OMEX I Underway Data Documentation Index

Parent

Home

The OMEX I underway data documentation contains one document file for each underway data file. These contain data from either a cruise leg or an entire cruise. The following documents are included:

1993 Cruises

RV Belgica	BG9309	19 Apr 1993 to 06 May 1993
FS Poseidon	PS200_7	23 Jun1993 to 04 Jul 1993
FS Valdivia	VLD137	23 Jun 1993 to 16 Jul 1993
RV Belgica	BG9322A	21 Sep 1993 to 29 Sep 1993
RV Belgica	BG9322B	03 Oct 1993 to 06 Oct 1993
RRS Charles Darwin	CD83	13 Dec 1993 to 13 Jan 1994
FS Meteor	M27_1	29 Dec 1993 to 17 Jan 1994

1994 Cruises

RRS Charles Darwin	CD84	18 Jan 1994 to 02 Feb 1994
RRS Charles Darwin	CD85	11 Apr 1994 to 07 May 1994
RV Belgica	BG94ZB	11 Apr 1994 to 14 Apr 1994
RV Belgica	BG9412	20 Apr 1994 to 05 May 1994
RRS Charles Darwin	CD86	18 May 1994 to 13 Jun 1994
FS Meteor	M30_1	06 Sep 1994 to 20 Sep 1994

1995 Cruises

RV Belgica	BG9506	03 Mar 1995 to 17 Mar 1995
RRS Charles Darwin	CD94	03 Jun 1995 to 20 Jun 1995
RRS Discovery	DI216	26 Aug 1995 to 12 Sep 1995

FS Poseidon	PS211	31 Aug 1995 to 11 Sep 1995
RV Belgica	BG9521	11 Sep 1995 to 20 Sep 1995
RV Belgica	BG9522	22 Sep 1995 to 29 Sep 1995
RRS Discovery	DI217	27 Sep 1995 to 22 Oct 1995
RRS Charles Darwin	CD97	12 Oct 1995 to 06 Nov 1995

<TIP> The hot links to the individual cruise documents are the BODC cruise mnemonics. These are used throughout the database to label data as belonging to that cruise.

Surface Underway Data for Cruise Belgica 9309

(19 April - 6 May 1993)

1) Components of the Underway Data Set

The underway data set for Belgica 9309 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the underway data file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)
Bathymetric depth (m) (J)

Meteorology: Atmospheric pressure (mb) (1)
Air temperature (°C) (a)
Absolute wind speed (knots) (Y)
Absolute wind direction (degrees blowing from) (Z)
Solar radiation (W/m^2) (O)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

Chemistry: Oxygen conc. at in-situ. temperature and salinity (µM) (Q)
pH (pH scale) (M)
Alkalinity (µEq/kg) ({)
Calculated pCO_2 (ppm) (E)
Calculated TCO_2 (µmol/kg) (H)

2) Underway Instruments and Methodology

Up to three temperature sensors may be mounted in the non-toxic inlet which was located in the bow at a 3.5 m depth. Two of these were Rosemount Pt resistance thermometers whilst the third was the remote thermistor of the SeaBird SBE-21 thermosalinograph. Operational practice is to have one of the Rosemounts on the ship whilst the other is back in Ostend for laboratory calibration checks. The temperature data set provided was derived from the SBE-21, filled in with Rosemount data in case of instrument failure.

The thermosalinograph was a SeaBird SBE-21. A SBE-19 SeaCat, mounted in a custom flow-through housing, is available as a backup for salinity data but was not required on this cruise.

Navigation was based on a GPS system.

Depth used for this data set was from an Altas Deso 33 kHz instrument capable of measuring down to approximately 1200 m. Depth quoted was corrected for sensor depth.

Meteorology data (except for solar radiation) came from a Friedrich Meteorological package mounted on a central mast. Solar radiation was measured by a Kipp and Zonen solar radiometer. This instrument was periodically intercalibrated with instruments based at Brussels University and was also calibrated by the manufacturer in the Netherlands on a regular basis.

Oxygen concentration was measured continuously using a KENT polarographic electrode calibrated against discrete samples analysed by the Winkler method.

pH was measured continuously using a combined ROSS electrode and was calibrated on the total proton scale using buffers proposed by Dickson (1993). The error on the pH was estimated at 0.005 pH units.

Total alkalinity was measured on a discrete sample approximately every 30 nautical miles or every half degree of longitude by electrotitration (Gran method) and was linearly interpolated between samples to give a value every five minutes for the carbon dioxide speciation calculations. Prior to 02/05/1993 a value of 2320 µeq/kg has been taken/assumed as being constant. Errors on measured alkalinity were estimated at 4 µeq/kg.

Carbon dioxide speciation (TCO_2 and pCO_2) have been calculated from alkalinity and pH using CO_2 constants from Mehrbach et al. (1973) for the period 20/4/93 to 3/5/93 and from Goyet and Poisson (1989) for the period 4/5/93 to 6/5/93. The borate constant was from Hansson (1973) and the carbon dioxide solubility coefficient from Weiss (1974). The calculation was done on a one minute time base and then averaged over five minutes. The error on pCO_2 is estimated to 8-10 ppm. Further details are given in Frankignoulle et al. (1986, 1996).

3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key. Data sets worked up post cruise were also merged, again linked using time. Note that some of the automatically logged data were supplied in Belgian local time (GMT+2), but have been corrected to GMT. The oxygen and carbonate system data were supplied with a GMT time channel.

Wind speeds supplied in m/s have been converted to knots by multiplying by 1.943845.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to carry out comparative screening checks between channels by overlaying data channels. Oceanographic context was taken into account through simultaneous display of a map of the cruise track.

4) BODC Calibration Procedures and Quality Control

4.1) Navigation and Bathymetry

At BODC a program was run that located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots.

Two gaps in navigation were found, one corresponding to Belgica being docked in Vigo for 3 days, between 24-27/04/1993 and the other on 02/05/93 07:16 which lasted nearly 2 hours. As the ship was on a straight track during the latter, the gap has been filled by linear interpolation. No speed check failures were encountered.

The bathymetry data in water deeper than 500m were extremely noisy with misleading shallow signals (possibly secondary reflections) and have been completely flagged out. The other underway channels were either clean or contained a small number of obvious spikes that have been flagged suspect. It is not known whether a correction for variation of sound velocity in sea water has been applied.

4.2) Meteorology

Visual inspection of the meteorology channels didn’t reveal any major problems.

A couple of obvious spikes on the atmospheric pressure and air temperature channels were flagged. The air temperature data compare well with the sea temperature data.

A small number of solar radiation spikes were flagged. Dawn and dusk times are credible.

Some spikes on wind speed and direction were flagged. No evidence of course changes influencing the data could be seen.

4.3) Physics

Temperature and Salinity

The thermosalinograph salinity record has no data prior to 09:20 on 27/04/1993. The values were set null in the data files supplied and are presumed to have been rejected by MUMM quality control.

The salinity data are exceedingly noisy during the 27th and 28th when Belgica was working in the rias in the NW of the Iberian peninsula, with frequent jumps of several PSU. These are regions of strong freshwater influence, making it difficult to differentiate instrumental artefacts from genuine signal. Consequently, flagging of the data at these times has been kept to a minimum, leaving decisions as to what is real to the user's judgement.

The visual inspection also revealed two worrying features in the data. Gaps in the record occur from 23:05 on 27/4/93 to 06:45 on 28/4/93 and from 12:00 to 12:30 on 29/4/93. The record before and after each of these gaps appears relatively stable but data values after the gaps show increases of 0.31 and 0.42 PSU respectively over the values prior to the gaps. An attempt was made to ascertain whether these jumps were real through detailed examination of the intercalibration against CTD salinities. However, the results were inconclusive due to the level of noise. Only three CTD casts coincided with times when the underway record was reasonably stable and the conclusion from these ranged from exact coincidence to the underway value being 1.1 PSU low. **Therefore the underway salinity values prior to 12:30 on 29/04/1993 should be used with caution.** After this time, the excellent agreement between CTD and thermosalinograph salinities show that the underway salinity data may be used with confidence.

The temperature was back calibrated against surface CTD data. A constant correction of -0.06927 °C was determined for the whole cruise and this has been applied to the data.

Surface CTD data were also used to calibrate salinity. From the statistical analysis, the required correction was determined as -0.00021: effectively zero. It should be noted that this calibration is based on CTD casts between 12:42 on 29/4/93 and 19:50 on 5/5/93.

4.4) Chemistry

All channels have been screened to remove spikes. Oxygen, alkalinity, pH and carbon dioxide speciation parameters were measured, interpolated or calculated every minute and then averaged over five minutes by the data originator.

pH

The pH data were supplied as calibrated data and have been entered into the data file unmodified. The error on pH was given as 0.005 pH units.

Oxygen

Data were supplied to BODC as oxygen saturation pre-calibrated against discrete samples analysed by the Winkler method. In-situ oxygen concentration has been calculated using the calibrated salinity and temperature data and the algorithm of Benson and Krause (1984). In cases where no valid salinity was available, an assumed value of 35 has been used.

Total Alkalinity and carbon dioxide speciation.

Data were supplied to BODC as fully worked up data - no further calibration has been applied beyond converting the alkalinity and TCO_2 data from mmol/kg to µmol/kg. Further details of the calibration procedures are given in Frankignoulle et al. (1986, 1996). Errors on the alkalinity and pCO_2 channels were estimated to be 4 µeq/kg and 8-10 ppm respectively.

5) Acknowledgements

The oxygen, pH, alkalinity and carbon dioxide speciation measurements were funded as part of the Belgian Impulse Programme on Global Change (contract no. GC/12/011). However, the data have been generously contributed by Michel Frankignoulle to enhance the OMEX data set.

6) Data Warnings

The thermosalinograph salinity data from the start of the included record (09:20 on 27/04/1993) to 12:30 on 29/04/1993 should be used with caution. There is no problem from this time until the end of the cruise.

7) References

Benson, B.B., Krause D. (1984). The concentration and isotopic fractionation of oxygen dissolved in fresh water and sea water in equilibrium with the atmosphere. ***Limnol.Oceanogr.*** 29 pp.620-632.

Dickson, A.G. (1993). PH buffers for sea-water media based on the the total hydrogen-ion concentration scale. ***Deep-Sea Research*** 40 pp.107-118.

Frankignoulle, M., Bourge, I., Canon, C., Dauby, P. (1986). Distribution of surface seawater partial CO_2 pressure in the English Channel and in the Southern Bight of the North Sea. ***Continental Shelf Research*** 16 pp.381-395.

Frankignoulle, M., Elskens, M., Biondo R., Bourge, I., Canon, C., Desgain S. & P. Dauby (1996). Distribution of inorganic carbon and related parameters in surface seawater of the English Channel during Spring 1994. ***Journal of Marine Systems*** 7 pp.427-434.

Goyet, C., Poisson A. (1989). New determination of carbonic-acid dissociation constants in sea-water as a function of temperature and salinity. ***Deep-Sea Research*** 36 pp.163-165.

Hansson I. (1973). A new set of acidity constants for carbonic acid and boric acid in sea water. ***Deep-Sea Research*** 20 pp.461-478.

Mehrbach, C., Culberson, C.H., Hawley, J.E. and Pytkowicz, R.M. (1973). Measurement of the apparent dissociateion constants of carbonic acid in seawater at atmospheric pressure. ***Limnol. Oceanogr.*** 18 pp. 897-907.

Weiss, R.F. (1974). Carbon dioxide in seawater: the solubility of a non-ideal gas. ***Marine Chemistry*** 2 pp. 203-215.

Surface Underway Data for Cruise Poseidon 200 Leg 7

(23 June - 4 July 1993)

1) Components of the Underway Data Set

The underway data set for Poseidon 200_7 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)
Distance Run (km) (K)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

Note that the binary merge file also contains two dummy channels (# and () because binary merge format requires at least 7 data channels. These are filled with null values.

2) Methodology Overview and Calibration Procedures

Obtaining information about the systems and operational procedures has proved to be surprisingly difficult. Several requests for information have failed to provide the detailed technical data we require for complete documentation. What follows is therefore a little sketchy.

The navigation system used is not known but it seems inconceivable that any system other than GPS would be used on a cruise in 1993.

The fact that a thermosalinograph was operating indicates that the ship is equipped with a continuous pumped seawater supply. The intake depth is not known. The type of thermosalinograph used is not known. The data supplied were initially sampled every five minutes but this increased to 2 minute sampling on June 26th. The data file supplied contained date/time, latitude, longitude, temperature and conductivity.

It is not known for certain how the temperature and conductivity data relate as we have no information on how the sensors were mounted. The fact that intercalibration against the CTD data required a small correction to temperature indicates that the temperature sensor was located in the pumped supply inlet. The relatively large salinity correction may indicate that the conductivity cell was elsewhere.

The time zone has not been explicitly stated but there is reasonable evidence that it is GMT (the record matches event timings in the cruise report that are explicitly labelled GMT).

3) BODC Data Processing

3.1) Reformatting and screening

Salinity was computed from the temperature and conductivity supplied by first dividing conductivity by 42.914 (to give conductivity ratio) and then using the standard UNESCO Practical Salinity algorithm (Fofonoff and Millard, 1982). The data were then merged onto a regular two minute time base.

A navigation check program was run that identifies gaps in the navigation and reports if the ship's speed exceeds 15 knots over the ground. The navigation data were shown to contain a lot of large (up to 8 hours duration) gaps, particularly prior to 13:30 on 27/06/1993 when the data points were at approximately 4-hourly intervals. More puzzling was the fact that the gaps in latitude and longitude did not coincide.

A number of unresolved speed check failures remain in the data:

60.7 knots from 00:05 to 00:15 on 27/06/93
29.6 knots from 13:33 to 16:41 on 27/06/93
33.4 knots from 12:45 to 13:05 on 01/07/93

Null values were filled by linear interpolation and the distance run channel was generated from adjacent latitude/longitude pairs using spherical trigonometry.

The data were inspected on a graphics workstation. This revealed that the latitude data from 13:30 to 17:00 on 27/06/93 had a very odd 'stepped' appearance that is probably the cause of one of the speed check failures described above.

Inspection of the temperature and salinity data revealed few problems and only odd isolated, relatively small spikes were flagged suspect.

3.2) Calibrations

The temperature was back calibrated against surface CTD data. A constant offset of -0.043 °C was determined for the whole cruise and this has been applied to the data.

Salinity was back calibrated against a surface CTD data set comprising 15 values. From this analysis, the required correction was determined as -0.352 PSU. This has been applied to the data.

4) Data Warnings

The navigation data from this cruise give cause for concern due to the large number of gaps and significant speed check failures. The latitude data between 13:30 and 17:00 on 27/06/93 have serious problems. Consequently, whilst the data may be deemed adequate for providing the temperature and salinity data with spatial context they should not be regarded as the primary master navigation for the cruise and higher regard should be paid to station positions from the cruise report.

5) Reference

Fofonoff, N.P., Millard Jr., R.C. (1983). Algorithms for computation of fundamental properties of seawater. UNESCO Technical Papers in Marine Science 44.

Surface Underway Data For Cruise Valdivia 137

(23 June - 16 July 1993)

1) Components of the underway data set

The underway data set for Valdivia 137 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation:	Latitude	(A)
	Longitude	(B)
	Distance Run	(K)
Meteorology:	Absolute Wind Speed	(Y)
	Absolute Wind Direction	(Z)
	Solar Radiation	(O)
	Dry Bulb Air Temperature	(a)
	Wet Bulb Air Temperature	(b)
	Dew Point Temperature	(c)
	Barometric Pressure	(1)

2) Methodology Overview

2.1) Data Acquisition

Logging and initial processing of the data was handled by the Valdivia logging system. Calibrated data were sent to BODC and merged into the underway file. It is not known when the instruments were last calibrated prior to the cruise.

2.2) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key on a 10 minute time base to match the data supplied. The time channel in the input data was explicitly labelled GMT.

The output from each sensor was screened for spikes using a combination of editing software and manual editing on workstations. Any spikes or periods of dubious data were flagged. Wherever possible, comparative screening checks between channels were performed.

3) Methodology and calibration procedures

3.1) Navigation

Global Positioning System (GPS) was the primary navigation system used on this cruise.

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground didn't exceed 15 knots. These null values were then filled by linear interpolation. The data from this cruise included a single gap from 21:00 to 23:00 on 06/07/1993. No speed check failures were encountered.

The distance run channel was calculated from latitude and longitude using spherical trigonometry.

3.2) Meteorology

Valdivia was fitted with a package of meteorological instruments comprising:

- psychrometers (dry and wet bulb temperatures)
- relative humidity sensor
- Vector anemometer (mean wind speed)
- Vector wind vane (mean wind direction)
- barometer (air pressure)
- Kipp and Zonen pyranometer (solar radiation)
- long wave pyranometers (upwelling/downwelling long wave radiation)

Air Temperature

Air temperature was measured by an aspirated psychrometer, incorporating Pt100 resistance thermometers. The calibration regime of the psychrometer is not known. Wet and dry bulb temperature readings were supplied as absolute values to BODC. Both dry and wet bulb temperatures contain credible data with few obvious spikes. The fine structure in the wet and dry bulb temperatures correlates well and therefore the data are thought to be of a high quality. No flagging was required.

Relative Humidity.

The relative humidity data had an obvious problem. Much of the record was saturated at 100% indicating rain. However, wet and dry bulb temperatures were nowhere near equal and the solarimeter values at midday were regularly exceeding 900 W/m^2 indicating bright sunshine. Consequently, the relative humidity channel has been deleted from the data set.

Dew Point Temperature

This channel was supplied to BODC in its final form. It had presumably been calculated from the wet and dry bulb data..

Wind Velocity

The wind velocity data set contains the absolute wind velocity corrected for the ship's velocity exactly as supplied to BODC. It is not known when the instrument was last calibrated prior to the cruise. Four anemometer channels were supplied. The data from the mainmast instrument were selected following advice from IFM Hamburg. Wind speed has been converted from m/s to knots by multiplying by 1.943845.

During screening no evidence of shadowing by the ship's superstructure was observed and it was apparent that the absolute wind velocity was truly independent of ship's velocity.

Barometric Pressure

Absolute barometric pressure values were supplied to BODC. The data were examined on a graphics workstation and a few small spikes were flagged suspect.

Radiation

The meteorological package included a Kipp and Zonen solarimeter plus upwelling and downwelling long wave radiation sensors. The Kipp and Zonen instrument measured 'short wave radiation' from 300-3000 nm (predominantly visible plus infrared) using a planar detector. Absolute readings were supplied to BODC. The data showed an excellent diurnal pattern.

The upwelling and downwelling long wave radiation signals were saturated at a constant value for much of the record and have consequently been deleted from the data set.

Surface Underway Data for Cruise

Belgica 9322 Leg A (21 - 29 September 1993)

1) Components of the Underway Data Set

The underway data set for Belgica BG9322 Leg A contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (degrees +ve N) (A)
Longitude (degrees +ve E) (B)

Meteorology: Atmospheric pressure (mb) (1)
Wind speed (knots) (Y)
Wind direction (degrees blowing from) (Z)
Solar radiation (W/m^2) (O)
Air temperature (°C) (a)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

Chemistry: Nitrate + nitrite (µM) (T)
Silicate (µM) (W)
Oxygen conc. at in-situ. temperature and salinity (µM) (Q)
pH (pH scale) (M)
Alkalinity (µEq/kg) ({)
Calculated pCO_2 (ppm) (E)
Calculated TCO_2 (µmol/kg) (H)

2) Underway Instruments and Methodology

Up to three temperature sensors were mounted in the non-toxic inlet which was located in the bow at 3.5 m depth. Two of these were Rosemount Pt resistance thermometers whilst the third was the remote thermistor of the SeaBird SBE-21 thermosalinograph. Operational practice was to have one of the Rosemounts on the ship whilst the other was back in Ostend for laboratory calibration checks. The SBE-21 was taken as the primary source of sea temperature data with infill from the Rosemounts in case of failures.

The thermosalinograph was a SeaBird SBE-21. A SBE-19 SeaCat was also mounted in a custom through-flow housing as a back up for salinity but was not required during this cruise.

Navigation was logged from a GPS system.

Meteorology data (except for solar radiation) came from a Friedrich Meteorological package mounted on the central mast. Solar radiation was measured by a Kipp and Zonen solar radiometer. This instrument was periodically intercalibrated with instruments based at Brussels University and was also calibrated by the manufacturer in the Netherlands on a regular basis.

Nutrients were determined using a Technicon AA2 autoanalyser taking discrete samples from a continuous non-toxic feed through a small tank mounted on the sample changer platform. MilliQ blanks were taken after each sample. The detection limits for nitrate and silicate were 0.1 and 0.5 µM respectively. The continuous water supply was pre-filtered through a 60 µm screen. Values were determined every 3 minutes and the instrument was calibrated every 2-4 hours.

Oxygen concentration was measured continuously using a KENT polarographic electrode frequently calibrated against discrete samples analysed by the Winkler method. Saturation was calculated using the equation proposed by Benson and Krause (1984). Oxygen was logged at 1 minute between 24/04/1994 21:20 and 26/04/1994 04:20 and averaged on 5 minutes for the binary merge file.

pH was measured continuously using a combined ROSS electrode and was calibrated on the total proton scale using buffers proposed by Dickson (1993). The error on the pH was estimated to 0.005 pH units.

Total alkalinity was measured about every 30 nautical miles by electrotitration (Gran method) and was linearly interpolated between samples for the carbon dioxide speciation calculations. Errors on alkalinity were estimated at 4 µeq/kg.

