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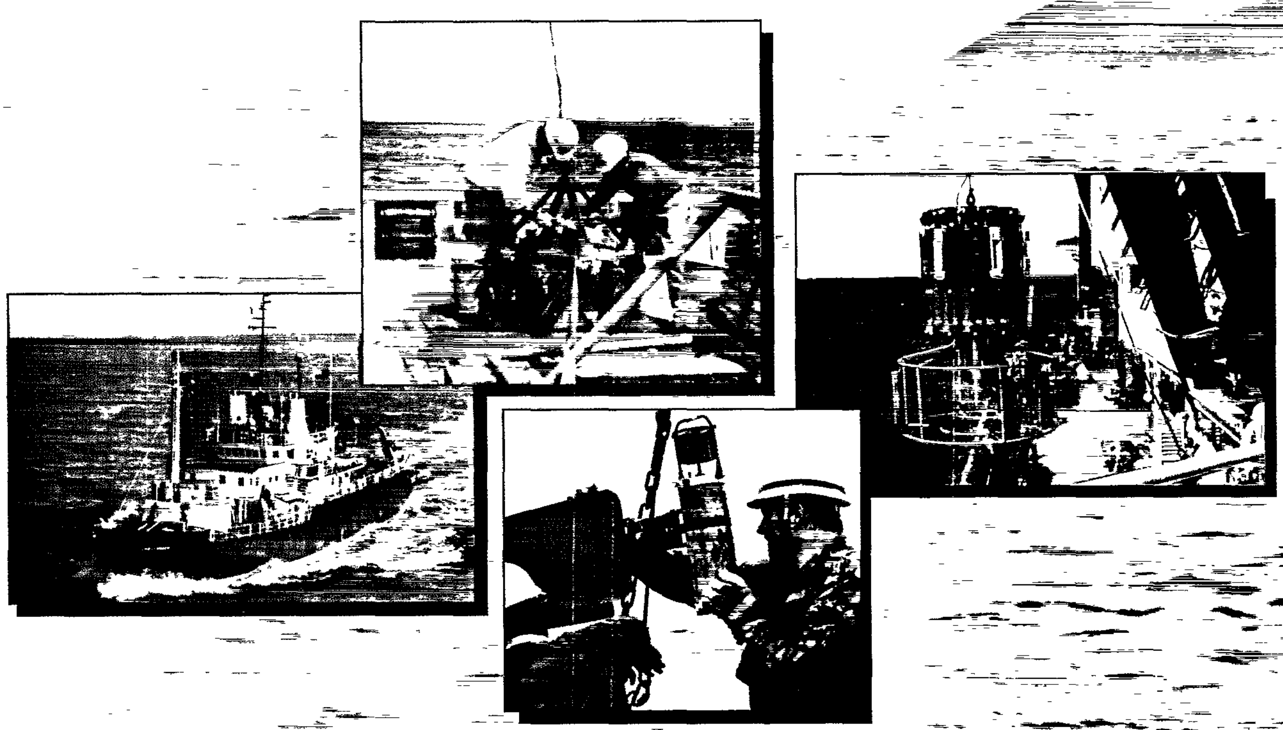
Cruise Report



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SOUTHAMPTON OCEANOGRAPHY CENTRE

CRUISE REPORT No. 17

RRS *DISCOVERY* CRUISE 223
28 SEP - 19 NOV 1996

VIVALDI '96

Principal Scientists
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1998

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DOCUMENT DATA SHEET

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ABSTRACT

RRS *Discovery* Cruise 223, VIVALDI '96, was a contribution to the UK WOCE Community Research Programme. The pattern of SeaSoar sections was designed to enable the upper ocean circulation in the Subpolar gyre of the North Atlantic to be mapped and in particular the course of the North Atlantic and Irminger Currents within the region to be determined. The sparse deep CTD survey was required to complement the upper ocean survey and provide estimates of total mass transport and an 'oceanographic opinion poll' of water mass properties, including CFCs.

The cruise commenced by repeating the well-established Rockall Trough CTD Section from Barra Head to Rockall Island. This was then extended north to Lousy Bank from where a CTD section measured before by Saunders across the Iceland Basin was repeated. From then onwards the cruise consisted principally of SeaSoar/ADCP sections interspersed with deep CTD casts (see track plot, Fig.1). These were placed on the 'Vivaldi Grid' (round 3° of latitude and multiples of 300 km west of 20°W) where possible, though the complex topography was taken into account. East of Greenland a more intense CTD section of 6 stations (12995-13001) was made along 60°N to cut the East Greenland Current. In addition 7 profiling floats were deployed in the Irminger Basin.

KEYWORDS

ADCP, CRUISE 223 1996, CTD OBSERVATIONS, *DISCOVERY*, EAST GREENLAND CURRENT, IRMINGER BASIN, LOUSY BANK, NORTH ATLANTIC SUBPOLAR GYRE, ROCKALL TROUGH, SEASOAR, VIVALDI 96, WOCE, ZOOPLANKTON

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WARNER, R.A.	2nd Officer
HOLMES, J.C.	3rd Officer
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HEBSON, H.R.	SG1A
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DUNCAN, A.S.	Mess Steward
ROBINSON, P.W.	Steward
OSBORN, J.A.	Steward

1. CRUISE NARRATIVE

1.1 Cruise Details

Expedition Designation: RRS *Discovery* Cruise 223, UK WOCE Cruise Vivaldi '96.
Co-principal Scientists: Dr Harry Leach (Liverpool) and Dr Raymond T. Pollard (SOC).
Ship: RRS *Discovery.*
Ports of Call: Falmouth via Reykjavik to Southampton.
Cruise Dates: 28th September to 19th November 1996 (with port call in Reykjavik 21st-22nd October).

1.2 Cruise Summary

1.2.1 Cruise Track and Stations

The cruise track with station positions is shown in Fig.1. Only small volume samples were taken, details are listed in Table 1. In Table 17 are listed the conversions of days of the year to conventional dates for the period of the cruise.

1.2.2 Equipment

The principal instruments used during the cruise were a NBIS Mark 3a CTD with oxygen sensor, transmissometer, fluorometer, *in situ* nitrate sensor, Simrad altimeter model 807-200m and IOSDL 10 kHz pinger. These were mounted together with a multisampler rosette equipped with 24 10-litre Niskin bottles. Two of these carried SIS digital reversing thermometers and one carried a reversing pressure meter. Upon recovery each bottle was sampled in turn for CFCs, dissolved oxygen, nutrients, salinity, oxygen isotope and the upper six bottles for chlorophyll analysis. All sampling was done on deck.

Between the CTD casts sections were worked with a SeaSoar (profiling CTD) carrying a NBIS mark 3 shallow CTD plus FSI conductivity cell and fluorometer. Data were collected from the upper 500m of the water column. Throughout the cruise the upper ocean currents (to about 300 m) were measured with an RDI 150 kHz acoustic Doppler current profiler. Navigation information was provided by a Trimble GPS receiver supplemented by a Chernikeef electromagnetic log and Sperry gyrocompass. Ships position and attitude were also measured by an Ashtech 3D GPS system. Additional measurements were made with a Simrad echosounder, FSI thermosalinograph and fluorometer, IOSDL meteorological package, shipborne wave recorder. Experimentally an acoustic correlation current profiler was also used and in the Irminger Sea profiling floats were deployed.

1.2.3 Sampling

Nominal depths sampled were: bottom, 5500, 5000, 4500, 4000, 3500, 3000, 2750, 2500, 2250, 2000, 1750, 1500, 1250, 1000, 750, 500, 400, 300, 200, 100, 75, 50, 25, 10m. On deep casts fewer shallow and intermediate bottles were fired. The maximum number of shallow bottles were fired to provide adequate coverage for interpretation of the chlorophyll data. Because of a shortage of Niskin bottles only 21 were used and this number was reduced to 19 in shallower water. The actual bottle depths are shown in Fig. 2.

1.2.4 Number of Stations Occupied

88 stations were occupied during the cruise (Fig.1). The first two CTD stations (12931 and 12932) were worked as test stations and all the bottles were fired at depth. 8960 km of SeaSoar data were collected.

1.2.5 Floats deployed

Seven profiling "ALACE" floats were deployed in the Irminger Sea.

1.3 Scientific Objectives

The cruise objectives were to:
1. To complete a CTD section from Scotland to Iceland including the Rockall Trough Section.
2. To survey the Subpolar gyre of the North Atlantic with high-resolution CTD and ADCP data to determine the circulation of the upper waters.
3. To complement the shallow survey with a sparse, deep CTD survey (including oxygen, nutrients, CFCs and oxygen isotope ratios).
4. To deploy profiling floats in the Irminger Basin.

1.4 Narrative

RRS *Discovery* Cruise 223, "Vivaldi'96", was a contribution to the UK WOCE Community Research Programme. The pattern of SeaSoar sections was designed to enable the upper ocean circulation in the Subpolar Gyre of the North Atlantic to be mapped and in particular the course of the North Atlantic and Irminger Currents within the region to be determined. The sparse deep CTD survey was required to complement the upper ocean survey and provide estimates of total mass transport and an "oceanographic opinion poll" of water mass properties, including CFCs.

The cruise commenced by repeating the well-established Rockall Trough CTD Section from Barra Head to Rockall Island. This was then extended north to Lousy Bank from where a CTD section measured before by Saunders across the Iceland Basin was repeated. From then onwards the cruise consisted principally of SeaSoar/ADCP sections interspersed with deep CTD casts (see track plot, Fig.1). These were placed on the "Vivaldi Grid" (round 3° of latitude and multiples of 300 km west of 20°W) where possible, though the complex topography was taken into account. East of Greenland a more intense CTD section of 6 stations (12995-13001) was made along 60°N to cut the East Greenland Current. In addition 7 profiling floats were deployed in the Irminger Basin.

1.5 Preliminary Results

A first glance at the results seems to show that the principal branch of the North Atlantic Current proceeds northwards west of the Banks following the topographic slope on the east side of the Iceland Basin. On the east side of the Reykjanes Ridge flow in the upper waters appears to be southwestward and on the west side northeastwards not unlike the well-known deep flow in this region.

1.6 Major Problems and Goals Not Achieved

Bad weather caused the loss of 6 out of 20 working days during Leg 1.

2. CONTINUOUS MEASUREMENTS
(on station and underway)

2.1 Navigation

Navigation data was converted from RVS format to PSTAR format in 12 hour segments using the following sequence of UNIX shell scripts:

navexec0: converted the RVS format navigation data into PSTAR format.

gpsexec0: converted DGPS navigation RVS format data to PSTAR format.

gyroexec0: converted the RVS format gyro-compass heading data into PSTAR.

ashexec0: read in heading (and attitude) RVS format data from Ashtech XII 3DF GPS receiver and converted to PSTAR format.

ashexec1: merged PSTAR Ashtech and gyro-compass data.

ashexec2: de-spiked Ashtech navigation data.

There were frequent, but usually short-lived gaps, in the DGPS data, due to poor satellite availability. In order to interpolate the DGPS heading data the available headings were plotted and spikes were removed before the values were interpolated over time.

Fig.3a shows the scatter of GPS positions in Falmouth; Fig.3b shows the DGPS scatter in Falmouth and Fig.3c shows the DGPS scatter in Reykjavik.

(M.E.McCulloch, J.E.O'Dwyer)

2.2 Meteorological Measurements

The usual mean meteorological measurements were supplemented by the addition of two fast-sampling anemometers for measurement of the wind stress, and a "CFD" system which logged data from an array of anemometers. All systems were running immediately after departure from Falmouth on 28th September, and all worked reliably until completion of the cruise in Southampton on Tuesday 19th November.

2.2.1 Main system

The mean Meteorological instrumentation consisted of an augmented RVS system, logged via rho-point modules to a PC using the COTD software GrhoMet. The RVS sensors used were; a hull-mounted platinum resistance thermometer (prt) for sea surface temperature estimates, an aneroid barometer located in the main lab., and air temperature and humidity sensors, two photosynthetically active radiation (PAR) and two total irradiance (TIR) sensors and a Young propeller vane anemometer all of which were mounted on the foremast platform. The additional sensors supplied by COTD were; two psychrometers located on the foremast platform and two Epply long wave radiometers on the foremast extension. All instruments were sampled at 5 second intervals via the rho-point modules. Both raw and calibrated data were logged via the RVS level B as well as to the hard disk of the PC.

Logging of the mean met data to the RVS system was not completely reliable. Although the times logged to the files on the hard disk of the PC were regularly spaced at 5 seconds, the data received by the level B system contained different times at more irregular intervals. In particular between days 288 and 292 only two thirds of the data logged to the hard disk was received by the level B system. The reason for the drop in data quantity was not identified but the problem disappeared after a reboot of the mean met system PC.

Wind stress measurements: A Solent sonic research anemometer, mounted on the starboard side of the foremast platform, output 3 components of wind speed at a rate of 21 Hz. Four 10 minute data sections were obtained every hour and logged to 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 system, with the raw data being logged directly to optical disk. The spectral information was used to produce estimates of the drag coefficient or wind stress. For purposes of comparison, a second research anemometer was installed on the starboard arm of the main mast cross-tree and logged in an identical fashion to a separate PC, also located in the plot.

The meteorological conditions throughout the cruise are shown in Fig.9.

2.2.2 Ship Calibration system

An additional rho-point based system, similar to the GrhoMet system, was also installed. 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 on the boat deck. Data were logged to a PC in the plot, and were backed up to the ship-board unix system via floppy disks. Data from the CFD system anemometers, the 2 research sonic anemometers and the Young propeller vane anemometer will be used to verify a computational fluid dynamics program ("Vectis"), which produces three dimensional simulations of the air flow over ships.

2.2.3 Ship-borne Wave Recorder

A ship-borne wave recorder (SBWR) was also installed and used to obtain one-dimensional wave spectra. Estimates of the average significant wave height over the 10 minute sampling period were obtained. Maximum significant wave heights recorded were greater than 13 metres.

(M.J.Yelland, E.C.Kent)

2.3 Acoustic Doppler Current Profiler (ADCP)

2.3.1 Calibration

The positional accuracy of the DGPS system satellite fixes was assessed while the ship was stationary in port at Falmouth, where the data showed a scatter of less than 5 m. The ADCP recorded throughout the cruise with 64 bins, each 8 m thick, and a 2.5 minute sampling period. The transducer depth was 5 m and the blank-beyond-transmit length was 3 m. The first bin was therefore centred on 12 m depth.

A zigzag calibration run (a series of eight 90-degree turns) was conducted between 6:30 and 9:11 on 30th September (day 2 of the cruise) in bottom tracking mode west of Scotland. The bearing of the ship was varied between 15 and 105 degrees over 20 minute intervals, and the ship achieved each turn within 4 minutes. The ADCP water velocities relative to the ship were converted to east and westward velocities using the ship's heading from the gyro-compass and these components were then recalculated using the, more accurate, ship's heading from the Ashtech 3DF GPS system. This correction was also applied throughout the cruise.

Using the water-tracking method of Pollard and Read (1989), and data from the zigzag calibration run, the misalignment angle between the ship's hull and the ADCP instrument was calculated as 3.57 degrees clockwise and the scaling factor was 1.0054. These values were confirmed using four bottom-track calculations. One calculation used bottom-track data from the ADCP obtained during the zigzag calibration run, and three other estimates were made using data from periods where the ship's heading and speed were constant over 77, 107 and 192 km (or 5, 7 and 13 hours).

(M.E.McCulloch)

2.3.2 Standard Processing

ADCP data was converted from RVS format to PSTAR format in 12 hour segments. These segments were staggered 5 minutes back relative to the 12 hour navigation data to help with merging. The following sequence of UNIX shell scripts were used:

adpexec0: Converted RVS format ADCP data to PSTAR format. This script produced two files, one contained the speed of the sea floor relative to the ship (bottom tracking file) and the other contained a gridded file of velocities in the water column.

adpexec1: Every few hours the difference between the time on the ADCP PC clock (the time seen in the ADCP data) and the ship's clock (the time in the navigation files) was recorded. If the difference was greater than 2 minutes the ADCP clock was reset. The time difference was input to adpexec1 which then corrected the ADCP data file's times.

adpexec2: Merged ADCP data with Ashtech navigation data.

adpexec3: The values of the misalignment angle (phi) of the ADCP transducer and the amplitude factor (A) (both determined from the calibration runs near the start of the cruise) were hard-wired into this script, which then corrected the ADCP velocities. The script also averaged data within 15 minute intervals.

adpexec4: Merged ADCP data with the ship navigation data and so calculated the absolute water velocities from the ADCP relative velocities.

adpexec5: Produced postscript plots of the data.

adpexec6: Averaged the data on variable "distrun" to reduce data volume.

(M.E.McCulloch)

2.3.3 Backscatter

The Vessel Mounted ADCP can provide backscatter measurements in addition to the underway currents. The following paragraphs give a description of the data processing route used to achieve calibration of the acoustic backscatter. The method relies heavily on PSTAR programs run within shell scripts called execs, these are shown in quotes.

The exec 'ampexec' supplies parameters that are required to run 'ampexec0', 'ampexec2' and 'ampexec4'. It prompts the user for an ADCP file number, start and stop times. 'ampexec' requires a clock drift correction file called 'times' that spans the ADCP file that is being created. It also needs a navigation file that spans the ADCP file. The file 'times' currently resides in the same directory as 'ampexec' while the navigation file is referenced via its full path name in 'ampexec4'. The script creates and maintains a file called lasttime which contains all of the ADCP file numbers and their respective start and stop times. The script 'compressor' tidies the directory of files prior to amp223$num.rel by compressing them and putting them in a sub directory called 'arch'.

ampexec - ampexec0 - datapup pcopya pheadr pcopyg pcalib pcopya pheadr pcalib
file created; amp223$num bam223$num

ampexec1 - ypstar pcalib parith pmerge parith pmerge parith
file created; aclock$num amp223$num.corr

ampexec2 - pcopya pedita adedit
file created; amp223$num.av

ampexec4 - pmerge adprl2
file created; amp223$num.abs

The reference level of the backscatter 'noise' was determined as follows; the ADCP data from CTD casts during yearday 275 (the output of 'ampexec') were copied into a PSTAR file. The variation of the ampl was plotted as a function of depth; the depth range where the backscatter signal had died away to a constant value was extracted using pcopyg (rows 59 - 64). phisto was used to determine the average value of ampl. This was 7.5 dB, which at 0.42 dB/count equates to 17.8 counts, but the lowest value of 7.2 dB was taken, equating to 17.14 counts.

The values of K1 (=183.15) and K2 (=8.95) were derived from the Echo Intensity Logsheet supplied with the transducers (pers. comm. J.Wynar RVS) combined with the supply voltage

(230.5V rms). The transducer depth was 5m and the electronics chassis temperature remained fairly constant at 22±2 °C. These values were used to construct an ASCII file called amplcal.dat that is used by the program calamp3 in its determination of the absolute acoustic backscatter. Its contents are listed below:

```
4.17e5
183.15,8.95
21,11
8,8,5
17.14
1
```

The raw SeaSoar files ss223rxx were moved to the backscatter directory. Time must be monotonically increasing. The exec 'no_of_cols' takes an ADCP file and calculates the interval for gridding in the horizontal, then runs pgrids. The output from pgrids is used in pmergg where the temperature and salinity are merged onto the ADCP file. The output was inspected for periods of absent data and gaps interpolated with gintr2.

Once the variables temperature and salinity have satisfactorily been incorporated into the ADCP data file, values of ampl that are less than the background noise threshold (7.2 dB) were removed. Then calamp3 is run, this applies a calibration to the variable ampl, producing target strength Sv in dB. The new variable is called amplcal.

The data from periods where the CTD was deployed were saved as individual files and compared to the record from the lowered ADCP. This enabled a calibration to be applied to the lowered ADCP.

(M.C.Hartman)

A listing of the ADCP files is given in Table 13.

2.4 Acoustic Correlation Current Profiler (ACCP)

A new ACCP (or Correlation Sonar, CS) system was supplied by RD Instruments, the transducer for which was installed in the ship's hull by RVS divers in Falmouth during the pre-cruise mobilisation period. The sea chest is located in the winch room; the 41-core cable to the deck unit in the main lab had been installed on a previous cruise (Discovery 214). The most significant modification for our purposes over the previous installation was the incorporation of a gyro interface, so the output data streams included real-time ship's heading.

The deck unit consisted of the VM chassis and a Pentium PC with Panasonic optical disk. As networking does not yet exist as a facility on the CS system, the optical disk was used for data transfer to the ship's computer system. Desired files were copied from the PC to optical, which was transferred to a second, networked, PC. An additional complication was that it was not possible to run both the networking software and the optical driver on the second PC, so it was set up with two operational modes, one to see the Sun, one to see the optical (thanks Vic Cornell). The data were copied therefore from optical to the second PC's hard drive, the PC was then rebooted and the data copied to the Sun.

The system was supplied with correlation sonar version 1.08, DSP firmware version 2.23 and I860 software version 1.05. To translate recorded data files to ASCII, processing software (CSLIST) was supplied (version 1.00). Translation is rather slow: about 7 Mb per hour, where 7 Mb is about one day's worth of data. A problem identified early on with CSLIST was its inability to output bottom-track files. A fix was requested from RDI which was sent to Reykjavik (CSLIST 1.01) together with updated versions of various other elements of the DSP. Puzzlement over the system's reluctance to bottom-track in about 1000m water depth (well within its capability) resulted in further correspondence with RDI, who identified a bug in the DSP related to bottom velocity initialisation. A fix is being prepared for the next cruise (224). It was only possible to collect bottom-track data on the run home up-Channel, so such data as were collected were not able to be calibrated.

Operationally, the system was a disappointment. Very little useful data were collected, this appearing to be a result of the bad weather experienced during the cruise. Its effectiveness (proportion of good pings, depth penetration) was greatly reduced in all but the calmest weather, however. This will be investigated in greater detail at a later time, and will be described elsewhere. At RDI's request, bottom-level raw pings were collected before Reykjavik and sent on optical to RDI, who will investigate reported problems.

The PSTAR processing path, with execs modified from those developed during D214, was set up by Gwyn Griffiths in Falmouth, and further modified at sea to take account of the ASCII output format of CSLIST. Particularly, a new program, psecond, was written to convert CSLIST time (Y-M-D-H-M-S) and other output variables to seconds (plus variables) in PSTAR format.

(S.Bacon)

2.5 Thermosalinograph

2.5.1 Temperature and Salinity

Underway temperature, salinity, fluorescence and transmittance 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 5m, and FSI conductivity and temperature sensors mounted in a polysulphanone housing in the hangar. A header tank was used to provide a constant flow of debubbled non-toxic water. Half-hourly or hourly calibration samples were taken from the thermosalinograph outflow, and header tank checks were made throughout the cruise. On 27 October (JDAY 301) it was noticed that the housing temperature sensor was producing suspect data and it was replaced with a new sensor.

TSG salinity is usually calculated from the measured conductivity and temperature at the instrument housing located in the hangar (temp_h). The temperature of the surface water is measured by the remote sensor (temp_m). After the housing temperature sensor had been replaced, the data from Leg 1 was given a closer look and it was discovered that temp_h was consistently in error and hence unreliable for calculating salinity. The temp_h data from the original sensor drifted such as to be unrecoverable and so the next best option was to use the remote temperature to calculate salinity from the conductivity. Temp_m was calibrated with the surface SeaSoar temperature data and a linear offset (-0.01°C) applied.

The hourly and half hourly bottle salinities from the non-toxic supply, plus surface bottle samples from CTD cast were used as true salinity from which to calculate an offset to be applied to the TSG salinities. CTD bottle samples were selected from a "master" sample file which consisted of all the appropriate sample files appended together. Datpik was used to select only CTD sample data from 0-10 dbars and this was further refined with pcopya to remove absent data, data with flags other than 2, and dcs where more than just the surface bottle from a particular cast had been selected. The CTD surface samples had their time added to the data file (pmerge), and were then merged with the underway samples. The file was sorted on ascending time (psort).

The new salinity was calculated (peos83) and absolute salinity calibration was derived from the bottle samples. The data were merged on time and a linear regression used to derive A1 and B1 coefficients (TSG salinity against bottle salinity). Prior to this, the difference between the bottle salinities and the TSG salinities was plotted to establish that there was no substantial drift with time or temperature. After calibration new residuals were calculated (parith) and the mean and standard deviation of the differences found with phisto. For Leg 1 the mean offset was 0.0000 and the standard deviation 0.0338 for all data (252 data points) and mean -0.0006, sd 0.0231 for data within ±0.05 (220 data points). For Leg 2 the mean offset was 0.0000, sd 0.0215 for all data (475 points) and mean 0.0015, sd 0.0114 for data within ±0.05 (460 data points).

The salinity differences of the standards are shown in Table 15 and Fig.8.

(N.P.Holliday, M.-M.Lee, C.J.Paulson)

2.5.2 Fluorescence

Underway fluorescence during Vivaldi 96 was continuously recorded by means of a Chelsea Instruments Aquatracka III fluorometer mounted in a tank in Discovery's hangar. A steady flow of debubbled water was provided by a header tank in connection with the non-toxic intake in the forward hold, at a depth of 5 m. Reference to hourly bottle samples obtained from the same non-toxic intake allowed the conversion of the fluorometric measurements thus made to underway chlorophyll a concentration.

The calibration algorithm involved the calculation of fluorescence yield R, the ratio of fluorescence to chlorophyll a concentration, wherever a bottle sample had been taken. The parameter R is highly variable, depending on a wide range of factors such as phytoplankton species composition and physiological state, ambient light field or nutrient supply. Given the large-scale character of the Vivaldi 96 survey, the hourly bottle sampling rate was regarded as sufficient for resolving changes in R in any spatial scales coarser than that of the finest natural phytoplankton patchiness. The diurnal fluctuations in R associated with the ambient light field were also properly described by this sampling rate.

In order to smooth out the influence of the fine natural patchiness mentioned above, while accounting for small errors in bottle sampling times, the fluorescence yield R was gridded into a regular time grid (pavrge) and subsequently smoothed by using autocorrelation statistics (modified version of pcorr). Linear interpolation (pintrp) at sampling gaps finally provided a fluorescence yield function that was continuous over most of the time domain extending between the first and the last bottle samples on each leg. Only during storm events, with no bottle samples available, was R left undefined.

The estimation of the underway chlorophyll a concentration hence simplified to a trivial calculation (parith) of the ratio between the measured fluorescence and the local value of the fluorescence yield function. As a measure of the calibration error, figures of 0.97 for the correlation coefficient between bottle and thermosalinograph chlorophyll a concentrations and 0.008 for their mean modulus relative deviation may be quoted. The mean modulus relative deviation is defined as

$$S_N = (1/N) * \Sigma \left|[chl(tsg)-chl(bot)]/chl(bot)\right| ,$$

with chl(tsg) = thermosalinograph chlorophyll a concentration,
chl(bot) = bottle chlorophyll a concentration at the same sample point
N = number of sample points
S_N = summation over N sample points.

Archiving

The calibrated chl a concentrations averaged in 1 min bins for Leg 1 were stored in a file named tsg223.1min.chl and archived as tsg223.JC .

The equivalent file for the calibrated section of Leg 2 (since the beginning of the Leg till 14.11.96 04:59:30) was called tsg223.2.1min.chl and archived as tsg223.2.FV .

(A.C.Naveira Garabato)

2.6 Shipboard Computing

2.6.1 Level ABC system

This was an unusual cruise from a computing perspective, with RVS supplying five workstations instead of the normal four, more disk space and the Hewlett-Packard XL-300 A3 colour Postscript plotter from the RRS Charles Darwin swath bathymetry system. In addition to this many scientists brought their computer systems (and also two printers) on board which were successfully integrated into the ship's network.

Level A Systems
The Level A systems take data in an instruments native format, time-stamp it from the GPS based master clock, and convert it to the SMP (Ship Message Protocol) format, before sending it to the Level B system via a serial or network link.

There are four types of Level A computer in use on the RRS Discovery. Mk 1 systems use the 8 bit Intel 8085 processor and are the oldest computer systems still in use by RVS Information Systems Group. Mk II systems using the 16/32 bit Motorola 68000 processor were introduced in 1992 and have gradually been replacing the ageing Mk 1 systems. Mk II CTD Level A uses the 32 bit 68030 processor with a 68882 maths coprocessor and is specifically aimed at taking in sub-second CTD data and averaging it to give 1 second data. PC based Level A systems such as the Seametrix winch monitoring system are also in use.

Mk I Level A computers
  MX1107 - Magnavox MX-1107 transit satellite navigator
  BOTTLES (see text) - Tonefire rosette firing system

Mk II Level A computers
  LOG_CHF - Chernikeeff two component speed log
  GPS_4000 - Trimble 4000DL GPS receiver with Skyfix corrections
  GPS_ASH - Ashtech 3DF attitude GPS
  GYROSYNC - Ship's gyro
  ANALOGUE - Three channel underway nitrate sensor
  BOTTLEM2(see text) - Tonefire rosette firing system
  EA500D1 - Simrad EA-500 echo sounder

Mk II CTD Level A computer
  CTD_12C & SEASOAR - Neil Brown Mk IIIC CTD units for deep vertical profiling and shallow towed profiling

PC Level A computers
  SURFLOG - Underway surface sampling
  GRHOMET - IOS met sensors
  WINCH - Seametrix cable metering system

The increased number of instruments on the CTD package (§ 3.1.2) resulted in a new arrangement for logging the different variables. The oxyc variable was logged onto the channel previously used for the ftemp (fast temp), the three variables generated by the nitrate sensor were logged on 3 multiplexed channels, as was the altimeter and the CTD voltage data. However problems arose due to confusion over how the numbers of the CTD channels related to those logged on the Level A system (they have quite different numbering systems). After some time it became obvious that data from the altimeter was being incorrectly named as one of the nitrate sensor variables. The variable names were subsequently changed using the RVS stream header editor in existing data files, and the data grabber modified to ensure future casts were logged correctly.

The second problem involved the logging of the times at which bottles were fired. At the beginning of the cruise a Mk I Level A was being used for this. This ceased to work on Day ??? and was replaced with the BOTTLEM2 application in a Mk II Level A. At Station 12984 the last three bottle times were not logged, and none of the bottles were logged on the following cast. This was found to be a loose connection between the Level A I/O cable and the bottle-firer.

On day 285 there were periods of more than 15 minutes when none of the GPS receivers on board (including Koden GMDSS and RadioCode clock) could see any satellites. It is believed that this was due to an Aurora. The RVS gaps utility reports the following gaps.

time gap : 96 285 18:05:19 to 96 285 18:38:57
time gap : 96 285 19:59:08 to 96 285 20:24:19
time gap : 96 285 21:39:30 to 96 285 21:55:57

Level B System

The Level B system worked well, only crashing once (and automatically rebooting itself), thankfully not during a CTD cast or SeaSoar run. The Level B's main function is to take all the data from the Level A computers and store it on tape as soon as possible. As well as doing this, it passes the data along the network (it can use a serial link if the network fails) to the Level C, provides a "First Look" system to check the data and keeps an eye on the Level A computers and alerts watchkeeper's if they stop sending data for longer than a specified period.

Level C System

The Level C system consists of a Sun SPARCstation IPC with 2 GB of local disk space. It takes data from the Level B and shipborne ADCP systems and stores it in RVS data streams format. The Level C's function is processing, display, and export of data to other systems such as PSTAR or MatLab. During this Leg several sets of processing were undertaken:

Log and Gyro data were combined to give a relative motion file by the relmov program. This data can then be used later on for dead reckoning when there is not Satnav or GPS fixes available.

Relmov data was combined with GPS data using the bestnav program to give a final navigation file with fixes, course & speed made good and distance run at thirty second intervals.

Echo sounder data was corrected for Carter area using the program.

CTD and SeaSoar data was processed from raw counts into real units.

The Level C system was also used to give a updating display of position for the CTD/SeaSoar operating position using a Falco terminal. A second terminal would have been useful as the CTD/SeaSoar operators also required winch and echo sounder data. This was eventually displayed on a laptop connected to a monitor, both of which were supplied by Chris Hunter of OSG.

The XL-300 A3 ink jet printer seemed to suffer from seasickness when the weather was particularly bad. This manifested itself with the printer indicating that its print carriage was jammed (all LED's flashing). During the period when the printer was not working, the Nicolet A0 plotter was used instead.

The A0 plotter was also used to produce large scale charts matching the scale of the commercially produced charts of the work area.

During SeaSoar runs the RVS bandplot program was used to produce a track of pressure (Y-axis) against time (X-axis) with the colour of the track changing to indicate the temperature of the water through which the vehicle was passing. At the end of the runs a hard copy was produced on the Deskjet 1200C/PS.

(P.Duncan, A.Taylor)

2.6.2 PSTAR System

The PSTAR software system was used for almost all data processing. Details are given under the specific sections. A list of execs used in given in Table 2.

2.6.3 PSTAR Data Archive

During the cruise all the data could not be kept on-line at all times due to the lack of disk space. Data files were copied to a holding directory using a pexec shell script (arch_cp) ready for archiving. When sufficient data existed in this directory the files were copied onto two separate media – quarter inch cartridges and optical disks. Listings of the copied files were recorded for each cartridge and optical disk enabling any file to be easily located and retrieved when needed. After archival the copied files were deleted from the holding directory.

The cartridges used on the cruise were the Sony Data Cartridges QD6150 (150 Mb) and QD6250 (250 Mb), and the disks were the 5.25 inch 3M 1.3 Gb optical disks.

(D.M.Gould)

2.7 Other Activities

The Non Toxic System was in continuous operation for the duration of the cruise.

The Milli-RO/Q water production system was used throughout the cruise, during which time a carbon pre-filter was changed.

The engineering workshop facility was made available during the cruise. Various repairs, modifications and manufacturing were undertaken by the RVS staff.

(P.Mason, J.Jones)

2.8 Echosounding

The bathymetric equipment aboard during RRS Discovery Cruise 223 consists of a Simrad EA500 hydrographic echosounder, a Precision Echo Sounding (PES) towed 'fish' and hull mounted transducer Array. Data were collected from the PES fish located on the port side for most of the cruise, apart from periods prior to, or after docking when the Hull transducer was used.

The Hull mounted transducer is located 5.3 metres below the sea surface and this value was entered into the Transceiver Menu of the EA500 whenever it was used. In order to determine the depth of tow of the PES fish however, it was necessary to switch between the hull-mounted transducer and the PES fish whilst hove to, over flat topography and in relatively calm conditions. This resulted in a fish depth below the waterline of 11.8 metres (this reduced to 9.5 metres at 8.0 knots typical SeaSoar towing speed). These measurements were made with the PES fish utilising a '30 metre' tow cable with one complete turn remaining on the drum and several metres used within the drum for the slip ring termination. It must be noted that a nominal 15 metres had been entered into the EA500 Transceiver menu for both Legs 1 & 2 for PES fish deployments.

