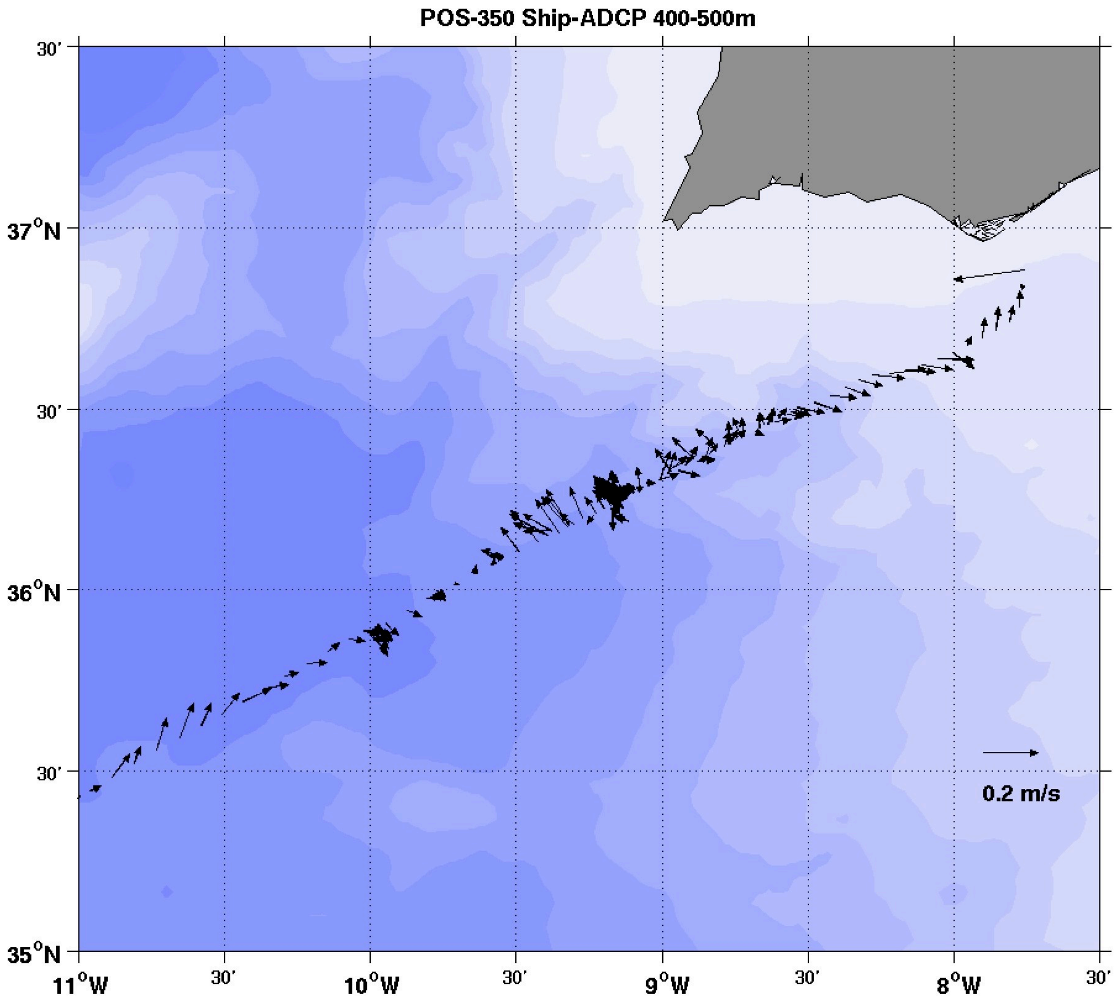


Figure 7: Ship-ADCP velocities at 400 to 500 m depth for the initial section B-A. Unfortunately the range of the instrument (max 800 m) for the particularly interesting Mediterranean outflow layer at about 1000 m depth.

4.4 Lowered ADCP measurements

Full CTD depth (generally 2000 m) ocean current profiles were collected with the help of two RDI workhorse ADCP systems attached to the rosette.

a) Technical aspects

During the cruise two RDI workhorse systems and a battery container were installed on the CTD rosette. One operated at a frequency of 300 kHz and the other at 1200 kHz. The low frequency system had a typical range of 50 to 150 m, which in most cases was just sufficient to obtain reliable current data. The 1200 kHz system had a range of only a few meters but a high vertical resolution of 0.5 m. Originally it was intended to add the data from the high frequency system into the complex lowered ADCP processing. The large amount of high vertical resolution data did, however, prevent this. We found that the processed profiles degraded in quality when the high frequency data was included. Likely causes are the higher susceptibility to the wake of the rosette which is directly visible by the 1200 kHz system and the higher uncertainties of its measurements.