Carbon dioxide speciation (TCO_2 and pCO_2) was calculated using constants from Goyet and Poisson (1989), borate constant from Hansson (1973) and the carbon dioxide solubility coefficient from Weiss (1974). The carbon dioxide parameters were measured every minute and averaged over 5 minutes. Further details are given in Frankignoulle et al. (1986, 1996).

A through flow Turner Designs fluorometer was plumbed in to the non-toxic supply for this cruise. MUMM reported that it did not work well due to rapid deterioration of the connections to the seawater supply. A visual examination of the data showed that whilst there were positive and negative numbers in the data set, a signal could be discerned. However, comparison with the extracted chlorophyll data showed no significant correlation (r=0.3) confirming MUMM's concerns. **Consequently, the data have been rejected and the channel deleted from the data set.**

3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key. Data sets worked up post cruise were also merged, again linked using time. Note that some of the automatically logged data were supplied in Belgian local time (GMT+2), but have been corrected to GMT. The meteorology, oxygen and carbonate system data were supplied with a GMT time channel.

Wind speeds supplied in m/s have been converted to knots by multiplying by 1.943845.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to carry out comparative screening checks between channels by overlaying data channels. Oceanographic context was taken into account through simultaneous display of a map of the cruise track.

4) BODC Calibration and Quality Control

4.1) Navigation

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots.

One significant gap in navigation was found, lasting 1 hour 26 minutes from 12:00 to 13:26 on 25/09/93. This was filled in by linear interpolation together with a number of smaller gaps of 1-2 minutes duration. There were no speed check failures.

4.2) Meteorology

Atmospheric Pressure

The atmospheric pressure data appeared generally good except for a small number of obvious spikes that have been flagged suspect. A jump from 1020 to 1024 mb between adjacent 5 minute readings at 12:30 on 25/09/1993 looked suspicious but has not been flagged.

Wind Velocity

The data appeared generally good with a handful of spikes flagged. On two occasions, significant changes in wind direction coincided with course changes. These may possibly be due to intermittent loss of signal from the equipment that provided ship velocity data to the data acquisition system.

Radiation

The solar radiation data showed a clear diurnal signal. A few spikes, including a short period of negative value dropout, required flagging. Values were low, under 100 W/m^2, but were in keeping with the bad weather encountered on this cruise.

Air Temperature

No problems were identified with these data and values appeared credible when compared to sea surface temperature.

4.3) Physics

Temperature and Salinity

Some flagging of the temperature channel was required, but the data were generally good.

The temperature was back calibrated against surface CTD data. A constant correction of -0.146 °C was determined for the whole cruise and this has been applied to the data.

Salinity quality was variable. The record was clean for much of the time but on 24/09/1993 and 25/09/1993 there were a large number of low value spikes that required flagging.

Surface CTD data were used to calibrate salinity. From the statistical analysis, the required correction was determined as +0.094 PSU prior to 24/09/1993 22:00 and +0.041 PSU afterwards. These have been applied to the data.

4.4) Chemistry

All channels have been screened to remove spikes. Oxygen, alkalinity, pH and carbon dioxide speciation parameters were logged every minute and averaged to five minutes by the data originator. Data were available for the period 21/09/1993 20:29 to 23/09/1993 02:23.

Nutrients

Nitrate plus nitrite and silicate were supplied to BODC as a worked up data set. No flagging was required.

pH

The pH data were supplied as calibrated data and have been entered into the data file unmodified. The error on pH was given as 0.005 pH units. A handful of pH values have been flagged.

Oxygen

Data were supplied to BODC as oxygen saturation pre-calibrated against discrete samples analysed by the Winkler method. In-situ oxygen concentration has been calculated using the calibrated salinity and temperature data and the algorithm of Benson and Krause (1984). In cases where no valid salinity was available, an assumed value of 35 has been used. Two spikes in the data set have been flagged.

Total Alkalinity and carbon dioxide speciation

Data were supplied to BODC as calibrated data: no further calibration has been applied. Further details of the calibration procedures are given in Frankignoulle et al. (1986, 1996). Errors on the alkalinity and pCO_2 channels were estimated to be 4 µeq/kg and 8 ppm respectively. The pCO_2 values corresponding to the flagged pH values have also been flagged.

5) Acknowledgements

The oxygen, pH, alkalinity and carbon dioxide speciation measurements were funded as part of the Belgian Impulse Programme on Global Change (contract no. GC/12/011). However, the data have been generously contributed by Michel Frankignoulle to enhance the OMEX data set.

6) References

Benson, B.B., Krause D. (1984). The concentration and isotopic fractionation of oxygen dissolved in fresh water and sea water in equilibrium with the atmosphere. ***Limnol.Oceanogr.*** 29 pp.620-632.

Dickson, A.G. (1993). PH buffers for sea-water media based on the the total hydrogen-ion concentration scale. ***Deep-Sea Research*** 40 pp.107-118.

Frankignoulle, M., Bourge, I., Canon, C., Dauby, P. (1986). Distribution of surface seawater partial CO_2 pressure in the English Channel and in the Southern Bight of the North Sea. ***Continental Shelf Research*** 16 pp.381-395.

Frankignoulle, M., Elskens, M., Biondo R., Bourge, I., Canon, C., Desgain S. & P. Dauby (1996). Distribution of inorganic carbon and related parameters in surface seawater of the English Channel during Spring 1994. ***Journal of Marine Systems*** 7 pp.427-434.

Goyet, C., Poisson A. (1989). New determination of carbonic-acid dissociation constants in sea-water as a function of temperature and salinity. ***Deep-Sea Research*** 36 pp.163-165.

Hansson, I. (1973). A new set of acidity constants for carbonic acid and boric acid in sea water. ***Deep Sea-Research*** 20 pp.461-478.

Weiss, R.F. (1974). Carbon dioxide in seawater: the solubility of a non-ideal gas. ***Marine Chemistry*** 2 pp. 203-215.

Surface Underway Data for Cruise

Belgica 9322 Leg B (3 - 6 October 1993)

1) Components of the Underway Data Set

The underway data set for Belgica 9322 Leg B contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the underway data file.

Navigation: Latitude (degrees +ve North) (A)
Longitude (degrees +ve East) (B)

Meteorology: Atmospheric pressure (mb) (1)
Wind speed (knots) (Y)
Wind direction (degrees blowing from) (Z)
Solar radiation (W/m^2) (O)
Air temperature (°C) (a)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

Chemistry: Oxygen conc. at in-situ. temperature and salinity (µM) (Q)
pH (pH scale) (M)
Alkalinity (µEq/kg) ({)
Calculated pCO_2 (ppm) (E)
Calculated TCO_2 (µmol/kg) (H)

Biology: Fluorometer output (Volts) (D)
Chlorophyll (mg/m^3) (G)

2) Underway Instruments and Methodology

Up to three temperature sensors were mounted in the non-toxic inlet which was located in the bow at 3.5 m depth. Two of these were Rosemount Pt resistance thermometers whilst the third was the remote thermistor of the SeaBird SBE-21 thermosalinograph. Operational practice was to have one of the Rosemounts on the ship whilst the other was back in Ostend for laboratory calibration checks. The SBE-21 was taken as the primary source of sea temperature data with infill from the Rosemounts in case of failures.

The thermosalinograph was a SeaBird SBE-21. A SBE-19 SeaCat was also mounted in a custom through-flow housing as a back up for salinity but was not required during this cruise.

Navigation was logged from a GPS system.

Meteorology data (except for solar radiation) came from a Friedrich Meteorological package mounted on the central mast. Solar radiation was measured by a Kipp and Zonen solar radiometer. This instrument was periodically intercalibrated with instruments based at Brussels University and was also calibrated by the manufacturer in the Netherlands on a regular basis.

Oxygen concentration was measured continuously using a KENT polarographic electrode frequently calibrated against discrete samples analysed by the Winkler method. Saturation was calculated using the equation proposed by Benson and Krause (1984). Oxygen was logged at 1 minute between 24/04/1994 21:20 and 26/04/1994 04:20 and averaged on 5 minutes for the binary merge file.

pH was measured continuously using a combined ROSS electrode and was calibrated on the total proton scale using buffers proposed by Dickson (1993). The error on the pH was estimated to 0.005 pH units.

Total alkalinity was measured about every 30 nautical miles by electrotitration (Gran method) and was linearly interpolated between samples for the carbon dioxide speciation calculations. Errors on alkalinity were estimated at 4 µeq/kg.

Carbon dioxide speciation (TCO_2 and pCO_2) was calculated using constants from Goyet and Poisson (1989), borate constant from Hansson (1973) and the carbon dioxide solubility coefficient from Weiss (1974). The carbon dioxide parameters were measured every minute and averaged over 5 minutes. Further details are given in Frankignoulle et al. (1986, 1996).

A through flow Turner Designs fluorometer was plumbed into the non-toxic supply for this cruise.

3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key. Data sets worked up post cruise were also merged, again linked using time. Note that some of the automatically logged data were supplied in Belgian local time (GMT+1), but have been corrected to GMT. The meteorology, oxygen and carbonate system data were supplied with a GMT time channel.

Wind speeds supplied in m/s have been converted to knots by multiplying by 1.943845.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to carry out comparative screening checks between channels by overlaying data channels. Oceanographic context was taken into account through simultaneous display of a map of the cruise track.

4) BODC Quality Control and Calibration Procedures

4.1) Navigation

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots.

Two large gaps were found in the navigation, from 04/10/1993 12:51 to 04/10/1993 15:47 and 04/10/1993 23:27 to 05/10/1993 06:15 One of these occurred during a short port call to Brest (ship stationary) and the other occurred during steady steaming along the Channel. Consequently, linear interpolation over these gaps was considered justified and has been applied. A short gap (26 minutes duration) at 23:00 on 03/10/1993 has also been interpolated.

There were no speed check failures.

4.2) Meteorology

Atmospheric Pressure

The atmospheric pressure data appeared generally good except for a small number of obvious spikes that have been flagged suspect.

Wind Velocity

The data appeared generally good with just a handful of spikes flagged. No effects could be seen in the data for changes in ship’s course indicating that there was no problem with the velocity correction.

Radiation

The solar radiation data showed a clear diurnal signal. A single spike (high value at night) required flagging. Values were low, under 100 W/m^2, but were in keeping with the bad weather encountered on this cruise.

Air Temperature

No problems were identified with these data and the values appeared credible when compared to sea surface temperature.

4.3) Physics

Temperature and Salinity

The temperature channel appeared generally clean with just the occasional spike requiring flagging. The salinity data included periods of up to two hours duration where signal dropped instantaneously followed by an exponential rise to the true value. These have been flagged out.

Neither temperature nor salinity could be calibrated for this leg of the cruise because there were no CTD casts or non-toxic salinity samples.

Visual examination of the data show them to be credible. At the end of the previous leg the salinity was reading 0.04 PSU low and the temperature 0.15 °C low which gives an indication of the magnitude of the possible error. However, thermosalinograph calibrations have a tendency to drift and jump. **Consequently, the fact that these data have not been intercalibrated should be borne in mind when making any use of them**.

4.4) Chemistry

Chemistry was logged over the period 04/10/93 16:30 until 06/10/93 06:00.

Oxygen

Data were supplied to BODC as oxygen saturation pre-calibrated against discrete samples analysed by the Winkler method. In-situ oxygen concentration has been calculated using the thermosalinograph salinity and temperature data and the algorithm of Benson and Krause (1984).

No thermosalinograph data were available 4/10/1993 23:27 to 5/10/1993 06:15. During this interval the temperature rose by 2 °C making a best estimate of temperature impossible. Consequently, no oxygen data are available for this period. An assumed salinity of 35.0 was used for a small number of data points where no salinity value was available.

No data were flagged.

pH

pH was supplied as calibrated data. The error on pH was quoted as 0.005 pH units. None of the data have been flagged.

Total Alkalinity and carbon dioxide speciation.

Data were supplied to BODC as fully worked up data. The alkalinity data set was based on seven discrete samples filled by linear interpolation by the data originator for the purposes of the speciation calculation. Further details of the calibration procedures are given in Frankignoulle et al. (1986, 1996). Errors on the alkalinity and pCO_2 channels were estimated to be 4 µEq/kg and 8 ppm respectively. None of the data have been flagged.

4.5) Biology

The fluorometer signal looked unusual, with negative values present. Nevertheless, a signal was present. On the first leg of the cruise, no clear relationship between the fluorometer data and extracted chlorophylls could be ascertained. However, for this leg the following relationship was determined:

$$\text{chlorophyll (mg/m}^3\text{)} = \text{Voltage}*0.5128 - 3.0603 \ (R^2 = 84\%: n=7)$$

The extracted data set used where **spectrophotometric assays** of acetone extracts calculated using the **SCOR equation** (Strickland and Parsons, 1975).

It should be noted that this calibration is only based upon 7 samples and was strongly influenced by a single high sample collected off the Belgian coast. **It should therefore be regarded as tentative and the data should be used with caution.**

5) Data Warnings

Neither surface CTD data nor discrete surface salinity bottle data were available to calibrate the thermosalinograph.

The chlorophyll calibration is based on just 7 points, including a single high sample which strongly influences the result.

6) Acknowledgements

The oxygen, pH, alkalinity and carbon dioxide speciation measurements were funded as part of the Belgian Impulse Programme on Global Change (contract no. GC/12/011). However, the data have been generously contributed by Michel Frankignoulle to enhance the OMEX data set.

7) References

Benson, B.B., Krause D. (1984). The concentration and isotopic fractionation of oxygen dissolved in fresh water and sea water in equilibrium with the atmosphere. ***Limnol.Oceanogr.*** 29 pp.620-632.

Dickson, A.G. (1993). PH buffers for sea-water media based on the the total hydrogen-ion concentration scale. ***Deep-Sea Research*** 40 pp.107-118.

Frankignoulle, M., Bourge, I., Canon, C., Dauby, P. (1986). Distribution of surface seawater partial CO_2 pressure in the English Channel and in the Southern Bight of the North Sea. ***Continental Shelf Research*** 16 pp.381-395.

Frankignoulle, M., Elskens, M., Biondo R., Bourge, I., Canon, C., Desgain S. & P. Dauby (1996). Distribution of inorganic carbon and related parameters in surface seawater of the English Channel during Spring 1994. ***Journal of Marine Systems*** 7 pp.427-434.

Goyet, C., Poisson A. (1989). New determination of carbonic-acid dissociation constants in sea-water as a function of temperature and salinity. ***Deep-Sea Research*** 36 pp.163-165.

Hansson I. (1973). A new set of acidity constants for carbonic acid and boric acid in sea water. ***Deep-Sea Research*** 20 pp.461-478.

Strickland, J.D.H., Parsons, T.R. (1975). A practical handbook of seawater analysis. ***Fish. Res. Bd. Can***. pp.167-311.

Weiss, R.F. (1974). Carbon dioxide in seawater: the solubility of a non-ideal gas. ***Marine Chemistry*** 2 pp. 203-215.

Surface Underway Data for Cruise Charles Darwin 83

(13 December 1993 - 13 January 1994)

1) Components of the Underway Data Set

The underway data set for Charles Darwin 83 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)
Distance run (km) (K)
Bathymetric depth (m) (J)

Meteorology: Photosynthetically available radiation (W/m^2) (L)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)
Optical attenuance (per m) (I)

Biology: Aquatracka raw fluorescence (V) (?)
Aquatracka chlorophyll (mg/m^3) (!)

2) Methodology Overview

2.1) Plumbing

The ship was fitted with a non-toxic pumped sea water supply with water drawn from an inlet approximately 2.5 m below the surface amidships on the starboard side. All ship's discharges were to port to minimise risk of contamination.

Water from the non-toxic pump was fed into a 130 litre black plastic header tank situated above the wet laboratory to remove bubbles. The supply from this tank fed the thermosalinograph. A separate feed supplied the Aquatracka fluorometer and transmissometer box.

2.2) Data Acquisition

For most parameters, data logging and initial processing was handled by the RVS ABC system. The Level A sampling microcomputer digitised an input voltage, applied a time stamp and transferred the data via the Level B disk buffer onto the Level C where the data records were assembled into files. Sampling rates varied from 10 seconds to several minutes.

It was not possible to log the output of the thermosalinograph to the RVS level B directly so it was logged by a PC in the main laboratory and the data transferred to the level B via floppy diskette. Note that as a result the time channel on the resulting data set was taken from the PC clock and not the master clock. No information is available on how well these clocks were synchronised.

The Level C included a suite of calibration software which was used to apply initial calibrations to convert raw ADC counts into engineering units. At the end of the cruise, the Level C disk base was transferred to BODC for further processing.

2.3) BODC Data Processing Procedures

Data from the Level C files were merged into a common file (the binary merge file) on a 60 second time base, using time as the primary linking key. The time channel supplied was GMT. Data values sampled more frequently than one minute were reduced by averaging. Data logged as voltages (e.g. PAR) were converted to engineering units.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to undertake all possible comparative screening checks between channels by overlaying parameter plots.

3) Quality Control and Calibration Protocols

3.1) Navigation

GPS was the primary navigation system used on this cruise. When no GPS fixes were available the ship's position was determined by dead reckoning based upon the ship's gyro and EM log. Once a fix was obtained after a period of dead reckoning, the surface drift velocity was computed. If this exceeded four knots, the data were automatically flagged suspect. The positional error due to surface drift was then retrospectively applied over the period of dead reckoning.

Distance run was computed from successive positional fixes using spherical trigonometry.

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots.

There were numerous gaps of up to several hours duration in the navigation. As no bridge logs were available, the cruise and scientific reports were used to manually enter as many positions as possible during the gaps. The remaining null values were filled by linear interpolation.

There were no speed check failures.

The distance run channel was checked to ensure it is progressive. The logged channel had been reset to zero several times. Consequently, it was replaced at BODC with data computed from successive positional fixes using spherical trigonometry to calculate the distance between them.

Bathymetric depth was determined using a Simrad EA500 deep echo sounder logged automatically by the ABC system. Carter's Table corrections were applied by the level C software. The quality of the bathymetry channel was variable with a clean signal interspersed with long periods of total noise requiring heavy flagging during quality control.

3.2) Meteorology

Radiation

Charles Darwin was equipped with two PML designed 2-pi PAR meters mounted on scaffold poles on either side of the 'Monkey Island' above the bridge. Note that these instruments measured irradiance which is significantly higher than radiance measured by instruments with planar geometry.

The PAR meters were logged as voltages and calibrated in W/m^2 by BODC using coefficients determined in February 1990. The calibration equations used were:

Port (sensor 4):	PAR = exp (Volts * -5.139 + 7.2376) / 100
Starboard (sensor 9):	PAR = exp (Volts * -5.052 + 6.7874) / 100

The PAR sensors were wired the wrong way round which gave rise to voltages ranging from -3 to +0.8, instead of the expected +3 to -0.8. This was corrected for by changing the sign of the calibration slope.

A merged PAR channel was produced (L), after spikes were flagged out, by taking the maximum of the port and starboard values to eliminate shading effects.

Visual inspection of the data showed a clear diurnal signal with dawn and dusk at the expected times. A single spurious data point during the hours of darkness was flagged suspect.

3.3) Physics

Temperature and Salinity

The thermosalinograph was an improvised 'CTD in a bucket' based on SeaBird components incorporating a remote temperature sensor (high quality thermistor) and an inductive-type conductivity cell mounted next to a second thermistor.

The remote temperature sensor was supplied by water from the intake side of the non-toxic supply. The sea surface temperature was therefore measured at near-ambient temperature as opposed to being warmed by the heating effects that may be induced by the pumping system. The conductivity cell and housing temperature thermistor were supplied by a flow-through system from the non-toxic supply.

The raw ADC counts were calibrated to give conductivity and two temperature channels based upon laboratory calibrations undertaken by RVS. Salinity was computed from the housing temperature and conductivity using the UNESCO 1978 Practical Salinity Scale (Fofonoff and Millard, 1982).

As previously mentioned, it was not possible to log the thermosalinograph directly to the Level B and instead the data were logged by a PC and transferred to the level B by floppy disk. There are significant gaps in the data of which those longer than an hour are as follows:

21/12/93 03:02 to 21/12/93 05:25	21/12/93 07:46 to 21/12/93 08:49
21/12/93 09:21 to 21/12/93 12:16	21/12/93 15:41 to 22/12/93 04:45
22/12/93 08:07 to 22/12/93 12:46	22/12/93 20:02 to 22/12/93 22:18
23/12/95 10:28 to 23/12/93 15:15	24/12/93 04:00 to 24/12/93 05:46
24/12/93 17:33 to 25/12/93 00:30	25/12/93 02:32 to 25/12/93 03:48
25/12/93 16:26 to 25/12/93 18:10	26/12/93 02:43 to 26/12/93 05:13
26/12/93 14:02 to 26/12/93 16:46	27/12/93 01:01 to 27/12/93 04:10
27/12/93 08:51 to 27/12/93 10:06	29/12/93 20:53 to 29/12/93 22:42
30/12/93 23:33 to 31/12/93 02:13	01/01/94 22:23 to 02/01/94 05:20
02/01/94 07:09 to 02/01/94 09:23	02/01/94 11:42 to 02/01/94 18:58
03/01/94 04:01 to 03/01/94 06:02	03/01/94 16:48 to 03/01/94 18:21
04/01/94 00:03 to 04/01/94 02:39	05/01/94 04:04 to 03/01/94 06:48
06/01/94 07:51 to 06/01/94 21:00	07/01/94 22:41 to 08/01/94 02:50
08/01/94 03:37 to 08/01/94 12:32	08/01/94 13:42 to 08/01/94 15:47
08/01/94 17:21 to 08/01/94 23:21	09/01/94 01:18 to 09/01/94 03:17
09/01/94 07:33 to 09/01/94 12:34	

The remote (i.e. sea surface) temperature was back calibrated against surface CTD data. Although all the CTD data corresponded to the gaps in the underway data set, it was possible to calibrate to the nearest underway data point which was within twenty minutes of the CTD cast. A constant correction of 0.009 °C was determined for the whole cruise. This has been applied to the data.

