CTD Data Documentation Index

The SES CTD data documentation is available on the LOIS CD-ROM for the following cruises:

1995 Cruises

RRS Charles Darwin	CD91B	22 Mar 1995 to 02 Apr 1995
RRS Charles Darwin	CD92B	13 Apr 1995 to 01 May 1995
RRS Charles Darwin	CD93A	07 May 1995 to 16 May 1995
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RRS Challenger	CH128B	27 Jul 1996 to 06 Aug 1996

CTD Data for Cruise Charles Darwin CD91B
(22nd March to 2nd April 1995)

1) Components of the CTD data set

The CTD data set for cruise CD91B consists of 10 vertical profiles. The data parameters are temperature, salinity, upwelling and downwelling irradiance, and optical attenuance.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor. The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre Niskin water bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling scalar irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling scalar irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 ms^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml/l for oxygen; mmho/cm for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml/l to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer's specified voltage by ratio by using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using a custom in-house graphics editor, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing was used to determine this. However, on this cruise a 'quiet fire' system was used to close the bottles and data point groupings were used in conjunction with CTD log sheets.

These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data except for the calibration to express attenuance in terms of suspended matter concentration.

Pressure

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). The following correction was applied:

$$P_{corr} = P + 0.25$$

NB This correction is based on data from two casts that were the only ones to log data in air.

Temperature

The CTD temperature was compared with the digital reversing thermometers attached to the instrument frame. These were found to agree within 0.002°C and consequently no temperature calibration has been applied.

Salinity

Salinity was calibrated against water bottle samples measured on the Guideline 55358 AutoLab Salinometer during the cruise. Samples were generally taken from the bottom bottle plus one or two other depths on deep casts. However, on the later casts the samples were taken from all bottles in an attempt to resolve the problem of identifying bottle misfires. (*See data warnings).*

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction determined for this cruise was:

$$S_{corr} = S + 0.026$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in February 1990 supplied by RVS.

Upwelling (#10): PAR (W m^{-2}) = exp (-5.090*volts + 6.6470)/100.0
Downwelling (#12): PAR (W m^{-2}) = exp (-4.978*volts + 6.7770)/100.0

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into μE/m^2/s which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.757V). The manufacturer's voltage for the instrument used (SN116D) was 4.810V.

Chlorophyll

200ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. Uncertainties in the bottle firing order reduced the sample data set for calibration purposes to 26 values in the range 0.02 to 0.27 mg/m^3. The following relationship was found between extracted chlorophyll levels and corresponding fluorometer voltages:

$$\text{Chlorophyll (mg/m}^3\text{)} = \exp(1.29 \cdot \text{volts} - 2.92) \quad (R^2 = 53\%, N=24)$$

Oxygen

No Winkler titration data were available from this cruise for the calibration of the dissolved oxygen sensor. It was hoped to use the fact that the North Atlantic is deeply mixed and in equilibrium with the atmosphere at this time of year to effect a calibration. However, there were significant differences in the form of the oxygen profiles between casts indicating instrumental problems. Consequently, no calibration was attempted and the oxygen data have been deleted from the data set.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

The tone fire system used on this cruise reported a large number of misfires, but for a significant proportion of these the bottle had actually fired. This led to a degree of uncertainty in the bottle firing depths (see the report in the Appendix for details). Consequently, salinity samples were taken from several bottles on each cast. However, owing to the well-mixed nature of the water during this stormy cruise, the salinity data did little to resolve the issue and there is still some uncertainty about the sample depths for some samples. The above calibrations have been only used data from samples where BODC has confidence in the bottle firing depths.

5) Reference

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater***. UNESCO Technical Papers in Marine Science*** 44.

Appendix
CD91B Bottle Data Quality Control

The problem

Ten CTDs were carried out on cruise Charles Darwin 91B and several water bottles fired on each cast. Unfortunately, the CTD electronics unit in the lab registered ‘misfires’ (‘short’ or ‘long’) on most attempts to fire bottles, rather than alternate ‘odd’ and ‘even’ codes which indicate successful bottle firing. A ‘long misfire’ is registered when the rosette has received the firing signal but does not return a confirmation signal - the rosette spindle has turned and the bottle has probably closed properly. A ‘short misfire’ is registered when the rosette has not received a clear firing instruction - it may or may not have attempted to fire the bottle, so the spindle may not move.

There is therefore some uncertainty as to which bottles on the rosette closed at which depth. The resolution of this problem is hindered by the lack of proper CTD operator log sheets - as none were available a rough log was used to scribble down the information.

Reversing thermometer temperatures, bridge salinities, chlorophyll profiles and gravimetric data have been received for this cruise which need some decisive bottle assignment if they are to be useful at all. In addition, the originator of POC/PON data for this cruise is awaiting a ‘definitive’ bottle assignment for the working up of his data.

Assumptions

Several broad sweeps at this problem have been made by BODC, with basically unsatisfactory results and tentative conclusions. With the benefit of hindsight and more knowledge of the CTD system used, a more successful attempt was made.

Of course, one has to have some starting point to an investigation. This was based on the following set of assumptions:

- The reversing thermometers were attached to the first bottle to fire.
- The CTD and reversing thermometers agree within 0.006°C.
- The CTD salinity calibration is between +0.026 and +0.034 PSU.
- For casts 4 to 10 (excluding 5 which was a transmissometer calibration cast) the number of salinity bottles filled indicates the number of rosette bottles closed.
- All ‘ODD’ and ‘EVEN’ return codes indicate successful bottle firing.

With this set of rules, and armed with the rough log, salinity data, reversing thermometer temperatures and SERPLO, a cast by cast analysis was undertaken with the following results:

CTD 1 (25/3/95 11:30 - 12:05 at N140)

The cast when the problem started. The log sheet is a mess and the water is very well mixed. Nothing we can do so all bottles to be flagged ‘O’.

CTD 2 (26/3/95 09:20 - 09:52 at N200)

The water column was extremely well mixed, so salinity and temperature data offer no clues.

9 bottles were fired, but on recovery it was seen that only 8 had closed. The 8th request (at 21m) registered return code ‘ODD’, leading to the conclusion that it was the 7th to close. Therefore, the 11m bottle also obeyed orders. This suggests very strongly that the failure occurred among the 7 deeper firings.

The RVS CTD operator on the cruise concluded that the second bottle (at 225m) had failed. This is consistent with my findings but not very convincing.

Summary: Niskin 7 (36m) → 21m
Niskin 8 (21m) → 11m
The rest flagged ‘O’ - firing order uncertain.

CTD 3 (26/3/95 18:35 - 19:15 at N300)

All 11 bottle firings returned ‘misfire’ codes, but on recovery 11 bottles were seen to have closed successfully. Therefore, there is no reason to suspect that anything untoward really happened on this cast.

CTD4 (27/3/95 19:45 - 20:40 at S700)

13 requests for bottle firing were made (2 attempts at 600m); all returned ‘misfire’ codes. On recovery, 11 bottles were sampled for salinity. I therefore conclude that 11 bottles closed successfully.

The reversing thermometer temperature was 8.925°C, compared with 8.885°C and 8.927°C recorded by the CTD on the upcast at the time of the 715m and 700m bottle firings respectively. This is a strong indication that no bottle closed at 715m, and that the reversing thermometers (and hence rosette bottle 1) closed at 700m.