Data output consisted of a screen display, a continuous colour paper chart trace and serial data logged to the Level B/C via a Level A at a rate governed by the depth of water and the 'sing around' time of the echosounder. Raw data were Carter corrected daily (prodep), suspect data flagged and the data placed in a Level B/C data file. Data were lost for a few minutes when the paper in the printer jammed causing the parallel printer port and subsequently the echosounder to 'hangup' resulting in a blank screen display. This condition was duly flagged by the Level B alarm monitor and reset by 'power cycling' the echosounder.

Raw data were transferred to PSTAR format (datapup), zero values due to null returns from the echosounder removed using datpik, and averaged (pavrge) in 30 second intervals into a dep223nn.ave file. Further editing (mlist, peditb, plxyed) incorporated comparing the real time echosounder paper record with any suspect values due to side echoes or the echosounder losing lock over rapidly changing topography. Data were then rejected where the ships' speed was less than two knots and finally merged (pmerge) with navigation to produce a final dep223nn.nav file.

Two Master files dep223D1 and dep223D2 for legs 1 & 2 were created of all the edited, averaged and merged bathymetry. Separate files were also created corresponding to specific cruise sections with data increasing with longitude (psort) in order that bathymetry could be plotted for specific CTD sections:

Rockall Trough	dep223RT
Rockall Trough - Lousy Bank	dep223RL
Lousy Bank - Iceland	dep223LI
Iceland Basin	dep223IB
Iceland - Irminger Basin	dep223II
East Greenland Current	dep223GC
Transect along 54 degrees North	dep223N4
Transect along 57 degrees North	dep223N7

A listing of the depth files is given in Table 14.

(C.Paulson)

3. ON-STATION MEASUREMENTS

3.1 CTD

3.1.1 Gantry and winch

The ten-tonne traction system was used to deploy the CTD package using the CTD conducting cable via the starboard gantry. This system was also used to deploy the plankton net to 500 metres on the CTD conducting cable.

The small auxiliary winch on the starboard gantry was used to deploy the plankton net to depths of 200 metres at each CTD station. During severe sea conditions the net was deployed outboard of the pendulum roller to guarantee a safe operation, preventing the weight swinging about or hitting the side of the ship.

The stability of the ship together with the handling capability of the starboard gantry allowed operations to continue for much of the cruise despite the appalling weather conditions.

(P.Mason, J.Jones)

3.1.2 Equipment

The deep profiler system used during the cruise included the following components:

Stainless steel, 24 bottle multisampler frame.
Neil Brown / General Oceanics Mk. IIIb CTD (SOC modified) DEEP01.
FSI 24 position Surefire Water Sampler (SFWS).
SeaTech Transmissometer (1 metre pathlength).
Chelsea Instruments Alphatracka MkII Transmissometer (25 cm. pathlength).
Chelsea instruments Aquatracka MkIII Fluorometer.
SOC / Valeport Ultraviolet Nitrate Sensor.
RD Instruments Self-Contained Broad Band Acoustic Doppler Current Profiler (LADCP)
24 x 10 litre Niskin bottles.

Lab equipment for data acquisition and archiving of both CTD and SeaSoar data consisted of the following items mounted in shock resilient transport cases. One power supply and one data terminal were each dedicated to profiling and SeaSoar operations.

Dual 486DX - 100 MHz. Personal Computers.
Dual Glassmann LV 300/3.5 DC Power Supplies (300v. / 3.5A.)
Dual FSI DT 1050 WS CTD Data Terminals.
OTD designed SeaSoar Controller / Deck Unit.

Cruise Preparation.

Preparation included modifications to the CTD instruments, rosette and multisampler frame. Special control and interface computer programs were written for use with the FSI pylons and the SeaSoar deck unit.

Both Deep 01 and Deep 02 CTDs were fitted with redesigned pressure case end-caps to accommodate 6-way multipole Seaconnector Systems 'Pie' connectors, to allow power and signal connections to external sensors to be added. The end-caps also had an extra lip to ease their removal from the pressure cases for servicing purposes. Each instrument has been fitted with an 8 channel, 12 bit analogue to digital converter to digitise signals from external sensors. The data from converter is multiplexed sequentially into the 16 Hz. data stream, thus each of the d.c. analogue channels are sampled at a rate of 2 Hz. Instruments using the d.c. analogue facilities are, transmissometers (1 metre and 25 cm. versions), fluorometer, altimeter and nitrate sensor (3 channels).

A new FSI designed 24-way rosette pylon system and data demodulator unit were used for the first time on this cruise. The units had been tried once before but required modification by the manufacturers and at SOC to cope with the high current levels required by the deep profiling system and peripheral sensors. Special software was written to provide communication with, and display information from, the rosette pylon in a clear and convenient form.

To enable the fitting of new sensors to the stainless steel profiling system frame all instrument support brackets were redesigned and fabricated prior to the cruise. New sensors were the nitrate sensor, a Chelsea Instruments 25 cm. pathlength transmissometer and RD Instruments LADCP with its separate battery pack pressure case. This LADCP in its short tube form was fitted centrally within the frame without requiring any extension of the standard height frame. Two complete sets of instrument power and signal cables were prepared for the new layout, prior to the cruise.

Equipment and sensors were assembled before setting sail. Water bottles were checked for integrity of seals, taps, stoppers and lanyards before being fitted and roped to the multisampler frame.

Deployment

After sailing two shallow water casts were carried out to check the LADCP performance and check for water bottle contamination. The new FSI water bottle pylon fired all bottles without any problems. Following this, the cruise program of deployments proper began.

CTD casts with the large multisampler frame and full set of sensors began to cause loading problems on the CTD cable when bad weather was encountered due to the drag of the package. This caused high peak loads which came close to the Rochester loading limit specifications. Two results of package drag in bad weather that occurred during the cruise were cable damage and loosening of water bottles. Several reterminations to the cable were made during the cruise to remove damaged cable, near the CTD rather than to replace failed electrical joints. On some deployments a few water bottles were shaken free of the frame mounts, but were retained by a safety line. Four bottles suffered damage to their lower fixing blocks and had to be replaced on the rig. Examination of bottles used during the cruise suggests dimensional variation between fixing blocks, making them more liable to working free, and lack of tension in some retaining pushrod springs.

CTD DEEP01 performed well during the cruise with little evident instrument drift and good accuracy. A loose water bottle fell onto the conductivity cell and snapped it off, but this was replaced without having to remove the sensor from the frame. The spare CTD DEEP02 was not required during the cruise.

The new 25 cm. pathlength transmissometer, fluorometer and altimeter gave good data throughout the whole cruise. Our old one metre pathlength SeaTech transmissometer was fitted to provide data for comparison with the new transmissometer. This unit was unreliable and data dropouts occurred during deployments. It was eventually removed from the profiler frame after enough data had been acquired for comparative purposes.

The LADCP fitted within the frame with a separate battery pressure case performed well and its performance and data are described fully elsewhere in this cruise report. This unit contains a compass and tilt sensors which could possibly provide useful information on the attitude and rotation of the whole profiler package throughout deployments.

The three analogue signals produced by the ultraviolet nitrate sensor were digitised within the CTD by the 12 bit digitiser and the data multiplexed onto the CTD data frame. At one point in the cruise signals from this digitiser became very noisy and it was noticed that one analogue signal level generated by the nitrate sensor had risen beyond the full scale level for the digitiser input. As a result, the multiplexer for the digitiser carried excess charge from channel to channel causing spurious signal noise. The nitrate sensor was removed from the profiler frame, resulting in clean data on the other multiplexed auxiliary channels. The nitrate sensor was opened and a simple potential divider circuit (2 x 10k ohm resistors) was added to the output of the overrange channel, to reduce the output level by a factor of two. When the sensor reinstalled on the profiler no further signal interference was seen throughout the rest of the cruise.

Bottle firing using the new FSI deck unit and pylon was very reliable during the cruise. The pylon has individual solenoid release catches, rather than a rotary solenoid arrangement used on GO pylons for many years. This built in duplication prevents a simple mechanical fault having a disastrous effect on a bottle firing sequence. Predeployment set-up of the release catches and bottle lanyards is now both easy and positive. Electrical noise spikes on the CTD cable did cause some corruption of the pylon memory, resulting in incorrect responses occasionally, however it was always possible to fire bottles by individually addressed commands.

Operationally this has been a successful cruise with virtually no time being lost due to mechanical or equipment failure.

(R.Kirk, J.Smithers, R.Bonner, S.Watts)

3.1.3 Data processing and calibration

CTD data were logged at 16 frames per second and passed from the CTD deck unit to the Level A processor where they were averaged to one datacycle per second. At the Level A the rate of change of temperature was calculated and a median sorting routine used to detect and remove pressure jumps exceeding 100 raw units (approx. 10 dbars).

The 1 second data were transferred to PSTAR format (datapup) and calibrated (ctdcal) with coefficients from laboratory calibrations. The down cast was extracted (pcopya) and a file of 10 second averages created (pavrge) for merging with the bottle firing times and discrete bottle samples.

Initial calibrations to the 1 second raw data were as follows:

$$\text{Pressure} = ((p_{raw} * 0.1) * 0.996263) + ((p_{raw} * 0.1)^2 * 0.005743) - 0.93832$$

Pressure should have been corrected for the effects of temperature but it was not, leading to a small error.

The upcast portion of the file (data after the maximum raw pressure) were corrected for the differences between the upcast pressure calibration and downcast calibration (hysteresis). The adjustment was based on laboratory measurements of the hysteresis and was linearly interpolated between the values shown in Table 3.

For casts less than 5500 dbar the correction is automatically adjusted so that it is zero at the maximum pressure (P is pressure from CTD upcast):

$$\text{Pressure} = P - (dp5500(P) - ((P/P_{max}) * dp5500(P_{max}))$$

The temperature calibration applied was:

$$\text{Temperature} = T_{raw} + \Delta T_{raw} * 0.20$$

where 0.20s is the time constant used to reduce the mismatch between the response time of the temperature and conductivity sensors as described in the SCOR WG51 report (Crease et al 1988). ΔT_{raw} is the change in temperature over one second calculated by the Level A.

Then the polynomial expression from laboratory tests was applied:

$$\text{Temperature} = -0.0165549 + (T * 0.000499282) + (T2 * 7.97259e\text{-}13)$$

At the start of the cruise the laboratory test-derived conductivity calibration coefficient (0.001000215) was applied to the raw data. For cast 12943 the bottle salinities were compared with the CTD upcast salinities and there was generally an offset of approximately -0.48 psu. A new conductivity ratio was re-calculated (cratio) from the CTD pressure, temperature and conductivity compared to the "true" salinity of the bottles. The new coefficient is the product of the new ratio and the original coefficient. Final corrections to the salinity were made by applying a constant offset to salinity on a cast by cast basis (see below). At Station 12970 the conductivity sensor was damaged by a loose Niskin bottle and a new sensor fitted. The same procedure was used to derive a new conductivity calibration from bottle salinities.

So for stations 12932 to 12970 Conductivity = C_{raw} * 0.000989924

for stations 12971 to 13018 Conductivity = C_{raw} * 0.000988156

Oxygen current (oxyc) was initially calibrated as follows:

oxyc = (ocraw * 0.001) * 1.35

and

oxyfrac = oxyc * exp ((-0.035 * ctemp) + (0.000145 * press))

where ctemp = (temp * 0.4) + ((1- 0.4) * oxyt)

Most of these parameters were rederived in later calibration (§ 3.1.4).

The altimeter, used primarily to detect the height of the CTD off the bottom when it was within 200m of the bottom of the cast, was calibrated as follows:

altimetry = 0.20299 + (altraw * 0.0051479) + (altraw2 * -5.861688e-8)

Two transmissometers were used; SeaTech (trans) and Chelsea Instruments No 003 (trans2). The transmittance was first calibrated using the polynomial expressions:

trans = -0.001719631 + (tnraw * 0.001219711) + (tnraw2 * 3.438596e-10)

trans2 = 0.00181789 + (tn2raw * 0.0012193) + (tn2raw2 * 6.05678e-10)

The transmittance was then further corrected for the ageing of the light source by comparing the clean air deck volts at the start of Di223 (e.g. 3.997 for SeaTech No 003) with the manufacturers calibration (e.g. for SeaTech No 003, water calibration of 1.002 when the air value was 4.28V).

trans => trans * 1.002 * 4.28 / 3.997

trans2 => trans2 * 1 * 4.66 / 4.732

The fluorescence was initially logged as uncalibrated voltage using the following equation to convert from the raw units:

fvolts = -0.001719631 + (fraw * 0.001219711) + (fraw2 * 3.438596e-10)

The nitrate sensor logged three channels of light attenuation at different wavelengths. The attenuation was initially logged as uncalibrated voltage using the following equation to convert each channel from the raw units:

avolts = 0.00181789 + (araw * 0.00121934) + (araw2 * 6.05678e-10)

(N.P.Holliday, R.T.Pollard)

Bottle Firing Depths and Sample Files

The CTD deck unit logged the time and confirmation code of each Niskin bottle firing, and the data were transferred to the Level A and subsequently into PSTAR files (datapup). On some occasions the firing times were not logged by the Level A, so the times were inferred from periods of constant pressure data in the upcast CTD file. This occurred at 3 stations when the Level A was not reset prior to the cast, and if the bottle data cable connecting the deck unit to Level A became loose.

The firing times were merged with the winch cableout data for each station, then the 10-second averaged upcast and 1-second downcast CTD data. Down cast data were matched (pbotle) with upcast data by potential temperature, and used only to calibrate the oxygen data (§ 3.1.4).

The firing data and merged CTD data were pasted into sample files along with other bottle sample data such as salinity, oxygen, nutrients and CFCs, and the reversing thermometer and pressure meter readings. Each sample file contained 24 datacycles, one per bottle on the rosette. The difference between the bottle salinity and the downcast CTD salinity was used to check for possible misfires, then to calibrate the CTD salinity data (see below). No problems with double firings or incorrect firing depths were encountered. Occasionally the CTD firing control panel returned a "bottle already fired" code and the operator fired another bottle at the same depth. The improved reliability of the bottle firings from the new pylon is much appreciated.

(N.P.Holliday)

Salinity Calibration

After the conductivity coefficient was calculated from bottle salinities early in the cruise, a mean offset was calculated for each cast. Values with large differences (leaky bottles, bad samples, and samples drawn in high salinity gradients) were excluded from the mean. The mean offset was also calculated for samples from >1000 dbar where there is less spread in salinity values. The two means determined the offset applied to each cast to match the CTD salinities to the bottle salinities. Table 4 contains all the calculated mean offsets, their standard deviation, and the offset applied. The offset drifts in a minor way throughout the cruise (Fig.4).

After calibration the residuals between the CTD upcast data and the bottle data were recalculated (Fig.5). The final mean of calibrated residuals across all D223 CTD casts was 0.0278 ± 0.3395 for all data points, but 0.0009 ± 0.0029 excluding offsets >0.02 and <

-0.02.

(N.P.Holliday)

A listing of the calibration file deepctd.cal is given in Table 11.

3.1.4 Oxygen calibration

There are several stages to the calibration of the oxygen current measurements from the CTD to give oxygen concentrations in mmol/l. Firstly a least squares fit is performed between the CTD oxygen current values and the bottle sample oxygens on a selection of the casts to find the best parameters with which to make an initial calibration. The best parameters are chosen and applied to the oxygen current values. The second stage of the process is to use a cubic spline fitting routine to reduce further the differences between the bottle sample oxygen concentrations and the calibrated CTD oxygen values. This stage may need several iterations to find suitable values. The final stage is to replace the surface CTD oxygen values with interpolated bottle sample concentrations as the CTD values are particularly unreliable near the surface.

Derivation of Calibration Parameters

The relationship between oxygen concentration and the parameters measured with the CTD is:

oxygen = oxycurr * rho * exp[alpha * T + beta * P] + oxysat(T, S)

where oxygen is the oxygen concentration (in mmol/l), oxycurr is the CTD oxygen current measurement (mamps), T is the temperature (°C), P is the pressure (dbar) and oxysat is the saturation oxygen concentration (in mmol/l) which is itself a function of temperature and salinity. Alpha, beta and rho are the fitting parameters.

Alpha, beta and rho need to be determined from a comparison of the oxygen bottle sample concentrations and the oxygen current measurements as a function of temperature, pressure and salinity. As the pressure and the temperature are both often monotonic with depth to about 2000 m the best fits are obtained with deep casts as these profiles have often reached depths where the temperature is approximately constant whilst the pressure still increases, allowing the effect of each to be determined. The procedure followed to find the 'constants' is as follows.

The script oxyexec reads values of pressure, temperature, salinity, oxygen current and bottle oxygen from the sample file. One complication that should be noted is that the CTD parameters measured on the down cast are compared with the bottle values measured on the upcast. The reason for this is that the upcast values for oxygen current are unreliable as the firing of the bottles on the upcast disrupts the oxygen measurement which takes a while to recover (B King, D189). If the CTD profile plots are examined it will be seen that the oxygen values on the up and on the down cast are usually offset by quite large values. The sample file therefore contains two pressure measurements, dpress and upress. dpress is an estimate of the pressure measured on the downcast where the salinity and temperature best match the values measured on the upcast when the bottle was fired. These two pressures are usually similar, except that dpress may be inaccurate in the surface layer where salinity and temperature are well mixed. dpress is the appropriate pressure value to use in oxyexec.

Oxyexec runs the program oxyca3 and requires initial estimates of alpha, beta, rho and two parameters 'frac' and 'offset'. frac is used when a lagged temperature is constructed from temperature and oxygen temperature (not measured on D223) and offset is a bias in the oxygen current. These were set to 1 (indicating that temperature alone is used instead of a lagged temperature) and 0 (no oxygen current offset). oxyca3 allows some or all of the parameters to be excluded from the fit. The script oxyexec was edited to initially fit all of alpha, beta and rho. Oxyexec prints a table of the input parameters and the fitted oxygen, a list of differences is plotted which is examined to see if any erroneous values are present. If errors (usually in the bottle sample value or near the surface) are found the exec is re-run excluding the bad values to get a better fit. The excluded values were checked with the oxygen sample analysis logs as there was sometimes a mistake in the sample value which can be corrected. If there is no mistake the sample can be flagged as suspect if appropriate. Oxyexec gives the option to calibrate the files, this was not be done at this stage.
Once a reasonable number of deep casts have been made, the values of alpha and beta can be chosen. Fig.6 shows how alpha and beta vary with depth for casts at the beginning of Leg 2.

As Leg 1 had few really deep casts the values of alpha and beta had been initially estimated to be -0.0001623 and 0.01659 respectively. These can be seen from the graphs to be similar to the Leg 2 values for depths around 2000 dbar. As the parameters are better defined for deep casts the values for Leg 2 were taken to be -0.0001402 and 0.02413 (averages for the deep casts 12996, 13002, 13004 and 13005). The calibration for Leg 1 was not recalculated.

With the parameters alpha and beta now fixed, oxyexec was edited to only fit rho, with alpha and beta fixed. A different value of rho is now found for each cast and the option to calibrate the data (both the CTD master file and the sample file, using the program oxygn3 within oxyexec) was taken.

The program oxspln was then used to fit cubic splines to the differences between the bottle and the CTD oxygens in the sample file. Oxygen samples can be excluded from the fit as necessary. Knot points are selected to give a smooth error curve that best corrects the CTD oxygen values towards the bottle values. These errors are used to correct the CTD file oxygen values. As the CTD oxygens are not reliable near the surface they are next replaced with interpolated bottle data. The file is first averaged to 9 second values using pfiltr. The bottle oxygen values are interpolated onto the CTD file and are used to overwrite the CTD oxygen values in the surface layer.

(M.-M.Lee, E.C.Kent)

3.1.5 Reversing Thermometers and Pressure Meters

SIS digital reversing thermometers and pressure meters were used on all CTD casts. Throughout the cruise the meters on the CTD multisampler rosette were T714 and P6132 on Bottle 1, and T743, T746 and P6243 on Bottle 4. Meters T401 and P6075 were kept as spare or for deeper stations using more bottles on the rosette. Laboratory calibrations were applied to all the meters (in Excel spreadsheets), and the resulting values used primarily as a check on the consistency and quality of the CTD data (ftp from Mac hard disk, ppaste into sample files). Experience shows that the CTD data is more stable than the reversing thermometers and pressure meters, so they were not used to correct the CTD data. However, the differences were used to check the calibration of the CTD thermometer after station 12971. The unit received a knock from a loose Niskin bottle and the conductivity sensor was damaged and replaced. The offsets of CTD temperature and pressure from the reversing meters confirmed that there was no change in the calibration of the CTD temperature and pressure sensors. Table 5 shows the mean and standard deviations of the differences between the CTD and meter data.

(N.P.Holliday)

3.2 Chemical tracers studies

Chemical tracer studies were primarily focused on the measurement of CFC- 11, CFC-12, CFC-113 and carbon tetrachloride in order to span rates of formation and spreading of the dominant water masses of the North Atlantic over the last 70 years. Water masses which were particularly targeted were the bottom waters of southern ocean origin, the northern overflow waters, Labrador Sea Water and the recently ventilated mixed layer water. Of particularly interest was the movement of Labrador Sea Water across the North Atlantic and its possible recirculation in the Rockall Trough. CFCs were measured at 34 of the closely spaced stations from the UK to Iceland and all of those along the section into Greenland. In addition samples were analysed from all but 5 of the stations during the SeaSoar survey.

3.2.1 CFC Sample Collection

All samples were collected from depth using the SOC 10 litre Niskin bottles, restricted for CFC work. All 'O' rings, seals and taps were removed from the bottles, at the beginning of the cruise and replaced with ones washed in deacon solution and propan-2-ol then baked in a vacuum oven for 24 hours. Reassembling of the bottles was carried out at the beginning of the cruise and the bottles immediately positioned on the rosette to minimise contamination. CFC-113 contamination was suspected from about station 13011, prompting the replacement of all the bottle taps and later of a couple of the bottles. However this failed to resolve the problem, indicating another source for the contamination. All bottles in use remained outside on deck throughout the cruise, those not in use were stored in aluminium boxes inside the hanger where there was a free flow of air to minimise contamination. Samples for analysis were drawn first from the Niskin bottles directly into 100 ml gas tight syringes and these were stored under clean sea water.

3.2.2 CFC Analysis

Chlorofluorocarbons CFC-11, CFC-12 and CFC-113 were measured at a total of 39 stations by DSW, SMB, CRH and CD during the first leg and a total of 23 station by SMB, CRH and CD on the second leg. The analytical measuring technique was as described in Boswell and Smythe-Wright (1996), with a modified pressure standard injection system enabling the system to be pressurises to 4 bar. This allowed for a maximum sample injection of 16 large loop volumes totalling 80 ml. Duplicate samples and air samples were run as often as analytical time allowed. Air samples were drawn in a clean 100 ml syringe at a windward location on the ship. All CFC analyses were calibrated using calibration curves constructed from a gas standard calibrated by NOAA CMDL. This standard had previously been cross calibrated for CFC-11 and CFC-12 to the SIO 1993 scale. At the commencement of the cruise some CFC-11 contamination was found in the large gas standard loop. Despite, cleaning the contamination persisted and the problem was alleviated by connecting the standard line from the GC/MS system used for the halocarbon analysis to the ECD system. About half way through the first leg the system was changed to the original configuration and standard injections from the small gas standard loop, which was found to be clean, used for the remainder of the cruise. Due to operator error at station 12977 water inadvertently entered the GC system rendering the A channel of the dual detector system non-operational. Both the A and B systems were found to have blocked precolumns. These were cleaned and analysis continued on the B channel. After some days the contamination on the A system ECD cleared and it was possible to run the A system to a limited extent. After the mid cruise port call the A channel precolumn was changed and both detectors used until station 13001 when channel A developed severe baseline noise which rendered accurate quantification impossible. At this point analysis was switched entirely to the B channel. Shortly after the start of the second leg the system developed severe contamination in the region of the CFC-12 peak. This continued throughout the Greenland section and intermittently for the rest of the cruise. It was eventually traced back to the vacuum oven, probably due to traces of oil mist from the vacuum pump. Despite thorough cleaning of the oven and all glassware contained therein, the problem reappeared on several occasions, requiring a bake out of the CFC analytical equipment. CFC-113 contamination from station 13011 onwards did not appear to be derived from the sampling bottles and may be related to the CFC-12 problem. Due to early suspicion falling on the drying material used (magnesium perchlorate), potassium carbonate was used in the drying tubes from station 13006 onwards. This appeared to be a superior desiccant but needs oven temperatures much higher than are compatible with some system components, possibly requiring the use of two ovens in the future. After station 12986, a new standards generator was tried, in order to calibrate for other compounds. However, this produced very high levels of carbon tetrachloride which swamped the system and led to problematic results for a number of stations into the 2nd leg.

3.2.3 Halocarbon Studies

The objective of the halocarbon analysis was to establish the ocean as a net source or sink of a number of halogenated compounds which are known to be produced by marine algae and are important in environment/climate change issues. The compounds involved are diverse, however as an initial study, the cruise work focused on the development of gas chromatography/ mass spectrometry techniques for the analysis of methyl chloride, methyl bromide, methyl iodide and methylene chloride at sea water concentrations. Samples were also analysed for CFCs to evaluate the GC/ECD system.

3.2.4 Halocarbon Sample Collection

Samples were collected directly from the Niskin bottles into 100 ml gas tight syringes, immediately following the CFC samples. Here possible, duplicate samples were taken to increase sample volume, and an extra bottle fired at the surface to permit a five- syringe injection to be made. Work was concentrated on the top six depths (down to 200 m) but 6 stations were analysed to full depth. In all, 211 samples were analysed from 24 stations.

3.2.5 Halocarbon Analysis

Analysis was carried out using a modified version of the normal CFC equipment. A single channel system with the two trapping valves mounted externally to the GC oven. The column itself provided the link between sample board and GC. Samples were stripped and trapped as normal, but using a 60 ml stripping chamber and 8 minutes stripping time. On completion of the first of a pair of duplicates the trap was closed but kept cold and the second sample loaded and stripped into the same trap. For injection into the mass spectrometer, a loop of the column was placed into a Dewar of liquid nitrogen and the analytes desorbed from the trap, thus refocusing them into a tight plug. Final injection was achieved by removing the column from the Dewar and wiping it between finger and thumb, the low thermal mass of the column requiring only minimal warming. Mass spectral analysis was performed using selective ion monitoring, whereby only ions specific to the compounds of interest were measured. This permits discrimination of poorly resolved compound while providing enhanced sensitivity over full scan mode due to the longer dwell time on ions of interest. The experimental nature of this set-up means that the system was not optimised for ultimate sensitivity, especially in terms of the column flow rate into the mass spectrometer which was much higher than recommended. However initial analysis of results suggest detection limits of 0.1 pmol/kg for CFC-11 and 0.3 pmol/kg for CFC-12. Calibration of other compounds was hampered by problems with the standards generator (see above), but will be addressed back at SOC.

(D.Smythe-Wright, S.M.Boswell, C.R.Harris)

3.3 Salinity Bottle Samples

Salinity samples were take from each bottle of each cast and determined using a Guildline Autosal salinometer. The values were entered into spreadsheets and PSTAR bottle files (q.v. §2.5.1 Thermosalinograph Temperature and Salinity and §3.1.3 CTD Data Processing and Calibration). At the beginning of Leg 1 there was a problem with the stability of the temperature in the Controlled Temperature Laboratory. The salinity differences for the standards are shown in Table 15 and Fig.8.

3.4 Oxygen Bottle Samples

Oxygen samples were drawn from every bottle following the collection of samples for CFC analysis. Duplicate samples were taken on each cast, usually from the first two bottles. Samples were drawn into clear, wide necked calibrated glass bottles and fixed on deck with reagents dispensed using Anachem bottle top dispensers. A test station was used to check on the oxygen bottle calibrations and as an opportunity to train a number of people to take the samples. The samples were shaken on deck and again in the laboratory 1/2 hour after collection, when the bottles were checked for the tightness of the stoppers and presence of bubbles. The samples were then stored under water until analysis.

Bottle temperatures were taken, following sampling for oxygen, using a hand held electronic thermometer probe. The temperatures were used to calculate any temperature-dependent changes in the sample bottle volumes. The probe used was damaged on station 12987 and had to be repaired.

Samples were analysed in the constant temperature laboratory, starting two hours after sample collection, following the Winkler whole bottle titration with an amperometric method of endpoint detection, as described by Culberson and Huang (1987). The equipment used was supplied by Metrohm and included the Titrino unit and control pad, exchange unit with 5 ml burette (unit 3) to dispense the thiosulphate in increments of 1 µl, with an electrode for amperometric end point detection.

The mean difference for the duplicate pairs sampled on each station was 0.799 µmol/l (0.25% full scale precision). The data quality may be affected by the amount of time that the Niskin bottles were open and warming up on deck prior to sampling. The rate limiting step in the sampling procedure was the CFC sampling where up to five replicates were taken on some occasions.

The thiosulphate normality was checked on each run and recalculated every time the reservoir was topped up, and every 3 days, against potassium iodate. The exact weight of this standard, the calibration of the 10 ml exchange unit (number 1a) driven by a Metrohm Dosimat and the 1L glass volumetric flask used to dispense and prepare the standard, were accounted for in the Mac worksheet used to calculate the oxygen values. This standardisation was also repeated when fresh iodate standard was prepared which was on five occasions during the cruise.

Very variable standardisation on first batch of standard was probably related to the variable laboratory temperature at the beginning of Leg 1 and the introduction of bubbles.

The introduction of oxygen with the reagents and impurities in the manganese chloride were corrected for by blank measurements made on each station, as described in the WOCE Manual of Operations and Methods (Culberson, 1991). The iodate standards were added to the excess reagents following the blank measurements as there was some question about the order of addition of the chemicals and standard material (the differences between adding iodate before or after the acid, iodide and manganous chloride appear to be related to reagent batch and adding the standard toe the excess reagent removes these differences).

The thiosulphate normality was checked against a commercially prepared standard (Sagami Chemical Company, Japan). It was dispensed using the Eppendorf 1 ml pipette and compared against the in house standard dispensed in the same way. On each occasion the thiosulphate normality was equivalent using the iodate working standard and that supplied by Sagami.

Data comparisons were made against CONVEX data. Six equivalent stations were compared by overlaying profiles:- The bottom water oxygen values differed by ± 4 µmol/l between station 12994 on this cruise and 62038 for the CONVEX data otherwise the stations showed good agreement.

References:

Culberson, C.H. and S.Huang, 1987. Automated amperometric oxygen titration. Deep Sea Research, 34, 875-880.

Culberson, C.H. 1991. 15 pp in the WOCE Operations Manual (WHP Operations and Methods) WHPO 91/1, Woods Hole.

(S.E.Holley, A.Mustard)

3.5 Nutrient Bottle Samples

A total of 84 casts were sampled for nutrients during the two Legs of this cruise. Depths ranged from 500m to over 3000m. Duplicate samples for nutrient measurements were collected following CFC and oxygen samples from each Niskin bottle. Water was collected in clean plastic diluvial containers that had been rinsed three times. One duplicate was stored in the refrigerator and analysed within 12 hours, whilst the other duplicate was stored at 5°C in the cold room. Water collected from the Niskins on each CTD cast was poured into individual 8 ml sample cups and mounted on the sampler turntable and analysed in sequence, with the results recorded by chart recorder and by computer run peak height analysis software. Concentrations of nitrate/nitrite, silicate and phosphate were determined by segmented flow analysis on a Chemlab Autoanalyser system with autosampling. Each sample was analysed in duplicate to ensure accuracy and increase precision. Several quality control samples were also analysed on each run to provide a measure of drift which is inherent in this type of analysis. The quality control samples were made up from standard solutions supplied by OSI in addition to a deep water sample collected from ca. 3000m. The OSI standards were made up and stored in calibrated plastic volumetric flasks. The deep water QC samples were decanted into clean rinsed plastic diluvial containers and stored in the refrigerator until required.

Primary standards used for the calibration of the autoanalyser were made up in calibrated 500 ml glass volumetric flasks (except for the silicate standard, which was made up in a calibrated polyethylene volumetric flask) in fresh water approximately every four weeks and stored in the refrigerator to reduce deterioration of the solutions. These primary standards were made up from pre-weighed salts that had been accurately weighed prior to the start of the cruise. Mixed working standards were made up approximately once per day in 100 ml calibrated polyethylene volumetric flasks in artificial seawater (@ 40g/l NaCl) . The concentrations of the working standards used for discrete nutrient analysis were as follows:

Silicate 40 μmol l^{-1}, 30 μmol l^{-1}, 20 μmol l^{-1}, 10 μmol l^{-1}
Nitrate 40 μmol l^{-1}, 30 μmol l^{-1}, 20 μmol l^{-1}, 10 μmol l^{-1}
Phosphate 2.0 μmol l^{-1}, 1.50 μmol l^{-1}, 1.00 μmol l^{-1}, 0.50 μmol l^{-1}

The autoanalyser, although reliable, required periodic maintenance throughout the course of the cruise. The tubing on the peristaltic pump was replaced at approximately two week intervals to maintain maximum sensitivity in the analysis. And a complete re-tubing of the analyser was performed at the end of the Leg 1 of the cruise. At this time the system was flushed with DECON and distilled water before further samples were analysed. Prior to each analysis, a set of standard solutions was run to check that the system was operating correctly. Reagents for each of the nutrients analysed were made up as and when required from pre-weighed salts.

A total of 6214 analyses were carried out over the duration of the two legs including standards, drifts and quality control samples. Results indicated reduced nutrient concentrations in the surface waters at the start of the Leg 1 with concentrations of all three nutrients measured increasing over the course of the Leg 2. Deep water nutrient concentrations whilst higher than at the surface showed significant rises as the course of the ship turned south.

Problems with the Autoanalyser.

A number of problems were encountered during the course of the two legs of this cruise with respect to re-tubing of the discrete autoanalyser system. Firstly, when the system is retubed the nitrate channel exhibited the peculiar action of sucking fluid back up the waste tube through the flow cell. This occurred at the same time as an increase in pressure in the system so much so that joints in the system between tubes burst apart. The problem eventually disappeared after continuous running of nitrate reagents, but required several days before becoming fully functional. This was not too great a problem during this cruise as the rate of sample acquisition was not too great, but if the workload had become much heavier then a serious backlog of samples would have built up very rapidly. On further investigation it appeared that when the cadmium column was replenished with extra cadmium particles, a fine dust accumulated in the column which caused a reduction in flow rate though the column to such an extent that the pressure in the column increased. To remedy this, a syringe filled with water was employed to clear away the dust from within the column. This was probably a result of the narrow bore of the cadmium column housing.

(M.S.Finch)

3.6 Nitrate Sensor

A prototype ultra violet nitrate sensor was mounted on the CTD rig in an attempt to determine the validity of using this type of sensor at sea for the continuous measurement of nitrate. During the Leg 1 it was noticed that the 300 nm channel was producing a voltage greater than 5.5V which was interfering with the A/D CTD system. This required the removal of the sensor from the CTD rig until the voltage could be brought down to below 5V. After consultation with colleagues at SOC, the sensor was modified to halve the voltage output on the 300 nm channel and the sensor was remounted on the CTD rig. This modification was carried out whilst on board ship by the addition of two 10K resistors. For further information see the section on CTD operation. Results from the Leg 2, whilst still to be analysed in detail, are encouraging. Some casts show hysteresis, particularly on the 220 nm channel, but not on the 240 nm channel. The results produced from the chemical analysis of nitrate from the CTD casts will be used to calibrate the results from the UV nitrate sensor.