Salinity was back calibrated against surface CTD data. The CTDs all correspond to gaps in the underway data. It was possible, however to use the surface salinity value from 19 CTDs which were obtained no more than twenty minutes away from any underway salinity data point. The salinity correction was found to be a function of the salinity concentration. Regression analysis gave the following calibration equation:

$$S_{corrected} = S_{observed} + ((S_{observed} * 1.0861) - 3.1217) \; (R^2 = 99.9\%)$$

This correction has been applied to the data.

The salinity data were variable in quality. The signal was clean for some of the time but contained a high proportion of spikes for significant periods of time, particularly between 24/12/1993 and 02/01/1994, that required heavy flagging.

Optical Attenuance

Optical attenuance was measured using a SeaTech 660 nm (red) 25 cm path length transmissometer contained in a plastic water bath continuously flushed by the non-toxic supply. The data were logged as voltages. These were corrected for light source decay using a ratio correction based on air voltage measured during the cruise and the air voltage measured when the instrument was new (cruise voltage in air 4.734V, manufacturer's figure 4.823V).

The percentage transmission (Volts*20) was converted to attenuance using the equation:

$$\text{Attenuance} = -4.0 \log (\% \text{ Transmission}/100).$$

Inspection of the data using a graphics workstation showed the data to have increased noise levels between 15:20 on 23/12/1993 10:28 and 06:00 on 02/01/1994. The noise levels between 15:20 on 23/12/1993 and 06:30 on 24/12/1993 and 10:15 on 25/12/1993 and 03:40 on 26/12/1993 were considered excessive and these data have been flagged out. The noisier signal was associated with an increase in attenuance and users should be aware that this may be an artefact.

3.4) Biology

Chlorophyll

Chlorophyll was measured by a Chelsea Instruments Aquatracka fluorometer calibrated against discrete samples taken from TSG outlet (285) and from surface CTD bottles (24). Samples were filtered through Whatman GF/F filters and frozen until analysed. The frozen filters were extracted in 2-5 ml 90% acetone using sonification, and centrifuged to remove cellular debris. **Analysis for pigments was performed by fluorometric assay of the acetone extract**.

The raw fluorometer data were first screened on a graphics workstation and any spikes flagged.

Calibration was achieved by regression of the log of the extracted chlorophyll value against the raw fluorometer voltage. The cruise data were treated as a single population.

$$\text{chlorophyll (mg/m}^3\text{)} = \exp(-2.8837 + (-2.965 * \text{raw\_voltage}))$$

The adjusted R^2 for this regression was 60.5%.

There was no correlation of calibration residuals with irradiance and a quench correction has not been applied.

Note that the coefficients in the above equation look strange, particularly the negative slope implying that chlorophyll decreases with increasing fluorescence. The reason for this is that the sign of the voltage in the input data had been transposed such that high chlorophyll produced a large negative voltage. The reason for this is not known but as it has no effect on the calibrated result no corrective action has been taken.

4) Data Warnings

The thermosalinograph data had a lot of gaps.

Transmissometer and thermosalinograph data quality were reduced between 24/12/93 and 02/01/94, probably due to bad weather.

5) Reference

Fofonoff, N.P., Millard Jr., R.C. (1983). Algorithms for computation of fundamental properties of seawater. ***UNESCO Technical Papers in Marine Science*** 44.

Surface Underway Data for Cruise Meteor 27 Leg 1

(29 Dec 1993- 17 Jan 1994)

1) Components of the Underway Data Set

The underway data set for Meteor cruise 27_1 contained the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)
Bathymetric depth (m) (J)

Meteorology: Combined solar radiation (W/m^2) (O)
UV radiation (W/m^2) (o)
Absolute wind speed (knots) (Y)
Absolute wind direction (degrees blowing from) (Z)
Barometric pressure (mb) (1)
Dry bulb air temperature (°C) (a)
Dew point temperature (°C) (c)
Relative humidity (%) (d)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

2) Methodology Overview

Obtaining information about the systems and operational procedures has proved to be surprisingly difficult. Several requests for information have failed to provide the detailed technical data we require for complete documentation. What follows is therefore a little sketchy.

The navigation system used is not known other than it was a GPS system.

The type of echo sounder used is unknown but from viewing the record it can be seen to have no problems with deep water.

The fact that a thermosalinograph was operating indicates that the ship was equipped with a continuous pumped seawater supply. Neither the intake

depth, the type of instrument used nor the configuration of the temperature and conductivity sensors is known.

An Atlas DVS 1300 METPAC was used for continuous meteorological sampling, including UV and solar radiation sensors, a barometer, wet and dry bulb thermometers and cup and vane anemometers. The precise location of the sensors on the ship is not known, but many of the instruments were duplicated on the port and starboard sides of the ship.

Nothing is known about the data logging protocols.

3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key on a time base of 1 minute. The time channel supplied was labelled UTC.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to undertake all possible comparative screening checks between channels.

4) BODC Quality Control and Calibration Procedures

4.1) Navigation and bathymetry

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots. The navigation data supplied were logged either every 2, 3 or 5 minutes except for 14:00 on 01/01/1994 to 19:00 on 02/01/1994 when they were logged hourly. A number of short gaps in the record were encountered thus:

01/01/1994 11:15 to 01/01/1994 11:38
03/01/1994 15:36 to 03/01/1994 15:53
05/01/1994 15:24 to 05/01/1994 15:34
05/01/1994 15:41 to 05/01/1994 15:59
10/01/1994 21:16 to 10/01/1994 22:32
12/01/1994 17:20 to 12/01/1994 20:14

Navigation at 1 minute sampling was generated from the data supplied by linear interpolation.

There were no speed check failures.

The bathymetry data at the start of the cruise on the shelf were plagued by shallow reflections. These have been flagged but it should be borne in mind that it was difficult at times to distinguish what was signal and what was noise. Data from deeper waters and subsequent visits to the shelf are of much better quality. There were a significant number of spikes but these were relatively easy to identify and flag. It is not known whether these data have been corrected for variations in sound velocity.

4.2) Meteorology

Barometric pressure

The barometric pressure data appeared to be of good quality except for a couple of isolated spikes which have been flagged suspect.

Radiation

The solar radiation data showed a clear diurnal pattern with dawn and dusk at the expected times. Dark values exhibited a curious saw-tooth pattern oscillating between -20 and -40 W/m^2 giving rise to some concern about the instrument calibration.

The UV radiation data again showed a credible diurnal pattern but had a strange quantised appearance as the data were supplied with a resolution of 1 W/m^2. Dark values oscillated between 0 and -1 W/m^2.

Air temperature and humidity

The port and starboard dry bulb air temperature channels showed good agreement with differences between the channels <0.5 °C. From time to time the signal on either (or sometimes both) channel became noisy. These were flagged suspect. The channels were combined by averaging, excluding any flagged values, to provide a single air temperature data channel. The air temperatures compared credibly with the sea surface temperatures.

The port and starboard relative humidity channels showed good agreement. Both channels contained occasional spikes which have been flagged suspect. A merged humidity channel was generated by averaging the good data from the port and starboard channels.

Dew point temperatures exhibited a common signal except for periods of several hours when the port wet bulb thermometer was obviously malfunctioning. These problems plus a few isolated spikes were flagged suspect. Differences between the channels ranged from zero to nearly a degree. A merged dew point channel has been generated by averaging the good data from the port and starboard channels.

Wind velocity

Wind speeds supplied in m/s were converted to knots by multiplying by 1.943845.

The data from both anemometers were examined on a graphics workstation and were shown to be virtually identical with no evidence of shadowing by the superstructure. It was decided that there was nothing to be gained by storing two virtually identical channels and the starboard channel was chosen for inclusion in the final data set. Course changes had no effect on the wind velocity data.

4.3) Physics

Both temperature and salinity were calibrated against surface CTD data. A constant correction of 0.140 °C and 0.419 PSU respectively, were determined for the whole cruise and these have been applied to the data.

Visual inspection of the salinity signal showed it to be very noisy and of poor quality throughout the cruise. The worst affected sections of the data have been flagged out but the remaining data were still more noisy than usual for this type of data. This level of noise obviously affected the quality of the calibration against the CTD.

The temperature signal was generally clean but included a number of upwards jumps that looked suspicious.

It is therefore recommended that the thermosalinograph data, particularly the salinity, from this cruise should be used with caution.

5) Data Warnings

The thermosalinograph salinity data from this cruise are very noisy and should be used with caution.

Surface Underway Data for Cruise Charles Darwin 84

(18 January - 2 February 1994)

1) Components of the Underway Data Set

The underway data set for Charles Darwin 84 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)
Distance run (km) (K)
Bathymetric depth (m) (J)

Meteorology: Photosynthetically available radiation (W/m^2) (L)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)
Optical attenuance (per m) (I)

Biology: Aquatracka raw fluorescence (V) (?)
Aquatracka chlorophyll (mg/m^3) (!)

2) Methodology Overview

2.1) Plumbing

The ship was fitted with a non-toxic pumped sea water supply with water drawn from an inlet approximately 2.5 m below the surface, amidships on the starboard side. All ship's discharges were to port to minimise risk of contamination.

Water from the non-toxic pump was fed into a 130 litre black plastic header tank situated above the wet laboratory to remove bubbles. The supply from this tank fed the thermosalinograph. A separate feed supplied the Aquatracka fluorometer and transmissometer box.

2.2) Data Acquisition

Data logging and initial processing was handled by the RVS ABC system. The Level A sampling microcomputer digitised an input voltage, applied a time stamp from the scientific master clock and transferred the data via the Level B disk buffer onto the Level C where the Level A messages were assembled into data files. Sampling rates varied from 10-30 seconds.

The Level C included a suite of calibration software which was used to apply initial calibration to convert raw ADC counts into engineering units. At the end of the cruise, the Level C disk base was transferred to BODC for further processing.

2.3) BODC Data Processing Procedures

Data from the Level C files were merged into a common file (the binary merge file) on a 30 second time base, using time as the primary linking key. The time channel supplied was GMT. Data values sampled more frequently than one minute were reduced by averaging. Data logged as voltages (e.g. PAR) were converted to engineering units.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to undertake all possible comparative screening checks between channels by overlaying parameter plots.

3) Protocol Details, Quality Control and Calibration Procedures

3.1) Navigation and bathymetry

GPS was the primary navigation system used on this cruise. When no GPS fixes were available the ship's position was determined by dead reckoning based upon the ship's gyro and EM log. Once a fix was obtained after a period of dead reckoning, the surface drift velocity was computed. If this exceeded four knots, the data were automatically flagged suspect. The positional error due to surface drift was then retrospectively applied over the period of dead reckoning.

Distance run was computed from successive positional fixes using spherical trigonometry.

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots.

A single large gap was reported from 18:31 to 22:16 on 01/02/1994. The bridge log was used to manually enter as many positions as possible during this interval. This included routine fixes every 30 minutes plus entries for

critical points such as course alterations and arrival and departure at stations. The remaining null values were filled by linear interpolation.

There were no speed check failures.

The distance run channel was checked to ensure it was progressive.

Bathymetric depth was determined using a Simrad EA500 deep echo sounder logged automatically by the ABC system. Carter's Table corrections were applied by the level C software. The quality of the bathymetry channel was variable with a clean signal interspersed with long periods of total noise requiring heavy flagging during quality control.

3.2) Meteorology

Radiation

Charles Darwin was equipped with two PML designed 2-pi PAR meters mounted on scaffold poles on either side of the 'Monkey Island' above the bridge. Note that these instruments measured irradiance which is significantly higher than radiance measured by instruments with planar geometry.

The PAR meters were logged as voltages and calibrated in W/m^2 by BODC using coefficients determined in February 1990. The calibration equations used were:

Port (sensor 4):	PAR = exp (Volts * -5.139 + 7.2376) / 100
Starboard (sensor 9):	PAR = exp (Volts * -5.052 + 6.7874) / 100

The PAR sensors were wired the wrong way round which gave rise to voltages ranging from -3 to +0.8, instead of the expected +3 to -0.8. This was corrected for by changing the sign of the calibration slope.

A merged PAR channel was produced (L), after spikes were flagged out, by taking the maximum of the port and starboard values to eliminate shading effects.

Visual inspection of the data showed a clear diurnal signal with dawn and dusk at the expected times. A single spurious data point during the hours of darkness was flagged suspect.

3.3) Physics

Temperature and Salinity

The thermosalinograph was an improvised 'CTD in a bucket' based on SeaBird components incorporating a remote temperature sensor (high quality

thermistor) and an inductive-type conductivity cell mounted next to a second thermistor.

The remote temperature sensor was supplied by water from the intake side of the non-toxic supply. The sea surface temperature was therefore measured at near-ambient temperature as opposed to being warmed by the heating effects that may be induced by the pumping system. The conductivity cell and housing temperature thermistor were supplied by a flow-through system from the non-toxic supply.

The raw ADC counts were calibrated to give conductivity and two temperature channels based upon laboratory calibrations undertaken by RVS. Salinity was computed from the housing temperature and conductivity using the UNESCO 1978 Practical Salinity Scale (Fofonoff and Millard, 1982).

The remote (i.e. sea surface) temperature was back calibrated against calibrated surface CTD data. A constant correction of -0.011 °C was determined for the whole cruise and this has been applied to the data.

Salinity was back calibrated using data set comprising 14 discrete salinity measurements on samples taken from the thermosalinograph outlet. Calibrated CTD data could not be used because all CTD casts coincided with gaps in the surface salinity record.

The conductivity cell was reported cracked and repaired at 20:10 on 22/01/1994. Separate calibrations were determined before and after the repair, yielding corrections of +0.297 PSU prior to the repair and -0.003 PSU afterwards. These corrections have been applied to the data.

The salinity data prior to the repair were very noisy and have been heavily flagged. After the repair the data were of good quality.

Optical Attenuance

Optical attenuance was measured using a SeaTech 660 nm (red) 25cm path length transmissometer contained in a plastic water bath continuously flushed by the non-toxic supply. The data were logged as voltages. These were corrected for light source decay using a ratio correction based on air voltage measured during the cruise and the air voltage measured when the instrument was new (cruise voltage in air 4.734V, manufacturer's figure 4.823V).

The percentage transmission (Volts*20) was converted to attenuance using the equation:

$$\text{Attenuance} = -4.0 \log (\% \text{ Transmission}/100).$$

Inspection of the data using a graphics workstation showed signal to be noisy between 10:00 on 21/1/1994 and 20:30 on 22/1/1994. Data in that period have been flagged suspect. Apart from that the instrument was performing well with just a few bubble spikes flagged in the remainder of the record.

3.4) Biology

Chlorophyll

Chlorophyll was measured by a Chelsea mk2 SA244 fluorometer calibrated against discrete samples taken from TSG outlet (4) and from surface CTD bottles (3). Samples were filtered through Whatman GF/F filters and frozen until analysed. The frozen filters were extracted in 2-5 ml 90% acetone using sonification, and centrifuged to remove cellular debris. Analysis for pigments was performed by **reversed high pressure liquid chromatography (HPLC)** using absorbance detection for chlorophyll (Mantoura and Llewellyn, 1983).

The raw fluorometer data were first screened on a graphics workstation and any spikes flagged.

Calibration was achieved by regression of the log of the extracted chlorophyll value against the raw fluorometer voltage. The cruise data were treated as a single population.

$$\text{chlorophyll (mg/m}^3\text{)} = \exp(-2.12 + 0.585 * \text{raw\_voltage})$$

The adjusted R^2 for this regression was 20.4 per cent. This is probably due to small calibration data set and very low chlorophyll concentration in this period (maximum 0.18 mg/m^3).

4) Data Warnings

Salinity data, prior to conductivity cell repair on 22/1/1994 at 20:30, should be treated with caution.

The chlorophyll calibration is very poor but this is of little consequence due to the low levels of chlorophyll encountered on this cruise.

5) References

Mantoura, R.F.C., Llewellyn, C.A. (1983). The rapid determination of algal chlorophyll and carotenoid pigments and their breakdown products in natural waters by reverse phase high performance liquid chromatography. ***Anal. Chim. Acta*** 151: 297-314.

Fofonoff, N.P., Millard Jr., R.C. (1983). Algorithms for computation of fundamental properties of seawater. ***UNESCO Technical Papers in Marine Science*** 44.

Surface Underway Data for Cruise Charles Darwin 85

(11 April - 7 May 1994)

1) Components of the Underway Data Set

The underway data set for Charles Darwin 85 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (degrees +ve N) (A)
Longitude (degrees +ve E) (B)
Distance run (km) (K)
Bathymetric depth (m) (J)

Meteorology: Photosynthetically available radiation (W/m^2) (L)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)
Optical attenuance (per m) (I)

Biology: Aquatracka raw fluorescence (V) (?)
Aquatracka chlorophyll (mg/m^3) (!)

2) Methodology Overview

2.1) Plumbing

The ship was fitted with a non-toxic pumped sea water supply with water drawn from an inlet approximately 2.5 m below the surface, amidships on the starboard side. All ship's discharges were to port to minimise risk of contamination.

Water from the non-toxic pump was fed into a 130 litre black plastic header tank situated above the laboratory to remove bubbles. The supply from this tank fed the thermosalinograph. The Aquatracka fluorometer and transmissometer were fed separately from the non-toxic supply

2.2) Data Acquisition

Data logging and initial processing was handled by the RVS ABC system. The Level A sampling microcomputer digitised an input voltage, applied a time stamp from the scientific master clock and transferred the data via the

Level B disk buffer onto the Level C where the Level A messages were assembled into data files. Sampling rates varied from 10-30 seconds.

The Level C included a suite of calibration software which was used to apply initial calibrations to convert raw ADC counts into engineering units. At the end of the cruise, the Level C disk base was transferred to BODC for further processing.

2.3) BODC Data Processing Procedures

Data from the Level C files were merged into a common file (the binary merge file) on a one minute time base, using time as the primary linking key. The time channel supplied was GMT. Data values sampled more frequently than one minute were reduced by averaging. Data logged as voltages (e.g. PAR) were converted to engineering units.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to undertake all possible comparative screening checks between channels by overlaying parameter plots.

3) Protocol Details, Quality Control and Calibration Procedures

3.1) Navigation and bathymetry

GPS was the primary navigation system used on this cruise. When no GPS fixes were available the ship's position was determined by dead reckoning based upon the ship's gyro and EM log. Once a fix was obtained after a period of dead reckoning, the surface drift velocity was computed. If this exceeded four knots, the data were automatically flagged suspect. The positional error due to surface drift was then retrospectively applied over the period of dead reckoning.

Distance run was computed from successive positional fixes using spherical trigonometry.

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots.

A number of small gaps of up to 20-30 minutes duration were present in the navigation data supplied. The bridge log was used to manually enter as many positions as possible during periods when navigation wasn't automatically logged. This covered critical points such as course alterations and arrival/departure at stations. Any remaining null values were filled by linear interpolation.

There were no speed check failures reported for this cruise.

The distance run channel was checked to ensure it was progressive.

Bathymetric depth was determined using a Simrad EA500 deep echo sounder logged automatically by the ABC system. Carter's Table corrections were applied by the level C software.

The bathymetry record from this cruise was exceptionally clean with less than a dozen points requiring flagging. There were, however, a significant proportion of null values scattered throughout the data set indicating that the data may have been subjected to destructive quality control procedures prior to submission to BODC.

3.2) Meteorology

Radiation

Charles Darwin was equipped with two PML designed 2-pi PAR meters mounted on scaffold poles on either side of the 'Monkey Island' above the bridge. Note that these instruments measured irradiance which is significantly higher than radiance measured by instruments with planar geometry.

The PAR meters were logged as voltages and calibrated in W/m^2 by BODC using coefficients determined in February 1990. The calibration equations used were:

Port (sensor 4):	PAR = exp (Volts * 5.139 + 7.2376) / 100
Starboard (sensor 9):	PAR = exp (Volts * 5.052 + 6.7874) / 100

The PAR sensors were wired the wrong way round which gave rise to voltages ranging from -3 to +0.8, instead of the expected +3 to -0.8. This was corrected for by changing the sign of the calibration slope.

The data were combined into a merged PAR channel, after spikes had been flagged out, by taking the maximum of the port and starboard values to minimise artefacts caused by shading.

Visual inspection of the data showed a clear diurnal signal with dawn and dusk at the expected times with no spurious data during the hours of darkness.

3.3) Physics

Temperature and Salinity

The thermosalinograph was an improvised 'CTD in a bucket' based on SeaBird components incorporating a remote temperature sensor (high quality

thermistor) and an inductive-type conductivity cell mounted next to a second thermistor.

The remote temperature sensor was supplied by water from the intake side of the non-toxic supply. The sea surface temperature was therefore measured at near-ambient temperature as opposed to being warmed by the heating effects that may be induced by the pumping system. The conductivity cell and housing temperature thermistor were supplied by a flow-through system from the non-toxic supply.

The raw ADC counts were calibrated to give conductivity and two temperature channels based upon laboratory calibrations undertaken by RVS. Salinity was computed from the housing temperature and conductivity using the UNESCO 1978 Practical Salinity Scale (Fofonoff and Millard, 1982).