Making the further assumption that only one of the two attempts to fire a bottle at 600m was successful, the following comparison of bridge and CTD salinity data results:

Bottle No.	Proposed depth	Bridge Salinity	CTD Salinity	Bridge -CTD	(Rough log firing depth)
1	700	35.3143	35.290	+0.024	(715)
2	650	35.3254	35.300	+0.025	(700)
3	600	35.3307	35.303	+0.028	(650)
4	500	35.3502	35.325	+0.025	(600)
5	400	35.3575	35.332	+0.026	(500)
6	300	35.3561	35.332	+0.024	(400)
7	200	35.3580	35.332	+0.025	(300)
8	100	35.3517	35.333	+0.018	(200)
9	30	35.3544	35.335	+0.019	(100)
10	15	35.3580	35.336	+0.022	(30)
11	5	35.3651	35.336	+0.029	(15)
12	Failed	None			(5)

This leads to a salinity correction of 0.024±0.003 which is possibly a bit low. (Taking out bottles 8 and 9, the result is 0.026±0.002).

CTD 5 (28/3/95 13:00 - 13:10 at S300)

A transmissometer calibration cast to 20m where all bottles were fired. There is no record of how many closed, but 3 returned ‘ODD’ or ‘EVEN’ codes. Hence at least three bottles fired at 20m on this cast.

CTD 6 (28/3/95 16:30 - 17:10 at S300)

Very well mixed water, no tell-tale return codes so nothing we can do. However, it is obvious that the salinity bottle values from Niskins 6, 7, 8 and 9 are about 0.01 PSU higher than the values for the other bottles. This is to be borne in mind when considering the salinity calibration.

CTD 7 (29/3/95 12:00 - 13:00 at S700)

This is a disappointing cast in many ways. The number of bottles sampled for salinity was 7, but the final return code was ‘EVEN’. Fortunately, the chlorophyll data solved this paradox by quoting the bottles sampled as numbers 1,2,3,5,6,7 and 8 - in other words, it was a long misfire on bottle 4, moving the spindle on but not opening the bottle. Hence, the last return code was ‘EVEN’.

So data from Niskins 7 and 8 were taken from 30m and 15m respectively. All other bottle entries are flagged ‘O’.

CTD 8 (29/3/95 15:42 - 17:32 at N1500)

A most satisfying mystery to solve.

The reversing thermometer agrees strikingly well with the CTD temperature at 800m (being more than 4°C higher than the bottom temperature). This indicates that the reversing thermometer snapped at 800m (on the 7th or 8th press of the bottle-fire button).

16 attempts to fire a bottle were made, and 8 bottles were sampled for salinity. The return code of the 15m bottle (15th press) was ‘ODD’, indicating that Niskin 7 closed at 15m. Hence Niskin 8 (the last to close) must have been at 5m.

So far, we have deduced that Niskin 1 fired at 800m, 7 at 15m and 8 at 5m. What happened in between is a thorny problem, but there are only 5 combinations allowed by the rough log records. Unfortunately, the strength of the analysis (and hence the credibility of the conclusions) is weakened by two factors. First, all the salinity samples were put through the salinometer, and there is some suspicion about the salinity of water collected in Niskin 4 as the CTD trace shows a consistent increase in salinity between 600m and 30m. It is also a shame that the 15m bottle, which can be confidently assigned, seems a little too saline. A few duff salinities here and there are to be expected however as the bottles were not analysed until Charles Darwin 93, more than a month later.

		Option 1			Option 2		
#	BRIDGE	DPTH	CTDVAL	CAL	DPTH	CTDVAL	CAL
1	35.3054	800	35.272	0.033	800	35.272	0.033
2		800	35.272		800	35.272	
3	35.3645	600	35.321	0.044	600	35.321	0.044
4	35.3582	200	35.331	0.027	200	35.331	0.027
5		200	35.331		100	35.330	
6	35.3625	100	35.330	0.032	30	35.331	0.031
7	35.3702	15	35.331	0.039	15	35.331	0.039
8		5	35.332		5	35.332	
	all in		mean	0.035		mean	0.035
			stdev	0.00631		stdev	0.00643
	w/o 4,7			0.036			0.036
				0.00610			0.00645

#	BRIDGE	Option 3 DPTH	CTDVAL	CAL	Option 4 DPTH	CTDVAL	CAL	Option 5 DPTH	CTDVAL	CAL
1	35.3054	800	35.272	0.033	800	35.272	0.033	800	35.272	0.033
2		600	35.321		600	35.321		200	35.331	
3	35.3645	200	35.331	0.033	200	35.331	0.033	200	35.331	0.033
4	35.3582	200	35.331	0.027	100	35.330	0.028	100	35.330	0.028
5		100	35.330		30	35.331		30	35.331	
6	35.3625	30	35.331	0.031	30	35.331	0.031	30	35.331	0.031
7	35.3702	15	35.331	0.039	15	35.331	0.039	15	35.331	0.039
8		5	35.332		5	35.332		5	35.332	
	all in		mean	0.033		mean	0.033		mean	0.033
			stdev	0.0043		stdev	0.0040		stdev	0.0040
	w/o 4,7			0.033			0.033			0.033
				0.0011			0.0011			0.0011

I think it is quite clear that rosette bottle 3 is more likely to have fired at 200m than at 600m. Scenarios 3, 4 and 5 bind the CTD and bridge salinity values together more tightly than scenarios 1 and 2. Sadly, there is simply not enough evidence to tie up the loose ends of bottles 2, 4 and 5. If only the other three salinity bottles has been put through the Autosal.

So : Niskin 1 (1531m) → 800m bottle
2 (1500m) → 600m or 200m
3 (1400m) → 200m bottle
4 (1200m) → 200m or 100m
5 (1000m) → 100m or 30m
6 (800m) → 30m bottle
7 (600m) → 15m bottle
8 (200m) → 5m bottle

In practice, the bottle entries for depths 1531m through to 1000m will be flagged ‘M’, and the bottle entries for depths 600m and 100m will be flagged ‘O’.

CTD 9 (31/3/95 14:29 - 31/3/95 14:56 at S140)

The bottle fire button was pressed 13 times during this cast, and all 12 bottles on the rosette were closed. The water column was very well mixed, salinity varying by less than 0.002 PSU. A quick comparison between the CTD value (~34.342) and the bridge salinities indicates that the bottle data from Niskins 9, 10 and 12 should be flagged suspect.

The tenth press (15m) returned an ‘EVEN’ code indicating that this bottle fired OK. This was followed by a maximum of 3 presses so must have been the tenth bottle to fire. Hence, the first 9 presses also successfully closed bottles at the prescribed depths. The last two presses, at least one of which was successful, occurred at 5m. It follows from the rough log that bottle 11 could have fired at 15m or at 5m, we can't tell which.

Data will be assigned to depths according to the rough log. No data will be loaded from bottle 11.

CTD 10 (1/4/95 13:48 - 14:15 at S200)

Another cast with very well mixed water. The fire button was pressed 9 times, and on recovery 8 bottles had closed.

The first bottle returned an 'ODD' code, so we can confidently say that Niskin bottle 1 was fired successfully at 230m. Unfortunately, there is nothing we can say about the rest - they will all be flagged 'O'.

Salinity values from Niskin bottles 5, 7, 9 and 10 have been excluded from consideration in the salinity calibration.

CTD Data for Cruise Charles Darwin CD92B
(13th April to 1st May 1995)

1) Components of the CTD data set

The CTD data set for cruise CD92B consists of 98 vertical profiles. The data parameters are temperature and salinity.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with a SeaBird SBE9/11 CTD fitted with standard SeaBird pressure, temperature, conductivity and dissolved oxygen sensors. It is unclear whether a fluorometer was fitted to the instrument. If it was, it clearly malfunctioned as described below.

A two-litre NIO bottle, fitted with either two SIS digital reversing thermometers or classical mercury reversing thermometers and a pinger, was attached to the CTD wire. This was used to collect calibration data. The firing depth (by brass messenger) was varied to ensure that the calibration encompassed a wide range of temperature and salinity values.