(M.S.Finch)

3.7 Oxygen Isotope Samples

The purpose of the ^{18}O sampling is its inclusion in a study of the contribution the regional sea make in the formation of North Atlantic Deep Water. ^{18}O acts as a tracer much like salinity, the ^{18}O distribution being primarily determined by the precipitation - evaporation regime.

However unlike salinity ^{18}O is left effectively unchanged by sea - ice processes giving it an extra degree of freedom where sea - ice processes occur.

Samples were taken from CTD casts at stations indicated in the cast list for analysis back at the University of East Anglia. The sea water is analysed using a modification of the standard CO_2 - H_2O ^{18}O isotope equilibration technique (Dennis et al. 1995). The samples were collected in new 150 ml Winchester bottles leaving head space for expansion, the small amount of CO_2 in the head space not affecting the ^{18}O value. The bottles being new only required one rinse. The bottles were then sealed with rubber lined metal caps and further sealed, within 24 hours, with Nesco film in order to prevent evaporation and consequent change in ^{18}O value.

Reference

Dennis P. F, R. D. Frew and A. Etchells, A rapid high precision system for O-18 determination of natural waters. Submitted to J. Atmos. Ocean Tech. 1995.

(T.A.Winters)

3.8 Plankton Speciation and Pigment analysis

Water samples were collected between 0-200 m for plankton speciation and plant pigment analysis in order to interpret the halocarbon data in relation to prevailing biological activity. Forty three stations were sampled. Samples for plankton identification were collected from 2 depths, usually surface and 25 or 50m. For each of the depths two 100 ml bottles, one containing 1 ml lugols solution and the other containing 2 ml 40% formalin were filled with water. 180 samples were taken overall. At the top 6 depths between 2 and 4 l of sea water were collected and immediately filtered through 25 mm GFF filters. The filters were subsequently placed in cryotubes and stored in liquid nitrogen. 258 samples were filtered. In addition some assessment of the less than 2 mm diameter cells to total chlorophyll was made at the same depths as the plankton speciation samples by filtering 100 ml water through 2 mm filters, passing the filtrate through 25 mm GFF filters and measuring the chlorophyll by normal acetone extraction procedure. This could then be compared with the conventional chlorophyll samples filtered through 25 mm GFF filters. Approximately 90 <2 mm samples were filtered.

(D.Smythe-Wright, S.M.Boswell, C.Deubert)

3.9 Chlorophyll Samples and Fluorescence Calibration

3.9.1 Chlorophyll Determinations

Chlorophyll samples were taken to calibrate the CTD fluorometer, the TSG fluorometer and consequently the SeaSoar. CTD chlorophyll sampling concentrated on the mixed layer with the top 2, 4 or 5 Niskin bottles being sampled depending on whether HPLC samples were being taken. Chlorophyll was the last sample that was taken from the bottle rosette. Also about every 5 stations water from below the mixed layer was sampled. Alberto Naveira Garabato advised that calibration was possible with just 2 to 3 mixed layer samples, even in daylight, because of the low chlorophyll concentrations at these latitudes during the cruise. Underway samples were taken hourly when the SeaSoar was deployed, and samples were drawn from the non-toxic hose in the hanger which is the same non-toxic supply as the TSG fluorometer.

Samples were collected in 500 ml plastic flasks which were rinsed in the sample prior to being filled. Immediately three 100 ml aliquots measured out in a cut off volumetric flask were filtered through 3 Whatman GF/F 25 mm filters at low pressure (<6 mm Hg). Filtering was done in reduced light, with the bottle annexe lights off and a black plastic bin liner covering the filters. Once the method produced sensible precise results this was reduced to two filters per sample. The papers were placed in glass vials and immediately in the dark at -20°C.

20 ml of 90% acetone was added to batches of 50 samples daily from an Anachem 25 ml adjustable autodispenser, to extract the chlorophyll, and they were placed in the freezer for 22 to 24 hours. Smaller batches of ten samples were then warmed to room temperature in a dark water bath before the fluorescence was measured in a Turner Designs Fluorometer (model 10-000R, serial no. 00859). Then 4 drops of 10% hydrochloric acid were added to the sample and the fluorescence remeasured.

Chlorophyll solutions (sigma chlorophyll) covering the expected range of the samples were used for calibration standards and were made up and measured along with blanks for each 50 samples. Two primary standards were used which were stored in the freezer and used to make up the standards. The chlorophyll concentration of these was calculated from the absorbance measured before and after acid at 665 and 750 nm in Pye Unicam SP6-500 spectrophotometer.

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 text files.

Equations

standard concentration:

Chlorophyll a (mg m^{-3}) = $26.7(665_b-665_a)v/l$

Phaeopigments (mg m^{-3}) = $26.7((1.7\times665_a)-665_b)v/l$

where: 665_b =3D Absorbance at 665 nm before acidification.

665_a =3D Absorbance at 665 nm after acidification.

v = Volume of extract (ml)

l = path length of cuvette (cm)

Sample concentrations:

Chlorophyll a (mg m^{-3}) $= F_D\times(F_m/(F_m-1))\times(F_b-F_a)\times(v/V)$

Phaeopigments (mg m^{-3}) $= F_D\times(F_m/(F_m-1))\times((F_m\times F_b)-F_a)\times(v/V)$

where: F_D = Chlorophyll Standard concentration / Chlorophyll standard Fluorescence before acidification.

F_b, F_a = Fluorescence value before and after acidification of sample.

$F_m = F_b/F_a$ of chl a standard solution.

v = volume of 90% acetone used in extraction(ml).

V = Volume of seawater filtered (ml).

During the cruise 1870 discrete chlorophyll samples were taken and analysed. The range of concentrations varied in the mixed layer from 0.2 mg m^{-3} to 0.7 mg m^{-3}, and in the coastal water close to Iceland were as high as 1.5 mg m^{-3}. The precision of the method was estimated by comparing the standard deviations of the duplicates of the underway chlorophyll measurements. This resulted in a standard deviation of 0.0053 . The main areas which were identified as the sources of inaccuracies were filtering leakages and imprecise measurements of sample volume in the cut off volumetric flask. The Turner fluorometer was also effected by the motion of the ship, and the normal readable accuracy of three significant figures was reduced because the needle swung with the ship.

References:

Holm-Hansen, O., and Riemann, B., (1978) Chlorophyll a determination: improvements in methodology. Oikos 30: 438-447.
JGOFS Protocols Draft March 1994.

(A.T.Mustard)

3.9.2 Fluorescence Calibration

A Chelsea Instruments Aquatracka III fluorometer mounted horizontally was included in the CTD package during Vivaldi 96. Conversion of continuous fluorometric measurements made with this device to profiles of chlorophyll a concentration could be accomplished by reference to bottle samples taken at various depths over each single cast.

Previously to the calibration, a constant offset fluorescence value of 0.98 (arbitrary fluorescence units) was substracted to the whole data set in order to improve the consistency of the derived deep chlorophyll a concentration data, optimising convergence of records from different stations at depth. Calculation of the fluorescence yield R (the ratio of fluorescence to chlorophyll a concentration) at every available sample point followed. As this parameter is highly variable, depending on a wide range of factors such as ambient light field, phytoplankton species composition and physiological state or nutrient supply, the change of R with depth was initially investigated.

Little dependence of fluorescence yield R on depth was appreciated within the well-mixed layer that dominated the top tens of meters over the whole Vivaldi 96 survey, small fluctuations (of magnitude ~5%) around a mean local value being most probably due to random sampling errors or natural patchiness. The larger (by up to an order of magnitude), apparently chaotic fluctuations in R encountered deeper down the water column are thought to be a fictitious effect introduced by the calculation of R as the ratio of two numbers close to zero. Given the reduced fluorescence readings at these depths, sensitivity of derived deep chlorophyll concentrations to the choice of R proved insignificant.

With this background, the strategy of estimating a single value of R for each fluorescence profile was adopted. By means of that simplification, the original shapes of the fluorescence profiles were rigorously preserved and derivation of chlorophyll a concentrations over the whole water column for those casts in which only a single bottle sample had been taken was made possible.

Only in certain strongly-illuminated locations had this approach to be modified. The reason for this was the light-dependency of R, usually referred to as light quenching. Namely, the relationship between fluorescence yield and ambient irradiance is that of a negative correlation, a consequence of the changing photoadaptive state of phytoplankton. Though quenching effects encountered during Vivaldi 96 were generally small in comparison with other often observed oceanic scenarios, they were by no means negligible.

Given that no irradiance meter had been mounted in the CTD frame that could assist the description of variations in R as a function of light intensity, several bottle samples were needed to infer those variations along the illuminated sector of the water column. Wherever the required samples were made available, linear interpolation (pintrp) between sample points provided a depth-dependent definition of R. When the number of bottle samples was insufficient, quenched data were edited out (peditb).

At this stage, having defined R over the widest range as it was judged possible, a trivial calculation (parith) of chlorophyll a concentration as the ratio of in situ fluorescence and the corresponding fluorescence yield remained.

The original fluorescence profiles were somewhat spiky, specially in gradient zones and below the mixed layer, and these features were obviously still present in chlorophyll a concentration profiles after calibration. Only the most prominent spikes were removed (peditb). Caution should be taken when considering fine structure in such profiles.
Errors introduced by the calibration are difficult to estimate and, given the natural patchiness of phytoplankton, may vary considerably with the number of bottle samples available per cast. Based on fluctuations in R as calculated from the different samples in a multiple sample cast, typical figures of ±0.01 and ±0.04 mg m^{-3} may be quoted for the expected error in the (mean mixed layer) calibrated chlorophyll a concentration of a three sample cast and a one sample cast, respectively. The concentrations so obtained were gridded and contoured for the three CTD sections in the Leg 1 and obvious correlation with oxygen concentration and salinity structures could be visually appreciated. Accordingly, calibrated chlorophyll data from the CTD fluorometer were found to be remarkably consistent with those recorded by a similar instrument mounted on the towed undulating fish Sea Soar, measurements from which underwent a completely independent calibration treatment.

A sampling strategy of 2/3 bottle samples per night-time cast and 3 samples per day-time cast, with emphasis in the top (probably quenched) 20 m, is recommended for future cruises where similar well-mixed, relatively weakly quenched water columns are encountered.

(A.C.Naveira Garabato)

3.10 Lowered Acoustic Doppler Current Profiler (LADCP)

The RDI 150 kHz ADCP consists of a 33 inch pressure case rated to 6000 metres with 4 transducers at one end in a convex arrangement and the beams diverging at 30 degrees from the vertical. At the opposite end to the transducers are two connectors one of which enables downloading of data and the other which connects it to another pressure case containing the power supply pack. This arrangement allowed the ADCP to be mounted centrally and vertically on the CTD frame whilst the battery pack was mounted horizontally near its base. A fly lead was left attached permanently to the unit, the other end of which was lashed to one of the CTD's vertical supports, this enabled a comms lead to be readily connected pre and post deployment.

Communications: The communications lead (which also allows external power to be supplied to the ADCP) was sufficiently long to route it through to the port side of the deck lab where it was connected to a dedicated PC and external power supply. The latter was set at 40+ volts and was left on whilst the ADCP was on deck. 10-15 minutes prior to deployment the external power supply was shut off, the instrument checked and the configuration file sent to the ADCP as described in the manual instructions. The ADCP end of the communications lead was fed back into the bottle annex to keep it from the elements. The free end of the fly lead was greased and the end cap refitted, this was then taped to the frame for security.

Post deployment: When the CTD/LADCP was brought inboard, the fly-lead connector was dried and the comms lead fed over the top of the CTD frame and connected to it. This stopped undue bending of the cable and kept it clear of the water bottles, aiding sampling. External power was applied again and the cast data downloaded as per the manual. The processing is accomplished using software developed by Eric Firing (Univ. of Hawaii) after transferring the data to a UNIX workstation.

Battery power was supplied to the ADCP in the form of 36 volts from 24 × 1.5 volt alkaline cells. Four of these packs were available for the cruise, as the ADCP will function at a minimum of 20 volts this was deemed an adequate stock for the duration. However the ADCP failed to log during the downcast of CTD 12964 at 900 metres, the battery voltage was measured when the unit was on deck and found to be 32.2 volts (the ADCP was using a bottom tracking configuration). No errors were reported by the unit and so it was deployed again. At 890 metres, during the upcast of CTD 12972, the unit stopped recording again in a bottom tracking mode. The voltage was 31.6 volts at the surface. The next cast reported an error code 00000080 and during the following CTD, 12974, the ADCP failed to log at a depth of 270 metres. The battery pack was replaced. It was evident that the supply of battery packs might not suffice. A spare pack was requested and arrived in Reykjavik. To avoid potential subsequent loss of data it would be advisable to renew the pack if the voltage drops to 32.2 volts. As it seems the power drain may be greater in bottom tracking modes it may be prudent to use only water tracking at lower voltages.

Data quality: Apart from the loss of data mentioned above the data quality from the ADCP was good throughout.

Backscatter: Acoustic backscatter from the ADCP is logged as a beam by beam measurement. BBLIST is an RDI program that allows data to be converted to an ASCII file format. This can be run in a batch mode by using BBBATCH. Once the files had been converted they were read into PSTAR and a program was written to enable the target strength to be generated after merging with the temperature and salinity data from the CTD. This compared favourably with the Vessel mounted ADCP data. Further investigation could, using the calibrated VMADCP as a standard yield quantitative values for acoustic backscatter throughout the water column

Remarks: The LADCP seems to function well and generates useful information on both currents and backscatter. The battery supply has its limitations though and thought should be given to alternatives to the present set-up as cold water seems to reduce the output of alkaline cells quite considerably.

(M.C.Hartman)

3.10.1 LADCP Processing for Current Profiles

A brief account of the LADCP current data processing, file nomenclature and directory structure is provided in the following lines. Little emphasis is put into a detailed description of the main programming tools used, since these are part of a standard software package developed by Eric Firing at the University of Hawaii.

Outline of LADCP current calculation method

This section aims to offer a very simple introduction to the LADCP current calculation method, so that the files and programs listed in sections below can be placed in their actual context. For a more self-explanatory account of this method, see reference.

The Broad Band LADCP used during Vivaldi 96 was designed to measure the instantaneous relative velocities of scatterers in the water column by taking advantage of the Doppler frequency shift, phase changes and correlation between coded pulses transmitted and received by the LADCP's four transducers. Conversion of this raw data stream to a profile of absolute currents involved an elaborate calculation method.

Firstly, Doppler shifts needed to be scaled to velocity units by taking into account the depth-dependent sound velocity (estimated from CTD T and S measurements). Directions could be inferred from trigonometric calculations based on the geometry of the transducer set, the orientation of the package (measured with a flux gate compass) and the local magnetic declination. The depth of the instrument was calculated from the integration of the measured vertical velocity and later adjusted to match the depth given by the CTD's pressure sensor.

The velocities corresponding to each single ensemble (or, in effect, to each transducer ping) were gridded in bins of depth set either to 8 or 16 meters, depending on the cast. Statistical rejection of spiky measurements within each of these bins followed.

In order to reject the unwanted motion of the instrument (but also the barotropic component of the current), shear profiles were calculated for each ensemble. A complicated editing scheme preceded this shear calculation. A final shear profile (baroclinic current) was derived by real-depth gridding of the shear profiles calculated for individual ensembles. It was hoped that any relative velocities introduced by the high-frequency motion of the CTD package would be smoothed out by this repeated averaging.

The barotropic component of the flow was finally calculated from bottom-tracking measurements (bottom-track mode) or, in most occasions, in an integral sense from differential GPS positions of the ship (water-track mode).

The definitive velocity profile was hence obtained as the sum of the baroclinic and barotropic components.

During Vivaldi 96, no specific error calculation was performed, but a figure of the order of ± 2 cm/s may be quoted from previous surveys. Profiles of shear standard deviation were included in the cast log sheet folder. Considerable contamination by tidal currents was appreciated all the way from Barra Head to Lousy Bank, while internal wave signals were obvious throughout the cruise.

Relevant PC files

The raw data were downloaded from the LADCP into a devoted PC after each cast and stored as a binary file called dNNN.000 in the c:\ladcp\d223\dNNN directory, where NNN stands for the last three digits of the CTD cast number, e.g. raw data from cast 12943 were stored in the file c:\ladcp\d223\d943\d943.000 .

The command file (named *.cmd, where * denotes any character string) containing the operating instructions (setting of track mode, bin depth, etc.) given to the LADCP previously to deployment was stored in the same directory.

Text files of the form dNNN.scn are the output from the program 'scanbb' and contain general information about the LADCP cast, such as start, bottom and stop times/ensemble numbers.

Text files called dNNN.cnt store information required by the program 'loadbb' to transfer the raw binary data to the CODAS database. Database files may be recognised by their .blk extension.

Other PC files

In the c:\ladcp\d223\dNNN directories, other files involved in the instrument deployment or data recovery might be encountered.
lady.def is a standard definition file for input to 'bbsc', the program that controls the LADCP deployment and data flow after recovery.
Also in the above directory, loadNNN.log keeps a log of the loading of raw binary data to the CODAS database by 'loadbb'.

In c:\bbadcp, files named dNNN.txt are the log of the 'bbtalk' session (testing the state and functioning of the instrument) previous to deployment. Only casts in Leg 1 and beginning of Leg 2 were logged into these files. The details of the sessions for every single cast in the cruise are to be found in the cast log sheets.

In c:\bbadcp\deploy, files of the type dNNN.log store the deployment information output by 'bbsc'.

Relevant SUN files

Cast directories: A directory called dNNN (where NNN again denotes the last three digits of the CTD cast number) was created for each cast under /data52/ladcp/ladcp/ladyproc/223_viv . Most PC files were copied across to this dNNN cast directory for processing.

A whole variety of files were created and manipulated during the different processing stages, and no mention will be made of the majority of them for reasons of clarity. The processing procedure may be summarised in four steps:

1- create a SUN version (files named dNNNs*.blk) of the CODAS database using the program 'mkblkdir' .

2- incorporate CTD pressure, temperature and salinity data into the CODAS database in order to obtain the best possible estimates of depth and sound velocity. This is done using 'add_ctdbb' after running the MatLab programs 'doctd' and 'set_NNN' .

3- use the Perl script 'domerge' to calculate mean shear profiles (baroclinic component of current) and apply corrections and editing options (these are stored in a file called merge_.cnt and were kept constant throughout the whole cruise).

4- introduce effect of ship's motion and calculate barotropic component of velocity. (The navigation data used for this purpose during Vivaldi 96 were the 1 s GPS positions from the ~/rawnav directory. The short FORTRAN program 'temp' was written to filter out redundant positions, since this was a cause for errors during later processing). The MatLab script 'do_abs' calculates absolute velocities and produces a standard set of curves for each cast. These plots were regularly stored with their correspondent cast log sheets.

LADCP directory: Under /data52/ladcp/ladcp/ladyproc/223_viv a directory called ladcp was created. The ASCII files containing the final absolute velocities averaged in 5 m bins for each single cast (nomenclature ldpNNN.asc) may be found in this directory, along with their PSTAR versions ldpNNNNN (where NNNNN stands for the five-digit cast number). The script 'ladcpexec' was used to do the ASCII to PSTAR format conversion. Another useful file, latlon.asc, stores a four-column list of NNN (three last digits of cast number), cast latitude, cast longitude and maximum depth from which the LADCP recorded good data.

Other SUN files: The SUN files that have not been mentioned in the above section follow the standard naming convention adopted in Nick Crisp, Lisa Beal and Robin Tokmakian's LADCP data processing manual. Most of them are either short logs of the execution of various processing programs or record fragments of the cast's data at different processing stages. Refer to the manual if further information is required.

Archiving: Data stored in the PC were recorded into an EO while conserving the original directory structure.

References

Fischer, J., and M. Visbeck 1993: Deep velocity profiling with self-contained ADCPs. J. Atmos. Oceanic Technol. 10, 764-773.

(A.C.Naveira Garabato)

3.10.2 LADCP Absolute Backscatter

An estimation of the absolute backscatter coefficient (Sv, measured in dB) for the whole water column surveyed in each single CTD station during Vivaldi 96 was obtained from echo intensity (E, in counts) measurements recorded by four transducers in an LADCP, which was lowered with the CTD package. The method used in this calculation was a variation of that described in RDI 1990 (see reference), which in mathematical terms may be expressed as

Sv = 10 * $\log_{10}$ [4.47*E-20 * K2 * Ks * (Tx + 273) * (10^(Kc * (E - Er) / 10) - 1) * R2) / c / P / K1 / E(-2 * a * R / 10)]

where

Tx = transducer temperature (°C)
P = transmit pulse length (m)
R = range along beam to scatterers (m)
Er = real-time reference level for echo intensity (count)
Kc = conversion factor for echo intensity (dB/count)
K2 = system noise factor
Ks = frequency-dependent system constant (ratio of system's AGC bandwidth and square of transducer's diameter)
K1 = real-time power into the water (W)
a = absorption coefficient of water (dB/m)
c = speed of sound (m/s)

Below follows a brief, step-by-step account of the algorithm developed for the calculation of Sv.

Data conversion to PSTAR

Data were extracted from the raw binary files in the LADCP PC (*.000 files) and converted to ASCII format by using BBLIST, a program included in the LADCP software package. The listing format was saved in a file named ascii2.fmt (which has been backed up along with the other PC files) and contained, in the following order, jday, transducer temperature (txtemp), bin depth (bindepth), echo intensity from each of the four transducers (amp1, amp2, amp3, amp4), % good pings from beam 4 (good), pitch of the CTD package (pitch), roll (roll) and heading of LADCP (heading).

The ASCII file thus created was copied to a SUN terminal and converted to PSTAR with the pascin exec ascinexec.

Absolute backscatter calculation routines

A series of scripts and a PSTAR program were written during the development of the absolute backscatter calculation routine. These will be listed and commented on in order of execution.

lacexec1

This short script copies the PSTAR file containing raw echo intensity data and the CTD file for the relevant station to the working directory, merges them on time (originally, LADCP and CTD files use different year day conventions, so this has to be accounted for) and calculates the pressure at the scattering layers by adding the pressure at the CTD package depth and the LADCP bindepths.

lacexec2

Another simple script, lacexec2 finds the data cycles (in the file output from lacexec1) for the turning points in the package pressure. This is so that the file can be split into a downcast and an upcast part at future stages.

lacexec3

lacexec3 produces the separate downcast and upcast files to be calibrated. These files include all the original LADCP variables and temperature and salinity from the CTD file.

lacal

The calculation of Sv is accomplished in the PSTAR program lacal. In essence, lacal applies the equation above to the raw LADCP echo intensities. The main practical difficulty consisted on estimating some of the terms in this equation, and this will be the subject of the following lines.

Being instrument-dependent parameters, K1, K2 and Ks should have been obtained from the manufacturer's specifications. However, no such information was available on the ship, so the decision was taken to introduce a scaling term multiplying the expression inside the log (this was expressed, taking advantage of the properties of logs, as a parameter (Z) added to the original Sv). Given that K1, K2 and Ks are supposed to be constant to a good approximation, this approach should be valid. The value of Z for each of the four LADCP transducer beams was determined by reference to the vessel-mounted ADCP backscatter measurements, which had been reliably calibrated with well-established system parameters. For the sake of a magnitude scaling, K1, K2 and Ks were set to typical values from a VMADCP of characteristics similar to our self-contained one:

K1 = 74.6 W
K2 = 3.46
Ks = 4.17 * E5
Z(beam1) = 27.0
Z(beam2) = 28.3

$Z(beam3) = 28.5$
$Z(beam4) = 31.7$

Kc was chosen accordingly:

$Kc = 0.42$ dB/count

The real-time reference level for echo intensity could be estimated by RDI's in situ method, by which Er is set to the value of E returned when the echo intensity counts reach a minimum value and flatten out, usually in deep water, well away from interfering signals generated by the ship. This revealed the following Er values:

$Er(beam1) = 32.0$
$Er(beam2) = 32.0$
$Er(beam3) = 37.0$
$Er(beam4) = 36.0$

Profiles of sound speed could be inferred from CTD T and S measurements, using

$$c = 1412.0 + 3.21 * T + 1.19 * S + 0.0167 * depth$$

The range along beam to scatterers was expressed as

$$R = (Bk + | (P - B) / 2 | + N * B + P / 4) / \cos ø * c / 1475.1$$

where

Bk = blank beyond transmit (m)
P = pulse length (m)
B = bin depth (m)
N = bin number
ø = angle of transducer beams to vertical = 30 ° in this case
c = sound speed

And the absorption coefficient

$$a = A1 * P1 * f1 * f2 / (f2 + f12) + A2 * P2 * f2 * f2 / (f2 + f22) + A3 * P3 * f2 \text{ (dB/km)}$$

where

f = LADCP frequency = 150 kHz

Boric Acid contribution:
$A1 = 8.86 / c * 10\wedge(0.78 * PH - 5)$ (dB/km/kHz)
$P1 = 1$
$f1 = 2.8 * (S / 35)\wedge0.5 * 10\wedge(4 - 1245 / (T + 273))$ (kHz)
$PH = 8$

$MgSO_4$ contribution:

A2 = 21.44 * S / c * (1 + 0.0025 * T) (dB/km/kHz)
P2 = 1 - 1.37 * E-4 * depth + 6.2 * E-9 * depth2
f2 = 8.17 * 10^(8 - 1990 / (273 + T)) / (1 + 0.0018 * (S -35)) (kHz)

Pure water contribution:
A3 = 4.937 * E-4 - 2.59 * E-5 * T + 9.11 * E-7 * T2 (dB/km/kHz)
P3 = 1 - 3.83 * E-5 * depth + 4.9 * E-10 * depth2

Besides the strict calculation of Sv, an editing scheme was designed to smooth out part of the high frequency noise that was originally encountered after the calculation. The criteria used were based on % good pings (beam 4 was used since it was noticed that it controlled the editing of the velocity data), pitch and roll, and statistical rejection of spikes (based on binning of data in depth cells and deletion of those data cycles which differed by more than a certain threshold from the mean value of echo intensity in their corresponding cell).

The editing control parameters for the pitch and roll criterion were input, along with Er values, Z values and system-dependent constants, in a control file named lacal.cnt . The factor controlling statistical editing was embedded in the body of the lacal program (a parameter called 'factor').

Having this information present, the operation of the lacal program is straightforward. Its output includes nine new variables: sv1, sv2, sv3, sv4 (Sv for each of the transducer beams), glin1, glin2, glin3, glin4 (parameters related to the expression inside the log in the equation for Sv, so that Sv = 10 * log10 (glin * E-11) + Z) and glinav (the average of glin1, glin2, glin3, glin4). The purpose of the glin variables is to ease data gridding in the future. It was judged that gridding of absolute backscatter coefficients should be implemented on the linear expression inside the log, and not on Sv itself, given the special properties of logarithms.

lacal was usually run in the form of a script: lacal.exec .

lacexec4

The script lacexec4 grids the output from lacal and produces a smoothing filter based on the autocorrelation statistics of the gridded data.

lacexec5 / lacexec5.b / lacexec6

These three short scripts apply the smoothing filter obtained by lacexec4. The variable svbest is the best estimate of Sv after calibration, editing, gridding, smoothing and beam averaging.

lacexec7

lacexec7 cleans up the working directory.

Future work

Over the range of the VMADCP, the LADCP showed the potential for measuring reliable absolute backscatter coefficients. Even with the crude calibration applied here, Sv, as measured by the LADCP, was usually within 3 dB of that measured by the VMADCP. It could be appreciated that VMADCP measurements are probably unreliable under 450 m, and that a lot of interesting structure is to be found in the deep ocean, outside the reach of the VMADCP. It might be feasible to use the LADCP, in conjunction with in situ net sampling, to survey deep zooplankton populations and ultimately use this approach to infer a calibration method for converting absolute backscatter coefficients into biomass concentrations. During Vivaldi 96, nets were deployed at several depths in a few single stations in order to infer the species compositions of various backscatter peaks. The samples were not analysed on board, but obvious differences in species between the peaks could be visually observed.

Archiving

Owing to this work having started as an experimental trial, no log was kept of processed data. Nevertheless, the following instructions should provide a sufficiently clear perspective into the character and contents of each file.

All archiving of LADCP backscatter data was performed onto EO22306

The PSTAR files containing the raw echo intensity data as read from the *.000 files in the PC were archived under directory 'source'. Their names followed the pattern lbsNNNNNN.sr (where NNNNN is the five-digit station number) and their data names lbsNNNNNN .

The non-gridded calibrated files were recorded under 'cal', named lbsNNNNNN.dn and lbsNNNNNN.up (for downcast and upcast, respectively) and same data name as above.

The gridded calibrated files, lbsNNNNNN.dn.gr and lbsNNNNNN.up.gr, were archived under 'cal.gr', with the same data name as above.

References

RDI 1990 Calculating absolute backscatter, Technical Bulletin ADCP-90-04, RD Instruments, San Diego, California, 24 pp.

(A.C.Naveira Garabato, M.C.Hartman)

3.11 Nets

At most CTD stations shallow plankton nets were used to collect zooplankton samples. The mesh size was 500 µm except for the cod-end which was 200 µm. The samples were preserved in kilner jars with formalin solution. Table 6 shows the depth of the net-haul at each station.

4. UNDERWAY MEASUREMENTS

4.1 SeaSoar

4.1.1 Winch

The horizontal drum SeaSoar winch was used for a total of 24 survey deployments during the cruise, without any operational delays. However the excessive rough weather took its toll on the cable and fairing, and some mechanical problems were encountered.

(R Bonner)

4.1.2 Deployment and Recovery

Following discussions with RVS prior to the cruise, it was proposed to hang the SeaSoar towing block off the starboard aft crane during launch and recovery, then transfer it to and from the Aft gantry auxiliary arm for survey towing. The SeaSoar winch was sited on the starboard side of the aft deck, in alignment with the auxiliary arm and a Lebus 3 tonne winch sited adjacent to it, with its warp running through the auxiliary arm block. This winch was to allow height adjustment of the SeaSoar block and enable its transfer to and from the crane.

Prior to deployment, restraining lines were fitted to the SeaSoar block and run through the vehicle wing ends. These were to assist with its control during launch. With the vehicle on deck under the gantry and the SeaSoar block hanging above it on the crane. The launch procedure was then to raise the vehicle with the SeaSoar winch, slowly swing it outboard with the crane, whilst slowly paying out on the winch. When the crane was fully extended aft, the vehicle could then be lowered into the sea and its stray lines pulled from the wings. Once in the water, the ships speed could be increased from 2 to 4 knots and the tow cable paid out to approximately 200 metres before transferring the SeaSoar block from the crane to the auxiliary arm. The gantry was then paid out, the SeaSoar block stray lines secured to cleats and the remainder of the cable paid out. After a few deployments, it became apparent that control of the vehicle using stray lines, was good enough to dispense with the use of the crane completely for launching and all further ones were done directly from the SeaSoar block. hanging via the auxiliary arm block. The recovery procedure was effectively the same as for launches but reversed. However the crane was still essential for recoveries in all but the calmest of seas, as it could position the SeaSoar block far enough aft to prevent the vehicle being washed against the stern and damaged.

When the winch was first run up on board, it was discovered that the drum had seized up. Only by continually driving it in alternate directions, did it eventually start to move - coupled with a heavy rumbling noise at the power pack end of the drum. Following lubrication of the bearings and drive gears, no further seizing was experienced. Hydraulic oil leakage was another problem. There were several in the system pipework, but the worst was from the brake unit cylinders, which appear to have corroded and damaged the seals. These will require urgent repair upon return to UK.

The vehicle was often recovered in heavy seas and gale force winds and on one occasion in winds in excess of 50 knots. Most of the damage done to the cable and fairing occurred during these operations. The conducting cable had to be reterminated 4 times, either because it had got hooked on the wing end plates (now modified), or because the vehicle had been flipped over by large waves immediately following launch. The cable was seriously damaged at the inboard end at sea level, when the CPR cable became entangled around it in rough weather during the second line. For the subsequent 22 lines, the vehicle had to be kept on a shorter tow, with the damaged section of cable remaining on the drum in order not to overload it. This shortened the usable length of the cable by 60 metres and the 4 reterminations shortened it by approximately a further 25 metres. This is on top of the cable already being supplied 40 metres short. Every recovery brought instances of damaged fairing which needed cutting off before winding on to the winch. The worst case of which was caused by a long-line running down the fairing. Further refinement of the winch spooling will reduce the amount of fairing damage and negate the need for someone to guide every length of fairing on to the spooling sheave with a broom.

(R Bonner)

The Sea Soar fish was deployed from the auxiliary arm on the aft gantry. The secondary sheave that Sea Soar was towed from, was transferred to the starboard crane during recovery to prevent it swinging about in rough seas.

(Pete Mason, Jeff Jones)

4.1.3 Equipment

The following equipment was fitted to the SeaSoar for this cruise.

Neil Brown / General Oceanics MkIIIb CTD (SOC modified)
Focal Technologies Optical Plankton Sampler (OPC)
Chelsea Instruments Aquatracka III Fluorometer.
Chelsea Instruments Photosynthetically Active Radiation (PAR) sensor.

The SOC SeaSoar winch MkII (horizontal drum, 750 metre cable capacity) was used for towing the vehicle throughout the cruise.

Cruise Preparation.

In preparation for the cruise a new 7-conductor Rochester cable was faired with a mixture of old and new fairing and wound onto the winch. The length of cable was found to be approximately 710 metres in length, some 40 metres shorter than the 750 metre capacity of the winch. The reason for this shortfall is believed to be due to the fact that an error was made when measuring out cable for our small winch, which was removed earlier from the single drum intended to supply both winches. Unfortunately this problem was only discovered late in preparation for the cruise and time was not available to replace this tow-cable

A new SeaSoar software/hardware vehicle controller system was prepared for use on a major cruise for the first time after initial tests on a trials cruise aboard RRS Charles Darwin earlier this year.

The SeaSoar vehicle and two hydraulic actuator units were prepared and tested at SOC before the cruise. A spare set of SeaSoar wings, hydraulic actuator with spares, two tail fins, an impeller and a bomb weight were supplied for the cruise.

SeaSoar Survey.

The first vehicle deployment (Run 1) was carried out with OPC, fluorometer and PAR sensor attached, on day 285. Whilst deployment was still underway, on a heading dictated by prevailing wind and sea swell direction, the water depth shallowed rapidly. Immediate action was taken by the winch driver and the bridge officer to recover the vehicle and gain deeper water. On recovery of the vehicle impact damage was seen to have torn the OPC and its mounting frame free of the vehicle, damaged the fibreglass nose of the vehicle and pushed the nose mounted fluorometer back into the main body of the vehicle. Following repair, fitting of a bomb weight, and cable retermination the vehicle was redeployed and run without the lost OPC sensor.

