Southampton
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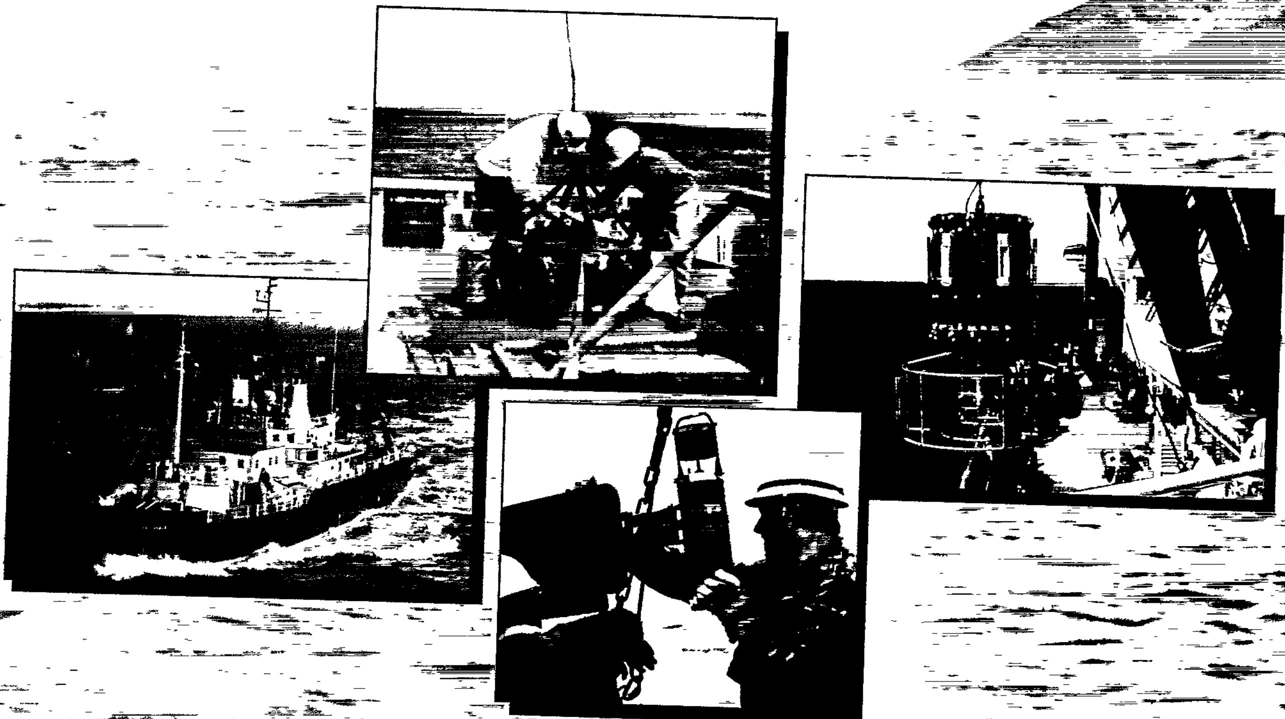
# Cruise Report



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# SOUTHAMPTON OCEANOGRAPHY CENTRE

## CRUISE REPORT No. 14

## RRS *DISCOVERY* CRUISE 224, LEG 1
## 27 NOV - 29 DEC 1996

OMEGA: Observations and Modelling of Eddy scale Geostrophic and Ageostrophic motion

Physical and biological observations in the eastern Alboran Sea (western Mediterranean)

*Principal Scientists*

**J T Allen[1] & T H Guymer[2]**

**1997**

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*ABSTRACT*

The first leg of RRS *Discovery* Cruise 224, 27/11/96 - 29/12/96, was one of two cruise programs designed to provide the experimental field observations for the EU MAST 3 project, OMEGA (Observations and Modelling of Eddy scale Geostrophic and Ageostrophic motion). Towing the undulating CTD vehicle, SeaSoar, two large scale and three fine scale SeaSoar surveys were made of the Almeria-Oran front region of the western Mediterranean. In addition a brief SeaSoar survey was made of the head of the Algerian Current. These hydrographic measurements of the upper 370 metres of the water column were accompanied by VM-ADCP and ACCP derived ocean currents, underway physical, chemical and biological analysis of surface water samples, multi-frequency acoustic backscatter measurements, meteorological observations and sea surface radiation measurements. Between the surveys, CTD stations were accompanied by detailed measurements of ocean optical properties at strategic locations along and across the front. In addition 8 towed deployments of a Longhurst Hardy Plankton Recorder were made to look at the change in plankton species composition across frontal zones.

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ACCP, ACOUSTIC CORRELATION CURRENT PROFILER, ACOUSTIC DOPPLER CURRENT PROFILER, ACRONYM, ADCP, ALBORAN SEA, ALGERIAN CURRENT, ALMERIA-ORAN FRONT, BIOLOGICAL OBSERVATIONS, CRUISE 224 LEG 1 1996, CTD OBSERVATIONS, *DISCOVERY*, GEOSTROPHIC FLOW, HYDROGRAPHIC DATA, LONGHURST HARDY PLANKTON RECORDER, OCEAN FRONT BIOLOGY, OMEGA, PHYSICAL OBSERVATIONS, SEASOAR, SURFACE BRIGHTNESS, TEMPERATURE, VM-ADCP, WESTERN MEDITERRANEAN

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# RRS *Discovery* Cruise 224 (leg 1) 27th Nov. 1996 - 29th Dec. 1996. OMEGA (Observations and Modelling of Eddy scale Geostrophic and Ageostrophic motion) Physical and Biological Observations in the Eastern Alboran Sea (Western Mediterranean).

J. T. Allen and T. H. Guymer

## ABSTRACT

The first leg of RRS *Discovery* cruise 224, 27/11/96 - 29/12/96, was one of two cruise programs designed to provide the experimental field observations for the EU MAST 3 project, OMEGA, Observations and Modelling of Eddy scale Geostrophic and Ageostrophic motions. Towing the undulating CTD vehicle, SeaSoar, two large scale and three fine scale SeaSoar surveys were made of the Almeria-Oran front region of the western Mediterranean. In addition a brief SeaSoar survey was made of the head of the Algerian Current. These hydrographic measurements of the upper 370 metres of the water column were accompanied by VM-ADCP and ACCP derived ocean currents, underway physical, chemical and biological analysis of surface water samples, multi-frequency acoustic backscatter measurements, meteorological observations and sea surface radiation measurements. Between the surveys, CTD stations were accompanied by detailed measurements of ocean optical properties at strategic locations along and across the front. In addition 8 towed deployments of a Longhurst Hardy Plankton Recorder were made to look at the change in plankton species composition across frontal zones.

## 1. INTRODUCTION & OBJECTIVES

OMEGA is an interdisciplinary collaborative project funded by the European Commission under the third Marine and Atmospheric Science and Technology (MAST) programme.

OMEGA has three main objectives; to determine the three-dimensional ageostrophic circulation at mesoscale (10-100 km) fronts and eddies and quantitatively estimate the vertical velocity, to evaluate the impact of the ageostrophic vertical motion on the biogeochemical properties in the upper 400 m, and to provide the scientific community with a standardised tool for the computation of vertical motions from routine CTD and ADCP data. Vertical motion couples the deep ocean with the near surface layers, providing an enhanced transport route for heat, nutrients and biomass. At these scales the distribution of primary production patchiness is driven by mesoscale physics (Strass 1992, Pinot et al. 1995) and successful research requires interdisciplinary observational strategies.

OMEGA is a comprehensive project combining an observational strategy of remote sensing and in-situ high resolution physical, biological and meteorological measurement with a numerical modelling/data assimilation strategy to quantify the errors involved in the diagnostic analysis of the observational data and make prognostic simulations of mesoscale features. Mesoscale eddies are ubiquitous in the ocean and the conclusions from OMEGA will be relevant to all ocean regions. However, the Alboran Sea and Almeria-Oran Front were selected as suitable experimental areas because of favourable environmental conditions and convenience for EC member countries.

Two cruise programmes provided the experimental field observations for OMEGA (**Figure 1**). The first of these involved the Spanish vessel *BIO Hesperides* and is described in Font et al (1997). The second involved the UK research vessel *RRS Discovery* and is the subject of this first-leg cruise report; relevant measurements were also made on the second leg (Pugh et al, 1997). These programmes presented a unique opportunity to survey two different frontal regions, using SeaSoar and CTD in conjunction with shipborne ADCP and 3D GPS, and observe the effect of mesoscale circulation on biological populations, using novel underway sampling techniques including flow cytometry, optical plankton counting, continuous net recording and light scattering. In addition they offered an opportunity to synchronise the acquisition of near real time satellite data from several new sensors, including those observing ocean colour variability, with high resolution in-situ surface and upper ocean measurements.

The objective of *RRS Discovery* Cruise 224 was to make quasi-synoptic, eddy scale resolution, multi-disciplinary observations of the Almeria-Oran Front and the region immediately to the east of the Alboran Sea gyre system. The whole area is bounded by the meridians 2.5° W and 2° E. The Almeria-Oran front forms at the eastern boundary of the Alboran Sea (Tintoré et al. 1988) and its position is considered to be variable on a time scale of weeks. To overcome this problem, near real time satellite data were to be supplemented by two large scale wide area SeaSoar surveys of the region prior to making three high resolution repeat SeaSoar surveys of a selected region of the Almeria-Oran Front. The cruise tracks were aligned with satellite passes so that the data could also be used to derive the absolute geostrophic current along a number of ERS1/2 and TOPEX/POSEIDON satellite tracks.

The pre-mobilisation cruise plan may be summarised as follows:

| | |
|---|---|
| - 1/12 - 4/12: | Large scale SeaSoar survey 1 |
| - 4/12 - 5/12: | Targeted CTD's, LHPR and SUMOS deployments |
| - 6/12 - 10/12: | Large scale SeaSoar survey 2 |
| - 11/12: | Port call in Almeria for personnel and equipment |
| - 11/12 - 14/12: | Fine scale SeaSoar survey 1 |

- 14/12 - 15/12: Targeted CTD's, LHPR and SUMOSS deployments
- 16/12 - 20/12: Fine scale SeaSoar survey 2
- 20/12 - 21/12: Targeted CTD's, LHPR and SUMOSS deployments
- 22/12 - 26/12: Fine scale SeaSoar survey 1
- 26/12 - 28/12: Targeted SeaSoar tows, CTD's, LHPR and SUMOSS deployments in the convergence of the Algerian Current

The large scale surveys comprised 7-10 parallel tracks, ~30 km apart, across the Alboran Sea/Algerian Basin. The fine scale surveys had 10-11 parallel tracks, ~10 km apart, and their location would be targeted at the Almeria-Oran front by near real-time analysis of available data. The work program further east, in the Algerian Current, planned for the last 3-4 days of the cruise was incorporated to support our involvement in the EU Mediterranean targeted project MATER and make highly efficient use of ship time.

## 2. NARRATIVE (Cruise Diary)

27th November (Day 332)

*Discovery* slipped from the Southampton Oceanography Centre at ~18:00 hrs having been delayed for a few hours by the need to fumigate the ship after a reported mouse infestation. A reasonable crowd had stayed to watch us depart and wish us well, this was much appreciated by all on board. The weather down the English Channel consisted of grey overcast skies and some drizzle. However the sea state was light.

28th November (Day 333)

Differential GPS was enabled by RACAL Skyfix during the morning and it was decided that an ADCP calibration should be attempted early that evening before leaving the North West European continental shelf through the western approaches to the English Channel. Using differential GPS navigation and Ashtech 3-D GPS heading data, this calibration was carried out over a straight line steam at 8 knots between 18:00 and 20:00 hrs with the ADCP in bottom track mode.

29th November - 1st December (Days 334-336)

The Bay of Biscay provided light force 7/8 seas and so despite the usual rolling *Discovery* made good time steaming at a steady 12.5 knots. The weather began to improve down the coast of Portugal and by the 1st conditions were sunny, calm and quite warm.

2nd December (Day 337)

Passage through the Strait of Gibraltar, between the 'Pillars of Hercules', was achieved during the first two hours. Once clear of the traffic separation zones we were able to deploy the

EA500 precision echo-sounder fish, the 'soap on a rope' SST thermistor probe and EK500 multi frequency echo-sounder fish for a 12 knot transit across to the northern end of the TOPEX/POSEIDON satellite line 096 (**Figure 1**). A little later it was noticed that the Ashtech 3-D GPS system had not produced any sensible data since ~08:30/1st (nearly 20 hours). This system accurately determines ships heading by ultra-short baseline relative navigation (signal phase differences) of four GPS antennae mounted on the ship's superstructure. Accurate heading information is necessary for high quality ADCP data processing (King and Cooper 1993). After inspection of the deck unit on the bridge it was found that no baseline phase differences were being calculated between the master antenna (number 1) and antenna number 2. The fault was traced firstly to a fault in either the pre-amp or the antenna, but after swapping pre-amps between antennae 1 and 2 this was narrowed down to the antenna. Unfortunately a failure in these components was not expected and no spares were kept on board. The fault was found to have been caused by severe corrosion of the aluminium baseplate and consequent salt water ingress. Attempts to dry out the faulty antenna were partially succesful and some good, although very patchy, data were recorded after the antenna had been re-fitted to its position on the starboard side of the wheelhouse top.

At 14:50 hrs Discovery arrived on station at the northern end of Topex line 096, point A (**Figure 2**) in just over 800 m of water, to make the first CTD station of the cruise (ctd22401, Discovery number 13018). A Secchi Disc was also deployed at this station: some amusement was found in a Secchi Disc equiped with a precision pressure sensor rather than the usual coloured tape graduated paying out rope, nonetheless progress should be encouraged. Following the station SeaSoar was deployed to begin Large Scale Survey 1 at ~16:15 hrs (Discovery station 13019#1).

During the late afternoon we heard that owing to diplomatic difficulties it would not be possible to work in Algerian waters prior to embarkation of an observer which had been scheduled for 11th December. Further diplomatic negotiations were instigated but these would take time and so an alternative large scale survey was hastily planned that would keep us on the Spanish side of the median line.

By 19:30 hrs it was clear that SeaSoar was not going to fly properly and so a recovery began about 12 km from point B (**Figure 2**). There was nothing obviously wrong with the vehicle but a 'sit on the wings' test indicated that the hydraulic pump may have become weak.

Good news arrived on the chemistry side as the underway auto-analyser appeared to be behaving itself and steady baselines were achieved on all three channels, nitrate, phosphate and silicate. A lesson worthy of mention here; a smouldering power distribution board could have had serious consequences. This had been placed under part of the auto-analyser where leaks from a sample tube could run; it is imperative that power supplies are kept to the walls of wet labs and are not allowed to sit on benches that might flood.

The hydraulic pump on SeaSoar was replaced with a spare. By 21:50 hrs the vehicle was back in the water, however, although the flight pattern appeared to have improved it was still not good. Nonetheless a reasonably repeatable although rather lurching flight path was achieved and held by the operators through the night.

3rd December (Day 338)

As morning broke SeaSoar's flight pattern began to deteriorate further and the inevitable recovery was initiated at 08:45 just after turning at point D (**Figure 2**). A small change in tension on the SeaSoar cable drum during removal of the strain gauge coupling was accompanied by the appearance of a 'cat's paw' (knot) in the cable a few turns onto the drum. This indicated significant torsion in the cable; recovery continued. As SeaSoar was lifted out of the water it spun like a top further indicating significant storage of torsion in the cable.

SUMOSS, the Southampton Underwater Multi-parameter Optical Spectrometer System, had failed to work under test in the deck lab during the transit to the Almeria-Oran Front region and a problem had been traced to the power distribution board. However, in an attempt to gather some information about optical characteristics of the water, a Secchi disc (Discovery station 13020) was deployed following the recovery of SeaSoar.

Much of the day was spent trying to take the torsion out of the SeaSoar cable by streaming it out behind the ship. Unfortunately all attempts to save the cable were met with the appearance of further knots and eventually we had to accept that the conductors were too badly damaged to make further attempts worthwhile. As fortune would have it we were carrying the old IOS vertical drum SeaSoar winch and cable in transit for transfer to *RRS Charles Darwin* at the end of the cruise. So at 15:00 hours the two winches were swapped over. Now attention turned to eliminating everything that could have caused the problem with the SeaSoar flight. During the late afternoon and overnight, the rudder was replaced with that on the spare SeaSoar body; for it had been noticed that the rudder bushes were very stiff and may have resisted any delicate balancing role that the rudder might play in normal flight: and the Optical Plankton Counter (OPC) was removed; having only been used once before on SeaSoar the hydrodynamic effects of this instrument were not well understood and for this cruise it had been fitted to a different SeaSoar body and further forward relative to the wings.

Scientifically, the time spent addressing the problems with SeaSoar was not wasted. Two CTD stations to ~800 m (Discovery stns.13021 and 13022)were made either side of the northern end of the Almeria-Oran Front between Modified Atlantic Water (MAW) and upwelled Levantine

Intermediate Water (LIW). Coloured Secchi discs, red/black, blue/black and green/black, had been made up during the previous two days and were deployed for the first time at these stations together with the more conventional white/black disc. The stations were followed by a short steam to the median line between Algeria and Spain during which a sonic anemometer survey was carried out to look at the turbulent wake behind the foremast.

4th December (Day 339)
Just west of point D a short 'tow-yo' CTD section (Discovery stn. 13023) in the frontal zone was initiated in the early hours. The vertical current shear was around 1-1.5 knots in the upper 100 m of the water column and so the depth of the 'tow-yo' was increased gradually to 400 m whilst carefully monitoring the CTD wire angle.

At 04:00 SeaSoar was both ready for redeployment and technical staff who had worked round the clock preparing it during the previous day had had sufficient sleep to support its launch. At 04:50 SeaSoar was in the water and almost immediately under control on a steady undulating flight path between the surface and ~360 m.

There had been developments on the diplomatic front and a boat transfer just off Oran at 09:00 on 6th December to embark an Algerian observer had now been arranged to minimise the disruption to the original survey strategy. In response to this diplomatic development, the loss of 24 hours SeaSoar data collection and a requirement to reach TOPEX/POSEIDON line 172 within 24 hrs of an overpass the survey pattern was hastily redesigned by removing several turning points that were originally scheduled before E and F (**Figure 2**).

At ~ 14:00 hours data and control signals from and to SeaSoar began to break up and SeaSoar was recovered for a re-termination of the cable. Course speed and direction were maintained and SeaSoar was redeployed at ~17:00 hrs to continue the section up to the northern end of TOPEX/POSEIDON line 172, point E.

5th December (340)
SeaSoar was recovered at the end of large scale survey 1 (**Figure 2**) at ~17:15 hrs after a long transect along the median line between Algerian and Spanish waters from point F to the intersection with TOPEX/POSEIDON line 096.

Steaming back along the median line at 12 knots to relocate the position of the Almeria-Oran front we were forced to stop and recover the EK500 fish when it was noticed that the towing cable was at a very shallow angle to the water and the data looked unusually noisy with no clear structure in any of the frequencies. During recovery the cable jammed in the sheeve and was superficially damaged. This was caused by the fairing which is rather too stiff and tries to take a route of minimum stretch around the block thus forcing the conducting cable to one side. Upon recovery of the 'fish' the tail was found to be missing. This was held in position on a single stainless steel threaded shaft (18 mm pre-threading diameter) through the end of the fish; however the shaft was found to have sheared off just inside the metal frame of the 'fish'.

By 20:50 we had established the position of the Almeria-Oran front and a CTD station (Discovery station 13024) was made just to the west of the front. After recovery of the CTD and a brief transit to recover distance drifted during the station, the Longhurst Hardy Plankton Recorder (LHPR) was deployed for the first time on the cruise (Discovery stn. 13025). It was towed on a non-conducting cable at a speed of around 4.5 knots for two hours on a transect back across the front. During the tow the cable was payed out to allow the vehicle to sample several selected depths to a maximum of ~400 m. The failure of the EK500 fish meant that the selection of towing depths for the LHPR had to be based on the appearance of scattering layers in the EA500 and ADCP signals.

6th December (Day 341)

Recovery of the LHPR a little after 01:00 hrs preceded the steam to Oran for the embarkation of our Algerian observer. *Discovery* arrived just outside Oran harbour at 08:00 hrs for a most expeditious boat transfer. Our observer was given a good welcome and a tour of the ship by a French-speaking scientist was quickly arranged. At 09:00 hrs we left Oran and steamed towards the start of large scale survey 2, point G, (**Figure 3**) at the southern end of TOPEX/POSEIDON line 096.

Before reaching point G the ship was stopped and SUMOSS was deployed at 16:00 hrs. After succesful lowering to a depth of 5 metres (Discovery stn. 13026), SUMOSS was eventually lowered to a depth of 40 metres at which point the power signal at the surface failed to show signs of switching at the instrument and, fearing water ingress, the instrument was recovered. Recovery was followed by the deployment of Secchi disks. It later emerged that the problem with SUMOSS had not resulted from water ingress.

By this time the OPC had been fitted to the spare SeaSoar body but further back so that it was not forward of the wings. At 17:30 hrs SeaSoar was deployed (Discovery stn. 13027) with the OPC and its initial response to control commands was watched closely. Within a few minutes it was clear that SeaSoar was flying well and under full deck control, and rather surprisingly, reaching the same depth as it had without the OPC. In addition to the other alterations whilst on deck, the hydraulic unit had been swapped for an experimental unit from Chelsea Instruments.

7th December (Day 342)

At ~17:30 hrs, Discovery was slowed briefly to 2 knots whilst the EA500 precision echo sounder fish was deployed. It had been recovered prior to the transit to Oran, and its re-deployment had been over looked until this time. The EA500 deck unit had been recording data, but only from the hull mounted transducer and thus at lower resolution and signal to noise ratio.

Unfortunately the previous good news regarding underway chemistry had been short lived. Two auto-analysers were on board in the deck lab. One of these for running discrete samples and the other connected to the non-toxic supply. Both machines were unreliable throughout the cruise, needing frequent re-tubing and coaxing. Despite valiant attempts to rectify the problems a decision had to be made at this stage in the cruise to abandon the machine connected to the non-toxic supply and concentrate on processing the discrete samples taken hourly from the non-toxic supply and from water bottles at CTD stations. Two particular problems were solved as a direct result of interaction between scientists/engineers from different disciplines, it is difficult to see how these problems could have been unique to this cruise and therefore they are described here. Fluctuations in phosphate values were found to be the result of small changes in light levels during the normal motion of the ship, roll etc. This was overcome by reducing the overall laboratory lighting and constructing a cardboard shield to fit over the detector cells component of the autoanalyser. A further souce of noise came from a conflicting earth being made through the path of the sample tubes to a metal connector tube in the body of the sample needle tower. This was overcome by taking the tube from the sampling needle directly to a free hanging nylon tubing connector and thence to the peristaltic pumps. Much later in the cruise a further attempt was made to operate the autoanalyser connected to the non-toxic supply when another member of staff had some extra time on their hands. However, a decision had to be made regarding where this considerable effort could be best directed and the machine was again turned off to allow more effort to be spent working up the excellent data achieved through the discrete sampling routines. Having the benefit of hind-sight it is now clear that two dedicated chemists are required to run two autoanalysers continuously during a cruise. This is especially true if there are known to be problems with the reliability and maintenance of the machines.

8th December (Day 343)

At 05:00 hrs at a position about two thirds of the way along leg KL (**Figure 3**), SeaSoar appeared to need re-terminating; both data and control signals had broken up. By 06:00 hrs the recovery of the vehicle was complete, but after careful consideration of both our geographical position and the overall timetable for the cruise the decision was made not to wait on station to re-deploy SeaSoar. Instead position L was moved further east so that an 8 knot steam to L could be achieved on a heading of around 0°. This was to enable us to refine our model of the ship's gyro error. Inertial errors in ship's gyros have a maxima and minima at headings of 0°

and 180° or vice-versa, i.e. in the direction of maximum rate of change of the Coriolis parameter.

The fault with SeaSoar took longer to find than usual as it turned out not to be a termination failure but water ingress at the three way joint between the various instrument cables inside the body of the vehicle. Nevertheless Seasoar was back in the water by 11:15 hrs near the end of leg LM.

At 23:30 SeaSoar suffered the same problem again, and was recovered at the end of leg MN. This time an older method of connecting the various instruments to the cable termination was used and the three way joint was avoided.

9th/10th December (Days 344/345)

SeaSoar was back in the water at point O by 04:40 hrs on 9th ready to complete the second large scale survey along legs OP and PD. SeaSoar was recovered at point D at 04:30 hrs/10th after completing the second large scale survey.

The recovery of SeaSoar was followed by a full depth CTD station to 1950 m (Discovery stn. 13028). After recovery of the CTD, Secchi discs were deployed (Discovery stn. 13029).

The Almeria-Oran front was located and crossed by steaming NE of point D and at ~09:00 hrs the LHPR was deployed and towed across the front from east to west (Discovery stn. 13030). After recovery of the LHPR, it was found that the self contained battery had discharged two thirds of the way through the tow and so the day's second LHPR deployment had to be abandoned.

During the previous few days a considerable number of modifications had been made to the SUMOSS instrument to allow more information to be obtained in real time up the conducting deployment cable. At around 12:30, SUMOSS was successfully deployed to 50 m and supported by Secchi disc observations after recovery (Discovery stn. 13031). Two CTD stations were made in lieu of an LHPR deployment, one east of the front (Discovery stn. 13032) accompanied by Secchi disc observations and a SUMOSS deployment, and one west of the front (Discovery stn. 13033) at 19:00 hrs accompanied by a SUMOSS deployment and an EK500 calibration. The tail-less EK500 fish was lowered into the water whilst the ship was allowed to drift and the three calibration targets (copper spheres of different sizes) were hung several metres below the fish. Calibration offsets were successfully obtained for the 38 and 120 kHz transducers but not for the 200 kHz transducer.

11th December (Day 346)

Following an early morning steam we docked in Almeria at 09:00 hrs. Our Spanish colleagues who would make the flow cytometry observations (counting of small particles less than 20 µm by light scattering) during the second part of the cruise were waiting for us on arrival and were welcomed on board. A new Ashtech 3D GPS antenna had been sent out from the UK and was fitted by our RVS computer support technician soon after tying up alongside. During the day DGPS was monitored in dock from two different ground stations, Cadiz, which was the nearest station and was generally used throughout the cruise, and Rome. After a pleasant lunch in the town, we departed from Almeria at 16:15 hrs and headed for the start of fine scale survey one (**Figure 4**). By 18:45, SeaSoar was in the water and the first fine-scale survey (Discovery stn. 13034) was underway.

12th/13th December (Days 347/348)

The weather began to deteriorate considerably as the survey continued; a blocking high pressure over NW Europe was forcing low pressure disturbances to pass to the north, and, more significantly for us, south over the Alboran Sea and western Mediterranean as a whole.

14th December (Day 349)

The morning began with an unpleasant confused sea somewhat rougher than the wind conditions might have led one to expect possibly as a result of a long fetch along the axis of the Alboran Sea. However this did not dampen any spirits as the Met. Office flight Lockheed Hercules 'Snoopy' was due to arrive at 10:30 am. First sighting took the form of a little black dot at 24000 ft. However, after an hour or so of slowly spiralling descent, sometimes in view, sometimes not, three low level passes were carried out across the ship. The objective of these overpasses was an intercalibration of radiometers and wind speed sensors. The Met. flight then went off to carry out a large scale survey of the region from 3 degrees west to 1 degree east before flying back to Valencia. In the evening, a fax was received from the Met. Flight team showing the SST values that they had recorded during the survey; this confirmed both the satellite pictures and our own *in situ* information regarding the position of the front and the meandering features just east of it.

15th December (Day 350)

The first fine scale survey ended after 3.5 days at 10:00 am. Following recovery of SeaSoar we headed for the centre of the survey region and the front, near point D (**Figure 2**). At midday we turned head to wind for another overflight by 'Snoopy' and an intercalibration of wind speed measurements. Following this the Met. Office aircraft went to make a more detailed survey of the front during which it was seen for a final time during a low level pass later that afternoon.

At ~14:30 Secchi disc observations were made (Discovery stn. 13035). During the afternoon the third LHPR tow of the cruise (Discovery stn. 13036) was accomplished, successfully navigated in a SSW direction across from the cold to the warm side of the front. A line of five 1000 m CTD stations across the front and parallel to the Spanish/Algerian median line was initiated at ~18:40 hrs (Discovery stns. 13037-41). At the first of these, the tail-less EK500 fish was again lowered into the water to obtain a calibration offset for the 200 kHz transducer. Unfortunately, for the second time, it was not possible to achieve a satisfactory calibration for this frequency.

All the station work following the recovery of SeaSoar was aimed at cross front transects and a most interesting discovery was that since crossing this area with SeaSoar during the first fine scale survey nearly 48 hours earlier, the position of the surface expression of the front had moved by more than 10 nautical miles towards the centre of the survey area.

16th December (Day 351)

Following recovery of CTD22412 just before dawn, we steamed back towards point D (**Figure 2**) to re-locate the front and set a start position for an LHPR deployment. The LHPR was deployed at 09:10 and after a successful tow ~NW across the front was recovered at 11:30 (Discovery stn. 13042).

The afternoon was spent steaming towards Almeria breakwater for a boat transfer to pick up a new tail for the EK500 fish. This had been urgently fabricated for us in the UK and transported to our agents in Almeria. Making the most use of available opportunities, a Secchi disc station was made at Almeria breakwater, ~16:30 hrs, on the way in (Discovery stn. 13043). The boat transfer was successful and by 18:00 hrs we were steaming back out towards the beginning of fine scale survey 2 (**Figure 5**). To make a second ADCP calibration this transit was made in a straight line at ~8 knots; it had been discovered that a small adjustment to the ship's gyro had been made after entering the mediterranean at the beginning of the cruise.

The new fibre glass tail and mounting stud (now made of a titanium alloy) were fitted to the EK500 fish during the transit from Almeria. This required some fitting and the fabrication of new locating screws where the tail located around the main body of the fish. Nevertheless both the EK500 and SeaSoar were back in the water at 21:10 hrs (Discovery stn. 13044) at the start of fine scale survey 2. SeaSoar was not flying as well as it had done during the first fine scale survey, requiring a large gain on the command signal to force the vehicle to turn around at the surface.

17th - 20th December (Days 352-355)

By 07:30 hrs it was clear that the hydraulic unit was now too weak to hold proper control of the maximum depth and the OPC had been giving noisy data for some hours: the vehicle was recovered just after beginning leg c. The Chelsea Instruments experimental hydraulic unit had indeed failed after considerably less than 100 hours and so the OTD unit was put back in. The fault with the OPC was due to a plastic click lock tie having chaffed through the OPC cable. The cable was replaced and cod line was used to restrain the cable in the SeaSoar body. During these operations Discovery circled round to redeploy SeaSoar where it had been recovered. In addition 2 secchi disc deployments (Discovery stn. 13044#2/3) were made at 08:10 and 09:20 hrs. SeaSoar was back in the water to continue the second fine scale survey at 10:15 hrs.

Fine scale survey 2 ended at the northern end of leg l (**Figure 5**) having already extended both legs k and l to less than 1000 m water depth near the Algerian coast. Both SeaSoar and the EK500 were recovered and in-board by ~18:15 hrs on the 20/12/96. The ship then made a transit back to point D (**Figure 2**) at 12 knots. At 23:00 hrs a CTD station was made to ~1900 m (full depth, Discovery stn. 13045) and all 12 water bottles were fired at full depth; some concern had been voiced previously that one or more of the bottles might have been leaking.

21st December (Day 356)

The CTD was recovered at 01:15 hrs and subsequent salinity analysis over the next 36 hours showed that all twelve bottles were closing properly. After steaming to correct the 2.5 nautical mile ship's drift from point D, the CTD was redeployed for a shallow high resolution vertical cast (Discovery stn. 13046) to 150 m at a deployment speed of 15 m/minute. This station was designed to establish the hydrographic, biological and chemical vertical structure in preparation for a SUMOSS station (Discovery stn. 13047) which began at 04:00 hrs, just after redeployment of the EK500, and successfully recorded day-break in the irradiance measurements. Following SUMOSS recovery real time data from the EK500 was used to find a cross front transect for the LHPR: and a successful LHPR tow (Discovery stn. 13048) across the Almeria-Oran front, in a WSW direction at 4.5 knots, was achieved before midday.

It had been noticed that, over the course of the cruise, the surface signature of the front had become more diffuse and defining the position of the front from underway surface data was becoming more difficult. Nonetheless at 13:00 hrs Secchi discs were deployed (Discovery stn. 13049) followed by SUMOSS at 13:25 (Discovery stn. 13050) at a position that was believed to be north-east of the front. After recovery of SUMOSS another shallow high resolution CTD station was made to define the vertical structure upper layers of the water column (Discovery stn. 13051). The CTD was back on deck at 15:30 hrs and course was set for a 12 knot steam to the start of fine scale survey 3 (**Figure 6**). By 20:00 hrs, the EK500 and SeaSoar were fully deployed and the 3rd fine scale survey had begun, this time at a speed of 9 knots through the water (Discovery stn. 13052).

22nd - 24th December (Days 357-359)
By Christmas Eve and nearing the end of the survey, the weather had become very rough. Eventually, at around 22:10 hrs and half way down leg k (**Figure** 6), continuous force 9/10 winds and a large but short wavelength sea forced us to abandon the survey pattern and steam gently into the swell.

25th December (Day 360)
By 10:15 hrs SeaSoar was recovered and fine scale survey 3 considered finished. During the night a gentle steam westwards into the swell had been necessary to avoid further damage to equipment on board and there would have been too large a temporal gap in the survey to warrant completion of the last two short legs of the survey. recovery of SeaSoar in such conditions was only possible by transferring the SeaSoar block to a crane and then extending the crane out through the A-frame. Once on deck it was noticed that a ‘cats paw’ had appeared in the cable ~3 m from SeaSoar and one or two stands of the outer winding had already broken.

Discovery steamed gently into a rough but quietening sea for most of the day, whilst all on board enjoyed a well deserved Christmas celebration. The organisation and catering was a magnificent tribute to the hard work of the ship’s personnel and much appreciated by all the scientific personnel.

At 18:00 hours the weather had calmed sufficiently to recover the EK500 fish. Once on deck it was clear that the swivel pin that holds the fish on the towing cable had lost its retaining nut and had vibrated half way out of the swivel. It was impossible to establish whether this had happened over some considerable time or whether the decision to recover the fish at that particular moment had been one of uncanny fortune. At 18:30 Discovery set an easterly course to reach a suitable starting position for a survey of the Algerian Current (**Figure 7**).