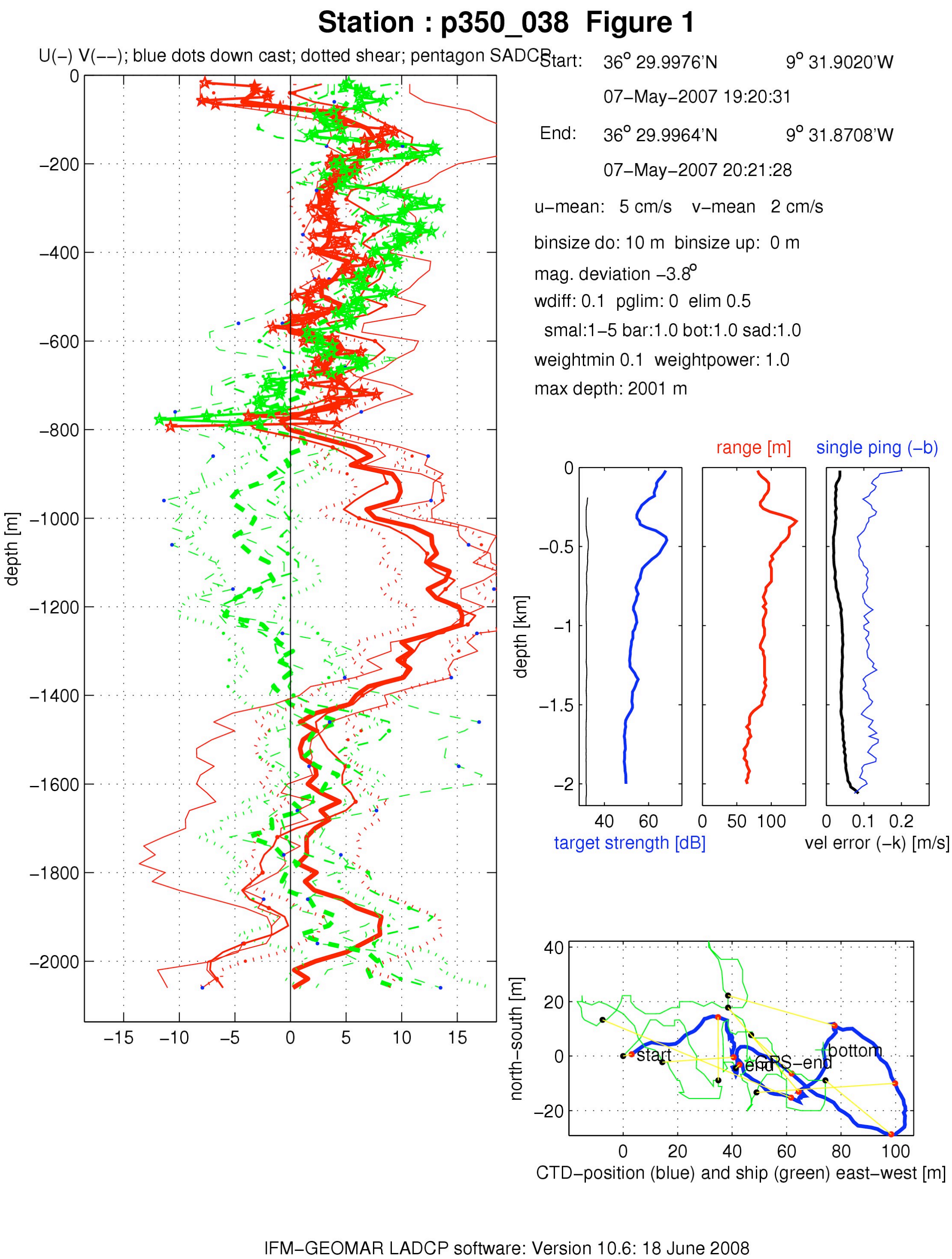


Figure 8: Example for the lowered ADCP profiles obtained during the cruise. This particular profile nicely shows the zonal currents (red) associated with the Meddy at the depth interval from 800 to 1400 m.

Without the additional data from the 1200 kHz system the lowered ADCP setup with a single 300 kHz workhorse operated at the limits of its capability. On all stations near the coast where more sound scatterers are typically encountered in the water column, the performance was good. On stations in the open ocean and especially under rougher sea state conditions the performance degraded so much that some LADCP profiles are not believed to be reliable, indicated by high error estimates in the processing.

After initially operating well, the system failed during CTD cast 5 when a leak developed in the battery container. By CTD cast 10 this failure had been repaired, and the system functioned well until the end of the cruise.

b) Preliminary results

With the help of the lowered ADCP data we were nicely able to map the deep boundary current. Further offshore we repeatedly encountered a Meddy and could observe the Meddy's rotation (see Figure 8 for an example current profile). Unfortunately the Meddy's actual shape and movement is not well constrained so that it is difficult to relate the currents to the Meddy's center.

4.5 OBH operations

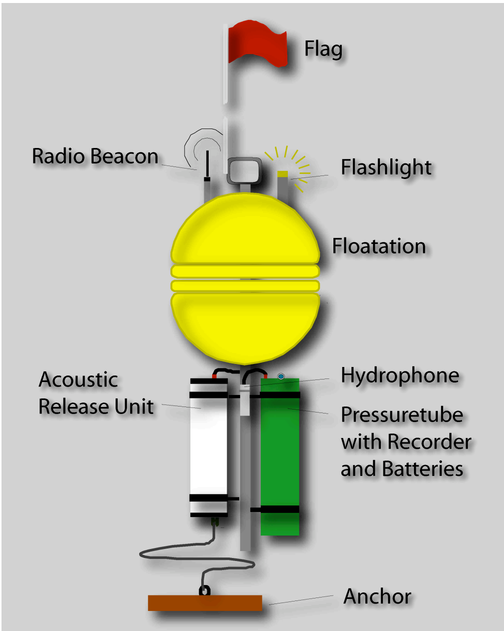
For detailed seismic processing it is essential to know the signature of the source wavelet, generated from the air-gun array towed behind the seismic vessel. Since the seismic vessel must be in motion during seismic operation, all necessary stationary work was performed from FS Poseidon.