Persistent poor weather conditions, over 26 deployments and recoveries and damage due to fishing lines led to a gradually reduced tow depth capability during the cruise. Initially over 400 metres was achieved but by the end of the cruise a maximum of only 365 metres depth could be reached under even ideal conditions. Several wing end plates were lost due to towing cable getting caught around the wing almost always during deployment or recovery operations. These snags also bent the impeller occasionally but these knocks could be straightened back into shape. One impeller blade was snapped requiring the use of the spare unit. After an initial cable termination, one precautionary termination and two repair terminations were made during the cruise. Winch performance and deck operations are discussed fully in another section of this report.

CTD SHALL01 had been modified to a dual conductivity cell format, so that if fouling occurred on one cell data could be used from the other cell until the fouling cleared itself. Data was rarely lost due to fouling of both cells. Data quality was good throughout and the CTD required no repair or internal adjustments.

Despite a rather heavy impact during Run 1 the Chelsea Instruments Aquatracka fluorometer worked satisfactorily on each run.

The PAR sensor also performed reliably. Some noise spikes were seen in its data output but this problem was cured by replacement of its electrical lead between the sensor and the CTD.

The SeaSoar hydraulic unit 02 was used throughout the cruise and showed no traces of leakage of hydraulic oil during periodic checks. The spare unit taken was therefore not required.

Vehicle 'flight' control was carried out by a software program running on a personal computer, and a hardware interface, both developed by John Smithers. During the Leg 1 of this cruise the program was further debugged and refined. It now provides the SeaSoar operators with a versatile control, and SeaSoar performance logging system, to replace the old hardware controller and chart recorders. This system was most successful and will be used on all further SeaSoar cruises.

The vehicle and sensors performed well during the cruise. Lack of working depth was disappointing but during a cruise in excess of 7 weeks carried out in such very poor weather conditions it would be unrealistic to expect to maintain optimum performance from any faired tow cable. A total of 24 runs were carried out over both Legs of the cruise during which SeaSoar was towed for a total distance of 8960 kilometres.

(R.Kirk, J.Smithers, R.Bonner, S.Watts)

4.1.4 Data Processing and Calibration

The SeaSoar was fitted with pressure, temperature, two conductivity cells, a fluorometer, oxygen and light sensors. Standard SeaSoar processing techniques were followed. Every 4 hours, the raw data were calibrated, plotted and corrected for salinity offsets to obtain the best possible relative calibration. Absolute calibration is described in 4.1.5. The initial calibration values used are listed in Table 12. Values for pressure, temperature, oxygen and light were taken from OTD calibration sheets. However, oxygen values were too noisy to be useful. Conductivity ratios for the two conductivity cells were adjusted so that initially obtained T/S curves were a reasonably close match to calibrated CTD T/S curves. Overplotting down and up T/S curves for the master conductivity cell (paired with the platinum resistance thermometer) showed slight hysteresis, which was minimised in the usual way by adjusting the time constant used to speed up the PRT from 0.15 to 0.18 seconds. However, slight hysteresis between the calculated salinities from the two cells remained.

Differences between down and up cast values of sal1-2 were initially small (plus minus 0.003) and were ignored. However, the offset increased to 0.01 or larger once the temperature range from top to bottom of each profile increased, making correction of salin using salin2 difficult. The T/S curves for salin2 showed definite hysteresis between down and up, so it was concluded that, for unknown reason, the two conductivity cells needed to be corrected using different temperature time constants. There is no facility for this in ctdcal, so a second shalctd(2).cal file was created with a different time constant in it. Ctdcal was run a second time. and the resulting files were pjoin'ed so that only salin2 was replaced. This was done as a trial on sa223085, but not applied to the master data set. It was found that 0.25 sec for C2 brought the T/S curves together, compared to 0.15 for C1. Plots showed that the hysteresis was much reduced but noise increased of course.

The new exec was used on sa223086. Plots of sal1-2 showed that the hysteresis was reduced, but noise was large, nearly swamping any temperature dependence. Pbins was therefore used it to bin sal1-2 as a function of temperature. Fit by eye to the resulting profiles (sa223086AN attached) looked close to 0.001 per degree C. Thus an arbitrary calibration of salin2 by

salin2 (new) = salin2 (old) -0.001 * (11 - potemp)

should reduce the effect. This leaves salin2 unchanged only at potemp = 11°C. ssexec1 was modified and applied to sa223087. It did reduce the oscillation of sal1-2 considerably. It was concluded that for 4-hourly processing (a) salin should be used as the master variable; (b) if salin is fouled with a constant offset, prefer to use finctd to correct it rather than swapping in salin2; (c) if salin fouls and drifts, swap in salin2, and use the values of sal1-2 at the start and end of the fouling to finctd the swapped bit of salin2. It is suspected that the electronics of the 2-cond old shallow CTD may be the problem, as similar problems occurred on the SWINDEX cruise Di213 (with FSI sensor in slot 2) and Polarstern. The problem went away on ps1 when P. Gwilliam tidied up the CTD boards and wiring. Possibly a vibration problem. Long term solution hopefully is to convert new shallow CTDs to use two conductivity sensors.

(R.T.Pollard, E.C.Kent)

A listing of the calibration file shalctd.cal is given in Table 12.

4.1.5 Salinity Calibration

The surface SeaSoar data were compared to a series of surface water bottle samples and the differences used to calculate final corrections to the SeaSoar salinities. The bottle samples were half-hourly and hourly underway bottle salinity samples were drawn from the ship's non-toxic supply in the Hangar. The non-toxic supply is drawn through an inlet pipe in the hull approximately 5m below the water line.

The underway samples were ftp'd from ASCII text files on a Macintosh and read into the PSTAR format (pascin) and time in seconds calculated (see § 2.5.1, Thermosalinograph Temperature and Salinity Calibration). Surface SeaSoar data were obtained by appending all the 4-hourly files and using datpik to select data in the pressure range of 3-7 dbar. The bottle data were merged (pmerg2) with the SeaSoar data and the difference between the salinities was calculated (parith). Plots of salinity difference against time and against SeaSoar salinity both gave approximately straight lines with a constant offset for extended periods of time. Changes in the offsets occurred during breaks in SeaSoar runs e.g. port call, CTD section (Table 7, SeaSoar Deployments). The mean offset was calculated with phisto, with limits being set to exclude those points giving large offsets (e.g. bad sample data and steep salinity gradients). The salinity differences prior to calibration are illustrated in Fig.7 and listed in Table 8. The calibration was applied to the master run files (pcalib) and sigma0 recalculated.

(N.P.Holliday)

4.1.6 Fluorescence Calibration to Chlorophyll

Continuous in situ fluorescence measurements in the top 400 m of the water column were recorded during RRS Discovery's Vivaldi 96 survey with a Chelsea Instruments Aquatracka III fluorometer mounted in the towed undulating fish Sea Soar. Chlorophyll a concentrations were inferred from these measurements by application of a modified version of the supporting point calibration method developed by V.H.Strass at the University of Kiel.

The supporting point calibration method is based on the surface chl a concentrations derived from underway TSG fluorescence data and so, ultimately, determined from bottle samples taken hourly from the ship's non-toxic intake. The calibrated TSG chl a (1 min) files were firstly regridded in 10 min bins (pavrge) and merged (pmerg2) on time with the gridded near-surface (6-14 m) Sea Soar fluorescence record (c.f. non-toxic intake at 5 m depth). The mismatch between the TSG and Sea Soar depths was regarded as unimportant, given the deep well-mixed layers that characterised the area surveyed during Vivaldi 96. A series of calibration points was obtained in this way.

Fluorescence yield, the ratio of fluorescence to chl a concentration was then calculated for each of the calibration points and later plotted versus (uncalibrated) light intensity. It is a well-established fact that the relationship between fluorescence yield and light intensity is that of a negative correlation, due to the photosynthesising apparatus of phytoplankton adapting to higher light levels by modifying its photoadaptive state. Besides this light quenching effect, other factors contribute to the high variability of the fluorescence yield: species composition, nutrient supply and physiological state of phytoplankton are known to heavily condition yield.

The supporting point method aims to account for these two types of contribution. Light quenching is removed by fitting a curve to the cloud of points in the fluorescence yield vs. light intensity plot, whereas species and other miscellaneous influences are brought into the calibration by shifting the curve vertically along the yield axis to a level determined by the local supporting calibration point. The assumptions are made that the variation of fluorescence yield with light follows, to a good approximation, the same curve for all the species present in the area (this seems to be confirmed by the reduced differences in scatter in the cloud of calibration points over the range of light intensities present), and that the curve level determined locally at the surface can be extrapolated to the whole water column (calibration of CTD fluorescence validates this hypothesis).

However, it should be noted that the reference yield time series used for calibration is not the simple ratio of fluorescence to chlorophyll a concentration calculated above, but a smoothed version of it. In the spatial scales at which underway sampling is performed, phytoplankton shows, in addition to broader trends, a fine natural patchiness which gets picked up by the yield. Considering that the horizontal spatial resolution of Sea Soar falls nearer the mesoscale range, this scattered small-scale information is, in practice, contamination, and has to be smoothed out. By using the central section of the yield's autocorrelation function (as calculated by a modified version of pcorr) as a filter (pfiltr), the desired smoothing can be accomplished, preserving yield variations at any scales larger than the fine phytoplankton patchiness but rejecting the latter.

Matlab facilities were used to find the best fit for the yield / light relationship. This turned out to be a function of the form

$$\text{thyld} = [\, k * \coth(a * \text{light} + b) + k_1 * \text{light}\,] * \text{weight} \quad (1)$$

where

$$\text{weight} = 0.89 - \text{atan}\,[\,(\text{light} + 28)/2 - 21\,]/z,$$

thyld stands for theoretical yield, and k, a, b, k_1, and z are variable fitting parameters.

In order to apply this function to the PSTAR SeaSoar gridded files, the PSTAR program flucal2 was written. The working routine of the programs consists, firstly, on calculating the local curve offset z3:

$$\text{z3(ref)} = \text{yield(ref)} - \text{thyld(ref)}$$

where yield(ref) is the yield at the local supporting calibration point and thyld(ref) is the theoretical yield at the same point as derived from (1). z3 is consequently extrapolated vertically. (Note that variables at the supporting points are labelled '14' in the output from flucal e.g. the light intensity at the supporting points is named 'light14'. The other new variables are referred to as in the equations above).

Once z3 is defined throughout the file, the yield can be derived at every single point n in the data set:

yield(n) = thyld(n) + z3(n)

And the chl a concentration is trivially calculated as

chl(n) = fluor(n) / yield(n)

Table 9 shows the values for the fitting parameters over the Sea Soar survey: These values were chosen after successive trials, and no exact mathematical routine was used. The error involved in this calibration is thought to be better than 10%. Obviously, the differences with TSG (and hence bottle) surface chl a concentrations are minimal, since the method forces the Sea Soar chl a to be very similar to the corresponding TSG chl a used for reference. A better way of estimating the uncertainty in SeaSoar chlorophylls is by comparison with CTD profiles between runs. A brief examination of these revealed errors of the order of the one quoted above. This figure is in agreement with the estimation in Strass' original calibration.

Archiving

The Sea Soar fluorescence was calibrated in sections consisting of five runs.

Runs 1 to 5 were saved in a file called ss223.chl.1-5 and archived as ss223r01.MJ .
Runs 6 to 10 were saved in ss223.chl.6-10 and archived as ss223r06.BG .
Runs 11 to 15 were saved in ss223.chl.11-15 and archived as ss223r11.BU .
Runs 16 to 20 were saved in ss223.chl.16-20 and archived as ss223r16.BV .

No calibration of the last four runs was produced on the cruise due to lack of time

References

Strass, V.H., 1989 On the calibration of large-scale fluorometric chlorophyll measurements from towed undulating vehicles. Deep Sea Research, 37, No. 3, 525-540.

(A.C.Naveira Garabato)

4.2 Optical Plankton Counter (OPC)

The OPC was lost on the first deployment of the SeaSoar on 11th October.

4.3 Continuous Plankton Recorder (CPR)

4.3.1 Deployment

Initially the CPR was deployed aft but on 13.10.96 the towing cable became entangled with the SeaSoar towing cable endangering it. Thereafter the CPR was towed from the port aft boom, which had been connected up to the auxiliary winch controls on the aft gantry. The CPR was deployed and recovered with the port crane and transferred to a cable from the auxiliary deck winch for towing. This proved to be successful and enabled safe deployment and recovery possible under the severe sea conditions experienced.

(P.Mason, J.Jones)

4.3.2 Sampling

SAHFOS supplied 1 CPR fish and 3 loaded inner mechanisms for surface plankton sampling during Vivaldi 1996. A further 6 graduated sample silks and cover silks were provided to be loaded at sea. These were standard 270 5m silks which are capable of each filtering for 500 nautical miles, with each graduation representing about 3m-3 of water. 40% formaldehyde, buffered with borax, was soaked into the cotton wool in the storage tank, to keep the samples preserved when they are in the CPR. The CPR was also fitted with a logging electromagnetic flow-meter designed not to impede flow through the recorder.

After initial bad experience the CPR was deployed from a boom at the port quarter of RRS Discovery so that it was within 5 m of the stern and about 2 to 3 m below the surface. This short length of cable reduced the chance of entanglement with the SeaSoar in rough weather. However, the spatial resolution of the CPR is not good enough for this to matter when comparing the zooplankton to the SeaSoar data. It was towed simultaneously with the SeaSoar with only one leg being missed on purpose to conserve silk to enable sampling onto the shelf at the end of the cruise. While on station the CPR was recovered and the inner mechanism checked and topped up with 40% formaldehyde, and the silk was wound on one graduation to separate each run's samples.

The CPR was intended to be used to calibrate OPC data, because of its long term data sets (since 1931) and the large amount of data it has produced (it has been towed for more than 4 million miles). Its data could be used, in the same way as underway data for chlorophyll, to calibrate OPC data while at the surface. However, it is still a useful biosurvey tool in its own right and its data is instructive.

The sample reels were removed from the mechanism and stored wrapped in lint in a 4% formalin atmosphere for analysis after the cruise.

A major problem of the silk snagging and ripping occurred on three runs, affecting two silks, (5.1, 5.2 and 6.1). Therefore data was lost entirely on runs 5.2 and 6.1, but only partly on run 5.1. This was a result of inexperienced loading of the complex inside mechanism. The logging system also came loose three times during silks 5, 6 and 9; but was secured with modification to the mounting.

A list of CPR deployments is given in Table 16.

Reference
Draft (1996) SAHFOS Operations Manual for Continuous Plankton Recorder.

(A.T.Mustard)

4.5 Underway Nutrients

4.5.1 Samples

In addition to the underway nutrient analyser, discrete surface nutrient samples were collected from the non-toxic seawater outlet of the thermosalinograph mounted in the hangar deck. Samples were collected at the same time as salinity and chlorophyll samples and analysed on the discrete nutrient analyser. Duplicate samples were collected at one hourly intervals (on the half hour) whilst the ship was underway . One duplicate sample was stored in the refrigerator and analysed within twenty four hours of collection and the other duplicate was stored in the cold room (at 5°C) in case the other sample spoiled. If this was not the case then the duplicate sample was discarded at a later time. 2032 underway samples were analysed over the course of the two Legs. The results from these analyses showed that initially surface nutrient concentrations were reduced. These values gradually increased throughout the course of the cruise.

4.5.2 Ultraviolet Measurements

A UV nitrate sensor similar to that used on the CTD-rig was mounted in the hangar deck and supplied with water from the non-toxic seawater supply. Measurements were made at a frequency of 0.5 Hz for the entire period of the cruise. The data was logged to the ship's level A. Nitrate concentrations derived from the analysis of the hourly discrete samples will be used to calibrate the underway data. The data from the nitrate sensor was imported into PSTAR and will be time averaged over 10 minutes and corrected for changes in salinity to produce a continuous record of surface nitrate concentrations measured over the course of the cruise.

(M.S.Finch)

4.6 Sample Chlorophyll

The chlorophyll samples from the non-toxic supply were analysed together with the samples from the bottles on the rosette sampler (see § 3.9)

5. FLOATS

Seven profiling ALACE floats, purchased from Webb Corp., were deployed in the Irminger Sea during the cruise. Deployment positions were chosen with reference to the axis of the basin, which runs roughly SW-NE, with a view to examining the (cyclonic?) circulation around the basin. Accordingly, 3 were deployed on 60°N in the western half and 4 on the old IGY line SE from Cape Farewell, in the eastern half.

Preparation, wake-up and deployment were essentially trouble-free and performed in accordance with the instructions in the "Owner's Handbook" provided by Webb Corp. with the floats. Deployment of the first four floats (see Table 10) was over the stern, on station after completion of other overside activities, with the rail down. Worsening weather made this seem rather unsafe; also, two of the TD floats had to be put over on the fly, so the remainder were deployed from the lee (starboard) quarter.

One item of damage occurred. The final float's aerial was bent about three inches from the end after a violent roll caused the float to slide off its preparation mount in the deck lab and hit the lab wall. The aerial was strengthened with a length of self-sealing shrink wrap.

(S.Bacon)

6. CRUISE LOGISTICS

Mobilisation

Mobilisation for the cruise took place in Falmouth, Cornwall and was scheduled to commence on Tuesday September 25th at 1200. However, to make cost effective use of the equipment transport, it was decided to use the same trailers that took equipment to Falmouth, to be used for the return of the previous cruise equipment to SOC. This necessitated all Di223 equipment with the exception of that in the boxvan, to be loaded on trailers by Friday 20th September at SOC, to meet the vessel on arrival at 0900 on Tuesday 24th.

The trailers were delivered to SOC on Thursday 19th and all loose non-delicate boxed items were loaded in 20' and 10' containers. The first trailer carried 2 x 20' containers, one with this cruise equipment and one empty Dutch-owned unit, for shipping equipment from the previous cruise back to Holland. The second trailer carried the 10' container plus all large deck mounted items, including the SeaSoar winch, CTD rosette frame, CTD deck track and the SeaSoar vehicle. Whilst the boxvan carried loose delicate items.

The trailers and boxvan were all at Falmouth docks to meet the vessel at 0900 and the first job was to offload the trailer loads on to the quay to enable backloading of the previous cruise equipment. Items in the boxvan were loaded directly on to the ship. Backloading of the trailers continued all day and into the next morning, until they were fully loaded and ready to depart. Loading of the vessel commenced before lunchtime and the initial requirement was to get the 20' container unloaded in order that the CFC equipment could be set up and purged with gas. delivery of the gas and liquid Nitrogen had taken place as arranged for that morning and once the CFC team had fitted extended bench tops in the Chemistry lab, the equipment could be installed. With the container unloaded and stowed in one of the container slots, the remaining priority was to load the deck mounted equipment. The SeaSoar winch and 2 RVS winches for the SeaSoar block and towing the CPR were fitted on the aft deck and the CTD track and CTD Rosette frame were fitted along the starboard deck, below the gantry. That morning the Met team had also arrived and commenced installation of the JRD met instruments and CFD instrumentation. On Thursday, with all equipment on board, the RVS divers were able to carry out the installation of the newly delivered ACCP, whilst setting up of equipment in the labs continued apace. By Friday evening everything was deemed as ready for sea and the vessel sailed on time on Saturday morning.

(R Bonner)

7. CRUISE DIARY

Table 17 gives the conversion of dates to days of the year for the period of the cruise.

Th 26.09.96
1000 Begin logging GPS data in port

Fr 27.09.96
1005 DGPS activated for tests in port

Sa 28.09.96
0800 Depart Falmouth
2208 ADCP logging ceased for unknown reason.

Su 29.09.96
1200 Two casts in the Irish Sea to test CTD, LADCP and collect water to calibrate CFC equipment.

Mo 30.09.96
0154 Lack of ADCP logging discovered. Recovered from PC hard disc.
0631-0910 Zigzag runs to calibrate ADCP.
a.m. Water found to have leaked into better of two salinometers.
1210 Start Rockall Trough Hydrographic Section at Barra Head.
2230 Wire test

Tu 01.10.96
2000 Problem with oil pressure sensor on winch
2200 Short circuit in conducting core cable.

Th 03.10.96
0045 Complete Rockall Trough Section at Rockall Island. Start hydrographic section to Lousy Bank.
0800 Loss of power to computers due to short in vacuum pump.
1400 Hove to due to swell causing excess loading on conducting core cable.

Fr 04.10.96
2345 Resume Rockall-Lousy Bank hydrographic section with station RL04/12960.

Su 06.10.96
0226 At station RL13/12969 end Rockall-Lousy Bank Section.
0400 Start Iceland Basin Section at station IB01/12970.
0453 At end of station IB01/12970 the conductivity cell was damaged by a Niskin bottle being shaken off its mounting and had to be replaced.
0710 Station IB02/12971 problem with CTD altimeter.
1140 Station IB04/12973 aborted due to heavy swell.
1415 After removal of old, large transmissometer, nitrate sensor and 5 Niskin bottles station IB04/12974 successfully attempted. Altimeter works again. Apparently bad nitrate sensor signal was affecting fluorometer and altimeter.

2015 After Station IB05/12975 station work was suspended by the Captain due to adverse weather conditions (Bft 8-9).

Mo 07.10.96
Hove to due to high winds (WSW 8) and heavy swell (~10m), though sunny.
It became apparent that the ancillary channels in the Level A/B/C logging of the data from the CTD package had been jumbled since the beginning of the cruise necessitating reprocessing of the CTD data and reappraisal of the apparently erroneous functioning of the in-situ nitrate sensor.
1900 Set course for Station IB06.

Tu 08.10.96
Still hove to. Wind WSW 9-10.

We 09.10.96
Still hove to.
2200 Attempt to start Station IB06/12977 but winch blew a fuse and cable needed reterminating.

Th 10.10.96
0100 Start Station IB06/12977. Hydrographic Section Lousy Bank-Iceland resumed, but only even stations.
1445 One of two Electron Capture Detectors on CFC equipment reported contaminated. Spare ordered for Reykjavik.

Fr 11.10.96
0830 End Station IB19/12983: End of Iceland Basin Section. Plankton net to 500m.
1335 SeaSoar deployed.
1745 SeaSoar recovered without optical plankton counter.
2340 SeaSoar redeployed.

Sa 12.10.96
1650 SeaSoar recovered to reterminate towing cable.
2010 SeaSoar redeployed.

Su 13.10.96
0400-0600 SeaSoar recovered with difficulty due to entanglement of towing cable with CPR towing cable. Since then hove to due to bad weather (ENE Force 10).

Mo 14.10.96
1605 Start hydrographic station near Z60/12984.
1910 Deploy SeaSoar.

Tu 15.10.96
1500 Deploy CPR from port airgun boom.
1800 Alter course to west at Z57 without stopping for a station.

We 16.10.96

0500 Recover SeaSoar and CPR. Lot of fairing damage, probably long line. Plenty fishing boats seen yesterday. Port crane u/s so CPR recovered using handy billy. Station YZ57/12985 at 57°N, 22° 40'W.

1045 SeaSoar tailfin/radiometer support damaged in attempted deployment when steadying line tangled.

1255 SeaSoar deployed.

1315 CPR deployed. Course 335° towards Y60.

Th 17.10.96

1300 Change course at Y60 to 305°, but no station.

1630 Recover CPR and SeaSoar for Station Y60A/12986: CTD and net

1950 Redeploy CPR and SeaSoar. Start following Topex/Poseidon track.

Fr 18.10.96

ca. 0300 Cross Reykjanes Ridge into Irminger Basin.

1330 Recover CPR and SeaSoar for deep CTD cast and net at Station X615/12987

1635 CPR and SeaSoar redeployed. Continue course NW towards centre of Irminger Basin.

Sa 19.10.96

0200 Recover CPR and SeaSoar for Station X63A/12988

0600 Redeploy SeaSoar but not CPR and tow off ENE towards Station Y63A.

Su 20.10.96

0230 SeaSoar recovered for Station Y63A/12989.
Steam back 25 miles for Station Y63B.

0955 Station Y63B/12990 completed. Only sampling for physics.
Set course for Reykjavik testing ADCP and ACCP on the way.

Mo 21.10.96

0800 Docked Reykjavik

Tu 22.10.96

0915 Sailed when safety briefing ended. Dogleg to first CTD station to avoid shallowest part of Reykjanes Ridge

2348 CTD 12991 at shelf edge, Y63.

We 23.10.96

0138 Begin SeaSoar Run 6

1300 Briefed crew.

Th 24.10.96

0143 CTD 12992 at Y60

0419 SeaSoar deployed but rope through wing handle knotted, took turns round bomb weight and tore it loose. Needed to bring into hangar to get at it. metal bracket bent. Metal cover needed cutting. Screw holes redrilled.

0553 Redeployed for SeaSoar Run 7

Fr 25.10.96
0312 Strong winds forced recovery of SeaSoar and CPR
0438 Hove to
1000 Return to SeaSoar break off point and try steaming along track.
1230 Redeploy to continue Run 7. Done by 1300. Only making 7 kn max but SeaSoar flying OK. Gradually improved as sea went down.
2100 Recover.
2156 CTD 12993 at 'X57.6'.
2200 Found that nontoxic supply to thermosalinograph and underway nutrient sensor had somehow been turned off. Also found thermosalinograph sensors had been inversely connected throughout cruise.

Sa 26.10.96
0030 Begin SeaSoar Run 8 on course 313° Deployment of CPR much eased by hydraulic ram connected to boom on port quarter.
1400 Recover SeaSoar for CTD on west side of Reykjanes Ridge.
1520 CTD 12994
1757 Redeploy SeaSoar to continue Run8.

Su 27.10.96
0657 Recovered SeaSoar in good conditions.
0824 CTD 12995 at W60, the first of 7 CTDs worked westward to Greenland shelf edge.
1117 First of 7 P-ALACE floats deployed.

Mo 28.10.96
0649 Begin 5th of CTDs, 12999. Found Level A not plugged in. Cast restarted at 0743.
0922 Begin run west across Greenland Shelf to examine current on the shelf.
1400 Alter course 090° for reverse run.
1535 Begin CTD 13000, westernmost of line.
1809 Begin last CTD 13001.
1953 Deploy SeaSoar for Run 9 south then southeast along Topex/Poseidon track.

Tu 29.10.96
0600 Alter course 130°
1546 CTD 13002 after recovering SeaSoar
1904 Begin SeaSoar Run 10 continuing SE towards W54 along T/P track.

We 30.10.96
1300 Cancelled CTD due in an hour just west of R Ridge because (1) weather marginal, risk of damaging gear to no great purpose, (2) CFC kit poor, needs long bakeout, (3) CTD cable leakage found, needs retermination, (4) if we run on, we may get to the other side of the weather front by tomorrow with better conditions, (5) and major scientific reason is that *Knorr* will occupy a section close to this one within a week, at much closer station spacing than we can achieve.

Th 31.10.96
0000 All clocks went berserk. Usual leap sec problem?
1015 Recovered SS at W54. Several minor problems.
1148 CTD 13003

1430 Last ALACE float deployed.
1504 Begin SeaSoar Run 11

Fr 01.11.96
1030 CTD 13004 at X54 after SeaSoar recovery.
1422 Begin SeaSoar Run 12.

Sa 02.11.96
1115 CTD 13005 at Y54 after SeaSoar recovery. After the cast, the wire was found to have a major kink in it a metre or two above the CTD. Not clear when it happened. Reterminated. Wind strengthened rapidly from 7 to 15 m/s in 3 h so
1440 SeaSoar deployed for Run 13 without repositioning ship.

Su 03.11.96
0958 CTD 13006 at Z54.
1430 SeaSoar deployed for Run 14 east across southern entrance to Rockall Trough.

Mo 04.11.96
0948 Turned southeast (140°) towards Irish Shelf parallel to intended Topex/Poseidon return track. Rolling unpleasantly from swell from westerly winds. No letup to weather from lows to north and west of us.
1729 Alter course to south.
1918 Ended turn to 320°, the Topex/Poseidon line. This had to be done rapidly to avoid rolling and anticlockwise to keep the CTD on the lee side. The SeaSoar was held near the surface during the turn. However, vehicle refused to respond shortly after profiling was recommenced. Recovered in poor conditions, and found badly bent wing plate, so wire must have wrapped round it. Hove to overnight.

Tu 05.11.96
0736 Wind had dropped a lot and swell organised, so returned to CTD position at east side to Rockall Trough.
0845 CTD 13007.
1122 Not ready to deploy SeaSoar. Wing end plates being reprofiled so less likely to foul. Then found data needed by new SeaSoar control program had been deleted during backup operations.
1249 SeaSoar deployed for Run 15 across Rockall Trough following satellite track.
1600 Conditions untenable, rolling serious. Primary phosphate standard broke in the refrigerator. SeaSoar recovered OK though pitching flooded afterdeck several times.
1658 Hove to.

We 06.11.96
0000 Still hove to.
1939 Conditions eased enough to redeploy SeaSoar (Run 15 continued) and run a dogleg course, initially 280°, to the CTD position on the west side of Rockall Trough. CPR cable kinked during deployment. Reterminated.

Th 07.11.96
0220 Alter course to 040°.
0834 Recover SeaSoar at end of Run 15

0944 CTD 13008 on west side of Rockall Trough.
1156 SeaSoar redeployed for Run 16 northwest (316°) across the southwest flanks of Rockall and Hatton Banks towards Z57.

Fr 08.11.96
1205 Recovered SeaSoar.
1310 CTD 13009 then 2 plankton nets, to 500m and 200m to look at daytime depth distribution.
1606 Ran east (081°) without SeaSoar to do a second CTD at 20°W.
1947 CTD 13010 on 1000m contour on western flank of Hatton Bank.
2102 SeaSoar deployed for Run 17 westward along 57°N.

Sa 09.11.96
1708 CTD 13011 at Y57. Excellent weather but forecast to break so did not spend time repositioning ship before and after CTD.
1955 SeaSoar deployed for Run 18.

Su 10.11.96
0000 Working west all day but slowed by strong winds and developing swell.
1832 Passed position for next CTD but deferred it because conditions too bad. Speed reduced to 5-7 knots so SeaSoar reaching 350m but not surface. Needed a northwest course to complete large circuit via Greenland, but wind 310°, so courses 280° and 330° either side of the wind preferred to gain a little speed. Speed 4-6 knots.

Mo 11.11.96
0649 Wind easing as we reached turning point. Shortened SeaSoar cable to allow quick turn.
0721 Steady on course 134°. Paid out cable to full length again. Passage a great deal more pleasant with wind and swell behind and reducing.
1421 Recover SeaSoar. Found kinks in wire right at cowtail and 1m up, also bridle bent sideways. Reterminated. Light channel lead replaced also as channel was becoming noisy.
1614 CTD 13012 at Z57 after some delay. The multisampler was noisy and fired a bottle randomly while on deck. Connector remade.
1826 CTD and net finished. Hove to awaiting completion of SeaSoar repairs.
2034 SeaSoar deployed for Run 19 southeast along a Topex/Poseidon track, due to continue for some days.

Tu 12.11.96
1200 CTD 13013. Some noise noted on the cast, so cable reduced by 50 m and reterminated after it.
1557 SeaSoar deployed for Run 20, but not CPR, as running out of silks.

We 13.11.96
Long run through Y54. Ashtech locked at 0713, took until 0815 to fix, had to start it from scratch, so lost all settings. Around midnight reset to Brian King's defaults. Double net on today's cast.

Th 14.11.96
SS deployed after double net then CTD. About an hour before remembered to plug in the level A so no data until 1640 or so.

Fr 15.11.96
0744 Station 13107.
1039 Start SS Run 23

Sa 16.11.96
0805 Station 13018.
1157 Start SS Run 24

Su 17.11.96
0401 End SS Run 24.
0545 Station 13019.

Mo 18.11.96
Evening Docked in Southampton.

8. ACKNOWLEDGEMENTS

The principal scientists would like to thank the Master, officers, crew and scientists of the RRS *Discovery* for making this such an enjoyable, as well as successful cruise.