26th December (Day 361)
At 09:30 we stopped at point Q (**Figure 7**) to make a line of three light/ocean optics stations across the Algerian current and as close to the Algerian coast as possible. At the first of these stations (Discovery stn 13053),point Q, only SUMOSS was deployed but at the other two stations (Discovery stns. 13054 and 13055) SUMOSS was supported by secchi disc observations. Close to the Algerian coast, the EK500 and LHPR were deployed for a 4.5 knot tow due north into the Algerian current jet at 14:40 hrs. At ~16:50 the LHPR was recovered and *Discovery* headed back towards the Algerian coast at point R. There is no continental shelf in this region of the coastline, having reached short swimming distance of the coast, the

ship was still in over 800 m of water. SeaSoar was deployed at ~18:10 (Discovery stn. 13057) to survey a line (RS) perpendicular to the coast back across the Algerian current.

At one point during the cruise it had been noticed that the optical plankton counter (OPC) attached to SeaSoar had recorded a different profile of counts/$m^3$ when SeaSoar was descending than when SeaSoar was ascending. It was not known whether this was a software algorithm problem or due to a disturbance of the flow through the OPC due to the attitude of the SeaSoar vehicle. At ~23:00 hours we had reached point S to begin an equilateral triangle S-T-U-S-T (**Figure 7**) of 9 nm sides. Each side of the triangle was completed with SeaSoar contolled to fly either level at a specified depth or undulating at a specified ascent/descent rate so that subsequent analysis may determine if the attitude of the vehicle affects the OPC data.

27th December (Day 362)

After completing the OPC trial, SeaSoar was towed back across the Algerian current to point V where, at ~07:45, it was recovered. Steaming back up the line VT, the LHPR was launched at ~09:30 for a 4.5 knot tow across the offshore edge of the Algerian current (Discovery stn. 13058). Following recovery and retracing our track along line VT, the LHPR was launched a second time at ~14:30 for a repeat tow (Discovery stn. 13059). The LHPR was recovered for a final time at ~16:45 near point W and the following two hours were spent making a calibration of the ship's Chernikief log over a measured mile. By comparison with DGPS navigation and ADCP currents, it had been noted for some time that the ship's Chernikief log appeared to consistently over-estimate the speed of the ship through the water; the calibration confirmed this error to be around 10%.

During the afternoon the stiff rudder had been put back on the SeaSoar vehicle ready for a brief flight trial. Just after 19:00 hrs SeaSoar was deployed to begin a zig-zag survey of the offshore edge of the Algerian current westwards to the southern end of the Almeria-Oran Front (W-X-Y-Z-AA-BB-CC in **Figure 7**). With the stiff rudder on, the SeaSoar vehicle made a reasonable oscillatory flight path to 300-350 m but did show a tendency to spin occasionally and therefore was recovered after ~45 minutes to replace the rudder. The test confirmed only that the stiff rudder could have contributed to the problems early in the cruise. At ~20:20 hrs SeaSoar was redeployed to continue the survey to point CC (Discovery stn. 13060).

28th/29th December (Days 363/364)

At 07:30, having reached point CC at the southern end of an ERS2 overpass due at 22:00 hrs that day, SeaSoar was recovered and a SUMOSS deployment, preceded and succeeded by Secchi disc observations, was made (Discovery stn. 13061). SeaSoar was deployed for the last time just after noon (Discovery stn. 13062) to begin a survey line along the ERS2 track from CC to DD. After recovery of SeaSoar at ~21:30, just half an hour before the ERS2 overpass, *Discovery* steamed to Cartagena, Spain where we moored alongside at 08:15 on the 29th.

Despite technical and diplomatic problems at the beginning of the cruise, all of the scientific objectives of the cruise had been achieved and enough time had been available at the end of the cruise to carry out some valuable equipment trials.

*Summary table*:

| | | |
|---|---|---|
| 18:00 27-11-96 | Left Empress dock, Southampton | |
| 18:00 28-11-96 | ADCP calibration run of ~2 hours duration | |
| 14:48 02-12-96 | CTD 22401 | Discovery No. **13018**<br>36° 25.8' N 02° 22.0' W |
| 16:15 02-12-96 | SeaSoar LSS1 began | Discovery No. **13019**#1<br>36° 25.5' N 02° 21.0' W |
| 19:30 02-12-96 | SeaSoar recovery for hydraulic pump replacement | 36° 03.9' N 02° 08.6' W |
| 21:50 02-12-96 | SeaSoar LSS1 continued | 36° 02.5' N 02° 06.7' W |
| 08:45 03-12-96 | SeaSoar recovery due to unacceptable flight characteristics | 36° 18.2' N 01° 42.9' W |
| 09:15 03-12-96 | Secchi disc station | Discovery No. **13020**<br>36° 19.2' N 01° 43.4' W |
| 15:40 03-12-96 | Secchi disc<br><br>CTD 22402<br><br>Secchi disc | Discovery No. **13021**#1<br>36° 17.6' N 01° 41.4' W<br>Discovery No. **13021**#2<br>36° 17.4' N 01° 41.4' W<br>Discovery No. **13021**#3<br>36° 17.1' N 01° 41.4' W |
| 18:30 03-12-96 | CTD 22403 | Discovery No. **13022**<br>36° 10.4' N 01° 43.7' W |
| 00:40-03:55 04-12-96 | CTD 'tow-yo' | Discovery No. **13023**<br>36° 08.2' N 01° 45.7' W<br>- 36° 09.8' N 01° 45.3' W |
| 04:50 04-12-96 | SeaSoar LSS1 continued | Discovery No. **13019**#2<br>36° 09.4' N 01° 44.8' W |
| 14:00 04-12-96 | SeaSoar recovery for re-termination | 37° 00.4' N 00° 53.0' W |
| 17:00 04-12-96 | SeaSoar LSS1 continued | Discovery No. **13019**#3<br>37° 19.2' N 00° 35.8' W |
| 17:15 05-12-96 | SeaSoar recovered. End of LSS1. | 36° 02.9' N 02° 08.8' W |

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|---|---|---|
| 19:30 05-12-96 | EK500 fish recovered following loss of tail | 36° 09.7' N 01° 54.7' W |
| 21:00 05-12-96 | CTD 22404 | Discovery No. **13024**<br>36° 16.0' N 01° 42.5' W |
| 22:40 05-12-96 | LHPR deployed | Discovery No. **13025**<br>36° 15.7' N 01° 42.0' W |
| 01:10 06-12-96 | LHPR recovered | 36° 21.0' N 01° 32.1' W |
| 08:00-09:00 06-12-96 | Anchored off Oran to pick up an Algerian observer by boat transfer | 35° 43.8' N 00° 38.4' W |
| 15:50 06-12-96 | SUMOSS station followed by Secchi disc deployments | Discovery No. **13026**<br>36° 45.9' N 01° 40.6' W |
| 17:40 06-12-96 | SeaSoar LSS2 began | Discovery No. **13027#1**<br>36° 45.3' N 01° 43.1' W |
| 05:30 08-12-96 | SeaSoar recovered for re-termination | 37° 02.1' N 01° 02.4' W |
| 11:15 08-12-96 | SeaSoar LSS2 continued | Discovery No. **13027#2**<br>37° 27.1' N 00° 43.2' W |
| 00:30 09-12-96 | SeaSoar recovered for re-termination | 36° 10.1' N 00° 06.1' W |
| 04:40 09-12-96 | SeaSoar LSS2 continued | Discovery No. **13027#3**<br>36° 21.2' N 00° 27.9' W |
| 04:30 10-12-96 | SeaSoar recovered. End of LSS2. | 36° 13.8' N 01° 49.4' W |
| 05:10 10-12-96 | CTD 22405 | Discovery No. **13028**<br>36° 13.9' N 01° 46.4' W |
| 07:50 10-12-96 | Secchi discs deployed | Discovery No. **13029**<br>36° 15.8' N 01° 40.4' W |
| 09:00 10-12-96 | LHPR deployed | Discovery No. **13030**<br>36° 15.1' N 01° 43.3' W |
| 11:20 10-12-96 | LHPR recovered | 36° 19.0' N 01° 33.4' W |
| 12:15 10-12-96 | SUMOSS deployment followed by Secchi discs | Discovery No. **13031**<br>36° 18.9' N 01° 35.1' W |
| 14:50 10-12-96 | CTD 22406 | Discovery No. **13032#1**<br>36° 19.6' N 01° 34.9' W |
| 16:50 10-12-96 | Secchi discs deployed | Discovery No. **13032#2**<br>36° 18.7' N 01° 35.8' W |
| 17:00 10-12-96 | Secchi discs deployed | Discovery No. **13032#3**<br>36° 18.7' N 01° 35.8' W |
| 17:10 10-12-96 | SUMOSS deployed | Discovery No. **13032#4**<br>36° 18.6' N 01° 35.9' W |
| 19:10 10-12-96 | SUMOSS deployed | Discovery No. **13033#1**<br>36° 11.3' N 01° 39.7' W |

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|---|---|---|
| 21:00 10-12-96 | CTD 22407 | Discovery No. **13033**#2<br>36° 12.2' N 01° 41.4' W |
| 23:10 10-12-96 | EK500 calibration | Discovery No. **13033**#3<br>36° 14.8' N 01° 43.0' W |
| 09:00-16:15 11-12-96 | Alongside in Almeria, Spain | |
| 18:30 11-12-96 | SeaSoar FSS1 began | Discovery No. **13034**#1<br>36° 36.0' N 02° 15.3' W |
| 11:25<br>12:10 14-12-96<br>14:00 | Met. Office Lockheed Hercules 'Snoopy' overflights | |
| 10:00 15-12-96 | SeaSoar recovered. End of FSS1. | 35° 51.9' N 00° 53.3' W |
| 12:00 15-12-96 | Met. Office Lockheed Hercules 'Snoopy' overflight | |
| 14:30 15-12-96 | Secchi discs deployed | Discovery No. **13035**<br>36° 16.3' N 01° 34.6' W |
| 14:40 15-12-96 | LHPR deployed | Discovery No. **13036**<br>36° 16.1' N 01° 34.7' W |
| 15:35-15:45 15-12-96 | 2 Met. Office Lockheed Hercules 'Snoopy' overflights | |
| 17:05 15-12-96 | LHPR recovered | 36° 09.9' N 01° 41.4' W |
| 18:40 15-12-96 | CTD 22408 followed by EK500 calibration | Discovery No. **13037**<br>36° 10.1' N 01° 51.4' W |
| 21:50 15-12-96 | CTD 22409 | Discovery No. **13038**<br>36° 14.0' N 01° 45.7' W |
| 23:55 15-12-96 | CTD 22410 | Discovery No. **13039**<br>36° 17.5' N 01° 40.1' W |
| 02:05 16-12-96 | CTD 22411 | Discovery No. **13040**<br>36° 21.7' N 01° 34.5' W |
| 04:05 16-12-96 | CTD 22412 | Discovery No. **13041**<br>36° 25.4' N 01° 28.8' W |
| 09:10 16-12-96 | LHPR deployed | Discovery No. **13042**<br>36° 11.6' N 01° 49.2' W |
| 11:30 16-12-96 | LHPR recovered | 36° 17.8' N 01° 42.5' W |
| 16:30 16-12-96 | Secchi discs deployed Almeria breakwater | Discovery No. **13043**<br>36° 49.2' N 02° 27.3' W |
| 17:15-17:30 16-12-96 | Boat transfer at Almeria breakwater for new EK500 tail | |
| 21:10 16-12-96 | EK500 and SeaSoar deployed. SeaSoar FSS2 began | Discovery No. **13044**#1<br>36° 36.8' N 02° 14.6' W |

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|---|---|---|---|
| 07:30 | 17-12-96 | SeaSoar recovered for hydraulic pump replacement and new OPC cable | 36° 38.3' N 01° 56.4' W |
| 08:10 | 17-12-96 | Secchi discs deployed | Discovery No. **13044**#2<br>36° 37.4' N 01° 56.6' W |
| 09:20 | 17-12-96 | Secchi discs deployed | Discovery No. **13044**#3<br>36° 39.1' N 01° 56.3' W |
| 10:15 | 17-12-96 | SeaSoar FSS2 continued | Discovery No. **13044**#4<br>36° 38.7' N 01° 56.5' W |
| 17:30 | 20-12-96 | SeaSoar recovered. End of FSS2. | 36° 17.7' N 00° 39.9' W |
| 23:10 | 20-12-96 | CTD 22413 | Discovery No. **13045**<br>36° 13.7' N 01° 45.7' W |
| 01:55 | 21-12-96 | CTD 22414 | Discovery No. **13046**<br>36° 13.9' N 01° 46.1' W |
| 04:00 | 21-12-96 | SUMOSS deployment | Discovery No. **13047**<br>36° 13.9' N 01° 45.8' W |
| 09:20 | 21-12-96 | LHPR deployed | Discovery No. **13048**<br>36° 14.7' N 01° 34.2' W |
| 11:40 | 21-12-96 | LHPR recovered | 36° 10.4' N 01° 43.8' W |
| 13:00 | 21-12-96 | Secchi discs deployed | Discovery No. **13049**<br>36° 17.9' N 01° 39.7' W |
| 13:25 | 21-12-96 | SUMOSS deployment | Discovery No. **13050**<br>36° 17.3' N 01° 39.5' W |
| 14:55 | 21-12-96 | CTD 22415 | Discovery No. **13051**<br>36° 15.7' N 01° 38.8' W |
| 19:50 | 21-12-96 | EK500 and SeaSoar deployed. SeaSoar FSS3 began | Discovery No. **13052**#1<br>36° 38.3' N 02° 13.9' W |
| 10:16 | 25-12-96 | SeaSoar recovered. End of FSS3. | 36° 00.6' N 01° 30.7' W |
| 09:35 | 26-12-96 | SUMOSS deployment | Discovery No. **13053**<br>36° 45.0' N 01° 26.7' E |
| 11:10 | 26-12-96 | SUMOSS deployment | Discovery No. **13054**#1<br>36° 39.4' N 01° 31.9' E |
| 11:50 | 26-12-96 | Secchi discs deployed | Discovery No. **13054**#2<br>36° 38.6' N 01° 35.0' E |
| 13:10 | 26-12-96 | SUMOSS deployment | Discovery No. **13055**#1<br>36° 35.0' N 01° 39.3' E |
| 13:50 | 26-12-96 | Secchi discs deployed and EK500 deployed | Discovery No. **13055**#2<br>36° 35.1' N 01° 40.5' E |
| 14:40 | 26-12-96 | LHPR deployed | Discovery No. **13056**<br>36° 35.2' N 01° 39.0' E |
| 16:50 | 26-12-96 | LHPR recovered | 36° 41.3' N 01° 38.9' E |

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|---|---|---|
| 18:10 26-12-96 | SeaSoar deployed | Discovery No. **13057**<br>36° 34.2' N 01° 38.7' E |
| 07:50 27-12-96 | SeaSoar recovered | 36° 32.1' N 01° 08.6' E |
| 09:40 27-12-96 | LHPR deployed | Discovery No. **13058**<br>36° 40.6' N 01° 14.0' E |
| 12:00 27-12-96 | LHPR recovered | 36° 49.9' N 01° 17.7' E |
| 14:30 27-12-96 | LHPR deployed | Discovery No. **13059**<br>36° 48.5' N 01° 17.0' E |
| 16:45 27-12-96 | LHPR recovered | 36° 57.0' N 01° 20.0' E |
| 17:20-18:55 27-12-96 | Calibration of Chernikief log over measured mile. | Mean pos.<br>36° 56.5' N 01° 18.9' E |
| 19:05 27-12-96 | SeaSoar deployed. Test stiff rudder. | Discovery No. **13060**#1<br>36° 56.6' N 01° 18.5' E |
| 19:50 27-12-96 | SeaSoar recovered to replace rudder. | 36° 57.5' N 01° 12.5' E |
| 20:20 27-12-96 | SeaSoar re-deployed. | Discovery No. **13060**#2<br>36° 57.7' N 01° 11.0' E |
| 07:30 28-12-96 | SeaSoar recovered. | 36° 26.4' N 00° 31.8' E |
| 08:15 28-12-96 | Secchi discs deployed | Discovery No. **13061**#1<br>36° 25.6' N 00° 30.8' E |
| 08:20 28-12-96 | SUMOSS deployment | Discovery No. **13061**#2<br>36° 25.5' N 00° 30.1' E |
| 11:35 28-12-96 | Secchi discs deployed | Discovery No. **13061**#3<br>36° 26.3' N 00° 26.7' E |
| 12:15 28-12-96 | SeaSoar deployed for ERS2 line | Discovery No. **13062**<br>36° 26.4' N 00° 28.5' E |
| 21:35 28-12-96 | SeaSoar recovered, end of science. | 37° 33.0' N 00° 14.1' E |
| 08:15 29-12-96 | Alongside in Cartagena, Spain | |

*JA & TG*

## 3. TECHNICAL SUPPORT

### RVS data logging and IT support *MB*

<u>Level A's</u>

| | |
|---|---|
| log_chf | MkII - serial smp |
| gyro | MkII - serial smp |
| gps_4000 | MkII - serial smp |
| gps_ash | MkII - serial smp |

| | |
|---|---|
| surflog | PC based - serial smp |
| grhomet | PC based - serial smp |
| sbwr | PC based - UDP message |
| echo | MkII - serial smp |
| seasoar | MkII (vme) - ethernet smp |
| ctd_12c | MkII (vme) - ethernet smp |

Level A's not mentioned below performed without mishap or were normal in their operation.

***gps_4000***

Differential corrections from Racal Skyfix were input via port 3 of the GPS receiver. The corrections were generated by decoders hired for this cruise. (This was a continuation of the hire from cruise D223). Two decoders were provided, one being configured for the Atlantic West satellite and the other for the Atlantic East satellite. The output from the decoder on Atlantic East used as the optimum base station for this cruise was Cadiz (ID 810). The data from Cadiz are only broadcast on Atlantic East.

During a mid cruise port call on Jday 346, the opportunity was taken to switch the decoder to provide correction signals from the Rome base station (ID 800). About three hours of corrections were gathered for each of the two stations during the port visit.

On Jday 356, just after midnight, correction signals from Cadiz ceased. This was detected at around 10:15 am on Jday 357 when the correction was switched to Rome. Subsequent broadcast messages from Cadiz indicated a major communication failure ashore.

***gps_ash***

During the passage south from Southampton to the working area, the quality of the received signals from one of the antennae on the wheelhouse roof deteriorated to such an extent that the receiver was unable to generate heading values necessary for the calibration of the gyro for use with the ADCP. Switching cables and pre-amplifiers between antennae one and two pointed to the fault being with antenna one rather than its cable or pre-amplifier. Once the antenna was removed from its base a lot of corrosion could be seen particularly around the connector. A deep score along one end had allowed moisture to penetrate behind the connector. Washing with fresh water and heating the antenna up with a hot air blower partially restored the signals, sufficient to enable headings to be generated again.

A replacement antenna was received and fitted during the mid cruise port call on Jday 346. As a result the signal to noise ratio on the remaining three antennae were now low by comparison.

No attempt was made during the cruise to investigate them as it was considered likely to make them worse if they were disturbed.

*surflog*

A fairly regular error in the time stamping of the data from the instrument resulted in the loss of about one record an hour. Investigation of the "basic" program showed that it should have been possible to prevent those messages with errors being transmitted. However to correct the original problem would have probably required a redesign of part of the program.

*sbwr*

The PC based shipborne wave recorder logger transmitted a "udp" message every 30 minutes over the computer network using service 10001. This message was received by "discovery2" and was stored locally in a file. The contents of this file were collected, passed through an "awk" script and "titsil"ed into a RVS data file.

*seasoar/ctd*

At the beginning of the cruise, the Level A had been run without a clock to reduce the data gaps which are generated by having an external clock. This was found to result in too high a clock drift rate, so the external clock signal was reinstated and the consequent 2 to 3 seconds data gap ever 30 minutes was accepted.

Level B

A potential Black Hole occurred towards the end of the cruise, but had recovered by the time it was investigated.(a Black Hole is where everything appears to be OK on the level B but in fact it is neither logging nor re-transmitting the data to the Level C). The alarm had sounded to indicate that the Level C was not receiving any data from the Level B. The backup tapes had switched after 93%. An error message had been logged on the Level B as follows;

DEBUG Write error on tape 1 (/mt1) 96 361 22:29:41, 43404 BLKS, 245

the next tape started at 22:30:32. There were no detectable gaps in the Level C data during this period.

Level C

The majority of the data processing was performed using the PSTAR suite of programs. The level C software was used to provide corrected navigation at 30 second intervals, corrected depth processing based on Carter corrections, and CTD and SeaSoar processing to enable real time screen plots to be displayed as required. A listing of position, cable out and depth was written to a terminal screen in the Main lab for reference.

Computing Systems

The Discovery computing system comprises two networks. The ABCnet links the Level C (discovery1) with the Level B and any VME based Level A (such as the CTD). The other network, shipnet, connects the remaining networkable devices. On D224 these included 4 Sun workstations, 3 terminal servers, 2 PCs and printers. In addition a number of user machines, including several MacOS machines, were also connected.

Each of the 4 Sun workstations had a number of data disks which were cross mounted so as to be available to each user regardless of which machine they logged onto. The only difficulty was that the user did not always benefit from being logged onto the correct machine to optimise their work. The majority of the data areas and the PSTAR software were mounted on "discovery5" as this was the fastest machine.

**RVS deck operations** *CD, DR and JW*

RVS SEG (Scientific Engineering Group) equipment and technical support was required for the following scientific operations during cruise Di224 A:

1. SEASOAR tows
2. CTD deployments
3. LHPR tows
4. SUMOSS operations
5. PES/EK500 deployments and recoveries
6. Non-toxic water supply
7. Milli-Q pure water system

The following additional SEG equipment was in service throughout the cruise to facilitate the various scientific operations:

1. Main 20T traction winch system and cable haulers
2. Main 10T traction winch system cable and haulers
3. Starboard gantry system
4. Stern gantry system
5. Mid-ships/AFT main hydraulic power pack and deck distribution system

6. Deck mounted portable winches
7. Stern mounted 30TM ACI~A cranes

SeaSoar Operations

The OTD SeaSoar was deployed using a portable deck mounted winch and cable. During the first towed deployment the vehicle data trace suggested the vehicle was travelling erratically through the water. On recovery of the vehicle it was discovered the towing cable had become severely damaged throughout its length, the damage suggesting the vehicle had been spinning as it travelled through the water inducing a significant torque on the cable. It was found that the cable cat's pawed throughout its length when tension was removed, the level of damage rendered the cable unusable for all future operations. Further SeaSoar deployments were made by means of a backup winch and cable stowed on the after deck.

CTD Operations

CTD operations were carried out using the OTD frame fitted with an ADCP. It was initially intended that the CTD package would be attached to the conducting hydrographic cable using a new conducting swivel. This proved to be unpopular with the electronics technicians, the general concern centred around the introduction of another variable into the system increasing the possibility of electrical problems. Consequently the swivel was not incorporated into the deployments. Only 15 CTD stations were made during the cruise, it was noted during several deployments the CTD had a tendency to rotate a number revolutions on being lifted out of the water, this further added to fears that a torque was being induced in the cable due to the CTD frame rotating as it travelled through the water column.

LHPR deployments

LHPR operations were conducted over the stern using the main winch system and the trawl cable. Good winch response was noted at low O/B loads (down to 200kg). Care had to be exercised when operating this vehicle in anything above moderate sea states. The vehicle was so light that even the slightest swell induced significant slack wire between the cable haulers and the stern gantry sheave during the early stages of deployment. With approximately 2-3 metres of swell, slack wire could reach within 2 metres of the AFT deck. For safety, the deck was cleared of non-essential personnel during deployment.

SUMOSS

This is an optical sensing package deployed on a conducting cable via a deck mounted slip ring winch. The package is approximately 1.5M high, 0.5M dia. and 40Kg in weight. The package was deployed over the port/stb quarter via the AFT 30TM cranes. A snatch block was hung from the crane hook, another fixed to a deck socket as a diverter. The package was deployed over which ever side of the ship was experiencing the maximum light intensity.

Precision Echo Sounder (PES) Fish/winch

The PES was used throughout the cruise; despite a fault with the winch park brake, about which a detailed report has been submitted, deployments and recoveries were carried out without problem.

EK500 Fish/winch

The EK500 fish was deployed from its own portable winch over the port side of the after deck. Several points should be noted regarding deployment and recovery operations.

a) There was suffcient clearance between the sheave block and the sheave cheek plates to allow the cable to be pulled between the two and become jammed.

b) During deployment, the EK500 fish floated for a considerable period of time while its hull filled with sea water. This allowed the swell to lift the fish generating slack wire between the fish and the winch drum.

c) The fairing material is quite inflexible and would not deform when the cable was passed over the sheave with the fairing pointing into the sheave groove.

d) The fairing securing clips are made from a significantly harder and tougher material than the cable skin. On the occasion when the cable became fast between the sheave and cheek plate the securing clips dug into the cable damaging the cable skin.

e) The brass fairing end clips did not adequately secure the fairing to the cable, this allowed the fairing to ride up the cable during towing operations.

Non-toxic water supply

The non-toxic supply was run throughout the cruise supplying the scientific spaces as required. No problems were encountered with this system.

Milli-Q pure water system

The Milli-Q 185 pure water production unit was run during the cruise with no problems.

Main 20T/10T winch systems

The main winch systems were used for the deployment and towing of the following equipment:
1. LHPR - 20T winch, trawl cable.
2. CTD - 10T winch, 10mm conducting cable.
Both systems functioned well during the cruise.

STBD Gantry

Whilst carrying out routine maintenance, it was noted that the after most gantry roller cylinder assembly and its guard had been damaged at some point prior to the cruise, however, this situation did not impede the use of the gantry for scientific operations required during this cruise.

Stern gantry system

The stern gantry was used to good effect during the cruise. No problems were encountered during operations.

Mid-ships / aft hydraulic power packs

Both power packs were used to power the portable winches mounted on the after deck. No operational problems were encountered during the cruise.

Stern 30tm acta cranes

Intermittent control problems had been noted with this crane. The electrical controls "dropped out" randomly (all services): operating the crane in manual override hydraulically for a brief period overcame the problem. The crane electrical controls could then be energised (green button on console), and all services operated as required: no cause was identified. The port slew solenoid control block failed during the cruise and was replaced.

**OTD SeaSoar/CTD/winch operations** *JS and BW*

Vertical Profiling CTD Operations.

The equipment used for CTD profiling during the OMEGA cruise was as follows:

Neil Brown MKIIIb CTD capable of measuring Pressure, Temperature, Conductivity and Oxygen Current, plus an 8 channel multiplexed 12 bit Analogue to Digital converter (ADC).
The ADC was interfaced to a variety of sensors as follows:
Chelsea Instruments Fluorometer.
Chelsea Instruments Transmissometer.
Simrad Altimeter with 200 metre range.

The sensor packages were mounted in a frame approximately 2 metres high and 2 metres diameter, carrying an FSI 24 bottle Rosette Multisampler. During this cruise only 12, 10 Litre, Niskin bottles were mounted in alternate positions around the Rosette.

SIS Reversing Thermometers and Pressure Meters were mounted on bottles 1, 6 and 11 as follows:
Bottle 1. T714, T401, P6132
Bottle 6. T746, P6293
Bottle 11. T743,

Data from the CTD were logged both on a dedicated PC and also collected by the RVS Level 'A' system where it was averaged over 1 second intervals and then passed to the level B and C systems for calibration and analysis during the cruise.

A total of 15 CTD stations were occupied during this cruise. There were a small number of minor problems. On a few occasions the reversing thermometer lanyards caught under the top caps of the Niskin bottles preventing correct operation. The firing of Niskin bottles was reliable throughout with one exception on station 13039 where the control software behaved in an erratic manner. A second Level 'A' was used to log the bottle firing times apart from a gap of 5 stations which were not logged due to a faulty connector. Bottle files were recovered in all but one case from the CTD PC acquisition system.

SeaSoar Operations.

Two SeaSoar vehicles were carried for the cruise and both were used. SeaSoar is a towed vehicle capable of undulating under control from a deck system between the limits of surface to 550 metres depth depending upon the length of faired cable used. In this case approximately 500 metres of cable layed on a vertically standing winch drum were used for all but the first deployment. Depths of 360 metres were achieved with this system.

The vehicle was towed at a ship's speed of 7.5 - 9 knots and carried the following sensor packages:

Neil Brown/GO MKIIIc CTD.
Chelsea Instruments Fluorometer.
Par Lightmeter.
SeaTech Light Scattering sensor.
Focal Optical Plankton Counter.

The first deployment was carried out using a horizontal winch carrying approximately 600 metres of faired cable. This winch was on loan from RVS. From the start of this first run, control was erratic and rarely achieved a full depth cycle. At times flight was totally random. It was decided to leave the vehicle deployed until morning. On recovery it soon became evident that the vehicle had been spinning. As load came off the cable large numbers of "cats paws" appeared. The cable was detached from the vehicle and streamed from the Ship with a weight in an attempt to relieve the torsion in the cable. This failed so it was decided to abandon use of this cable and use the vertical drum OTD winch which had been brought as a backup. The precise cause of the random behaviour of the vehicle was not clear but a number of factors could have influenced it. The rudder assembly was fitted with tight bearings, there was up to 2 knots of current shear at right angles to the tow line and the OPC was mounted beneath the vehicle in a position slightly forward of the wings.

The sensors were transferred to the second SeaSoar vehicle but without the OPC and the first large scale survey completed. This survey provided an opportunity to try a hydraulic unit of new design manufactured by Chelsea Instruments. This performed satisfactorily at first but failed after approximately 100 hours of use.

During the first and second large scale surveys, the vehicle was recovered three times due to failure of the electrical termination to the tow cable. A multi-pin connector was used to terminate the tow cable, this was then split to serve the various sensors. It was the three way splice that failed on each occasion. After this an older method of separating the tow cable conductors into groups for each sensor was used and performed without failure.

The OPC was re-fitted to the vehicle for the second large scale survey and the three fine scale surveys but mounted approximately 4 inches further back from it's original position. Performance of the vehicle did not appear to be impaired in any way this time. The fine scale surveys were completed without problems.

An opportunity was provided at the end of the cruise to test the flight of the vehicle with the tight rudder assembly and try to provide an answer to the conundrum over earlier flight problems. The vehicle did appear to spin once or twice in the down cycle but achieved the required minimum and maximum depths with a reasonable performance. The only conclusion from this test was that the rudder certainly influenced the performance but was not the sole cause of the loss of flight control.

## 4. SCIENTIFIC INVESTIGATIONS

### Navigation/Heading/Gyro *GN, GG and MB*

The key points here are:
*(i)* that real time differential GPS (DGPS) was available on this cruise.
*(ii)* that the Ashtech, 3D GPS system, antenna #2 was found to be faulty and replaced midway through the cruise; after this it performed much better

Differential GPS

A real time differential GPS (DGPS) service was purchased from Racal Skyfix for this cruise, as in the Vivaldi II cruise, Di223, and the first Omega cruise in October 1996 on BIO *Hesperides*. Its availability greatly improved the accuracy of GPS positional fixes. This was found to give much smoother ship velocities, important for calculating water velocities from the ADCP.

Tests of its accuracy were performed while the ship was tied up in Almeria harbour on the 11th December. Using fixes from the Cadiz transmitter [~ 370 km from Almeria] over a three hour period in the morning, standard deviations of 0.4m [40cm] in both longitudinal and latitudinal positions were obtained (**Figure 8**). Fixes were taken in the afternoon from the Rome transmitter, ~ 1470 km distant. The positions obtained from the Rome transmissions were less accurate, but still good, with standard deviations of 1.5 and 2.2m in longitudinal and latitudinal positions (**Figure 8**). These accuracies of ~2m are probably more representative of those which might normally be obtained in the open ocean. Accuracies of <0.5m would probably only be obtained close to DGPS transmitters, perhaps in coastal waters. The accuracy of the fixes is in any case limited by the movement of the antenna as a result of ship motion. Since the antenna is high on the ship, at a height of ~30m, a normal roll of ~5° will lead to lateral motion of 6m peak to peak (standard deviation ~1m).

The Almeria trials were particularly useful as in fact the Cadiz transmitter later failed (in the early morning of Saturday 21 Dec) and transmissions had to be taken from Rome for the remainder of the cruise. Apart from this failure of the Cadiz transmitter, availability of DGPS transmissions was generally very good with only a few breaks longer than 30 seconds.

Ashtech 3D GPS

The quality of the information on the ship's orientation (heading) gained from the Ashtech 3D GPS system was, as usual, variable. Particular problems were however found on this cruise.

It had been noted on the Vivaldi II cruise, Di223, that Ashtech coverage was poor. This was also the case early in this cruise. It was discovered that the problem was associated with a signal to noise ratio for antenna #2 that was 20dB lower than for the other antennae. After checking the preamplifier and cable, the problem was isolated to the #2 antenna itself, where corrosion of the baseplate had allowed salt water to enter. The problem worsened, and by the time the Mediterranean was entered on the 2nd of December, the Ashtech gave very few good orientations at all. The antenna base was then removed, dried out and refitted, enabling Ashtech orientation fixes to resume. However the signal to noise ratio for antenna #2 was still poor and the orientation fixes were still patchy [e.g. on the 8th Dec, from 719 two minute periods only 328 had acceptable orientation values]. Hence a new antenna was ordered, to be installed at the midway port call in Almeria on the 11th. After the new antenna had been installed on the 11th, a marked improvement in the number of good fixes was obtained [e.g. 522 good two minute periods of attitude measurement were obtained on the 22nd].

Since headings from the Ashtech are not continuously available, they are not used directly. Instead they are used to correct headings from the ship's gyro compass, which may be in error typically by 1–2°. The construction of this correction is not straightforward, as many of the Ashtech headings are degraded by excessive pitch and roll, or an unsatisfactory constellation of satellites. Further noise in the apparent value of the correction arises from the interplay of ship motion, with periods of seconds, and a phase lag or lead of 1-2 seconds between the apparent gyro and Ashtech times.

Even after obviously poor headings are eliminated, considerable noise still remains. Furthermore typically perhaps 200/720 2-minute periods in the day have no good Ashtech headings, so corrections have to be created for those periods, either by interpolation or perhaps by model. The observed correction varies rapidly after course changes. It executes clockwise 'Schuler oscillations' [with magnitudes of ~0.3°, periods of ~84mins] as the gyro settles down after the turn. Corrections observed on this cruise also seem to show spikes *as* the ship turns, perhaps associated with a gyro response which is too slow. It is thus difficult to model the dynamic correction simply where there is no data and the course is changing. This is clearly more of a problem on a fine scale survey with short legs than on long sections.

On this cruise, corrections were therefore made manually. 1-second Ashtech headings with poor satellite constellation were eliminated, together with those at high values of pitch and roll or abnormally large differences from the gyro. Histograms of pitch, roll satellite quality and correction magnitude were inspected, and data outside the central peaks excluded. The corrections were then averaged over 2-minute periods. Extensive manual editing using a graphical editor was then performed, together with despiking. The resulting 'good' corrections, rather reduced in number and still a little noisy, were stored as 'real' corrections. For reference, in **Figure 9**, gyro corrections, after processing in the manner described, are plotted against gyro heading for the period 6/12/96-25/12/96. Corrections for those periods with no data were found either (i) [for the large scale survey and fine-scale surveys 1 & 2] from Griffith's cosine cusp model of gyro error against heading (Griffiths, 1994), or (ii) [for fine-scale survey 3] by simple linear interpolation. These created 'model' corrections. In the latter case the interpolation was followed by smoothing of the whole correction set.