Two OBHs (obh01 and obh02) were already deployed from RRS Discovery during D315 leg 1. These two OBHs were recording the seismic signature of leg 1 and then recovered from FS Poseidon. OBH03 was deployed from FS Poseidon to register the source signature of the seismic array towed behind RSS Discovery during D315b/P350. The OBH was therefore 'moored' 500 meters above the seafloor, to separate the direct arrival from the seafloor reflections.

Additionally, 2 OBHs were deployed, again 500 meters above the seafloor, in Area A, to record water-column reflections on tethered OBHs for testing and calibration. Along line GO-LR-07 a seismic refraction profile was acquired to investigate the impact of an inhomogeneous water-column on first arrivals (direct wave). 7 OBHs were deployed on the seafloor along this seismic line. All stations were deployed and recovered successfully.

a) Technical aspects

For the OBH all components are centered around a main tube with a handhold on its top to make it possible to retrieve the instrument from the water. On this handhold a 2 m long flagstick is mounted. The buoyant body is made of two hemispheres, 550 mm in diameter. Between the two hemispheres additional discs can be placed, each of them provides an additional 3.5 kg of flotation. The fixed upper hemisphere is used as the attachment for a flasher and a radio beacon. Underneath the buoyant body the acoustic release (iXSea or KUMQUAT) and the 0.8 m long pressure tube with the data logger and its batteries (up to 60 R20 or lithium cells) are mounted. The hydrophone is mounted



between the acoustic release and the pressure cylinder. The acoustic release has its own power supply and an additional time release programmable for safety reasons. On the bottom of the acoustic release there is a movable hook to which an anchor (a 40-50 kg piece of railway track) is attached to fix the whole system to the bottom. A 2 m long wire is used between the anchor and the release unit to prevent the system from contacting the seafloor. Via a transponder which hangs on a cable beneath the hull an acoustic signal is sent from the ship to release the anchor. The total weight of the system is about 125 kg without the anchor. The descent and ascent speeds are about 1 to 1.2 m/s.

b) Preliminary results

Firing an air gun releases a bubble of compressed air into the surrounding water. As the bubble rises, and its maximum pressure decreases, the oscillation period increases. The result is a signal whose "ringiness" has to be known for detailed seismic studies. Secondly, it generates a source ghost, which is an undesirable signal component due to reflections at the water surface and interferes with the primary pulse. Figure 9 shows the recordings of obh 03 with the direct wave interfered by the ghost signal and the bubble pulses. All phases are strongly angle dependant and are therefore recorded for all angles (0-70°).

This information is used in further processing steps to maintain “true” amplitudes.

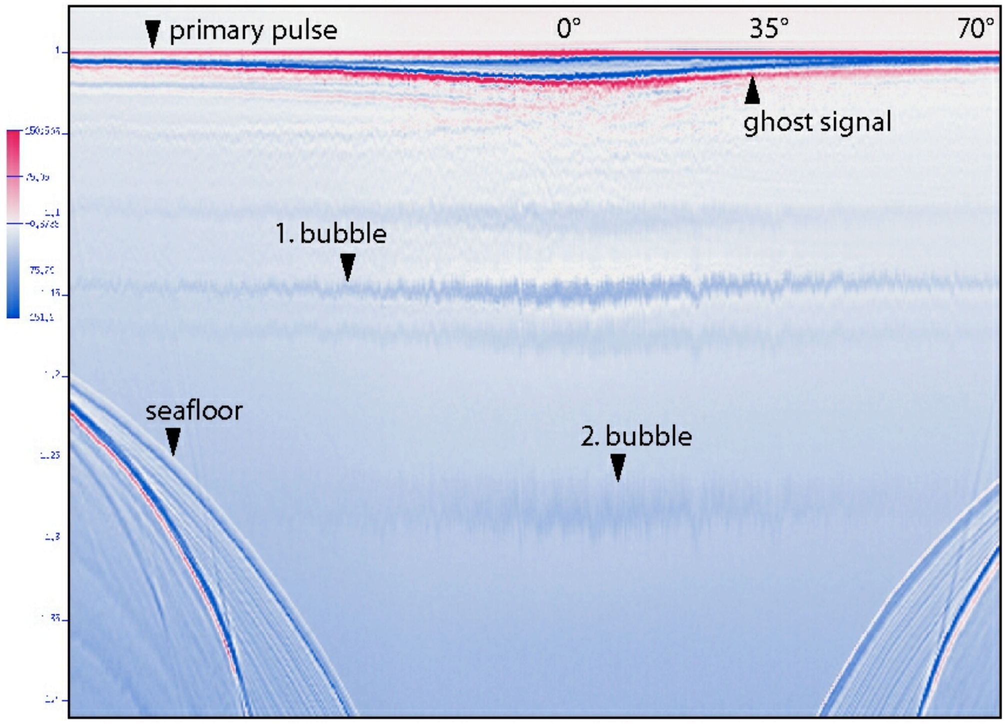


Figure 9: Seismic section of obh03, corrected for a constant direct arrival, recorded along line GO-LR-05 and showing the plain source signature of the used air-gun array. The interference of the primary pulse and the ghost signal is affecting the amplitudes of the source signal with changing angles. The bubble pulse is part of the signal and must be identified to separate its signal in all seismic experiments.