The remote (i.e. sea surface) temperature was back calibrated against surface CTD data. A constant correction of -0.033 °C was determined for the whole cruise and this has been applied to the data.

Visual inspection of the temperature channel showed it to be generally clean with low levels of noise and just occasional spikes requiring flagging. A dramatic exception to this was the data from the afternoon of 29/04/1994 where noise levels of up to a degree suddenly appeared. Experience from other cruises has shown this type of data to be associated with bright sunny conditions and calm seas causing the formation of a diurnal thermocline at approximately the depth of the non-toxic inlet. No attempt was made to flag these data as the phenomenon is believed to be real.

Salinity was back calibrated by comparison with CTD data from the same depth (26 values) and 8 discrete salinity measurements on samples taken from thermosalinograph outlet. From this analysis, the required correction was determined as +0.009 PSU prior to 11:00 on 05/05/1994 and +0.039 PSU thereafter.

The salinity record was generally clean with only occasional spikes, usually due to low values. The instrument experienced problems between 09:30 and 14:00 on 28/04/1994 and from 01:00 to 11:00 on 05/05/1994. The salinity data for these periods have been flagged out. The data exhibited increased levels of noise on the afternoon of 29/04/1996 as a result of high noise levels in the temperature data used to compute salinity from conductivity.

Optical Attenuance

Optical attenuance was measured using a SeaTech 660 nm (red) 25 cm path length transmissometer contained in a plastic water bath continuously flushed by the non-toxic supply. The data were logged as voltages. These were corrected for light source decay using a ratio correction based on air voltage measured during the cruise and the air voltage measured when the

instrument was new (cruise voltage in air 4.654V, manufacturer's figure 4.738V).

The percentage transmission (Volts*20) was converted to attenuance using the equation:

Attenuance = -4.0 log (% Transmission/100).

Inspection of the data using a graphics workstation showed the instrument to have been malfunctioning between 11/04/1994 and 24/04/1994. The signal ramps steadily upwards, reaching values of 2 per m before dropping suddenly to more normal values of 0.7 per m after a 12 hour gap. Data from this period have been flagged suspect.

The remainder of the record showed the instrument was functioning well and the signal was free from the 'bubble spikes' that can plague underway transmissometer data. The record showed the instrument was cleaned at 10:00 on 28/04/1994 and 20:30 on 04/05/1994 with no effect on the signal afterwards. Spurious data during maintenance have been flagged suspect.

3.4) Biology

Chlorophyll

Chlorophyll was measured by a Chelsea mk2 Aquatracka fluorometer, mounted in the same tank as the transmissometer, calibrated against 28 discrete samples taken from thermosalinograph outlet. The extracted chlorophyll data were obtained by **spectrophotometric assay using the Lorenzen Equation** (Strickland and Parsons, 1975) on frozen samples.

The raw fluorometer data were first screened on a graphics workstation which showed the record to be clean except for instrument maintenance at 10:00 on 28/04/1994 which has been flagged suspect.

Calibration was achieved by regression of the log of the extracted chlorophyll value against the raw fluorometer voltage. The cruise data were treated as a single population.

chlorophyll (mg/m^3) = exp (-3.29 + 1.45 * raw_voltage)

The adjusted R^2 for this regression was 77.6 per cent.

4) Data Warnings

There were problems with the transmissometer data for the first period of the cruise (prior to 24/04/94). Where the data values were obviously in error (too

high) they have been flagged suspect but any unflagged data from this period should be treated with caution.

5) References

Fofonoff, N.P., Millard Jr., R.C. (1983). Algorithms for computation of fundamental properties of seawater. ***UNESCO Technical Papers in Marine Science*** 44.

Strickland, J.D.H., Parsons, T.R. (1975). A practical handbook of seawater analysis. ***Fish. Res. Bd. Can***. pp.167-311.

Surface Underway Data for Cruise Belgica 94ZB

(11 April - 14 April 1994)

1) Components of the Underway Data Set

Belgica cruise BG94ZB was a passage leg from Zeebrugge to Bordeaux prior to OMEX cruise BG9412. A comprehensive surface chemistry section down the Channel was collected which provides a useful comparison for the Cork to Zeebrugge leg of BG9412 nearly a month later. Hence its inclusion in the OMEX data set.

The underway data set for Belgica 94ZB contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

Biology: Turner Designs fluorescence (V) (D)
Turner Design chlorophyll (mg/m^3) (G)

Chemistry: Oxygen conc. at in-situ. temperature and salinity (µM) (Q)
pH (pH scale) (M)
Alkalinity (µEq/kg) ({)
pCO_2 (ppm) (E)
TCO_2 (µmol/kg) (H)

2) Underway instruments and methodology

Temperature sensors were mounted in the non-toxic inlet located in the bow of the ship at a depth of 3.5 metres. Two of these were Rosemount Pt resistance thermometers whilst the third was the remote thermistor of the SeaBird SBE-21 thermosalinograph. Operational practice was to have one of the Rosemounts on the ship whilst the other was back in Ostend for laboratory calibration checks. The thermosalinograph was taken as the primary source of sea surface temperature data.

The thermosalinograph was a SeaBird SBE-21.

A Turner Designs fluorometer was used. Data were calibrated to nominal chlorophyll (mg/m^3) using the manufacturer's equation. Drift was shown to be small.

Navigation was logged from a GPS system.

Oxygen concentration was measured continuously using a KENT polarographic electrode frequently calibrated against discrete samples analysed by the Winkler method. Saturation was calculated using the equation proposed by Benson and Krause (1984). Oxygen was logged at 1 sample per minute between 24/04/94 21:20 and 26/04/94 04:20.

pH was measured continuously using a combined ROSS electrode and was calibrated on the total proton scale using buffers proposed by Dickson (1993). The error on the pH was estimated to be 0.005 pH units.

Total alkalinity was measured about every 30 nautical miles by electrotitration (Gran method) and was linearly interpolated between samples for the carbon dioxide speciation calculations. Errors on alkalinity were estimated to be 4 µEq/kg.

Carbon dioxide speciation (TCO_2 and pCO_2) were calculated using constants from Goyet and Poisson (1989), borate constant from Hansson (1973) and the carbon dioxide solubility coefficient from Weiss (1974). The carbon dioxide parameters were measured every minute and averaged to 5 minutes. Further details are given in Frankignoulle et al. (1986, 1996).

3) BODC Data Processing Procedures

The data for this cruise were supplied by University of Liege in a single file. All data, including channels logged by Belgica's data acquisition system had been reduced to a 5 minute GMT time base. This was simply reformatted into a binary merge file with five minute sampling.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to undertake all possible comparative screening checks between channels.

4) BODC Calibration Procedures

4.1) Navigation

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots. A gap in the navigation channels occurred

between 01:55 and 04:50 on13/04/1994. A similar gap appeared in all other channels.

4.2) Physics

Temperature and Salinity

There were no surface CTD data available to BODC to obtain a back calibration of the thermosalinograph. The data have therefore been left uncalibrated. As a guide, data from the following cruise showed the thermosalinograph salinity to be 0.078 PSU low and the temperature 0.2 °C low at the start of the cruise, drifting to 0.1 °C low by the end of the cruise.

4.3) Biology

Chlorophyll

Chlorophyll was measured by a Turner Designs 10-AU-005 fluorometer calibrated against extracted chlorophyll data. The raw fluorometer data were first screened on a graphics workstation and any spikes flagged.

The calibration data set comprised 18 samples. Calibration was achieved by regression of the extracted chlorophyll value (**spectrophotometric method using the SCOR equation** (Strickland and Parsons, 1975)) against the raw fluorometer voltage averaged over 2 minutes. The cruise data were treated as a single population.

The resulting equation was:

$$\text{chlorophyll (mg/m}^3\text{)} = -1.07441 + 0.300 * \text{raw\_voltage}$$

The adjusted R^2 for this regression was 84.9 per cent.

4.4) Chemistry

All channels have been screened to remove spikes.

Oxygen

Data were supplied to BODC as oxygen saturation pre-calibrated against discrete samples analysed by the Winkler method. In-situ oxygen concentration has been calculated using the salinity and temperature data and the algorithm of Benson and Krause (1984). No further calibration has been applied.

A number of low oxygen values in the data set have been left unflagged due to their proximity to the coast. The data set exhibits a number of sudden upwards jumps. One of these at 06:30 on 12/04/1994 was associated with a

bloom in mid-Channel but no explanation can be seen for the series of jumps between 16:00 and 20:00 on the same day. It is unclear whether the problem is with the data before or after each jump so the data have been left unflagged.

pH

pH was supplied as calibrated data. The error on pH was given as 0.005 pH units.

Total Alkalinity and carbon dioxide speciation.

Data were supplied to BODC as calibrated data - no further calibration has been applied. Further details of the calibration procedures are given in Frankignoulle et al. (1986, 1996). Errors on the alkalinity and pCO_2 channels were estimated to be 4 µeq/kg and 8 ppm respectively.

5) Data Warnings

Surface CTD data was not available to calibrate the thermosalinograph. The data have therefore not been calibrated.

The oxygen data between 16:00 and 20:00 on 12/04/1994 included unexplained jumps in the signal and should be used with caution.

6) Acknowledgements

The oxygen, pH, alkalinity and carbon dioxide speciation measurements were funded as part of the Belgian Impulse Programme on Global Change (contract no. GC/12/011). However, the data have been generously contributed by Michel Frankignoulle to enhance the OMEX data set.

7) References

Benson, B.B., Krause D. (1984). The concentration and isotopic fractionation of oxygen dissolved in fresh water and sea water in equilibrium with the atmosphere. ***Limnol.Oceanogr.*** 29 pp.620-632.

Dickson, A.G. (1993). PH buffers for sea-water media based on the the total hydrogen-ion concentration scale. ***Deep-Sea Research*** 40 pp.107-118.

Frankignoulle, M., Bourge, I., Canon, C., Dauby, P. (1986). Distribution of surface seawater partial CO_2 pressure in the English Channel and in the Southern Bight of the North Sea. ***Continental Shelf Research*** 16 pp.381-395.

Frankignoulle, M., Elskens, M., Biondo R., Bourge, I., Canon, C., Desgain S. & P. Dauby (1996). Distribution of inorganic carbon and related parameters in surface seawater of the English Channel during Spring 1994. ***Journal of Marine Systems*** 7 pp.427-434.

Goyet, C., Poisson A. (1989). New determination of carbonic-acid dissociation constants in sea-water as a function of temperature and salinity. ***Deep Sea Research*** 36 pp.163-165.

Hansson, I. (1973). A new set of acidity constants for carbonic acid and boric acid in sea water. ***Deep Sea Research*** 20 pp.461-478.

Strickland, J.D.H., Parsons, T.R. (1975). A practical handbook of seawater analysis. ***Fish. Res. Bd. Can***. pp.167-311.

Weiss, R.F. (1974). Carbon dioxide in seawater: the solubility of a non-ideal gas. ***Marine Chemistry*** 2 pp.203-215.

Surface Underway Data for Cruise Belgica 9412.

(20 April - 5 May 1994)

1) Components of the Underway Data Set

The underway data set for Belgica 9412 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)
Bathymetric depth (m)(J)

Meteorology: Atmospheric pressure (mb)(1)
Air temperature (°C) (a)
Absolute wind speed (knots) (Y)
Absolute wind direction (degrees) (Z)
Solar radiation (W/m^2) (O)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

Biology: Turner Designs fluorescence (Volts) (D)
Turner Designs chlorophyll (mg/m^3) (G)

Chemistry: Oxygen concentration at in-situ temperature and salinity (µM) (Q)
pH (pH scale) (M)
Alkalinity (µEq/kg) ({)
pCO_2 (ppm) (E)
TCO2 (µmol/kg) (H)
Nitrate+nitrite (µM) (T)
Silicate (µM) (W)

2) Underway instruments and methodology

Up to three temperature sensors were mounted in the non-toxic inlet which was located in the bow at a 3.5 m depth. Two of these were Rosemount Pt resistance thermometers whilst the third was the remote thermistor of the SeaBird SBE-21 thermosalinograph. Operational practice was to have one of the Rosemounts on the ship whilst the other was back in Ostend for laboratory calibration checks. The thermosalinograph was used as the

primary source of sea surface temperature, with the Rosemounts providing a backup.

The thermosalinograph was a SeaBird SBE-21.

Navigation was by a Magnavox 200MX GPS system backed up by Shipmate RS4000 and Navstar 602D DECCA systems. Accuracy of the primary system was quoted as typically 50m.

Meteorology data (except for solar radiation) came from a Friedrich Meteorological package mounted on the central mast. Solar radiation was measured by a Kipp and Zonen solar radiometer. This instrument was periodically intercalibrated with instruments based at Brussels University and was also calibrated by the manufacturer in the Netherlands on a regular basis.

Nutrients were determined using a Technicon AA2 autoanalyser taking discrete samples, alternating with MilliQ blanks, from a reservoir on the sample changer platform continuously flushed by the non-toxic supply. The detection limits for nitrate and silicate were 0.1 and 0.5 µM respectively. The continuous water supply was pre-filtered through a 60 µm screen. Values were determined every 3 minutes and the instrument was calibrated every 2-4 hours.

Oxygen concentration was measured continuously using a KENT polarographic electrode frequently calibrated against discrete samples analysed by the Winkler method. Saturation was calculated using the equation proposed by Benson and Krause (1984). Oxygen was logged at 1 minute intervals then averaged by the originator to 5 minutes.

pH was measured continuously using a combined ROSS electrode and was calibrated on the total proton scale using buffers proposed by Dickson (1993). The error on the pH was estimated to 0.005 pH units.

Total alkalinity was measured about every 30 nautical miles by electrotitration (Gran method) and was linearly interpolated between samples for the carbon dioxide speciation calculations. Errors on alkalinity were estimated at 4 µEq/kg.

Carbon dioxide speciation (TCO_2 and pCO_2) was calculated using constants from Goyet and Poisson (1989), borate constant from Hansson (1973) and the carbon dioxide solubility coefficient from Weiss (1974). Further details are given in Frankignoulle et al. (1986, 1996).

A through flow Turner Designs 10-AU-005 fluorometer was plumbed in to the non-toxic supply.

Bathymetry was measured using an Atlas Deso 20 scientific echo sounder with 33 and 210 kHz transducers. The 33 kHz transducer has a range of

approximately 1500m in good weather conditions, but rarely exceeded a measured depth of 1000 m in practice.

3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key. Data sets worked up post cruise were also merged, again using time as the primary link. All data were supplied with GMT time channels.

Wind speeds supplied in m/s have been converted to knots by multiplying by 1.943845.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to carry out comparative screening checks between channels by overlaying data channels. Oceanographic context was taken into account through simultaneous display of a map of the cruise track.

4) BODC Calibration and Quality Control

4.1) Navigation and bathymetry

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots.

The program discovered that the navigation supplied was either on a 1 or 5 minute sampling interval. One minute navigation was generated by linear interpolation. A gap in the navigation from 10:26 on 28/04/1994 to 04:20 on 01/05/1994 was a concern until it was realised that this was whilst the ship was stationary in Cork Harbour sheltering from the weather. The gap has been filled by linear interpolation.

A single speed check failure (29.6 knots) was detected at 15:39 on 22/04/1994. This was eliminated by linearly interpolating over the affected data.

The bathymetry record was generally fairly clean except in deep (>1000m) water where the signal deteriorated to random noise caused by the effective range of the instrument being exceeded. Affected portions of the record plus a small number of isolated spikes have been flagged suspect. It is not known whether a correction for sound velocity variations in sea water has been applied to the data.

4.2) Meteorology

Atmospheric pressure

The atmospheric pressure data appeared generally good except for a small number of obvious spikes that have been flagged suspect.

Wind velocity

The data appeared generally good with a handful of spikes flagged. No evidence of course changes affecting the data could be found.

Radiation

The solar radiation data showed a clear diurnal signal with dawn and dusk at the expected times. A few spikes, an isolated high value at night plus three isolated values in excess of 1000 W/m^2, were flagged suspect. Dark values ranged between -1 and zero W/m^2 providing confidence in the calibration.

Air Temperature

There was no problem with the data other than a few isolated spikes which have been flagged suspect. The values appeared credible when compared to sea surface temperature.

4.3) Physics

Temperature and Salinity

The temperature record was clean with no flagging required. However, the quality of the salinity record was variable. The record was clean prior to 23/04/1994 and after 08:00 on 25/05/1994. In between these times very heavy flagging was required to eliminate large numbers of low value spikes. These often took the form of an instantaneous drop in salinity of up to several PSU followed by an exponential rise back to the correct value over a period of about an hour.

Both temperature and salinity were back calibrated against surface CTD data. In case of temperature a correlation was found between the correction and time. The following correction has been applied:

Correction = cycle number * 0.000012 - 0.209

For salinity a constant offset of 0.078 PSU was determined for the whole cruise and this has been applied to the data.

4.4) Biology

Chlorophyll

Chlorophyll was measured by a Turner Designs fluorometer calibrated against extracted chlorophyll data. The raw fluorometer data were first screened on a graphics workstation and any spikes flagged.

The calibration data set comprised 23 samples. Calibration was achieved by regression of the extracted chlorophyll value against the raw fluorometer voltage averaged over 2 minutes. The cruise data were treated as a single population.

The resulting equation was:

$$\text{chlorophyll (mg/m}^3\text{)} = 0.048 + 0.233*\text{raw\_voltage}$$

The adjusted R^2 for this regression was 67.6 per cent.

Note: Two chlorophyll data sets were tried for the calibration purposes, derived using the Lorenzen and SCOR equations (Strickland and Parsons, 1975). **The SCOR chlorophyll-a values provided a much better fit to the fluorometer data and have been used for the calibration**.

4.5) Chemistry

All channels have been screened and any spikes identified have been flagged suspect.

Oxygen

Data were supplied to BODC as oxygen saturation pre-calibrated against discrete samples analysed by the Winkler method. In-situ oxygen concentration has been calculated using the calibrated salinity and temperature data and the algorithm of Benson and Krause (1984). No salinity data were available for a small number of points on the shelf break. An assumed salinity of 35.5 was used in this case.

Oxygen values between 12:00 on 21/04/1994 and 06:00 on 22/04/1994 have been flagged suspect. The data exhibited an instantaneous jump to nearly 120 per cent saturation and remained high in a region shown by the fluorometer to have low chlorophyll.

pH

pH was supplied as calibrated data. The error on pH was given as 0.005 pH units. Isolated spikes have been flagged suspect.

Total Alkalinity and carbon dioxide speciation.

Data were supplied to BODC in fully worked up form. No further calibration has been applied. Further details of the calibration procedures are given in Frankignoulle et al. (1986, 1996). Errors on the alkalinity channel were estimated to be 4 µEq/kg.

Nitrate and Silicate

The nutrient data were supplied to BODC in fully worked up form. No further calibration has been applied.

5) Acknowledgements

The oxygen, pH, alkalinity and carbon dioxide speciation measurements were funded as part of the Belgian Impulse Programme on Global Change (contract no. GC/12/011). However, the data have been generously contributed by Michel Frankignoulle to enhance the OMEX data set.

6) References

Benson, B.B., Krause D. (1984). The concentration and isotopic fractionation of oxygen dissolved in fresh water and sea water in equilibrium with the atmosphere. ***Limnol.Oceanogr.*** 29 pp.620-632.

Dickson, A.G. (1993). PH buffers for sea-water media based on the the total hydrogen-ion concentration scale. ***Deep-Sea Research*** 40 pp.107-118.

Frankignoulle, M., Bourge, I., Canon, C., Dauby, P. (1986). Distribution of surface seawater partial CO_2 pressure in the English Channel and in the Southern Bight of the North Sea. ***Continental Shelf Research*** 16 pp.381-395.

Frankignoulle, M., Elskens, M., Biondo R., Bourge, I., Canon, C., Desgain S. & P. Dauby (1996). Distribution of inorganic carbon and related parameters in surface seawater of the English Channel during Spring 1994. ***Journal of Marine Systems*** 7 pp.427-434.

Goyet, C., Poisson A. (1989). New determination of carbonic-acid dissociation constants in sea-water as a function of temperature and salinity. ***Deep-Sea Research*** 36 pp.163-165.

Hansson I. (1973). A new set of acidity constants for carbonic acid and boric acid in sea water. ***Deep-Sea Research*** 20 pp.461-478.

Strickland, J.D.H., Parsons, T.R. (1975). A practical handbook of seawater analysis. ***Fish. Res. Bd. Can***. pp.167-311.

Weiss, R.F. (1974). Carbon dioxide in seawater: the solubility of a non-ideal gas. ***Marine Chemistry*** 2 pp. 203-215.

Surface Underway Data for Cruise Charles Darwin 86.

(18 May - 13 June 1994)

1) Components of the Underway Data Set

Charles Darwin 86 was an OMEX benthic cruise with the ship chartered by NIOZ. Only navigation and underway bathymetry were logged.

The underway data set contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (degrees +ve N) (A)
Longitude (degrees +ve E) (B)
Distance Run (km) (K)
Bathymetric Depth (m) (J)

Note that three other channels (heading, and ship's velocity as components) are also included. Although these may contain data, they are essentially padding and have been included solely to fulfil the requirement of the binary merge format that at least seven data channels be present. They should therefore be ignored.

2) Methodology Overview

2.1 Data Acquisition

Data logging and initial processing were handled by the RVS ABC system. The level A sampling microcomputer digitised an input voltage, applied a time stamp and transferred the data via the Level B disk buffer onto the Level C where the data records were assembled into files. Sampling rates varied according to channel.