## SeaSoar/CTD data *DS and HS*

SeaSoar data

During RRS Discovery cruise 224 a SeaSoar fitted with a CTD, a fluorometer, a light sensor and a back scatter sensor was deployed. A detailed description of the processing stages was given in the data report from the first Omega cuise aboard BIO Hesperides (Allen et al., 1997). Here we give only a brief description and note the differences in procedures between the two cruises.

### *Data acquisition*

The times when seasoar was deployed are listed after the cruise narrative in section 2

*Large scale survey 1*

A large scale survey of the northern part of the frontal region (**Figure 2**). Problems in control of SeaSoar resulted in a restriction in the range of depths that were sampled during the first half of the survey. There were some problems in time stamping by the level A software. These are described later.

*Large scale survey 2*

A large scale survey of the whole region between 2° 20' W and 0° 30' E. (**Figure 3**)

*Fine scale surveys 1, 2 and 3*

High resolution surveys of the Almeria-Oran frontal region. Fine scale survey 2 was comprised of 12 legs (**Figure 5**). The other surveys followed the same track but had to be shortened because of time contraints, fine scale survey 1 had 11 legs (**Figure 4**), and extreme weather conditions, fine scale survey 3 had 10 legs (**Figure 6**). Approximately 30 minutes of data was lost due to a failure of the level A system at 21:57 on day 356 (fine scale survey 3). This data was recovered from the tapes written by the deck unit data acquisition PC.

*Algerian current survey*

The Algerian current east of the Almeria-Oran front was surveyed and data were collected along a further ERS-2 track (**Figure 7**). Trials of the OPC and seasoar stability were also conducted during this time

***Data processing***

Data from the CTD deck unit were passed to an RVS level A acquisistion system in which the data were averaged to one second values and a time stamp was added to each record. The number of frames in the average and the rate of change of temperature were also evaluated. Data were subsequently passed to level B (logging) and level C (processing).

The data were read from the RVS level C using datapup, to enable further processing with PEXEC software, every four hours. Extreme values of pressure, temperature and salinity were deleted from the raw data before applying the initial calibration described below. During the cruise it was noted that there were a significant number of records with low (<16) numbers of frames. Therefore an additional step in processing was introduced to filter out records for which the number of frames was less than 16 or greater than 40. Typically one in two thousand records were affected.

The initial calibrations applied to the data were

$press(\text{dbar}) = -43.6421057 + 3.2280473 \times (0.01 \times praw)$

$temp(°\text{C}) = -2.70934 + 4.93708996 \times (0.0001 \times traw) + 0.000239076 \times (0.0001 \times traw)^2$

$cond(\text{mmho}/cm) = -0.012146727 + 0.960765192 \times (0.001 \times craw) + 0.0000461212 \times (0.001 \times craw)^2$

$fvolts(\text{volts}) = -4.960675 + 1.51391 \times (0.0001 \times fraw) + -0.000002982 \times (0.0001 \times fraw)^2$

$bscat(\text{volts}) = -4.960675 + 1.51391 \times (0.0001 \times braw) - 0.000002982 \times (0.0001 \times braw)^2$

$light(\text{volts}) = -4.960675 + 1.51391 \times (0.0001 \times lraw) - 0.000002982 \times (0.0001 \times lraw)^2$

The platinum thermometer has a slower response than the conductivity cell. Thus the temperature values needed to be advanced. This was done by calculating a corrected value, $T_c = T + \tau \times deltat$ , where deltat is the change in temperature during the one second average as evaluated by the RVS level C software. The time lag, $\tau$, was chosen to be 0.15 seconds by inspection of T/S profiles using a number of different lag times. The choice was made to minimise salinity spikes where there were rapid changes in vertical temperature gradient.

Salinity was evaluated from the calibrated values of conductivity, temperature and pressure. Frequently there are low spikes in salinity where the SeaSoar reaches the surface. After examination of a histogram of salinity values a cut off was selected (for each 4 hour file) below which all salinity data were set to zero. The cut-off values varied from 36.0 to 36.7.

Material can get caught in the aperture of the conductivity cell resulting in sudden drops in the value of salinity. Sometimes this appears as a constant offset with salinity stepping up to the correct value when the cell clears or the value drifts back over a period of time. To overcome this problem all of the profiles were examined both on temperature-salinity plots and salinity-pressure plots. When a fouling event was found either a constant correction was applied if there was a constant offset, or the affected cycles were set to absent if there was a drifting offset. The number of such offsets was relatively small compared to that found when towing SeaSoar in Atlantic waters. There were large variations in the temperature-salinity characteristics in the area studied (**figure 10**). Therefore two areas, one either side of the front were selected to compare the temperature salinity characeristics of the measurements in the different surveys. These comparisons suggested that any drift in the salinity was small (less than .02). A detailed analysis will be made by comparison with the calibrated TSG data.

Values of light in physical units were calculated from the calibration: $\ln\left(light(Wm^{-2})\right) = -11.65617 + 4.854 \times lvolts$. Because light varies exponentially with depth, the values have been left in log form. A consistent difference between the up and down cast was evident for light values just above the threshhold of the sensor This could be indicative of a variation in the attiude of seasoar. However, a preliminary examination of the data suggests hysteresis.

A Sea-Tech optical backscatter probe was fitted to SeaSoar during both of the Omega cruises. The sensor projects light into the water from two 880 nm LEDs and backscattered light is measured by a solar-blind silicon detector mounted next to the LEDs but sparated by a light stop. Within the upper 4m the backscatter probe gave unrealistically high (low) values during the day (night). These values have not been edited from the data at this time.

After initial calibration and editing, the SeaSoar data were merged with navigation data so that distance run could be added to each record. The navigation data used was averaged to one minute intervals. Merging was done using the common time variable. At about 12 noon on day 342 (7/12/97) a difference of a few minutes between the seasoar time (added by the RVS level A) and the ships clock was noted. Unfortunately the exact difference was not recorded. The seasoar/CTD clock was reset at 12:14. However, a few hours later a drift between the ships clock and the CTD clock was again apparent. To overcome this problem a system was set up so that the seasoar/CTD clock was reset using the ship's clock every 30 minutes during the remainder of the cruise. As a consequence:

1) There is an unknown and uncorrected drift of up to 2 minutes in the seasoar time between the start of the second large scale survey (16:47 on Jday 341) and 12:13 on Jday 342.
2) There is an apparent gap in data from 12:13 to 12:14:34 on Jday 342
3) A linear correction to the time was applied to the level C from 12:14:34 to 17:15 on Jday 342.
4) From 17:15 on Jday 342 onwards there are one or two records missing every 30 mins when the clock was reset; and there may be differences of a few seconds between the seasoar/CTD time and the ships clock.

The same unit was used for the level A logging of data from the lowered CTD and corrections to that data were also made for CTDs on Jdays 338, 339, and 340 (further details are given later). It is therefore also likely that there were errors in the Seasoar time during the first large scale survey.

At the end of each survey the one second data were appended and averaged into an 8 m vertical by 4 km along track horizontal grid to enable near real time visualisation of the data (**Figure 11**). Salinity calibrations during the cruise were made against hourly water bottle samples from the non-toxic seawater supply and a thermosalinograph calibration, described later. The linear calibration applied took the form

$$Sc = 36 + a + b(Sr - 36)$$

where Sc is the calibrated salinity, Sr is the un-calibrated salinity and a and b were

-0.007 and 1.000 for LSS1
-0.006 and 1.000 for LSS2
-0.005 and 1.000 for FSS1
-0.001 and 0.994 for FSS2
-0.004 and 0.997 for FSS3.

CTD data

During this cruise 15 lowered CTD stations were made. Twelve bottles, a fluorometer, a transmissometer, an altimeter and an ADCP were also mounted on the CTD frame.

### *Data acquisition*

A summary of the 15 CTD profiles is given in **Table 1**.

### *Data processing*

Data from the CTD deck unit was passed to the level A acquisistion system in which the data were averaged to one second values and a time stamp was added to each record. The number of frames in the average and the rate of change of temperature were also evaluated. Data were subsequently passed to level B (logging) and level C (processing). Data were then copied from the RVS level C to enable further processing using PEXEC software. Extreme values of pressure, temperature and salinity were deleted as were records for which the number of frames was less than 12 or greater than 20. The initial calibrations described below were then applied.

$$press(\text{dbar}) = -9.3832 + 0.996263 \times praw + 5.743323 \times 10^{-7} \times (praw)^2$$

Further corrections were made (by the program *ctdcal*) for the effects of temperature and hysteresis.

$$temp(°\text{C}) = -.0165549 + 4.99282 \times 10^{-4} \times traw + 7.97259 \times 10^{-13} \times traw^2$$

The platinum resistance thermometer has a slower response than the conductivity cell. Thus the temperature values have to be advanced; this was done by calculating a corrected value, $T_c = T + \tau \times deltat$ , where deltat is the change in temperature during the one second average as evaluated by the RVS level C software. A constant time lag, $\tau$, of 0.2 seconds, was chosen to minimise salinity spikes where there were rapid changes in vertical temperature gradient.

$cond(\text{mmho}/cm) = 0.988156 \times 10^{-3} \times craw$

Conductivity values were then corrected for the cell material deformation using the default values in *ctdcal.*

Salinity was evaluated from the calibrated values of conductivity, temperature and pressure. The vertical gradient of salinity was very large, up to 0.04 $m^{-1}$. Thus large discrepencies between the calculated salinity values and those measured from the bottle samples were found within the halocline. A final calibration has not yet been made.

$trans(\text{volts}) = 0.00181789 + 1.21934 \times 10^{-3} \times traw + 6.05678 \times 10^{-10} \times traw^2$

The values were then multiplied by the ratio of the nominal air value (4.2) to the deck air value (4.692).

$temp(°\text{C}) = -.0165549 + 4.99282 \times 10^{-4} \times traw + 7.97259 \times 10^{-13} \times traw^2$

No further calibration to chlorophyll samples has been made at this stage.

$oxyc = 1.35 \times (0.001 \times oxycraw)$

$oxyt = 0.128 \times oxytraw$

$oxyfrac = oxyc \times e^{\{(-0.03 \times oxyt)+(0.00015 \times pres)\}}$

However, no oxygen titrations were made from the bottle samples on this cruise to validate the calibration.

During seasoar operation a problem with the software clock in the seasoar/ctd unit was noticed. Examination of the CTD data showed that four CTD casts (Discovery stns. 13021, 13022, 13023, 13024) had been affected. Corrections were made to the time variable for these casts in the form of a linear calibnaration. The values of the corrections were determined by comparing the rate of change of pressure in the CTD data with the rate of change of cable out recorded in the winch file (in which the time was given by the ships clock). The corrected time is correct to within a few seconds. To overcome this problem a system was set up so that the seasoar/CTD clock was reset using the ship's clock every 30 minutes during the remainder of the cruise (see SeaSoar section).

**Salinity bottle sample analysis and thermosalinograph data** *HS, SA, JA and TG*

Salinity bottle samples

Salinity samples were taken from each CTD Niskin using 200ml glass sample bottles, closed with disposable plastic inserts and screw-on caps. Each bottle and cap was rinsed three times with sample water to remove any old sample and any salt crystals from the neck of the bottle, and then filled to the base of the neck and sealed. Once every hour a sample was also taken from the outflow of the thermosalinograph for calibration purposes. Samples were left in the constant temperature laboratory for at least 24 hours before being analysed to allow the temperature of the samples to reach equilibrium.

All analyses were carried out using a Guildline Autosal model 8400A fitted with an Ocean Scientific International peristaltic sample intake pump. An Autosal model 8400 was also on board and operable but was used as a backup system only. The salinometers were situated in the constant temperature laboratory. The laboratory temperature was set at 18°C and the salinometer water-bath temperature was set at 21°C. The laboratory consistently ran at slightly below 20°C (as measured by a laboratory thermometer) under these settings. The Air Conditioning compressor cut out once during the cruise (day 358) leading to an increase in the lab. temperature to 25°C. This returned to 20°C by the end of the day, and no salinity samples were analysed during this time to allow the salinometer to regain a constant water bath temperature.

Two major improvements had been made to using the 8400A salinometer on Discovery. Before sailing the salinometrer was fitted with a new conductivity cell, as the geometry of the old cell had made it notoriously difficult to fill. The new cell revolutionized the measurement procedure with only 3 or 4 bubbles forming during the entire cruise. The second improvement was the provision of a fully adjustable, stable chair, which made analysis possible, even comfortable, during classic Discovery roll events. All analyses were carried out by Helen Snaith, Steve Alderson and John Allen with two special guest appearances by the PSO, Trevor Guymer. The stability and ease of use of the 8400A salinometer were fully tested by the ability of the PSO to take quality measurements after only a brief introduction. If it were not for the inherent monotony of the task itself and the incredibly depressing nature of the CT lab, with no company and a constant howling gale around the ears, salinity analysis on this cruise might almost have been pleasurable.

Standardisation was achieved by use of IAPSO standard seawater ampoules. Only a single standard batch P130 was used during the cruise. Standards were run at the beginning and end of each crate of 24 hourly TSG samples, or samples from every two CTD casts (typically 20-26 samples). The correction to the Guildline ratio obtained from the standards throughout the cruise is shown in **Figure 12**. The corrections to the Guildline ratios determined from the standards were all less than 0.00006, or 0.0338 Salinity Equivalent (SE). The variability in the standrds was very small over the cruise, (s.d 0.00008, 0.0002 SE) with no discernable drift over time until the last four readings when the value increased.

Duplicates were drawn from Niskin bottle 1 on each cast and also from a second bottle, usually near half depth. In addition, repeat firings were often made in the near surface water to allow for extra sampling. These repeat firings were "blind" to the analysts. In all 42 duplicates were taken. The standard deviation of salinity differences between all these duplicate readings was 0.0029. Duplicates from the deepest bottles were always more consistent than those from shallower firings, but it is thought this may be due to sampling errors. The worst, results were from repeat firings at shallow depths and these larger differences may represent true differences between samples. A summary of the duplicate results is given in **table 2**.

Thermosalinograph

Underway surface conductivity and temperature measurements from the thermosalinograph (TSG) were continuously logged using the RVS surflog system. The equipment consisted of :
a) Falmouth Scientific Inc (FSI) Remote temperature sensor mounted near the non-toxic intake in the forward hold, at a depth of 5 m.
b) FSI conductivity and temperature sensors mounted in a polysufanone housing in the hangar lab. A header tank was used to provide a constant flow of debubbled non-toxic water to the polysufanone housing. The header tank was checked periodically throughout the cruise.

The data were sampled at 1Hz and averaged over 20 s periods before logging. The temperature and conductivity modules were initially calibrated using laboratory standards and calibration data. The 20 s averaged conductivity measurements were used to determine salinity, given a pressure of 0 bar and the housing temperature (peos83). These salinity values were then despiked (pmdian), records being rejected if salinity differed by more than 0.05 from a 5 point median. The data were than averaged over one minute periods (pavrge) and merged on time with the bestnav (1 minute averaged) navigation data (pmerge) to add latitude and longitude. No temporal adjustment has been made for the time taken by the nontoxic supply to travel from the intake to the TSG. By looking for sharp temperature gradients in the remote and housing temperatures from the TSG, and measuring the time offset between them this has been estimated as being of the order of 90 seconds.

In order to calibrate the TSG salinity values, the data were merged on time with salinity values from the hourly bottle samples (pmerge). The TSG salinities were then calibrated using a linear fit of bottle salinity to TSG values and these calibrated salinities were then merged with the bottle salinities to give the final residuals. On approach to Oran on day 341 the non-toxic supply to the header tanks was switched off for 8 hours. During the mid-cruise port call to Almeria (day 346) the supply was again switched off for 11 hours, and the conductivity and temperature sensors were also switched off. The changes in response noted after each of these shut downs led to the data being processed as three discrete sections: Southampton-Oran (001), Oran-Almeria (002) and Almeria-Catagena (003).

The mean offset of the TSG salinity values was approximately 0.2 (reading high) compared with the sample data. A time drift in salinity was detected when the bottle data were merged with the TSG data for the entire cruise. However, there were also several jumps in the bottle difference which tended to offset this drift and so no overall time calibration was applied to the data. The major error in calibration appeared to be timing of the bottle samples. Where the salinity gradient was small, the rms difference of the sample and TSG salinities was also small. The results of the calibration for the three sections of data are shown in **table 3**. **Figure 13** shows the calibration for the third section, covering the three fine scale surveys.

**Optical Plankton Counter (OPC)** *SA and JA*

The OPC instrument (Herman, 1992) used on SeaSoar was fitted with an acrylic flow insert to reduce the tunnel cross section to 0.001 $m^2$ for towed use and was mounted beneath the SeaSoar body in place of the usual torpedo shaped balance weight. This cruise was only the second time that an OPC instrument had been mounted on SeaSoar and it was discovered that certain mounting positions may inhibit a stable flight path through the water. These problems are discussed in detail earlier in this report. The OPC estimates the equivalent spherical diameter (ESD) of particles which break a 640 nm wavelength LED light beam. The instrument is designed to resolve ESDs between 250 μm and 3 mm.

Data from the Optical Plankton counter were written to a partition on the Unix system mounted on a PC deck unit. Every four hours, a new output file was opened and the previous one closed, in order to process the data in manageable sized files. Preliminary processing was performed on the these four hour files using the processing route developed by Raymond Pollard (Pollard et al., 1996). Two main problems arose. Firstly the proprietary software controlling the PC was confusing to use and, on a number of occasions, lead to new files being created with the wrong filename. Secondly, because the PC filename was incremented using a 2 digit code, later files appeared with the same number, which lead to confusion during the subsequent processing.

Detailed examination of a 4 hour data file from the second large scale survey appeared to show a large difference in the vertical profile of particle counts between ascending and descending SeaSoar profiles. There was no obvious explanation for this and insufficient time during the cruise to examine all the raw data in this detail: however, contoured sections from LSS2 and the three fine scale surveys looked normal and correlated well with the upper ocean structures apparent in the fluorometer and IR backscatter data. One possible explanation was a problem in the processing of the raw data stream. A mistake in one of the recently developed software algorithms was not considered very likely as these had been developed, tested and used successfully on a cruise only 11 months before. An offset in the time stamp between the OPC and the SeaSoar data streams due to the level A clock signal errors, discussed earlier, was also considered but was not identified. A second possible explanation was that the attitude of the SeaSoar vehicle was affecting the flow through the OPC instrument in different ways during ascent and descent. Towards the end of the cruise there was sufficient time to carry out an experiment designed to test this. There was, however, insufficient time to work up the data from this experiment and reach any conclusions before the end of the cruise.

## Vessel Mounted Acoustic Doppler Current Profiler (VM-ADCP) *SR and GG*

ADCP bottom track calibration

The ADCP deck unit was set up to record data for 100 bins, each 4 m thick, with an offset of 8 m and a 2 minute ensemble period. The bottom track calibration was done on the Celtic Shelf, Jday 333 between 1800 and 2000 hours, at a ship speed of 8 Knots.

ADCP data was processed with PSTAR software after logging through the RVS level C. The data were read into PEXEC using *adpexec0* with the clock correction provided by *adpexec1*. Heading was obtained from Gyro and Ashtech with *gyrexec0* and *ashexec0* respectively. The Ashtech heading had significant gaps and many outliers were removed using *peditc* after manual assessment using *phisto* on pitch, roll and heading (see earlier discussion). The difference between Ashtech and gyro (a-ghdg) was averaged to 1 minute intervals using *pavrge* then after interpolating over gaps in gyro heading, *pgyro* was used to model missing values of a-ghdg.

The ashtech and adcp data sets were merged using *adpexec2*, which also corrected the adcp heading. The average bottom track velocity was computed over the calibration period and compared to the average ship velocity over the ground from DGPS position fixes at the start and the end of the calibration run.

From ADCP bottom track:

bottomew:150.49 cm/s
bottomns: 345.23 cm/s

to give:

magnitude = 376.60 cm/s and direction = 203.53 degrees

From DGPS:

velew:170.69 cm/s

velns: 336.99 cm/s

to give:

magnitude = 377.76 cm/s and direction = 206.86 degrees

The misalignment and scale factor derived from these data were:

A=1.0031

phi=3.31

These compare well with A=1.0054 and phi=3.57 derived on the immediately preceeding cruise.

ADCP data processing

ADCP data was gathered in files of 12 hours using *adpexec0*. The data is stored in two different files, one gridded (depth dependent parameters) and another non-gridded (depth independent parameters). Clock correction was applied with *adpexec1* to both the gridded and non-gridded files.

Velocities relative to the ship's axes were rotated to velocities relative to geographic axes with *adpexec2*. This macro merges adcp data with Ashtech derived heading corrections using *pmerge*, calculates speed and direction from ADCP E and N velocities with *pcmcal*, corrects heading (using a-ghdg values) by running *parith* and finally converts speed and corrected direction back to ADCP E and N velocities. The ADCP data were then corrected for misalignment angle and scaling factor in *adpexec3*.

Finally, in *adpexec4* the ship's velocitiy over the ground was calculated from one second differential GPS positions 120 seconds apart. And the absolute water velocity profiles were derived by removing the ship's velocity from the corrected ADCP relative velocity profiles.

**Lowered ADCP (LADCP)** *NC*

Following on from the preceeding Vivaldi cruise, D223, the CTD set-up used for this cruise contained a recently developed Lowered ADCP package. With the installation in place, is was decided that it be used on most CTD stations, especially the deeper ones which extend beyond the range of the shipboard ADCP. The instrument in the CTD frame was an RDI 150kHz BroadBand ADCP (phase III), with 30 degree beam angles. The instrument was brand new for Vivaldi, and had a shorter pressure case, than other ADCPs used in this way to date by SOC. This had the advantage that it can be fitted centrally in the standard CTD frame, with a separate in-house 36 volt alkaline battery pack located nearby. The use of alkaline battery packs was a temporary solution for providing power to the LADCP. A system of rechargeable battery packs should be in place for future cruises.

The instrument was set-up 5 minutes prior to each CTD cast, using a water-track setup as described later in this section. A bottom track setup was not used as this had caused loss of data during the previous cruise due to battery voltage dropping sufficiently to cause the instrument to turn-off. With a half used battery pack already installed in the frame, and not very many CTD stations planned, it was decided that bottom tracking was not essential - the use of differential GPS and comparisons with the shipboard ADCP for absolute velocities were considered sufficient.

Whilst being set-up prior to CTD casts, and for downloading data, external power was supplied to the unit via the communications lead. There was sufficient diode protection inside the ADCP for the battery supply to be overriden by applying external power at a slightly higher voltage (i.e. 40 volts, with the battery packs used on this installation).

Data Processing

The processing of LADCP data was carried out using software developed by Eric Firing at the University of Hawaii. His software used a combination of 'PERL' scripts and MATLAB 'm' files to process the data, which are stored in a CODAS database. The processing stages are summarised below :

1) Binary ADCP files were extracted from the instrument, and scanned using 'scanbb.exe' to obtain useful information about the cast - e.g. time in water, out of water, number of good ensembles, and the cast depth as an estimate of integrated vertical velocity.

2) The ADCP data were then loaded into a CODAS database. These data included magnetic variation (-2.75 degrees in this case), nominal cast position, times, and good ensembles specified by the previous 'scanbb' step.

3) At this point, all of the raw data, and database files were copied to a location on the SUN using PC_NFS. The database files from the PC were then converted to SUN format CODAS files. Then a first look at the data was obtained by editing and running two macros, one of which was a MATLAB 'm' file.

4) Generally, the next stage of processing involved manipulation with the calibrated CTD data for the cast. The CTD depth data were interactively matched to the ADCP vertical velocities

within MATLAB, and then this true depth information was merged into the CODAS database for the cast, together with sound speed data corrected for temperature and salinity.

5) GPS information was also included at this stage to obtain absolute currents (necessary if bottom tracking was not used, as in this case). GPS positions were only required for the time the instrument went into the water and the time the instrument came out of the water on each cast.

6) Further data processing in MATLAB; firstly, differentiated the ensemble velocity profiles with depth to obtain shear (baroclinic velocity) profiles and averaged the shears into 5 m depth bins; and secondly, integrated the averaged shear profile into upcast and downcast absolute velocity profiles using the GPS position information. This stage removed high frequency package motion and put back the depth-averaged (barotropic) velocity component (equivalent to ship's diplacement during the station), which was removed when calculating the shears.

Processing of LADCP data on this cruise was not a priority task. Comparisons of LADCP, VM-ADCP, and ACCP data have been made on earlier cruises (Bryden, 1995) and so are not included here. Brief comparisions during the cruise did, however, show good agreement.

**Acoustic Current Correlation Profiler (ACCP)** *GG*

This was the third *Discovery* cruise for the acoustic correlation current profiler (ACCP), see reports Bryden (1995) and Leach and Pollard (1997), cruises D214 and D223, for previous details. The ACCP is manufactured by RD Instruments, San Diego, but it is not a production item, rather it is an experimental pre-production prototype. It has several deficiencies in performance and we are working with RD Instruments to fully characterise the instrument and hopefully to improve its suitability for routine use.

As little attention had been given previously to establishing the bottom tracking performance a comprehensive calibration against DGPS velocities and the Ashtech 3DF heading was completed. The main results were as follows.

1) The velocity scaling factor *A* ($Speed_{DGPS}/Speed_{ACCP}$) was 0.9391 with a standard error of 0.0038, a regression coefficient squared of 0.9975 and a zero intercept of 2.8 cm $s^{-1}$.

2) There was no correlation between *A* and ship's speed, but there was a statistically significant correlation between *A* and depth, best fitted with a quadratic relationship (r=0.603) that showed $Speed_{DGPS}/Speed_{ADCP}$ to decrease by 3% between 500 and 2500 m.

3) The offset angle $f$ varied from 2.95° to 0.26° with a mean of 1.52°. The gyro error dependent on the course steered was a significant factor - contributing 25% to the observed variance.

4) The depth measurement performance of the ACCP was less than satisfactory, while 69 % of measurements over the depth range were within 30 m of those from a Simrad EA500 10 kHz precision echo sounder, 25 % differed by over 100 m. A deficiency in the bottom tracking algorithm resulted in the instrument recording false bottom echoes for extended periods.

ACCP water track performance on D223 had been particularly disappointing (Leach and Pollard, 1997), partly due to poor weather. The instrument was particularly sensitive to flow noise and bubbles near the transducer mounting. Operating at the low frequency of 22 kHz it was also susceptible to sea state noise.

Previous results had shown poor performance in the upper 200 m. A postulated explanation was ringing of the transducer and or mounting well. An experiment of (a) removing the top-hat, (b) replacing it, but with sound absorbing material around the stem showed no difference in performance. The upper 200 m data remained biased towards zero. Further observation noted that the Simrad EA500 echo sounder, when operating with the hull transducer, showed 'blanketing' in the upper 50 m, a phenomenon that was reduced to 20 m and less when operating with the tow fish. A question remains as to whether there might be a common type of problem with low frequency transducers on RRS *Discovery*.

Under ideal weather conditions, at the moderate speed of 8 kt, ACCP current profiles were obtained to 1000 m. Close agreement was found between the ACCP and ADCP at a level of 241 m, but there was a tendency for the ACCP velocity components to echo the ship's velocity at deeper depths. This could be accounted for by a change in the calibration factor $A$ with bindepth. As bindepth is closely related to signal to noise ratio, the reason may well be that a bias towards zero occurs as the signal to noise ratio decreased. An initial analysis showed a correlation coefficient between ACCP absolute current and ship velocity of 0.81 at 1170 m decreasing to 0.47 at 768 m and to 0.09 at 594 m. The fact that this bias survived both the RDI poor data quality flag and subsequent editing (based on *pmdian* run in both depth and time) was worrying.

The data processing was slightly extended from that done on D223, scripts *csbtexec0*, *csbtexec1* and *csbtexec2* were written to handle the bottom track velocities, and the two dimensional editing stage was added to *csexec2*. Correction for gyro errors and calculation of absolute currents were done manually, usually after editing the files using the *plared* interactive vector graphical editor.

The ACCP is still far from being a routine instrument like the ADCP. There remain difficulties with the acoustics and with the calibration of the water track mode.

**ADCP backscatter/EK500** *NC, GG and PV*

ADCP Backscatter

It has recently been appreciated that the amplitude of the backscattered signal recieved by the ADCP transducer heads holds information about the density of particles in the water column. For a 150 kHz ADCP, particles 3-4 mm in size and larger are responsible for scattering the transmitted signal. This will include some of the larger zoo-plankton species (Flagg and Smith, 1989; Zhou et al., 1994).

There are two principal components to the calibration of backscatter amplitude, firstly the estimation of the background instrumental noise level at the transducer heads and secondly the determination of the attenuation of the sound signal by the water column. This second component is a function of the hydrography and therefore the determination of absolute backscatter amplitude, Sv (Mean Volume Backscatter Strength), at a particular bindepth must take account of the integrated attenuation over the water column between that bindepth and the transducer heads. A full description of the procedure for calibration for the background instrumental noise level at the transducer heads is given in RDI Technical note ADCP-09-04 Dec. 1990. This was followed on this cruise to determine the noise threshold value, ER, given below. SeaSoar hydrographic data were used to determine the attenuation of the water column.

The 2 minute time-corrected data from the Shipboard ADCP were appended into master files to coincide with the various SeaSoar surveys. In order to have finer resolution calibrated Sv data, these were not averaged onto a coarser time base, or onto distance-run to match SeaSoar 4km gridding, as has been usual in the past. Instead, the SeaSoar non-gridded data were averaged onto 2 minute intervals, and to 4 metre bins to coincide with those of the ADCP (In order to exactly match the time base of the ADCP, the ADCP data was also averaged onto a new 2 minute time base). To fill in the missing data in the horizontal from SeaSoar, 'gintr2' was then used.

Once the two data sets were of equal size and matching times, they were 'pjoin'ed into a single file, and 'calamp3' was run to calculate Sv (Allen et al., 1997; Roe et al., 1995). The system-dependant, environmental, and noise data used for calamp3 are given below:

| | |
|---|---|
| KS = 4.17e5 | System constant - frequency dependant |
| K1 = 183.15 | Power into water (Watts) |

| | |
|---|---|
| K2 = 8.95 | Dimentionless noise factor - average of the four beams |
| TE = 25.5 degrees | Temperature of water at surface (not used if no absent SeaSoar data at the surface) - an average for each survey |
| TX = 16.5 degrees | Electronics temperature, mean value logged during each survey |
| BL = 4m | Bin size |
| PL = 4m | Pulse length in metres |
| BK = 5m | Blank beyond transmit |
| ER = 15.88 | Noise measurement in counts. |
| FLAG = 1 | If 1, assumes that input data has had nominal calibration (0.42dB/count) applied. 0 for otherwise. |

Good quality Sv data were obtained throughout the entire depth range of the adcp (e.g. 406m), except during the few periods of very bad weather where the quality of the ADCP was sometimes severely degraded (good data to depths less than 100 m).

SIMRAD EK500 Echosounder

The SIMRAD EK500 is a scientific multi-frequency echo-sounder, of 3 frequencies at 38, 120 and 200kHz. It has an extremely wide (150 dB) dynamic range which enables it to measure target strengths reliably down to -120dB and thus, as well as measuring individual targets (which it has algorithms for resolving), it is ideal for measuring Mean Volume Backscatter Strengths (MVBS, or Sv). The 2 lower frequency transducers are split-beam transducers made up of 4 quadrants (4 separate transducers). They transmit as one, but receive individually so that differences in the phase and amplitude of the returned signal can be used to give position information of targets relative to the orientation of the beam. The 200kHz transducer is a standard single beam unit.

This was the first time the EK500 had been used on board RRS Discovery. The system was self-contained, comprising a portable winch with fixings for a 1m matrix which included a cradle for the tow-fish when in-board, and a davit arm which enabled the fish to be deployed over the ships rail without the need for a cut-away or gate. The winch drum contained 50m of cable, 25m of which was faired, and there was a junction box on the side of the drum for inter-connection cables to the lab-electronics. Slip-rings were not used because of the sensitivity of the equipment to external noise. The tow-fish was built from a stainless-steel framework, with fibreglass nose and tail, and clear polycarbonate covers in the central section where the three transducer heads were mounted.

The winch was installed on RRS Discovery the day before sailing, but not without minor modifications to the bulwark. It was positioned on the port side, aft of the funnel, between the cover to the hold and the side of the ship. This was the only viable position for installation on Discovery, but here the winch was a very tight fit up against the hold cover and it was necessary to fabricate a mounting frame to raise it 8 inches off the deck and to allow misalignment with the deck's 1m matrix. It was also necessary to remove a cleat from the bulwark which was obstructing installation of the fish in it's cradle. Even with this removed, ths fish had to be installed inboard with the nose facing aft (the same scenario had happened on RRS Charles Darwin) so that on deployment and recovery it had to be swung through 180 degrees.

An additional problem with this installation was the distance between the winch and the nearest convenient laboratory for the electronics (the deck lab.). The cables made up for the RRS Charles Darwin trials cruise (CD98a) were 25 metres in length, sufficient only to get one third of the way along the hangar on Discovery. Thirty metre extension cables were made at the beginning of the cruise, enabling the system to be connected in the deck lab with 5 metres to spare. This cabling route was not, however, ideal, passing several high current switch boxes in the hangar. Consideration should be made for installing permanent cabling on vessels that this system will use regularly - ideally the cables should be routed through steel pipes.

As documented in an earlier report of the trials cruise CD98a (Griffiths et al., 1996), the system electronics and cabling are very sensitive to noise. After trying the system electronics in various positions in the deck lab, it was found that the proximity of the transducer cabling to nearby computer monitors was the main source of noise contamination. Finally, the deck unit was installed on a short piece of benching just aft of the sink in the deck lab. In this position, the cables could be routed through the bottle annex, such that only 1.5 metres of cable entered the deck lab. In this position, the background noise values were changed from -121, -111 and -141 dB for the 200, 120 and 38kHz respectively, to between -139 and -141 dB for all three frequencies. These do not vary hugely from the values between -138 and -144 dB encountered on RRS Charles Darwin, although we would expect higher noise values with the extra 30m of cabling installed on RRS Discovery.