4.6 VSP operations

The concept of a vertical acquisition geometry in seismic oceanography was tested for the first time during this cruise. The concept is an analogue to conventional seismic VSP measurements. Where geophones are placed in a borehole in geologic settings, here in the water-column we used the FS Poseidon to lower Hydrophones on a cable to record the seismic signals (Fig. 10, right). While the seismic (source) vessel RRS Discovery was shooting a circular pattern, FS Poseidon maintained its position in the center. This geometry allows us to generate a 3-D image of water-column reflections.
Two VSP experiments were carried out during P350. On the first VSP 20 hydrophones were attached to the cable, lowered to a depth of 475m below the sea surface. A second experiment was carried out with only 10 hydrophones.

a) Technical aspects

Special frames were designed for this experiment to attach the standard OBH pressure tubes (for data loggers and batteries) and the hydrophones to the cable (Fig. 10, left). During the first VSP all hydrophones were attached directly to the frame. Due to the poor data quality, caused by strong vibrations of the cable, the layout was changed and during the second experiment the hydrophones were hanging freely decoupled from the ship's cable.
The equipment used for the VSP are all standard devices normally used in the OBH system. During VSP1 operation, 20 hydrophones were attached to the cable with 20 meters spacing and then lowered to 100 - 475 meters. 10 hydrophones, equally spaced at 30 meters were lowered to 150 – 420 meters during the second VSP.

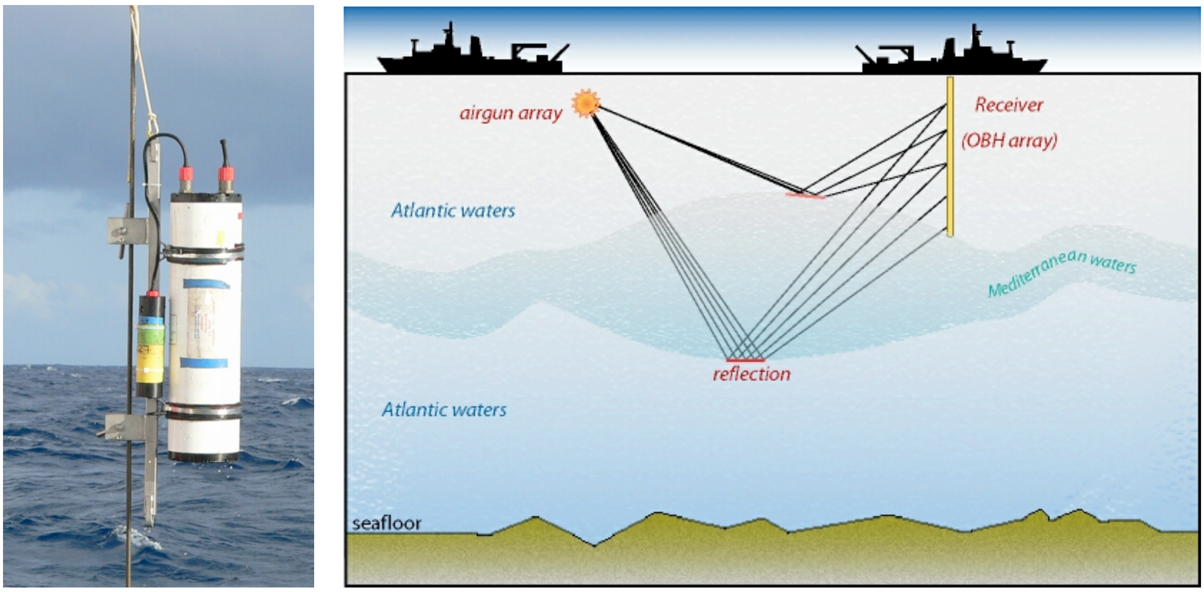


Figure 10: Left panel shows the frame attached to the cable before lowered to 200 meters below the sea surface. The frame was designed to 'clip' the OBH pressure tube and hydrophone to the cable. The right panel displays the geometry for the VSP experiment.

b) Preliminary results

The results of the first VSP experiment were disappointing due to the poor signal quality. The recordings were severely covered by strong noise, generated from vibrations of the cable.

The modified layout during the second experiment resulted in much better quality data. After pre-processing of the raw data (Fig. 11), reflections from within the water-column are clearly visible. Water reflections are of 3 magnitudes lower than the seafloor reflection and therefore prone to noise and hard to detect in ‘unstacked’ data. To have imaged these weak seismic signals is a first success of the VSP experiment.

To generate a 3-D image of this data, an exact knowledge of source and receiver position is necessary. This aspect was not given as the Poseidon was moving during acquisition and secondly the hydrophone string (cable) was not hanging vertically due to tidal currents. This misfit in positions destroys the seismic image and further processing steps will be needed to visualize the weak water-column reflections. Additionally, the dynamic nature of the water masses distort the seismic image, especially in a circular geometry.
These aspects must be analyzed in more detail to continue processing and interpreting the VSP data.