The instrument was regularly returned to the manufacturer for recertification. Recommended practice was for this to be done every six months.

2.2) Data Acquisition

Data were logged on a PC running standard SeaBird Seasave data acquisition software. Normally, data were only logged during the downcast. However on casts where the calibration samples were collected near the surface data were also logged on the upcast up to the level where the sample was taken.

2.3) Processing and Calibration Procedures

Digital, protected and unprotected reversing thermometer data were collected during the cruise. Equilibration times of 10 seconds were allowed for digital thermometers and 4 minutes for mercury thermometers. Salinity samples were collected in rinsed, 200 ml Besser 'Meplat' glass bottles with zwischenscholt-stopfen plastic seals. Salinity was determined back in the laboratory using a Guildline Autosal bench salinometer.

All temperature calibrations were done to the IPTS-68 standard. Digital reversing thermometer data calibrated to the ITS-90 standard were converted to IPTS-68 by multiplying by 1.00024 before being used for calibration purposes.

The maufacturer's calibration coefficients were adjusted for temperature and conductivity on the basis of this calibration data. The pressure coefficients were adjusted on the basis of pinger depths determined by a Simrad EA500 echo sounder and thermometric pressures determined from protected and unprotected reversing thermometers.

The adjusted calibration file was used to generate a calibrated one-decibar data set using the standard SeaBird Seasoft program.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were supplied to BODC as ASCII files on floppy disks and comprised pressure, temperature, salinity, chlorophyll and dissolved oxygen values at one-decibar intervals. They were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor.

The reformatting software included a check that suppressed any data values that were constant. This eliminated the chlorophyll channel from every series indicating that if a fluorometer was fitted to the CTD system then it wasn't working properly.

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Spikes on all data channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

No additional calibration work was undertaken at BODC other than the conversion of the temperature data from the IPTS-68 standard to the ITS-90 standard. This was achieved by multiplying the data by 0.99976. Note that this conversion was undertaken within the LOIS (SES) database to bring all CTD temperature data within that database to a common standard. The version of the data held in the BODC National Oceanographic Database is as supplied by the data originator (IPTS-68 standard).

As no dissolved oxygen samples were taken during the cruise, the CTD dissolved oxygen data set has been excluded from the final data set in the LOIS (SES) database. It is retained in the version of the data in the National Oceanographic Database.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

There are no data warnings for the pressure, temperature and salinity data from this cruise.

CTD Data for Cruise Charles Darwin CD93A
(7th May to 16th May 1995)

1) Components of the CTD data set

The CTD data set for cruise CD93A consists of 59 vertical profiles. The data parameters are temperature, salinity, upwelling and downwelling irradiance, optical attenuance, total suspended matter, dissolved oxygen and chlorophyll.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor (fed by a SeaBird pump). The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame was a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre Niskin water bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was corrected using a modified algorithm to allow for the pumped water supply and arbitrary calibration coefficients. The result was data in arbitrary units, linearly proportional to the true value that could be screened and held, pending delivery of the true calibration coefficients.

- Transmissometer voltages were corrected to the manufacturer's specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, clusters of points recorded while the CTD was held stationary were used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational DataBase Management System.

For this cruise, the RVS Neil Brown Mk 3B CTD system was equipped with a SeaBird pump, which sent water at a constant rate through the housing containing the existing Beckman oxygen electrode. Problems associated with the plumbing of the pump to the oxygen probe resulted in many profiles only recording good oxygen data on upcasts. Hence the upcast of the oxygen, temperature and salinity channels were flagged to remove any spikes and the downcast oxygen values loaded into ORACLE were substituted for upcast oxygen data by isopycnal matching.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

Pressure

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). The following correction (consistent throughout both legs of CD93 within ±0.05 dbar) was applied:

$$P_{corr} = P - 0.43$$

Temperature

The CTD temperature was compared with the digital reversing thermometers attached to the instrument frame. As the platinum resistance thermometer and the reversing thermometer were found to agree within 0.006°C no calibration has been applied.

Salinity

During screening a number of offsets were noted in the salinity trace. These were attributed to the conductivity cell contamination. The following corrections have been applied:

CP 23	0.01 PSU added between 204.0 db and 210.6 db
CP 30	0.01 PSU added above 154.0 db
CP 35	0.006 PSU added between 26.7 db and 33.67 db
CP 52	0.005 PSU added between 0.0 db and 147 db

Salinity was calibrated against water bottle samples measured on the Guideline 55358 AutoLab Salinometer during the cruise. Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction determined for this cruise was:

$$S_{corr} = S + 0.027 \text{ (standard deviation 0.004)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in February 1990 supplied by RVS.

Upwelling (#10): $PAR\ (W\ m^{-2}) = \exp(-5.090 * volts + 6.6470)/100$
Downwelling (#12): $PAR\ (W\ m^{-2}) = \exp(-4.978 * volts + 6.7770)/100$

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into $\mu E/m^2/s$, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.789V). The manufacturer's voltage for the instrument used (SN115D) was 4.805V.

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368*\text{Atten}) - 0.801 \quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including Charles Darwin cruise CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

408 extracted chlorophyll concentrations (range 0.01 to 5.11 mg/m^3) were regressed against corresponding fluorometer voltages. It was found that the fluorometer exhibited a different response at low chlorophyll levels from that seen at higher levels. In order to reduce the error at the high chlorophyll end of the scale without grossly overestimating low chlorophyll values, a subset of samples where the corresponding fluorometer reading exceeded 1.25 volts was used for the calibration. To retain a large calibration data set, both legs of cruise CD93 were pooled.

After much consideration, the following relationship was found:

$$\text{Chl (mg/m}^3\text{)} = \exp(1.77*\text{volts} - 3.69) \quad (r^2 = 64\%, \text{ number of values } 348)$$

Feedback from the project community suggested that there was considerable inhibition at the surface - in other words, the chlorophyll levels were in reality much higher than those indicated by the fluorescence signal in the surface water. Further evidence for the presence of this effect was provided by the CTD transmissometer, which on many casts showed a consistent signal in the upper mixed layer, as opposed to the marked decrease seen in the fluorescence data.

This calibration was based on pooled sample data from legs A and B of this cruise.

Attempts were made to derive a correction based on ambient light levels recorded by the CTD radiation sensors, but with no success for those casts where surface inhibition was most evident.

The calibration equation above was applied to the whole data set.

The surface inhibition problem was addressed by manual editing of fluorometer voltages. The fluorometer voltage readings in the top 10 metres were manually edited where both of the following criteria were satisfied:

- calibrated CTD values at the surface were more than 0.8 mg/m^3 lower than the corresponding extracted chlorophyll value.
- the CTD fluorescence signal was not supported by the transmission signal in the top 10 metres.

No casts from this leg of the cruise satisfied these criteria.

Dissolved Oxygen

Dissolved oxygen concentrations were determined by micro-Winkler titration of seawater samples taken from a range of depths on several CTD casts. These values were compared with oxygen readings derived from the oxygen sensor membrane current, oxygen sensor temperature, sea temperature and salinity values recorded by the CTD on the upcast. Hilary Wilson (University of North Wales, Bangor) carried out this work under the supervision of Dr. Paul Tett. The following equation was supplied to BODC and the coefficients A and B were applied to the data:

$$[O_2] = (A*C + B)*S' \text{ ml/l}$$

where A = 2.527
C = oxygen sensor current (µA)
B = -0.0220
S'= oxygen saturation concentration (a function of water temperature and salinity).