The Level C included a suite of calibration software which was used to apply initial calibrations to convert raw ADC counts into engineering units. At the end of the cruise, the Level C disk base was transferred to BODC for further processing.

2.2 BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged.

3) Methodology and Calibration Procedures

3.1) Navigation

GPS was the primary navigation system used on this cruise. When no GPS fixes were available the ship's position was determined by dead reckoning based upon the ship's gyro and EM log. Once a fix was obtained after a period of dead reckoning, the surface drift velocity was computed. If this exceeded four knots, the data were automatically flagged suspect. The positional error due to surface drift was then retrospectively applied over the period of dead reckoning.

Distance run was computed from successive positional fixes using spherical trigonmetry.

At BODC the latitude and longitude channels were scanned for null values and checked to ensure that the ship's speed over the ground did not exceed 15 knots. There were no speed check errors. However, there were four gaps in the navigational record:-

20/05/94	00:16	to	20/05/94	00:22	6 minutes
06/06/94	08:47	to	06/06/94	09:34	47 minutes
11/06/94	19:14	to	11/06/94	19:52	38 minutes
11/06/94	19:53	to	11/06/94	21:27	94 minutes

The large gap on the 11/06/94 was due to logging problems with the RVS computers. The bridge logs were used to manually enter as many positions as possible during the above periods where the navigation was not automatically logged. The remaining null values were filled by linear interpolation and a further speed check was undertaken to confirm the validity of the interpolation.

The distance run channel was checked to ensure that it was progressive. This check showed that the parameter was reset to zero at 08:47 on 06/06/94 due to a Level C failure. Data was also lost between 19:14 and 21:27 on 11/06/94. The channel has therefore been recomputed from latitude and longitude.

Bathymetric depth was determined using a Simrad EA500 deep echo sounder logged automatically by the ABC system. Carter’s Table corrections were applied by the level C software. The channel required only minor screening to remove artefact spikes.

Surface Underway Data for Cruise Meteor 30 Leg 1

(6 - 20 September 1994)

1) Components of the Underway Data Set

The underway data set for M27_1 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve N) (B)
Bathymetric depth (m) (J)

Meteorology: Solar radiation (W/m^2) (O)
UV radiation (W/m^2) (o)
Absolute wind speed (knots) (Y)
Absolute wind direction (degrees blowing from) (Z)
Barometric pressure (mb) (1)
Air temperature (°C) (2)
Dew point temperature (°C) (k)
Relative humidity (%) (d)
Atmospheric particle concentration (cm^{-3}) (w)

Physics: Sea surface temperature (%) (C)
Salinity (PSU) (F)

2) Methodology Overview

Obtaining information about the systems and operational procedures has proved to be surprisingly difficult. Several requests for information have failed to provide the detailed technical data we require for complete documentation. What follows is therefore a little sketchy.

The navigation system used is not known other than it was a GPS system.

The type of echo sounder used is unknown but from viewing the record it can be seen to have no problems with deep water.

The fact that a thermosalinograph was operating indicates that the ship was equipped with a continuous pumped seawater supply. Neither the intake

depth, the type of instrument used nor the configuration of the temperature and conductivity sensors is known.

An Atlas DVS 1300 METPAC was used for continuous meteorological sampling, including UV and solar radiation sensors, a barometer, wet and dry bulb thermometers and cup and vane anemometers. The precise location of the sensors on the ship is not known, but many of the instruments were duplicated on the port and starboard sides of the ship.

Atmospheric particle concentration was measured on a continuous air stream taken from a sampling inlet located on a beam extending into the air flow just above the flying bridge, some 30m above sea level. A length of electrically conducting tubing less than 5m in length carried the air to the ship's air chemistry laboratory where it was sampled by a TSI model 30 condensation nucleus counter. The data were continuously recorded, integrated over periods of five minutes. A coincidence correction has been applied to the data.

Nothing is known about the data logging protocols.

3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key on a time base of 1 minute. The time channel supplied was labelled UTC, except for the UV radiation data which had a GMT+1 time channel. This has been corrected to GMT.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to undertake all possible comparative screening checks between channels.

4) BODC Quality Control and Calibration Procedures

4.1) Navigation and bathymetry

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots. The navigation data supplied were logged every 10 minutes.

Navigation at 1 minute sampling was generated from the data supplied by linear interpolation. There were no speed check failures.

The bathymetry data appear to be relatively clean with a small number of obvious spikes requiring flagging. It is not known whether these data have been corrected for variations in sound velocity.

4.2) Meteorology

Barometric pressure

The barometric pressure data appeared to be of good quality except for a single isolated spiked which has been flagged suspect.

Radiation

The solar radiation data showed a clear diurnal pattern with dawn and dusk at the expected times. Dark values exhibited a curious saw tooth pattern oscillating between -20 and -40 W/m^2 giving rise to some concern about the instrument calibration, but the maximum values of between 900 and 1000 W/m^2 seemed credible.

The UV radiation data again showed a credible diurnal pattern but have a strange quantised appearance as the data were supplied with a resolution of 1 W/m^2. Dark values oscillated between 0 and -1 W/m^2. The UV data were supplied as 1 minute averaged values.

Air temperature and humidity

The port and starboard dry bulb air temperature channels showed good agreement with differences between the channels <0.5 °C. From time to time the signal on either (or sometimes both) channel became noisy. These were flagged suspect. The channels were combined by averaging, excluding any flagged values, to provide a single air temperature data channel. The air temperatures compared credibly with the sea surface temperatures.

The port and starboard relative humidity channels showed good agreement. Both channels contained occasional spikes which have been flagged suspect. A merged humidity channel was generated by averaging the good data from the port and starboard channels.

The port and starboard dew point temperatures exhibited a common signal. A few isolated spikes, predominantly on the port channel, were flagged suspect. A merged dew point channel has been generated by averaging the good data from the port and starboard channels.

Wind velocity

Wind speeds supplied in m/s were converted to knots by multiplying by 1.943845.

The data from both anemometers were examined on a graphics workstation and were shown to be virtually identical with no evidence of shadowing by the superstructure. It was decided that there was nothing to be gained by storing two virtually identical channels and the starboard channel was chosen for inclusion in the final data set. Course changes had no effect on the wind velocity data.

Atmospheric particle concentration

These data were supplied with a quality control channel that has been applied to the data. Values specified as 'not good' or 'polluted' by the originator have been flagged suspect. No additional quality control has been applied.

4.3) Physics

Both temperature and salinity were calibrated against surface CTD data. Constant corrections of -0.187°C and -0.018 PSU respectively, were determined for the whole cruise and these have been applied to the data. Note that there was exceptionally high variance (standard deviation 0.03) in the offset between CTD salinity and thermosalinograph salinity. These data should not be used if high accuracy is required.

Visual inspection of the salinity signal showed the data between 16:00 on 13/09/1994 and 20:00 on 15/09/1994 to be unacceptably noisy and these have been totally flagged out.

The temperature signal was generally clean.

5) Data Warnings

The thermosalinograph salinity calibration was unusually poor and these data are not recommended for applications requiring high accuracy.

Surface Underway Data for Cruise Belgica 9506.

(3 - 17 March 1995)

1) Components of the Underway Data Set

The underway data set for Belgica 9506 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)
Bathymetric depth (m)(J)

Meteorology: Atmospheric pressure (mb)(1)
Air temperature (°C) (a)
Absolute wind speed (knots) (Y)
Absolute wind direction (degrees) (Z)
Solar radiation (W/m^2) (O)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

Biology: Turner Designs fluorescence (Volts) (D)
Turner Designs chlorophyll (mg/m^3) (G)

Chemistry: Oxygen concentration at in-situ temperature and salinity (µM) (Q)
pH (pH scale) (M)
Alkalinity (µEq/kg) ({)
pCO_2 (ppm) (E)
TCO_2 (µmol/kg) (H)

2) Underway instruments and methodology

The thermosalinograph used was a SeaBird SBE-21 with one thermistor temperature sensor mounted in the non-toxic inlet on the bow at a depth of 3.5m. A second thermistor was mounted adjacent to the conductivity cell for the determination of salinity from conductivity.

Navigation was by a Magnavox 200MX GPS system backed up by Shipmate RS4000 and Navstar 602D DECCA systems. Accuracy of the primary system was quoted as typically 50m.

Bathymetry was measured using an Atlas Deso 20 scientific echo sounder with 33 and 210 kHz transducers. The 33 kHz transducer has a range of approximately 1500m in good weather conditions, but a maximum working depth of 1000 m was more usual in typical sea conditions.

Meteorology data (except for solar radiation) came from a Friedrich Meteorological package mounted on the central mast. Solar radiation was measured by a Kipp and Zonen solar radiometer. This instrument was periodically intercalibrated with instruments based at Brussels University and was also calibrated by the manufacturer in the Netherlands on a regular basis.

A through flow Turner Designs 10-AU-005 fluorometer was plumbed in to the non-toxic supply.

Oxygen concentration was measured continuously using a KENT polarographic electrode frequently calibrated against discrete samples analysed by the Winkler method. Saturation was calculated using the equation proposed by Benson and Krause (1984). Oxygen was logged at 1 minute intervals then averaged by the originator to 5 minutes.

pH was measured continuously using a combined ROSS electrode and was calibrated on the total proton scale using buffers proposed by Dickson (1993). The error on the pH is estimated to 0.005 pH units.

Total alkalinity was measured about every 30 nautical miles by electrotitration (Gran method) and was linearly interpolated between samples for the carbon dioxide speciation calculation. Errors on alkalinity are estimated at 4 µEq/kg.

Carbon dioxide speciation (TCO_2 and pCO_2) was calculated using constants from Goyet and Poisson (1989), borate constant from Hansson (1973) and the carbon dioxide solubility coefficient from Weiss (1974). Further details are given in Frankignoulle et al. (1986, 1996).

3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key. All data were supplied with GMT time channels.

Wind speeds supplied in m/s have been converted to knots by multiplying by 1.943845.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to carry out comparative screening checks between channels by overlaying data channels. Oceanographic context was taken into account through simultaneous display of a map of the cruise track.

4) BODC Calibration and Quality Control

4.1) Navigation and bathymetry

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots.

Two major gaps in the navigation were found from 19:34 on 06/03/1995 to 07:00 on 08/03/1995, and from 11:02 on 10/03/1995 to 19:55 on 12/03/1995. These correspond to mid-cruise port calls at Brest and Bayonne respectively and therefore the gaps have been filled by linear interpolation. A number of small gaps of a few minutes duration have also been filled by linear interpolation. There were no speed check failures.

The bathymetry record was generally fairly clean at depths of less than 500 m. At greater depths the signal deteriorates to random noise caused by the effective range of the instrument in poor weather being exceeded. Affected portions of the record from 21:45 on 08/03/1995 to 09:30 on 09/03/1995, 13:00 on 09/03/1995 to 05:00 on 10/03/1995 and 23:58 on 12/03/1995 to 08:00 on 14/03/1995 were flagged suspect or null. A small number of isolated spikes have also been flagged suspect. It is not known whether a correction for sound velocity variations in sea water has been applied to the data.

4.2) Meteorology

Atmospheric pressure

The atmospheric pressure data appear generally good except for a small number of obvious spikes that have been flagged suspect.

Wind velocity

The data appear generally good with a handful of spikes flagged. No evidence of course changes affecting the data could be found.

Radiation

The solar radiation data show a clear diurnal signal with dawn and dusk at the expected times. A few spikes were flagged suspect. Dark values ranged between -3 and zero W/m^2 providing confidence in the calibration.

Air Temperature

There is no problem with the data other than a few isolated spikes which have been flagged suspect. The values appear credible when compared to sea surface temperature.

4.3) Physics

Temperature and Salinity

The temperature record is clean except for a short period between 07:59 and 10:01 on 06/03/1995. Temperature was back calibrated against surface CTD data. A constant offset of -0.021 °C was determined over the whole of the cruise and this has been applied to the data

The salinity data were subdivided into three segments for the purposes of calibration for the cruise legs from Boulogne to Brest, Brest to Bayonne and Bayonne to Zeebrugge.

For the Boulogne to Brest leg, the quality of the salinity signal was variable. Problems commenced late on 04/03/1995 on 05/03/1995, with much of the data between 22:40 and 09:30 the following day requiring heavy flagging. Further problems were encountered between 15:00 and 17:30 on 05/03/1995. An observed rise in salinity as the ship approached Brest harbour was regarded as suspicious and flagged out.

The calibration of the salinity data for this leg of the cruise posed a problem as there were no CTD or discrete sample data available. Further, large steps could be observed in the raw signal. The data were corrected on the assumption that the salinity of Channel surface water was 35.1, as confirmed by data from the return leg to Zeebrugge, and that the steps in the data should be eliminated. The following corrections have been applied:

03/03/1995 09:13 to 05/03/1995 00:19	+0.210 PSU
05/03/1995 00:20 to 05/03/1995 03:27	+0.260 PSU
05/03/1995 03:28 to 05/03/1995 15:44	no correction
05/03/1995 15:45 to 05/03/1995 19:38	+0.212 PSU

Due to the empirical nature of this calibration, the salinity data from this leg should be used with caution.

The ship was in port between 19:38 on 06/03/1995 to 07:00 on 08/03/1995 and there is a corresponding gap in the data record.

After leaving Brest, the salinity signal was extremely noisy and has been heavily flagged up to 16:30 on 08/03/95. The data were relatively clean from then until a gap in the data between 14:07 to 15:39 on the 09/03/1995. The data following this exhibited an offset from the preceding data and have been

calibrated separately. The data following the gap also showed a significant increase in noise and have been heavily flagged until 23:30 on 09/03/1995. The instrument was switched off on arrival at Bayonne at 10:24 on 10/03/1995.

Surface CTD data have been used to calibrate the salinity data for the Brest to Bayonne leg and the following model was found to be the best fit to the observed data:

Corrected salinity = Raw salinity + (Cycle number * Slope) + Offset

The following coefficients were determined:

08/03/1995 07:00 to 09/03/1995 15:38	slope	0.0000137	offset	0.1430
09/03/1995 15:39 to 10/03/1995 10:28	slope	0.0000137	offset	0.1588

These corrections have been applied to the data.

The data for the Bayonne to Zeebrugge leg commenced at 20:38 on 12/03/1995. The record was relatively clean except for the period between 06:30 and 18:00 on 15/03/1995 when the data were extremely noisy and required heavy flagging.

Surface CTD data were used to calibrate the salinity data for this leg of the cruise. A constant offset of -0.0025 PSU was determined and has been applied to the data.

4.4) Biology

Chlorophyll

Chlorophyll was measured by a Turner Design fluorometer calibrated against extracted chlorophyll data. The raw fluorometer data were first screened on a graphics workstation and any spikes flagged. The raw data were characterised by substantial negative and positive jumps. These jumps were removed by addition of an appropriate ‘offset’ to remove the jump from the data set.

The baseline offsets applied were as follows:

03/03/1995 09:13 to 05/03/1995 05:51	Zero
05/03/1995 05:52 to 05/03/1995 17:30	+0.4317
05/03/1995 17:31 to 05/03/1995 18:01	Zero
05/03/1995 18:02 to 05/03/1995 20:06	-0.4316
05/03/1995 20:07 to 06/03/1995 13:47	Zero
06/03/1995 13:48 to 06/03/1995 19:38	+0.5504
08/03/1995 07:00 to 09/03/1995 12:26	Zero
09/03/1995 12:27 to 09/03/1995 15:38	+1.1248
09/03/1995 15:39 to 10/03/1995 08:10	+0.9222

10/03/1995 08:11 to 10/03/1995 11:01	+2.1775
12/03/1995 19:56 to 15/03/1995 03:43	+0.6688
15/03/1995 03:44 to 15/03/1995 22:03	+0.4731
15/03/1995 22:04 to 16/03/1995 12:44	+0.3814
16/03/1995 12:45 to 16/03/1995 18:37	+0.5251
16/03/1995 18:38 to 17/03/1995 08:35	+0.5969

The calibration was divided into three segments; one for each leg of the cruise with a total calibration data set of 60 samples. Two extracted chlorophyll-a data sets were tried for the calibration purposes, derived using the Lorenzen and SCOR equations (Strickland and Parsons, 1975). **The SCOR chlorophyll-a values provided a much better fit to the fluorometer data and have been used for the calibration**.

Calibration was achieved by regression of the extracted chlorophyll value against the offset-corrected fluorometer voltage averaged over 5 minutes.

The resulting calibration equations were:

Boulogne - Brest:

chlorophyll (mg/m^3) = (0.079933*raw voltage) + 0.0171 + baseline offset

Brest - Bayonne:

chlorophyll (mg/m^3) = (0.225151*raw voltage) - 0.600 + baseline offset

Bayonne - Zeebrugge:

chlorophyll (mg/m^3) = (0.179650*raw voltage) + 0.144 + baseline offset

The adjusted R^2 for the regressions were 41, 80 and 88 percent respectively. Due to the small number of samples collected at concentrations above 5 mg/m^3 high chlorophyll fluorometer values should be used with caution. However, these form only a very small subset of the total data, resulting from the approach to Zeebrugge at the end of the cruise.

4.5) Chemistry

All channels have been screened and any spikes identified have been flagged suspect.

<u>Oxygen</u>

Data was supplied to BODC as oxygen saturation pre-calibrated against discrete samples analysed by the Winkler method. In-situ oxygen concentration has been calculated using the calibrated salinity and temperature data and the algorithm of Benson and Krause (1984). No

salinity data were available for a small number of data points. An assumed salinity of 35.5 was used in these cases.

The surface oxygen saturation for much of the cruise is around 90%, peaking up to 100%. These values are significantly lower than expected. The bottle oxygen data from this cruise have been rejected as suspect by BODC quality control and uncalibrated CTD data taken in preference. As bottle data analysed at the same time were used to calibrate the underway oxygen, it is strongly believed that there is a systematic error throughout this data set. **It should therefore be used with extreme caution.**

pH

pH was supplied as calibrated data. The error on pH is given as 0.005 pH units.

Total Alkalinity and carbon dioxide speciation.

Data were supplied to BODC in fully worked up form. No further calibration has been applied. Further details of the calibration procedures are given in Frankignoulle et al. (1986, 1996). Errors on the alkalinity channel are estimated to be 4 µEq/kg.

5) Data Warnings

The thermosalinograph salinity was calibrated against estimated Channel surface salinity for the leg from Boulogne to Brest and should be used with caution.

The fluorometer calibration is weighted to low levels of chlorophyll measured in the extracted chlorophyll samples and extrapolation to higher concentrations may therefore not be appropriate.

The oxygen data are believed to be systematically low by some 10 per cent.

6) Acknowledgements

The oxygen, pH, alkalinity and carbon dioxide speciation measurements were funded as part of the Belgian Impulse Programme on Global Change (contract no. GC/12/011). However, the data have been generously contributed by Michel Frankignoulle to enhance the OMEX data set.

7) References

Benson, B.B., Krause D. (1984). The concentration and isotopic fractionation of oxygen dissolved in fresh water and sea water in equilibrium with the atmosphere. ***Limnol.Oceanogr.*** 29 pp.620-632.

Dickson, A.G. (1993). PH buffers for sea-water media based on the the total hydrogen-ion concentration scale. ***Deep-Sea Research*** 40 pp.107-118.

Frankignoulle, M., Bourge, I., Canon, C., Dauby, P. (1986). Distribution of surface seawater partial CO_2 pressure in the English Channel and in the Southern Bight of the North Sea. ***Continental Shelf Research*** 16 pp.381-395.

Frankignoulle, M., Elskens, M., Biondo R., Bourge, I., Canon, C., Desgain S. & P. Dauby (1996). Distribution of inorganic carbon and related parameters in surface seawater of the English Channel during Spring 1994. ***Journal of Marine Systems*** 7 pp.427-434.

Goyet, C., Poisson A. (1989). New determination of carbonic-acid dissociation constants in sea-water as a function of temperature and salinity. ***Deep-Sea Research*** 36 pp.163-165.

Hansson I. (1973). A new set of acidity constants for carbonic acid and boric acid in sea water. ***Deep-Sea Research*** 20 pp.461-478.

Strickland, J.D.H., Parsons, T.R. (1975). A practical handbook of seawater analysis. ***Fish. Res. Bd. Can***. pp.167-311.

Weiss, R.F. (1974). Carbon dioxide in seawater: the solubility of a non-ideal gas. ***Marine Chemistry*** 2 pp. 203-215

Surface Underway Data for Cruise Charles Darwin 94

(3 - 20 June 1995)

1) Components of the Underway Data Set

The underway data set for Charles Darwin 94 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the underway data file.

Navigation: Latitude (degrees +ve N) (A)
Longitude (degrees +ve E) (B)
Distance run (km) (K)
Bathymetric depth (m) (J)

Meteorology: Photosynthetically available radiation - irradiance (W/m^2) (L)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)
Optical attenuance (per m) (I)

Biology: Aquatracka raw fluorescence (V) (?)
Aquatracka chlorophyll (mg/m^3) (!)

2) Methodology Overview

2.1) Plumbing

The ship was fitted with a non-toxic pumped sea water supply with water drawn from an inlet approximately 2.5 m below the surface, amidships on the starboard side. All ship's discharges were to port to minimise risk of contamination.

Water from the non-toxic pump was fed into a 130 litre black plastic header tank situated above the laboratory to remove bubbles. The supply from this tank fed the thermosalinograph. The Aquatracka fluorometer and transmissometer were fed separately from the non-toxic supply.