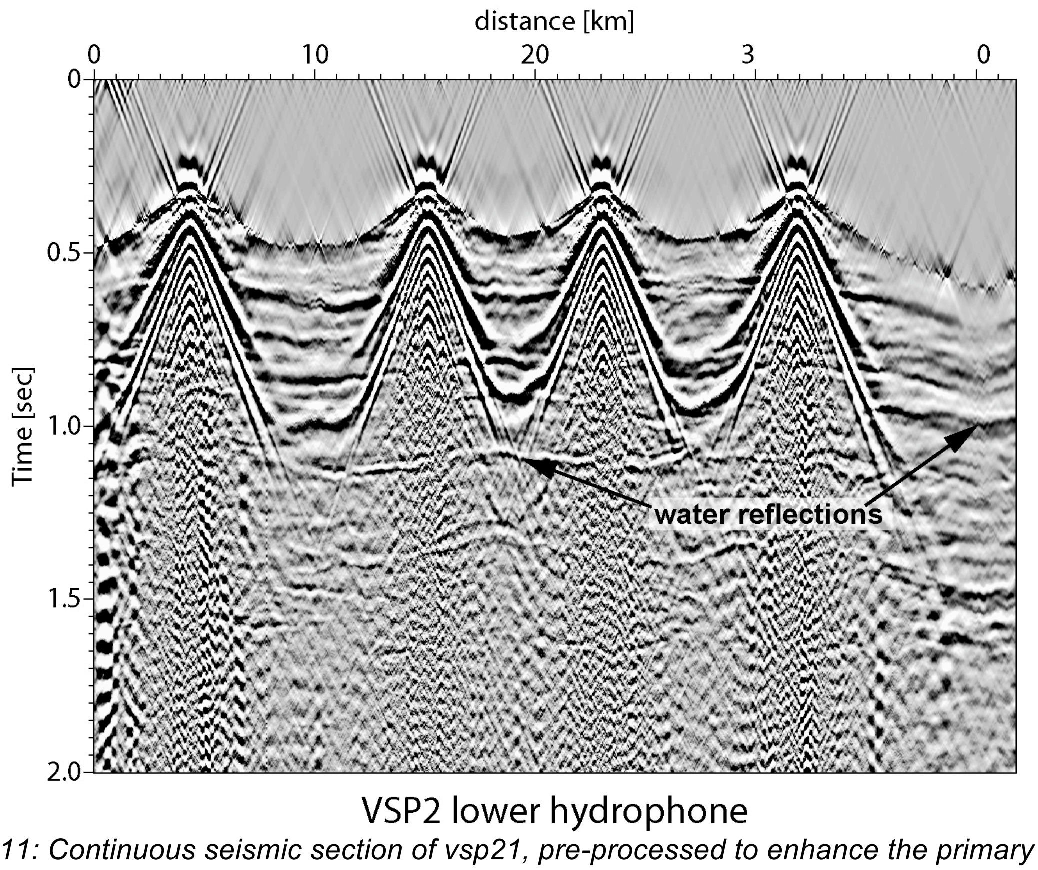


Figure 11: Continuous seismic section of vsp21, pre-processed to enhance the primary water reflections.

4.7 Autonomous Glider operations

Two autonomous gliders (systems ifm03 and ifm04) manufactured by Webb Research in Falmouth/USA were prepared in Kiel and Falmouth for deployment during the cruise.

a) Technical aspects

Before leaving the port of Funchal a ballasting test was performed in the harbor. One glider was lowered from a derrick into the water and performed a dive to 2 m depth. After reaching an overtime abort the glider resurfaced. During the lowering from the deck the steering mechanism of the glider might have been damaged when it touched the ship's hull. During a test deployment on April 28, 2007 the glider was not able to steer and 5 hours later was recovered.

Both gliders also suffered from a unpredictable errors when their main computers were not able to communicate with other parts of the system. The same problem had already occurred during P347 and had been reported to the manufacturer who was not able to solve this. During cruise P350 finally discovered the problem. A 10 kHz pinger system was installed in both gliders for easier tracking. When this system operated, the high voltage of the pinger could cause erroneous data on the serial communication lines between the different systems in the glider and thus render it inoperable. Unfortunately this was discovered only 3 days before the end of the cruise and it was decided not to deploy the second glider.

Appendix

Table A1: *CTD stations, water sampling, and current measurements during P350 (S - salinity, L – lowered ADCP). All CTD casts were collected with the IFM-GEOMAR SBE-3 CTD system.*