Finally, the data were converted to µM by multiplication by 44.66.

Considerable manipulation of the oxygen data, such as the substitution of downcast data by isopycnal-matched upcast data, was required to produce the oxygen data channel in the final data set. This, combined with the uncertainties involved in the calibration of oxygen data, might mean that some users would wish to re-examine the oxygen processing. To facilitate this, BODC have systematically archived the raw data (including oxygen current and temperature) from both upcasts and downcasts. These data are available on request.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

Oxygen saturation has been computed using the algorithm of Benson and Krause (1984).

4) Data Warnings

A comparison of the extracted chlorophyll data and the calibrated CTD data shows that on average the CTD data underestimates the ‘true’ chlorophyll level by about 10% across the whole data set, with the lowest percentage errors (2-5%) at the highest chlorophyll levels.

5) References

Benson B.B. and Krause D. jnr. 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.

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** 44.

CTD Data for Cruise Charles Darwin CD93B
(16th May to 30th May 1995)

1) Components of the CTD data set

The CTD dataset for cruise CD93B consists of 137 vertical profiles of the parameters temperature, salinity, upwelling and downwelling irradiance, optical attenuance, dissolved oxygen and chlorophyll.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor (fed by a SeaBird pump). The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre water bottles. These comprised a mixture of Niskin and ultra-clean teflon lined Go-Flo bottles as dictated by sampling requirements. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available scalar radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was corrected using a modified algorithm to allow for the pumped water supply and arbitrary calibration coefficients. The resultant data were in arbitrary units, linearly proportional to the true value, which could be screened and held, pending delivery of the true calibration coefficients.

- Transmissometer voltages were corrected to the manufacturer’s specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{Attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

For this cruise, the RVS Neil Brown Mk 3B CTD system was equipped with a SeaBird pump, which sent water at a constant rate through the housing containing the existing Beckman oxygen electrode. Problems associated with the plumbing of the pump to the oxygen probe resulted in many profiles only recording good oxygen data on upcasts. To overcome this, the upcast data for oxygen, temperature and salinity channels were flagged to remove any spikes. The downcast oxygen values loaded into ORACLE were then replaced where necessary by upcast oxygen data using isopycnal (rather than pressure) matching to determine the replacement values to be used.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

Pressure

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). The following correction (consistent throughout both legs of CD93 within ±0.05 dbar) was applied:

$$P_{corr} = P - 0.43 \qquad \text{(standard deviation = 0.05)}$$

Temperature

The CTD temperature was compared with SIS digital reversing thermometers attached to the instrument frame. These were found to agree within 0.007°C. No correction has been applied as the platinum resistance thermometer is believed to be at least as reliable as the reversing thermometers.

Salinity

During screening a number of offsets were noted in the salinity trace. These were attributed to the conductivity cell contamination. The following corrections have been applied:

CP 89	0.02 PSU added between 366.6 db and 446.2 db
CP 89	0.01 PSU added between 559.6 db and 566.1 db
CP 90	0.016 PSU added between 0 db and 340 db
CP 110	0.006 PSU added between 627.0 db and 632.5 db
CP 116	0.019 PSU less between 344.0 db and 349.0 db
CP 183	0.012 PSU added between 158.0 db and 182.1 db
CP 183	0.01 PSU added between 188.8 db and 192.1 db
CP 188	0.0214 PSU added between 12.0 db and 30.0 db
CP 188	0.0096 PSU added between 0 db and 625 db

Salinity was calibrated against water bottle samples measured on the Guideline 55358 AutoLab Salinometer during the cruise.

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction determined for this cruise was:

$$S_{corr} = S + 0.027 \qquad \text{(standard deviation 0.006)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in February 1990 supplied by RVS.

Upwelling (#10): PAR (W m^{-2}) = exp (-5.090*volts + 6.6470)/100
Downwelling (#12): PAR (W m^{-2}) = exp (-4.978*volts + 6.7770)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into μE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.789V). The manufacturer's voltage for the instrument used (SN115D) was 4.805V.

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368*\text{Atten}) - 0.801 \quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including Charles Darwin cruise CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

200ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. 352 extracted chlorophyll concentrations (range 0.04 to 5.38 mg/m^3) were regressed against the corresponding fluorometer voltages. The following relationship was found:

$$\text{Chlorophyll (mg m}^{-3}) = \exp(1.77 * \text{volts} - 3.69) \quad (R^2 = 63.8\%, n = 348)$$

This calibration was based on pooled sample data from legs A and B of this cruise.

Attempts were made to derive a correction based on ambient light levels recorded by the CTD radiation sensors, but with no success for those casts where surface inhibition was most evident.

The calibration equation above was applied to the whole data set.

The surface inhibition problem was addressed by manual editing of fluorometer voltages. The fluorometer voltage readings in the top 10 metres were manually edited where both of the following criteria were satisfied:

- calibrated CTD values at the surface were more than 0.8 mg/m^3 lower than the corresponding extracted chlorophyll value.

- the CTD fluorescence signal was not supported by the transmission signal in the top 10 metres.

The following profiles from this cruise leg have been edited to remove surface quench effects:

CP61	CP62	CP63	CP76	CP89
CP92	CP100	CP101	CP102	CP103
CP194				

Dissolved Oxygen

Dissolved oxygen concentrations were determined by micro-Winkler titration of seawater samples taken from a range of depths on several CTD casts. These values were compared with oxygen readings derived from the oxygen sensor membrane current, oxygen sensor temperature, sea temperature and salinity values recorded by the CTD on the upcast. Hilary Wilson (University of Wales, Bangor) carried out this work, under the supervision of Dr. Paul Tett. The following equation was supplied to BODC and the coefficients A and B were applied to the data:

$$[O_2] = (A*C + B)*S' \text{ ml/l}$$

where A = 1.760 (casts 148 & 159),
2.754 (casts 60 to147, 149 to158, 160 to196)
C = oxygen sensor current (µA)
B = -0.309 (casts 148 & 159),
-0.0176 (casts 60 to147, 149 to158, 160 to196)
S'= oxygen saturation concentration (a function of water temperature and salinity).

Finally, the data were converted to µM by multiplication by 44.66.

Considerable manipulation of the oxygen data, such as the substitution of downcast data by isopycnal-matched upcast data, was required to produce the oxygen data channel in the final data set. This, combined with the uncertainties involved in the calibration of oxygen data, might mean that some users would wish to re-examine the oxygen processing. To facilitate this, BODC have systematically archived the raw data (including oxygen current and temperature) from both upcasts and downcasts. These data are available on request.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

Oxygen saturation has been computed using the algorithm of Benson and Krause (1984).

4) Data Warnings

The dissolved oxygen data from this cruise are believed to be 10-20% high.

5) References

Benson B.B. and Krause D. jnr. 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.

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** 44.

CTD Data for Cruise Challenger CH120
(18^{th} July to 6^{th} August 1995)

1) Components of the CTD data set

The CTD data set for cruise CH120 consists of 52 vertical profiles. The data parameters are temperature and salinity.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with a SeaBird SBE9/11 CTD fitted with standard SeaBird pressure, temperature, conductivity and dissolved oxygen sensors. It is unclear whether a fluorometer was fitted to the instrument. If it was, it clearly malfunctioned as described below.

A two-litre NIO bottle, fitted with either two SIS digital reversing thermometers or classical mercury reversing thermometers and a pinger, was attached to the CTD wire. This was used to collect calibration data. The depth at which this was fired (by brass messenger) was varied to ensure that the calibration encompassed a wide range of temperature and salinity values.

The instrument was regularly returned to the manufacturer for recertification. Recommended practice was for this to be done every six months.