2.2) Data Acquisition

Data logging and initial processing was handled by the RVS ABC system. The Level A sampling microcomputer digitised an input voltage, applied a time stamp from the scientific master clock and transferred the data via the

Level B disk buffer onto the Level C where the Level A messages were assembled into data files. Sampling rates varied from 10-30 seconds.

The Level C included a suite of calibration software which was used to apply initial calibrations to convert raw ADC counts into engineering units. At the end of the cruise, the Level C disk base was transferred to BODC for further processing.

2.3) BODC Data Processing Procedures

Data from the Level C files were merged into a common file (the binary merge file) on a one minute time base, using time as the primary linking key. Data values sampled more frequently than one minute were reduced by averaging. Data logged as voltages (e.g. PAR) were converted to engineering units.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to undertake all possible comparative screening checks between channels by overlaying parameter plots.

The data from this cruise, with the exception of bathymetry, were generally of good quality with only occasional spikes flagged out. The bathymetry data required heavy flagging in parts but at other times were virtually noise free. Users are strongly advised against ignoring the quality control flags that have been applied.

3) Protocol Details, Quality Control and Calibration Procedures

3.1) Navigation

GPS was the primary navigation system used on this cruise. When no GPS fixes were available the ship's position was determined by dead reckoning based upon the ship's gyro and EM log. Once a fix was obtained after a period of dead reckoning, the surface drift velocity was computed. If this exceeded four knots, the data were automatically flagged suspect. The positional error due to surface drift was then retrospectively applied over the period of dead reckoning.

Distance run was computed from successive positional fixes using spherical trigonometry.

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots.

On this cruise, three short (1 minute, 5 minutes and 15 minutes) gaps were identified and filled by linear interpolation.

Four speed check failures were encountered, caused by spikes in the navigation. These were replaced by linearly interpolated values.

The distance run channel was checked to ensure it was progressive.

Bathymetric depth was determined using a Simrad echo sounder logged automatically by the ABC system. Carter's Table corrections were applied by the Level C software.

3.2) Meteorology

Radiation

Charles Darwin was equipped with two PML designed 2-pi PAR meters mounted on scaffold poles on either side of the 'Monkey Island' above the bridge. Note that these instruments measured irradiance which is significantly higher than radiance measured by instruments with planar geometry.

The PAR channels were logged as voltages and calibrated in W/m^2 by BODC using coefficients determined in February 1990. The calibration equations used were:

Port (sensor 4):	PAR = exp (Volts * -5.139 + 7.2376) / 100
Starboard (sensor 9):	PAR = exp (Volts * -5.052 + 6.7874) / 100

A merged PAR channel was produced (L), after spikes were flagged out, by taking the maximum synchronous port and starboard values to eliminate shading effects.

Visual inspection of the data showed a clear diurnal signal with dawn and dusk at the expected times with no spurious data during the hours of darkness.

3.3) Physics

Temperature and Salinity

The thermosalinograph was an improvised 'CTD in a bucket' based on SeaBird components incorporating a remote temperature sensor (high quality thermistor) and an inductive-type conductivity cell mounted next to a second thermistor.

The remote temperature sensor was supplied by water from the intake side of the non-toxic supply. The sea surface temperature was therefore measured at near-ambient temperature as opposed to being warmed by the heating effects that may be induced by the pumping system. The conductivity cell

and housing temperature thermistor were supplied by a flow-through system from the non-toxic supply.

The raw ADC counts were calibrated to give conductivity and two temperature channels based upon laboratory calibrations undertaken by RVS. Salinity was computed from the housing temperature and conductivity using the UNESCO 1978 Practical Salinity Scale (Fofonoff and Millard, 1982).

The temperature was calibrated against surface CTD data. A constant correction of –0.011 °C was determined for the whole cruise and this has been applied to the data. An interesting detail is that the same correction was obtained for Charles Darwin 84 cruise (Jan 1994).

Salinity was back calibrated using a combined data set comprising discrete salinity measurements on samples taken from thermosalinograph outlet and calibrated CTD surface samples. The calibration was split into four segments defined by discrete steps in the underway salinity record revealed during screening. The segments and corresponding applied offsets were:

1. 03/06/95 05:45 - 04/06/95 02:00 ..... 0.009 PSU
2. 04/06/95 02:03 - 04/06/95 10:48 ..... All flagged suspect
3. 04/06/95 10:49 - 15/06/95 04:00 ..... 0.009 PSU
4. 15/06/95 04:01 - 20/06/95 07:53 ..... –0.068 PSU

For the first segment, no calibration was possible and the calibration from the third segment has been applied. The second segment is clearly bounded by a clear drop in salinity at the start and a gap at the end. This has been interpreted as fouling and subsequent cleaning of the conductivity cell. **Users are advised to treat salinity data from the first segment with caution**.

Optical Attenuance

Optical attenuance was measured using a SeaTech 660 nm (red) 25 cm path length transmissometer (serial number 101D) contained in a plastic water bath continuously flushed by the non-toxic supply. The data were logged as voltages. These were corrected for light source decay using a ratio correction based on air voltage measured during the cruise and the air voltage measured when the instrument was new (cruise voltage in air 4.771V, manufacturer's figure 4.823V).

The percentage transmission (Volts*20) was converted to attenuance using the equation:

$$\text{Attenuance} = -4.0 \log (\% \text{ Transmission}/100).$$

Apart from a small number of isolated spikes, the graphic screening showed the signal to be steady throughout the cruise.

3.4) Biology

Chlorophyll

Chlorophyll was measured by a Chelsea mk2 SA244 fluorometer calibrated against discrete samples taken from the thermosalinograph outlet. Samples were filtered through Whatman GF/F filters and frozen until analysed. The frozen filters were extracted in 2-5 ml 90% acetone using sonification, and centrifuged to remove cellular debris. Analysis for pigments was performed by reversed **high pressure liquid chromatography (HPLC)** using absorbance detection for chlorophyll (Mantoura and Llewellyn, 1983).

Calibration was achieved by regression of the log of the HPLC chlorophyll-a values against the raw fluorometer voltage. The cruise data were treated as a single population and gave the relationship:

$$\text{chlorophyll } (mg/m^3) = \exp(-2.69 + 1.24 * \text{raw\_voltage})$$

The adjusted R^2 for this regression was 80.7 per cent.

4) Data Warnings

The salinity data prior to 10:49 on 04/06/1995 could not be properly calibrated and should be used with extreme caution.

5) References

Mantoura, R.F.C., Llewellyn, C.A. (1983). The rapid determination of algal chlorophyll and carotenoid pigments and their breakdown products in natural waters by reverse phase high performance liquid chromatography. ***Anal. Chim. Acta*** 151: 297-314.

Fofonoff, N.P., Millard Jr., R.C. (1983). Algorithms for computation of fundamental properties of seawater. ***UNESCO Technical Papers in Marine Science*** 44.

Surface Underway Data for Cruise Discovery DI216

(26 August - 12 September 1995)

1) Components of the Underway Data Set

The underway data set for the Discovery cruise DI216 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)
Distance run (km) (K)
Bathymetric depth (m) (J)

Meteorology: Barometric pressure (mb) (1)
Dry bulb air temperature (°C) (a)
Relative humidity (%) (d)
Wind speed (knots) (Y)
Wind direction (degrees blowing from) (Z)
Photosynthetically available radiation (W/m^2) (t)
Solar radiation (W/m^2) (O)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)
Optical attenuance (per m) (I)

Biology: Aquatracka raw fluorescence (Volts) (?)
Aquatracka chlorophyll (mg/m^3) (!)

2) Methodology Overview

2.1) Plumbing

The ship was equipped with pumped non-toxic sea water supply with an inlet on the starboard side at approximately 3 m depth. All ship's discharges are to port to keep contamination to a minimum. The thermosalinograph and transmissometer/fluorometer tank had independent feeds from the distribution manifold.

2.2) Data Acquisition

Data logging and initial processing was handled by the RVS ABC system. The Level A sampling microcomputer or PC digitised an input voltage,

applied a time stamp and transferred the data via the Level B disk buffer onto the Level C where the data records were assembled into files. Sampling rates varied from 10 seconds to 30 seconds.

The Level C included a suite of calibration software which was used to apply initial calibration to convert raw ADC counts into engineering units. At the end of the cruise, the Level C disk base was transferred to BODC for further processing.

2.3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) on a one minute time base using time as the primary linking key. Data sampled more frequently were reduced by numeric averaging except for direction channels where spot values were taken.

Data logged as voltages (e.g. transmittance) were converted to engineering units. Wind velocity was corrected for ship's motion and heading.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to undertake all possible comparative screening checks between channels (e.g. to ensure corrected wind velocity data are not influenced by changes in ship's heading).

3) Methodology and Calibration Procedures

3.1) Navigation

GPS was the primary navigation system used on this cruise. When no GPS fixes were available the ship's position was determined by dead reckoning based upon the ship's gyro and EM log. Once a fix was obtained after a period of dead reckoning, the surface drift velocity was computed. If this exceeded four knots, the data were automatically flagged suspect. The positional error due to surface drift was then retrospectively applied over the period of dead reckoning.

Distance run was computed from successive positional fixes using spherical trigonometry.

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots. The quality of the navigation channels were good. No gaps of longer than a couple of minutes duration were encountered. These small gaps were filled by linear interpolation. A single speed check fail

(19.1 knots), caused by a latitude spike, was noted. This was corrected by linear interpolation.

The distance run channel was checked to ensure it is progressive.

Bathymetry was measured using a SimRad EA500 deep echo sounder using a hull transducer. Standard Carter's Tables corrections were applied on the Level C. The bathymetry record was patchy. There are periods of good clean data but these are interspersed with periods that required heavy flagging to eliminate spurious shallow reflections and a few periods where no signal was discernible at all. These have been flagged out completely.

3.2) Meteorology

The scientific meteorological package on the rebuilt Discovery was mounted on a large platform running some 8m from port to starboard at the junction of the two main stanchions of the foremast. This was approximately 15.5 metres above sea level.

Barometric Pressure

Barometric pressure was measured by a Vaisala aneroid barometer, calibrated by the manufacturer with direct output to the PC Level A in millibars. No correction has been applied for height above sea level.

The data were examined on a graphics workstation and it was found that flagging was unnecessary. The pressures were also checked against the routine 6-hourly pressure observations taken by the bridge for the Meteorological Office and showed good agreement.

Air Temperature and Humidity

The Metpac fitted to Discovery for this cruise included two Vector Instruments psychrometers fitted to the port and starboard wings of the foremast platform. Data were logged as voltages and converted to temperature using a third order polynomial calibration. Humidity was measured by a Vaisala humidity sensor that output percentage humidity to the PC Level A.

Port and starboard dry bulb temperature channels were screened on a graphics workstation and suspect data were flagged. After inspection, which showed good agreement between the two, port and starboard channels were merged into one by averaging.

Comparison of the binary merge file with 6-hourly observations taken on the bridge showed that the scientific data were 2.5 °C less than the bridge observations; a correction of +2.5 °C has been applied to the binary merge channel.

The humidity record was clean and credible except for a small number of very obvious spikes. These have been flagged suspect.

Wind Velocity

Wind velocity was measured by a Vaisala cup anemometer and wind vane located on a pole above the port side of the foremast platform. Relative wind speed was output directly in m/s and was converted to knots on the Level C by multiplying by 1.94. Relative wind direction was output in degrees with a zero reading when wind was on the stern.

Conversion from relative to absolute wind velocity was undertaken at BODC. The ship's heading was added to the wind direction relative to the ship to give wind direction relative to compass co-ordinates. The ship's velocity over the ground was computed from GPS navigation, and then subtracted from the relative wind velocity to give absolute wind velocity. Note that this is effectively a vector addition because the wind direction is expressed in terms of 'blowing from' whereas the ship's velocity is expressed in terms of 'steaming towards'. Due to the ship's gyro not being logged (and hence no heading available) there is no calibrated wind velocity data from 31/08/95 05:59 to 02/09/95 12:54.

Comparative screening checks were made to ensure that the absolute wind velocity was truly independent of the ship's velocity and heading. The only problem noted were spikes in the wind direction when the ship was turning due to meteorology and navigation being sampled at different frequencies. These have been flagged suspect. The data were compared against the bridge observations and showed good agreement.

Radiation

Discovery was equipped with two Didcot cosine collector PAR sensors (spectral range 400-700 nm) located port and starboard on the foremast (respective serial numbers 0150 and 0151), and two Kipp and Zonen total radiance sensors (92015 and 92016 located port and starboard). It should be noted that Didcot PAR sensors measure radiance unlike the PML 2-pi PAR meters which measure irradiance. Radiance values are considerably lower than irradiance. All data were calibrated as W/m^2 on the Level C using manufacturers' calibrations.

Only the port PAR sensor was operational. The data present in channel (t) are therefore liable to shading effects. Visual inspection of this channel showed the values at night to 20-30 W/m^2. The midday values do not exceed 200 W/m^2 which seems low, even for radiance considering the solarimeters were recording values of up to 1000 W/m^2 and BODC personnel on the cruise remember bright sunny days. **This indicates either calibration problems or dirty sensors and it is recommended that these PAR data are used with caution**. It should be noted that data quality deteriorated further prior to the port sensor failing completely on the next cruise.

The individual solarimeter channels were screened to remove any obvious 'electrical' spikes. A merged radiance channel (O) was produced by taking the maximum of the port and starboard values to minimise shading effects. No doubts were raised about the quality of the solarimeter data.

3.3) Physics

Temperature and Salinity

The instrument used was a Falmouth Scientific Instruments thermosalinograph incorporating a remote temperature sensor and an inductive-type conductivity cell mounted next to a second thermometer.

The remote temperature sensor was located in the intake of the non-toxic supply. The sea surface temperature was therefore measured at near-ambient temperature. The conductivity cell and housing temperature thermistor were supplied by a flow-through system from the non-toxic supply.

The raw ADC counts were calibrated to give conductivity and two temperature channels based upon laboratory calibrations undertaken by RVS. Salinity was computed from the housing temperature and conductivity using the UNESCO 1978 Practical Salinity Scale (Fofonoff and Millard, 1982). All this processing was done on the ship's Level C computer.

Salinity was back calibrated using calibrated CTD and non-toxic supply surface samples. From this analysis, it was apparent that the salinity data prior to 29/08/95 04:36 and from 19:45 on 01/09/95 until the end of the cruise are significantly in error. This has been attributed to problems with the non-toxic supply to the thermosalinograph. All affected data have been flagged suspect.

For the period when sea water was freely flowing through the cell, the thermosalinograph measured approximately 0.5 PSU higher than the discrete CTD and non-toxic supply samples. The salinity correction was also found to be a function of the salinity. A regression of salinity against correction required showed a good correlation (r^2 = 98.8%), hence the following correction has been applied:

$$S_{corrected} = S_{observed} + ((S_{observed} * 0.009) - 0.534)$$

The remote (i.e. sea surface) temperature was back calibrated against surface CTD data. The temperature exhibited a straight offset which did not alter throughout the cruise. The following correction has been applied:

$$T_{corrected} = T_{observed} - 0.005°C$$

Visual inspection of the temperature channel showed it to be an exceptionally clean signal. Isolated spikes and occasional short periods of noise have been flagged suspect.

Optical Attenuance

Optical attenuance was measured using a SeaTech 660 nm (red) 25 cm path length transmissometer contained in a plastic water bath continuously flushed by the non-toxic supply. The data were logged as voltages (originally mV which were converted to V at BODC). These were corrected for light source decay using a ratio correction based on air voltages measured during the cruise and the air voltage measured when the instrument was new (cruise voltage in air 4.776 V, manufacturer's figure 4.823V).

The percentage transmission (Volts*20) was converted to attenuance using the equation:

Attenuance = -4.0 log (% Transmission/100).

Inspection of the data using a graphics workstation showed them to be of a very high quality with only a few 'bubble spikes' to flag suspect. The instrument was cleaned at 15:30 on 31/08/1995 and 09:35 on 10/09/1995 with no discernible offset in the data. Data collected during maintenance have been flagged suspect.

3.4) Biology

Chlorophyll

Chlorophyll was measured by a Aquatracka fluorometer calibrated against extracted chlorophyll data. Samples were taken from the non toxic supply, filtered through Whatman GF/F filters and analysed on board. The filters were extracted in 2-5 ml 90% acetone using sonification, and centrifuged to remove cellular debris. Analysis for pigments was performed **by reversed high pressure liquid chromatography (HPLC)** using absorbance detection for chlorophyll (Mantoura and Llewellyn, 1983).

The raw fluorometer data were screened on a graphics workstation which showed a very clean record requiring no flagging.

The calibration data set comprised 23 samples. Calibration was achieved by regression of the log of the extracted chlorophyll value against the raw fluorometer voltage averaged over 3 minutes. The cruise data were treated as a single population.

The resulting equation was:

chlorophyll (mg/m^3) = exp (-4.53 + 2.67*raw_voltage)

The adjusted R^2 for this regression was 79.9 per cent.

There was no significant correlation between calibration error and PAR and therefore a quench correction was not applied to this cruise.

4) Data Warnings

There is a gap in wind velocity data between 31/08/95 05:59 and 02/09/95 12:54 due to failure to log the gyro for this period.

The PAR data are believed to be of poor quality and should be used with caution.

Salinity data are only valid between 29/08/95 04:36 and 19:45 01/09/95 due to problems with the non-toxic supply to the thermosalinograph.

5) References

Mantoura, R.F.C., Llewellyn, C.A. (1983). The rapid determination of algal chlorophyll and carotenoid pigments and their breakdown products in natural waters by reverse phase high performance liquid chromatography. ***Anal. Chim. Acta*** 151, pp. 297-314.

Fofonoff, N.P., Millard Jr., R.C. (1983). Algorithms for computation of fundamental properties of seawater. ***UNESCO Technical Papers in Marine Science*** 44.

Surface Underway Data for Cruise Poseidon 211

(31 August - 11 September 1995)

1) Components of the Underway Data Set

The underway data set for Poseidon 211 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)

Meteorology: Absolute windspeed (knots) (Y)
Absolute wind direction (degrees blowing from) (Z)
Barometric pressure (1)
Dry bulb air temperature (°C) (a)
Wet bulb air temperature (°C) (b)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

Chemistry: Aqueous pCO_2 (ppm) (E)
Atmospheric pCO_2 (u)

2) Methodology Overview and Calibration Procedures

Obtaining information about the systems and operational procedures has proved to be surprisingly difficult. Several requests for information have failed to provide the detailed technical data we require for complete documentation. What follows is therefore a little sketchy.

A continuous supply of surface seawater was provided by a pump fitted to the moon pool of the ship.

The navigation system used is not known but it seems inconceivable that any system other than GPS would be used on a cruise in 1995.

The type of thermosalinograph used is not known. Data were supplied as temperature and salinity.

The meteorological package is of unknown type and the location of the sensors is not known.

Atmospheric and aqueous pCO_2 were measured by a fully automated system. Seawater concentrations were determined by analysis of a sample of air that had been equilibrated with a continuous flow of seawater. The air was dried with Sicapent, separated by gas chromatography and measured, after reduction by H_2 on an activated Ni catalyst, with an FID. Two calibration gases, two uncontaminated air samples pumped from the ship's bow and four seawater samples were measured during an 80 minute system cycle.

3) BODC Data Processing

3.1) Reformatting and screening

The data supplied had a 1 minute GMT time base except for the pCO_2 data that were sampled every 20 (seawater) or 40 (atmosphere) minutes. All channels have been merged onto a regular one minute time base.

Navigation

A program was run that checked for gaps in the navigation and that the ship's speed did not exceed 15 knots. Two large gaps were found, from 14:29 on 03/09/1995 to 09:15 on 04/09/1995 and 19:00 on 04/09/1995 to 03:18 on 05/09/1995. These have been filled by linear interpolation. There were no speed check failures.

Barometric Pressure

No flagging of barometric pressure was required as the signal was perfectly clean. It was noted that the maximum value in the record of 1036 mb on 02/09/1995 is exceptionally high but not incredible. RRS Discovery was on the Goban Spur at the time and was recording approximately 1022 mb. However, Poseidon was a considerable distance away, just south of Iceland, and so this difference of 14 mb between the two ships is possible.

Air Temperature

The port and starboard dry bulb air temperature channels showed excellent (within 0.1 of a degree) agreement for much of the time with the exception of periodic episodes where the starboard value rose above the port value by up to 10 degrees. Some, but not all, of these are associated with times when solar heating would be expected. The rate of temperature change during these episodes indicates that they are an artefact, probably caused by inadequate screening of the sensor. Consequently, the elevated starboard values were flagged suspect and a combined air temperature produced by averaging all values that were not flagged suspect. The air temperatures compared credibly with the sea surface temperature.

A similar pattern was observed in the wet bulb temperatures and the same processing strategy was adopted. The merged wet and dry bulb channels exhibited a credible interrelationship.

Wind Velocity

Initial examination of the corrected wind velocity data supplied gave cause for concern. At the start of the cruise, when barometric pressure was 1020 mb and rising, wind speeds of 20-30 knots were recorded. Moreover, there were a number of segments of wind speed data exhibiting a sudden and significant offset from the rest of the data. Further investigation showed that these were associated with changes in course or the ship stopping. Additional checks showed that the ship's velocity correction had been applied with the wrong sign.