TABLES

FIGURES

Station Number	Station Name	Date	Day of Year	Time Start	Down	End	Lat (N)	Lat (N)	Lon (W)	Lon (W)	Water Depth (m)	Max Press (dbar)	O18	CFCs	HPLC filter
LEG 1															
Irish Sea															
12931	-	29.Sep.96	273	12.26	12.42	12.50	54.2794	54 16.76	5.1033	5 06.20	126	124	-		-
12932	-	29.Sep.96	273	13.15	13.26	13.42	54.2819	54 16.91	5.1123	5 06.74	124	123	-		-
Barra Head to Rockall															
12933	13G	30.Sep.96	274	12.26	12.33	12.49	56.7842	56 47.05	8.0067	8 00.40	116	113	Y	Y	Y
12934	T	30.Sep.96	274	14.10	14.27	14.44	56.8368	56 50.21	8.3376	8 20.26	130	125	-	-	-
12935	15G	30.Sep.96	274	15.33	15.46	16.01	56.8840	56 53.04	8.5036	8 30.22	126	124	-	-	-
12936	S	30.Sep.96	274	17.14	17.24	17.39	56.9528	56 57.17	8.7820	8 46.92	123	120	-	Y	-
12937	R	30.Sep.96	274	18.33	18.47	19.03	57.0007	57 00.04	8.9962	8 59.77	131	128	Y	-	-
12938	Q	30.Sep.96	274	19.57	20.21	20.44	57.0538	57 03.23	9.2126	9 12.76	306	287	Y	Y	Y
12939	-	30.Sep.96	274	21.43	Cast aborted due to bad weather								-	-	-
12940	P	01.Oct.96	275	01.02	02.08	03.14	57.1230	57 07.38	9.4439	9 26.63	1498	1489	Y	-	-
12941	O	01.Oct.96	275	04.24	05.30	06.34	57.1406	57 08.44	9.6888	9 41.33	1934	1928	Y	Y	-
12942	N	01.Oct.96	275	08.13	09.25	10.34	57.2269	57 13.61	10.0740	10 04.42	2126	2120	-	-	-
12943	M	01.Oct.96	275	11.41	12.55	14.00	57.3066	57 18.40	10.3733	10 22.40	2215	2215	Y	Y	-
12944	L	01.Oct.96	275	15.12	16.11	17.05	57.3593	57 21.56	10.6542	10 39.25	2200	2200	-	Y	-
12945	K	01.Oct.96	275	18.01	18.36	19.06	57.3958	57 23.75	10.8631	10 51.78	804	794	Y	Y	-
12946	J	02.Oct.96	276	01.21	02.01	02.32	57.4497	57 26.98	11.1001	11 06.01	580	571	-	Y	-
12947	I	02.Oct.96	276	03.23	04.07	04.36	57.4737	57 28.42	11.3151	11 18.91	750	734	Y	Y	-
12948	H	02.Oct.96	276	05.33	06.35	07.27	57.4913	57 29.48	11.5176	11 31.06	2022	2018	Y	Y	Y
12949	G	02.Oct.96	276	08.43	09.32	10.20	57.4928	57 29.57	11.8233	11 49.40	1797	1795	-	Y	-
12950	F	02.Oct.96	276	11.56	12.58	13.50	57.5194	57 31.16	12.2497	12 14.98	1811	1805	Y	Y	-
12951	E	02.Oct.96	276	15.52	16.37	17.28	57.5302	57 31.81	12.6152	12 39.91	1671	1664	Y	Y	-
12952	D	02.Oct.96	276	18.36	19.18	19.49	57.5411	57 32.47	12.8677	12 52.06	1062	1088	Y	Y	-
12953	C	02.Oct.96	276	20.47	21.06	21.20	57.5493	57 32.96	13.0096	13 00.58	298	285	Y	Y	Y
12954	B	02.Oct.96	276	22.42	22.58	23.11	57.5682	57 34.09	13.3370	13 20.22	188	172	Y	Y	-
12955	A	03.Oct.96	277	00.17	00.35	00.44	57.5680	57 34.08	13.6364	13 38.18	132	120	-	-	-
Rockall to Lousy Bank															
12956	RL01	03.Oct.96	277	03.20	03.35	03.44	57.9679	57 58.07	13.7503	13 45.02	211	197	-	-	-
12957	RL02	03.Oct.96	277	05.44	05.59	06.16	58.2019	58 12.11	13.7582	13 45.49	274	262	-	-	-
12958	RL03	03.Oct.96	277	08.14	09.13	09.48	58.3789	58 22.73	13.7849	13 47.09	1078	1074	Y	Y	Y

Table 1

Station Number	Station Name	Date	Day of Year	Time Start	Down	End	Lat (N)	Lat (N)	Lon (W)	Lon (W)	Water Depth	Max Press	O18	CFCs	HPLC filter
12959	-	03.Oct.96	277	13.39	Cast aborted due to bad weather								-	-	-
12960	RL04	04.Oct.96	278	23.42	00.20	01.06	58.5728	58 34.37	13.8121	13 48.73	1294	1287	Y	Y	-
12961	RL05	05.Oct.96	279	03.23	04.05	04.42	58.7249	58 43.49	13.8260	13 49.56	861	847	Y	Y	-
12962	RL06	05.Oct.96	279	07.08	07.30	07.51	58.9262	58 55.57	13.8448	13 50.69	473	458	-	-	-
12963	RL07	05.Oct.96	279	10.05	10.49	11.19	59.2144	59 12.86	13.6654	13 39.92	1063	1056	Y	Y	Y
12964	RL08	05.Oct.96	279	12.40	13.40	14.18	59.4123	59 24.74	13.5024	13 30.14	1230	1218	Y	Y	-
12965	RL09	05.Oct.96	279	15.22	16.19	17.09	59.5860	59 35.16	13.3886	13 23.32	1268	1262	Y	Y	Y
12966	RL10	05.Oct.96	279	18.17	18.53	19.28	59.7547	59 45.28	13.2362	13 14.17	1163	1158	-	-	-
12967	RL11	05.Oct.96	279	20.37	21.05	21.41	59.9163	59 54.98	13.1306	13 07.84	981	971	Y	Y	Y
12968	RL12	05.Oct.96	279	23.02	23.24	23.53	60.1003	60 06.02	12.9464	12 56.78	710	699	Y	Y	-
12969	RL13	06.Oct.96	280	01.33	01.58	02.21	60.2827	60 16.96	12.8552	12 51.31	404	398	-	-	-
Lousy Bank to Iceland															
12970	IB01	06.Oct.96	280	04.10	04.31	04.53	60.4823	60 28.94	12.7019	12 42.11	408	402	-	-	-
12971	IB02	06.Oct.96	280	06.47	07.24	07.48	60.5598	60 33.59	12.8805	12 52.83	596	578	Y	-	-
12972	IB03	06.Oct.96	280	08.47	09.26	10.11	60.6503	60 39.02	13.0512	13 03.07	1043	1041	Y	Y	Y
12973	-	06.Oct.96	280	11.07	Cast aborted due to bad weather								-	-	-
12974	IB04	06.Oct.96	280	14.10	14.56	15.41	60.7396	60 44.38	13.2145	13 12.87	1445	1443	Y	Y	-
12975	IB05	06.Oct.96	280	17.17	18.14	19.02	60.8464	60 50.74	13.4220	13 25.32	1665	1663	Y	Y	Y
12976	IB06	10.Oct.96	284	00.55	01.56	02.49	60.9055	60 54.33	13.5822	13 34.93	1655	1654	Y	Y	Y
12977	IB08	10.Oct.96	284	07.19	08.24	09.16	61.3879	61 23.28	14.5806	14 34.83	2103	2103	Y	Y	Y
12978	IB10	10.Oct.96	284	13.35	14.37	15.38	61.8193	61 49.16	15.5901	15 35.41	2304	2301	Y	Y	-
12979	IB12	10.Oct.96	284	19.08	20.03	21.00	62.2976	62 17.85	16.3089	16 18.54	2139	2138	Y	Y	Y
12980	IB14	11.Oct.96	285	23.54	00.36	01.24	62.6814	62 40.89	16.8020	16 48.12	1837	1829	Y	Y	Y
12981	IB16	11.Oct.96	285	03.03	03.39	04.22	62.9023	62 54.14	17.0155	17 00.93	1535	1533	Y	Y	-
12982	IB18	11.Oct.96	285	05.56	06.22	06.50	63.1060	63 06.36	17.2507	17 15.04	1179	1169	Y	Y	-
12983	IB19	11.Oct.96	285	07.44	08.04	08.32	63.1995	63 11.97	17.3641	17 21.84	678	696	Y	Y	-
SeaSoar Grid															
12984	Z60	14.Oct.96	288	16.04	17.01	18.05	60.1737	60 10.42	19.8432	19 50.59	2681	2680	Y	Y	Y
12985	YZ57	16.Oct.96	290	07.18	08.35	09.49	56.9991	56 59.94	22.6636	22 39.82	3056	3064	Y	Y	Y
12986	Y60A	17.Oct.96	291	17.27	18.12	19.06	60.2871	60 17.22	26.2301	26 13.81	2155	2157	Y	Y	Y
12987	X615	18.Oct.96	292	14.00	14.41	15.33	61.6362	61 38.17	29.9993	29 59.96	2154	2162	Y	Y	Y
12988	X63	19.Oct.96	293	02.49	03.56	04.55	62.2829	62 16.98	32.2177	32 13.06	2708	2709	Y	Y	Y
12989	Y63A	20.Oct.96	294	03.37	04.09	04.42	63.3842	63 23.05	26.3813	26 22.88	1027	1021	Y	Y	Y

Station Number	Station Name	Date	Day of Year	Time Start	Down	End	Lat (N)	Lat (N)	Lon (W)	Lon (W)	Water Depth	Max Press	O18	CFCs	HPLC filter
12990	Y63	20:Oct:96	294	08.47	09.25	10.14	63.2141	63 12.85	27.2847	27 17.08	1269	1268	Y	-	-
Leg 2															
SeaSoar Grid															
12991		22.Oct.96	296	23:45	00.17	00.49	63.0004	63 0.02	23.3884	23 23.30	1017	1015	Y	Y	Y
12992	Y60A	24.Oct.96	298	01.40	02.33	03.42	60.0009	60 0.05	25.4313	25 25.88	2282	2285	Y	Y	Y
12993		25.Oct.96	299	21.47	22.44	23.40	57.6372	57 38.23	31.1634	31 09.81	2245	2115	Y	Y	Y
12994		26.Oct.96	300	15.11	16.06	17.18	58.8747	58 52.48	33.7911	33 47.46	2447	2488	Y	Y	Y
12995	G1	27.Oct.96	301	08.25	09.22	10.45	59.9964	59 59.78	36.5824	36 34.95	3085	3082	Y	Y	Y
12996	G2	27.Oct.96	301	15.50	16.46	18.04	59.9957	59 59.74	38.3655	38 21.93	2983	2997	-	Y	-
12997	G3	27.Oct.96	301	20.57	21.47	22.53	60.0039	60 00.23	39.4252	39 25.51	2682	2696	-	Y	-
12998	G4	28.Oct.96	302	02.22	03.14	04.15	59.9926	59 59.56	40.5099	40 30.60	2284	2289	Y	Y	-
12999	G5	28.Oct.96	302	07.40	08.18	09.12	59.9838	59 59.03	41.3246	41 19.48	1957	1957	-	Y	-
13000	G7	28.Oct.96	302	15.34	16.00	16.32	59.9985	59 59.91	42.0853	42 05.12	768	770	-	Y	Y
13001	G6	28.Oct.96	302	18.04	18.49	19.38	59.9881	59 59.29	41.7762	41 46.58	1850	1836	-	Y	-
13002		29.Oct.96	303	15.43	16.49	18.03	58.0337	58 02.03	40.4398	40 26.39	3192	3210	-	Y	Y
13003	W54	31.Oct.96	305	11.41	12.38	13.52	54.0864	54 5.19	33.4114	33 24.69	2523	2527	-	Y	Y
13004		01.Nov.96	306	10.18	11.30	13.08	53.9860	53 59.16	29.1799	29 10.79	3070	3084	Y	-	Y
13005	Y54	02.Nov.96	307	11.09	12.22	14.13	53.9983	53 59.9	24.5784	24 34.71	3367	3385	Y	Y	Y
13006	Z54	03.Nov.96	308	11.16	12.19	13.55	53.9943	53 59.66	20.3348	20 20.09	2651	2658	-	Y	-
13007	A53	05.Nov.96	310	08.41	09.43	10.56	53.2210	53 13.26	15.1453	15 8.72	2598	2612	Y	Y	Y
13008		07.Nov.96	312	09.43	10.24	11.21	54.5795	54 34.77	17.2051	17 12.3	1986	2015	-	Y	Y
13009	Z57	08.Nov.96	313	13.12	13.54	14.45	56.9103	56 54.62	21.2004	21 12.02	1941	1943	-	Y	Y
13010		08.Nov.96	313	19.47	20.07	20.32	57.0014	57 0.09	19.9984	19 59.91	967	967	-	-	-
13011	Y57	09.Nov.96	314	17.19	18.12	19.22	56.9975	56 59.85	24.9765	24 58.59	2881	2887	-	Y	Y
13012	X57	11.Nov.96	316	16.14	17.02	18.08	57.0068	57 0.41	29.8785	29 52.71	2494	2501	-	Y	Y
13013		12.Nov.96	317	12.55	13.50	15.08	55.5093	55 30.56	27.2126	27 12.75	3043	3057	-	Y	Y
13014		13.Nov.96	318	17.47	18.57	20.23	52.9923	52 59.54	23.3045	23 18.27	3818	3830	-	Y	Y
13015		14.Nov.96	319	13.28	14.13	15.22	51.5273	51 31.64	21.4072	21 24.43	2508	2509	Y	-	Y
13016	Z51	15.Nov.96	320	07.44	08.55	10.35	50.0576	50 3.46	19.5934	19 35.6	4021	4045	Y	Y	Y
13017		16.Nov.96	321	08.05	09.15	10.55	50.4608	50 27.65	15.0016	15 0.10	3965	3988	-	Y	Y
13018		17.Nov.96	322	05.45	06.18	06.59	50.7785	50 46.71	11.4738	11 28.43	1295	1284	-	Y	-

Table 2. Main processing execs and file names

CCC = Cruise number, here 223.
n, nn, nnn, nnnnn = sequential number, one, two, three or five characters long

Navigation	
navexec0	Reads in bestnav data and appends to abnvCCCn
gpsexec0	Reads in raw gps_4000 data and creates/appends to gpsCCCnn
gyroexec0	Reads in gyro data and creates/appends to gyrCCCnn
ashexec0	Reads in gps_ash data into ashCCCnn
ashexec1	Merges gyro, creates a-ghdg, into ashCCCnn.mrg
ashexec2	Edits .mrg file to retain only good a-ghdg values, creates ashCCCnn.edit and a file of 2-minute averages ashCCCnn.ave
ashexec2a	Remaining steps done manually aided by ashexec2a.pdf
ADCP	
adpexec0	Reads in ADCP 2-minute profiles to adpCCCnn and botCCCnn
adpexec1	Corrects PC time base to adp(bot)CCCnn.corr
adpexec2	Converts from gyro to AshTech headings in adp(bot)CCCnn.true
adpexec3	Applies A and phi calibrations outputting to adp(bot)CCCnn.cal
adpexec4	Merges with abnvCCCn to create absolute velocities in adpCCCnn.abs still with 2-minute resolution. Can be averaged on time or distrun
CTD	
ctdexec0	Reads in raw 1-sec CTD data into ctdnnnnn.raw
ctdexec1	Calibrates to ctdnnnnn.du and averages to ctdnnnnn.10s
ctdexec1a	Copies the down cast from ctdnnnnn.du to ctdnnnnn
SeaSoar	
ssexec0	Reads in raw 1-sec CTD data into sarawnnn with dataname saCCCnnn
ssexec1	Calibrates using shalctd.cal to saCCCnnn
ssexec2	Plots 4-hour data files

Table 3. Pressure sensor hysteresis correction

Pressure dbar	**dp5500(p) dbar**
0	0
500	6.3
1000	6.0
1500	5.6
2000	4.8
2500	3.4
3000	3.0
3500	2.4
4000	1.8
4500	1.2
5000	1.0
5500	0.0

Table 4

Station Numbei	Mean Offset (All Depths)	Standard Deviation (All Depths)	Mean Offset (>1000dbar)	Standard Deviation (>1000 dbar)	Number of Samples >1000 dbar	Station Number	Correction Applied
12931	-	-	-	-	-	12931	-0.004
12932	-	-	-	-	-	12932	-0.004
12933	-0.0041	0.0030	-	-	-	12933	-0.004
12934	-0.0034	0.0011	-	-	-	12934	-0.003
12935	-0.0024	0.0004	-	-	-	12935	-0.002
12936	-0.0031	0.0007	-	-	-	12936	-0.003
12937	-0.0028	0.0007	-	-	-	12937	-0.003
12938	-0.0024	0.0009	-	-	-	12938	-0.002
12940	-0.0005	0.0011	-0.0002	0.0007	3	12940	0.000
12941	0.0029	0.0011	0.0039	0.0004	5	12941	0.003
12942	0.0013	0.0013	0.0020	0.0007	6	12942	0.002
12943	0.0008	0.0011	0.0015	0.0009	6	12943	0.001
12944	0.0020	0.0010	0.0023	0.0008	6	12944	0.002
12945	0.0034	0.0053	-	-	-	12945	0.003
12946	0.0010	0.0015	-	-	-	12946	0.001
12947	0.0010	0.0013	-	-	-	12947	0.001
12948	0.0014	0.0010	-	-	-	12948	0.001
12949	0.0037	0.0023	0.0031	0.0017	5	12949	0.003
12950	0.0045	0.0025	0.0058	0.0006	5	12950	0.005
12951	0.0060	0.0009	0.0060	0.0011	4	12951	0.006
12952	0.0051	0.0010	0.0046	0.0005	2	12952	0.005
12953	0.0067	0.0023	-	-	-	12953	0.007
12954	0.0082	0.0005	-	-	-	12954	0.008
12955	0.0086	0.0024	-	-	-	12955	0.009
12956	0.0083	0.0017	-	-	-	12956	0.008
12957	0.0078	0.0017	-	-	-	12957	0.008
12958	0.0068	0.0006	-	-	-	12958	0.007
12960	0.0053	0.0006	0.0061	0.0003	3	12960	0.005
12961	0.0063	0.0025	-	-	-	12961	0.006
12962	0.0075	0.0013	-	-	-	12962	0.007
12963	0.0056	0.0011	0.0042	0.0014	2	12963	0.006
12964	0.0048	0.0020	-	-	-	12964	0.005
12965	0.0028	0.0011	0.0048	0.0012	2	12965	0.003
12966	0.0030	0.0017	0.0049	0.0036	2	12966	0.003
12967	0.0026	0.0008	-	-	-	12967	0.002
12968	0.0024	0.0021	-	-	-	12968	0.002
12969	0.0036	0.0011	-	-	-	12969	0.004
12970	0.0034	0.0005	-	-	-	12970	0.003
12971	0.0021	0.0018	-	-	-	12971	0.002
12972	0.0040	0.0010	0.0030	0.0009	2	12972	0.004
12974	0.0045	0.0011	0.0034	0.0004	4	12974	0.004
12975	0.0050	0.0011	0.0045	0.0014	7	12975	0.005
12976	0.0027	0.0012	0.0019	0.0009	9	12976	0.002
12977	0.0031	0.0013	0.0025	0.0012	10	12977	0.003
12978	0.0019	0.0016	0.0010	0.0014	11	12978	0.001
12979	0.0027	0.0013	0.0021	0.0013	10	12979	0.002
12980	0.0038	0.0012	0.0032	0.0011	8	12980	0.003
12981	0.0041	0.0016	0.0033	0.0014	6	12981	0.003
12982	0.0048	0.0026	0.0016	0.0001	2	12982	0.004
12983	0.0046	0.0019	-	-		12983	0.004
12984	0.0031	0.0024	0.0015	0.0019	12	12984	0.003
12985	0.0026	0.0033	0.0016	0.0024	15	12985	0.002
12986	0.0023	0.0048	0.0029	0.0013	11	12986	0.003
12987	0.0058	0.0025	0.0043	0.0015	11	12987	0.004
12988	0.0051	0.0042	0.0025	0.0024	12	12988	0.003
12989	0.0064	0.0026	0.0047	0.0006	2	12989	0.005
12990	0.0050	0.0009	0.0049	0.0010	8	12990	0.005
12991	0.0041	0.0011	-	-	-	12991	0.003
12992	0.0031	0.0017	0.0022	0.0017	11	12992	0.002
12993	0.0039	0.0023	0.0024	0.0016	10	12993	0.002
12994	0.0026	0.0031	0.0011	0.0024	11	12994	0.001
12995	0.0029	0.0042	0.0003	0.0028	13	12995	0.000
12996	0.0032	0.0047	0.0000	0.0032	12	12996	0.000
12997	0.0031	0.0043	0.0004	0.0021	11	12997	0.000

Table 4

Station Numbei	Mean Offset (All Depths)	Standard Deviation (All Depths)	Mean Offset (>1000dbar)	Standard Deviation (>1000 dbar)	Number of Samples >1000 dbar	Station Number	Correction Applied
12998	0.0039	0.0035	0.0020	0.0020	9	12998	0.002
12999	0.0047	0.0028	0.0033	0.0035	8	12999	0.003
13000	0.0072	0.0070	-	-	-	13000	0.004
13001	0.0066	0.0040	0.0036	0.0014	6	13001	0.004
13002	0.0037	0.0042	0.0010	0.0029	14	13002	0.002
13003	0.0041	0.0019	0.0026	0.0014	10	13003	0.003
13004	0.0031	0.0028	0.0012	0.0025	11	13004	0.001
13005	0.0020	0.0030	0.0008	0.0033	13	13005	0.001
13006	0.0029	0.0019	0.0025	0.0024	11	13006	0.002
13007	0.0022	0.0014	0.0016	0.0015	11	13007	0.002
13008	0.0057	0.0023	0.0050	0.0013	8	13008	0.005
13009	0.0062	0.0018	0.0062	0.0007	9	13009	0.006
13010	0.0027	0.0010	-	-	-	13010	0.003
13011	0.0007	0.0052	0.0010	0.0024	11	13011	0.001
13012	0.0057	0.0026	0.0043	0.0020	13	13012	0.004
13013	0.0028	0.0030	0.0012	0.0027	14	13013	0.001
13014	0.0006	0.0054	-0.0008	0.0037	14	13014	0.000
13015	0.0022	0.0031	0.0014	0.0020	11	13015	0.001
13016	0.0008	0.0031	-0.0004	0.0035	14	13016	0.000
13017	-0.0004	0.0031	-0.0015	0.0035	14	13017	0.000
13018	0.0038	0.0014	0.0022	0.0009	4	13018	0.003

Table 5. Differences between CTD and reversing thermometer and pressure meter data.

	Measured Range (°C)	Sample no	mean Difference	standard deviation
T401	6.138 - 10.733	5	-0.0767	0.1086
T714	1.384 - 11.515	72	-0.0066	0.0665
T743	2.507 - 13.338	72	0.0057	0.0099
T746	2.505 - 13.338	72	0.0063	0.0166

	Measured Range (dbar)	Sample no	mean Difference	standard deviation
P6132	110.388 - 4063.050	68	5.8956	7.9712
P6293	22.700 - 3304.210	71	4.4905	15.2962

Table 6

Zooplankton Net Log

Station	Date JDay	Time in	Time out	Depth (m)
12983	285	09 45	10 50	500
12984	288	18 10	18 30	200
12985	290	10 00	10 15	200
12986	291	19 10	19 35	200
12987	292	15 50	16 15	200
12988	293	04 55	05 15	200
12989	294	04 50	05 10	200
12991	297	01 05	01 25	200
12992	298	03 50	04 10	200
12993	299	23 50	00 05	200
12994	300	17 20	17 40	200
12995	301	10 55	11 10	200
12996	302	16 30	16 51	200
12997	302	23 10	23 32	200
13002	303	18 10	18 30	200
13003	305	02 05	02 20	200
13004	306	13 15	13 35	200
13005	307	14 30	14 50	200
13006	308	14 05	14 25	200
13007	310	11 10	11 30	200
13008	312	11 25	11 45	200
13009	313	15 44	15 56	200
13009	313	15 03	15 35	500
13010	313	20 30	20 50	200
13011	314	19 30	19 50	225
13012	316	18 10	18 30	200
13013	317	15 12	15 30	200
13014	318	20 30	20 50	200
13014	318	20 55	21 25	500
13015	319	12 18	12 48	500
13015	319	12 58	13 14	200
13016	320	06 40	07 15	500
13016	320	07 20	07 40	200
13017	321	11 04	11 14	200
13017	321	11 20	11 50	500
13018	322	04 42	05 15	500
13018	322	05 22	05 40	200

Table 7
SeaSoar Deployments

Leg 1:

Run no.	Deployed Day:Time	Position N	Position W	km	Recovered Day:Time	Position N	Position W	km	Duration Day:Time	Run km	Total SS run	4-hour files	Reasons for recovery	Station No.
1	285:1336	63.243	17.333	2829	285:1731	63.301	17.359	2836	0:0356	7	7	1-9	1. check damage	
	285:2338	62.994	17.543	2893	286:1654	61.006	19.044	3155	0:2117	262	269		2. repairs	
	286:2012	61.001	18.993	3159	287:0457	60.189	19.799	3279	1:1533	120	389		3. bad weather	
2	288:1912	60.165	19.81	3545	290:0538	57.025	22.725	4069	1:1026	516	905	11-19	1. CTD YZ57	12985
3	290:1257	56.997	22.733	4089	291:1657	60.308	26.207	4518	1:0400	424	1329	20-26	1. CTD Y60A	12986
4	291:1657	60.308	26.207	4518	292:1328	61.661	30.038	4673	0:2031	155	579	27-35	1. CTD station	12987
	292:1612	61.636	30.038	4784	293:0222	62.307	32.209	4929	1:1025	404	1733		2. CTD X63	12988
5	293:0521	62.289	32.228	4937	294:0316	63.386	26.375	5273	0:2155	336	2069	36-41	1. CTD Y63A	12989
													2. CTD station	12990
													2. CTD station	12991

Leg 2

Run no.	Deployed Day:Time	Position N	Position W	km	Recovered Day:Time	Position N	Position W	km	Duration day:time	km	Total SS run	4-hour files	Reasons for Recovery	Station No.
6	297:0148	63.012	22.396	5898	298:0047	59.995	25.460	6262	0:2259	360	2429	42-47	1. CTD station	12992
7	298:0433	60.001	25.451	6272	298:0438	59.998	25.471	6274	0:0005	2	2431	48-56	1. foul in line	
	298:0603	60.000	25.518	6295	299:0425	58.313	29.838	6590	0.2227	295	2726		2. bad weather	
	299:1253	58.365	29.673	6667	299:2127	57.637	31.192	6788	1:2154	121	2847		3. CTD station	12993
8	300:0033	57.624	31.086	6807	300:1437	58.908	33.798	7018	0:1404	211	3268	57-64	1. CTD station	12994
	300:1801	58.840	33.822	7035	301:0748	60.042	36.584	7245	0:1347	210	3478		2. CTD G1	12995
													3. CTD G2-G7	12996-13001
9	302:1941	59.967	41.789	7660	303:1516	58.040	40.403	7965	0:1935	355	3833	65-70	1. CTD station	13002
10	303:1859	58.032	40.507	7978	305:1107	54.093	33.331	8608	1:0608	620	4453	71-81	1. CTD W54	13003
11	305:1506	54.079	23.358	8620	306:0938	53.952	29.205	8899	0:1832	279	4732	82-86	1. CTD X54	13004
12	306:1428	54.018	29.121	8921	307:1036	53.989	24.620	9228	0:2008	307	5039	87-92	1. CTD Y54	13005
13	307:1450	53.989	24.579	9239	308:1040	54.013	20.386	9537	0:1950	298	5337	93-98	1. CTD Z54	13006
14	308:1419	53.993	20.346	9548	309:2021	53.046	14.826	10004	1:0602	456	5793	99-106	1. Bad weather	
													2. CTD station	13007

Table 7
SeaSoar Deployments

Run	Deployed	Position		km	Recovered	Position		km	Duration	km	Total	4-hour	Reasons for	Station No.
no.	Day:Time	N	W		Day:Time	N	W		day:time		SS run	files	Recovery	
15	310:1248	53.292,	15.113	10082	310:1657	53.498,	15.643	10132	0:0409	50	5843	107-11	1. Bad weather	
	311:1926	53.544,	16.786	10221	312:0857	54.591,	17.168	10419	1:1331	198	6041		2. CTD station	13008
16	312:1152	54.593,	17.231	10429	313:1238	56.925,	21.221	10792	1:0046	363	6404	112-11	1. CTD Z57	13009
													2. CTD station	13010
17	313:2058	57.005,	20.000	10873	314:1704	56.992,	24.987	11179	0:2006	306	6710	118-12	1. CTD Y57	13011
18	314:1948	57.009,	24.952	11183	316:0857	57.544,	30.877	11658	1:1309	476	7186	122-12	1. Change of direction	
19	316:0857	57.544,	30.877	11658	316:1505	56.956,	29.892	11750	0:0608	92		133-13	1. CTD station	13012
	316:2028	57.025,	29.932	11764	317:1219	55.487,	27.239	12007	1:1551	243	7535		2. CTD station	13013
20	317:1557	55.515,	27.271	12018	318:1724	52.967,	23.349	12405	1:0124	387	7922	139-14	1. CTD station	13014
21	318:2122	53.001,	23.302	12412	319:1153	51.509,	21.420	12633	0:1411	221	8143	146-14	1. CTD station	13015
22	319:1635	51.522,	21.372	12656	320:0615	50.030,	19.618	12870	0:1340	214	8357	150-15	1. CTD X51	13016
23	320:1039	50.066,	19.595	12879	321:0723	50.459,	14.937	13214	0:2044	335	8692	155-15	1. CTD station	13017
24	321:1157	50.464,	15.008	13223	322:0401	50.827,	11.455	13491	1.11389	268	8960	161-16	1. CTD station	13018

Table 8. SeaSoar Salinity Calibrations

Run	Mean Offset	Standard Deviation
1-5	-0.012	0.006
6-8	-0.011	0.005
8-16	-0.014	0.005
17-24	-0.014	0.005

Table 9. Fitting Parameters for SeaSoar Fluorometer Calibration

Start Day:Time	k	a	b	k1	z
285:141322	0.35	2.30	0.32	0.0	1000.0
286:012921	0.35	2.30	0.35	0.0	13.0
306:083516	0.35	2.30	0.35	0.0	20.0
306:185446	0.35	2.30	0.35	0.0	13.0
318:103349	0.35	2.30	0.35	0.0	20.0
318:133258	0.35	2.30	0.35	0.0	13.0

Table 10. P-ALACE Float Deployments

ID	Type	Y-Day-H-M	Stn	Position Lat	Long	Depth (m, corr)
78K	CTD	96-301-1118	12995	60.0062N	36.6177W	3066
77K	CTD	96-301-1809	12996	59.9986N	30.4028W	2975
80K	CTD	96-302-0425	12998	59.9826N	40.5080W	2297
79K	CTD	96-303-1839	13002	58.0283N	40.4253W	3195
82K	TD	96-304-0615	none	56.9749N	38.3325W	3278
83K	TD	96-304-1655	none	55.9015N	36.4022W	2428
81K	TD	96-305-1425	13003	54.0912N	33.3803W	2548

Table 11. Listing of deepctd.cal

```
:di223 DEEP01 29-09-96
:cals from JS file for temp, press, cond, oxyc, oxyt, fluor, trans
:att220, att240, att300, alt
:original file from cruise 199
:cond ratio corrected according to bottle sals after first few casts (old
:value was 1.00215) nph 4.10.96
:
temp     1   -0.0165549  0.000499282   7.97259e-13    0.   0.
deltat   .20      0.       0.          0.   0.   0.
press    .1      -9.3832   0.996263   5.743323e-7 0. 0.
cond     .001     0.       0.989924    0.   0    0.
:cond2    .001   -1.93815  0.953600    0.   0    0.
: n cruise 199 cond2 = FSI cond cell, estimated to be
: NBIS cond = 0.956774* FSI cond - 1944.6
oxyc     .001     0.       1.35        0.   0.   0.
oxyt     .128    0.       1.        0.   0.   0.
:oxyfrac  -.03594  0.000161 0.4       300.  0.6  0.
oxyfrac  -.030    0.000150 1.0       0.   0.   0.
:fvolts   .001     0.       1.        0.   0.   0.
fluor    1.     -1.719631e-3    1.219711e-3   3.438596e-10     0.   0.
:trans is Seatech No 31 reassembled Nov 94 with new air voltage
trans    1.   -1.719632e-3   1.219711e-3   3.438596e-10     0.   0.
potran   3.997    4.28    1.002    0.    0.   0.
atten    0.     9.     0.       1.   0.   0.
:temp2    0.0005   -2.     1.       0.   0.   0.
:cond2    .001     0.      1.       0.   0    0.
nframes  1.     0.      1.       0.   0.   0.
alt      1.0    0.20299     5.1479e-2      -5.861688e-8    0.   0.
:trans2 is new Chelsea Instr transmissometer
trans2   1.0     1.81789e-3  1.21934e-3  6.05678e-10 0. 0.
potran2  4.732   4.2        1.0        0.        0. 0.
atten2   0.      20.0      0.       0.25    0.  0.
att220   1.0      1.81789e-3  1.21934e-3  6.05678e-10 0. 0.
att240   1.0      1.81789e-3  1.21934e-3  6.05678e-10 0. 0.
att330   1.0      1.81789e-3  1.21934e-3  6.05678e-10 0. 0.
utility  1.0      0.    0.    0.    0.   0.

amended after conductivity sensor replaced:
:this version3 for second cond sensor on 12971 onwards  nph 10.10.96
cond     .001     0.      0.988156    0.   0    0.
```

Table 12. Listing of shalctd.cal

```
:calibration file for shallow ctd
:cal sheet is headed Imshall1 which John S tells me
:is the double cond oldish shallow CTD
:cal file used on Di223 from 27/2/96 OSI calibration
: for each sensor I give OSI consts A B C D E and ours
: press Digiquartz 220D SN 4119
:press 0,0,2.00950585046711D-10,9.9877377233D-3,-3.0142296
press    .01    -3.01423   0.9987738   0.0000020095  0.0  0.0
:temp 0,0,2.57193D-12,4.9933737D-4,-0.1145938339
temp     .0005  -0.1145938  0.9986747   0.0000102877  0.0  0.0
:cond2 ('ftemp')0,0,-2.79996169D-11,0.98854502D-3,-2.7999617D-2
:cond2 ratio increased by .0022 so profiles match ctd 11/10/96
cond2    .001   -0.02799962 0.990745   -0.000028      0.0  0.0
:cond 0,0,0,0.9934444236D-3,-1.525280722D-2
:cond ratio increased by .0004 so profiles match CTD 11/10/96
cond     .001   -0.0152528  0.9938444   0.0           0.0  0.0
:fluor 0,0,0,1.22070703D-3,0
:constant subtracte from fvolts to bring close to zero deep
fvolts   .001   -0.4        1.220707    0.0           0.0  0.0
:exp(0)=1 so subtract 1 from fluor in cal4
fluor    1.000   0.0        1.         -1.0           0.0  0.0
:oxyc 0,0,1.2492276D-7,-1.0049533D-5,-1.24931343D-2
oxyc     .001   -0.01249   -0.0100495   0.12492276    0.0  0.0
:no oxyt     .128    0.        1.0       0.0  0.0
oxyfrac  -.022   0.000135   1.0         0.0           0.0  0.0
oxygen   .0      0.0        0.0         0.0           0.0  0.0
:irrad 0,0,0,1.22070703D-3,0
:PAR (ln uW/cm2) = -8.4489+5.0705V
light .001220707 -13.05407  5.0705      0.0           0.0  0.0
:zvolts (drawn by CTD) 0,0,0,1.13D-2,0
zvolts   0.01    0.0        1.13        0.0           0.0  0.0
:time constant taken from PS1 to start with
:then increased from .15 to .18
deltat   0.18    0.0        0.0         0.0           0.0  0.0
nframes  1.      0.         1.          0.            0.   0.

shalctd2.cal mod for second conductivity sensor
:MODDED TO TRY DIFFERENT TIME CONSTANT FOR COND2
deltat   0.25    0.0        0.0         0.0           0.0  0.0
```