2.2) Data Acquisition

Data were logged on a PC running standard SeaBird Seasave data acquisition software. Normally, data were only logged during the downcast. However on casts where the calibration samples were collected near the surface data were also logged on the upcast up to the level where the sample was taken.

2.3) Processing and Calibration Procedures

Digital, protected and unprotected reversing thermometer data were collected during the cruise. Equilibration times of 10 seconds were allowed for digital thermometers and 4 minutes for mercury thermometers. Salinity samples were collected in rinsed, 200 ml Besser ‘Meplat’ glass bottles with zwischenscholt-stopfen plastic seals. Salinity was determined back in the laboratory using a Guildline Autosal bench salinometer.

All temperature calibrations were done to the IPTS-68 standard. Digital reversing thermometer data calibrated to the ITS-90 standard were converted to IPTS-68 by multiplying by 1.00024 before being used for calibration purposes.

The maufacturer's calibration coefficients were adjusted for temperature and conductivity on the basis of this calibration data. The pressure coefficients were adjusted on the basis of pinger depths determined by a Simrad EA500 echo sounder and thermometric pressures determined from protected and unprotected reversing thermometers.

The adjusted calibration file was used to generate a calibrated one-decibar data set using the standard SeaBird Seasoft program.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were supplied to BODC as ASCII files on floppy disks and comprised pressure, temperature, salinity, chlorophyll and dissolved oxygen values at one-decibar intervals. They were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor.

The reformatting software included a check that suppressed any data values that were constant. This eliminated the chlorophyll channel from every series indicating that if a fluorometer was fitted to the CTD system then it wasn't working properly.

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Spikes on all data channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

No additional calibration work was undertaken at BODC other than the conversion of the temperature data from the IPTS-68 standard to the ITS-90 standard. This was achieved by multiplying the data by 0.99976. Note that this conversion was undertaken within the LOIS (SES) database to bring all CTD temperature data within that database to a common standard. The version of the data held in the BODC National Oceanographic Database is as supplied by the data originator (IPTS-68 standard).

As no dissolved oxygen samples were taken during the cruise, the CTD dissolved oxygen data set has been excluded from the final data set in the LOIS (SES) database. It is retained in the version of the data in the National Oceanographic Database.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

There are no data warnings for the pressure, temperature and salinity data from this cruise.

CTD Data for Cruise Challenger CH121A
(10th August to 18th August 1995)

1) Components of the CTD data set

The CTD data set for cruise CH121A consists of 29 vertical profiles containing the parameters temperature, salinity, chlorophyll, upwelling and downwelling irradiance and attenuance.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor (fed by a SeaBird pump). The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre Niskin bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml l^{-1} to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer’s specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples were collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

<u>Pressure</u>

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). No single consistent pressure correction could be found, but the following sub-groups were identified:

Casts 2 to 7:	$P_{corr} = P + 0.91$	(σ= 0.22 dbar)
Casts 8 to11:	$P_{corr} = P + 1.99$	(σ = 0.23 dbar)
Casts 12 to 24:	$P_{corr} = P + 1.04$	(σ = 0.19 dbar)

Casts 25 to 27:	$P_{corr} = P + 1.65$	(σ = 0.22 dbar)
Casts 28 to 30:	$P_{corr} = P + 0.96$	(σ = 0.14 dbar)

NB: CTD cast CP1 was not successfully logged.

Temperature

The CTD temperature was compared with the digital reversing thermometers attached to the instrument frame. The two instruments were found to agree within 0.001°C. Hence, no correction has been applied to the temperature data.

Salinity

During screening an offset was noted in the salinity trace. This was attributed to the conductivity cell contamination. The following correction has been applied:

CP 29 0.006 PSU added between 148.0 db and 158.5 db

No bottle salinity data were collected during this cruise. The salinity calibration (+0.026 PSU) determined for the initial casts of the next cruise leg (CH121B) has been assumed valid for this.

Upwelling and Downwelling Irradiance

The light meters were only used during cruise CH121A for the first 10 CTD casts. The PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 supplied by RVS.

Upwelling (#2): PAR (W m^{-2}) = exp (-4.97*volts + 6.878)/100
Downwelling (#1): PAR (W m^{-2}) = exp (-4.90*volts + 7.237)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into μE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.651V). The manufacturer's voltage for the instrument used (SN103D) was 4.758V.

An empirical correction for baseline drift was required on other SES cruises where SN103D was deployed. Careful examination of the data from this cruise revealed that no such correction was required. However, the problem could be seen to be developing on a number of casts where features that looked like intermediate nepheloid layers were present on the downcast but had disappeared a few minutes later when the upcast was taken. These features were considered to be instrumental artefacts and were flagged suspect.

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368*\text{Atten}) - 0.801 \quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including cruise Charles Darwin CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

200 ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. The chlorophyll data (range 0.07 to 1.17 mg m^{-3}) for legs A & B of the cruise were combined in order to produce a calibration. All chlorophyll values below 0.10 mg m^{-3} were removed from the data set for calibration purposes. The following relationship was found between extracted chlorophyll levels and corresponding fluorometer voltages:

$$\text{Chlorophyll (mg m}^{-3}) = \exp(1.59*\text{volts} - 3.56) \quad (R^2 = 61\%, n = 174)$$

Dissolved Oxygen

No Winkler titration data were available from this cruise for the calibration of the dissolved oxygen sensor. Consequently, the dissolved oxygen data have been excluded from the final data set.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

No salinity bottle samples were taken and consequently the salinity calibration has been based on data from another cruise (CH121B).

5) Reference

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** 44.

CTD Data Cruise Challenger CH121B
(18th August to 1st September 1995)

1) Components of the CTD Data Set

The CTD data set for cruise CH121B consists of 171 vertical profiles containing the parameters temperature, salinity, upwelling and downwelling irradiance, chlorophyll, attenuance and dissolved oxygen.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor (fed by a SeaBird pump). The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre Niskin bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml l^{-1} to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer's specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples were being collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

For this cruise, the RVS Neil Brown Mk 3B CTD system was equipped with a SeaBird pump, which sent water at a constant rate through the housing containing the existing Beckman oxygen electrode. Problems associated with the plumbing of the pump to the oxygen probe resulted in many profiles only recording good oxygen data on upcasts. To overcome this, the upcast data for oxygen, temperature and salinity channels were flagged to remove any spikes. The downcast oxygen values loaded into ORACLE were then replaced where necessary by upcast oxygen data using isopycnal (rather than pressure) matching to determine the replacement values to be used.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

NB: CTD casts CP123 and CP125 were not successfully logged.

Pressure

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). The air readings were quite scattered and no sub-groups could be identified. Hence the following correction was applied:

$$P_{corr} = P + 1.23 \qquad \text{(standard deviation = 0.42 dbar)}$$

Temperature

The CTD temperatures were compared with digital reversing thermometer data. The two instruments were found to agree within 0.001°C. Hence, no correction has been applied to the temperature data.

Salinity

During screening a number of offsets were noted in the salinity trace. These were attributed to the conductivity cell contamination. The following corrections have been applied:

CP38	0.006 PSU added between 130.0 db and 134.0 db
CP47	0.008 PSU added below 114.0 db.
CP127	0.007 PSU added between 17.5 db and 45.5 db.
CP131	0.010 PSU added between 24.0 db and 29.2 db.

Salinity was calibrated against water bottle samples measured on the Guideline 55358 AutoLab Salinometer during the cruise.