The corrected wind velocity was recomputed with BODC software and all the artefacts noted in the original data disappeared. However, two artefacts, upward jumps in wind speed of 5-7 knots, were introduced into the data of 05/09/1995. These were investigated and the conclusion was that the corrected data were consistent with the raw data. Immediately prior to the ship stopping, the raw wind direction showed the ship to be steaming obliquely into the wind. On stopping, the raw wind speed increased whereas a decrease would be expected. Two possible explanations come to mind. First, the anemometer vane had jammed, indicating the wind to be on the forward quarter when it was in fact on the aft quarter. Secondly, the anemometer was sheltered whilst steaming and moved out of shelter when the ship turned head to wind to heave to. Data believed to be affected by this problem have been flagged suspect.

No ship's velocity data were logged for the following periods, which were filled with interpolated data by the originator:

14:29 on 03/09/1995 to 10:00 on 04/09/1995
19:01 on 04/09/1995 to 03:17 on 05/09/1995
10:15 on 05/09/1995 to 11:00 on 05/09/1995

During the first two periods, there is every indication that the ship was sailing a steady course and therefore it is believed that the corrected wind data computed using the interpolated wind data are reasonably accurate. During the third period, the ship slowed considerably and the wind speed data are considered unreliable and would have been flagged suspect had they not already been flagged for the reason discussed above.

As a final check, the Poseidon data from September 8th were compared with data from Discovery DI216. The two ships passed within 50 miles of each other on this day. Both data sets show wind speeds decreasing from 20 to 12 knots during the day with directions backing from 310 to the low 200s.

It should be noted that the BODC conversion software option to input relative wind speed in m/s and output absolute wind speed in knots was operative. The conversion factor used was 1.943845.

Temperature and Salinity

Inspection of the temperature and salinity data revealed few problems and only odd isolated, relatively small spikes were flagged suspect. There are two gaps in the thermosalinograph data set:

00:00 on 06/09/1995 to 00:00 on 07/09/1995
00:00 on 10/09/1995 to 14:14 on 10/09/1995

These have been filled by the originator with linearly interpolated data and have been flagged 'I' in the binary merge file.

There were no CTDs or salinity calibration samples from this cruise and therefore no independent check or calibration was possible on the thermosalinograph data. **The absolute values from the thermosalinograph should therefore be used with caution.**

4) Data Warnings

A problem with the wind speed data from this cruise on September 5th was detected and the affected data flagged. However, this problem was revealed by the ship stopping and there is a possibility that data from elsewhere in the cruise have been affected but not detected.

The thermosalinograph data have not been calibrated to the usual BODC standard due to the absence of CTD and sample data from this cruise. The absolute values should therefore be used with caution.

Surface Underway Data for Cruise Belgica 9521.

(11 - 20 September 1995)

1) Components of the Underway Data Set

The underway data set for Belgica 9521 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)
Bathymetric depth (m)(J)

Meteorology: Atmospheric pressure (mb)(1)
Air temperature (°C) (a)
Absolute wind speed (knots) (Y)
Absolute wind direction (degrees) (Z)
Solar radiation (W/m^2) (O)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

Biology: Turner Designs fluorescence (Volts) (D)
Turner Designs chlorophyll (mg/m^3) (G)

Chemistry: Oxygen concentration at in-situ temperature and salinity (µM) (Q)
pH (pH scale) (M)
Alkalinity (µEq/kg) ({)
pCO_2 (ppm) (E)
TCO_2 (µmol/kg) (H)

2) Underway instruments and methodology

Up to three temperature sensors could be mounted in the non-toxic inlet which was located in the bow at a 3.5 m depth. Two of these were Rosemount Pt resistance thermometers whilst the third was the remote thermistor of the SeaBird SBE-21 thermosalinograph. Operational practice was to have one of the Rosemounts on the ship whilst the other is back in Ostend for laboratory calibration checks. The primary source of sea surface temperature data was the SBE-21, with back up in case of system failure provided by the Rosemount.

The thermosalinograph was a SeaBird SBE-21.

Navigation was by a Magnavox 200MX GPS system backed up by Shipmate RS4000 and Navstar 602D DECCA systems. Accuracy of the primary system was quoted as typically 50m.

Bathymetry was measured using an Atlas Deso 20 scientific echo sounder with 33 and 210 kHz transducers. The 33 kHz transducer has a range of approximately 1500m in good weather conditions, but a range of 1000 m or less was common in normal Atlantic conditions.

Meteorology data (except for solar radiation) came from a Friedrich Meteorological package mounted on a central mast. Solar radiation was measured by a Kipp and Zonen solar radiometer. This instrument was periodically intercalibrated with instruments based at Brussels University and was also calibrated by the manufacturer in the Netherlands on a regular basis.

Oxygen concentration was measured continuously using a KENT polarographic electrode frequently calibrated against discrete samples analysed by the Winkler method. Saturation was calculated using the equation proposed by Benson and Krause (1984). Oxygen was logged at 1 minute intervals then averaged by the originator to 5 minutes.

pH was measured continuously using a combined ROSS electrode and was calibrated on the total proton scale using buffers proposed by Dickson (1993). The error on the pH was estimated at 0.005 pH units.

pCO_2 was measured continuously. Sea water from the non-toxic supply was fed into the top of an equilibrator constructed from a 1 metre length of plexiglass tubing filled with glass marbles. Clean air, taken from an inlet at the bow of the ship, was pumped into the base of the equilibrator using an aquarium pump. The equilibrated air from the top of the tower was passed through a drying column into a LiCor CO_2 analyser. The data were logged onto a laptop computer with its clock carefully synchronised with the main data acquisition system computer. The system included a temperature probe at the base of the equilibrator and a barometer to provide data for the correction of the pCO_2 to in-situ conditions at one bar atmospheric pressure.

Total alkalinity was measured by electrotitration (Gran method) on discrete samples and was interpolated by computation from the pCO_2 and pH data. Errors on alkalinity were estimated at 2 µEq/kg.

Total inorganic carbon (TCO_2) was calculated using constants from Goyet and Poisson (1989), borate constant from Hansson (1973) and the carbon dioxide solubility coefficient from Weiss (1974). Further details are given in Frankignoulle et al. (1986, 1996).

A through flow Turner Designs 10-AU-005 fluorometer was plumbed in to the non-toxic supply.

3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key. All data were supplied with GMT time channels.

Wind speeds supplied in m/s have been converted to knots by multiplying by 1.943845.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to carry out comparative screening checks between channels by overlaying data channels. Oceanographic context was taken into account through simultaneous display of a map of the cruise track.

4) BODC Calibration and Quality Control

4.1) Navigation and bathymetry

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots. There were no speed check failures. A gap in the navigation between 16:43 and 16:48, and another between 17:28 and 18:24 on the 12/09/1995 have been filled by linear extrapolation.

The bathymetry record was generally fairly clean down to depths of 1000m up to 11:35 on 15/09/1995. Between 11:35 on 15/09/1995 and 06:50 on 17/09/1995 the data are extremely noisy with misleading shallow signals (possibly secondary reflections) and have therefore been flagged out. The signal was again noisy on the 18/09/1995 between 06:50 and 12:00 and again between 14:30 and 16:15: these data have been heavily flagged.

4.2) Meteorology

<u>Atmospheric pressure</u>

The atmospheric pressure data appeared generally good except for a small number of obvious negative spikes of up to 10 mb on the 14/09/1995 and 18/09/1995 which have been flagged suspect.

Wind velocity

The data appeared generally good with a handful of spikes flagged. The only problem to report concerned the wind direction data between 00:00 and 12:00 on 17/09/1995. A number of very unnatural looking jumps of up to 50-60 degrees occurred in this period. No cause could be attributed to these but the affected data have been flagged suspect. No evidence of course changes generating systematic effects in the data could be found.

Radiation

The solar radiation data showed a clear diurnal signal with dawn and dusk at the expected times. A few pre-dawn spikes were flagged suspect. Dark values ranged between -2 and zero W/m^2 providing confidence in the calibration.

Air Temperature

There were no problems with the data other than a few isolated spikes which have been flagged suspect. The values appeared credible when compared to sea surface temperature and diurnal solar heating was taken into account.

4.3) Physics

Temperature and Salinity

Salinity quality was variable. The record was clean for much of the time but between 23:10 on 13/09/1995 and 23:30 on 14/09/1995 the signal was noisy and there were a large number of low value spikes requiring heavy flagging.

The temperature record was clean with virtually no flagging required.

Both temperature and salinity were back calibrated against surface CTD data using regression techniques. The cruise data were treated as a single population. The resulting equations were:

$$temperature_{(corrected)} = (1.000063 * temperature_{(raw)}) - 0.01668 \quad R^2 = 99.9\%$$

$$salinity_{(corrected)} = (0.934438 * salinity_{(raw)}) + 2.378039 \quad R^2 = 99.2\%$$

4.4) Biology

Chlorophyll

The raw fluorometer data were first screened on a graphics workstation and any spikes flagged.

Chlorophyll was measured by a Turner Design fluorometer calibrated against extracted chlorophyll data. Two chlorophyll data sets were considered for the

calibration. Both were assayed **spectrophotometrically** by the University of Liege but using two different protocols. The first derived chlorophyll-a and phaeopigments using the Lorenzen equation. The second derived chlorophyll-a, chlorophyll-b, chlorophyll-c and carotenoid pigments using the SCOR equation. These protocols are specified in detail in Strickland and Parsons (1975). **The SCOR chlorophyll-a values provided a much better fit to the fluorometer data and have been used for the calibration.**

The calibration data set comprised 40 discrete extracted chlorophyll samples. Calibration was achieved by regression of the extracted chlorophyll value against the raw fluorometer voltages averaged over 2 minutes.

The form of the calibration equation is:

$$\text{chlorophyll}(mg/m^3) = (\text{slope} * \text{fluorometer voltage}) + \text{offset}$$

The raw data were characterised by a series of substantial negative and positive jumps. These were corrected out of the data set by adjusting the calibration offset as appropriate giving a series of calibration coefficients thus:

11/09/1995 10:36 to 11/09/1996 13:58	slope 0.10296	offset -0.15800
11/09/1995 13:59 to 11/09/1995 16:04	slope 0.10296	offset +0.10969
11/09/1995 16:05 to 11/09/1995 21:50	slope 0.10296	offset -0.15800
11/09/1995 21:51 to 12/09/1995 06:22	slope 0.10296	offset +0.48035
12/09/1995 06:23 to 15/09/1995 09:26	slope 0.10296	offset +1.07752
15/09/1995 09:27 to 18/09/1995 00:59	slope 0.10296	offset +0.48035
18/09/1995 01:00 to 19/09/1995 07:46	slope 0.10296	offset -0.15800
19/09/1995 07:47 to 19/09/1995 09:30	slope 0.10296	offset -0.51836

The adjusted R^2 for the regression against step-corrected raw data was 65.6 percent.

4.5) Chemistry

All channels have been screened and any spikes identified have been flagged suspect.

<u>Oxygen</u>

Data were supplied to BODC as oxygen saturation pre-calibrated against discrete samples analysed by the Winkler method. In-situ oxygen concentration has been calculated using the calibrated salinity and temperature data and the algorithm of Benson and Krause (1984). No salinity data were available for a small number of points on the shelf break. An assumed salinity of 35.5 was used in this case.

pH

pH was supplied as calibrated data. The error on pH was given as 0.005 pH units. Isolated spikes have been flagged suspect.

Total Alkalinity and carbon dioxide speciation.

Data were supplied to BODC in fully worked up form. No further calibration has been applied. Further details of the calibration procedures are given in Frankignoulle et al. (1986, 1996). Errors on the alkalinity and pCO2 channels were estimated to be 2 µEq/kg and 6 ppm respectively.

5) Acknowledgements

The oxygen, pH, alkalinity and carbon dioxide speciation measurements were funded as part of the Belgian Impulse Programme on Global Change (contract no. GC/12/011). However, the data have been generously contributed by Michel Frankignoulle to enhance the OMEX data set.

6) References

Benson, B.B., Krause D. (1984). The concentration and isotopic fractionation of oxygen dissolved in fresh water and sea water in equilibrium with the atmosphere. ***Limnol.Oceanogr.*** 29 pp.620-632.

Dickson, A.G. (1993). PH buffers for sea-water media based on the the total hydrogen-ion concentration scale. ***Deep-Sea Research*** 40 pp.107-118.

Frankignoulle, M., Bourge, I., Canon, C., Dauby, P. (1986). Distribution of surface seawater partial CO_2 pressure in the English Channel and in the Southern Bight of the North Sea. ***Continental Shelf Research*** 16 pp.381-395.

Frankignoulle, M., Elskens, M., Biondo R., Bourge, I., Canon, C., Desgain S. & P. Dauby (1996). Distribution of inorganic carbon and related parameters in surface seawater of the English Channel during Spring 1994. ***Journal of Marine Systems*** 7 pp.427-434.

Goyet, C., Poisson A. (1989). New determination of carbonic-acid dissociation constants in sea-water as a function of temperature and salinity. ***Deep-Sea Research*** 36 pp.163-165.

Hansson I. (1973). A new set of acidity constants for carbonic acid and boric acid in sea water. ***Deep-Sea Research*** 20 pp.461-478.

Strickland, J.D.H., Parsons, T.R. (1975). A practical handbook of seawater analysis. ***Fish. Res. Bd. Can***. pp.167-311.

Weiss, R.F. (1974). Carbon dioxide in seawater: the solubility of a non-ideal gas. ***Marine Chemistry*** 2 pp. 203-215.

Surface Underway Data for Cruise Belgica 9522

(22 - 29 September 1995)

1) Components of the Underway Data Set

The underway data set for Belgica 9522 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (deg +ve N) (A)
Longitude (deg +ve E) (B)
Bathymetric depth (m)(J)

Meteorology: Atmospheric pressure (mb)(1)
Air temperature (°C) (a)
Absolute wind speed (knots) (Y)
Absolute wind direction (degrees) (Z)
Solar radiation (W/m^2) (O)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)

Biology: Turner Designs fluorescence (Volts) (D)
Turner Designs chlorophyll (mg/m^3) (G)

Chemistry: Oxygen concentration at in-situ temperature and salinity (µM) (Q)
pH (pH scale) (M)
Alkalinity (µEq/kg) ({)
pCO_2 (ppm) (E)
TCO_2 (µmol/kg) (H)

2) Underway instruments and methodology

Up to three temperature sensors could be mounted in the non-toxic inlet which was located in the bow at a 3.5 m depth. Two of these were Rosemount Pt resistance thermometers whilst the third was the remote thermistor of the SeaBird SBE-21 thermosalinograph. Operational practice was to have one of the Rosemounts on the ship whilst the other is back in Ostend for laboratory calibration checks. The primary source of sea surface temperature data was the SBE-21, with back up in case of system failure provided by the Rosemount.

The thermosalinograph was a SeaBird SBE-21.

Navigation was by a Magnavox 200MX GPS system backed up by Shipmate RS4000 and Navstar 602D DECCA systems. Accuracy of the primary system was quoted as typically 50m.

Bathymetry was measured using an Atlas Deso 20 scientific echo sounder with 33 and 210 kHz transducers. The 33 kHz transducer has a range of approximately 1500m in good weather conditions, but a range of 1000 m or less was common in normal Atlantic conditions..

Meteorology data (except for solar radiation) came from a Friedrich Meteorological package mounted on a central mast. Solar radiation was measured by a Kipp and Zonen solar radiometer. This instrument was periodically intercalibrated with instruments based at Brussels University and was also calibrated by the manufacturer in the Netherlands on a regular basis.

Oxygen concentration was measured continuously using a KENT polarographic electrode frequently calibrated against discrete samples analysed by the Winkler method. Saturation was calculated using the equation proposed by Benson and Krause (1984). Oxygen was logged at 1 minute intervals then averaged by the originator to 5 minutes.

pH was measured continuously using a combined ROSS electrode and was calibrated on the total proton scale using buffers proposed by Dickson (1993). The error on the pH was estimated at 0.005 pH units.

pCO_2 was measured continuously. Sea water from the non-toxic supply was fed into the top of an equilibrator constructed from a 1 metre length of plexiglass tubing filled with glass marbles. Clean air, taken from an inlet at the bow of the ship, was pumped into the base of the equilibrator using an aquarium pump. The equilibrated air from the top of the tower was passed through a drying column into a LiCor CO_2 analyser. The data were logged onto a laptop computer with its clock carefully synchronised with the main data acquisition system computer. The system included a temperature probe at the base of the equilibrator and a barometer to provide data for the correction of the pCO_2 to in-situ conditions at one bar atmospheric pressure.

Total alkalinity was measured by electrotitration (Gran method) on discrete samples and was interpolated by computation from the pCO_2 and pH data. Errors on alkalinity were estimated at 2 µEq/kg.

Total inorganic carbon (TCO_2) was calculated using constants from Goyet and Poisson (1989), borate constant from Hansson (1973) and the carbon dioxide solubility coefficient from Weiss (1974). Further details are given in Frankignoulle et al. (1986, 1996).

A through flow Turner Designs 10-AU-005 fluorometer was plumbed into the non-toxic supply.

3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) using time as the primary linking key. All data were supplied with GMT time channels.

Wind speeds supplied in m/s have been converted to knots by multiplying by 1.943845.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to carry out comparative screening checks between channels by overlaying data channels. Oceanographic context was taken into account through simultaneous display of a map of the cruise track.

4) BODC Calibration and Quality Control

4.1) Navigation and bathymetry

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots. There were no speed check fails nor large gaps in the navigation. The odd gap of one minute duration has been filled by linear extrapolation.

The bathymetry record was generally clean down to depths of 450 m. Below 450 m in rough weather, no useful data was collected e.g. the gap in bathymetry between 19:41 on 22/09/1995 to 11:19 on 23/09/1995. From 05:00 on 24/09/1995 to 16:40 on 25/09/1995 the data were extremely noisy with a misleading shallow signal (possible secondary reflections), but after substantial flagging some bathymetry is available to depths of around 1000 m.

4.2) Meteorology

Atmospheric pressure

The atmospheric pressure data channel was clean and required no flagging.

Wind velocity

The data appeared generally good with a handful of spikes flagged. On two occasions, significant changes in wind direction coincide with course changes (23/09/1995 22:32 to 23:22 and 26/09/1995 18:03 to 19:10) indicating a problem (probably temporary loss of ship's velocity information) with the data correction for ship’s heading and velocity. However, equally

dramatic changes in course at other times had no effect on the wind velocity data.

Radiation

The solar radiation data showed a clear diurnal signal with dawn and dusk at the expected times. Dark values ranged between -2 and zero W/m^2 providing some confidence in the calibration.

Air Temperature

There were no problems with these data. The values exhibited a diurnal solar heating cycle and were credible when compared to sea surface temperature.

4.3) Physics

Temperature and Salinity

Salinity quality was variable. The record was clean for much of the time but for periods during 24/09/1995 to 27/09/1995 there were a large number of low value spikes that required heavy flagging. There was a downward step in the salinity signal of 0.086 PSU between 19:32 and 21:33 on the 25/09/1995 which has been corrected through the calibrations specified below.

The temperature record was clean with no flagging required.

Surface CTD data were used to calibrate both salinity and temperature. The salinity correction was determined as +0.050 PSU prior to 19:32 on 25/09/1995, +0.136 PSU between 19:32 and 21:33 on 25/09/1995, returning to +0.050 for the remainder of the cruise.

A constant temperature offset (-0.0083 ºC) was obtained for the whole cruise.

These calibrations have been applied to the data.

4.4) Biology

Chlorophyll

Chlorophyll was measured by a Turner Design fluorometer calibrated against extracted chlorophyll data. The raw fluorometer data were first screened on a graphics workstation and any spikes flagged. The raw data were characterised by substantial negative and positive jumps. These jumps were removed by addition of a nominal ‘offset’ included in the calibration coefficients given below..

The calibration data set comprised 14 discrete extracted chlorophyll samples, assayed **spectrophotometrically** using the **Lorenzen equation** to give chlorophyll-a and phaeopigments. Calibration was achieved by regression of the extracted chlorophyll value against the raw fluorometer voltage averaged over 2 minutes.

The resulting equation was:

$$\text{chlorophyll}(mg/m^3) = (\text{slope} * \text{fluorometer voltage}) - \text{offset}$$

The adjusted R^2 for the regression was 87.8 percent.

The slopes and offsets used are given below.

22/09/1995 07:14 to 22/09/1995 13:16	slope 0.103691	offset -0.25676
22/09/1995 13:17 to 23/09/1995 05:27	slope 0.103691	offset -0.51598
23/09/1995 05:28 to 24/09/1995 23:03	slope 0.103691	offset -0.25676
24/09/1995 23:04 to 26/09/1995 22:42	slope 0.103691	offset -0.87891
26/09/1995 22:43 to 29/09/1995 07:14	slope 0.103691	offset -0.41229

Due to the small number of calibration samples and the uncertainty involved in the differentiation of real data features from voltage steps, the corrected data should be used with a degree of caution.

Note: Two chlorophyll data sets were tried for the calibration purposes, derived using the Lorenzen (chlorophyll-a and phaeopigments) and SCOR (chlorophyll-a, chlorophyll-b, chlorophyll-c and carotenoids) equations (Strickland and Parsons, 1975). **The Lorenzen chlorophyll-a values provided a much better fit to the fluorometer data and have been used for the calibration**.

4.5) Chemistry

All channels have been screened and any spikes identified have been flagged suspect.

Oxygen

Data were supplied to BODC as oxygen saturation pre-calibrated against discrete samples analysed by the Winkler method. In-situ oxygen concentration has been calculated using the calibrated salinity and temperature data and the algorithm of Benson and Krause (1984). No salinity data were available for a small number of points. An assumed salinity of 35.5 was used in these cases.

pH

pH was supplied as calibrated data. The error on pH was given as 0.005 pH units. Isolated spikes have been flagged suspect.