The fish was first deployed at 02:20 GMT on the 2nd of December. Running the system initially in passive mode to monitor the noise, yielded values of -129, -130, and -138 dB underway at 6 knots - a 10dB increase in noise for the 120 and 200 kHz frequencies. In normal running (active) mode, the useful ranges of the different frequencies were 60, 100 and > 800m respectively. This was poor performance compared to previous installation on RRS *Charles Darwin* where 100m and >200m (200 and 120kHz) ranges were achieved. At 21:00 that evening it was decided to try using the non-standard settings of Long pulse lengths and Narrow bandwidth for the 120 and 200kHz transducers. These are suggested by SIMRAD when the background noise is high. The narrow bandwidth (1.2kHz and 2.0kHz for 120 and 200kHz respectively) filters out a lot of unwanted acoustic noise, but with a loss in vertical resolution with the longer pulse lengths (approx. 3 times longer at 1.0ms and 0.6ms respectively). However, the consequent resolution of about 0.5m was of little significance to our measurements using 1m bins for these frequencies. Following these changes, the improvement was immediate - ranges of >125m and >175m were possible with the 200 and 120kHz frequencies. For the rest of the cruise, the system ran without any noise related problems. However, a few notable events are discussed here regarding the tow-fish and winch systems.

On the 5th December at ~18:40 hrs, it was noticed that the data from the EK500 was not as it should have been, but as though the instrument were on deck, or not connected at all. The tow-fish was found to be at the surface being pulled through the water without it's fibreglass tail, and was therefore immediately recovered. The recovery was made, perhaps, too speedily, however, and the fairing not going through the block correctly, forced the cable to come off the sheave and jam against one of the face plates. It was eventually freed, and recovery completed, but there was some damage to the cable's outer covering where it had jammed. Fortunately, the damaged part of the cable was far enough from the tow-fish that on subsequent deployments it could be kept out of the water. A repair was made with self-amalgamating tape and finished off with PVC tape.

Inspection of the rear of the tow-fish revealed that the 18mm bolt holding the tail on, had sheared off. The fish had not been towed above 10 knots on the RRS Charles Darwin, yet here we had had it in the water at 12 knots. There is obviously substantial stress on this bolt, either from the drag on the tail, or perhaps vibration induced, and it was generally accepted that the strength of Stainless steel can be questionable, or at least unreliable. Calls back to the laboratory were made and a new tail moulding and high-grade titanium bolt ordered. The replacement parts arrived by boat transfer at Almeria, on the 16th December and thanks to the efforts of Bob Wallace and Derek Rees, the fish was back in the water that evening just before the start of the 2nd Fine Scale SeaSoar survey. A decision was made, to bring the fish out, during subsequent periods of steaming above 10 knots.

On another occasion, just prior to a SUMOSS deployment, the EK500 fish was brought to just below the surface to avoid any possible tangling of the two cables. Unfortunatrly, the cables to the lab were not disconnected before rotating the winch. Consequently, the cables were wrapped around the winch drum shaft and put under significant stress. At the rear of the winch the cables were attatched to a vertical aluminium pole to get them above head height across the deck into the bosun's locker. This attatchment was a weak link, achieved with PVC tape. However, the cables snagged on some ironwork as they were pulled in towards the drum and a small patch of one of the PVC cable sheaths was damaged. Although the damage was superficial, the cables were recovered and checked at ~1000 volts e.m.f. to see if the insulation between any of the conductors was damaged but fortunately, all readings were > 70 MOhms and so the cables were not replaced. The data from the instrument looked as normal, except for a few 'drop-outs' in the 38kHz signal, but these, although not having been noiticed earlier in the cruise (the 'drop-outs' were only visible on the display in the 500m to 1000m range, and we usually displayed only the top 500m) only seemed to occur during the rough weather we had at the time, or during periods of manouvering, and so the operation of the EK500 was not interrupted to look further into the problem.

The final event of some concern, occured on Christmas day when recovering the EK500 fish, in order to steam off east to coincide with an ocean colour MOS satellite pass. After recovering the fish inboard, it was noticed that a nut was missing on the main pivot bolt attaching the fish to the winch cable, despite a steel locking washer with flaps bent up against 2 of the flats of the nut, and the bolt had shifted more then 1 inch to one side. Another few inches and the fish would have broken free, only attatched by the conductors to the junction box inside the tail. Before redeploying the following day, a replacement nut was manufactured and both nuts were locked in place with steel pins into the bolt.

### *EK500 Calibration*

The first attempt at calibrating the EK500 was made on the 11th December between midnight and 2am. A mono-filament line was attatched to the tail structure of the fish, just aft of the transducers, and three copper calibration spheres were attatched to the line and hung at depths of 12, 18, and 24 m from the fish, the smallest sphere nearest to the fish etc.. The calibration was carried out using the 'LOBE' program supplied by SIMRAD. This software ran on a PC connected to the echosounder via RS232 communications so that it could both control the deck unit and receive target strength data.

Details of the calibration method are not given here, but the basic method is described below:

The PC 'LOBE'program displayed the four quadrants of the beam as a circle divided into four quarters. The depth of the relevant target sphere was entered into the program, and it began to collect target strength data, showing the target's position in the beam (when it was visible). Ideally the program would run until at least 100 samples had been collected, with roughly an equal number of samples taken in each quadrant. When ready, the user interrupted the program and a polynomial fit was aplied to the data. One could subsequently look at plots of target strength versus angle from the vertical, and the transducer gain parameters including beam alignment offsets could be sent directly to the echosounder, or they could be stored in an ASCII file for later perusal. As we were using a combination of pulse lengths and bandwidths on the system, calibrations were attempted with both sets of settings for each frequency (e.g. Medium pulse length and wide bandwidth or Long pulse length and narrow bandwidth).

During our calibrations, we found that the relative motions of the ship, fish and calibration spheres were such that only on a very few occasions were the spheres visible on the starboard quadrants of the beams, however, the distributions between the port side quadrants was fairly even, enabling a reasonable quality calibration to be done.

Although the 200kHz transducer was just a single beam, it was initially thought that the 'LOBE' program could still be used to collect target strength (TS) data. However, the software crashed when this was attempted, and so we resorted to logging the data on a SUN workstation. Unfortunately, no targets at the depth of the 200kHz (smallest) sphere were recorded; the current shear was too strong. The sphere was occasionally visible on the EK500 display, but only as a very weak target, perhaps in a side-lobe of the beam, and was not processed as a single-fish-detection, as is required for the TS measurements. For the 38 and 120kHz transducers, the calibration results are given in **table 4**.

### *Data acquisition and processing*

The details of the EK500 data processing will be given in a forthcoming data report. Here we will only outline the basic procedures. Initial acquisition and processing was carried out using PEXEC macros.

Data from the EK500 were broadcast over the ethernet in Universal Datagram Protocol (UDP) packets. The two telegram types from the EK500 were set up to use a different UDP port numbers so that each acquisition could deal with a specific telegram type. The SIMRAD program ‘record’ was incorporated in *ekexec0* to acquire the telegrams. The two telegram types were for Sv echograms and TS (target strength) data. *Ekexec0* was set up to acquire the telegrams and write the data to two series of consecutive files of a convenient length (normally 2 hours); eksvpelNUM.JDAYHHMM.bin for Sv echograms and ektsNUM.JDAYHHMM.bin for TS data, where NUM was the consecutive file number.

Two macros were written for the next stage of processing, one for each data type, *ekexec1.sv* and *ekexec1.ts*. These macros performed batch processing on the data files written by *ekexec0*. The data were split by frequency using ‘datpik’ and averaged over two minute intervals using ‘padpav’. Finally the macros each wrote three output files, one for each frequency. Six short macros were written to append the averaged files into convenient sized data sets (e.g. a single survey), compress them and copy them to an archive directory.

During this cruise a MATLAB 'm' file called 'ts2.m' was written. This allowed data formerly read in to MATLAB and saved as a '.mat' file using the test version of 'pmatlb', to be read in and plotted, as shown in **figure 14.** The user supplied start and stop times and start and stop layer numbers whilst the colour bar was autoscaled to fit the data to the nearest value of 5 counts (TS detections). The resultant plots were stacked vertically each representing a layer (which is user defined on the EK500) and each showed a contour of number of detections agains time and TS class in 1.5dB increments. **Figure 14**, from the 38kHz frequency transducer, shows a diurnal migration of targets ranging in TS from -60 to ~-30 dB.

**Remotely sensed data acquisition** *HS and TG*

Satellite and aircraft data are an important component of the OMEGA project; to establish a temporal and spatial context for the in situ measurements and for studies of the inter-relationships of the biology and physics and the extent to which surface signatures are representative of the underlying water column. During the cruise remotely sensed data were also used in near real-time to aid cruise planning. The principal sources were infra red images of sea surface temperature (SST) obtained by the AVHRR sensor on NOAA satellites, sea surface height measurement by radar altimeters on ERS-2 and TOPEX/POSEIDON, and SSTs given by an infra red radiometer on the UK Met. Office's Hercules.

The AVHRR data were acquired by NERC's Satellite Receiving Station in Dundee and then sent electronically via NERC's Image Analysis Unit in Plymouth and RVS in Southampton to the ship in a compressed file. Images were then displayed on a PC using 'iphoto'. During the first part of the cruise several cloud free images were obtained (**figure 15**). These showed the location of the Almeria-Oran Front, the east Alboran gyre and warm water intrusions to the east of the Front. There was a strong correspondence with SST gradients measured from the ship during the initial large scale surveys. In particular the surface signatures were shown to extend well below the surface and so could be used with confidence in mapping dynamically significant structures. This information was an important input into designing the orientation and size of the fine scale surveys. The delay between acquisition and reception on the ship was 1-2 days, apart from weekends; some of this was due to data being sent to SOC too late for the daily email transfer and there being insufficient justification for dedicated transmissions.

TOPEX altimeter data were processed by NOAA, Washington to give sea surface heights every 0.1 deg latitude relative to pass earlier in the year along the same ground track . The data were sent by email to the ship. Similar data were available from ERS-2 but with the difference that the referencing to an earlier pass was carried out on the ship. Although this information is limited by the infrequency of the passes and the width of the swath it does provide data on subsurface flow and is not constrained by cloud conditions. Because of the higher variability observed on one particular ERS-2 track it was decided to include this transect as one of the legs in the fine scale surveys (leg e in **figures 4, 5 and 6**).

The Met. Office Hercules overflew the observational area on two consecutive days, 14 and 15 December spending ~ 10 hours in the air after taking off from Valencia, Spain. On both days the aircraft carried out vertical profiles from 27,000 ft to 50 ft (for radiation and aerosol studies), large scale SST mapping at a height of 300 ft and some low level intercomparisons with the ship in which the aircraft passed within 50 ft laterally of the ship at an altitude of 100 ft. Communication on marine band VHF presented no problems. On approaching *Discovery's* position significant aspects of the temperature, humidity and wind profiles were obtained from the most recent radiosonde ascent and relayed to the aircraft. It had been planned to send data from each aircraft leg to the ship via fax; however, this did not succeed and data were faxed at the end of the flights from Valencia. These near real-time data were again useful in establishing the overall oceanographic context and compared favourably with *in situ* and satellite SSTs, once allowance for an atmospheric correction had been made.

**Surface meteorology** *PT, SJ and RP*

Introduction

Meteorological measurements were made during the Omega experiment with the following scientific objectives:

(i) To determine the effects of the ocean front on the air-sea fluxes; in particular to observe any modification of boundary layer structure either side of the front.

(ii) To test parametrisations for determining the incoming longwave and shortwave radiative fluxes.

(iii) To obtain measurements of the ocean surface skin temperature in order to improve our knowledge of the surface skin effect with particular application to the interpretation of satellite derived SST data.

(iv) To obtain measurements for verification of Computational Fluid Dynamics modelling of the airflow over the ship which is needed in interpreting previous wind stress measurements obtained on RRS *Discovery*. As opportunity allowed, to obtain further wind stress data.

The instrumentation deployed to achieve these objectives included a suite of meteorological sensors (GrhoMet), sonic anemometers and an anemometer mast, a radiosonde sounding system, and two types of sea surface temperature radiometers.

A new version of the GrhoMet meteorological instrumentation system was installed on RRS *Discovery* at the start of D223. This system uses the RVS Rhopoint network for connection to foremast, hull and laboratory sensors. Additional sensors to the usual RVS sensor suite were mounted on the foremast and connected into the logging system. A total of 14 sensors were logged, measuring air temperature, air pressure, wind speed, wind direction, downward long and shortwave radiation. (**table 5** and **figure 16**). The system acquired data at 5 second sampling rate and generated data files in raw and calibrated format, these were written to the PC's hard disk. The GrhoMet system also outputs raw data via an RS232 link to the RVS level 'B', where the data was logged by the RVS computer system. A new feature of the Discovery installation was that both the ships clock and a Vaisala barometric pressure sensor were read through serial ports. The pressure sensor data was added to the normal sensor suite, whereas the ships clock was used to update the PC clock once every 6 hrs when a new data file was opened. During cruise D223 a software error had been noted wher the Julian day number could be incorrect for the first data record after midnight. A software change was made on Jday 346 to correct the fault, along with a modification to display pressure on the GrhoMet display. Otherwise, the logging system worked continuously and without fault throughout the cruise except for the period 01:43, Jday 341, to 09:12, Jday 341, when the systems were powered down for the passage through Algerian waters where, at that time, we did not have permission to work.

On previous cruises over the last several years a number of macros and pexec programs have been developed for processing the meteorological data. On this cruise an effort was made to rationalise these macros, and the required file structure, and to further improve the available documentation.

Air temperature and humidity

Air temperature and humidity measurements were important to determine the transfers of sensible and latent heat on either side of the Almeria-Oran front and an accuracy of ±0.1°C is desirable. However past experience has shown that such accuracy is difficult to achieve using a ship mounted instrument and a modified design of aspirated wet and dry bulb psychrometer has been developed at SOC. Cruises D223 and D224 were the first trials of commercially manufactured versions of these instruments.At the start of the cruise it was noted that psychrometer HS2019 was exhibiting occassional calibration shifts in the dry bulb of several tenths °C. A similar problem had been reported on D223. On Jday 341 HS2019 was replaced by HS2029 and the problem disappeared. During the cruise it became apparent that the psychrometers were affected by direct sun light, causing the temperatures to vary by typically 2 to 3 tenths of a degree, even though the psychrometers were mounted side by side. The difference between the psychrometers depended upon the ships orientation relative to the sun. Investigation showed that the tubes covering the PRT's (Platinum Resistance Thermometers) were translucent allowing varying light levels to affect the PRT's. A change in materials has occurred from the prototypes developed at SOC to those manufactured commercially. To resolve the problem baking foil was wrapped around the outside of the tubes which initially seemed promising but in strong sun, still showed some affects. Therefore the foil was wrapped around the inner tube to greater effect. Care was also needed to ensure that the wet bulb wicks were fully primed, particularly when a new psychrometer was mounted.

On Jday 342 the RVS Air temp sensor failed, investigation into the cause failed to effect a cure, so the sensor was no longer logged and the GrhoMet channel was used to log air temp as measured by the humidity sensor from Jday 348 onwards.

Data spikes caused by radio frequency interference from the ship's VHF system or the hand held radio sets used on the ship were a continual problem. The channels worst affected by this were the aft psychrometer [psy1td] dry bulb, the trailed thermistor [SST2], and the starboard solarimeter [STIR].

Wind Measurements

Wind measurements were obtained during the cruise in two ways. The mean wind was measured, for determining air sea fluxes, using the standard RVS propeller/vane anemometer on the foremast. In addition, measurements for determining wind stress using the "inertial dissipation" method were obtained from a Solent Sonic Research anemometer (asymetric version). This was mounted on the starboard side of the foremast platform and determined the three components of wind speed at a 21Hz sampling rate. Four 10 minute data sections were obtained every hour and logged by a PC in the plot. The logging software “fftset” also performed a spectral analysis of the data. The wind spectra and summaries of the spectral levels and mean wind speeds were backed up to the ship-board unix computer system, where raw data were logged directly to optical disk.

Interpretation of wind stress data requires knowledge both of the height at which the measured turbulence originated and, to calculate the drag coefficient, the true wind speed. Both these quantities are affected by the airflow disturbance caused by the ship. Because excellent wind stress data sets had been obtained on previous RRS *Discovery* cruises (particularly the WOCE cruises in the Southern Ocean) it was important to quantify the airflow disturbance caused by RRS *Discovery*. Computational Fluid Dynamics (CFD) modelling was being used for that purpose and measurements were taken on this cruise to help in verifying the CFD predictions. For this purpose a second Solent Sonic Research anemometer was installed on the starboard arm of the main mast cross-tree and logged in an identical fashion to that on the foremast on a separate PC, also located in the plot. In addition a special “CFD” system was used. This was an additional rho-point based system, similar to the GrhoMet system. The “CFD” system sampled data, at intervals of 5 seconds, from a Windmaster Solent sonic anemometer boomed out from the port side of the foremast platform, and 5 Vector cup anemometers located on a 6m mast positioned on the centre line of the vessel at the forward edge of the wheelhouse top. Data were logged by a PC in the plot, and were backed up to the ship-board unix system via floppy disks. On sailing the order (top to bottom) of the anemometers was 2557 / 2778 / 2621 / 1991 / 2620. On day 346 the order was rearranged to 2620 / 1991 / 2621 / 2778 / 2557. From day 350 onwards anemometer 2621 had an intermittent fault but the other sensors worked well.

Because the Fine Scale Survey tracks were orientated approximately north-south whereas the stronger winds were from the west, relatively little of the wind stress data collected on this cruise were obtained with the relative wind direction within 10° of the bow (the preferred direction). However suitable data were collected on Christmas Eve with the ship hove-to in strong winds and with a short, confused sea. A large data set was obtained for verification of the CFD modelling.

Radiation

The primary aim of the radiation study conducted during the cruise was to evaluate the performance of various empirical formulae commonly used in climatological analyses to estimate the air-sea fluxes of longwave and shortwave (solar) radiation. Uncertainty over which was the most appropriate formula for each of these components and had hampered attempts to close the heat budget of the Mediterranean. Uncertainty also existed over the effect of atmospheric aerosol loading on the shortwave flux at the sea surface; Gilman and Garrett (1994) claimed that a reduction due to the attenuating effects of aerosols, originating primarily in North Africa, was necessary in order to close the heat budget and we wanted to test whether this was a reasonable assumption by combining radiometric measurements made on the ship with in situ measurements of the aerosol properties made during a Met. Office flight, C-130, overpass.

The instrumentation (**Table 5**) used to measure the radiative fluxes is summarised below:

i) Downwelling (atmospheric) longwave flux - (large scale surveys 1 and 2) 2 Eppley pyrgeometers (LW1-code no.27225 and LW2-code no.31170) mounted on a fixed platform on top of the foremast. 27225 replaced by 31171 for the fine scale surveys.

ii) Total shortwave - Kipp and Zonen CM sensors gimbal mounted on the port and starboard side of the foremast platform.

iii) Photosynthetically Available shortwave Radiation (PAR) - 2 Didcot DRP-1 sensors gimbal mounted on port and starboard side of the foremast platform. Output from the radiation sensors was logged onto the GrhoMet system every 5 seconds and processed using standard meteorological data PSTAR macros.

iv) Cloud observations - (total cover, and amount and type of low, middle and high altitude cloud) were made at 3 hourly intervals on passage, increasing to hourly in the daylight period (during which more reliable observations could be made) between 0600 and 1800 once the ship entered the Mediterranean.

v.) C-130 aircraft - In addition to the ship-based instrumentation, the Met.Office Research Flight C-130 aircraft carried radiometers and a suite of instrumentation for measuring aerosol characteristics (particle size distribution, scattering and absorption coefficients) whilst flying vertical profiles to 7000m in the vicinity of the ship on Julian days 349 and 350.

A difference in slopes was noticeable in the relative measurements made by the two longwave sensors during the large scale surveys, suggesting a calibration error. The two sensors were in reasonable agreement for downwelling fluxes of order 350 W/m2 but at lower values 27225 read consistently higher than 31170 the difference being of order 10 W/m$^2$ at 280 W/m$^2$. In addition, further analysis indicated that 27225 suffered from shortwave contamination. It was replaced by an alternative sensor (Code No. 31171) during the port call at Almeria on Julian Day 346 improving the agreement with the other sensor and therefore suggesting that the calibration problem lay with 31170. Note that the agreement at high longwave fluxes corresponded to conditions under which calibration of the sensors had been possible in the lab; further calibration at colder temperatures may allow the divergence at low fluxes to be removed. The shortwave sensors suffered from an offset of order 15 W/m$^2$ between port and starboard which persisted at night. An additional met team shortwave sensor was used to replace one of the RVS sensors on Julian day 336 but the offset remained.

A wide range of cloud cover enabled the Clark and Bignami longwave bulk formulae to be tested under both clear sky ('typical' Mediterranean) and overcast Sc ('typical' Atlantic) conditions. The formula suggested by Bignami et al. (1995) was found to give better estimates than expected over a wide range of conditions during the large scale surveys, with the Clark et al. (1974) formula overestimating by 30 W/m$^2$ in the Mediterranean. In contrast, while on passage in the Atlantic, the estimates obtained using the Clark formula were in good agreement with the radiometer measurements while those obtained with Bignami were biased low. Preliminary analysis of results from the fine scale surveys suggests, however, that the Clark formula performed well in the Mediterranean when the longwave flux was high due to a low cloud base.

**Radiosonde launches** *SJ, RP and PT*

Radiosondes were launched throughout the cruise, between two and four times daily, providing vertical profiles of temperature, humidity and wind speed in the troposphere. As well as providing a record of the general atmospheric conditions, the radiosonde releases enable an analysis to be made of changes in the stability of the boundary layer across the Almeria-Oran front. In addition, the profiles may be used in conjunction with a radiative transfer model in order to see whether the difference in the empirical parameterisations used to estimate the downwelling longwave flux in the Atlantic and the Mediterranean, can be explained in terms of a change in the mean atmospheric profile characteristics between the two regions.

Radiosondes were launched from a platform on top of the winch cabin towards the stern on the starboard side. The location of the launch site was far from ideal as the proximity of the stowed Acta 75 TM crane and the necessity of avoiding the A-frame at the stern made launches with the wind coming from the starboard quarter difficult. Under these conditions, provided the wind was sufficiently light, the balloon was carried across the hanger deck and deployed on the port side aft of the funnel; with strong winds this manoeuvre was not possible, several attempts made under these conditions resulted in the balloon bursting against the crane. As SeaSoar was deployed for much of the cruise, alteration of the ships heading to create more favourable winds was usually not possible. Two types of sonde were released, the new RS80-15G (which made use of differential GPS to give wind speed as well as temperature and humidity ) and the standard PTU sonde RS80-15.

Despite the difficulties arising from the location of the platform, the majority of sondes were successfully launched, with only 2 launches aborted out of 77 attempts. However, it should be noted that the winds during the cruise were generally light to moderate and that under the stronger wind conditions which are more typical of the open ocean a successful program of balloon launches would prove difficult with the current set-up unless the ship was able to alter course. The problems encountered under high winds were evident over a two day period from Jday 358 at 23:00 to Jday 360 at 21:00 during which no launches were possible. Failures occurred at the moment of release due to snapping of the string which attaches the sonde to the balloon and less seriously as a result of the balloon bursting against obstructions (in the latter cases successful launches followed using a second balloon). An additional problem encountered was the failure of the wind signal from the GPS sondes which affected 7 out of 75 flights; monitoring of the GPS reception statistics suggested that on these occasions the sonde was unable to see enough satellites (a minimum of four are required for winds to be obtained). Unusual behaviour was also observed in the logged humidity data on three occasions where it became evident that at high altitudes temperature rather than humidity was being returned by the sonde; the response of the sensor was also noticeably slow at lower altitudes during these particular launches. The average number of balloons inflated per gas cylinder was 7.8, due to the extra pressure requirement for GPS sondes, in contrast on previous cruises, where only PTU sondes were deployed, the rate was closer to 9 per cylinder.

Transmissions from the sondes were received by a new DigiCORA II MW15 GPS receiver, the aerial for which was located on the starboard side of the wheel house roof (monkey island), and logged to a PC. Three types of file were logged: .PTU files containing the pressure, temperature and humidity at 1.5 second sampling intervals, .RAW files containing wind speed, north and east components and direction also at 1.5 second intervals and .WIN files containing 10 second averaged wind data. Software upgrades were received from Vaisala just prior to sailing and as a result the message format changed slightly causing the .WIN files to have corrupted records. Further software modifications were made to remedy this problem from Jday 340 at 23:00 hrs onwards. Some confusion arose over the east and north components of the wind speed which were defined in the opposite sense to that which might be expected i.e. as components of the vector giving the direction from which the wind is blowing rather than that to which it is blowing. Further, the output component values were actually in the opposite order to that listed in the manual. Corrections for these irregularities were included in the processing macro for the winds. Data from each ascent was transferred by diskette to the Unix Sun system. Macros all_scrp.ptu and all_scrp.raw were used to process the .PTU and wind data respectively. These converted the ascii output to pstar, calculated several thermodynamic variables and the components of the wind speed, and produced postscript plots of the profiles. Post-processing was carried out to remove spikes from the data using a five-point median filter with tolerance limits of 1°C for the temperature variables, 5mb for the pressure, 5% for relative humidity, 0.4 g/kg for specific humidity and 0.02 g/kg for air density. The despiked fields were then averaged onto 10 mb levels from 1040 mb to 10mb and appended into a single file from which time-height plots were produced using the pstar program 'ucontr'.

**Sea surface radiometers** *PT, RP and SJ*

Measurements of sea surface temperature were taken with the following aims:

(i) to provide bulk temperatures for evaluating the air sea fluxes of heat and water in the area of the Almeria-Oran front;

(ii) to increase the data set available for evaluating and modelling the sea surface skin effect;

(iii) to provide measurements of the skin temperature of the ocean for validation of satellite SST data.

The sensors used for measuring sea surface temperature were as listed in **table 6**. The two Tasco radiometers were mounted on the outside case of the SIL radiometer with one Tasco viewing the sea (parallel to the SIL at about 20° to the vertical) and the other viewing the section of sky which would be reflected into the sea view of the SIL radiometers (i.e. looking upward at about 20° to the vertical). The periods of deployment for the radiometers are shown in **table 7** and for the trailing thermistor in **table 8**.

**Table 9** gives the mean differences between the different SST sensors. The trailed thermistor ("soap") was a new version with improved mechanical construction where the bead thermistor was attached to the end of the cable. It performed well, staying within ±0.1 °C of the thermosalinograph reading from deployment until the end of the cruise. The time response of the soap was similar to that of the TSG. In contrast, the hull sensor exhibited a longer time constant and also a fixed calibration offset of about (-0.55°C). The raw data from the two radiometric SST sensors were, in the mean, cooler than the TSG. However this did not indicate the magnitude of the surface skin effect because at this stage in the analysis the correction for reflected sky radiation had not been fully applied. The SIL radiometer had been corrected assuming a constant sky temperature of 240K while the Tasco values assumed an emissivity of 1 and had no sky radiation correction. Perhaps the most notable feature of these comparisons was that the histogram of the difference between the Tasco and the Thermosalinograph showed marked maxima at about 0.2°C and 0.6°C (**figure 17**). The larger differences corresponded to periods of low sky temperature with clear skies and large heat loss from the ocean. The extent to which the measured differences represented variations in the skin effect or variations in the reflected sky radiation remain to be determined. However the these results suggested that the Tasco data were of good quality with lower noise levels than the SIL radiometer.

## Shipborne Wave Recorder (SBWR) *RP*

Data from the Shipborne Wave Recorder (SBWR) on RRS *Discovery* were recorded to provide ERS2 altimeter validation, for interpretation of wind stress data and to verify a new version of the Shipborne Wave Recorder and UDP data transfer protocol.

A new version (MK IV) of the Shipborne Wave Recorder (SBWR) was installed on Discovery for the first time at SOC prior to sailing. The MK IV version of the IOS designed SBWR was developed through a collaborative programme between Ocean Technology Division and W.S. Ocean Systems Ltd. The major change from the MK III was that the electronic control and processing unit had been replaced by a PC running an application developed using LabWindows CVI. The new system converted pressure and accelerometer signals into a wave height signal. This signal was periodically processed to produce a wave energy spectrum. Data were logged to the hard disk in the form of four data files: .RAW files storing wave height data generated during the processing period, .SPC files storing spectral data, .PAR files storing parameter data and .INF files storing housekeeping data. In addition the program sent a UDP datagram over the network at the end of each data acquisition period. Plots of the parameters which were included in the UDP datagram were produced, to establish that all datagrams were received satisfactorily by the ship's Sun based computer system.

A number of different setups were tried throughout the cruise (**table 10**) to test the SBWR system and to check data quality and zero drift. These included an hour long data acquisition period in an effort to collect an hour's continuous raw data: however, the system failed to settle, exhibiting a large zero drift, and consequently was reset to a shorter acquisition period.

**Nutrient data; nitrate,silicate,phosphate** *VH and SF*

Two Chemlab autoanalysers were used for the analysis of silicate, phosphate, nitrate and nitrite. These were set up for the previous cruise.(Leach and Pollard, 1997). The discrete autoanalyser was used for the analysis of hourly surface samples and CTD samples. The continuous autoanalyser was connected to the nontoxic seawater supply.

Discrete samples were taken in duplicate and stored in 30 ml plastic 'diluvial' containers that had been rinsed three times with the sample. Samples were either frozen and then defrosted in the dark prior to analysis or stored in the refrigerator and analysed within 24 hours of collection.

Primary calibration standards had been prepared for the previous cruise. Secondary standards were prepared from primary standards, by diluting 5 ml to 100 ml in glass volumetrics, except for the silicate standard which was made up in a polyethylene volumetric flask. These were made up fresh every 2 weeks. Four mixed working standards were made up fresh every 1-2 days in 100 ml polyethylene volumetric flasks with Analar grade artificial seawater. There was some adaptation from the standard concentrations used on the previous cruise as the surface nutrient values tended to be lower. In addition a nitrite standard was made fresh every 1-2 days in order to calculate the efficiency of the cadmium column, and two mixed quality control standards were made from Ocean Scientific International standards.

The AAII methods of analysis for silicate, phosphate, nitrate and nitrite were used (Hydes; 1984).

<u>Discrete hourly samples.</u>

Duplicate hourly samples were collected throughout the cruise from the non-toxic seawater outlet of the thermosalinograph mounted on the hangar deck, at the same time as salinity and chlorophyll samples. Standards were adapted so that the maximum standard for silicate was 10 micromols/l, nitrate 5 micromols/l and phosphate 2 micromols/l.

CTD Samples

Duplicate nutrient samples were collected from 14 CTD stations, of depths ranging from 150 metres to over 2000 metres. Again samples were collected in 30 ml plastic 'diluvial' containers, rinsed three times and stored frozen or analysed fresh from the refrigerator. A maximum standard of 10 micromols/l for silicate and nitrate, and 2 micromols/l for phosphate were used.

The continuous autoanalyser.

This second Chemlab autoanalyser, adapted to measure low nutrient concentrations, was set up in the deck lab. Once the standards had been run through, the carousel was replaced with a sampler block through which the non-toxic seawater supply was pumped. The analyser was only used for less than a week at the beginning of the cruise, due to problems described later. Once running, the block was sampled at 135 second intervals for a period of up to 11 hours. Standards were prepared as before with maximum standards of 2 micromols/l for nitrate, 3 micromols/l for silicate and 0.5 micromols/l for phosphate. The standards were, however, changed at various times due to problems associated with having the colorimeter gain turned to maximum.

Problems encountered with the autoanalysers

Both autoanalysers had been previously setup and maintained during RRS *Discovery* cruise 223: however, due to a necessary fumigation of the ship between cruises it was decided that they should be unloaded and then reloaded and setup as before prior to departure for cruise 224.

The planned schedule was to run the continuous autoanalyser and the discrete autoanalyser in parallel throughout the cruise, using the hourly samples to calibrate the continuous data. As later noted from the previous cruise, there were a number of problems with the continuous autoanalyser, and considerable manpower was required for maintenance. To prevent any growth within the tubing and sampler block connected to the non-toxic pump, which had resulted in diminished nutrient results in the previous cruise, Decon solution flushed through every 3 days. The sample connector to the silicate line also became quickly coated in some form of blue precipitate which then blocked the line and altered the flow of reagents and water, so that this also had to be cleaned with Decon solution on an almost daily basis. A variety of other minor problems occurred including drifting and erratic baselines so that more time was spent maintaining than running the machine. After one week, a backlog of hourly samples, stored frozen, forced the decision to shut-down the continuous autoanalyser and run samples on the discrete autoanalyser. It was not possible to run both autoanalysers simultaneously, and so it was decided to concentrate on the discrete hourly samples.

A number of usual and some unusual problems were encountered with the discrete autoanalyser. As with the continuous, after having run Decon solution through the system, it took quite a while for the flow rate to settle down. Increased pressure in the cadmium column as noted on the previous cruise also occurred. The major problems found, however, were with the phosphate line, some of which were resolved by the end of the second week, others not at all. The baseline was consistently erratic, with a tendency to be even more so in rough weather. It was discovered that phosphate measurement was extremely light sensitive and a porthole left open adjacent to the autoanalyser was one of the causes. Once this was resolved, it was noted that even moving above the instrument caused variation in the baseline, this was resolved by a combination of turning the gain down on the colorimeter and building a housing above to cut out any light entering. This reduced the problem, but strangely the baseline still mimicked the role of the ship, shown very clearly in one experiment where the recorder speed was increased along with the amplitude, and the resulting trace was very similar to a wave recorder. Turning the instrument 90 degrees so that it was more effected by pitch than role, could have been a possible solution, but by this point little of the cruise was left for experimentation.

The second major problem with the phosphate line was that, even after a reasonably stable baseline had been achieved, once the sample line was switched on and the first sample/standard taken from the carousel the baseline would become extremely erratic, and then continue to be so until the last sample had been sampled. After communication with David Hydes at SOC, it was suggested that there could be an earthing problem. Eventually we found that as the tube from the sampler passed through a metal connection housed within the main sampler unit it carried an electrical disturbance with it. Once the tube was disconnected so that it bypassed the sampler unit, the problem disappeared.

## Chlorophyll samples *SF, CG, FJ and AS*

Introduction

Water samples were analysed for their chlorophyll and phaeopigment content to calibrate the CTD fluorometer, the TSG fluorometer and subsequently the SeaSoar fluorometer. Additionally, the analyses were used to obtain a rapid view of biological properties of the water, to allow a comparison with physical data obtained continuosly at real time and to calibrate data from SUMOSS and satellite images.

CTD chlorophyll samples were taken at 5, 50, 100 and 200m depth at every CTD station, with a further sample taken at the chlorophyll maximum. Underway samples were taken hourly when SeaSoar was deployed and were drawn from the non-toxic supply in the hanger which also feeds the TSG fluorometer.

During the 2nd and 3rd fine scale surveys, a suplementary effort was made to reveal the gross size structure of primary producers and its relationship with mesoscale physical structures by looking at the chlorophyll fluorescence due to organisms larger than 20 μm ESD (Equivalent Spherical Diameter).