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The CTD salinity showed evidence of drift during the cruise. Consequently, the calibration was split into the following sub-groups of casts:

Casts CP31 to CP46:	$S_{corr} = S + 0.026$	($\sigma = 0.003$)
Casts CP47 to CP143:	$S_{corr} = S + 0.034$	($\sigma = 0.003$)
Casts CP144 to CP163:	$S_{corr} = S + 0.045$	($\sigma = 0.002$)
Casts CP164 to CP203:	$S_{corr} = S + 0.058$	($\sigma = 0.003$)

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 supplied by RVS.

Upwelling (#2): PAR (W m^{-2}) = exp (-4.97*volts + 6.878)/100
Downwelling (#1): PAR (W m^{-2}) = exp (-4.90*volts + 7.237)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into μE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.673V). The manufacturer's voltage for the instrument used (SN103D) was 4.758V.

Reports were received from UWB that the clear water attenuance values measured by the transmissometer used on this cruise were anomalously high. A careful investigation was initiated to look at this problem. This involved examination of clear water attenuance values from casts deeper than 500 m and an inter-comparison of the surface attenuance values with contemporaneous data from the underway transmissometer. It must be stressed that this exercise was comparative, looking at differences in the relationship between the CTD and underway instruments. No attempt was made to render both data sets numerically identical as experience has shown that the mechanical effects of the pump on the suspended particulate material modify the attenuance of water in the non-toxic supply.

Further information on the pattern of corrections required was obtained by examination of the superimposed attenuance profiles from groups of series on a graphics editor.

The exercise worked well except for casts after 27/06/1995 (CP180-CP203) when the underway instrument was obviously drifting upwards. The correction given below for these casts is based on the clear water attenuance from a single deep cast and data obtained from the following cruise leg. Consequently, the correction for these casts should be regarded as tentative.

The following corrections were derived and have been applied to the data:

Casts CP31 to CP131:	No correction
Casts CP132 to CP173:	$Attenuance_{corr}$ = attenuance – 0.03
Cast CP174	$Attenuance_{corr}$ = attenuance – 0.05
Casts CP175 to CP179:	$Attenuance_{corr}$ = attenuance – 0.03
Casts CP180 to CP203:	$Attenuance_{corr}$ = attenuance – 0.04

In addition, the following corrections were applied to the attenuance data to repair obvious errors identified by comparison of upcasts and downcasts in stable water masses.

Cast CP97 0.02 subtracted for pressures>37.7 db
Cast CP98 0.02 subtracted for pressures between 82 and 138.7 db

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368*\text{Atten}) - 0.801 \quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including cruise Charles Darwin CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

<u>Chlorophyll</u>

200 ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. The chlorophyll data (range 0.07 to 1.17 mg m^{-3}) for legs A & B of the cruise were combined in order to produce a calibration. All chlorophyll values below 0.10 mg m^{-3} were removed from the data set for calibration purposes. The following relationship was found between extracted chlorophyll levels and corresponding fluorometer voltages:

$$\text{Chlorophyll (mg m}^{-3}) = \exp(1.59*\text{volts} - 3.56) \quad (R^2 = 61\%, n = 174)$$

<u>Dissolved Oxygen</u>

Dissolved oxygen concentrations were determined by micro-Winkler titration of seawater samples taken from a range of depths on several CTD casts. These values were compared with oxygen readings derived from the oxygen sensor membrane current, oxygen sensor temperature, sea temperature and salinity values recorded by the CTD on the upcast. Hilary Wilson (University of Wales, Bangor), under the supervision of Dr. Paul Tett, carried out this work. The following equation was supplied to BODC and the coefficients A and B were applied to the data:

$$[O_2] = (A*C + B)* S' \text{ ml/l}$$

where A = 2.0833
C = oxygen sensor current (μA)
B = -0.0285
S'= oxygen saturation concentration (a function of water temperature and salinity).

Finally, the data were converted to μM by multiplication by 44.66. (See data warnings).

Considerable manipulation of the oxygen data, such as the substitution of downcast data by isopycnal-matched upcast data, was required to produce the oxygen data channel in the final data set. This, combined with the uncertainties involved in the calibration of oxygen data, might mean that some users would wish to re-examine the oxygen processing. To facilitate this, BODC have systematically archived the raw data (including oxygen current and temperature) from both upcasts and downcasts. These data are available on request.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

Oxygen saturation has been computed using the algorithm of Benson and Krause (1984).

4) Data Warnings

No tone fire system was available for the CTD on this cruise. Consequently, the oxygen upcast traces were corrupted by disturbances due to membrane depolarisation when bottles were fired. This had two consequences. First, it made determination of reliable sensor readings for calibration difficult. Secondly, when combined with data loss from the downcasts due to problems with the pump the inevitable result was significant gaps in the oxygen record for many of the casts.

The transmissometer on this cruise had an intermittent fault that caused variation in the signal baseline. Data from a significant number of casts have been rejected totally or for a significant proportion of the profile. An empirical calibration, based on intercalibration with the underway instrument, has been applied but this was considered tentative for casts CP180 to CP203. Data from these casts should be used with caution.

5) References

Benson B.B. and Krause D. jnr. 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.

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** 44.

CTD Data Cruise Challenger CH121C
(1st September to 8th September 1995)

1) Components of the CTD data set

The CTD data set for cruise CH121C consists of 32 vertical profiles including the parameters temperature, salinity, chlorophyll, upwelling and downwelling irradiance and attenuance.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor (fed by a SeaBird pump). The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre Niskin bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml l^{-1} to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer’s specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Secondly, spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples were being collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

<u>Pressure</u>

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). A consistent air reading was exhibited and the following correction applied:

$$P_{corr} = P + 1.53 \qquad \text{(standard deviation = 0.35 dbar)}$$

<u>Temperature</u>

The CTD temperature was compared with the digital reversing thermometers attached to the instrument frame. The two instruments were found to agree within 0.008°C. Hence, no correction was applied to the temperature data.

Salinity

Salinity was calibrated against water bottle samples measured on the Guideline 55358 AutoLab Salinometer during the cruise.

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction applied for this cruise was:

$$S_{corr} = S + 0.060 \qquad \text{(standard deviation = 0.002)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in February 1990 supplied by RVS.

Upwelling (#2): PAR (W m^{-2}) = exp (-4.97*volts + 6.878)/100
Downwelling (#1): PAR (W m^{-2}) = exp (-4.90*volts + 7.237)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into μE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.673V). The manufacturer's voltage for the instrument used (SN103D) was 4.758V.

Reports were received from UNW that the clear water attenuance values measured by the transmissometer used on this cruise were anomalously high. A careful investigation was initiated to look at this problem. This involved examination of clear water attenuance values from casts deeper than 500 m and an inter-comparison of the surface attenuance values with contemporaneous data from the underway transmissometer. It must be stressed that this exercise was comparative, looking at differences in the relationship between the CTD and underway instruments. No attempt was made to render both data sets numerically identical as experience has shown that the mechanical effects of the pump on the suspended particulate material modify the attenuance of water in the non-toxic supply.

The exercise worked well and the following corrections were derived and have been applied to the data:

Casts CP204 to CP212:	Corrected attenuance = attenuance – 0.04
Casts CP213 to CP218:	Corrected attenuance = attenuance – 0.07
Casts CP219 to CP220:	Corrected attenuance = attenuance – 0.10
Casts CP221 to CP235:	No correction

Note that these data show the problem with the transmissometer was getting progressively worse until the instrument suddenly repaired itself. This pattern of behaviour was also observed during subsequent cruises when SN103D was used. It is believed to reflect an intermittent electronic fault in the instrument.