Total Alkalinity and carbon dioxide speciation.

Data were supplied to BODC in fully worked up form. No further calibration has been applied. Further details of the calibration procedures are given in Frankignoulle et al. (1986, 1996). Errors on the alkalinity and pCO2 channels were estimated to be 2 µEq/kg and 6 ppm respectively.

5) Acknowledgements

The oxygen, pH, alkalinity and carbon dioxide speciation measurements were funded as part of the Belgian Impulse Programme on Global Change (contract no. GC/12/011). However, the data have been generously contributed by Michel Frankignoulle to enhance the OMEX data set.

6) References

Benson, B.B., Krause D. (1984). The concentration and isotopic fractionation of oxygen dissolved in fresh water and sea water in equilibrium with the atmosphere. ***Limnol.Oceanogr.*** 29 pp.620-632.

Dickson, A.G. (1993). PH buffers for sea-water media based on the the total hydrogen-ion concentration scale. ***Deep-Sea Research*** 40 pp.107-118.

Frankignoulle, M., Bourge, I., Canon, C., Dauby, P. (1986). Distribution of surface seawater partial CO_2 pressure in the English Channel and in the Southern Bight of the North Sea. ***Continental Shelf Research*** 16 pp.381-395.

Frankignoulle, M., Elskens, M., Biondo R., Bourge, I., Canon, C., Desgain S. & P. Dauby (1996). Distribution of inorganic carbon and related parameters in surface seawater of the English Channel during Spring 1994. ***Journal of Marine Systems*** 7 pp.427-434.

Goyet, C., Poisson A. (1989). New determination of carbonic-acid dissociation constants in sea-water as a function of temperature and salinity. ***Deep-Sea Research*** 36 pp.163-165.

Hansson I. (1973). A new set of acidity constants for carbonic acid and boric acid in sea water. ***Deep-Sea Research*** 20 pp.461-478.

Strickland, J.D.H., Parsons, T.R. (1975). A practical handbook of seawater analysis. ***Fish. Res. Bd. Can***. pp.167-311.

Weiss, R.F. (1974). Carbon dioxide in seawater: the solubility of a non-ideal gas. ***Marine Chemistry*** 2 pp. 203-215.

Surface Underway Data for Cruise Discovery DI217

(27 September - 22 October 1995)

1) Components of the Underway Data Set

The underway data set for the Discovery cruise DI217 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the binary merge file.

Navigation: Latitude (degrees +ve North) (A)
Longitude (degrees +ve East) (B)
Distance run (km) (K)
Bathymetric depth (m) (J)

Meteorology: Barometric pressure (mb) (1)
Dry bulb air temperature (°C) (a)
Relative humidity (%) (d)
Wind speed (knots) (Y)
Wind direction (degrees blowing from) (Z)
Photosynthetically available radiation (W/m^2) (t)
Solar radiation (W/m^2) (O)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)
Optical attenuance (per m) (I)

Biology: Aquatracka raw fluorescence (V) (?)
Aquatracka chlorophyll (mg/m^3) (!)

2) Methodology Overview

2.1) Plumbing

The ship was equipped with pumped non-toxic sea water supply with an inlet on the starboard side at approximately 3 m depth. All ship's discharges were to port to keep contamination to a minimum. The thermosalinograph and transmissometer/fluorometer tank had independent feeds from the distribution manifold.

The non-toxic supply was switched off from 14:00 to 20:00 on 02/10/1995 to prevent the discharge interfering with boat transfers off Falmouth. All data from the transmissometer, fluorometer and thermosalinograph have been flagged suspect for this period.

2.2) Data Acquisition

Data logging and initial processing was handled by the RVS ABC system. The Level A sampling microcomputer or PC digitised an input voltage, applied a time stamp and transferred the data via the Level B disk buffer onto the Level C where the data records were assembled into files. Sampling rates varied from 10 seconds to 30 seconds.

The Level C included a suite of calibration software which was used to apply initial calibration to convert raw ADC counts into engineering units. At the end of the cruise, the Level C disk base was transferred to BODC for further processing.

2.3) BODC Data Processing Procedures

Data from the underway files were merged into a common file (the binary merge file) on a one minute time base using time as the primary linking key. Data sampled more frequently were reduced by numeric averaging except for direction channels where spot values were taken.

Data logged as voltages (e.g. transmittance) were converted to engineering units. Wind velocity was corrected for ship's motion and heading.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to undertake all possible comparative screening checks between channels (e.g. to ensure corrected wind velocity data are not influenced by changes in ship's heading).

3) Methodology and Calibration Procedures

3.1) Navigation and Bathymetry

GPS was the primary navigation system used on this cruise. When no GPS fixes were available the ship's position was determined by dead reckoning based upon the ship's gyro and EM log. Once a fix was obtained after a period of dead reckoning, the surface drift velocity was computed. If this exceeded four knots, the data were automatically flagged suspect. The positional error due to surface drift was then retrospectively applied over the period of dead reckoning.

Distance run was computed from successive positional fixes using spherical trigonometry.

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the

ground did not exceed 15 knots. The quality of the navigation channels was good. Seven gaps of between 1 and 20 minutes were located. These have been filled by linear interpolation. There were no speed check failures.

The distance run channel was checked to ensure it was progressive. No problems were detected.

Bathymetry was measured using a SimRad EA500 deep echo sounder using a hull transducer. Standard Carter's Tables corrections were applied on the Level C. The bathymetry record was generally good except for occasional periods, sometimes of several hours duration, where the signal is dominated by noise from spurious shallow reflections. These have been flagged suspect.

3.2) Meteorology

The scientific meteorological package on the rebuilt Discovery is mounted on a large platform running some 8 m from port to starboard at the junction of the two main stanchions of the foremast. This is approximately 15.5 metres above sea level.

Barometric Pressure

Barometric pressure was measured by a Vaisala aneroid barometer, calibrated by the manufacturer with direct output to the PC Level A in millibars. No correction has been applied for height above sea level.

The data were examined on a graphics workstation and it was found that the record is totally free from spikes or excessive noise. Consequently, no flagging was necessary.

Air Temperature and Humidity

The Metpac fitted to Discovery for this cruise included two Vector Instrument psychrometers fitted to the port and starboard wings of the foremast platform. Data were logged as voltages and converted to temperature using a third order polynomial calibration. Humidity was measured by a Vaisala humidity sensor that output percentage humidity to the PC Level A.

An initial look at the air temperature data showed that it was obviously some time since these instruments had been calibrated. From the start of the cruise until 16:20 on 12/10/1995 the starboard instrument was reading some 2 °C lower than the port. Further, the instruments showed air temperature to be consistently at least 3 °C cooler than the sea surface temperature which is deemed unlikely.

At 16:20 on 12/10/1995 there was an instantaneous drop of some 3 °C in the starboard sensor. This was corrected at 09:30 on 14/10/1995 which brought the starboard sensor in line with the port sensor but both sensors were 2 °C

cooler than the sea temperature. Within 12 hours the starboard sensor had again drifted to a degree lower than port.

The record gives little confidence in the starboard instrument and indicates that the port instrument is reading significantly low. On the previous cruise both sensors were observed to give good agreement and the average of the two values was calibrated against the routine bridge meteorological observations giving a result of 2.5 °C low. On the basis of this it has been decided to scrap the output from the starboard sensor and set the air temperature channel in the final file to the port sensor reading plus 2.5. Users should be aware that this procedure is an attempt to salvage data from poorly calibrated instruments and should use the data with caution.

The humidity record was clean and credible except for data dropout which had been set to 999.0. These have been flagged suspect.

Wind Velocity

Wind velocity was measured by a Vaisala cup anemometer and wind vane located on a pole above the port side of the foremast platform. Relative wind speed is output directly in m/s and was converted to knots on the Level C by multiplying by 1.94. Relative wind direction was output in degrees with a zero reading when wind is on the stern.

Conversion from relative to absolute wind velocity was undertaken at BODC. The ship's heading was added to the wind direction relative to the ship to give wind direction relative to compass co-ordinates. The ship's velocity over the ground was computed from GPS navigation, and then subtracted from the relative wind velocity to give absolute wind velocity. Note that this is effectively a vector addition because the wind direction is expressed in terms of ‘blowing from’ whereas the ship’s velocity is expressed in terms of ‘steaming towards’.

Comparative screening checks were made to ensure that the absolute wind velocity was truly independent of the ship's velocity and heading. The only problem noted were spikes in the wind direction when the ship was turning due to meteorology and navigation being sampled at different frequencies. These have been flagged suspect.

Radiation

Discovery was equipped with two Didcot cosine collector PAR sensors (spectral range 400-700 nm) located port and starboard on the foremast (respective serial numbers 0150 and 0151), and two Kipp and Zonen total radiance sensors (92015 and 92016 located port and starboard). It should be noted that Didcot PAR sensors measure radiance unlike the PML 2-pi PAR meters which measure irradiance. Radiance values are considerably lower than irradiance. All data were calibrated as W/m^2 on the Level C using manufacturers’ calibrations.

Visual inspection of the data showed that all was not well with the PAR data. First, the starboard sensor was inoperative throughout the cruise. The port sensor was reading around 20 W/m^2 in the dark with midday values of approximately 150 W/m^2. At 23:59 on 07/10/95 dark value suddenly dropped to zero which was maintained until the instrument expired at 08:30 on 11/10/95. Looking at the data one gets the distinct impression that the drop in dark values was accompanied by an equal drop in midday values. However, with only 3 days of data it is difficult to be certain. All the PAR values were significantly lower than expected when compared to the solar radiation data indicating that the sensors were in need of either recalibration or a clean. The PAR channel in the data set obviously only contains data from the port sensor. **These data are considered to be significantly in error and should only be used for determining relative PAR levels and even then should only be used with extreme caution.**

The solar radiation data did not present a happy story either. The starboard sensor read consistently lower than the port instrument, including a dark value of -20 W/m^2. The calibration for this instrument has therefore been considered to be incorrect and the data have been rejected. Data from the port sensor appeared fine until 23:50 on 08/10/1995 when the dark value jumped from 1 W/m^2 to 20-30 W/m^2 for a period of some 4 hours. On subsequent nights, the dark value could be seen to be slowly drifting upwards until it reached a value of 9 W/m^2 in the early hours of 14/10/1995. At 03:30 on this night the dark signal became higher and noisy and dark values were erratic and noisy ranging from -50 to +80 W/m^2. The data included in the data file were from the port sensor. Consequently, no elimination of shading effects through combination of data from two sensors has proved possible. All data after 03:30 on 14/10/1995 have been flagged suspect. However, an element of caution is also advised when using any of the solar radiation data after 23:50 on 08/10/1995.

3.3) Physics

Temperature and Salinity

The instrument used was a Falmouth Scientific Instruments thermosalinograph incorporating a remote temperature sensor and an inductive-type conductivity cell mounted next to a second thermometer.

The remote temperature sensor was located in the intake of the non-toxic supply; the sea surface temperature was therefore measured at near-ambient temperature as opposed to being warmed by the heating effects that may be induced by the pump. The conductivity cell and housing temperature thermistor were supplied by a flow-through system from the non-toxic supply.

The raw ADC counts were calibrated to give conductivity and two temperature channels based upon laboratory calibrations undertaken by RVS. Salinity was computed by BODC, from the housing temperature and

conductivity using the UNESCO 1978 Practical Salinity Scale (Fofonoff and Millard, 1982).

Screening the data showed both the temperature and the salinity channels to be of good quality.

Salinity was back calibrated using calibrated CTD data and non-toxic samples (79). A constant offset was determined for the whole cruise and applied to the data:

$$S_{corrected} = S_{observed} - 0.225$$

with standard deviation of 0.00984.

The remote (i.e. sea surface) temperature was back calibrated against surface CTD data (37). The temperature exhibited a straight offset which did not alter throughout the cruise. The following correction has been applied:

$$T_{corrected} = T_{observed} -0.015$$

with standard deviation of 0.00797.

Optical Attenuance

Optical attenuance was measured using a SeaTech 660nm (red) 25cm path length transmissometer contained in a plastic water bath continuously flushed by the non-toxic supply. The data were logged as voltages (originally mV which were converted to V at BODC). These were corrected for light source decay using a ratio correction based on air voltages measured during the cruise DI216 (as no readings were taken during DI217) and the air voltage measured when the instrument was new (cruise voltage in air 4.776V, manufacturer's figure 4.823V).

The percentage transmission (Volts*20) was converted to attenuance using the equation:

$$\text{Attenuance} = -4.0 * \ln(\%\text{Trans}/100).$$

Inspection on a graphics workstation showed the data to be generally of a very high quality. The instrument was cleaned at 13:30 on 06/10/1995 with no detectable offset in the data before and after cleaning. The data during maintenance plus a small but significant number of bubble spikes have been flagged suspect.

3.4) Biology

Chlorophyll

Chlorophyll was measured by an Aquatracka fluorometer calibrated against **fluorometrically assayed** extracted chlorophyll data. Samples were taken from the non-toxic supply, filtered through Whatman GF/F filters and frozen until analysed. The frozen filters were extracted in 2-5 ml 90% acetone using sonification, and centrifuged to remove cellular debris. Analysis for pigments was performed using a Turner Design bench fluorometer calibrated against absolute chlorophyll standards.

The raw fluorometer data were first screened on a graphics workstation and any spikes flagged.

The calibration data set comprised 33 samples. Calibration was achieved by regression of the natural log of the extracted chlorophyll value against the raw fluorometer voltage averaged over 4 minutes. The cruise data were treated as a single population.

The resulting equation was:

$$Chl\ (mg/m^3) = \exp(-3.01 + 1.21 * raw\_voltage)$$

The data showed great scatter, with the adjusted R^2 for the regression being 31.1%.

4) Data Warnings

The air temperature data have been empirically recalibrated using data from the previous cruise and should be used with caution.

The PAR data were not good. Only one sensor was operational. The data from that had low midday values, a dark value that suddenly switched from 20 W/m^2 to zero and the sensor failed completely during the cruise. These data should be used with extreme caution.

Solarimeter data were from the port sensor only. Consequently, no correction for shading has been possible. This sensor failed to give credible data on 03:30 on 14/10/1995. However, there is an indication that problems started at 23:50 on 08/10/1995 and any data after this time should be used with caution.

The fluorometer calibration was more scattered than usual and this should be borne in mind when using the calibrated channel. The raw voltages are also included in the data file.

5) Reference

Fofonoff, N.P., Millard Jr., R.C. 1983. Algorithms for computation of fundamental properties of seawater. ***UNESCO Technical Papers in Marine Science.*** 44.

Surface Underway Data for Cruise Charles Darwin 97

(12 October - 6 November 1995)

1) Components of the Underway Data Set

For most of the time, this cruise was working in the area 29-38N, 25-36W which is not of concern to OMEX. However, an XBT section was done over the Goban Spur and continuous underway data were available from this area and up the Channel as far as the Isle of Wight. These data, from 00:00 on 03/11/95 until the end of the cruise are included in the OMEX data set.

The underway data set for Charles Darwin 97 contains the following data channels. The single character following each channel in parentheses is the corresponding channel identifier in the underway data file.

Navigation: Latitude (degrees +ve N) (A)
Longitude (degrees +ve E) (B)
Distance run (km) (K)

Meteorology: Photosynthetically available radiation - irradiance (W/m^2) (L)

Physics: Sea surface temperature (°C) (C)
Salinity (PSU) (F)
Optical attenuance (per m) (I)

Biology: Aquatracka raw fluorescence (V) (?)
Aquatracka chlorophyll (mg/m^3) (!)

2) Methodology Overview

2.1) Plumbing

The ship was fitted with a non-toxic pumped sea water supply with water drawn from an inlet approximately 2.5 m below the surface, amidships on the starboard side. All ship's discharges were to port to minimise risk of contamination.

Water from the non-toxic pump was fed into the thermosalinograph and the tank containing the fluorometer and transmissometer.

2.2) Data Acquisition

Data logging and initial processing was handled by the RVS ABC system. The Level A sampling microcomputer digitised an input voltage, applied a time stamp from the scientific master clock and transferred the data via the Level B disk buffer onto the Level C where the Level A messages were assembled into data files. Sampling rates varied from 10-30 seconds.

The Level C included a suite of calibration software which was used to apply initial calibration to convert raw ADC counts into engineering units. At the end of the cruise, the Level C disk base was transferred to BODC for further processing.

2.3) BODC Data Processing Procedures

Data from the Level C files were merged into a common file (the binary merge file) on a one minute time base, using time as the primary linking key. Data values sampled more frequently than one minute were reduced by averaging. Data logged as voltages (e.g. PAR) were converted to engineering units.

Each data channel was inspected on a graphics workstation and any spikes or periods of dubious data were flagged. The power of the workstation software was used to undertake all possible comparative screening checks between channels by overlaying parameter plots.

The data from this cruise were generally of good quality with only occasional spikes flagged out.

3) Protocol Details, Quality Control and Calibration Procedures

3.1) Navigation

GPS was the primary navigation system used on this cruise. When no GPS fixes were available the ship's position was determined by dead reckoning based upon the ship's gyro and EM log. Once a fix was obtained after a period of dead reckoning, the surface drift velocity was computed. If this exceeded four knots, the data were automatically flagged suspect. The positional error due to surface drift was then retrospectively applied over the period of dead reckoning.

Distance run was computed from successive positional fixes using spherical trigonometry.

At BODC a program was run which located any null values in the latitude and longitude channels and checked to ensure that the ship's speed over the ground did not exceed 15 knots. No null values were identified in the navigation channels, but a large number of interpolated flags had been applied by the Level C software covering intervals of 1-5 minutes throughout

the file. There were 24 speed check failures with speeds in the range 19-22 knots. No readily identifiable cause for these could be found (usually they are associated with spikes in latitude or longitude) and hence no corrective action was possible. The fact that the navigation is of lower quality than is usual from GPS should be borne in mind.

The distance run channel was checked to ensure it was progressive. Note that it does not start from zero because only part of the original data set has been extracted.

3.2) Meteorology

Radiation

Charles Darwin was equipped with two PML designed 2-pi PAR meters mounted on scaffold poles on either side of the 'Monkey Island' above the bridge. Note that these instruments measured irradiance which is significantly higher than radiance measured by instruments with planar geometry.

The PAR channels were logged as voltages and calibrated in W/m^2 by BODC using coefficients determined in August 1995. The calibration equations used were:

Port (sensor 4):	PAR = exp (Volts * -5.080 + 6.590) / 100
Starboard (sensor 6):	PAR = exp (Volts * -5.010 + 6.311) / 100

A merged PAR channel was produced (L), after spikes were flagged out, by taking the maximum synchronous port and starboard values to eliminate shading effects.

Visual inspection of the data showed a clear diurnal signal with dawn and dusk at the expected times with no spurious data during the hours of darkness.

3.3) Physics

Temperature and Salinity

The thermosalinograph was a brand new Falmouth Scientific Instruments unit incorporating a remote temperature sensor and an inductive-type conductivity cell mounted next to a second temperature sensor.

The remote temperature sensor was supplied by water from the intake side of the non-toxic supply. The sea surface temperature was therefore measured at near-ambient temperature as opposed to being warmed by the heating effects that may be induced by the pumping system. The conductivity cell and housing temperature thermistor were supplied by a flow-through system from the non-toxic supply.

The raw ADC counts were calibrated to give conductivity and two temperature channels based upon laboratory calibrations undertaken by RVS. Salinity was computed from the housing temperature and conductivity using the UNESCO 1978 Practical Salinity Scale (Fofonoff and Millard, 1982).

The thermosalinograph salinity was calibrated during the cruise against 4-hourly bottle samples taken from the thermosalinograph outlet. The correction obtained (-0.195 PSU) has been applied to the data.

The temperature sensor was checked against surface CTD data during the cruise and no temperature correction was found necessary.

Visual examination of the temperature and salinity data shows them to be exceptionally clean and free from noise

Optical Attenuance

Optical attenuance was measured using a SeaTech 660nm (red) 25cm path length transmissometer (serial number 101D) contained in a plastic water bath continuously flushed by the non-toxic supply. The data were logged as voltages.

No air reading was available from this cruise, but values for the same instrument from cruise CD94 have been assumed to be still current. This air reading was used to correct for light source decay using a ratio correction (assumed cruise voltage in air 4.771V, manufacturer's figure 4.823V).

The percentage transmission (Volts*20) was converted to attenuance using the equation:

Attenuance = -4.0 log (% Transmission/100).

The attenuance data were exceptionally clean and free from noise.

3.4) Biology

Chlorophyll

Chlorophyll was measured by a Chelsea mk2 SA244 fluorometer calibrated against discrete samples taken from the thermosalinograph outlet. Samples were filtered through Whatman GF/F filters and frozen until analysed. The frozen filters were extracted in 2-5 ml 90% acetone using sonification, and centrifuged to remove cellular debris**. The extracts were fluorometrically assayed.**

Calibration was achieved by regression of the log of the chlorophyll-a values against the raw fluorometer voltage. The cruise data were treated as a single population and gave the relationship:

$$\text{chlorophyll (mg/m}^3\text{)} = \exp(-3.61 + 1.35 * \text{raw\_voltage})$$

The adjusted R^2 for this regression was 46.9 per cent and the number of samples included was 56.

4) Reference

Fofonoff, N.P., Millard Jr., R.C. (1983). Algorithms for computation of fundamental properties of seawater. ***UNESCO Technical Papers in Marine Science*** 44.