CTD Station	Poseidon Station	Date	Time	Latitude	Longitude	Profile Depth	Other
1	273	2007-04-27	19:00:44	34°40.57'N	12°34.51'W	2024	
2	274	2007-04-28	14:54:16	35°53.95'N	9°58.80'W	2022	L, S
3	275	2007-04-28	16:49:58	35°54.19'N	9°58.36'W	2022	L
4	276	2007-04-28	21:35:23	35°59.46'N	9°46.51'W	2024	L
5	278	2007-04-29	00:30:38	36°05.01'N	9°33.03'W	2024	
6	280	2007-04-29	03:38:02	36°10.39'N	9°19.49'W	2026	
7	282	2007-04-29	06:25:41	36°16.00'N	9°06.00'W	2029	
8	284	2007-04-29	09:14:41	36°21.46'N	8°52.54'W	2022	
9	290	2007-04-30	21:31:32	36°14.96'N	9°09.97'W	2020	S
10	291	2007-05-01	16:09:08	36°14.08'N	9°10.54'W	1974	L
11	292	2007-05-01	18:58:52	36°19.17'N	8°58.87'W	2010	L
12	294	2007-05-01	21:58:41	36°23.94'N	8°46.81'W	2026	L
13	296	2007-05-02	00:51:30	36°28.96'N	8°34.44'W	1956	L
14	304	2007-05-03	12:21:25	36°37.45'N	8°07.99'W	857	L, S
15	305	2007-05-03	14:54:05	36°36.02'N	8°21.64'W	1194	L
16	306	2007-05-03	18:22:42	36°41.05'N	8°19.03'W	686	L
17	309	2007-05-03	22:10:53	36°32.49'N	8°10.84'W	1078	L
18	309	2007-05-03	23:39:59	36°31.72'N	8°17.56'W	1479	L
19	311	2007-05-04	02:06:19	36°41.80'N	8°12.42'W	704	L
20	312	2007-05-04	03:59:10	36°37.99'N	8°11.98'W	803	L
21	317	2007-05-04	07:48:47	36°35.89'N	8°17.56'W	966	L
22	317	2007-05-04	10:12:05	36°32.26'N	8°26.17'W	1759	L, S
23	319	2007-05-04	13:37:15	36°26.98'N	8°39.11'W	2024	L
24	321	2007-05-04	16:45:03	36°21.92'N	8°51.58'W	2023	L
25	323	2007-05-04	19:28:11	36°16.95'N	9°04.26'W	2020	L
26	325	2007-05-05	01:30:13	36°06.61'N	9°28.93'W	2022	L
27	330	2007-05-05	04:35:55	36°01.21'N	9°41.52'W	2023	L
28	332	2007-05-05	07:19:37	35°56.65'N	9°53.28'W	2018	L
29	334	2007-05-05	10:04:39	35°52.59'N	10°03.61'W	2023	L, S
30	338	2007-05-05	13:23:24	35°48.21'N	10°14.29'W	2025	L
31	343	2007-05-05	17:13:20	35°43.93'N	10°25.00'W	2019	L
32	343	2007-05-05	19:29:38	35°46.78'N	10°17.86'W	2022	L
33	344	2007-05-05	21:43:44	35°49.66'N	10°10.72'W	2024	L
34	345	2007-05-05	23:53:40	35°52.50'N	10°03.58'W	2010	L
35	346	2007-05-06	19:44:27	36°04.99'N	9°49.29'W	2032	L, S
36	356	2007-05-07	14:27:52	36°12.10'N	9°41.92'W	2018	L, S
37	358	2007-05-07	17:36:00	36°21.16'N	9°32.92'W	2021	L
38	360	2007-05-07	20:22:32	36°30.00'N	9°31.90'W	2024	L

39	*362*	*2007-05-07*	*23:08:47*	*36°24.39'N*	*9°36.41'W*	*2024*	*L*
40	*364*	*2007-05-08*	*01:51:04*	*36°21.49'N*	*9°48.46'W*	*2023*	*L*
41	*366*	*2007-05-08*	*04:54:09*	*36°16.66'N*	*10°01.39'W*	*2024*	*L*
42	*368*	*2007-05-08*	*08:45:04*	*36°16.96'N*	*9°55.05'W*	*2022*	*L, S*
43	*370*	*2007-05-08*	*11:45:49*	*36°10.57'N*	*9°40.36'W*	*2016*	*L*
Yoyo 1	*290*	*2007-04-30*	*23:13:38*	*36°15.00'N*	*9°09.98'W*	*2019*	*L, S*
Yoyo 2	*346*	*2007-05-07*	*00:59:05*	*36°10.47'N*	*9°40.35'W*	*1718*	*L*

***Table A2:** XBT stations during P350 (T-10 probes to max 200 m, T-5 probes to max 1760 m). Missing XBT station numbers (first column) denote failed XBT sondes, typically a second probe was deployed shortly after but with a new XBT station number.*

XBT Station	*Poseidon Station*	*Date*	*Time*	*Latitude*	*Longitude*	*Type*
3	*273-2*	*2007-04-27*	*19:12*	*34°40.16'N*	*12°33.12'W*	*T-10*
4	*276*	*2007-04-28*	*19:23*	*35°56.28'N*	*9°56.29'W*	*T-5*
5	*278*	*2007-04-28*	*22:22*	*36°2.29'N*	*9°39.61'W*	*T-5*
6	*279*	*2007-04-29*	*1:24*	*36°7.78'N*	*9°19.48'W*	*T-5*
7	*281*	*2007-04-29*	*4:23*	*36°13.32'N*	*9°12.70'W*	*T-5*
9	*283*	*2007-04-29*	*7:09*	*36°18.74'N*	*8°59.23'W*	*T-5*
10	*285*	*2007-04-29*	*10:02*	*36°24.25'N*	*8°45.73'W*	*T-5*
11		*2007-04-30*	*0:08*	*36°15.02'N*	*9°10.01'W*	*T-5*
12		*2007-04-30*	*1:59*	*36°15.04'N*	*9°9.94'W*	*T-5*
14	*290-3*	*2007-04-30*	*4:00*	*36°15.07'N*	*9°9.91'W*	*VSP station 1, T-5*
15	*290-4*	*2007-04-30*	*6:00*	*36°14.97'N*	*9°10.04'W*	*VSP station 1, T-5*
16	*290-5*	*2007-04-30*	*8:02*	*36°14.99'N*	*9°10.00'W*	*VSP station 1, T-5*
17	*290-6*	*2007-04-30*	*10:00*	*36°14.99'N*	*9°10.00'W*	*VSP station 1, T-5*
18	*290-7*	*2007-04-30*	*12:02*	*36°14.99'N*	*9°10.00'W*	*VSP station 1, T-5*
19	*290-8*	*2007-04-30*	*14:01*	*36°15.00'N*	*9°9.97'W*	*VSP station 1, T-5*
21	*290-9*	*2007-04-30*	*15:58*	*36°15.06'N*	*9°9.96'W*	*VSP station 1, T-5*
23		*2007-04-30*	*17:01*	*36°16.71'N*	*9°4.32'W*	*T-5*
24	*293*	*2007-04-30*	*19:45*	*36°21.31'N*	*8°53.61'W*	*T-5*
25	*295*	*2007-04-30*	*22:41*	*36°26.77'N*	*8°39.43'W*	*T-5*
26	*297*	*2007-05-01*	*1:36*	*36°31.29'N*	*8°28.05'W*	*T-5*
27	*299*	*2007-05-01*	*2:51*	*36°34.48'N*	*8°34.33'W*	*T-5*
29		*2007-05-01*	*3:21*	*36°35.61'N*	*8°17.48'W*	*T-5*
30	*305*	*2007-05-03*	*13:17*	*36°36.79'N*	*8°15.01'W*	*T-5*
32	*308*	*2007-05-03*	*19:05*	*36°36.76'N*	*8°14.95'W*	*T-5*
33	*310*	*2007-05-04*	*0:34*	*36°36.81'N*	*8°15.01'W*	*T-5*
34		*2007-05-04*	*8:40*	*36°33.31'N*	*8°23.58'W*	*T-5*
35	*318*	*2007-05-04*	*11:15*	*36°31.10'N*	*8°31.65'W*	*T-5*
36	*320*	*2007-05-04*	*14:25*	*36°24.93'N*	*8°44.62'W*	*T-5*
38	*322*	*2007-05-04*	*17:38*	*36°18.83'N*	*8°59.12'W*	*T-5*
39	*325*	*2007-05-04*	*22:20*	*36°13.50'N*	*9°12.68'W*	*T-5*
40	*329*	*2007-05-05*	*2:15*	*36°4.88'N*	*9°33.43'W*	*T-5*
42	*331*	*2007-05-05*	*5:29*	*35°58.84'N*	*9°48.17'W*	*T-5*