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368*\text{Atten}) - 0.801 \quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including cruise Charles Darwin CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

<u>Chlorophyll</u>

200 ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. The chlorophyll data set (range 0 to 1.02 mg m^{-3}) for calibration purposes comprised 48 values. The following relationship was found between extracted chlorophyll levels and corresponding fluorometer voltages:

$$\text{Chlorophyll (mg m}^{-3}) = \exp(2.28*\text{volts} - 4.60) \quad (R^2 = 65\%, n = 48)$$

<u>Dissolved Oxygen</u>

No Winkler titration data were available from this cruise for the calibration of the dissolved oxygen sensor. Consequently, no dissolved oxygen channel has been included in the final version of the data set.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

None.

5) Reference

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater*. **UNESCO Technical Papers in Marine Science*** 44.

CTD Data for Cruise Challenger CH123A
(15th November to 29th November 1995)

1) Components of the CTD data set

The CTD data set for cruise CH123A consists of 21 vertical profiles of the parameters temperature, salinity, upwelling and downwelling irradiance, and optical attenuance.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor. The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10 litre Niskin bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml l^{-1} to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer's specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{attenuance (m}^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

<u>Pressure</u>

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). A consistent air reading was exhibited and the following correction applied:

$$P_{corr} = P - 2.02 \qquad \text{(standard deviation 0.30 db)}$$

<u>Temperature</u>

The CTD temperature was compared with the digital reversing thermometers attached to the instrument frame. These were found to agree within 0.001°C. Consequently no temperature calibration has been applied.

Salinity

During screening a number of offsets were noted in the salinity trace. These were attributed to the conductivity cell contamination. The following corrections have been applied:

CP 16	0.005 PSU added between 87.0 db and 113.0 db
CP 16	0.01 PSU added between 43.0 db and 162.0 db

Salinity was calibrated against water bottle samples measured on the Guideline 55358 AutoLab Salinometer during the cruise.

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction applied for this cruise was:

$$S_{corr} = S + 0.025 \text{ (standard deviation 0.003)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 supplied by RVS.

Upwelling (#10): PAR (W m^{-2}) = exp (-4.98*volts + 6.565)/100
Downwelling (#8): PAR (W m^{-2}) = exp (-4.97*volts + 6.426)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into μE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.748V). The manufacturer's voltage for the instrument used (SN079D) was 4.744V.

During data screening, it was noted that the attenuance values were in the range 0.6-0.9 per m for all casts. The minimum values are unusually high but the weather during this cruise was noted as being exceptionally bad and a significant proportion of the CTD casts was collected on an opportunistic basis whilst the ship was sheltering behind Islay.

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368*\text{Atten}) - 0.801 \quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including Charles Darwin cruise CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

200 ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. The chlorophyll data for both legs of the cruise were combined in order to produce a calibration. The sample data set for calibration purposes comprised 224 values in the range 0.04 to 0.43 mg m^{-3}. The following relationship was found between extracted chlorophyll levels and corresponding fluorometer voltages:

$$\text{Chlorophyll (mg/m}^3) = \exp(1.21*\text{volts} - 3.59) \quad (R^2 = 56\%)$$

Dissolved Oxygen

No Winkler titration data were available from this cruise for the calibration of the dissolved oxygen sensor.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

None.

5) Reference

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** 44.

CTD Data for Cruise Challenger CH123B
(1^{st} December to 15^{th} December 1995)

1) Components of the CTD data set

The CTD data set for cruise CH123B consists of 93 vertical profiles of the parameters temperature, salinity, dissolved oxygen, chlorophyll, upwelling and downwelling scalar irradiance, and optical attenuance.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor. The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10 litre Niskin water bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The datas et was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml l^{-1} to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer's specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{attenuance (m}^{-1}\text{)} = -4 \log_e \text{(\% transmission/100)}$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

Pressure

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). A consistent air reading was exhibited and the following correction applied:

$$P_{corr} = P - 3.00 \qquad \text{(standard deviation 0.31 dbar)}$$

Temperature

The CTD temperature was compared with the digital reversing thermometers attached to the instrument frame. These were found to agree within 0.009°C.

No correction has been applied because the platinum resistance thermometer is believed to be as reliable as the reversing thermometers.

Salinity

During screening a number of offsets were noted in the salinity trace. These were attributed to the conductivity cell contamination. The following corrections have been applied:

CP27	0.008 PSU added between 160.0 db and 169.5 db
CP39	0.0093 PSU added between 315.0 db and 351.0 db
CP51	0.02 PSU added between 211.0 db and 225.0 db
CP53	0.01 PSU added between 118.0 db and 124.0 db
CP57	0.015 PSU added between 368.0 db and 379.0 db
CP70	0.005 PSU added between 128.0 db and 140.0 db
CP81	0.014 PSU added between 153.4 db and 172.0 db

Salinity was calibrated against water bottle samples measured on the Guideline 55358 AutoLab Salinometer during the cruise.

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction applied for this cruise was:

$$S_{corr} = S + 0.034 \qquad \text{(standard deviation 0.008)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 supplied by RVS.

Upwelling (#10): PAR (W m^{-2}) = exp (-4.98*volts + 6.565)/100
Downwelling (#8): PAR (W m^{-2}) = exp (-4.97*volts + 6.426)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into μE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.748V). The manufacturer's voltage for the instrument used (SN079D) was 4.744V.

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368*\text{Atten}) - 0.801 \quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including cruise Charles Darwin CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

200 ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. The chlorophyll data for both legs of the cruise were combined in order to produce a calibration. The sample data set for calibration purposes comprised 224 values in the range 0.04 to 0.43 mg m^{-3}. The following relationship was found between extracted chlorophyll levels and corresponding fluorometer voltages:

$$\text{Chlorophyll (mg/m}^3) = \exp(1.21*\text{volts} - 3.59) \quad (R^2 = 56\%)$$

Dissolved Oxygen

The oxygen calibration procedure adopted for this cruise differed from those operated on cruises for two reasons. First, the SeaBird pump fitted to the oxygen sensor malfunctioned during the cruise and was removed after cast CP66.

Secondly, particular attention was paid to the casts where the pump was fitted to ensure that good data were obtained on the downcast. The operational procedure to achieve this was to lower the CTD until the oxygen signal on the real-time display was seen to stabilise (usually to a depth of 50-100 m). The CTD was then raised to the surface and immediately lowered to the seabed to obtain the downcast data stored in the database. As a result of this procedure, the incorporation of upcast oxygen data was not required.

The standard BODC regression procedure was used to calibrate the casts where the SeaBird pump was not fitted (CP67-CP93) based on 9 bottle samples from casts CP67 and CP87. The resulting calibration was:

$$O_{cal} = O_{raw} * 2.27 + 8.5 \quad (R^2 = 90\%)$$

This calibration has been applied to the data and the result was checked to ensure that the surface calibrations were sensible.

Oxygen bottle data were available for three of the casts where the pump was fitted (CP14, CP53 and CP57). The UNW calibration procedure was applied to each of these casts individually but produced significantly different coefficients for each profile. This presented a problem for the calibration of those casts in the first group for which no bottle data were available. A compromise solution was adopted in which the simple BODC regression approach was used to provide a mean calibration from the available bottle data. The calibration obtained was:

$$O_{cal} = O_{raw} * 2.15 + 19.9 \quad (R^2 = 90\%)$$

Users should be aware that the calibration technique adopted is less precise than the UNW technique used with large bottle data sets on other cruises. Consequently, the oxygen data from this cruise have a lower, but still acceptable, accuracy. Users might wish to re-examine the oxygen calibration for this cruise.

To facilitate this, BODC have systematically archived the raw data (including oxygen current and temperature) from both upcasts and downcasts. These data are available on request.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

Oxygen saturation has been computed using the algorithm of Benson and Krause (1984).