Chlorophyll Analysis - large scale surveys 1 and 2

Samples were collected in blacked out 2.5 litre nalgene bottles, which were rinsed twice in the sample prior to filling to 1 litre. Immediately three 100ml aliquots, measured out using a cut off plastic volumetric flask (rinsed in sample), were filtered through 3 Whatman GF/F 25mm diameter filters at low pressure (<6mmHg). Filtering was done in reduced light, with the bottle annexe lights off and a black plastic bin liner covering the filtration equipment. The samples were placed in individually numbered glass vials and immediately transferred to -20° C storage in the dark. A problem arose at this stage of the procedure at the beginning of the cruise. Filtering pressure was initially erratic and high. On investigation the cause was a partially blocked filtering column: this was later cleared by soaking in hydrochloric acid overnight.

20ml of acetone was added to batches of 50 frozen samples daily (where possible) from an Anachem 25ml adjustable autodispenser, to extract the chlorophyll. They were then replaced in the freezer for a further 22 to 24 hours. After this period smaller batches of 10 samples were warmed to room temperature in a dark water bath before the fluorescence was measured in a Turner Designs (TD) Fluorometer (model 10-000R, serial no. 00859). Then 3 drops of 10% hydrochloric acid was added to the sample and the fluorescence remeasured.

The TD Fluorometer was calibrated using standard chlorophyll solutions. These were made from a primary standard (1 mg sigma chlorophyll *a* pellet dissolved in 1 litre acetone), whose exact chlorophyll concentration was ascertained from its absorbance measured before and after acidification at 665 and 750 nm wavelength using a Pye Unicam SP6-500 spectrophotometer. Secondary standards used to calibrate the TD Fluorometer were dilutions of the primary to cover the expected range of chlorophyll concentrations from samples.

Chlorophyll and phaeopigment concentrations were calculated using the equations from the JGOFS protocols (1994) in Microsoft excel and the resulting values were imported into pstar in tab delimited text files.

Equations
1⁻ standard concentration:

$$\text{Chlorophyll}a\ (mg\ m^{-3}) = {26.7(665b - 665a)v}/{l}$$

$$\text{Phaeopigments}\ (mg\ m^{-3}) = {26.7((1.7 \times 665a) - 665b)v}/{l}$$

where: 665b = Absorbance at 665nm before acidification.
665a = Absorbance at 665nm after acidification.
v = Volume of extract (ml)
l = path length of cuvette (cm)

Sample concentrations:

$$\text{Chlorophyll}a\ (mg\ m^{-3}) = FD\left({Fm}/{(Fm-1)}\right)(Fb - Fa)\left({v}/{V}\right)$$

$$Phaeopigments\ (mg\ m^{-3}) = FD\left({Fm}/{(Fm-1)}\right)((Fm \times Fb) - Fa)\left({v}/{V}\right)$$

where: FD = Chlorophyll Standard concentration / Chlorophyll standard Fluorescence before acidification.
Fb, Fa = Fluorescence value before and after acidification of sample.
Fm = Fb/Fa of chlorophyll *a* standard solution.
v = volume of 90% acetone used in extraction.
V = Volume of seawater filtered.

Samples were taken in the above manner from Jday 336 to Jday 350. On Jday 348 chlorophyll sampling was taken over by a group of Spanish scientists from the Universities of Malaga and Cadiz who joined the ship in Almeria, Spain. To allow for differences in sampling and analysis methods an overlap of 3 days where samples were analysed using both methods was considered sufficient. The two sets of data were then plotted to obtain a regression for comparison of values.

Possible areas of error were filtering leakages, imprecise measurements of sample volume in the cut off volumetric flask and any discrepencies in adding acetone (e.g volume and % concentration of acetone). The TD Fluorometer was affected by the motion of the ship (an observation also noted on D223), and the normal readable accuracy of three significant figures was reduced.

Chlorophyll Analysis - fine scale surveys 1, 2 and 3

Samples for total chlorophyll were filtered (500 ml) on glass-fibre *Millipore* APFF filters (size-pore about 0.7 µm): pigments were extracted in 7 ml 90% acetone in a dark and cold place (about 4° C) over a period of 12 hours. Then the chlorophyll concentration values were calculated from fluorescence readings according to the fluorometric method proposed by Yentsch and Menzel (1963) using a TD Fluorometer. The TD Fluorometer had been previously calibrated as described above so that each measurement of fluorescence corresponded to a chlorophyll concentration through a linear regression function.

Values of total chlorophyll due to size classes larger than 20 µm ESD were obtained by re-filtering the fraction previously captured but with a mesh of 20 µm pore size. For this analysis a larger volume of water was used (1 litre in the 2nd fine scale survey and 2 litres in the 3rd fine scale survey).

**Longhurst Hardy Plankton Recorder (LHPR) tows** *SF, BW and CD*

The LHPR is a vehicle designed to be towed in a single V-shaped profile through the upper 450 m of the water column. It has a large Aluminium frame with polypropylene tail fin. A nose cone at the front channels water through a 280 µm net to the cod-end. The cod end contains 2 spools of gauze which wind round one third of a revolution every 2 minutes sandwiching a sample of plankton, thus allowing semi-discrete samples. Attached to the frame, one each side, are two cylinders containing a rechargable battery pack and the electronics for driving the cod-end, monitoring the sensors (seabird conductivity meter, temperature probe, depth sensor and flowmeter) and communicating with the surface. To assist the sampler to dive a 45 kg depressor weight is attached to the underside front and a drogue streams from the back of the frame to assist stability.

On this cruise the LHPR was run in internal logging mode. This permitted a maximum time of 180 minutes in the water (the data holding capacity of the software cylinder before overwriting), including deployment and recovery: to err on the side of caution tows were limited to around two and a half hours. A delay of 6 minutes before the first wind on of gauze was added to allow time for deployment. Deployment of the LHPR was from the main A frame over the stern of RRS *Discovery* using the main towing warp. 20m of wire was initially payed out at the start of each haul and the LHPR held there to allow one wind on of the gauze. The wire was then payed out at 30m per minute until the LHPR was at an estimated depth of around 400 m. This was equated to 1200 m wire out (i.e depth ≈ wireout/3). The LHPR was then held at maximum depth for 5-10 minutes before hauling in at 30m per minute. During hauling, several depths of interest, as shown by anomalies in ADCP/EK500 backscatter, were stopped at and sampled for a further 5-10 minutes. Upon retrieval, the cod-end was removed from the frame. The third spool holding the sandwiched zooplankton was placed in a bucket containing 4% formaldehyde and then both net and cod-end were washed in preperation for the next tow.

It was considered advantageous to deploy the LHPR before or after a SeaSoar survey, and through a frontal system. This was achieved with all tows. There were three problems that occured throughout the total of 8 tows (**table 11**). In omega2 (10/12/96) the battery failed in the latter half of the tow. The consequence of this was that only the down haul held useful data. It is believed that this was a result of undercharging, and it is worth noting for future reference that the battery exhibited a very sharp decline in voltage as it became exhausted. The second problem occured after rough weather, during which the canvas was ripped off the drogue frame whilst the LHPR was lashed on deck. Omega6 was towed with a metal bucket to replace the drogue. After downloading the data the depth achieved by the LHPR was around 560m (with 1200m wire out). It was decided that the bucket was too heavy and the depth reached too close to the electronics cylinders pressure limits. As a result a traditionally constructed canvas drogue was made to replace it. The subsequent tows (omega7 and omega8) were successful in that the tow profiles ressembled those with the original drogue. The third problem was less serious, the tip of the flowmeter came off mid tow and lodged in the cod-end. It was sugested that replacement bearings will avoid this happening in the future.

## Optically Active Parameters (OAPs) / Gelbstoff *PC and JSc*

Water Quality Measurements (OAPs).

All optical measurements were accompanied by water quality measurements to allow calibration of the SUMOSS and Secchi discs. Parameters measured were:

a) -Suspended Particulate Matter (SPM)

Two litres of water were filtered through preweighed GF/F (0.7μm pore, 47mm diameter) filter papers (with 1 or 2 replicates plus a blank) which were store in a -20°C freezer and brought back to Southampton for analysis (to give total, inorganic and organic SPM concentrations).

b) -Spectral Absorption Coefficient

The methods described by Mitchell (1990) and by Aguirre-Gomez (1997) were used. Two litres of water were filtered through each of of 2 GF/F filter papers, which were stored in plastic petri-slides at -20°C and brought back to Southampton for analysis. The filtrate for each sample was refrigerated and brought back to Southampton for use in the analysis.

c) -Phytoplankton Counts

Two 200ml water samples were taken at each station; one preserved using Lugol's Iodine, the other using 4% formalin. These were stored and shipped back to Southampton for analysis.

Gelbstoff measurements

The objective of these measurements was to study the distribution and variability of dissolved organic matter in the area under investigation. Dissolved organic matter, otherwise known as gelbstoff or yellow substance, can be either a product of the biological activity of living phytoplankton and zooplankton, or a product of their decomposition. It can also be of terrestrial and anthropogenic origin. In principle, being relatively stable, it can be used as a tracer of past biological activity or of contamination by various effluents. However, gelbstoff is still poorly known and understood and the present activity aims to a definition of its occurrence and distribution in a mesoscale system.

Yellow substance concentration is measured in terms of its absorption coefficient at a reference wavelength, i.e. 440 nm. Thus, the quantity measured is absorption, usually by means of a spectrophotometer. Unfortunately this kind of measurement is affected by errors due to scattering, mainly by inorganic particles, phytoplankton cells and other micro-organisms. Moreover, the pigments contained in the phytoplankton contribute significantly to absorption itself. So it is necessary to remove as many particles as possible by filtration before taking the absorption measurements. During RRS *Discovery* cruise 224, filters with a pore size of 0.2 μm were used to virtually eliminate all the phytoplankton cells and greatly reduce the effects due to other scatterers. As a result, the spectra were in good agreement with the widely adopted exponential shape of the yellow substance absorption curve in the visible and UV:

$$a_y(\lambda) = a_y(440)e^{(S_y(\lambda-440))}$$

where the most common value for $S_y$ from the literature is 0.014 $nm^{-1}$. By taking full spectra in the visible and UV at an adequate resolution and fitting (in a least-squared sense) the above exponential to them, it is possible to compute the value of the slope and to extrapolate the value $a_y$ (440) which is, in oligotrophic waters, too small to be directly measured.

Samples were collected to coincide with interesting oceanographic features and from particular CTD bottles. During the 3rd fine scale survey samples were collected on a hourly basis to attempt to make a detailed description of the spatial distribution of gelbstoff. This density of analysis required a large manpower commitment and was not possible throughout the cruise.

Water samples were gently passed through Whatman cellulose nitrate filters (pore size 0.2 μm), adopting particular measures to avoid any contamination of the samples. This filtering stage was particular time consuming, typically 20-30 minutes per sample. The samples were then analyzed using a Camspec M350 Vis/UV spectrophotometer using 4 cm quartz cuvettes. All the spectra were taken with reference to a Milli-Q quality blank. Finally the spectral interval 300 to 500 nm for each spectrum was used to find the values of $a_y$ (440) and $S_y$ for each sample.

**SUMOSS/Secchi disc observations** *JSc, PC, AS, RP and NC*

The Southampton Underwater Multiparameter Optical Spectrometer System (SUMOSS) is a fibre-optic based instrument which measures apparent and inherent optical properties at high spectral resolution. Developed by ORC and DOC, the instrument completed preliminary shallow water tests in July, and RRS *Discovery* cruise 224, OMEGA, was seen as an open ocean trial.

The SUMOSS was deployed several times during the first two weeks, without any useful data being collected. The only physical problem during deployment was that, in a strong current, the instrument lay obliquely in the water with the irradiance arm facing upwards. The floatation system designed to allow the irradiance arm to fall into a horizontal position was then ineffective, since the arm was resting inwards against the main instrument housing. This problem was overcome by placing the arm under tension using a rope and weight tied from the top of the arm to the base frame.

Technical problems began with mis-wiring, owing to a lack of communication with the engineer who connected the winch supply to the lab. Numerous difficulties then arose, although it is unclear which were related to mis-wiring and which resulted from a hardware upgrade completed just before the cruise (leaving no time for full testing of the new system). The chief problems and our solutions follow:

-damage to a power distribution board was suspected as power was reaching the board but not leaving it. The system was stripped down and every component on the board tested with an oscilloscope. The board was intact, and the problem traced to bent pins in the waterproof connector to the on/off switch which activates the power regulators on the board. The connector was repaired as far as possible, the cable plugged in and tested, and left in position for the remainder of the cruise to avoid further damage.

-odd-looking spectra measured during the third deployment led to a suspicion of fibre-switch failure and CCD misalignment. The SUMOSS was brought back into the lab and both these systems checked: the CCD alignment was good, but the fibre-switches were found to be unreliable, possibly owing to blockage of the switching mechanism by excess length of optical fibre in the switch. Failing to alleviate the problem, I bypassed the switches completely by sending the transmission input signal directly to the spectrometer.

-odd-looking spectra were still being recorded despite the above work. After checking the optical system thoroughly, and measuring spectra successfully using the standard CCD software, a SUMOSS software error was suspected and the software checked extensively. Improvements were made to the software at this stage, particularly to the autoset function which had always given problems in extreme light conditions, however the odd-looking spectra were finally attributed to a reversal of the input-fibre order at the CCD entrance during the recent hardware upgrade (channel 1 became channel 7 etc.). This fact had been mentioned before departure and forgotten during pre-cruise preparation.

While the instrument was in the lab, Paolo Cipollini and others took on the task of enabling communication between SUMOSS and the deck via the RS232 cable which had not yet been implemented. The communications link was achieved using a standard 3-way RS232 connected to communication port 1, placing a command to receive input from com1 in the autoexec.bat file, and loading PC-NFS onto the SUMOSS computer. Further modifications to the SUMOSS software produced a system by which data collection (but not quality) could be monitored continuously via telnet, and data uploaded from the SUMOSS via Kermit file transfer. This arrangement was found to be an improvement on the old system, by which the status of the instrument could be monitored only be watching the current drawn on the lab supply, and the data transferred from the SUMOSS only by opening the main housing and connecting a monitor, keyboard and floppy disk drive to the SUMOSS motherboard. The SUMOSS is a cumbersome, 200lb instrument, and opening it up was neither particularly safe nor simple.

Ostensibly, successful deployments of the SUMOSS were made on some six occasions, however data transfer takes over 24 hours per station and so only a small portion of the data has been examined so far. It is intended to add the new SUMOSS data to the existing dataset for ongoing calibration of the instrument against water quality. A set of three stations coincided with a MOS colour satellite overpass, and the data will be used for ground-truth comparisons with the satellite image.

Three coloured Secchi discs (red/black, blue/black and green/black) were made during the period when SUMOSS was under repair, and these were deployed along with a standard black/white disc at every opportunity. Initial deployments made use of the taped 1 m markers on the rope, however these were found to slip along the rope when wet, so that the SUMOSS' pressure sensor was shackled to each disc in turn for all remaining deployments. This system had the additional advantages of being simple, fast and independent of absent-mindedness of the deployer (miscounting depth markers), however since the disc was often pulled away from the ship by strong currents, the desired measurement of distance through which the disc was visible through water could be replaced by the actual depth of the disc. This was acceptable when the current effect was constant over deployment of the whole disc set and only ratios were compared between stations. Otherwise corrections had to be made using estimates of the rope displacement angle.

**Flow Cytometry** *FJ, AC and CG*

The objective of these measurements was to determine the functional composition (cell density) and size structure of the phytoplanktonic community in the size range of 0.5 to 20 μm in near real time to match the surface spatial scales of physical data obtained by SeaSoar, SUMOSS, CTD, satellite images, etc. The mothod involved the novel ship -board use of a flow cytometric particle counter.

Sampling

Surface samples were taken hourly (on the 1/2 hour) from the non-toxic continuous flow (indirect line) during SeaSoar surveys, SUMOSS and LHPR deployments. Several additional samples were taken when requested. This sampling frequency was applied for the period of the three fine scale surveys and the survey along the Algerian current.

Vertical profiles were obtained by sampling the CTD Rossette bottles. The samples were taken from the bottles triggered at different depths: 5, 25, 50, 75, 100 and 200 for the CTD transect (Discovery stns 13037-13041) across the Almeria-Oran front; and 0, 20, 40, 60, 80, 100 and 150 m for Discovery stns 13046 and 13051.

Analysis

Flow cytometric analysis was carried out with a FacScan Becton-Dickinson particle counter (FCM) equiped with a 488 nm Argon ionic laser. Each sample was processed at two different instrument settings in order to identify the main phytoplanktonic groups. Size structure and functional composition of phytoplankton can be analysed by the FCM in the size range 0.5 to

20 μm (ESD). The conditions for acquisition of signals in each one of the instrument settings (voltage set 1 and 2) are given in **table 12**.

The flow of sample was set to high (54 μl/min) and the time of acquisition was fixed to 5 minutes when voltage set 1 was used, and to 2 min when voltage set 2 was applied. This gives an analysed volume of 0.270 ml and 0.108 ml per sample respectively. The data were logged on a Macintosh Centris 650 through the program CellQuest® and analysed with the program Attractors®, both from Becton-Dickinson.

The combination of the red fluorescence (wavelength > 607 nm), orange fluorescence (563-607 nm), forward and side light scattering allows the identification and enumeration of five ataxonomic cell groups: prochlorophytes, cyanobacteria, ultraplanktonic eukaryota, cryptophytes and nanoplankton. **Figure 18** shows the two typical bivariate plots in which these ataxomomic groups can be distinguished and counted.

## 5. DISCUSSION OF EARLY RESULTS

The OMEGA project is an interdiscplinary project to study mesoscale motion, in particular vertical motion, and its effect on biological processes. OMEGA makes use of both in-situ measurements, remotely sensed observations and modelling studies.

On RRS *Discovery* cruise 224 the towed, undulating, CTD, SeaSoar, was deployed to survey the upper 350m of the water column in the Eastern Alboran Sea during December 1996. Fluorescence, optical back scatter, light and 0.25-3.00 mm particle abundance were measured along with conductivity, temperature and pressure with an effective along track resolution of 4km. Two large scale surveys of the area enabled a detailed description of the different surface water types and the fronts that separate them. A fine resolution survey of the Almeria - Oran front was repeated 5 times during the period 12/12/96 to 17/1/95 to examine the temporal evolution of the front. The first three of these repeated surveys were descibed in this report, the last two were carried out during RRS *Discovery* cruise 224 (leg 2) and are described in Pugh et al. (1997).

A wide variety of instruments were used to monitor, directly or indirectly, the Ship's non-toxic supply. As a result, high spatial resolution measurements of temperature, salinity, chlorophyll fluorescence, light transmittance, nutrient concentration, dissolved organic material and 0.5-20.0 μm particle abundance in the surface water were made.

The hull mounted ADCP is now a well understood instrument for determining water velocity profiles of the upper water column and the provision of DGPS navigation enabled unprecedented accuracy to be achieved. The new vessel mounted ACCP data complemented that from the ADCP by providing water velocity profiles to much greater depths. Acoustic backscatter signal strength from the ADCP was used to make qualitative measurements of the larger zooplankton/fish abundance. But, deployment of the dedicated multi-frequency EK500 sonar system has enabled quantitative acoustic measurement of size class abundance ( > a few mm).

To complete the picture, a large number of meteorological parameters were measured both on the ship and in profile through radiosonde launches. And coincident remote sensing of the sea surface was achieved from the ship, from a dedicated meteorological flight aircraft and from satellites.

Atlantic water enters the Alboran Sea via the strait of Gibraltar and circulates around a system of gyres before forming the Algerian current (**Figure 19**). The eastern boundary of the eastern gyre forms the Almeria-Oran Front. **Figure 11** showed temperature, salinity and potential density contoured for SeaSoar section PD, along the axis of the Western Mediterranean from 1.8° W to 1° E, of the second large scale survey (**figure 3**). The extreme western end of the section lay in the eastern gyre of the Alboran sea. Within the gyre relatively warm fresh (salinity < 36.7 psu) water overlay cooler saltier Levantine Intermediate Water (LIW) (salinity > 38.4 psu). Between these was a transitional layer about 150m deep. To the east of the Almeria-Oran Front the transitional layer reached the surface. The resulting large horizontal density gradient across the front resulted in a strong (> 1 $ms^{-1}$) geostrophic flow along the front. The highest levels of chlorophyll fluorescence and optical back scatter were found in this frontal region. Near the eastern end of the section, a second front separated the transitional waters from the relatively warm and salty Mediterranean surface water. Mediterranean surface water is also marked by low chlorophyll fluorescence and optical back scatter. However, compensating changes in temperature and salinity result in only a small density change across this front and, therefore, associated currents are relatively weak. The LIW was characterised by a temperature maximum in the deeper waters (**figure 10**). Above this there was a temperature minimum which lay approximately on the surface $\sigma_0$=28.9. Temperature variations on this layer were found to be correlated with changes in layer thickness and an anticyclonic eddy of anomalously cold water can be seen in the centre of the section.

During the cruise, the surface signature of the Almeria Oran Front became more diffuse. This was probably due to the onset of poorer weather and consequent increased buoyancy loss and vertical mixing of the surface layers. Most immediately apparent in the thermosalinograph data, this was also seen in the satellite remote sensing data being acquired in near real time. Early analysis of the atmospheric profile data, from the radiosonde launches, has revealed several cases where an apparent change of atmospheric stability occurs across the Almeria-Oran front. In particular a sequence of profiles across the front was obtained on Julian day 345 which indicate a transition from a stable boundary layer over the cool water north of the front to marginally unstable conditions over the warmer water to the south. Time-height plots of the wind speed throughout the cruise clearly showed the development of intense winds between 400 and 100mb at intervals of order a week probably due to a southward displacement of the jet stream.

Absolute water velocity vectors from the VM-ADCP for the repeated fine scale surveys of the Almeria-Oran Front, showed strong vertical shear in the upper 150 m of the water column (**figure 20**) such that the along front jet was no longer apparent below this depth. The rapid repetition of the fine scale surveys showed that the position of the Almeria-Oran Front was variable on a timescale of hours/days; this was apparent in remote sensing data and hydrographic measurements but perhaps most striking in the VM-ADCP current vectors (**figures 20 and 21**). North/east of the front the current vectors showed regions of mesoscale eddy like re-circulation. It is clear that in all three fine scale surveys there was strong horizontal shear on the eastern side of the Almeria-Oran Front current. This shear created large cyclonic relative vorticity to the left of the current. For the first time, early analysis of data sets whilst on board ship included the calculation of vorticity and its mapping on isopycnal surfaces. These maps suggested that this creation of cyclonic relative vorticity was balanced in the pycnocline by an increase in layer thickness (decrease in stratification) as potential vorticity was conserved, however it is too early to present this analysis without review.

In general, throughout the cruise, the EK500 data showed strong diurnal migration of the larger zooplankton and fish, but also some strong backscattering layers associated with density surfaces indicated in the SeaSoar data. The effect of the frontal systems encountered was noticeable, sometimes breaking down, or delaying the migration process and, in general, signals in the surface 0-150m were weakest in the cooler Modified Atlantic water of the eastern Alboran gyre. A deep, very strong (MVBS > -56dB) backscattering layer was observed throughout the cruise ranging from 200 to sometimes 600 m, and the intensity of this was reduced after the evening migration had occured. Occasionally, there were short gaps of less than 2 hours duration in this layer, although these did not seem to coincide with any hydrographic features. Additional thin layers of high acoustic backscatter above this deep layer, sometimes only a few metres thick, occurred frequently and these were targeted during the LHPR tows.

Total chlorophyll (>0.7 µm) concentration was higher to the north and east of the Almeria-Oran front, especially in the northeast. During the first survey (**figure 22**) appeared the highest values of chlorophyll (>2 μg/l) and there was a clear distinction between surface waters in the south of the front, with probable oligotrophic features, and the northern region where higher values of chlorophyll were found. A comparison with flow cytometry results revealed a predominance of larger cells (nanoplankton and probably also >20 μm autotrophic organisms) in this chlorophyll rich region. These patterns are similar to those found for the second and, especially, the third survey (**figure 23**), although chlorophyll values were lower and there were some displacements of the maxima. Chlorophyll in larger cells (>20 μm) reached much higher values during the second survey, mainly concentrated in maxima near to the front. During the third survey, values were lower and the maxima appeared mainly in the southeast. The nanoplanktonic cells (size range between 4 and 12 μm ESD) were most abundant on the North-East side of the region (that is in the colder and saltier waters). This pattern was correlated with the chlorophyll distribution. In contrast the smallest cells (prochlorophytes and cyanobacteria, size range 0.5-2 μm) tended to appear in the South-Western side of the region. Similar patterns were found in all three fine scale surveys.

Preliminary results of the analysis for dissolved organic material showed quite clearly extremely low values of gelbstoff in this region of the Mediterranean ($a_y$(440) is in the range 0.01-0.07 $m^{-1}$), but also that mediterranean waters north of the Almeria Oran Front were richer in gelbstoff than Atlantic waters. A transect across the front during the 2nd fine scale survey showed an evident increase in gelbstoff concentrations from 0.3 to 0.7 $m^{-1}$ while going from Atlantic to Mediterranean waters. The preliminary results for the 3rd survey are plotted in **figure 24**. It shows higher concentrations of gelbstoff in the Mediterranean surface waters north of the front and very low values in the Atlantic inflow. It is not always well correlated with the distribuion of chlorophyll, but, of course, gelbstoff may be an indicator of past rather than present biological activity.

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**TABLE 1**

CTD timetable

| | Time at bottom of cast | | | | | | |
|---|---|---|---|---|---|---|---|
| Station | Jday | time | Lat | Lon | Depth (m) | Press (m) | Comment |
| 13018 | 337 | 15:51 | 36.4312 | -2.3636 | 828 | 829.5 | |
| 13021 | 338 | 16:39 | 36.2906 | -1.6905 | 1992 | 808.5 | |
| 13022 | 338 | 18:46 | 36.1732 | -1.728 | 1964 | 801.7 | |
| 13023 | 339 | 03:50 | 36.1634 | -1.7572 | 1928 | 404.9 | yo-yo ** |
| 13024 | 340 | 21:24 | 36.2675 | -1.7034 | 1987 | 808.3 | |
| 13028 | 345 | 05:47 | 36.7275 | -1.7749 | 1948 | 1952.4 | |
| 13032 | 345 | 15:35 | 36.3239 | -1.5877 | 2211 | 2232.0 | |
| 13033 | 345 | 21:22 | 36.1942 | -1.6843 | 1961 | 811.2 | |
| 13037 | 350 | 19:34 | 36.1689 | -1.8527 | 1828 | 1010.8 | |
| 13038 | 350 | 23:14 | 36.7327 | -1.7537 | 1946 | 1007.9 | |
| 13039 | 351 | 00:54 | 36.2903 | -1.6673 | 2022 | 1010.4 | |
| 13040 | 351 | 02:58 | 36.3614 | -1.5758 | 2283 | 1011.1 | |
| 13041 | 351 | 04:56 | 36.4226 | -1.4835 | 2404 | 1011.2 | |
| 13045 | 356 | 00:30 | 36.2073 | -1.7287 | 1922 | 1951.1 | |
| 13046 | 356 | 02:08 | 36.2313 | -1.7645 | 1924 | 154.0 | * |
| 13051 | 356 | 15:07 | 36.2582 | -1.6457 | 2015 | 154.7 | * |

* time at surface

** time and position at end of yo-yo

**TABLE 2**

Standard deviations of duplicate salinity samples.

| | No. of samples | Standard deviation of salinity differences |
|---|---|---|
| Duplicates | 42 | 0.0029 |
| Duplicates from > 800m | 22 | 0.0003 |
| Repeat Firings | 35 | 0.0109 |
| Repeat firings from >800m | 23 | 0.0004 |
| Repeat firings from <800m | 35 | 0.0183 |
| All duplicates and repeats | 77 | 0.0077 |

**TABLE 3**

TSG calibration parameters

| Section | calibration intercept | calibration slope | $r^2$ | mean difference | s.d. of residuals |
|---|---|---|---|---|---|
| 001 | -.1466580 | .9983089 | 0.99 | -.2090 | 0.006 |
| 002 | -.0839882 | .9967650 | 0.99 | -.2041 | 0.009 |
| 003 | .1314746 | .9910113 | 0.99 | -.2015 | 0.016 |

**TABLE 4**

EK500 calibration data for the 38 Khz and 120 Khz transducers using brass calibration spheres.

| Frequency | Old TS gain | New TS gain | operational settings | Ref. Target TS |
|---|---|---|---|---|
| 38kHz | 26.50 dB | 25.98 dB | Long and Narrow | -33.60 dB |
| 38kHz | 26.50 dB | 25.40 dB | Medium and Wide | -33.60 dB |
| 120kHz | 23.00 dB | 24.20 dB | Long and Narrow | -40.40 dB |
| 120kHz | 23.00 dB | 23.97 dB | Medium and Wide | -40.40 dB |

**TABLE 5**

Variables and sensors logged by the GrhoMet system. The variable names in the data files are shown [thus]. For each instrument (RVS) indicates that the sensor is part of the standard ship's system; (SOC) that the instrument was added for the D223 and D224 cruises.

| Variable | Position | Instrument | Period (JDAY) |
|---|---|---|---|
| Wet and Dry Bulb [psy1td psy1tw] | STBD side of foremast platform (forward sensor) | Psychrometer HS2019 (SOC) | 334 - 341 (1500 hrs) |
| | | Psychrometer HS2029 (SOC) | (1500 hrs)341 - 364 |
| Wet and Dry Bulb [psy2td psy2tw] | STBD side of foremast platform (aft sensor) | Psychrometer HS2020 (SOC) | 334 - 364 |
| Humidity [hum] | PORT side of foremast platform | Vaisala HMP 35A (RVS) | 334 - 364 |
| Air temp [atemp] | STBD side of foremast platform | Vector Inst. T351 (RVS) | 334 - 346 |
| Longwave [lw1] | Top of foremast (port sensor) | Eppley PIR 27225 (SOC) | 334 -346 (1340 hrs) |
| | | Eppley PIR 31170 (SOC) | (1340 hrs) 346 - 364 |
| Longwave [lw2] | Top of foremast (starboard sensor) | Eppley PIR 31171 (SOC) | 334 - 364 |
| ShortWave [ptir] | Gimbal mounted on port side of foremast platform | Kipp & Zonen CM6B 962301 (RVS) | 334 - 364 |
| ShortWave [stir] | Gimbal mounted stbd side of foremast platform | Kipp & Zonen CM6B 962276 (RVS) | 334 - 336 (1700 hrs) |
| | | Kipp & Zonen CM11 903289 (SOC) | (1700 hrs) 336 - 364 |
| Photosynthetically active radiation [ppar] | Gimbal mounted on port side of foremast platform | Didcot DRP-1 1678 (RVS) | 336 - 364 |
| Photosynthetically active radiation [spar] | Gimbal mounted stbd side of foremast platform | Didcot DRP-1 1752 (RVS) | 336 - 364 |
| Wind Speed & Direction [ws1 wd1] | PORT side of foremast platform | RM Young AQ (RVS) | 336 - 364 |
| SST [sst2] | Trailing from 6 M scaffold pole off port Bow | Trailing Thermistor pd002 (electronics 51) (SOC) | 336 - 364 |

| | | | |
|---|---|---|---|
| SST [sst1] | Hull mounted approx. 5 meters depth. | PRT (RVS) | 336 - 364 |
| Pressure [baro] | Lab | Vaisala DPA21 (RVS) | 336 - 364 |
| Time | Lab | Ship's clock (RVS) | 336 - 364 |

**TABLE 6**

SST sensors used during RRS *Discovery* cruise 224.

| Sensor | Position | Measurement | Logging system |
|---|---|---|---|
| Hull | Forward hold | bulk at ≈ 3.5m | GrhoMet |
| Trailing thermistor | Port bow | bulk at ≈ 0.5 m | GrhoMet |
| Thermosalinograph | Intake pipe in forward hold | bulk at ≈ 5.0m | RVS Underway sensors |
| SIL radiometer | bow | skin | PC system |
| Tasco radiometers | bow | skin + sky | PC system |

**TABLE 7**

Deployment log for the SIL and Tasco radiometers

| day | time | Comment |
|---|---|---|
| 337 | 1358 | SIL Radiometer & Tascos deployed |
| 339 | 1144 | SIL radiometer stopped, Hot Black Body temp. high |
| 339 | 1708 | Radiometer reassembled, sampling restarted |
| 339 | 2259 | Bad weather: swung inboard and capped |
| 341 | 0137 | powered down for passage to Oran |
| 341 | 1148 | powered up, still viewing inboard |
| 341 | 1510 | radiometer deployed |
| 343 | 1953 | Bad weather: swung inboard and capped |
| 344 | 0920 | Redeployed |
| 344 | 1215 | Bad weather: swung inboard and capped |
| 344 | 2245 | Redeployed |
| 346 | 1413 | Logging off for file backup |
| 346 | 1430 | Logging restarted |
| 348 | 1150 | Possible bad weather: swung inboard and capped |
| 350 | 1100 | Redeployed |
| 356 | 0705 | logging stopped to change Tasco batteries |
| 356 | 0745 | restart logging |
| 356 | 1541 | logging stopped to reconfigure sampling onto separate computers for SIL and Tasco's |
| 356 | 1627 | logging restarted |
| 357 | 0127 | Tasco logging stopped to alter display |
| 357 | 0139 | logging restarted |
| 357 | 0252 | SIL logging stopped for software change |
| 357 | 0302 | logging restarted |
| 357 | 0914 | SIL logging stopped for software change |
| 357 | 1021 | logging restarted |
| 357 | 1310 | SIL program crashed |
| 357 | 1424 | logging restarted |
| 358 | 0954 | logging off for bucket calibration |
| 358 | 1040 | Bucket calibration starts |
| 358 | 1506 | end of bucket calibration |
| 358 | 1533 | Radiometers redeployed, Logging restarted |

| | | |
|---|---|---|
| 358 | 1641 | Logging off for data transfer |
| 358 | 1652 | logging restarted |
| 359 | 0512 | Bad weather: swung inboard and capped |
| 361 | 0910 | Redeployed |

**TABLE 8**

Deployment log for the trailing thermistor ("Soap")

| Jday | time | Comment |
|---|---|---|
| 334 | 17:00 | Connected but on deck |
| 337 | 02:40 | Deployed, sensor PD0002 +electronics 51 |
| 338 | 16:55 | Brought nearer to surface for CTD station |
| 338 | 17:30 | Paid out for towing |
| 341 | 04:00 | Recovered for passage in Algerian waters |
| 341 | 10:00 | Redeployed after Oran |
| 346 | 07:30 | Recovered for docking at Almeria |
| 346 | 17:15 | Redeployed |
| 347 | 15:15 | Recovered for bucket cals |
| 347 | 17:10 | Redeployed |
| 350 | 14:35 | Brought nearer surface for LHPR tow |
| 351 | 16:14 | Recovered for boat transfer at Almeria |
| 351 | 18:08 | Redeployed |
| 356 | 13:00 | Brought nearer surface while on station |
| 356 | 16:45 | Paid out for seasoar survey |
| 358 | 10:30 | Recovered for SIL radiometer calibration |
| 358 | 15:17 | Redeployed after calibration |

**TABLE 9**

Mean difference between the various SST sensors used during RRS *Discovery* cruise 224. Note that the radiometers have not been fully corrected for reflected sky radiation.

| Comparison | Mean | s.d. | No. | No. out |
|---|---|---|---|---|
| Soap -TSG | 0.001 | 0.035 | 28396 | 2 |
| Hull - TSG | -0.553 | 0.066 | 34435 | 0 |
| SIL -TAS | 0.086 | 0.356 | 36410 | 198 |
| SIL - TSG | -0.298 | 0.335 | 34162 | 273 |
| Tas -TSG | -0.4110 | 0.333 | 34341 | 94 |

**TABLE 10**

SBWR setup trials used during RRS *Discovery* cruise 224

| SETUP | Day 335 | Day 339/1734 | Day 354 /1252 | Day 354/1425 |
|---|---|---|---|---|
| Rec. Length (min) | 10 | 20 | 60 | 20 |
| Sample Interval (microsec) | 585937 | 390625 | 781250 | 781250 |
| No. sections | 2 | 3 | 4 | 3 |
| Samples/section | 512 | 1024 | 1024 | 512 |
| Bin width | 3 | 4 | 8 | 4 |

**TABLE 11**

Longhurst Hardy Plankton Recorder (LHPR) deployments.

| Station Number | Jday deployed | Jday recovered | Time deployed | Time recovered | Position deployed | Position recovered |
|---|---|---|---|---|---|---|
| 13025/ omega1 | 340 | 341 | 22:47 | 01:10 | 36 15.79N 1 41.80W | 36 21.01N 1 32.08W |
| 13030/ omega2*[1] | 345 | 345 | 09:03 | 11:19 | 36 15.09N 1 43.29W | 36 18.96N 1 33.48W |
| 13036/ omega3 | 350 | 350 | 14:40 | 17:05 | 36 16.15N 1 34.65W | 36 9.94N 1 41.43W |
| 13042/ omega4 | 351 | 351 | 09:08 | 11:28 | 36 11.62N 1 49.25W | 36 17.85N 1 42.57W |
| 13048/ omega5 | 356 | 356 | 09:17 | 11:42 | 36 14.66N 1 34.17W | 36 10.35N 1 43.84W |
| 13056/ omega6*[2] | 361 | 361 | 14:34 | 16:55 | 36 35.09N 1 39.01E | 36 41.26N 1 38.92E |
| 13058/ omega7 | 362 | 362 | 09:35 | 12:04 | 36 40.65N 1 13.96E | 36 50.01N 1 17.62E |
| 13059/ omega8 | 362 | 362 | 14:30 | 16:47 | 36 48.50N 1 17.08E | 36 57.08N 1 20.03E |

*[1] = Battery failed halfway through haul.
*[2] = Bucket as drogue - haul very deep.