44	333	2007-05-05	8:15	35°54.04'N	9°59.88'W	T-5
45	336	2007-05-05	11:08	35°50.42'N	10°8.92'W	T-5
46	340	2007-05-05	14:42	35°46.00'N	10°19.00'W	T-5
48	357	2007-05-07	15:16	36°15.00'N	9°38.00'W	T-5
50	359	2007-05-07	18:17	36°24.90'N	9°29.20'W	T-5
51	361	2007-05-07	21:20	36°25.60'N	9°31.40'W	T-5
52	363	2007-05-07	23:55	36°23.50'N	9°40.50'W	T-5
53	365	2007-05-08	2:40	36°20.60'N	9°53.00'W	T-5
55	367	2007-05-08	6:28	36°18.90'N	10°0.20'W	T-5
56	369	2007-05-08	9:40	36°14.90'N	9°50.94'W	T-5
58 to 84	371	2007-05-08 to 2007-05-09	18:28 to 5:57	36°10.57'N	9°40.37'W	VSP station 2, T-5
85 to 111	372	2007-05-09	8:14 to 9:15	Along transit	to Lisbon	Old expired T-10 XBTs

Table A3: *OBH deployments during P350.*
**) obh01 and obh02 were deployed from RRS Discovery during leg D315a and recovered by FS Poseidon. Hydrophones deployed during the first VSP experiment: vsp01-vsp20; during second VSP: vsp21-vsp30. 7 obhs (eq01-eq07)were deployed along track GO-LR-07.*

OBH Station	Deployment		Recovery		Latitude	Longitude	Depth
	Date	Time	Date	Time			
*obh 01	-	-	2007-04-29	12:50	36°28.79'N	008°36.06'W	2480 m
*obh 02	-	-	2007-04-29	11:17	36°27.86'N	008°38.26'W	2028 m
obh 03	2007-05-07	09:25	2007-05-04	20:15	36°14.99'N	009°10.01'W	3489 m
obh A1	2007-05-03	07:25	2007-05-04	05:55	36°39.48'N	008°17.58'W	757 m
obh A2	2007-05-03	07:50	2007-05-04	05:20	36°38.71'N	008°16.80'W	796 m
vsp 01	2007-04-29	18:00	2007-04-30	20:24	36°15.30'N	009°10.20'W	575 m
vsp 02	2007-04-29	18:08	2007-04-30	20:17	36°15.30'N	009°10.20'W	550 m
vsp 03	2007-04-29	18:16	2007-04-30	20:10	36°15.30'N	009°10.20'W	525 m
vsp 04	2007-04-29	18:23	2007-04-30	20:03	36°15.30'N	009°10.20'W	500 m
vsp 05	2007-04-29	18:31	2007-04-30	19:55	36°15.30'N	009°10.20'W	475 m
vsp 06	2007-04-29	18:40	2007-04-30	19:49	36°15.30'N	009°10.20'W	450 m
vsp 07	2007-04-29	18:50	2007-04-30	19:41	36°15.30'N	009°10.20'W	425 m
vsp 08	2007-04-29	18:58	2007-04-30	19:34	36°15.30'N	009°10.20'W	400 m
vsp 09	2007-04-29	19:07	2007-04-30	19:27	36°15.30'N	009°10.20'W	375 m
vsp 10	2007-04-29	19:16	2007-04-30	19:20	36°15.30'N	009°10.20'W	350 m
vsp 11	2007-04-29	19:25	2007-04-30	19:11	36°15.30'N	009°10.20'W	325 m
vsp 12	2007-04-29	19:33	2007-04-30	19:01	36°15.30'N	009°10.20'W	300 m
vsp 13	2007-04-29	19:41	2007-04-30	18:53	36°15.30'N	009°10.20'W	275 m
vsp 14	2007-04-29	19:49	2007-04-30	18:45	36°15.30'N	009°10.20'W	250 m
vsp 15	2007-04-29	19:56	2007-04-30	18:37	36°15.30'N	009°10.20'W	225 m
vsp 16	2007-04-29	20:07	2007-04-30	18:29	36°15.30'N	009°10.20'W	200 m
vsp 17	2007-04-29	20:15	2007-04-30	18:21	36°15.30'N	009°10.20'W	175 m
vsp 18	2007-04-29	20:23	2007-04-30	18:12	36°15.30'N	009°10.20'W	150 m
vsp 19	2007-04-29	20:33	2007-04-30	18:03	36°15.30'N	009°10.20'W	125 m
vsp 20	2007-04-29	20:42	2007-04-30	17:56	36°15.30'N	009°10.20'W	100 m