Table 13

List of ADCP files

Name	Start	End	adp	adp .cor	adp .tru	adp .cal	adp .abs	adp .ave	bot	bot .cor	bot .tru	bot .cal	bot .abs
adp22301	274 004000	274 015200	AF	AH	appended		to 02.cor		AI	AK	app.	to 02.corr	
adp22302	272 084500	274 015200	AD	AJ	AP	AT	BL		AF	AL	BF	BI	CA
adp22303	74 004000	275 050000	AB	CE	CK	CO	CR		AC	BX	BY	CB	CH
adp22304	75 050001	276 050000	AC	AF	AL	AP	AS		AD	AG	AM	AP	AT
adp22305	276 050000	277 050000	AC	AF	AL	AP	AS		AC	AF	AL	AO	AS
adp22306	277 050000	278 050000	AC	AF	AL	AP	AS		AC	AF	AL	AO	AS
adp22307	278 050000	279 050100	AC	AF	AL	AP	AS		AC	AF	AL	AO	AS
adp22308	279 050100	280 050200	AC	AF	AL	AP	AS		AC	AF	AL	AO	AS
adp22309	280 050000	280 180000	AC	AF	AL	AP	AS		AC	AF	AL	AO	AS
adp22310	280 180001	281 050000	AC	AF	AL	AP	AS	BH	AC	AF	AL	AO	AU
adp22311	281 050001	282 050000	AC	AF	AL	AP	AS	AX	AD	AF	AR	AU	BA
adp22312	282 050000	283 050000	AC	AF	AL	AP	AS	AX	AC	AF	AL	AO	AU
adp22313	283 050001	284 045800	AI	AL	AR	AV	AY	BC	AI	AL	AR	AU	BA
adp22314	284 050001	285 050000	AO	AR	AX	BB	BE	BO	AC	AX	BD	BG	BM
adp22315	285 050001	286 050000	AC	AF	AL	AP	AW	BB	AC	AF	AL	AO	AY
adp22316	286 050001	287 050000	AC	AF	AL	AP	AS	BP	AC	AF	AL	AO	AU
adp22317	287 050001	288 050000	AC	AF	AL	AP	AS	BA	AC	AF	AL	AO	AU
adp22318	288 050001	289 050000	AC	AF	AL	AP	AS	BB	AC	AF	AL	AO	AU
adp22319	289 050001	290 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AU
adp22320	90 050001	291 050000	AC	AF	AL	AP	AS	AW	AC	AF	AL	AO	AU
adp22321	291 050001	292 045500	AC	AF	AL	AP	AS	AW	AC	AF	AL	AO	AW
adp22322	292 045501	293 160000	BC	BF	BL	BP	BS	BU	BB	BE	BK	BN	BT
adp22323	293 160001	294 190000	AC	AF	AL	AP	AS	AV	AA	AF	AL	AO	AU
adp22324	294 190000	295 091000	AC	AF	AL	AR	AU	AX	AG	AH	AN	AV	AZ
adp22325	No ADCP data were collected while docked in Reykjavik												
adp22326	296 100616	297 050000	AC	AG	AM	AQ	AT	AX	AE	AH	AN	AQ	AW
adp22327	297 050000	298 050000	AC	AF	AL	AP	AS	BJ	AC	AF	AL	AO	AU
adp22328	298 050000	299 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AU
adp22329	299 050000	300 050000	AC	AF	AL	AP	AS	AZ	AC	AF	AL	AO	AU
adp22330	300 050000	301 050000	AC	AF	AL	AP	AS	AW	AC	AF	AL	AO	AS
adp22331	301 050000	302 050000	AC	AF	AL	AP	AS	BB	AC	AF	AL	AO	AS
adp22332	302 050000	303 050000	AC	AF	AL	AP	AS	BF	AC	AF	AL	AO	AS
adp22333	303 050000	304 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AS
adp22334	304 050000	305 050000	AC	AF	AL	AP	AS	AU	AC	AF	AL	AO	AS
adp22335	305 050000	306 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AS
adp22336	306 050000	307 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AS
adp22337	307 050000	308 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AS
adp22338	308 050000	309 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AQ	AU
adp22339	309 050000	310 050000	AC	AF	AL	AP	AS	AU	AC	AF	AL	AO	AS
adp22340	310 050000	311 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AS
adp22341	311 050000	312 050000	AC	AF	AL	AP	AS	AU	AC	AF	AL	AO	AS
adp22342	312 050000	313 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AS
adp22343	313 050000	314 050000	AC	AF	AL	AP	AS	AW	AC	AF	AL	AO	AS
adp22344	314 050000	315 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AS
adp22345	315 050000	316 050000	AC	AF	AL	AP	AS	AU	AC	AF	AL	AO	AS
adp22346	316 050000	317 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AS
adp22347	317 050000	318 050000	AC	AF	AL	AP	AS	AV	AC	AF	AL	AO	AS
dp22348	318 050000	319 050000	AC	AF	AL	AP	AS	AU	AC	AF	AL	AO	AS
adp22349	319 050000	320 050000	AC	AF	AL	AP	AS	AU	AC	AF	AL	AO	AV

Table 14

List of depth files

Name	Start	End	.ave	Description	Notes
dep22301	273 225758	276 175958	AE	sequential	
dep22302	276 180001	277 235959	AE	sequential	
dep22303	279 000002	280 112630	AF	sequential	day hove to omitted
dep22304	280 120001	285 075959	AC	sequential	
dep22305	285 080002	289 180000	AC	sequential	
dep22306	289 180002	290 050000	AC	sequential	
dep22307	290 050005	293 045957	AC	sequential	
dep22308	293 050002	294 185933	AC	sequential	ends at shelf
Reykjavik port call					
dep22309	296 094149	301 045956	AC	sequential	starts from port
dep22310	301 050002	303 050000	AC	sequential	
dep22311	303 050005	305 045958	AC	sequential	
dep22312	305 050002	307 045956	AC	sequential	
dep22313	307 050002	310 045959	AC	sequential	
dep22314	310 050003	312 045957	AC	sequential	
dep22315	312 050002	314 045959	AC	sequential	
dep22316	314 050003	316 045958	AC	sequential	
dep22317	316 050002	318 045955	AC	sequential	
dep22318	318 050001	320 045954	AC	sequential	
dep22319				sequential	
dep223RT	274 092045	277 011500	AD	Barra Head to Rockall	
dep223RL	277 030930	280 032500	AC	Rockall to Lousy Bank	short just north of Rockall
dep223LI	280 032500	285 074200	AJ	Lousy Bank to Iceland shelf	
dep223IB	285 132630	290 050000	AB	Iceland to 57N 22.5W	ends mid-basin
dep223II	290 050000	295 050000	AA	crosses Reykjanes Ridg	starts/ends mid-basin
				last leg to Iceland not extracted	
dep223D1	273 225745	294 185930	AG	leg 1 master file	.ave files appended + nav
dep223GC	301 111930	302 140400	AB	across E Greenland Cur	along 60N
dep223N4	303 191200	309 173130	AB	54N and SE/NW to Gre	not quite shelf to shelf
dep223N7	301 072900	313 212000	AM	57N Greenland to Hatto	composite excudes EGC
dep223L2				leg 2 master file	.ave files appended + nav
dep223D2				leg 2 edited master file	

Table 15

Salinity Standards

Standard No.	Sal-diff
1	1.8291E-06
2	1.8291E-06
3	0.00059132
4	0.00039482
5	1.8291E-06
6	0.00098431
7	0.0021633
8	0.0017703
9	0.00039482
10	0.00393178
11	0.00059132
12	0.00019833
13	0.0015738
14	0.0019668
15	0.00078781
16	0.00019833
17	1.8291E-06
18	0.00019833
19	0.00039482
20	0.00059132
21	0.0019668
22	0.00118081
23	0.00118081
24	0.00098431
25	-0.00078415
26	-0.00058766
27	1.8291E-06
28	-0.00039116
29	0.00078781
30	0.00019833
31	0.00078781
32	0.00019833
33	1.8291E-06
34	0.00039482
35	0.00019833
36	0.00019833
37	1.8291E-06
38	-0.00019467
39	0.00039482
40	0.00039482
41	1.8291E-06
42	1.8291E-06
43	0.00039482
44	0.00019833
45	-0.00098065
46	-0.00039116
47	-0.00039116
48	-0.00019467
49	-0.00019467
50	-0.00019467
51	1.8291E-06
52	-0.00019467
53	-0.00058766
54	-0.00078415
55	-0.00117714
56	-0.00117714
57	-0.00117714
58	-0.00176663
59	-0.00294559
60	-0.0027491
61	-0.0027491
62	-0.00235611
63	-0.00235611
64	-0.00235611
65	-0.0027491
66	-0.00294559
67	-0.0025526
68	-0.00294559
69	-0.0027491
70	-0.00333858
71	-0.00333858
72	-0.00314209
73	-0.00373156
74	-0.00432104
75	-0.00353507
76	-0.00432104
77	-0.00471403
78	-0.00412455
79	-0.00392806
80	-0.00451753
81	-0.00412455
82	-0.00471403
83	-0.00471403
84	-0.00471403

Table 16

Log for Continuous Plankton Recorder

Silk no.	JDay start	Time start	JDay end	Time end	Deployed N, W	Recovered N, W	Distance km
1	285	14 05	285	17 15	63.243, 17.333	63.301, 17.359	7
	285	23 40	286	16 20	62.994, 17.543	61.006, 19.044	262
	286	20 40	287	04 00	61.001, 18.993	60.231, 19.846	120
	289	15 00	290	05 00	57.483, 19.994	56.945, 22.794	516
2	290	13 15	291	16 30	56.997, 22.733	60.308, 26.207	424
	291	19 50	292	13 00	60.375, 26.278	61.611, 30.032	155
	292	16 35	293	02 00	61.636, 30.038	62.278, 32.244	404
3	297	01 50	298	00 45	63.012, 22.396	59.988, 25.487	360
	298	06 20	299	04 30	59.996, 25.623	58.313, 29.838	295
	299	12 45	299	21 35	58.365, 29.673	57.637, 31.192	121
	300	00 40	300	14 00	57.624, 31.086	58.908, 33.798	211
4	300	18 00	301	0715	58.840, 33.822	60.042, 36.584	210
	302	2000	303	14 46	59.967, 41.789	58.040, 40.403	355
	303	19 09	304	11 00	58.032, 40.507	56.563, 37.466	620
5	305	15 00	306	09 30	54.079, 23.358	53.952, 29.205	279
	306	13 50	307	10 30	54.018, 29.121	53.989, 24.620	307
6	307	14 50	308	10 00	53.989, 24.579	54.013, 20.386	298
	308	14 30	309	20 00	53.993, 20.346	53.046, 14.826	456
	310	12 34	310	16 30	53.292, 15.113	53.551, 15.564	50
7	311	20 20	312	08 45	53.522, 16.510	54.591, 17.168	198
	312	12 00	313	13 00	54.593, 17.231	56.925, 21.221	363
	313	21 00	314	17 00	57.005, 20.002	56.992, 24.987	306
8	314	20 00	316	12 50	57.009, 24.952	56.899, 29.881	476
	316	20 30	317	11 50	57.025, 29.932	55.487, 27.239	243
9	318	21 30	319	11 55	53.000, 23.286	51.522, 21.477	221
	319	15 30	320	06 18	51.511, 21.477	50.184, 19.634	214
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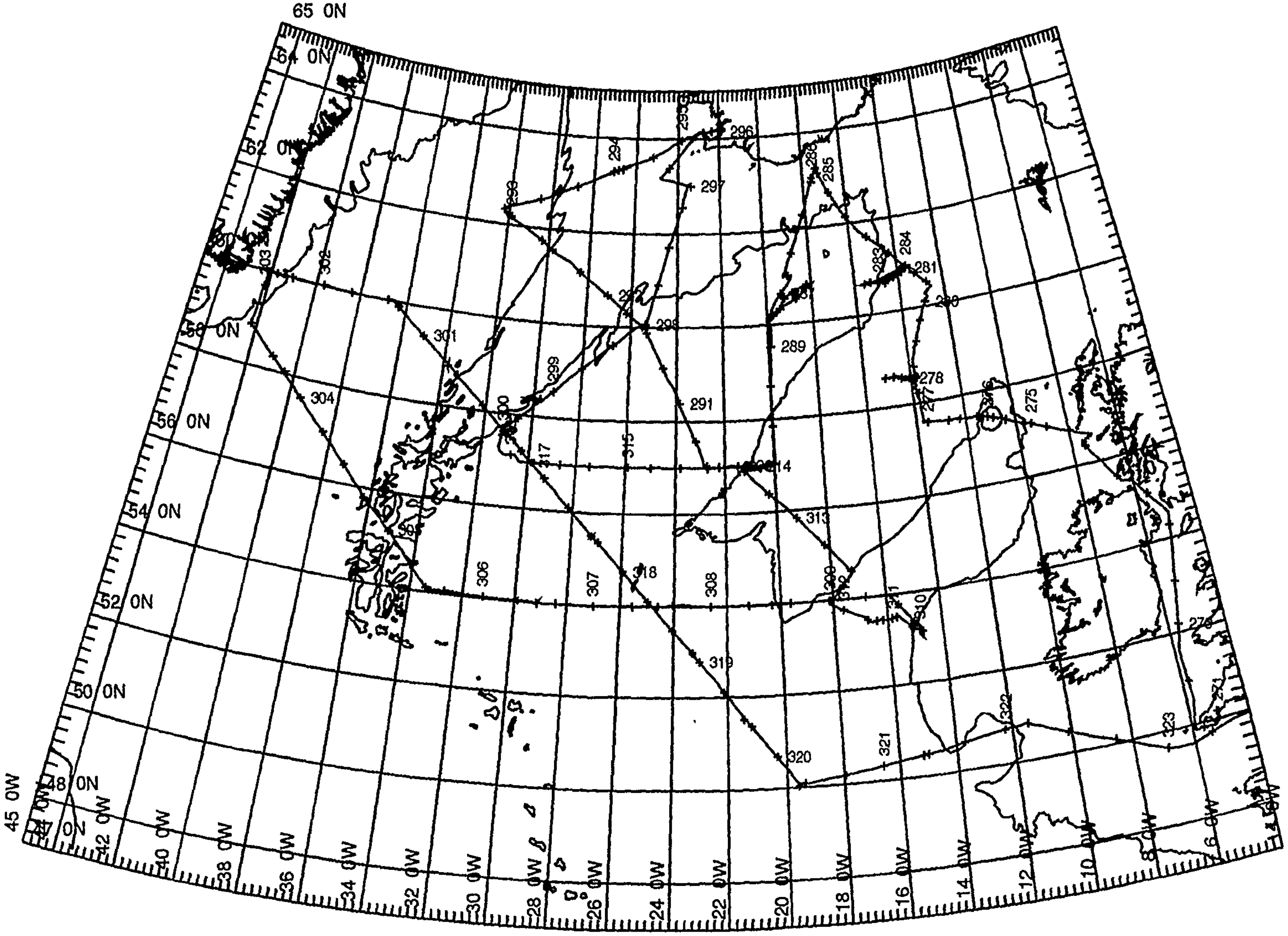


RV

TRANSVERSE MERCATOR PROJECTION

SCALE 1 TO 12500000 (NATURAL SCALE AT C M)

C M 24W International Spheroid

GRID NO. 1

— Track plotted from bestnav

+

Ship's Track During Discovery 223

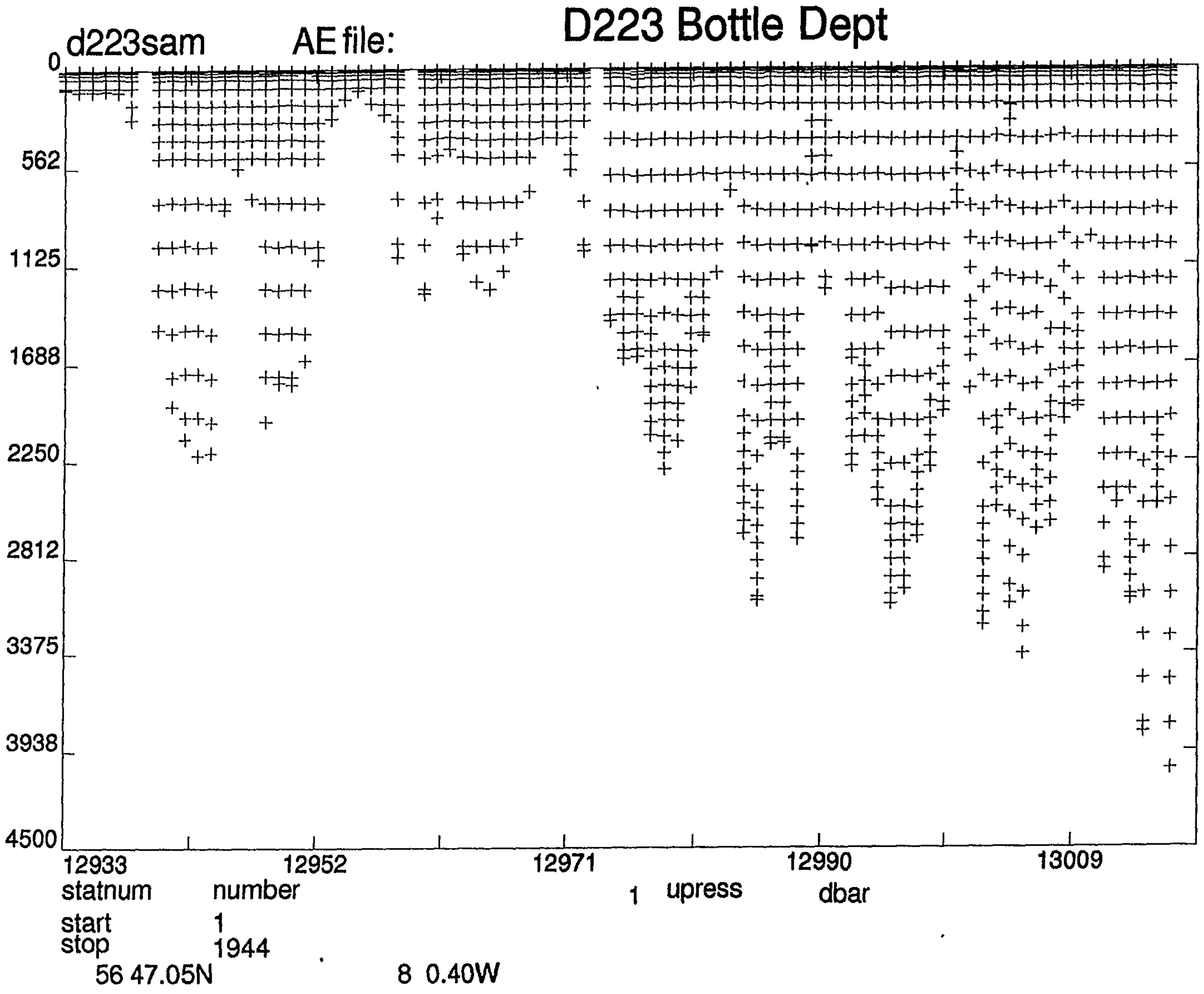


Fig.2 Vertical distribution of bottle samples

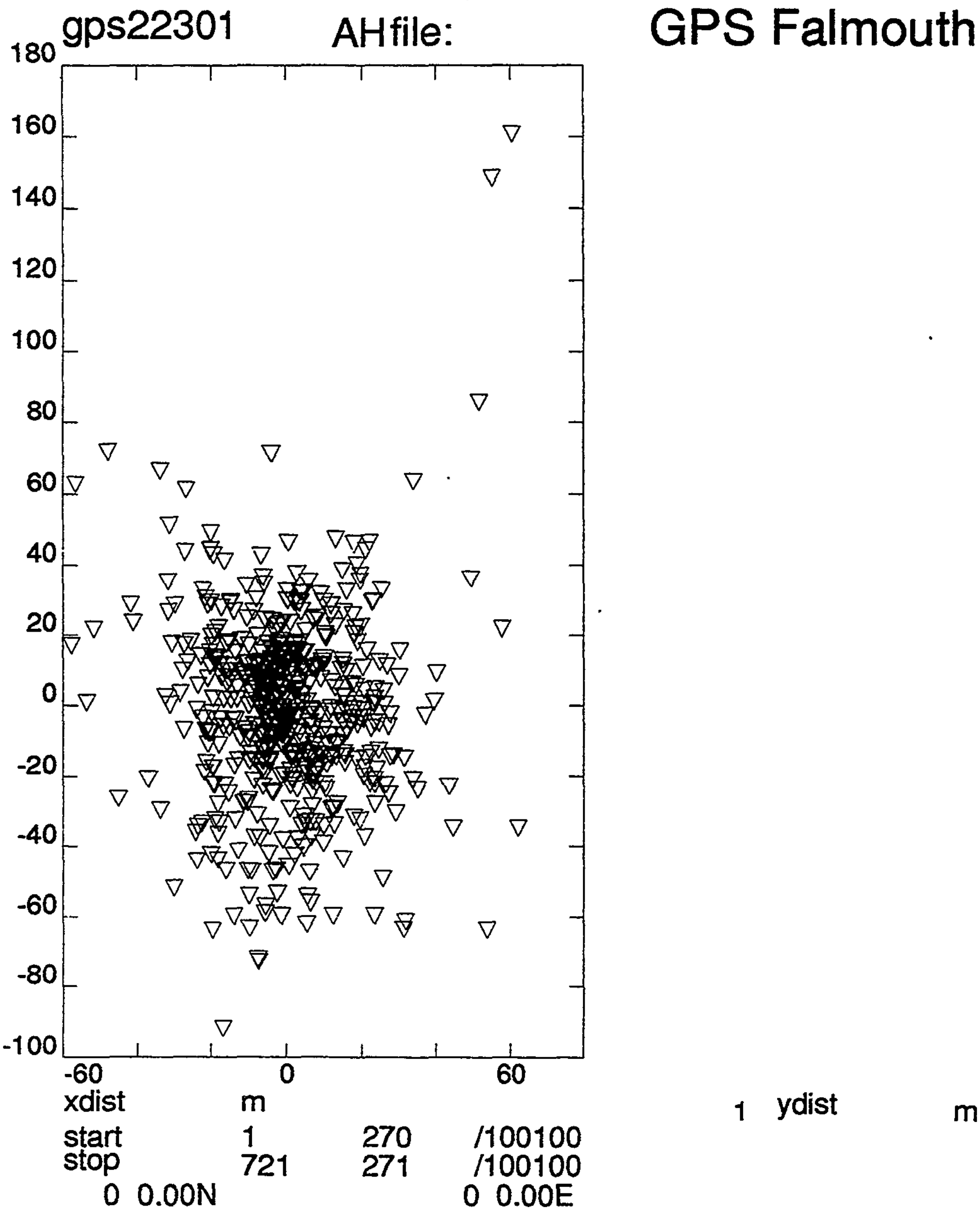


Fig.3 (a) Scatter plot of GPS positions in Falmouth.

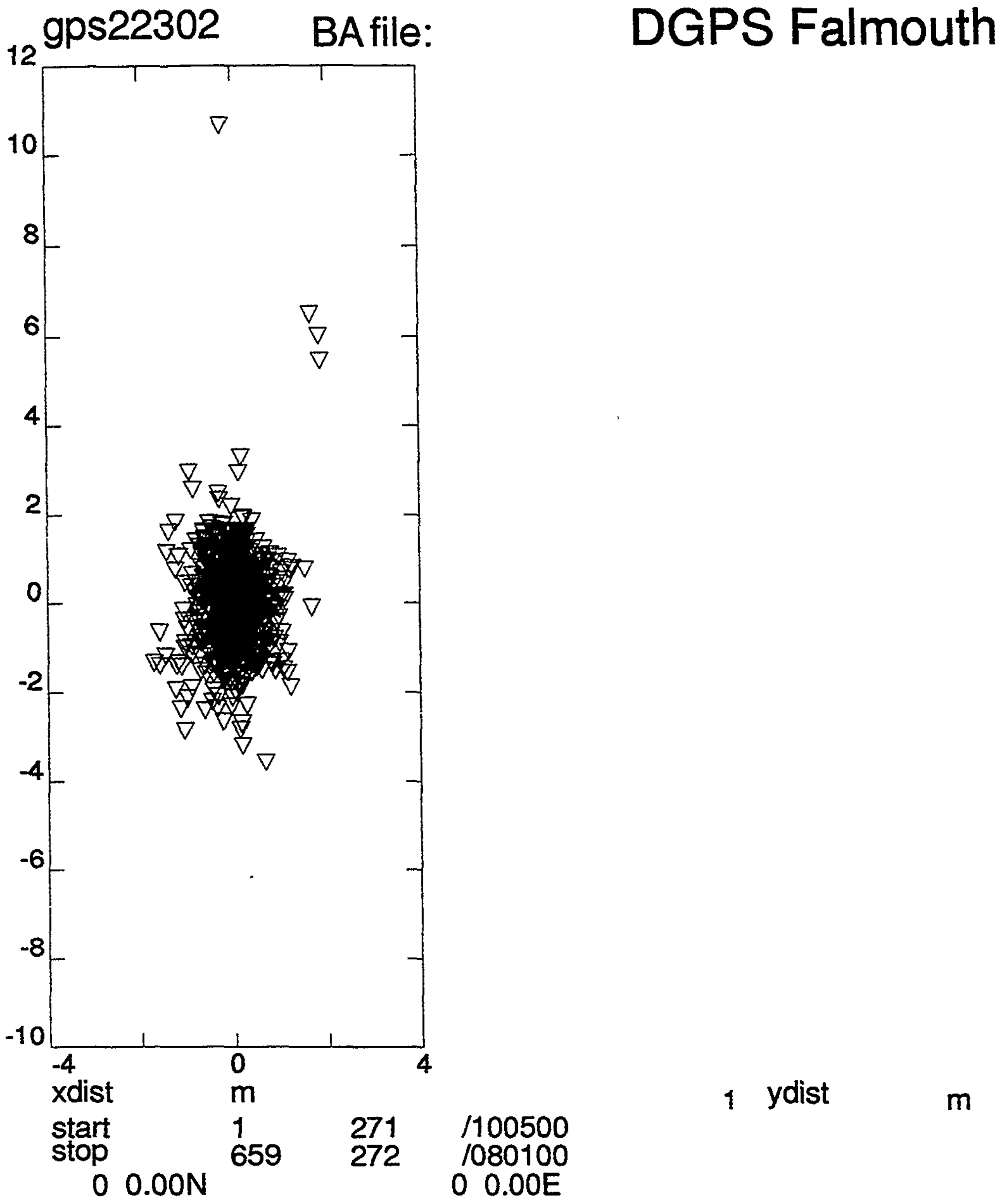


Fig.3 (b) Scatter plot of DGPS positions in Falmouth.

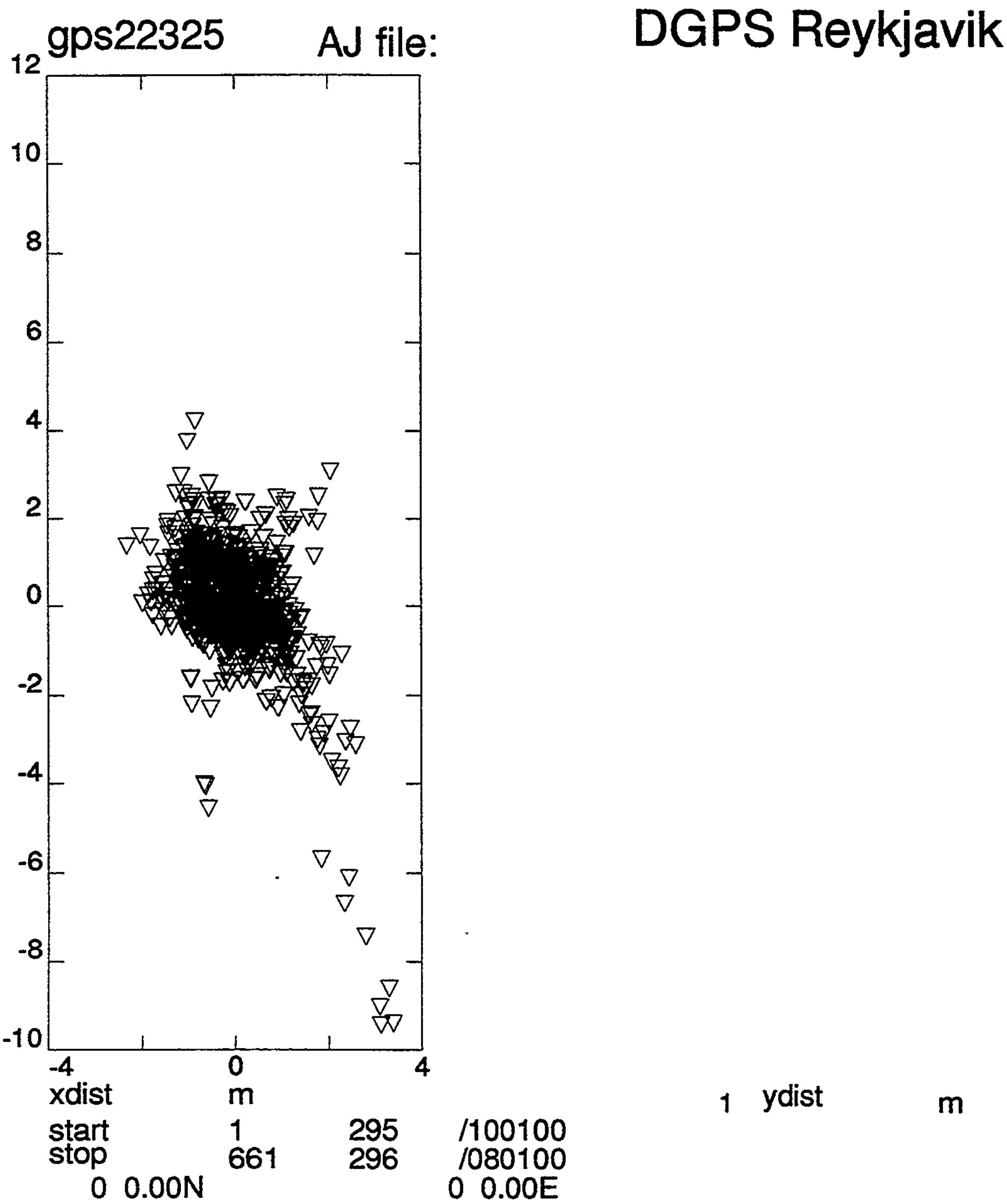


Fig.3 (c) Scatter plot of DGPS positions in Reykjavik.

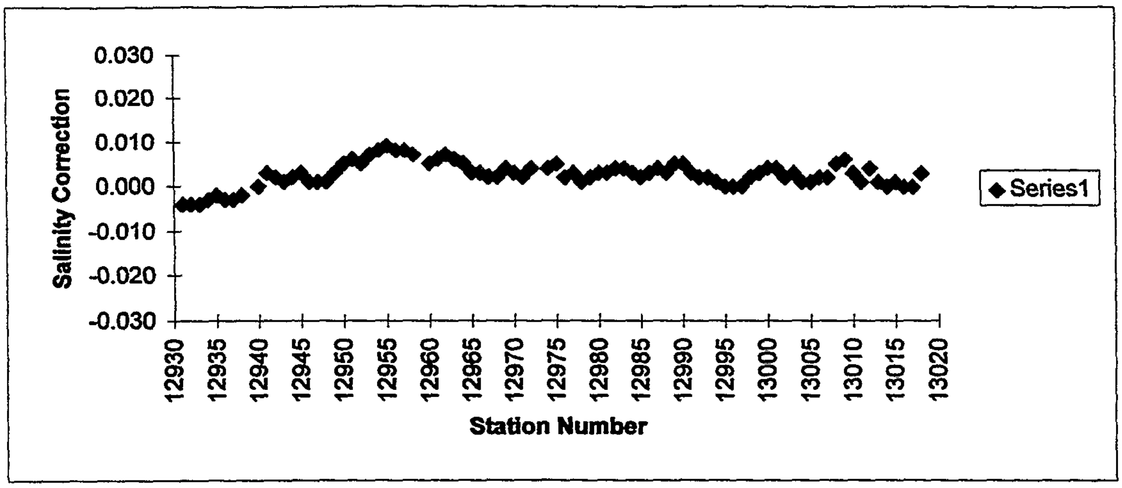


Fig.4 Salinity offset as a function of time.

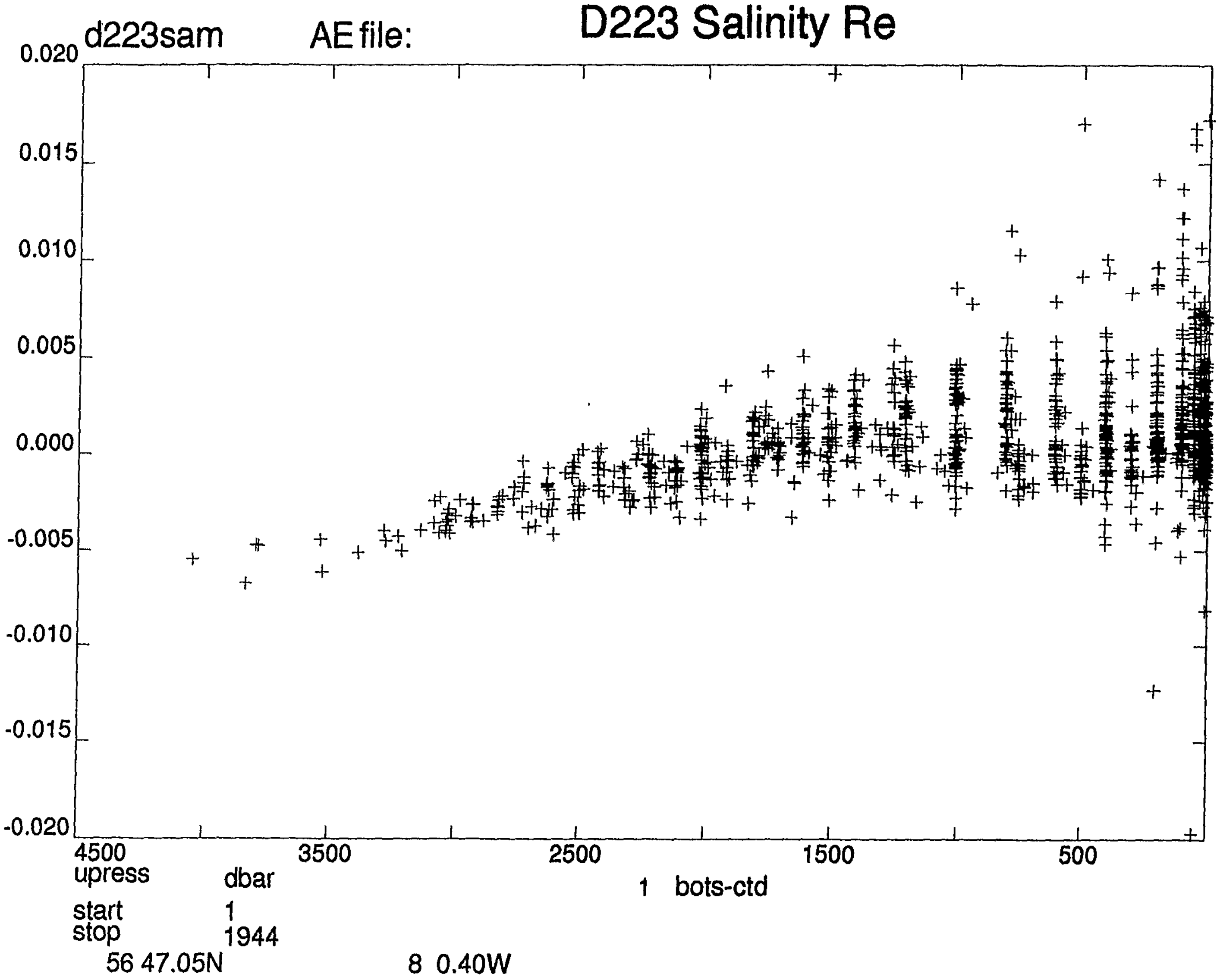


Fig.5 Bottle-CTD salinity residuals.