**TABLE 12**

Flow Cytometry equipment settings.

| Parameter | Detector | Voltage set 1 | Voltage set 2 | Mode |
|---|---|---|---|---|
| Forward scattering | FSC | E00 | E01 | LOG |
| Side scattering | SSC | 271 | 402 | LOG |
| Green fluorescence | FL1 | 450 | 450 | LOG |
| Orange fluorescence | FL2 | 450 | 555 | LOG |
| Red fluorescence | FL3 | 300 | 651 | LOG |
| *Threshold* | FL3> | 10 | 328 | LOG |

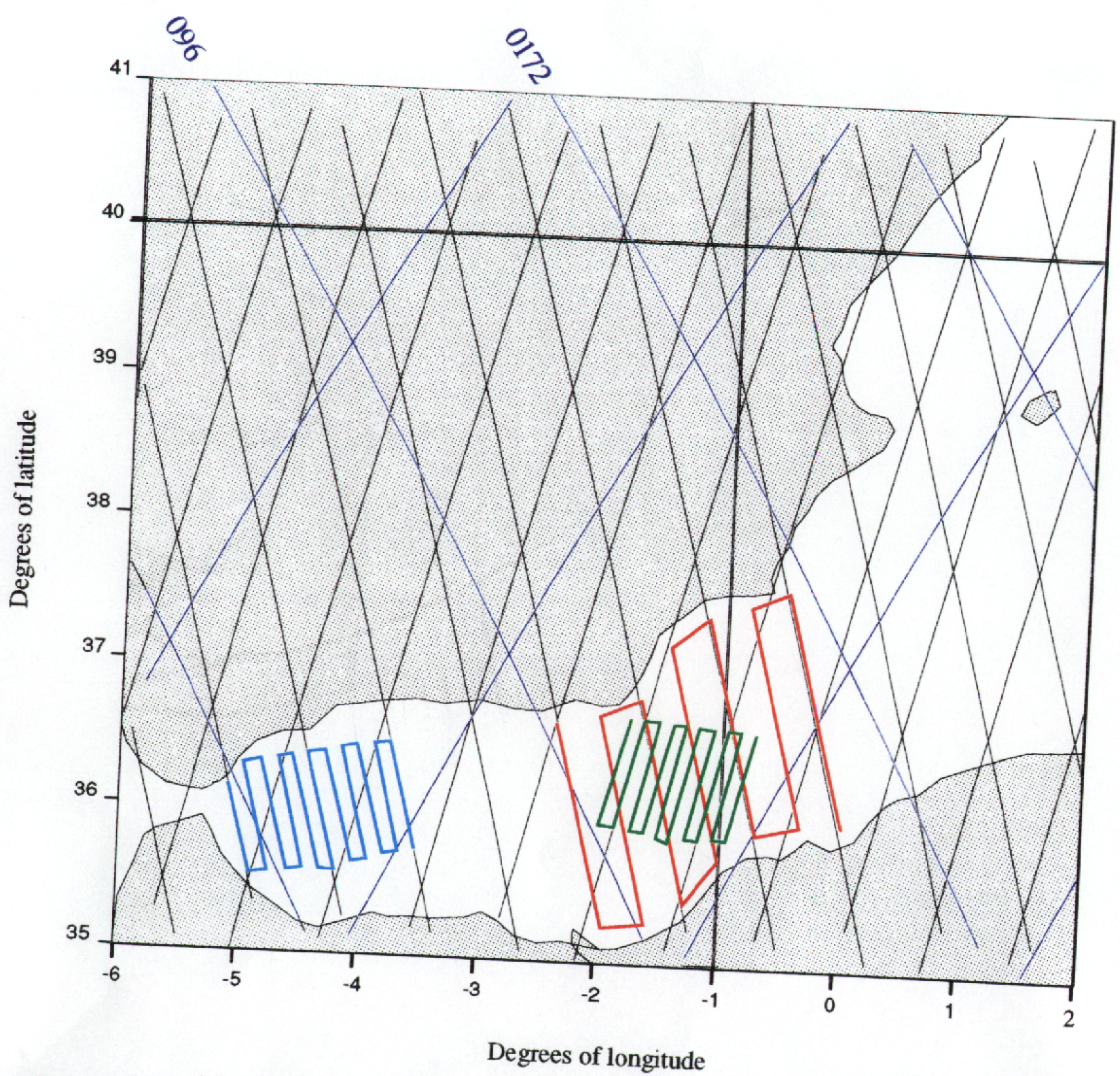



Figure 1. Cruise tracks for *RRS Discovery* (red and light green) and *BIO Hesperides* (light blue). Grey (purple) lines are ERS1/2 (Topex-Poseidon) satellite passes. For *RRS Discovery*, the large scale survey SeaSoar track is shown in red and an example of a fine scale survey track is shown in green.

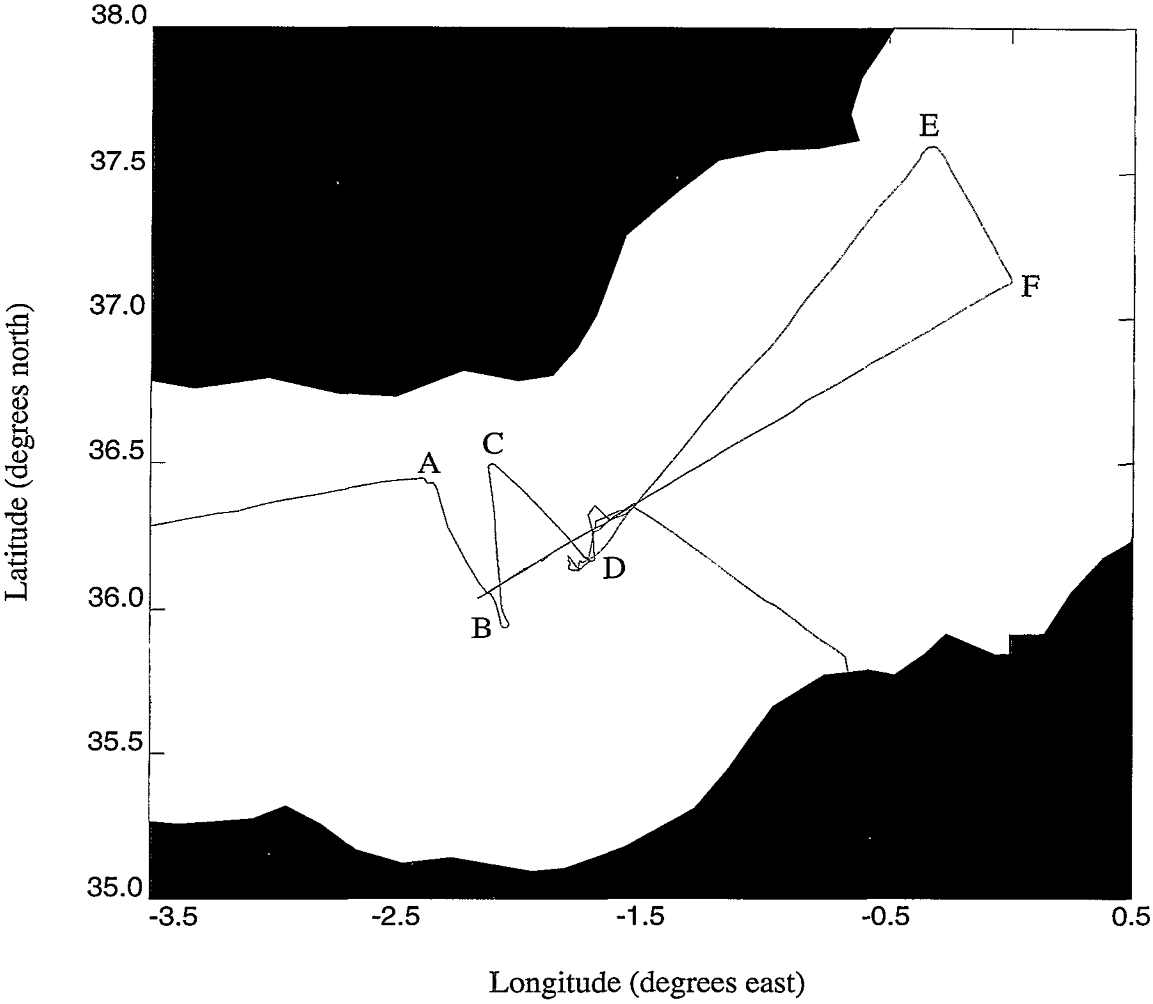



Figure 2. Cruise track for the first large scale survey.

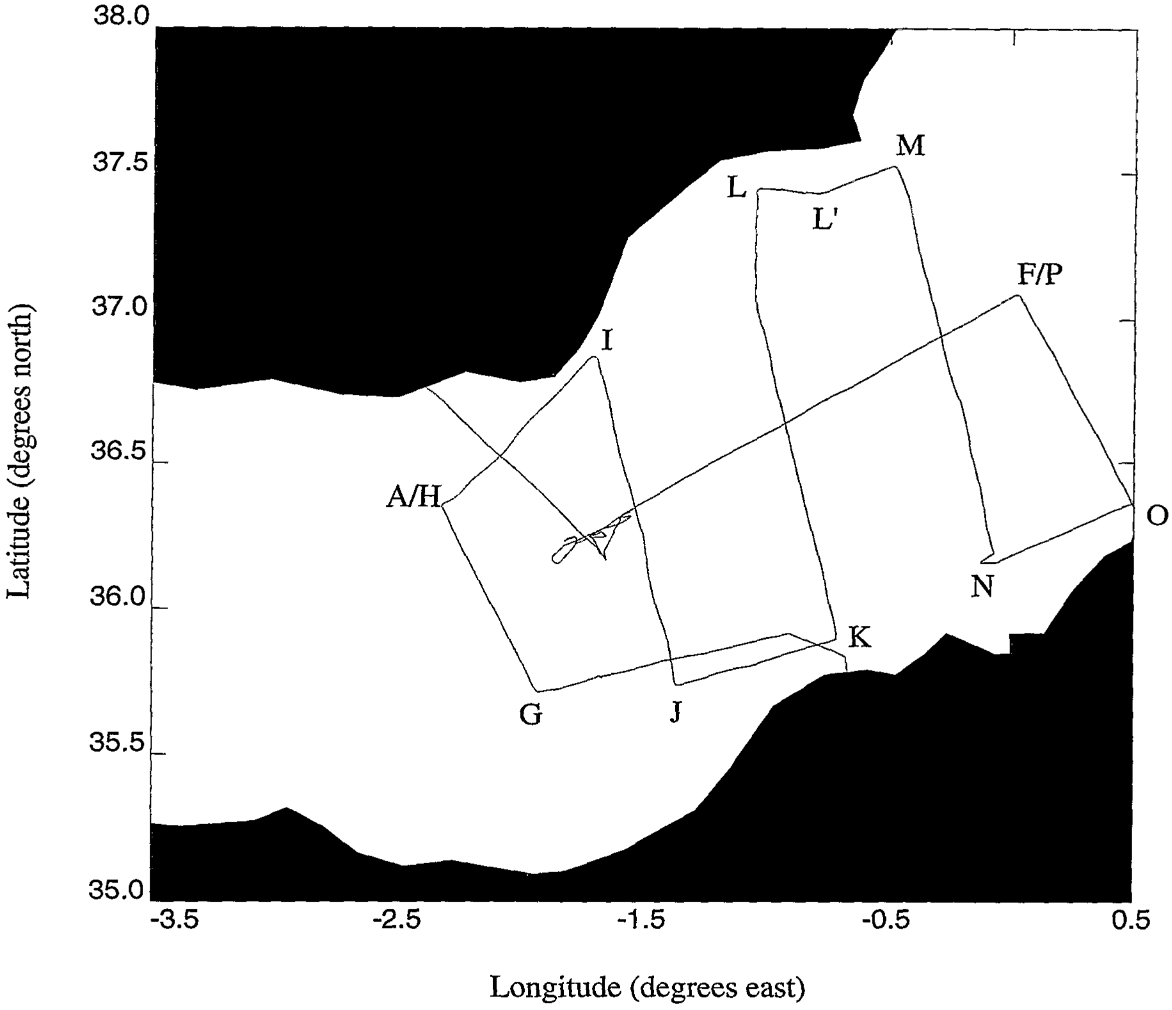



Figure 3. Cruise track for the second large scale survey.

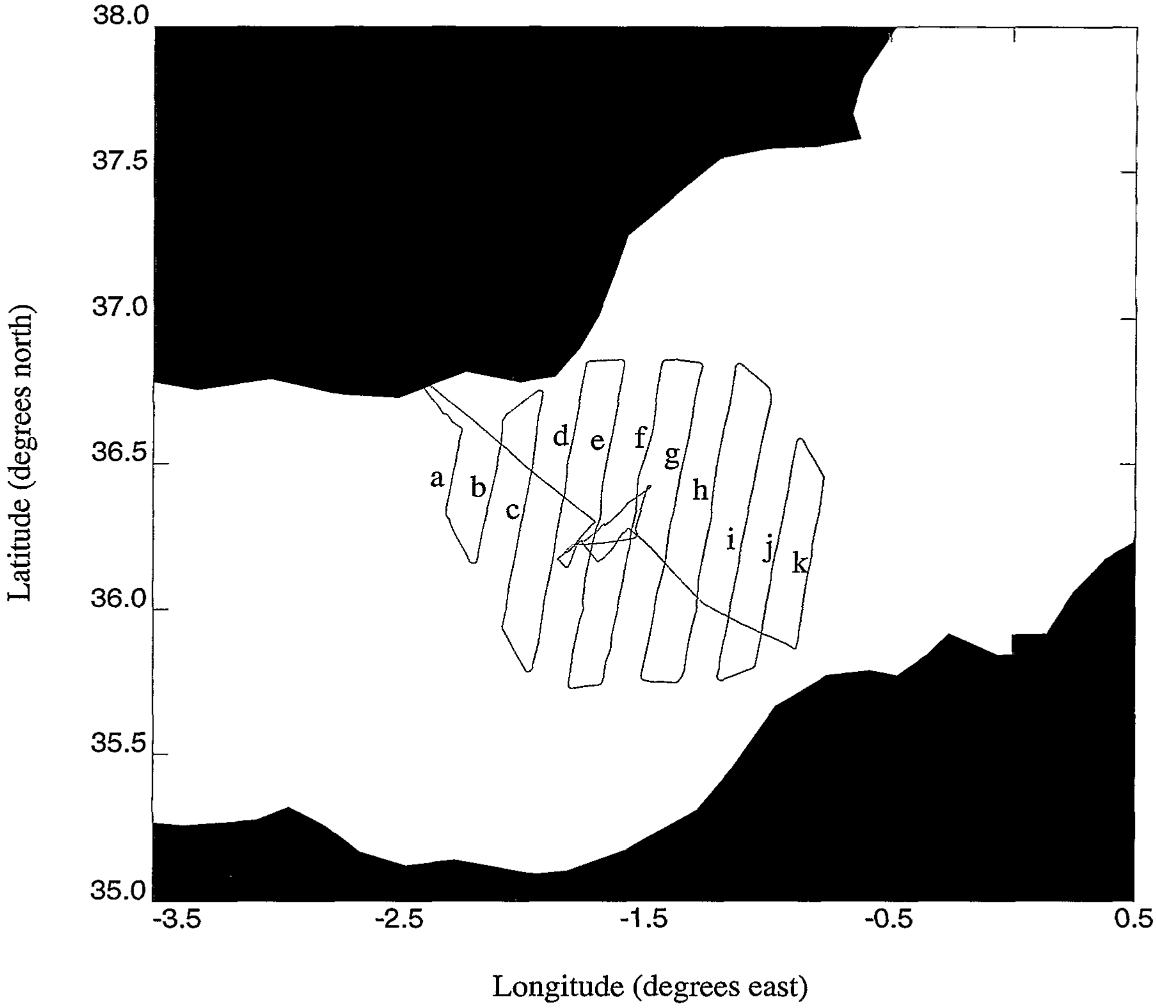



Figure 4. Cruise track for the first fine scale survey.

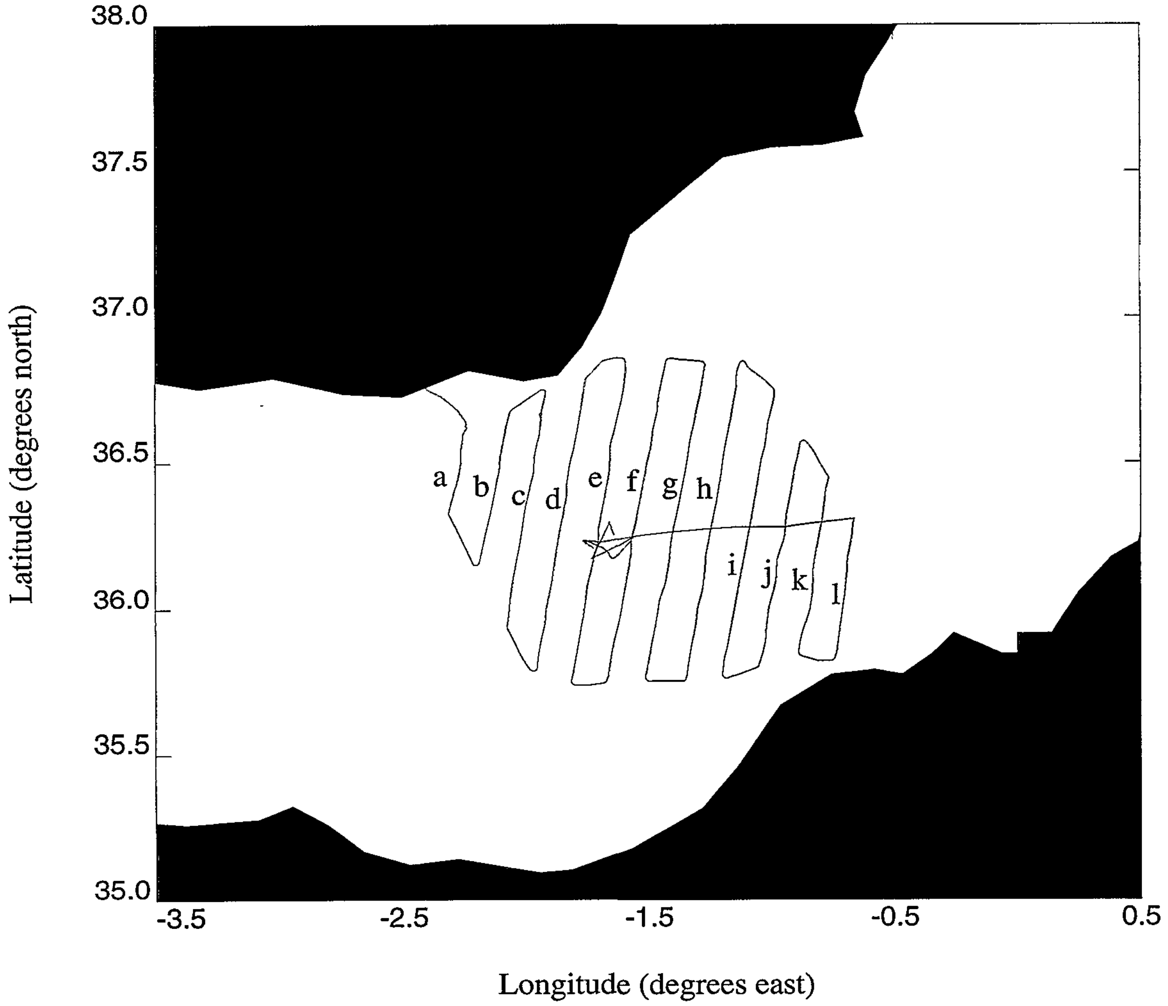



Figure 5. Cruise track for the second fine scale survey.

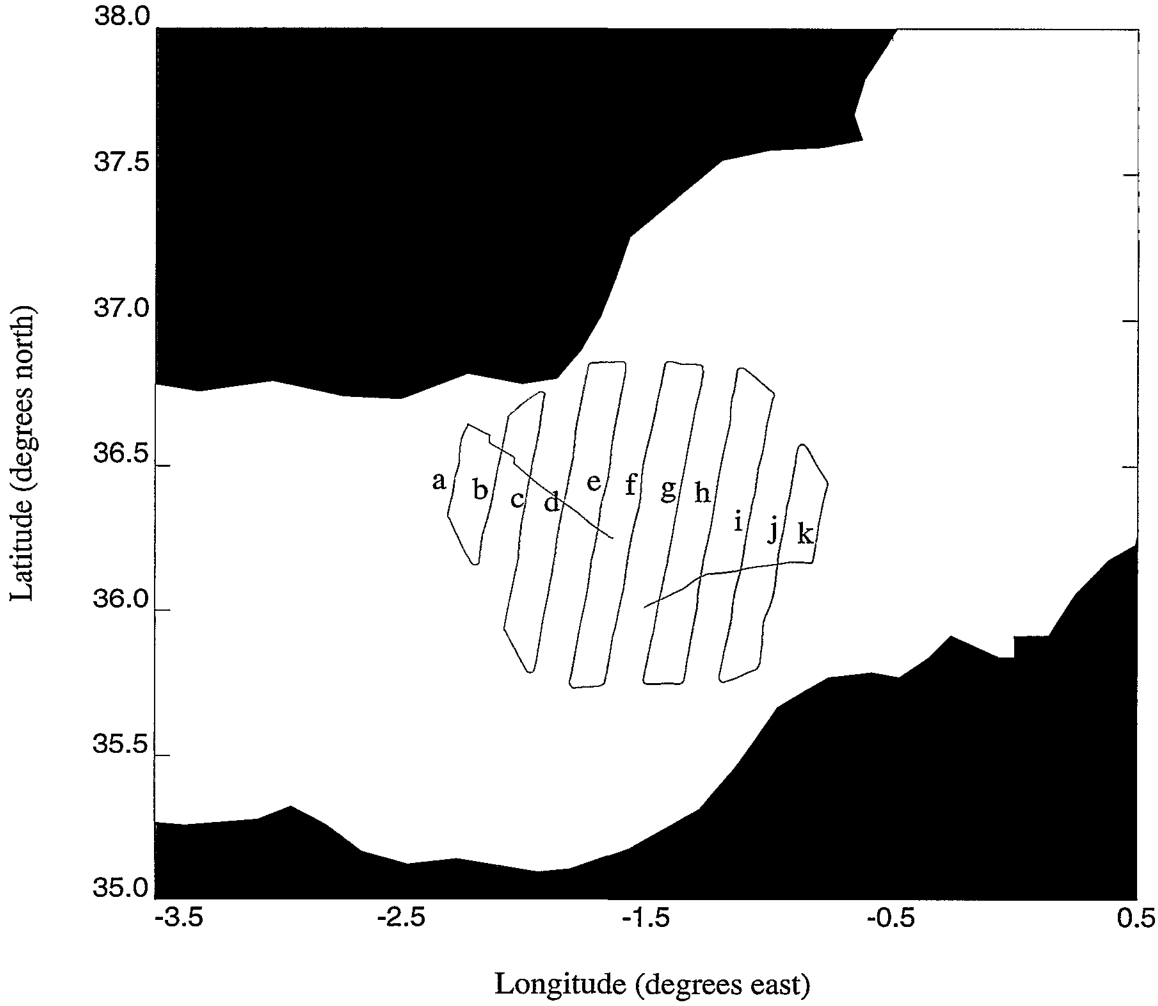



Figure 6. Cruise track for the third fine scale survey.

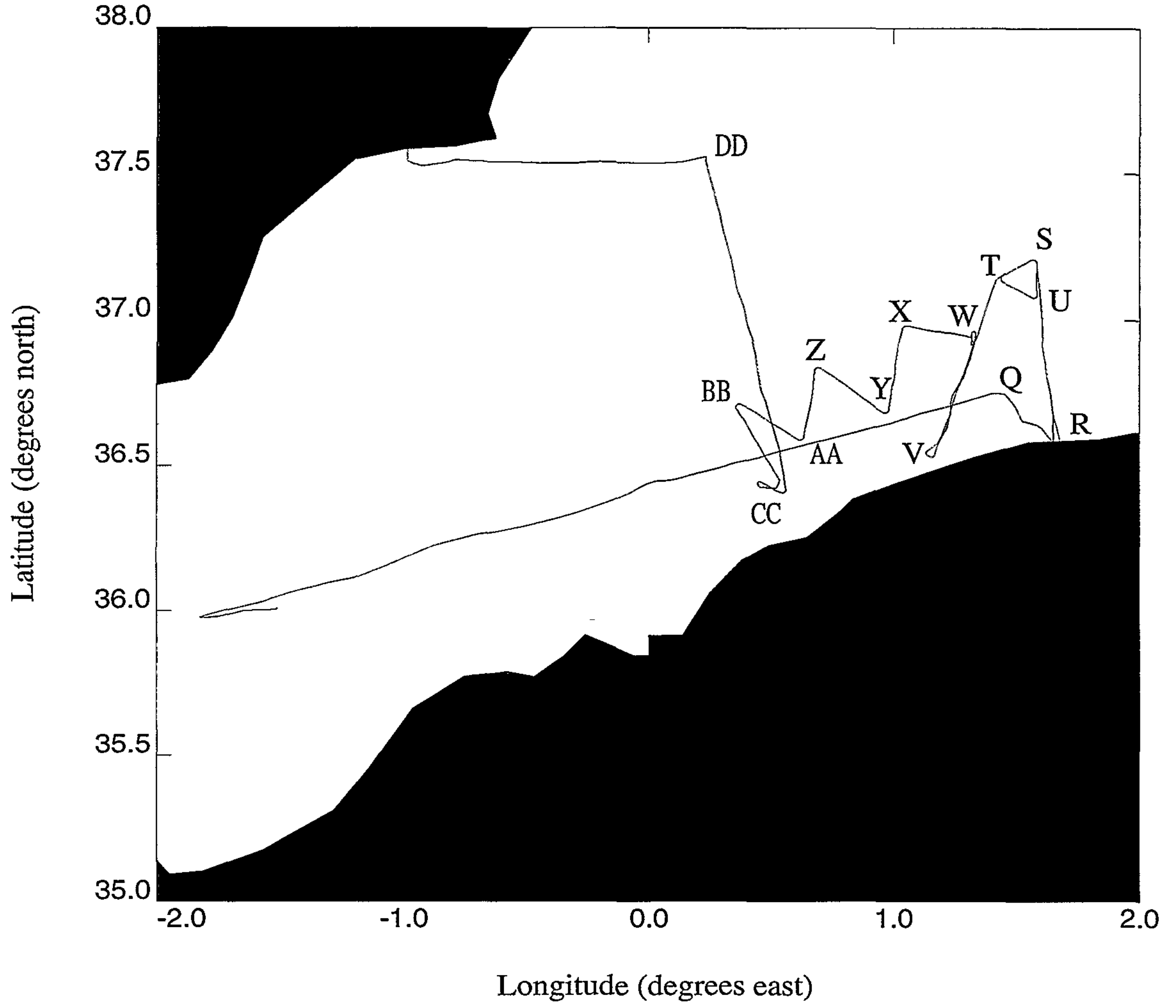



Figure 7. Cruise track for the Algerian Current survey.

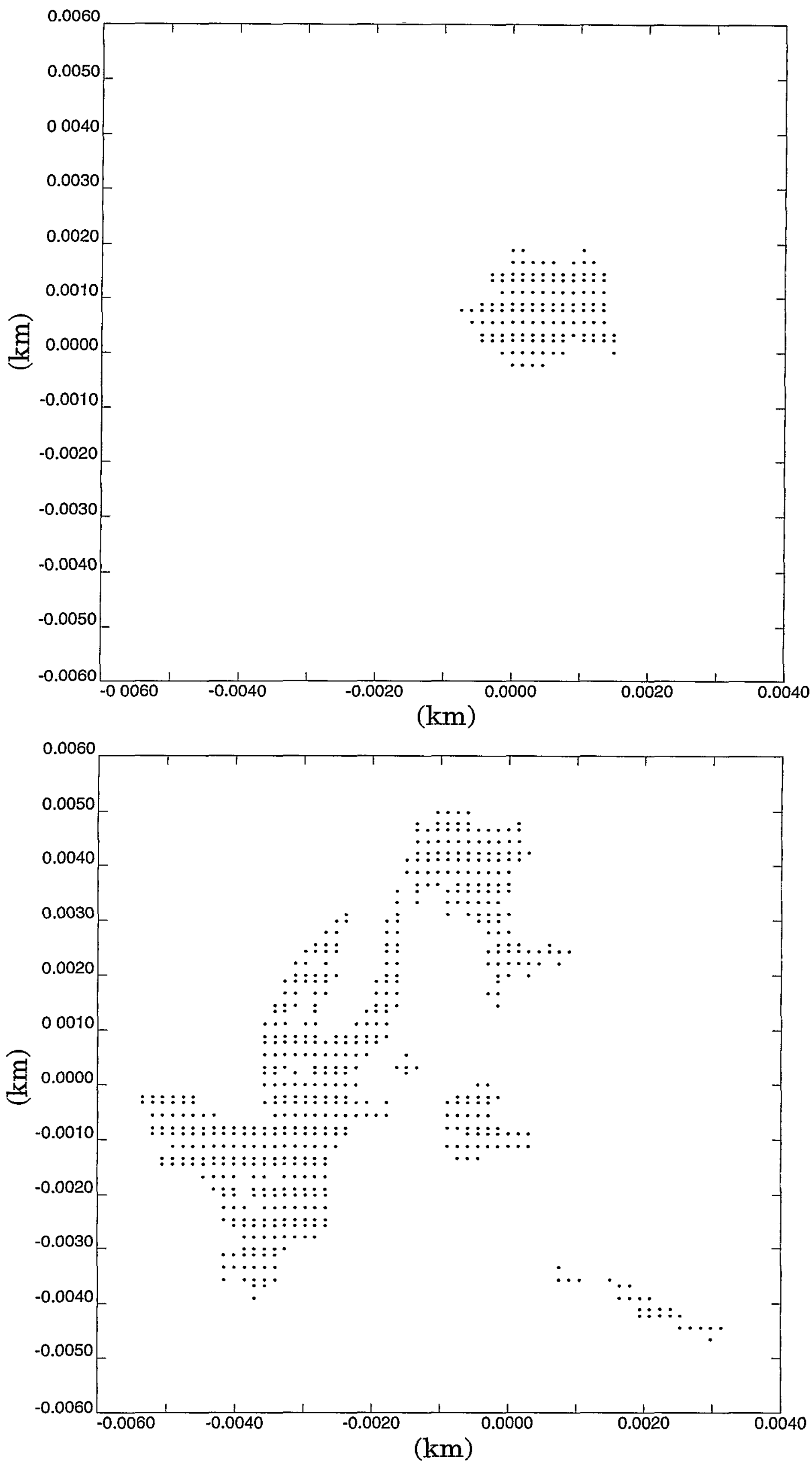



**Figure 8.** The position of the ship whilst moored alongside in Almeria, Spain as determined by RACAL 'Skyfix' differential GPS referenced to Cadiz (top) and Rome (bottom). The x and y axes represent distance in kilometres east and north respectively relative to the position 36.83590° North, 2.47217° West.