vsp 21	*2007-05-08*	*18:00*	*2007-05-09*	*07:06*	*36°10.58'N*	*009°40.39'W*	*420 m*
vsp 22	*2007-05-08*	*18:09*	*2007-05-09*	*06:58*	*36°10.58'N*	*009°40.39'W*	*390 m*
vsp 23	*2007-05-08*	*18:16*	*2007-05-09*	*06:51*	*36°10.58'N*	*009°40.39'W*	*360 m*
vsp 24	*2007-05-08*	*18:23*	*2007-05-09*	*06:44*	*36°10.58'N*	*009°40.39'W*	*330 m*
vsp 25	*2007-05-08*	*18:30*	*2007-05-09*	*06:37*	*36°10.58'N*	*009°40.39'W*	*300 m*
vsp 26	*2007-05-08*	*18:38*	*2007-05-09*	*06:31*	*36°10.58'N*	*009°40.39'W*	*270 m*
vsp 27	*2007-05-08*	*18:43*	*2007-05-09*	*06:24*	*36°10.58'N*	*009°40.39'W*	*240 m*
vsp 28	*2007-05-08*	*18:51*	*2007-05-09*	*06:18*	*36°10.58'N*	*009°40.39'W*	*210 m*
vsp 29	*2007-05-08*	*18:58*	*2007-05-09*	*06:11*	*36°10.58'N*	*009°40.39'W*	*180 m*
vsp 30	*2007-05-08*	*19:10*	*2007-05-09*	*06:04*	*36°10.58'N*	*009°40.39'W*	*150 m*
eq01	*2007-05-05*	*10:08*	*2007-05-06*	*13:05*	*35°52.56'N*	*010°03.58'W*	*4584 m*
eq02	*2007-05-05*	*10:50*	*2007-05-06*	*12:02*	*35°51.12'N*	*010°07.16'W*	*4617 m*
eq03	*2007-05-05*	*11:30*	*2007-05-06*	*10:50*	*35°49.69'N*	*010°10.76'W*	*4628 m*
eq04	*2007-05-05*	*13:43*	*2007-05-06*	*09:50*	*35°48.25'N*	*010°14.32'W*	*4617 m*
eq05	*2007-05-05*	*14:22*	*2007-05-06*	*08:32*	*35°46.82'N*	*010°17.88'W*	*4549 m*
eq06	*2007-05-05*	*15:09*	*2007-05-06*	*07:16*	*35°45.34'N*	*010°21.43'W*	*4519 m*
eq07	*2007-05-05*	*15:52*	*2007-05-06*	*05:23*	*35°43.95'N*	*010°25.01'W*	*4675 m*

IFM-GEOMAR Reports

No.	Title
1	RV Sonne Fahrtbericht / Cruise Report SO 176 & 179 MERAMEX I & II (Merapi Amphibious Experiment) 18.05.-01.06.04 & 16.09.-07.10.04. Ed. by Heidrun Kopp & Ernst R. Flueh, 2004, 206 pp. In English
2	RV Sonne Fahrtbericht / Cruise Report SO 181 TIPTEQ (from The Incoming Plate to mega Thrust EarthQuakes) 06.12.2004.-26.02.2005. Ed. by Ernst R. Flueh & Ingo Grevemeyer, 2005, 533 pp. In English
3	RV Poseidon Fahrtbericht / Cruise Report POS 316 Carbonate Mounds and Aphotic Corals in the NE-Atlantic 03.08.–17.08.2004. Ed. by Olaf Pfannkuche & Christine Utecht, 2005, 64 pp. In English
4	RV Sonne Fahrtbericht / Cruise Report SO 177 - (Sino-German Cooperative Project, South China Sea: Distribution, Formation and Effect of Methane & Gas Hydrate on the Environment) 02.06.-20.07.2004. Ed. by Erwin Suess, Yongyang Huang, Nengyou Wu, Xiqiu Han & Xin Su, 2005, 154 pp. In English and Chinese
5	RV Sonne Fahrtbericht / Cruise Report SO 186 – GITEWS (German Indonesian Tsunami Early Warning System 28.10.-13.1.2005 & 15.11.-28.11.2005 & 07.01.-20.01.2006. Ed. by Ernst R. Flueh, Tilo Schoene & Wilhelm Weinrebe, 2006, 169 pp. In English
6	RV Sonne Fahrtbericht / Cruise Report SO 186 -3 – SeaCause II, 26.02.-16.03.2006. Ed. by Heidrun Kopp & Ernst R. Flueh, 2006, 174 pp. In English
7	RV Meteor, Fahrtbericht / Cruise Report M67/1 CHILE-MARGIN-SURVEY 20.02.-13.03.2006. Ed. by Wilhelm Weinrebe und Silke Schenk, 2006, 112 pp. In English
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