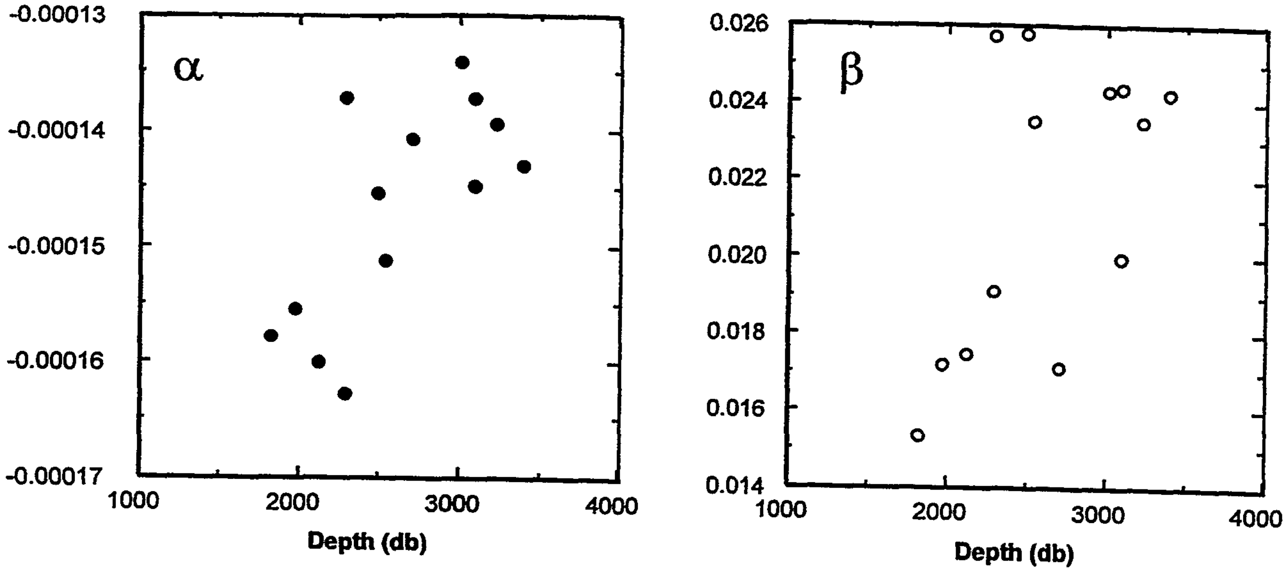


Fig.6 Oxygen Calibration Parameters Alpha and Beta as a Function of Depth.

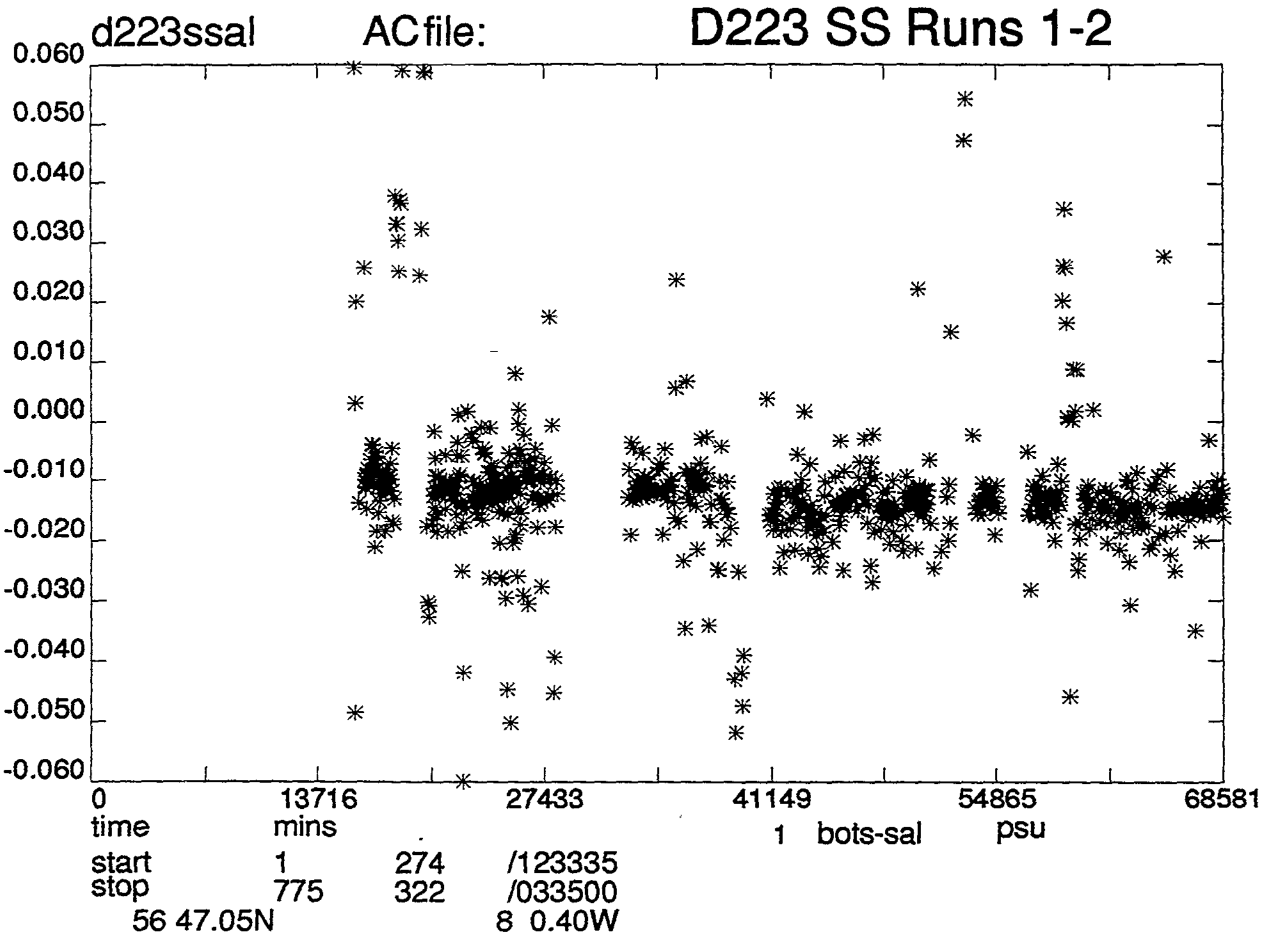


Fig.7 Difference between surface SeaSoar data and bottle salinity samples for RRS *Discovery* Cruise 223.

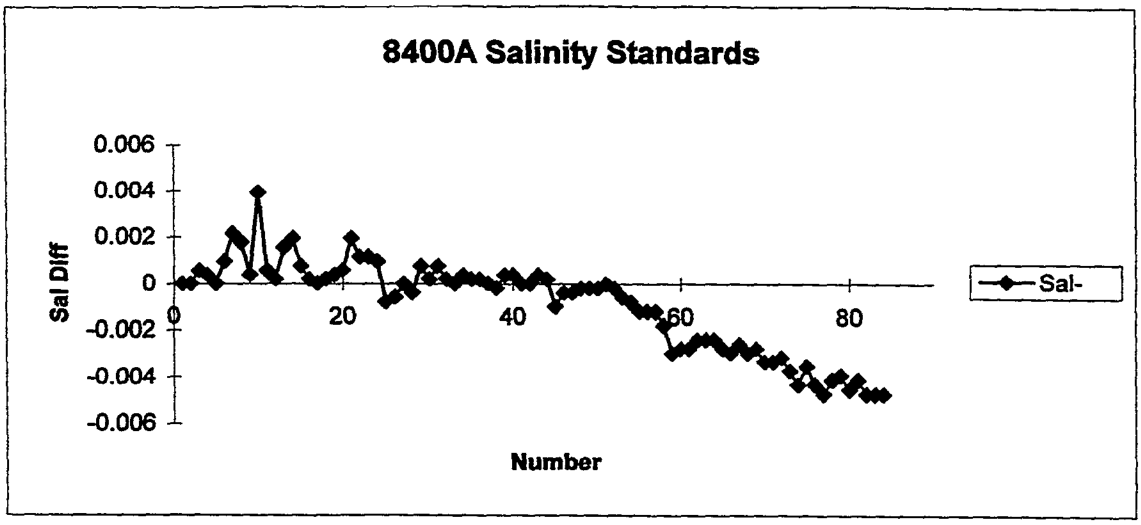
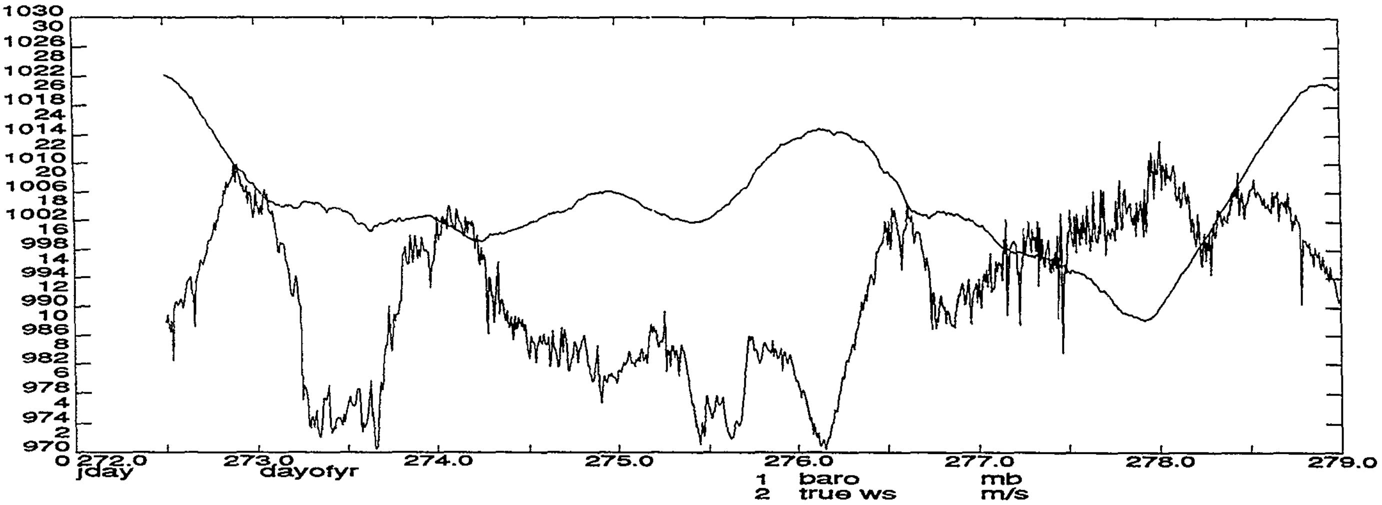


Fig.8 Salinity differences of the Salinity Standards.