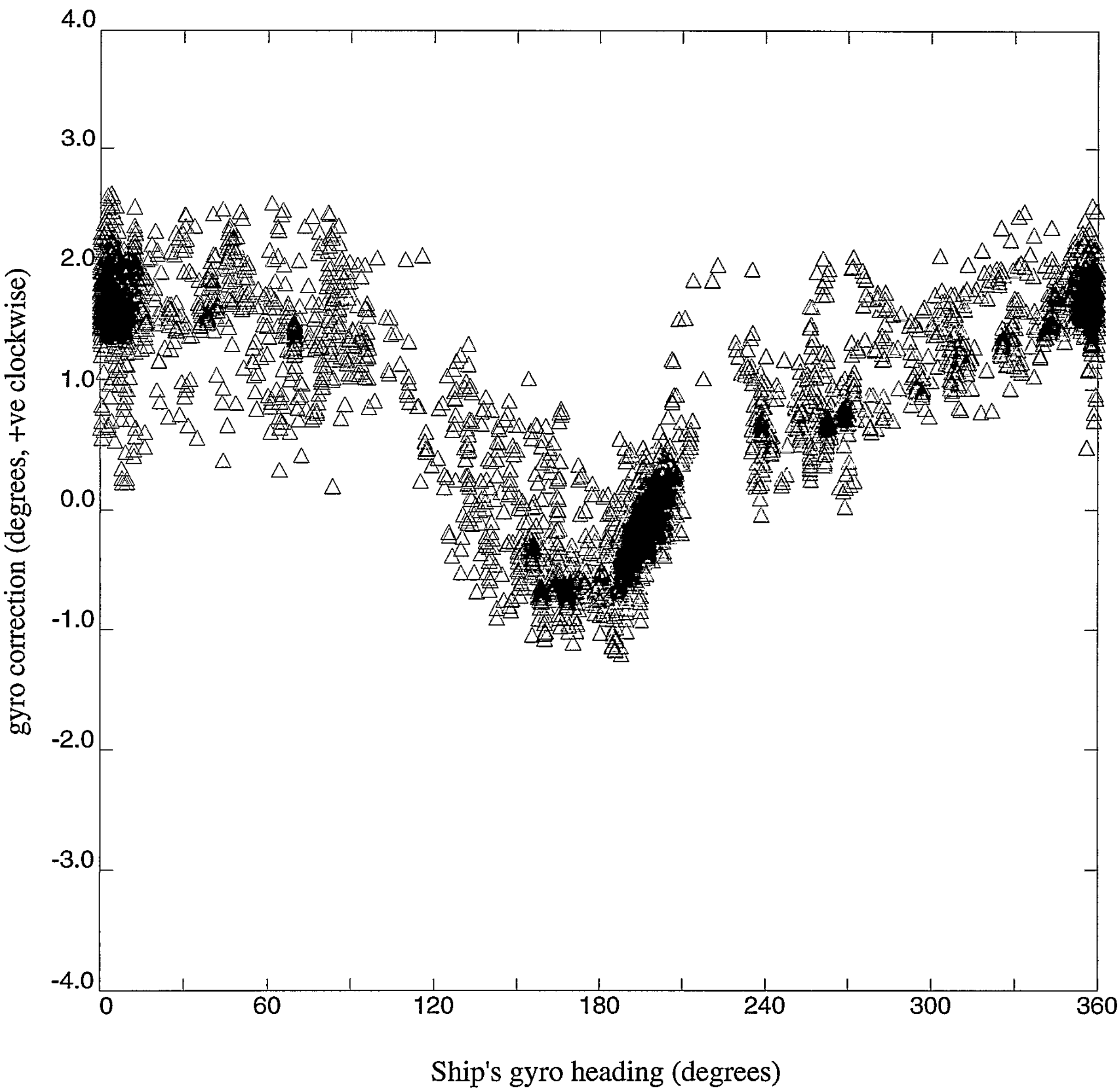



Figure 9. Ship's gyro heading correction derived from the Ashtech 3D GPS system and after filtering and manual editing.

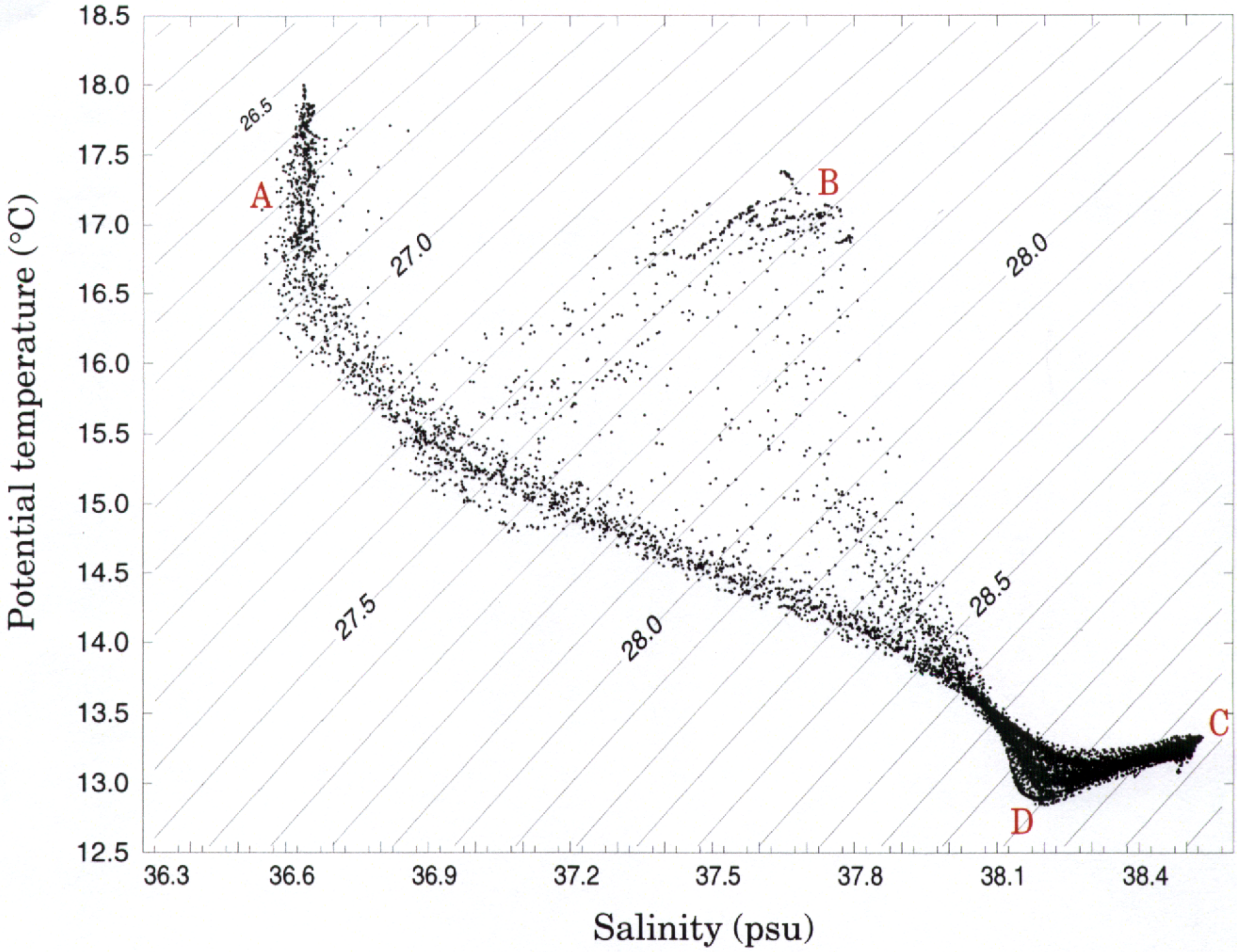



**Figure 10.** Potential temperature as a function of salinity for all the SeaSoar data collected during the second large scale survey. Lines of constant density are also shown at intervals of 0.1 $kg/m^3$. Note the relatively fresh surface waters of in the eastern Alboran gyre (A), the warm salty Mediterranean surface waters (B), the Levantine water (C) and the temperature minimum layer (D)

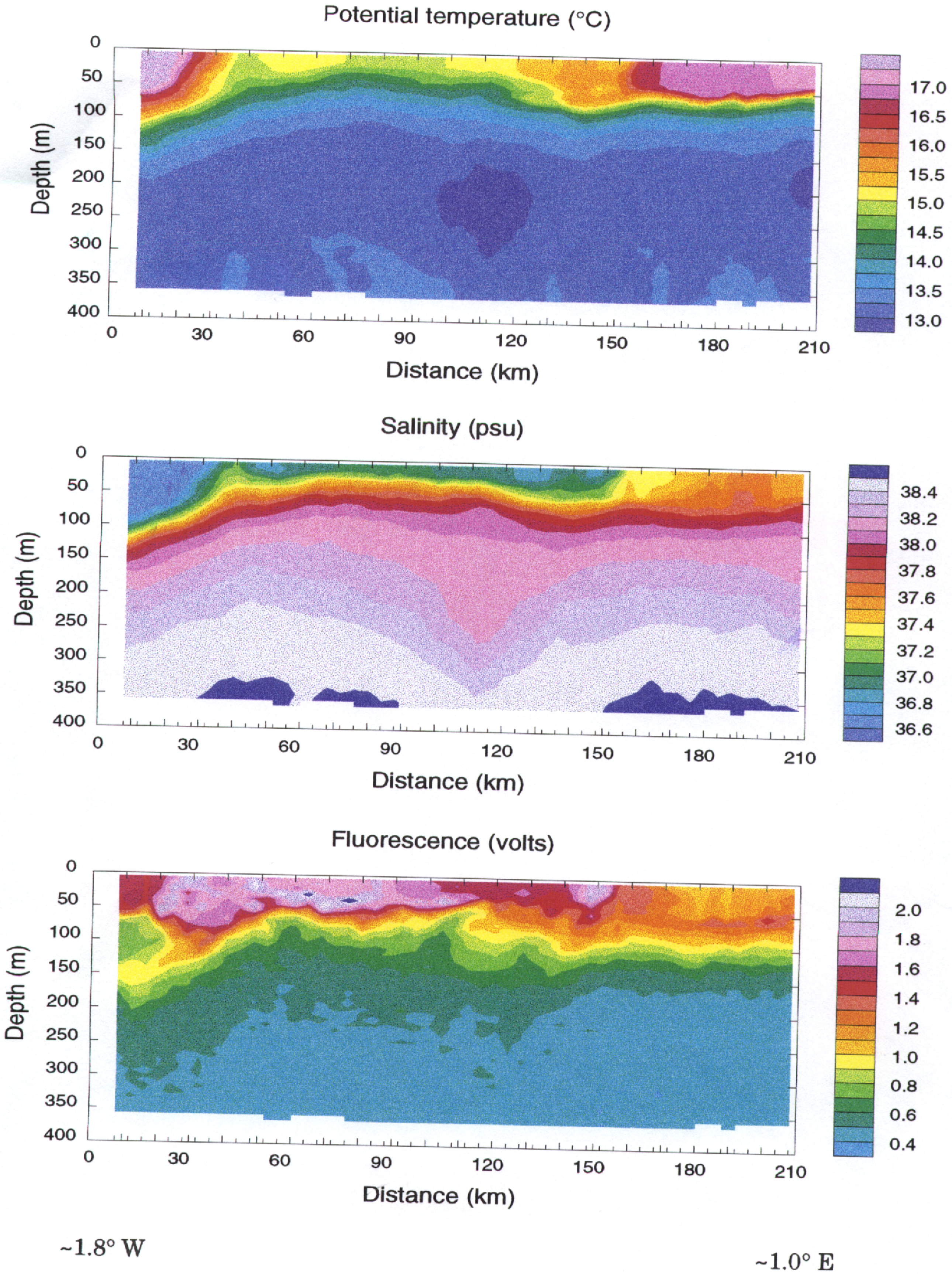



**Figure 11**. SeaSoar section DP (**Figure 3**) showing potential temperature, salinity and uncalibrated fluorescence in the upper 400m.

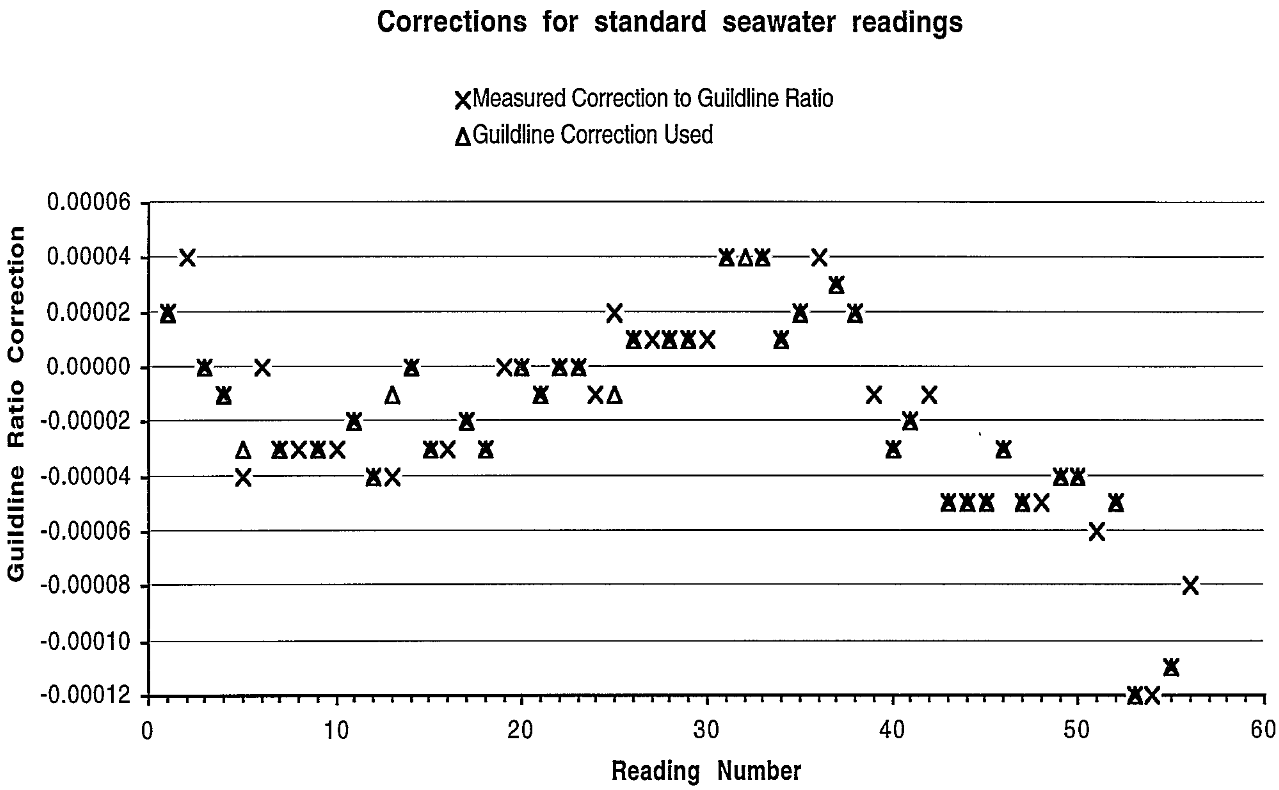
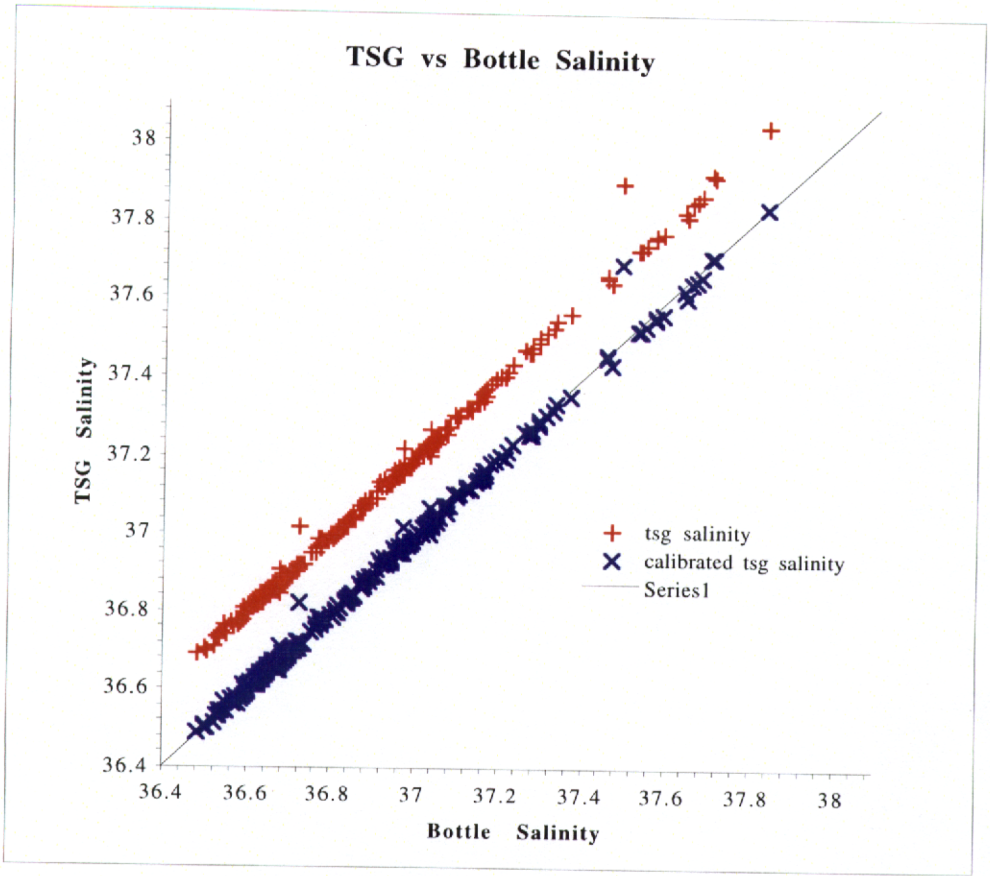



Figure 12. Correction to Guildline ratio obtained from P130 batch IAPSO seawater standards during the cruise.



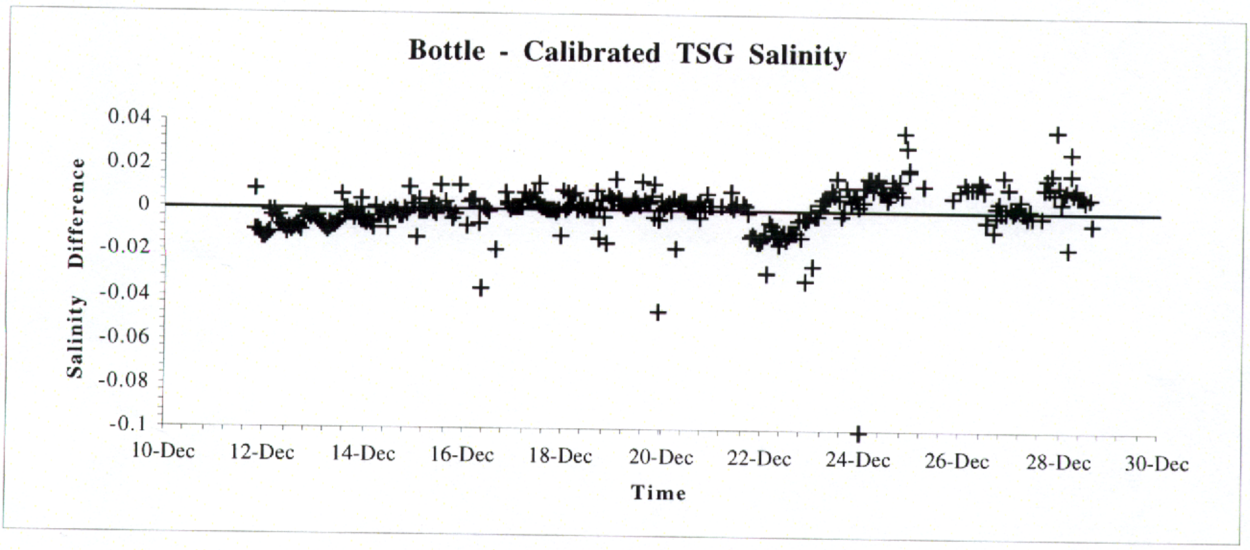




Figure 13. TSG salinities vs. bottle salinities (top) and residual noise between bottle salinities and calibrated TSG salinities (bottom), from the beginning of the first fine scale survey to the end of the cruise.

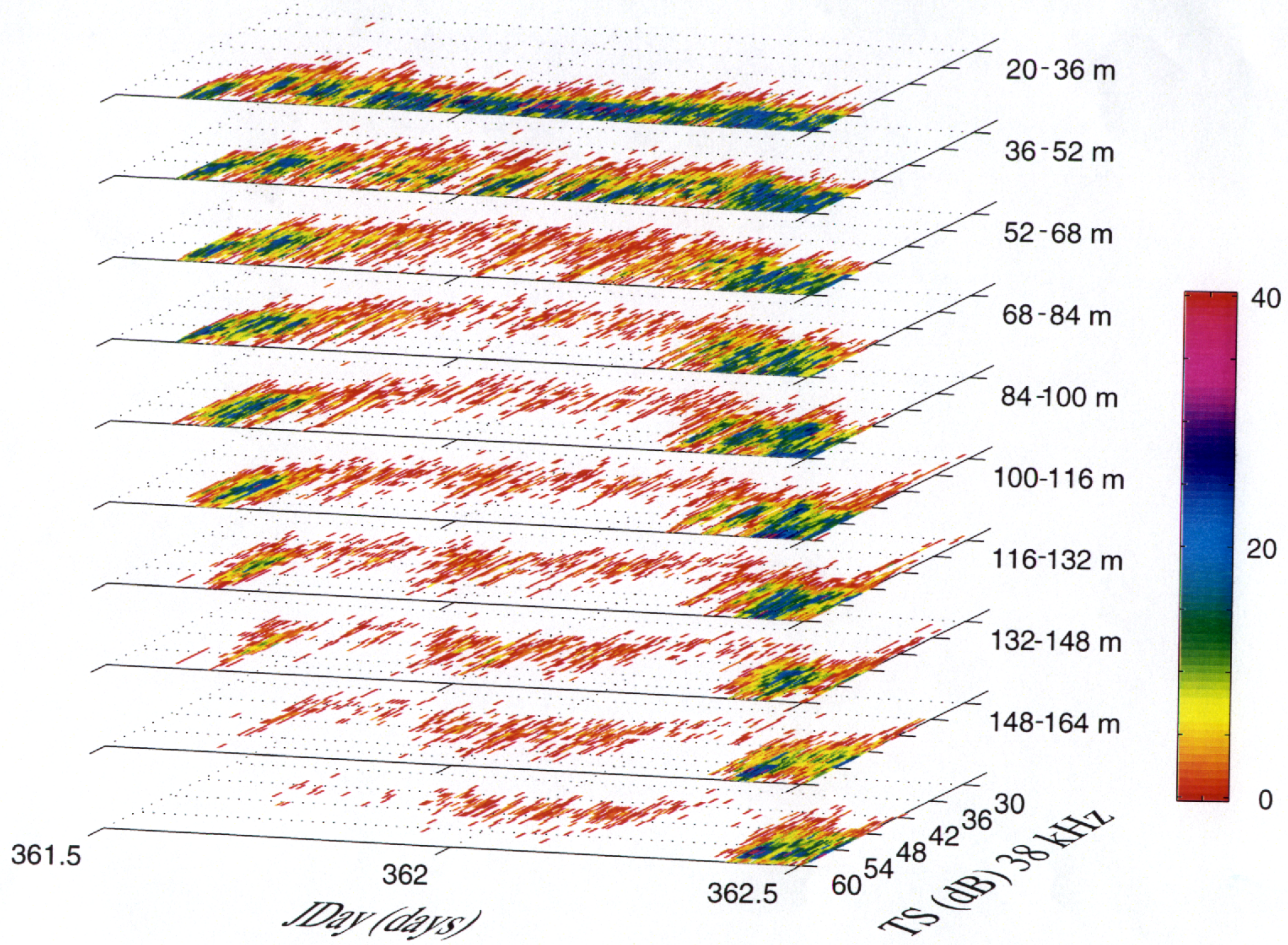



Figure 14. EK500 data. Number of detections contoured against target strength and time for specific depth layers.

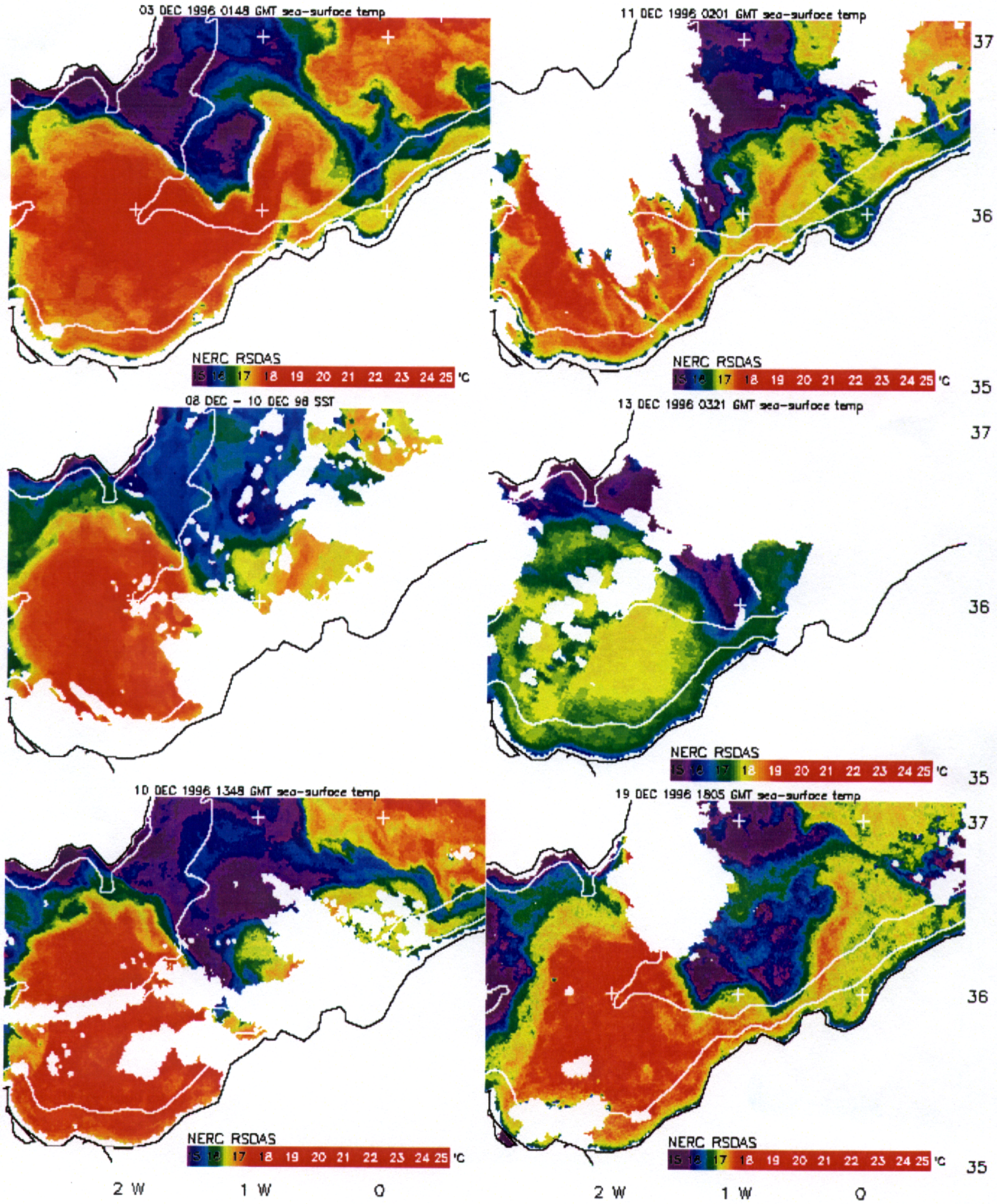



Figure 15. AVHRR images obtained in near real time via NERC's Satellite Receiving Station in Dundee and Image Analysis Unit in Plymouth.

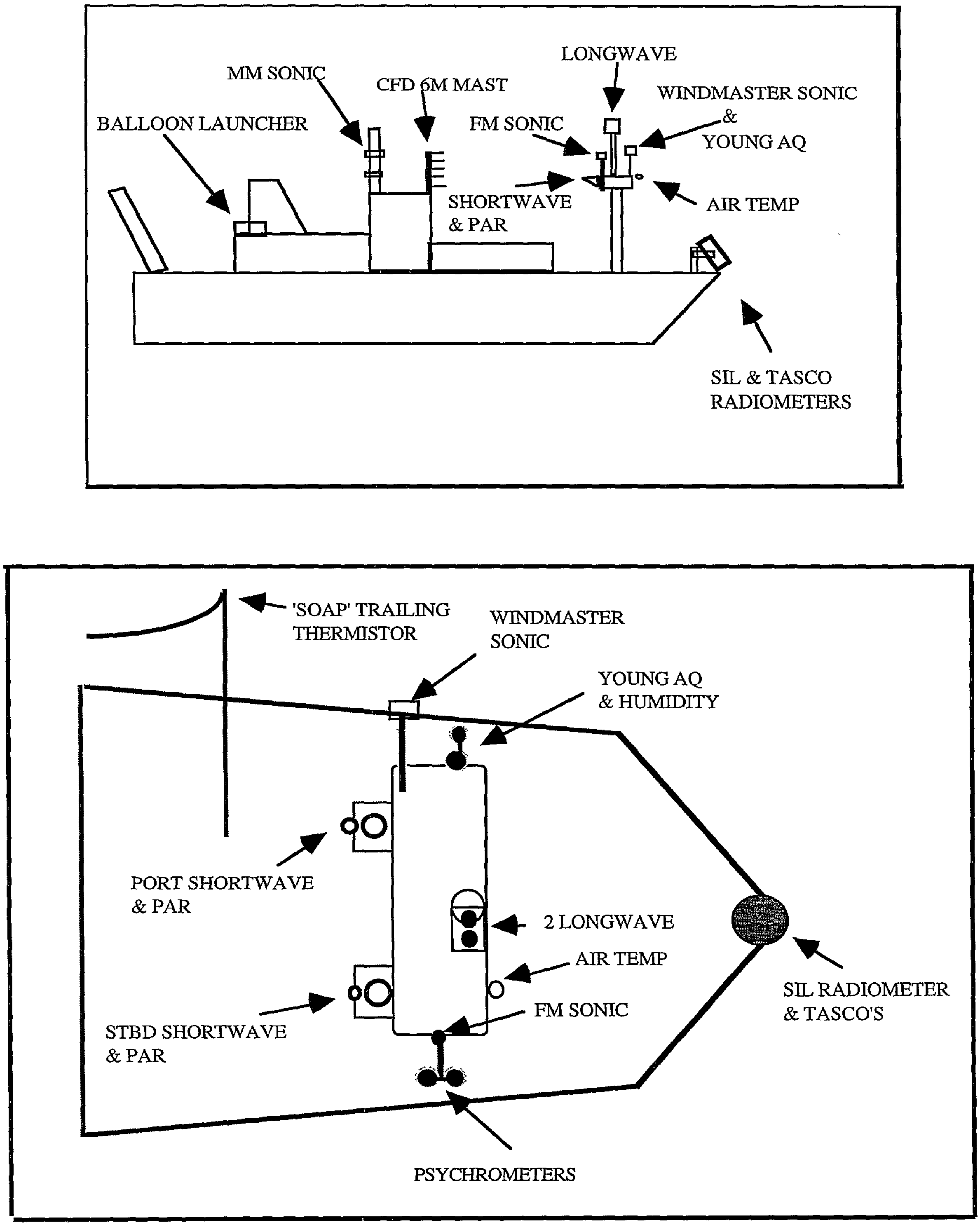



Figure 16. Meteorological sensor positions for Discovery Cruise D224.

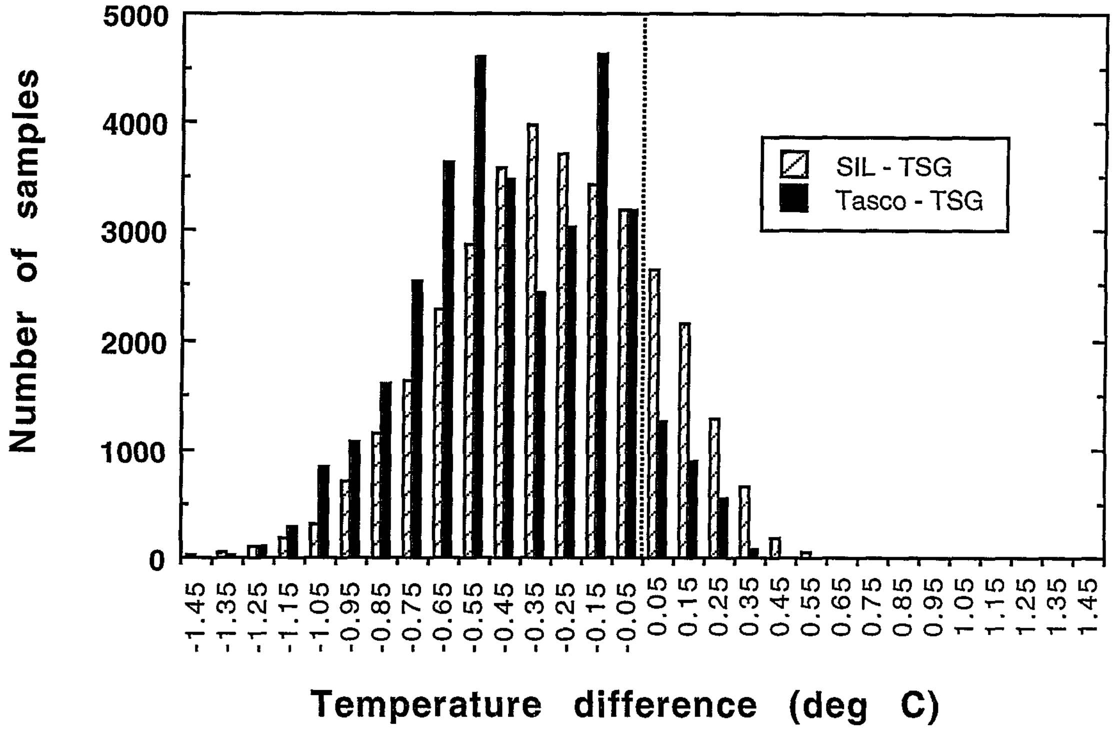



Figure 17. Histogram of mean temperarure differences between the SST data from the SIL and Tasco radiometers and the Thermosalinograph (TSG).

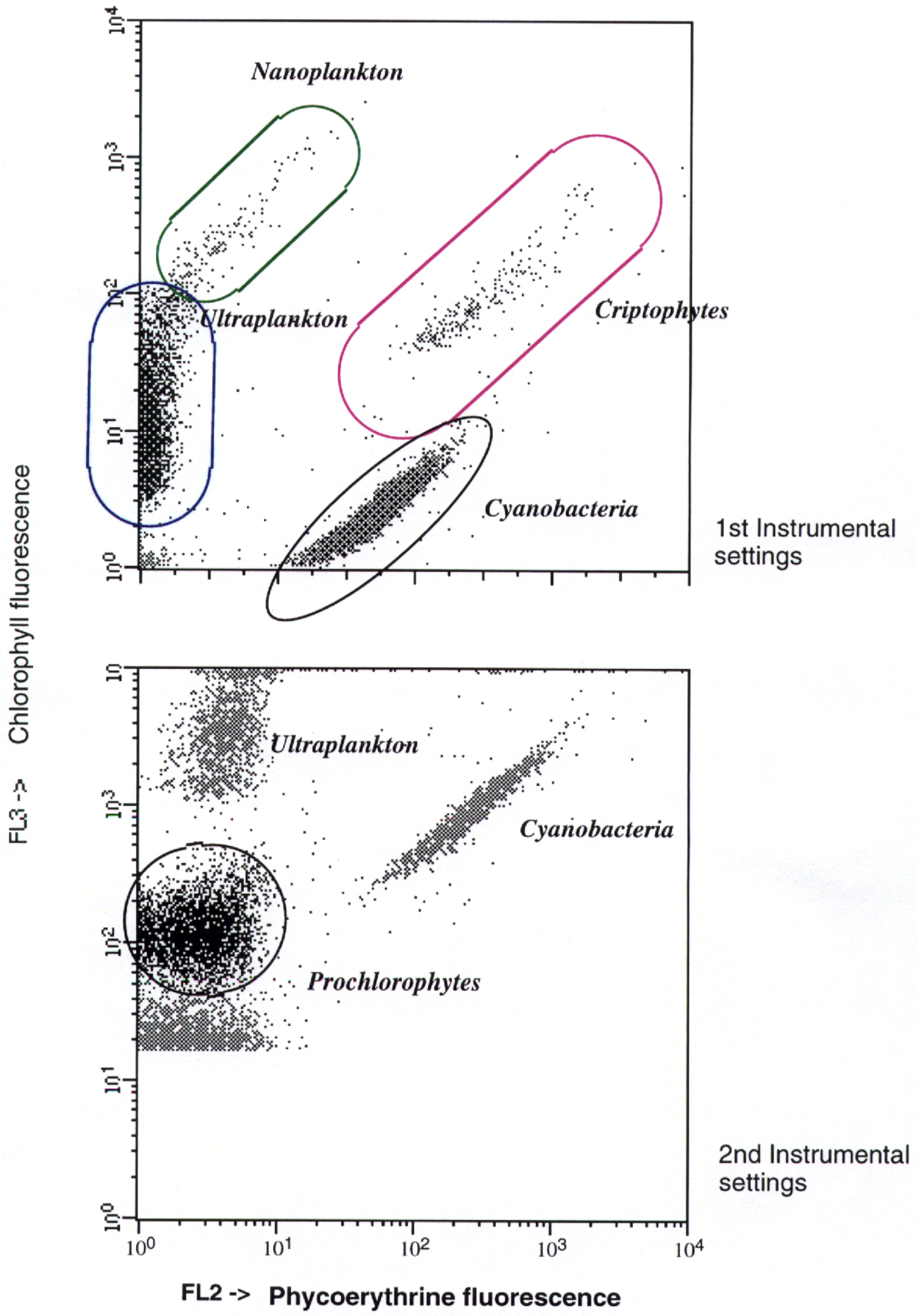



Figure 18. Flow Cytometry bivariate plots of the FL3 (chlorophyll fluorescence) versus FL2 (phycoerythrine fluorescence) signals for the two different instrumental settings. The diagrams show the main phytoplanktonic groups identified.

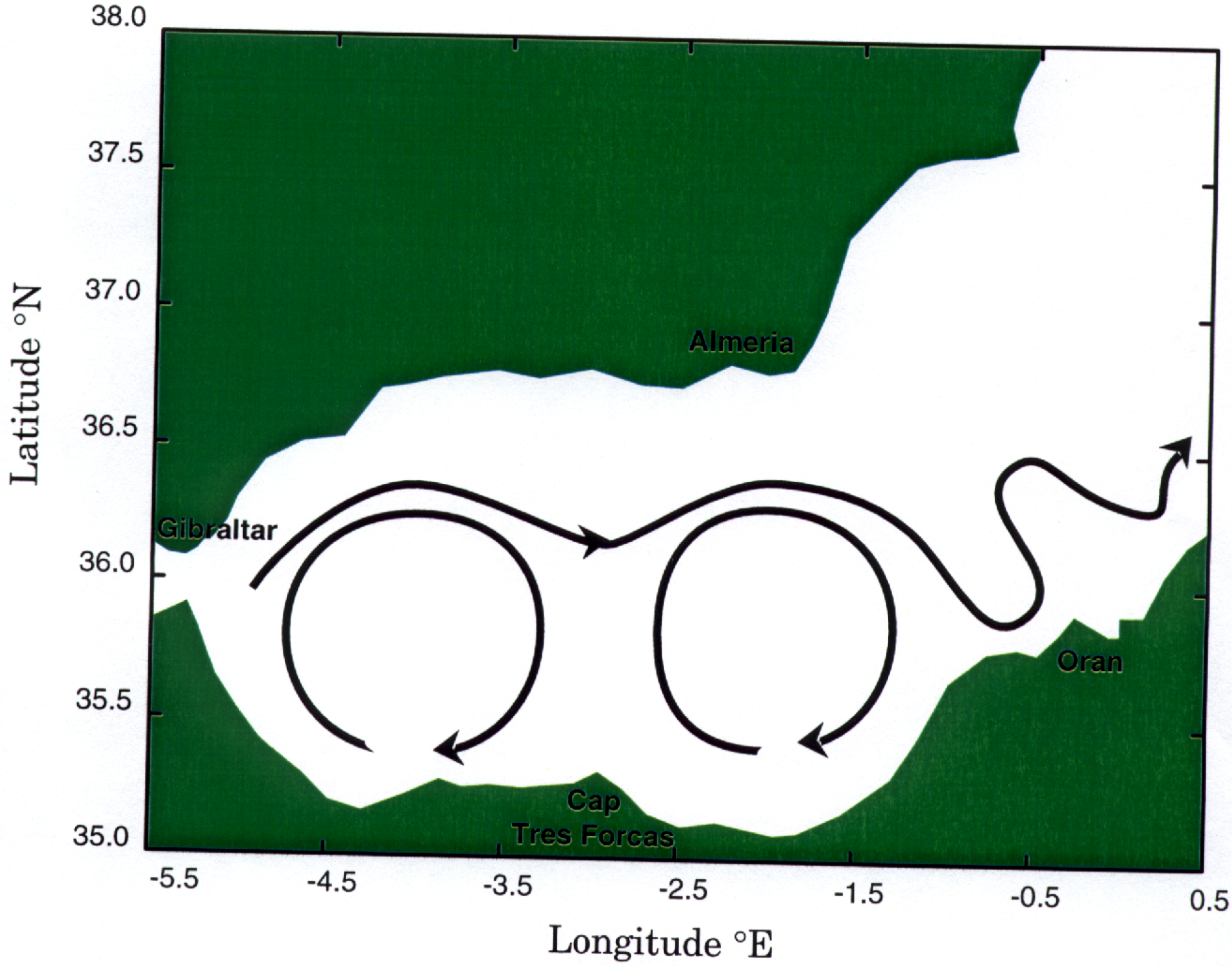
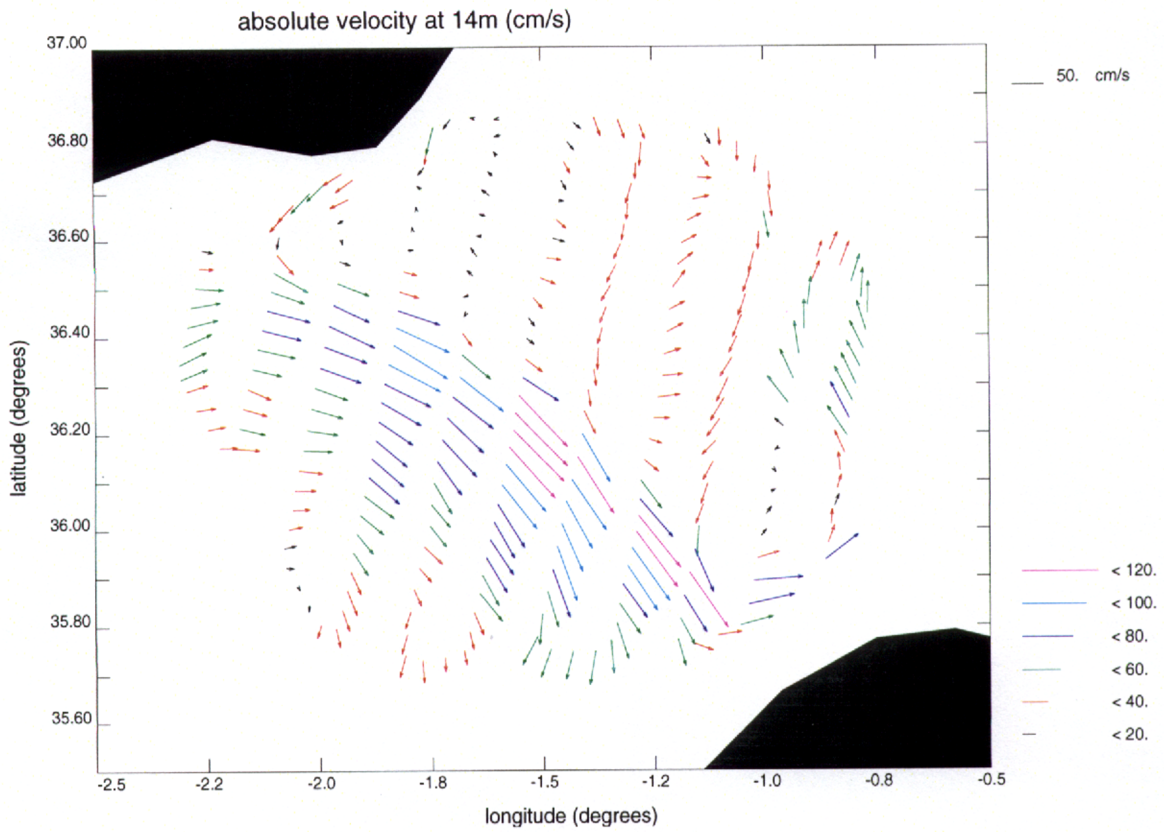



Figure 19. Schematic of the circulation of the surface waters in the Alboran Sea.



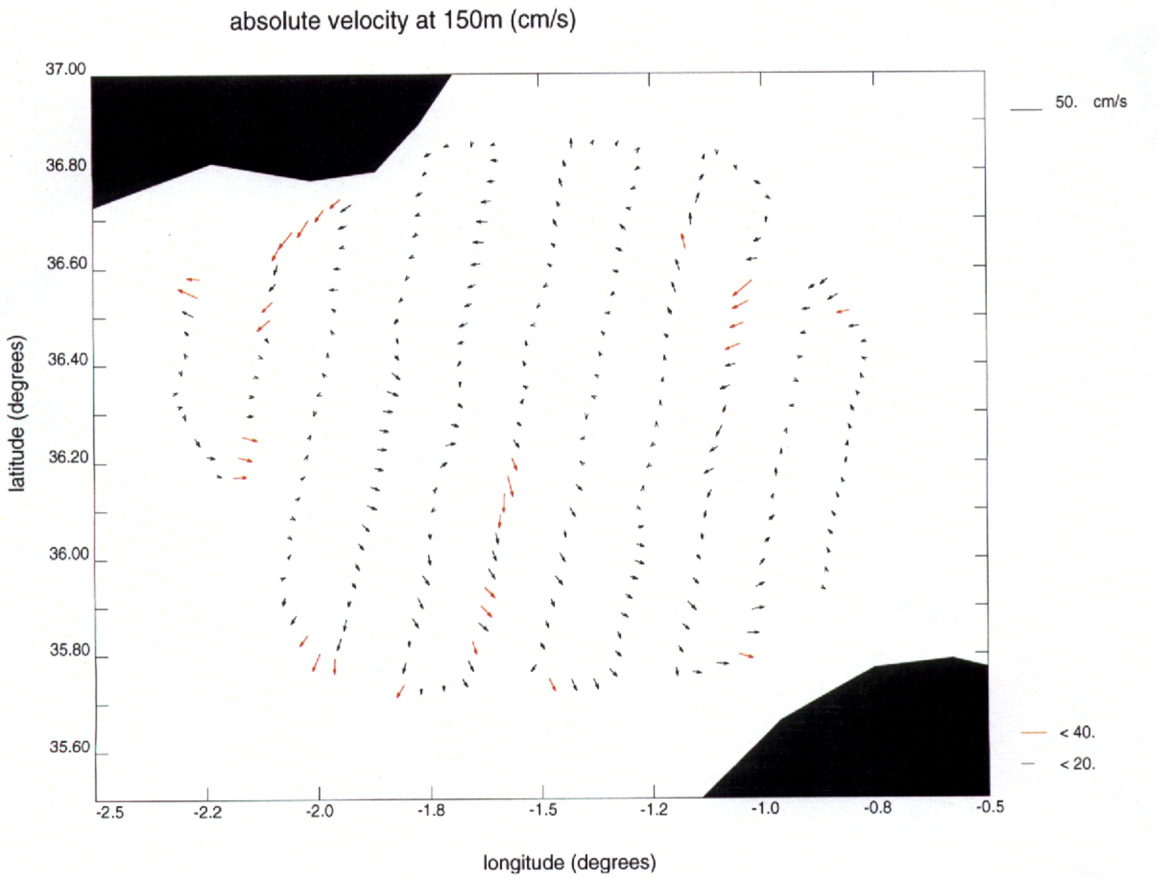
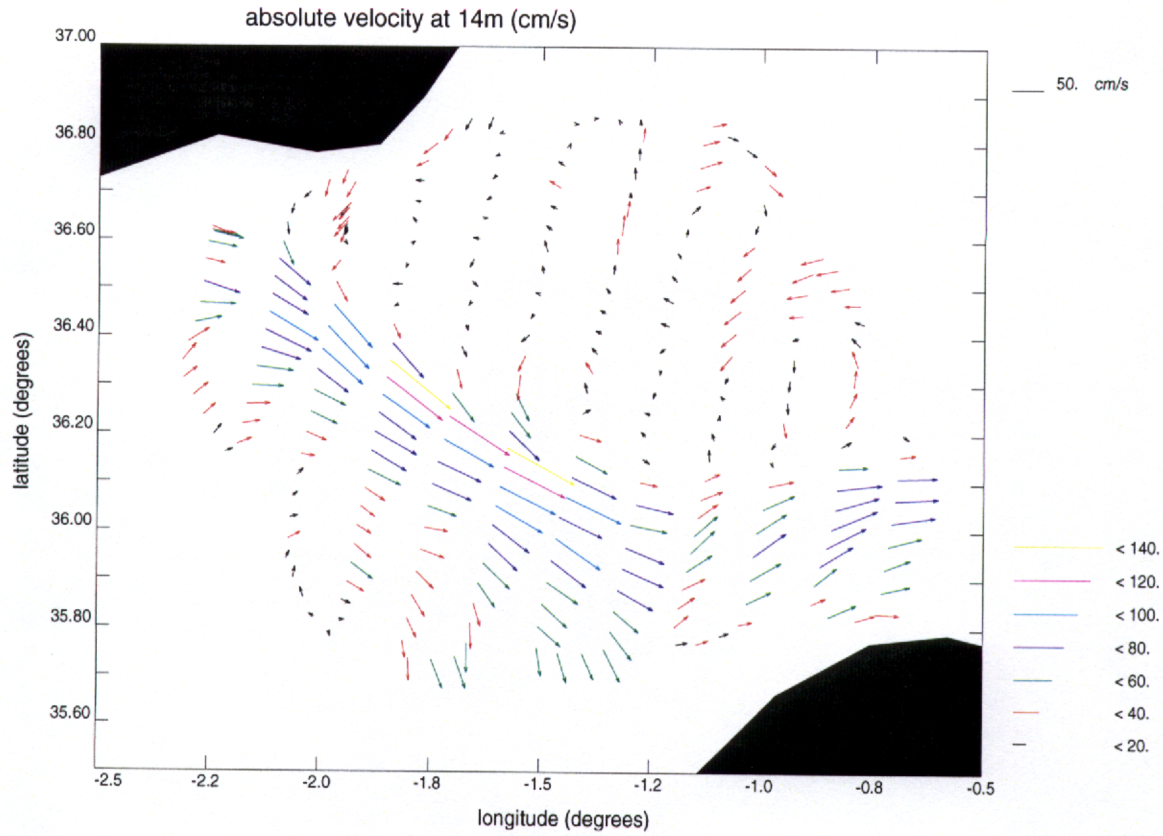




Figure 20. VM-ADCP current vectors for fine scale survey 1.



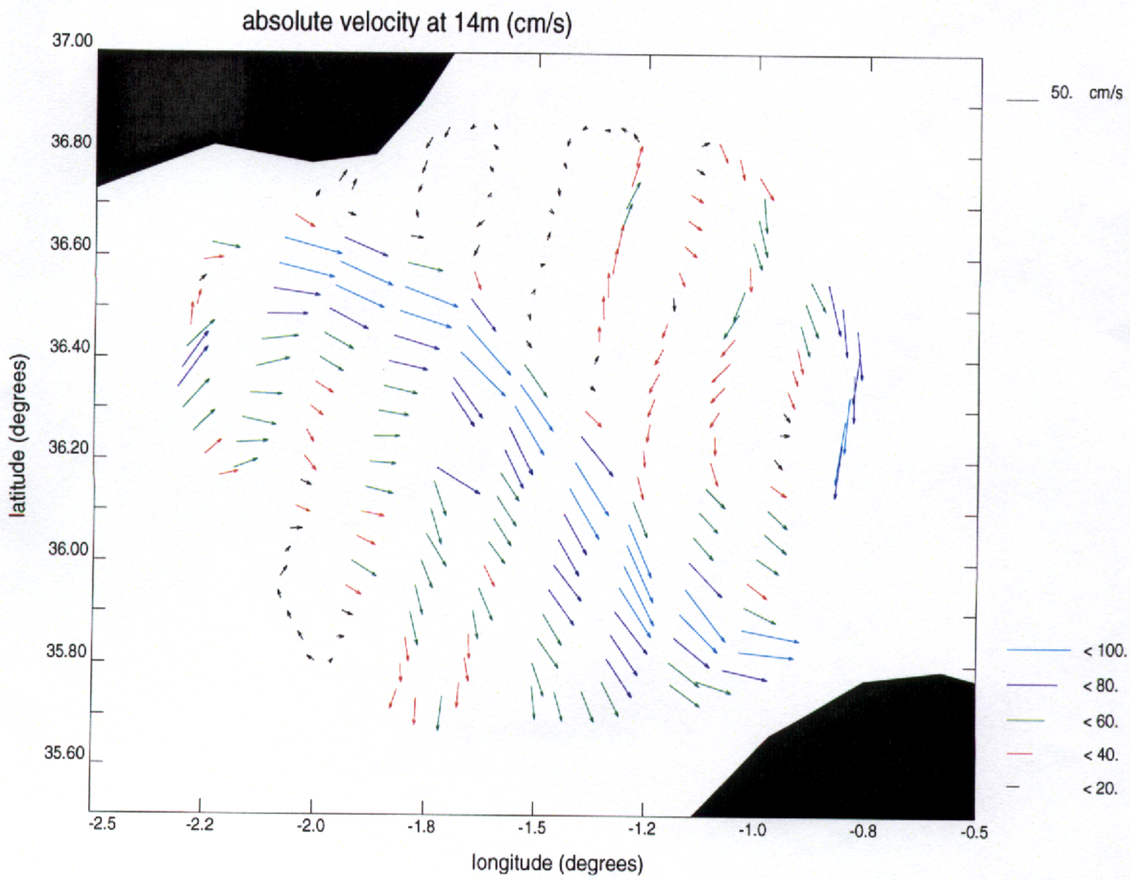




Figure 21. VM-ADCP current vectors for fine scale survey 2 (top) and fine scale survey 3 (bottom).

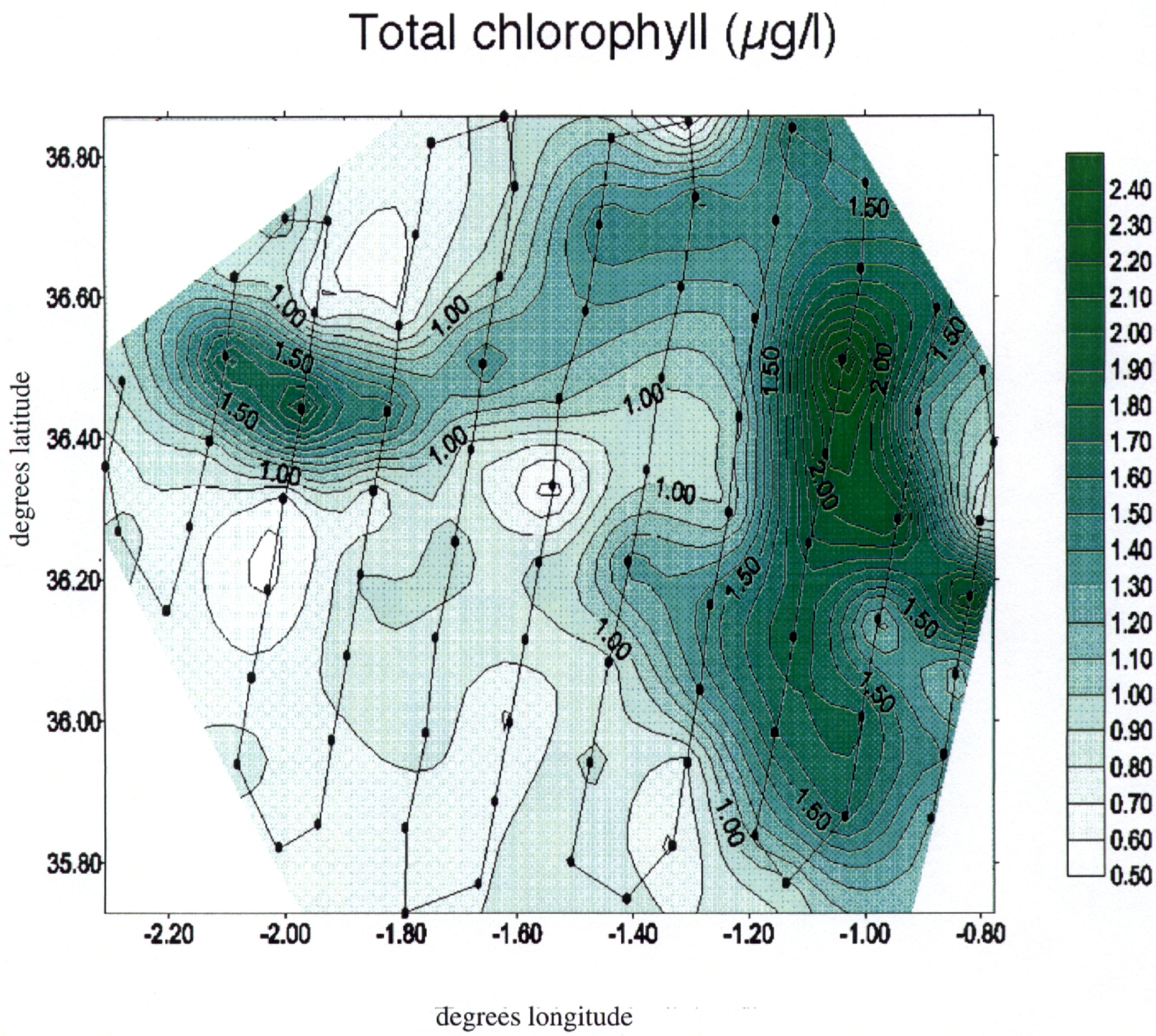



Figure 22. Chlorophyll concentration measured in hourly non-toxic surface supply samples during the first fine scale survey.

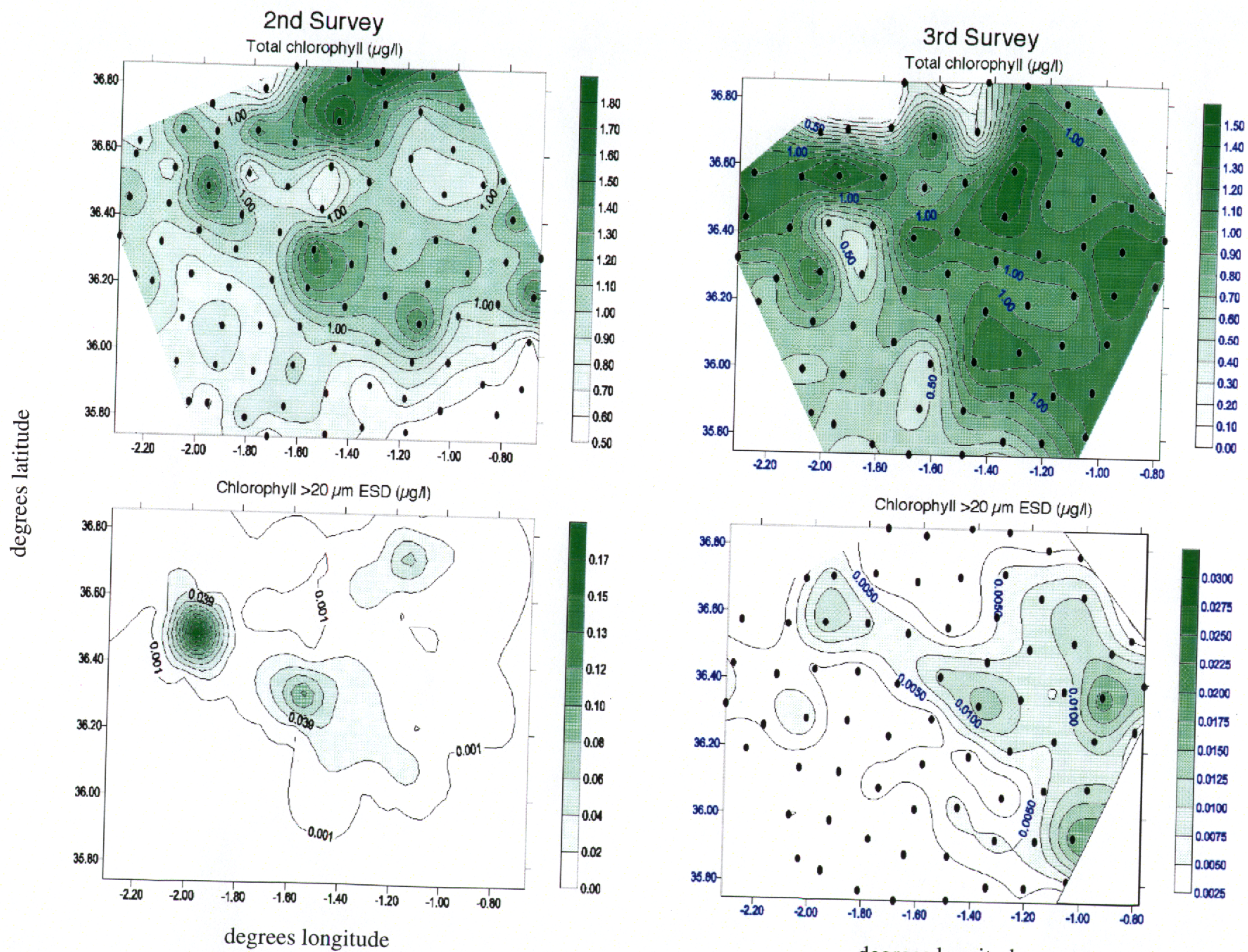



Figure 23. Chlorophyll concentration measured in hourly non-toxic surface supply samples during the second and third fine scale surveys

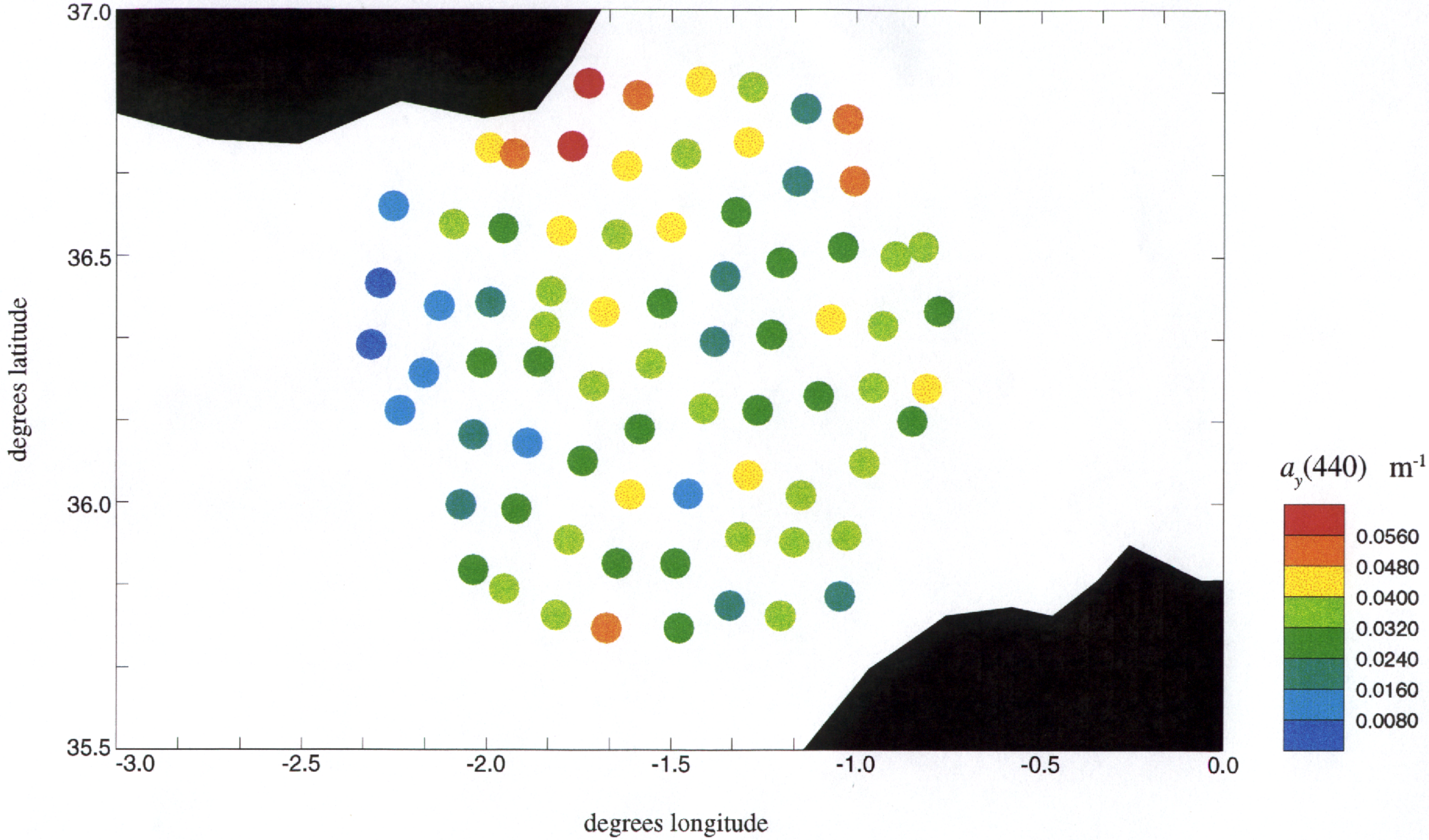
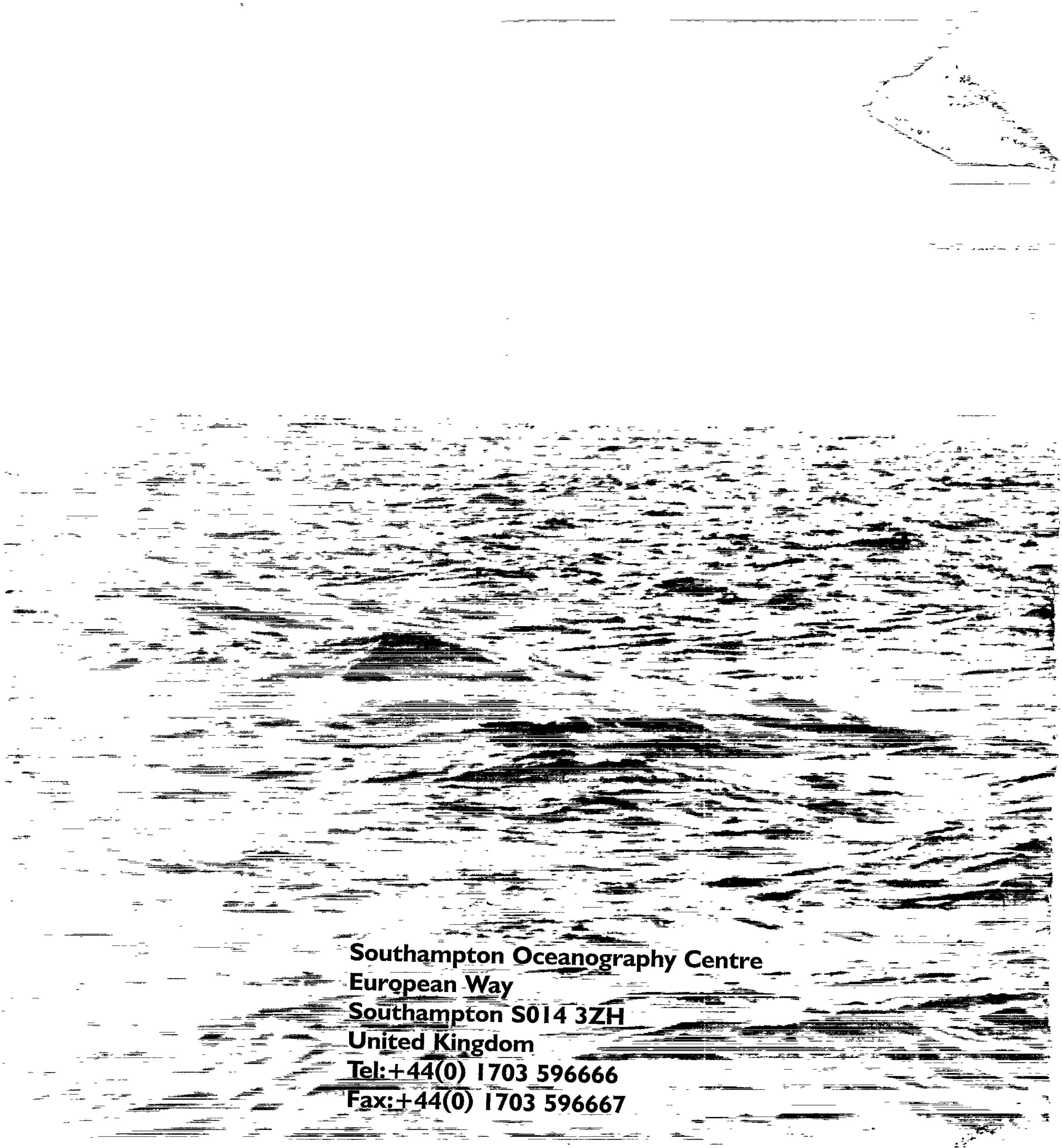



Figure 24. Absorption coefficient of dissolved organic matter at 440 nm, measured in hourly non-toxic surface samples during the third fine scale survey.



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