Fig.9 Meteorological conditions during RRS *Discovery* Cruise 223.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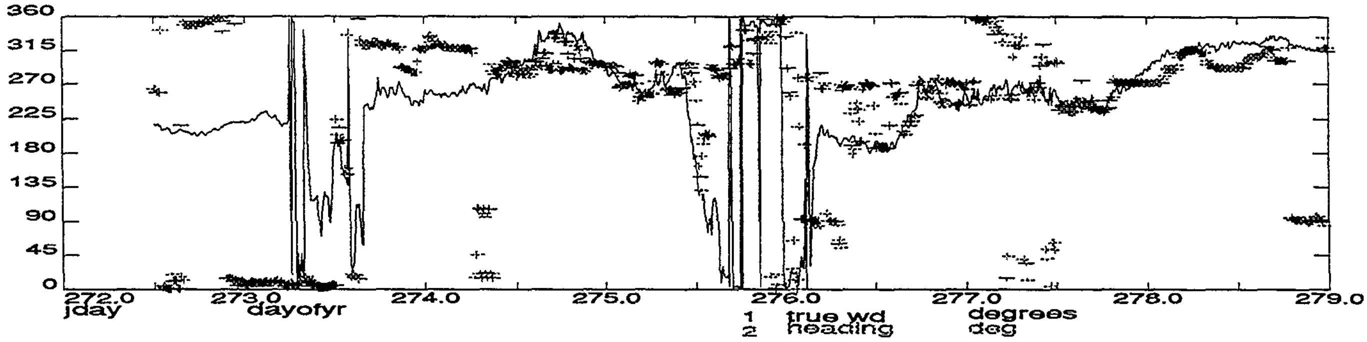
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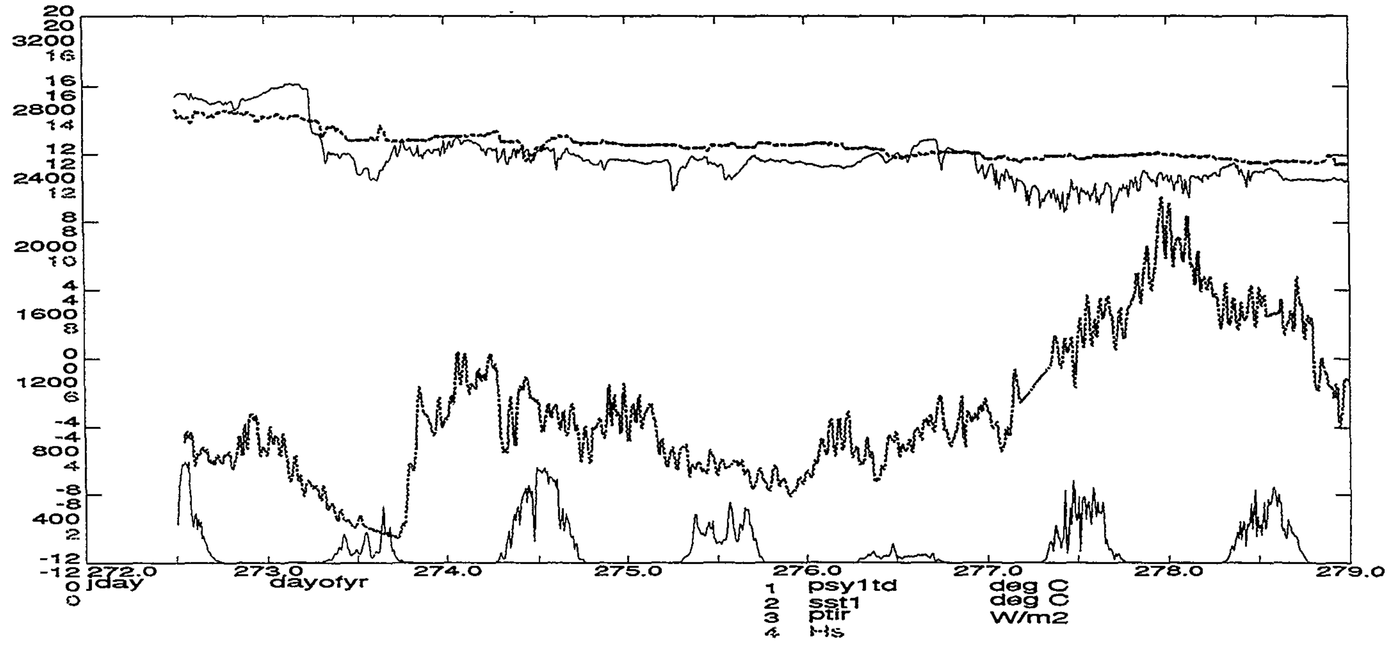
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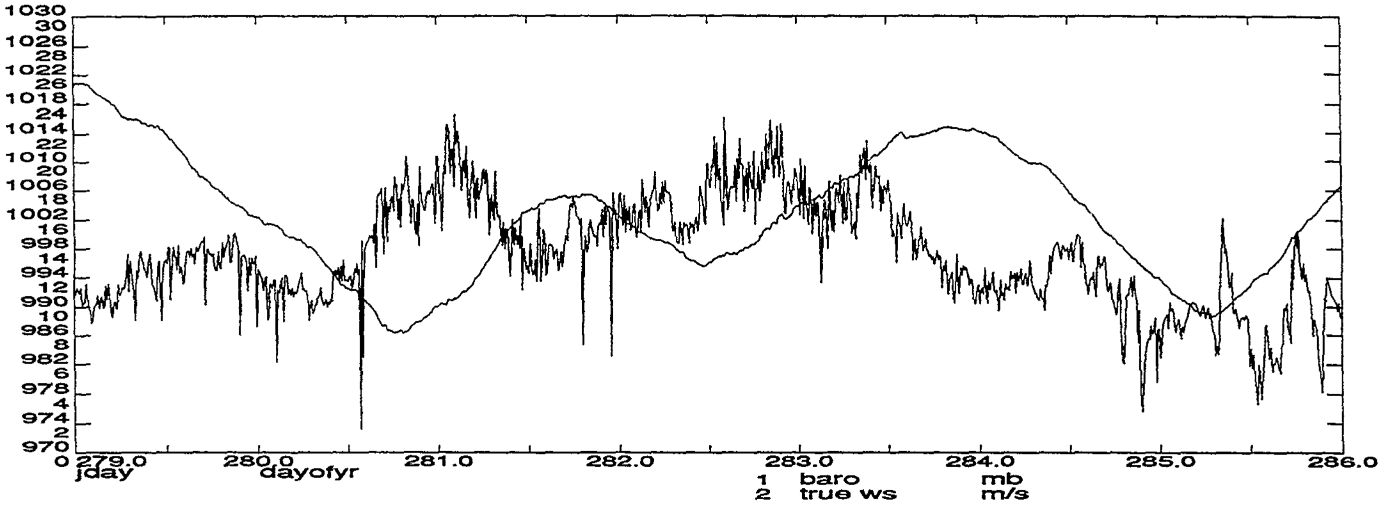
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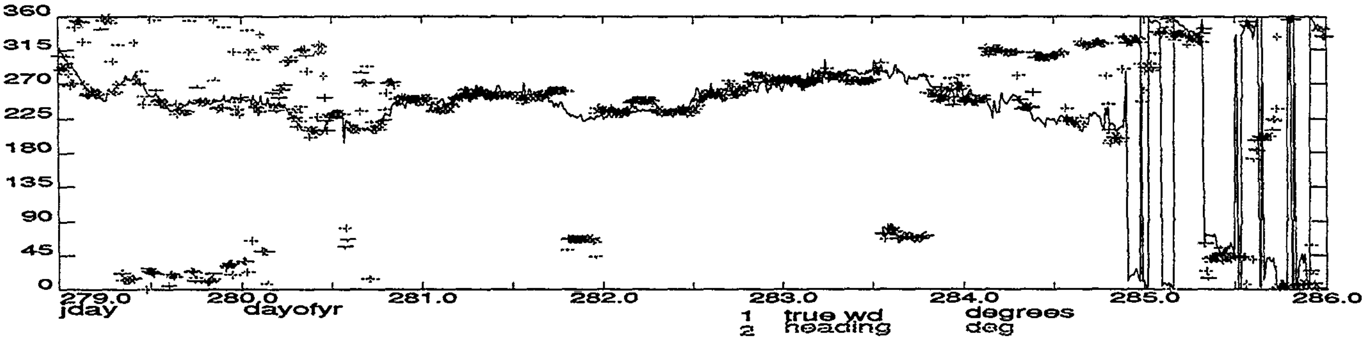
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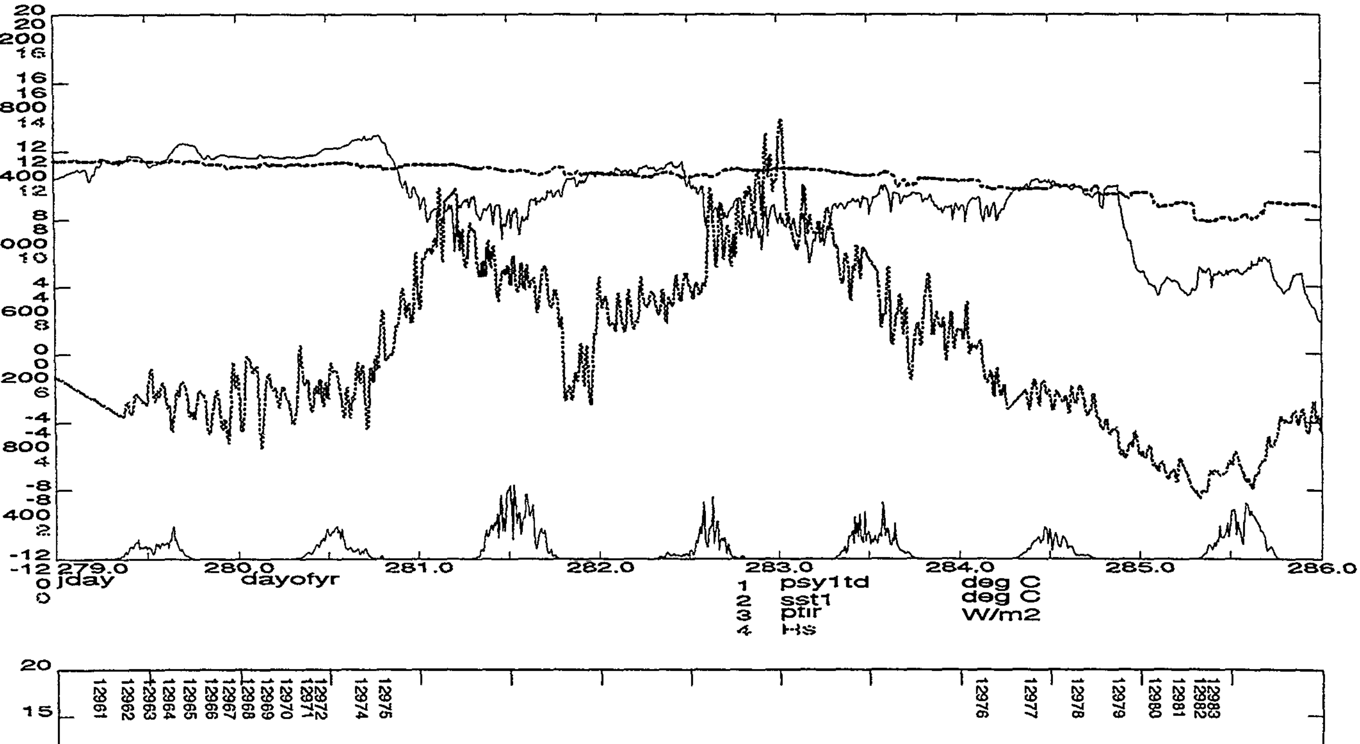
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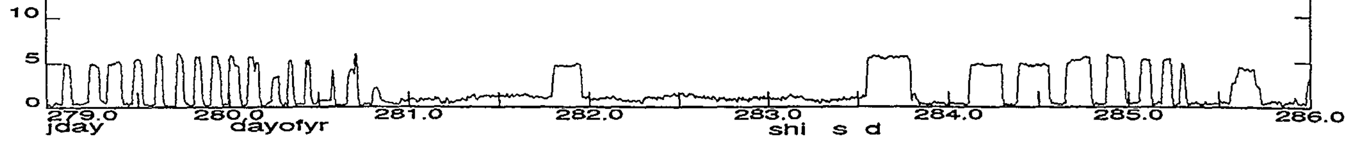
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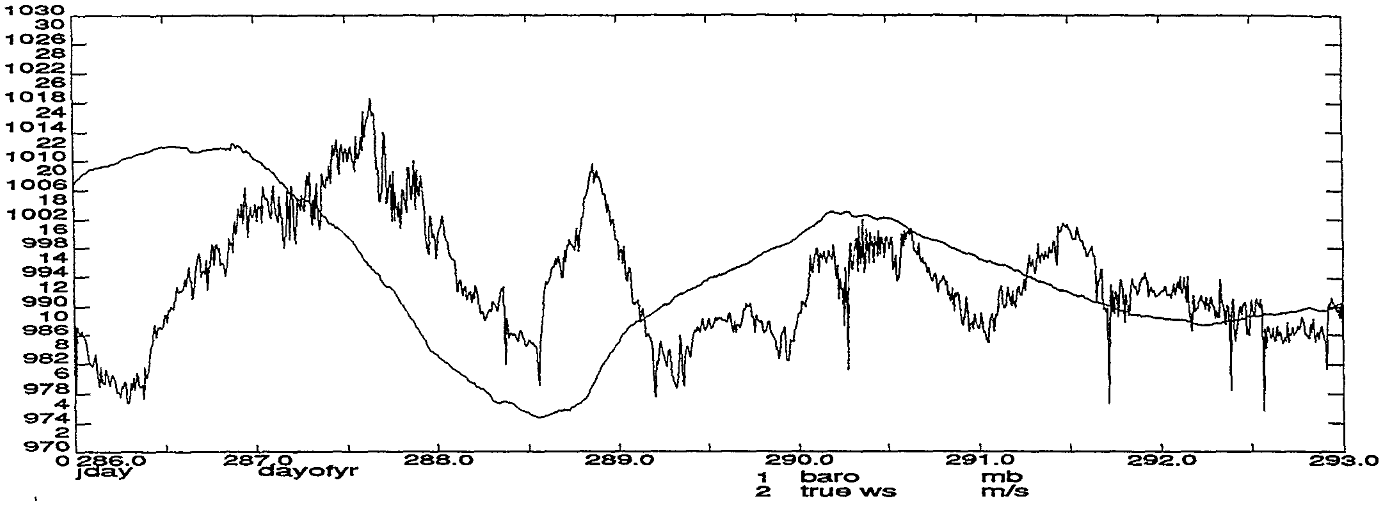
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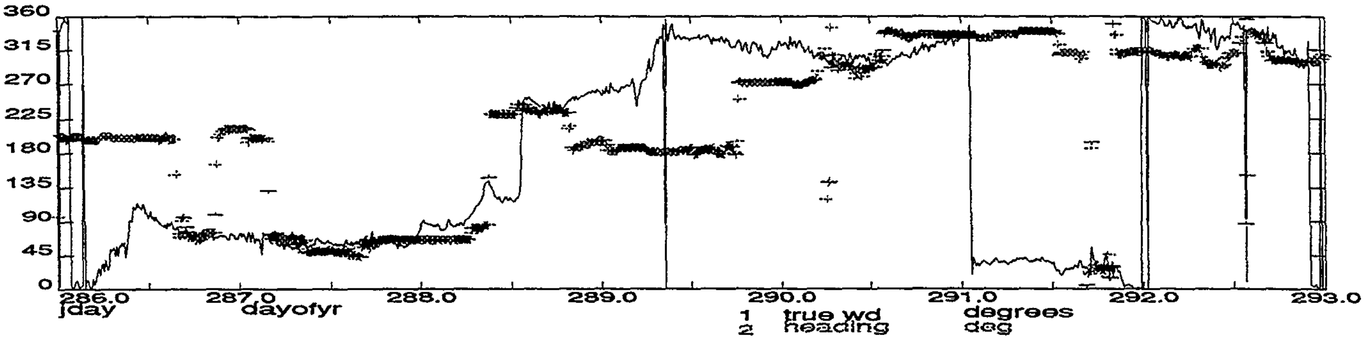
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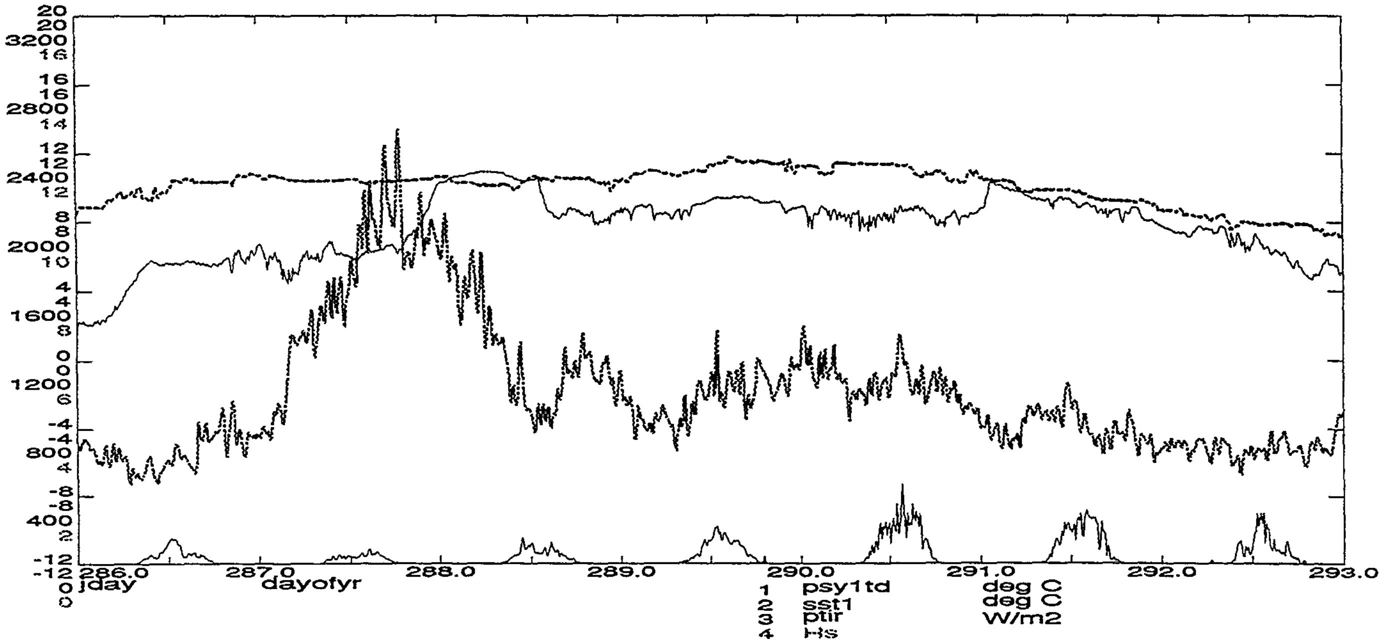
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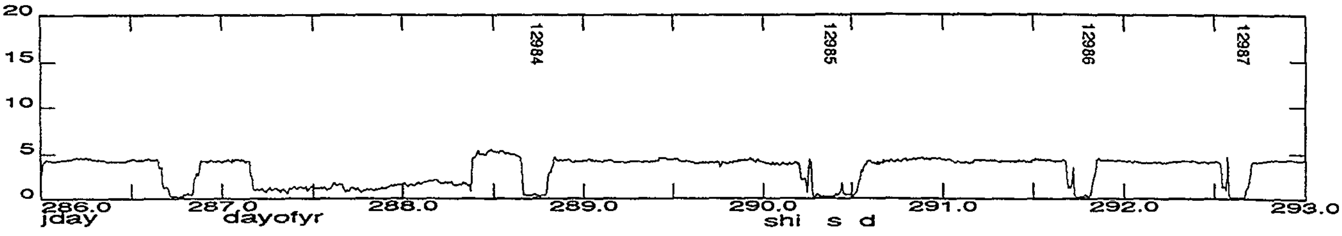
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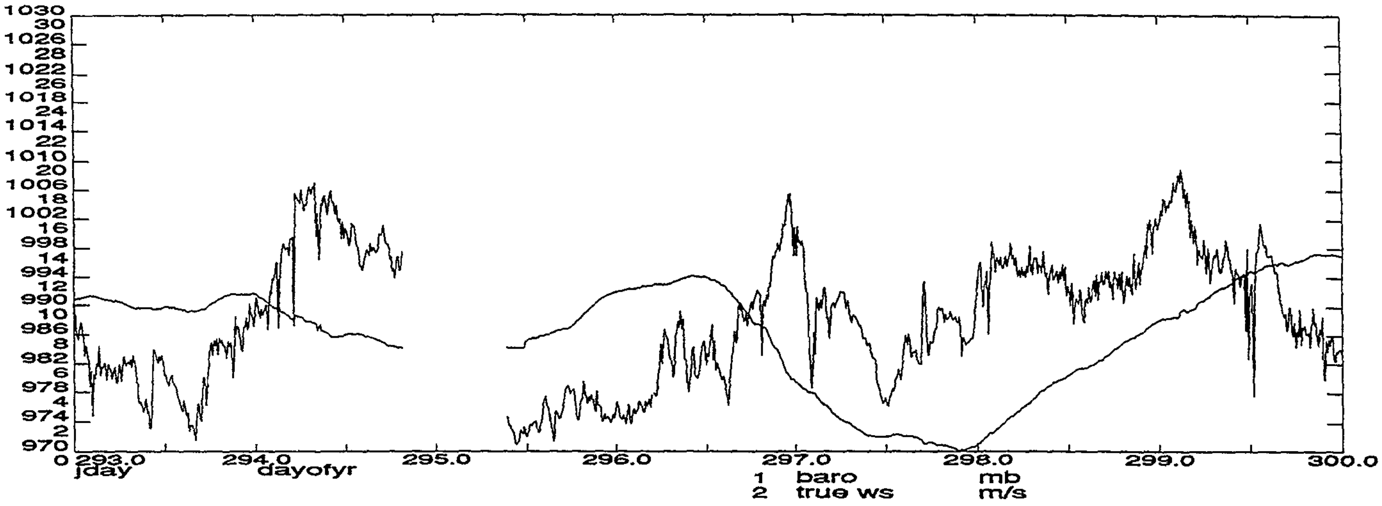
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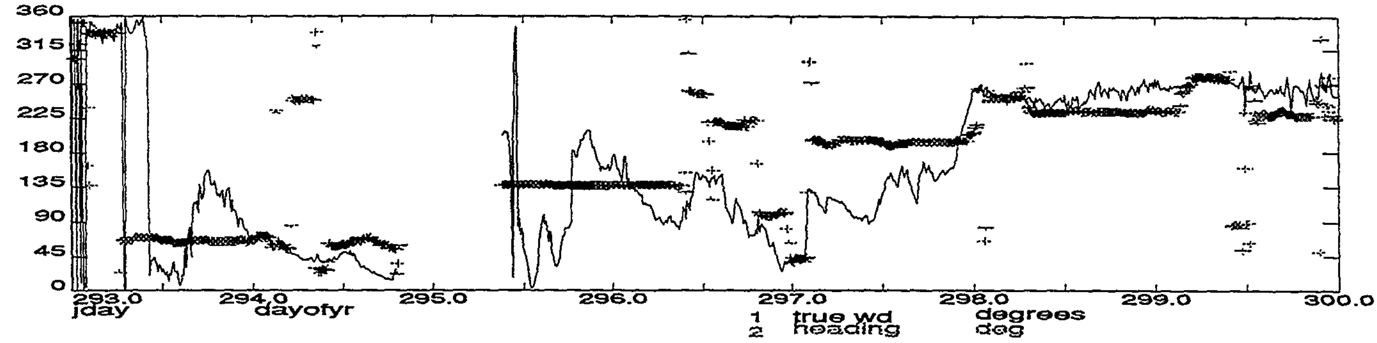
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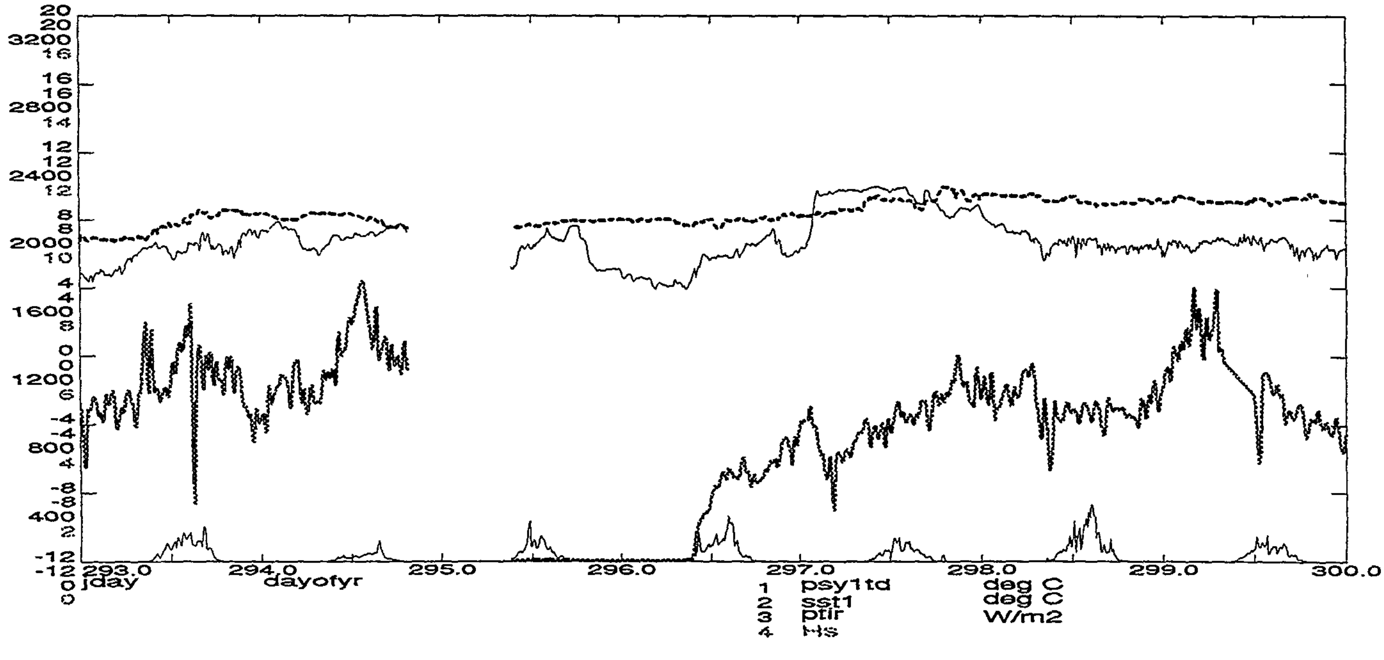
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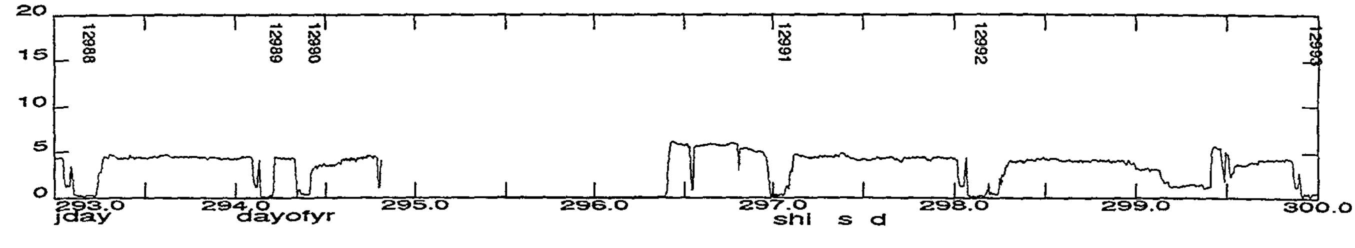
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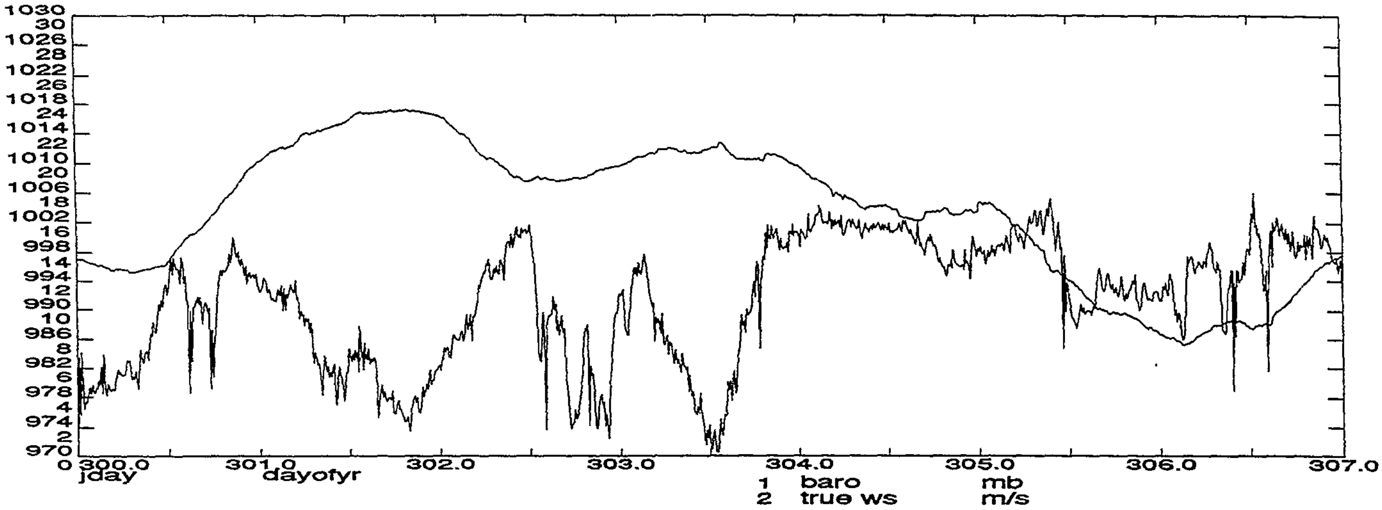
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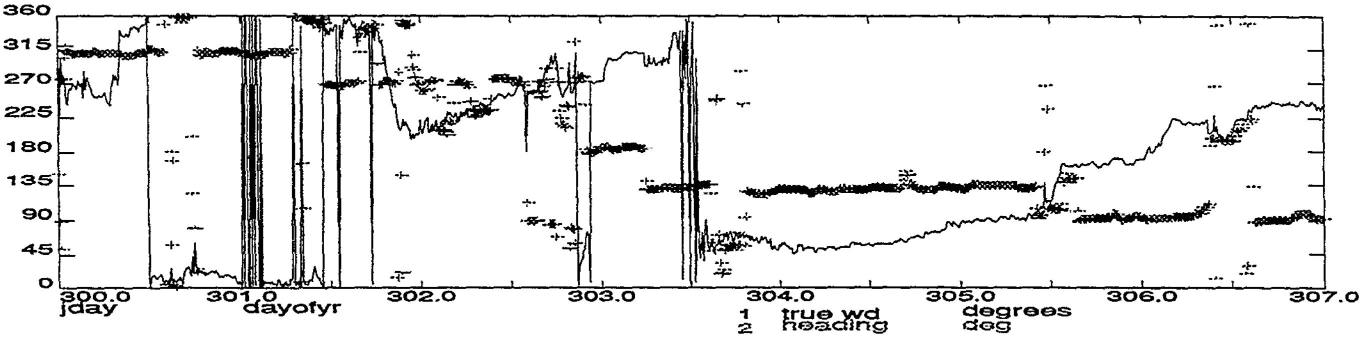
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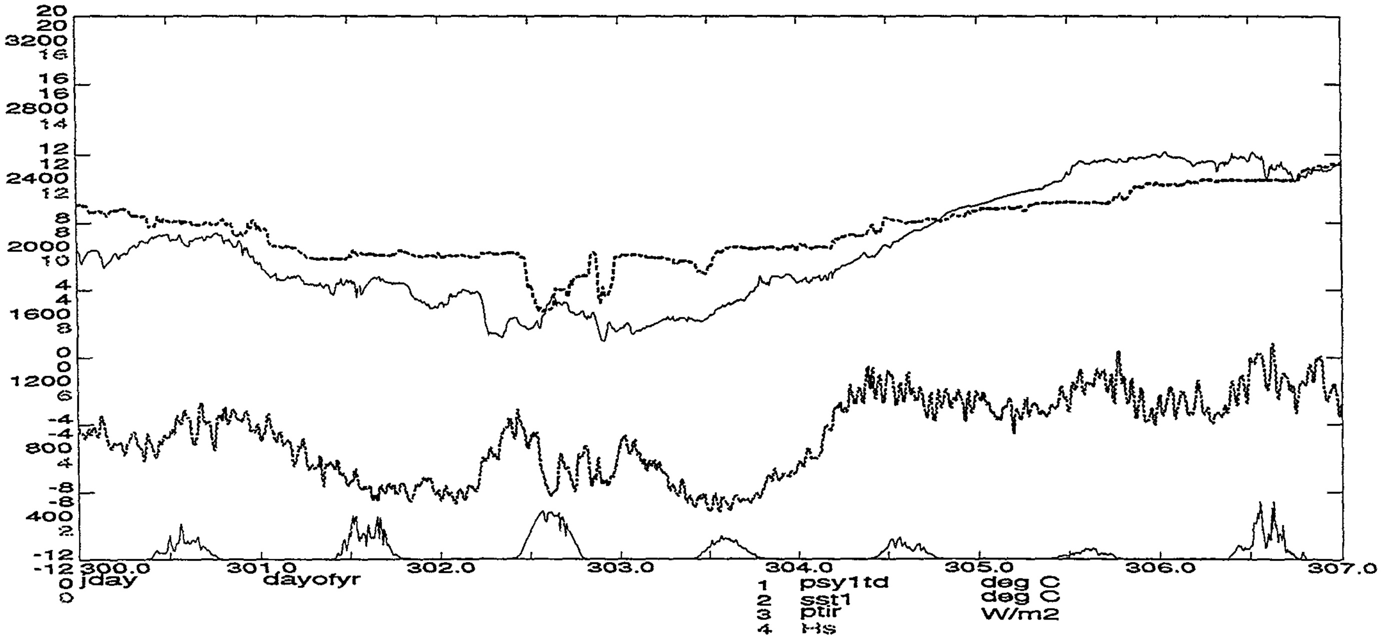
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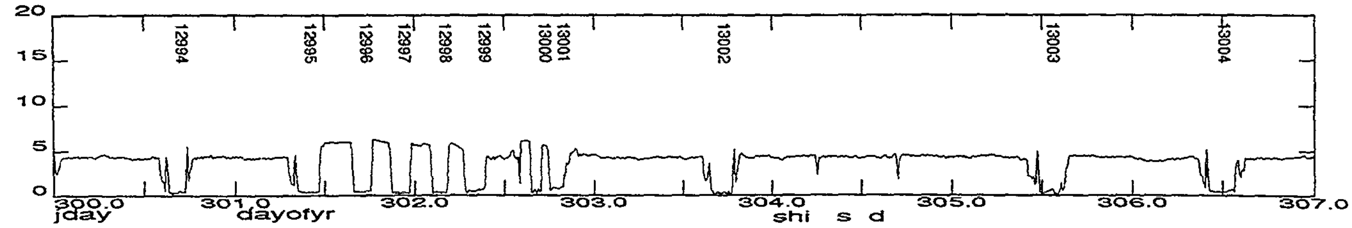
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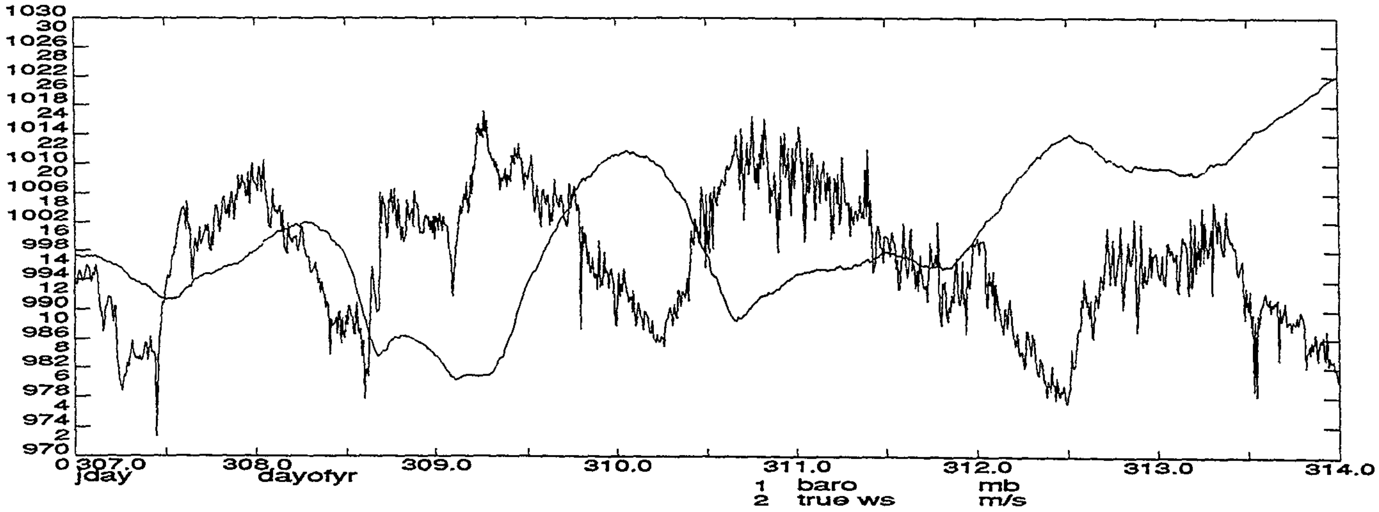
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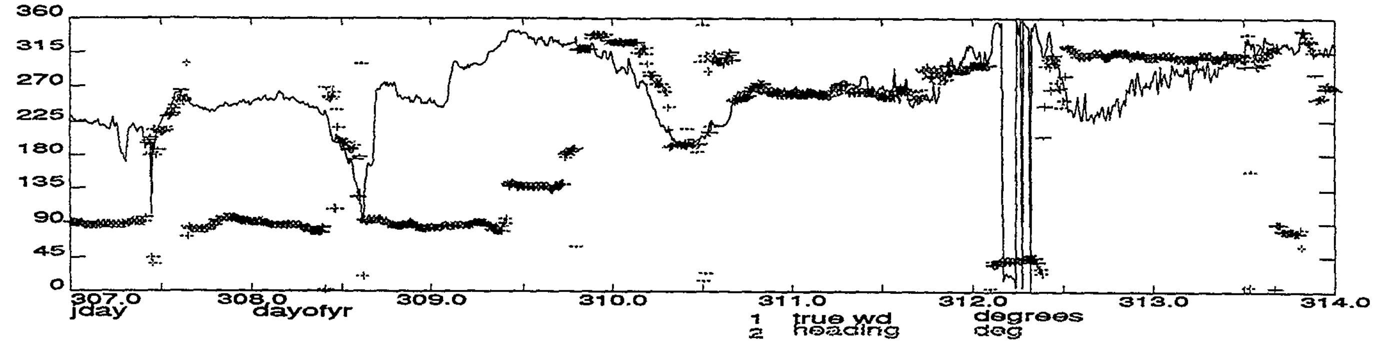
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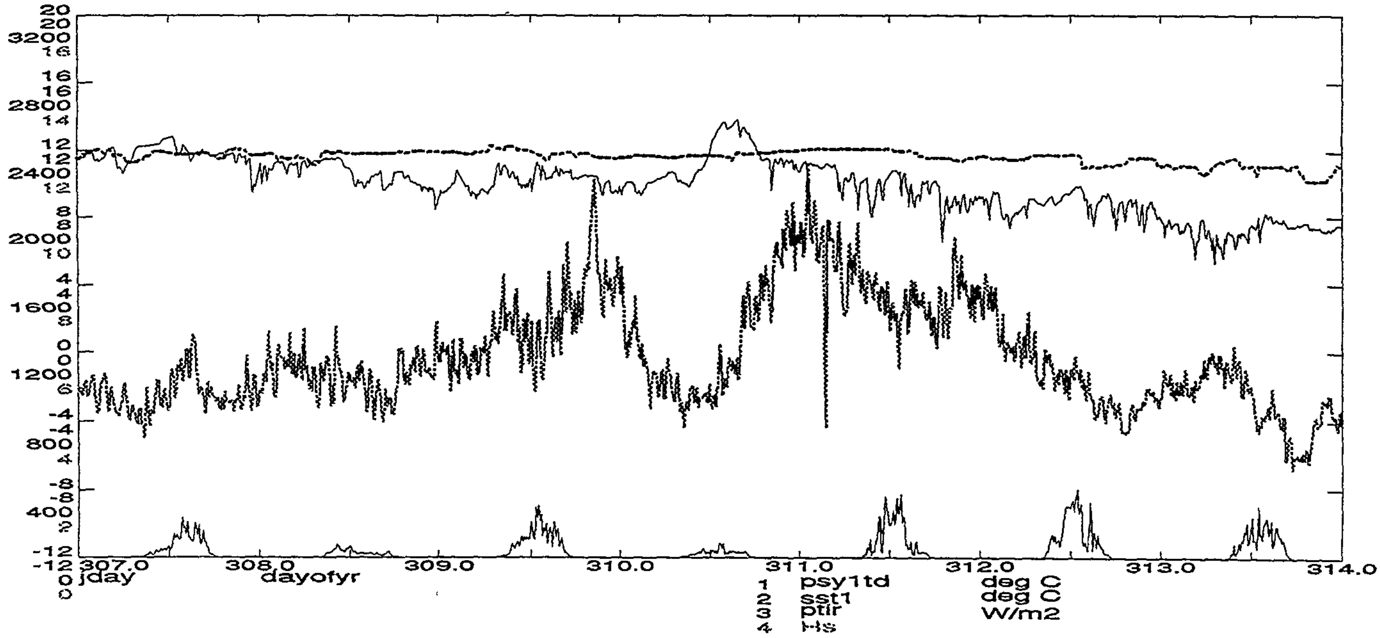
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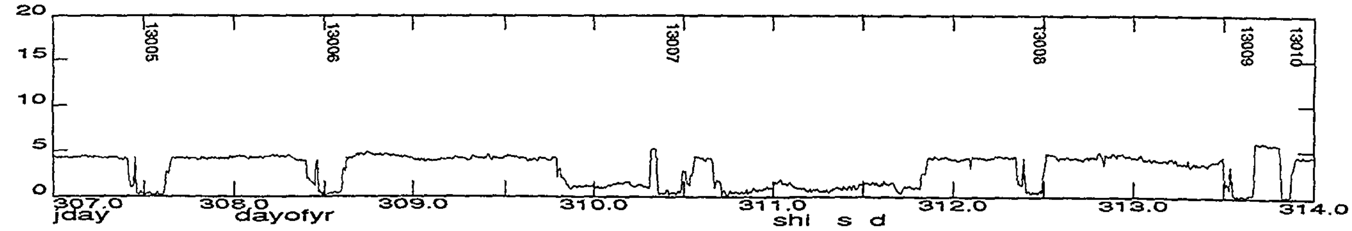
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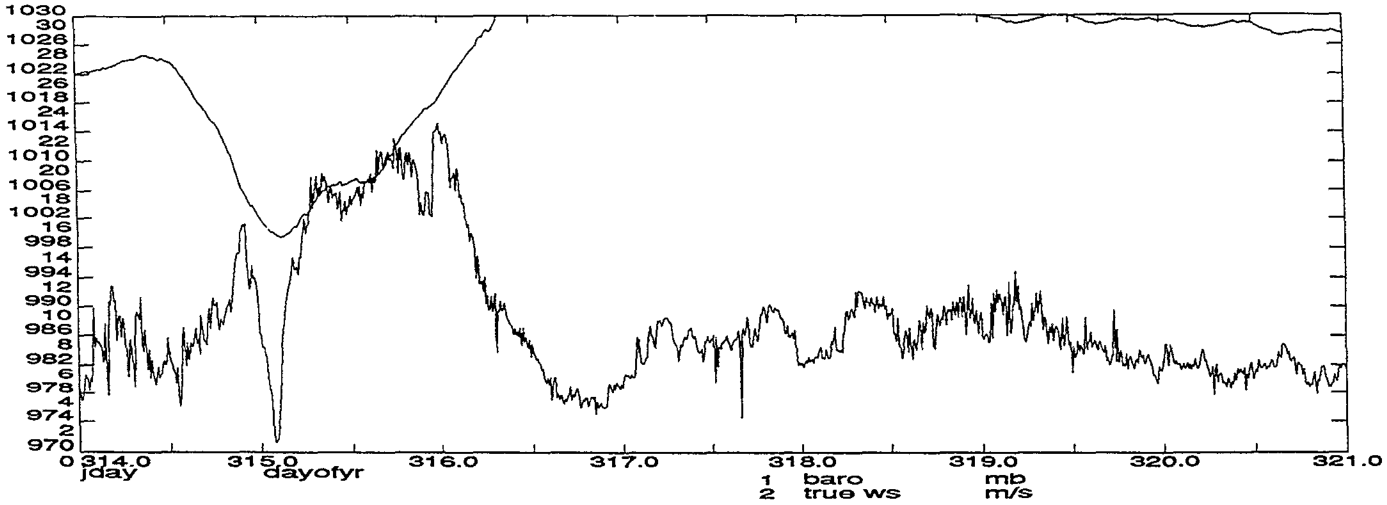
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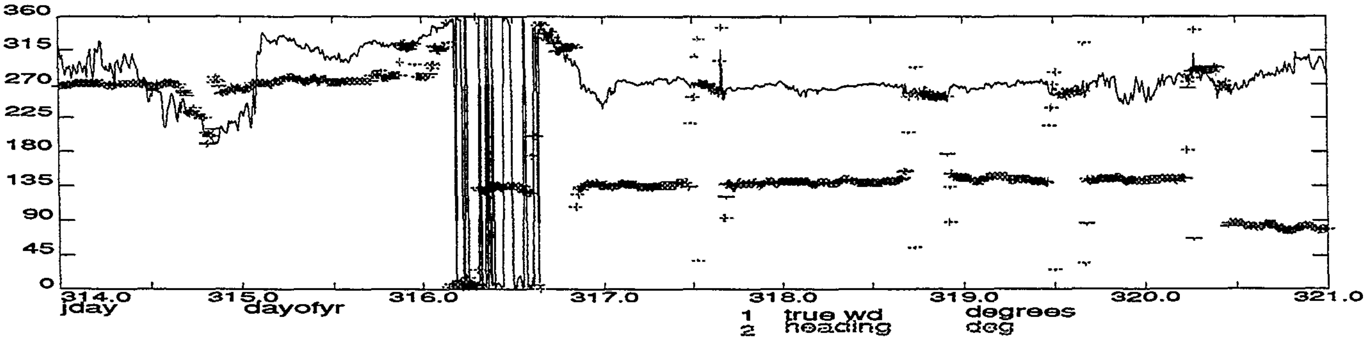
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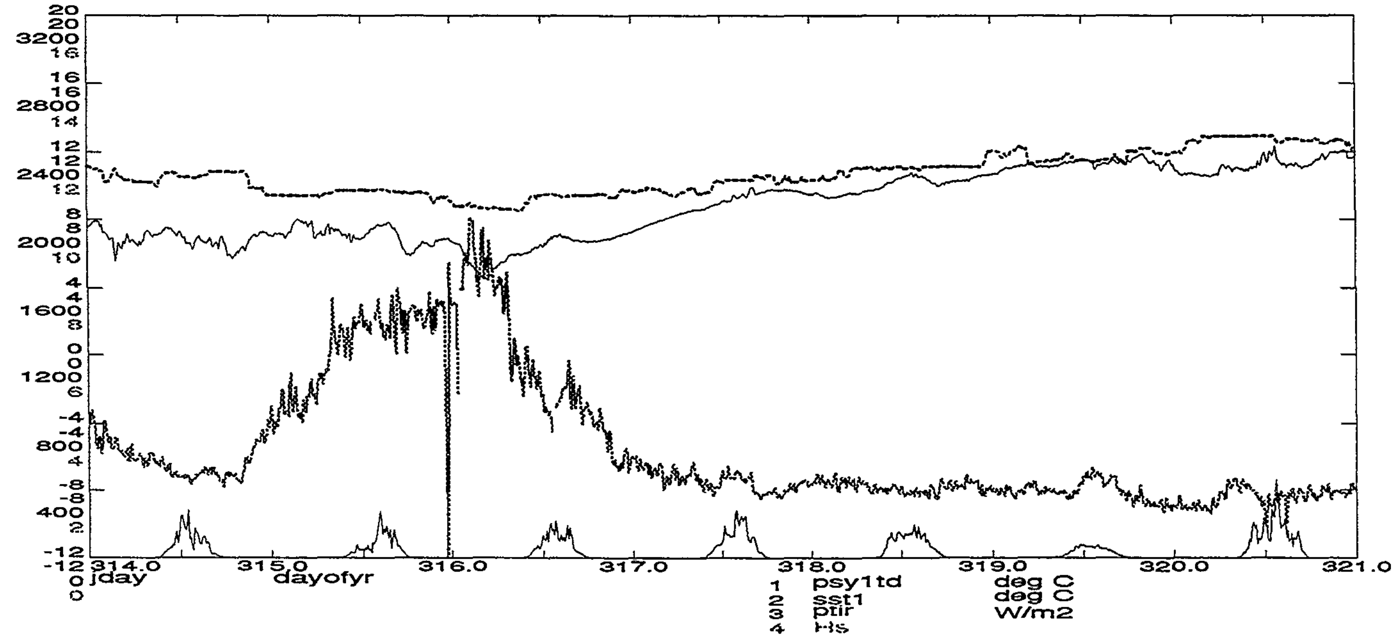
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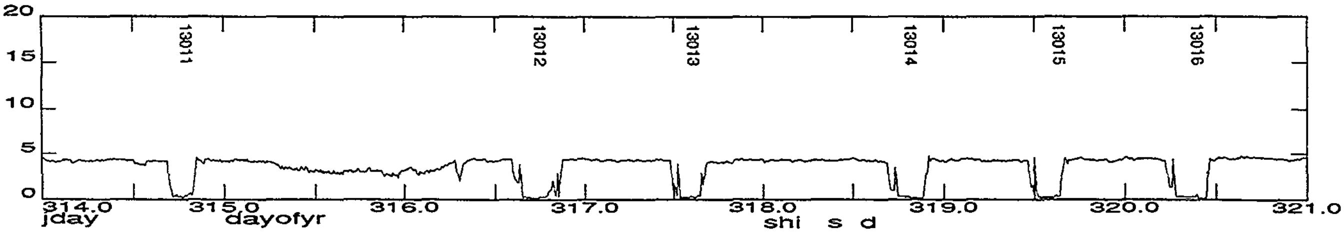
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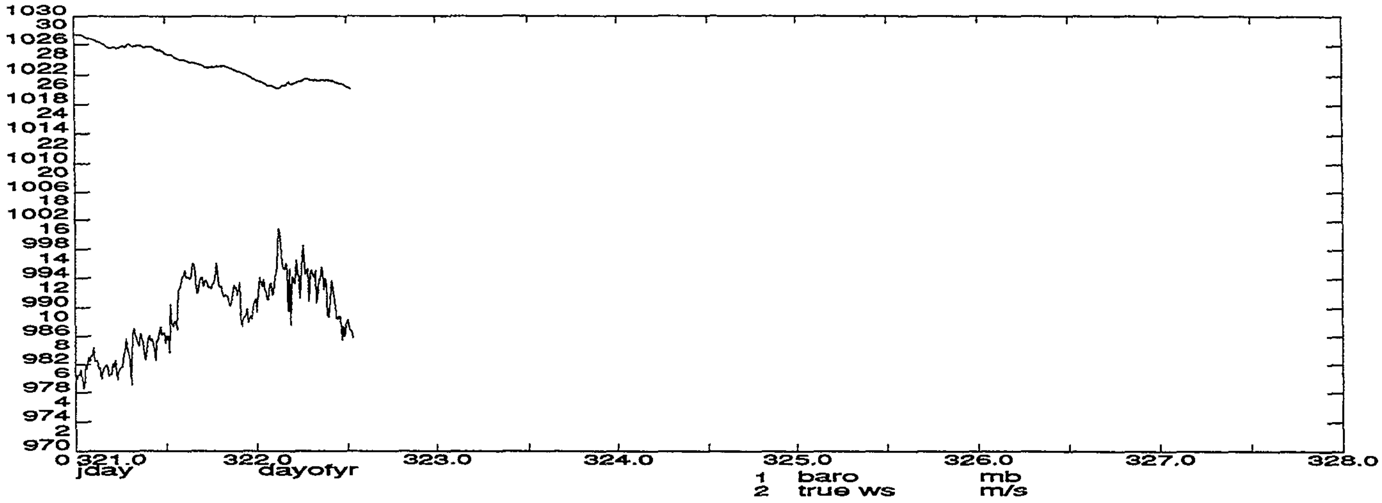
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1010
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1002
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12
990
10
986
8
982
6
978
4
974
2
970
0
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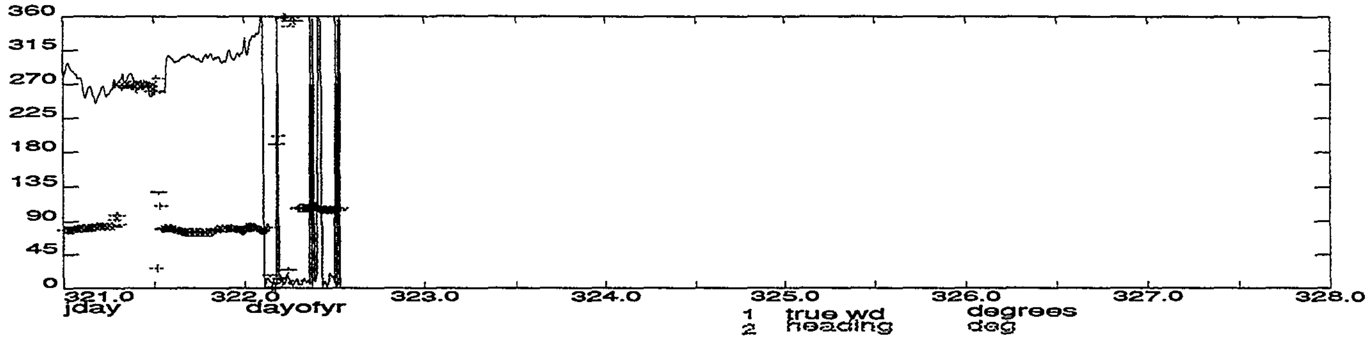
324.0
325.0
326.0
327.0
328.0
jday
dayofyr
1 baro mb
2 true ws m/s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90
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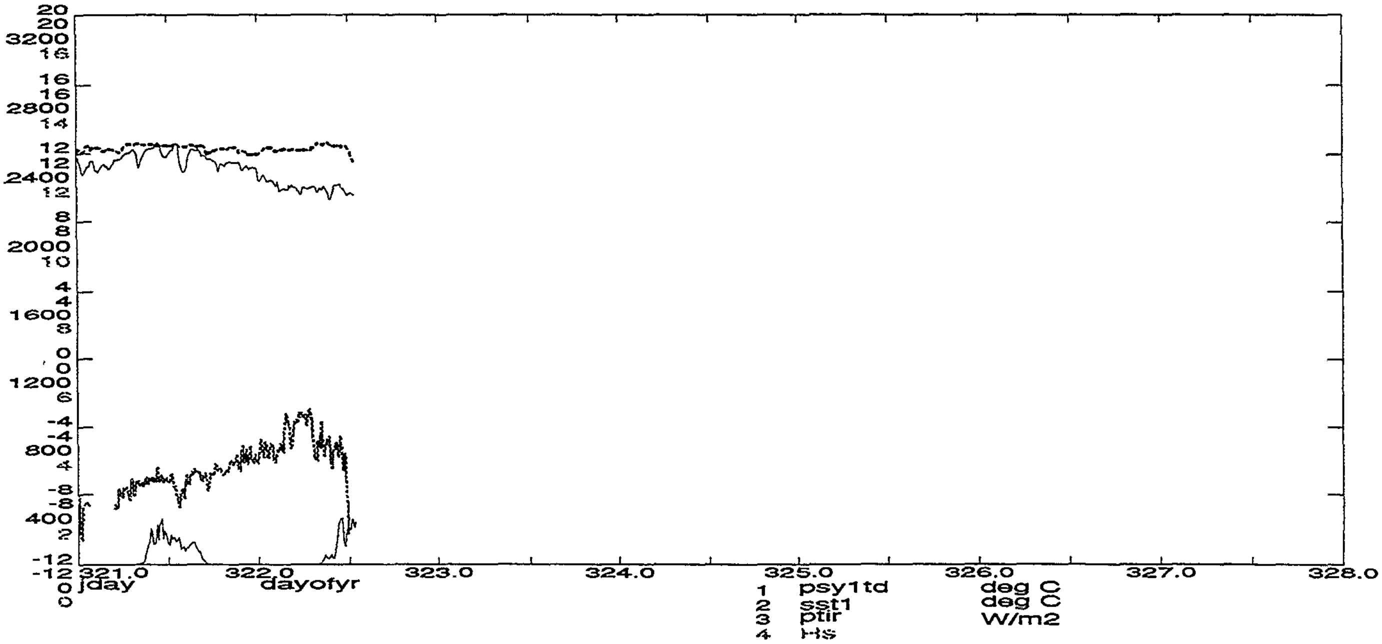
jday
dayofyr
1 true wd degrees
2 heading deg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2000
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1600
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0
0
1200
6
-4
-4
800
4
-8
-8
400
2
-12
-12
0
0
321.0
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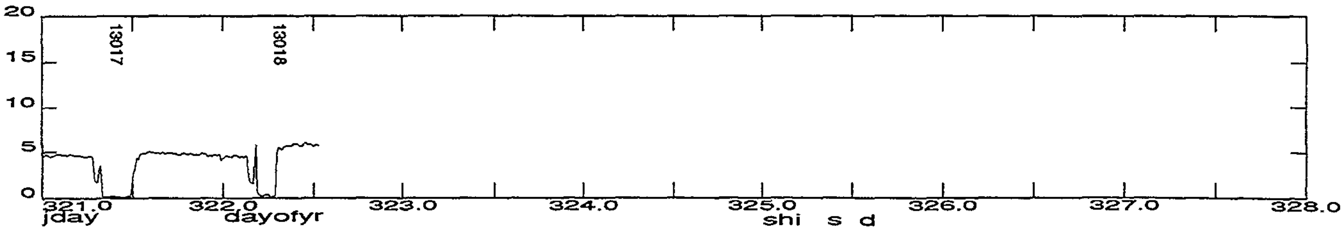
jday
dayofyr
1 psy1td deg C
2 sst1 deg C
3 ptir W/m2
4 Hs


20
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jday
dayofyr
shi s d

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