4) Data Warnings

The oxygen calibration water bottle data set from this cruise was restricted due to operational reasons forcing a less rigorous calibration procedure than the one used for other SES cruises. The oxygen data should therefore be regarded as being potentially of lower accuracy and are not recommended for applications requiring accuracy better than ±10%.

5) References

Benson B.B. and Krause D. jnr. 1984. The concentration and isotopic fractionation of oxygen dissolved in fresh water and sea water in equilibrium with the atmosphere. ***Limnol. Oceanogr.*** <u>29</u> pp.620-632.

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** <u>44</u>.

CTD Data for Cruise Challenger CH124
(7th to 27th January 1996)

1) Components of the CTD data set

The CTD data set for cruise CH124 consists of 77 vertical profiles. The data parameters are temperature and salinity.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with a SeaBird SBE9/11 CTD fitted with standard SeaBird pressure, temperature, conductivity and dissolved oxygen sensors. It is unclear whether a fluorometer was fitted to the instrument. If it was, it clearly malfunctioned as described below.

A two-litre NIO bottle, fitted with either two SIS digital reversing thermometers or classical mercury reversing thermometers and a pinger, was attached to the CTD wire. This was used to collect calibration data. The firing depth (by brass messenger) was varied to ensure that the calibration encompassed a wide range of temperature and salinity values.

The instrument was regularly returned to the manufacturer for recertification. Recommended practice was for this to be done every six months.

2.2) Data Acquisition

Data were logged on a PC running standard SeaBird Seasave data acquisition software. Normally, data were only logged during the downcast. However on casts where the calibration samples were collected near the surface data were also logged on the upcast up to the level where the sample was taken.

2.3) Processing and Calibration Procedures

Digital, protected and unprotected reversing thermometer data were collected during the cruise. Equilibration times of 10 seconds were allowed for digital thermometers and 4 minutes for mercury thermometers. Salinity samples were collected in rinsed, 200 ml Besser ‘Meplat’ glass bottles with zwischenscholt-stopfen plastic seals. Salinity was determined back in the laboratory using a Guildline Autosal bench salinometer.

All temperature calibrations were done to the IPTS-68 standard. Digital reversing thermometer data calibrated to the ITS-90 standard were converted to IPTS-68 by multiplying by 1.00024 before being used for calibration purposes.

The maufacturer’s calibration coefficients were adjusted for temperature and conductivity on the basis of this calibration data. The pressure coefficients were adjusted on the basis of pinger depths determined by a Simrad EA500 echo sounder and thermometric pressures determined from protected and unprotected reversing thermometers.

The adjusted calibration file was used to generate a calibrated one-decibar data set using the standard SeaBird Seasoft program.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were supplied to BODC as ASCII files on floppy disks and comprised pressure, temperature, salinity, chlorophyll and dissolved oxygen values at one-decibar intervals. They were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor.

The reformatting software included a check that suppressed any data values that were constant. This eliminated the chlorophyll channel from every series indicating that if a fluorometer was fitted to the CTD system then it wasn’t working properly.

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Spikes on all data channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

No additional calibration work was undertaken at BODC other than the conversion of the temperature data from the IPTS-68 standard to the ITS-90 standard. This was achieved by multiplying the data by 0.99976. Note that this conversion was undertaken within the LOIS (SES) database to bring all CTD temperature data within that database to a common standard. The version of the data held in the BODC National Oceanographic Database is as supplied by the data originator (IPTS-68 standard).

As no dissolved oxygen samples were taken during the cruise, the CTD dissolved oxygen data set has been excluded from the final data set in the LOIS (SES) database. It is retained in the version of the data in the National Oceanographic Database.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

There are no data warnings for the pressure, temperature and salinity data from this cruise.

CTD Data for Cruise Challenger CH125A
(31st January to 12th February 1996)

1) Components of the CTD data set

The CTD data set for cruise CH125A consists of 47 vertical profiles containing the parameters temperature, salinity, chlorophyll, upwelling and downwelling irradiance and optical attenuance.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor (fed by a SeaBird pump). The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre Niskin bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml l^{-1} to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer’s specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{Attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

<u>Pressure</u>

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). No single consistent pressure correction could be found, but the following correction were applied to the CTD pressure data from 45 casts:

$$P_{corr} = P - 2.87 \text{ (standard deviation 0.26 dbar)}$$

Temperature

The CTD temperature was compared with the digital reversing thermometers attached to the instrument frame. These were found to agree within 0.007°C. Consequently no temperature calibration has been applied.

Salinity

Salinity was calibrated against water bottle samples measured on the Guideline 55358 AutoLab Salinometer during the cruise.

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction applied for this cruise was:

$$S_{corr} = S + 0.030 \qquad \text{(standard deviation 0.004)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 supplied by RVS.

Upwelling (#2): PAR (W m^{-2}) = exp (-4.97*volts + 6.878)/100
Downwelling (#1): PAR (W m^{-2}) = exp (-4.90*volts + 7.237)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into µE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.622V). The manufacturer's voltage for the instrument used (SN103D) was 4.758V.

Reports were received from UNW that the clear water attenuance values measured by the transmissometer used on this cruise were anomalously high. A careful investigation was initiated to look at this problem. This involved examination of clear water attenuance values from casts deeper than 500 m and an inter-comparison of the surface attenuance values with contemporaneous data from the underway transmissometer. It must be stressed that this exercise was comparative, looking at differences in the relationship between the CTD and underway instruments. No attempt was made to render both data sets numerically identical as experience has shown that the mechanical effects of the pump on the suspended particulate material modify the attenuance of water in the non-toxic supply.

The exercise worked well and the following correction was derived and has been applied to the data:

$$Atten_{corr} = Atten - 0.066 \qquad \text{Casts CP40 to CP47 only}$$

The attenuance data for the other casts from this cruise required no further correction.

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368*\text{Atten}) - 0.801 \ (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including cruise Charles Darwin CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

200 ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. 73 extracted chlorophyll concentrations (range 0 to 0.93 mg m^{-3}) were regressed against the corresponding fluorometer voltages. The following relationship was found between extracted chlorophyll levels and corresponding fluorometer voltages:

$$\text{Chlorophyll (mg m}^{-3}) = \exp(1.95*\text{volts} - 5.0) \quad (R^2 = 76.6\%, n = 73)$$

Dissolved Oxygen

No Winkler titration data were available from this cruise for the calibration of the dissolved oxygen sensor. Consequently, no dissolved oxygen channel has been included in the final version of the data set.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

None.

5) Reference

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** 44.

CTD Data for Cruise Challenger CH125B
(13th February to 3rd March 1996)

1) Components of the CTD data set

The CTD data set for cruise CH125B consists of 131 vertical profiles containing the parameters temperature, salinity, chlorophyll, dissolved oxygen, upwelling and downwelling irradiance and optical attenuance.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor (fed by a SeaBird pump). The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre Niskin bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml l^{-1} to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer's specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{Attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

For this cruise, the RVS Neil Brown Mk 3B CTD system was equipped with a SeaBird pump, which sent water at a constant rate through the housing containing the existing Beckman oxygen electrode. Problems associated with the plumbing of the pump to the oxygen probe resulted in many profiles only recording good oxygen data on upcasts. To overcome this, the upcast data for oxygen, temperature and salinity channels were flagged to remove any spikes. The downcast oxygen values loaded into ORACLE were then replaced where necessary by upcast oxygen data using isopycnal (rather than pressure) matching to determine the replacement values to be used.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

<u>Pressure</u>

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). The following mean correction was determined for the cruise:

$$P_{corr} = P - 2.87 \qquad \text{(standard deviation 0.31 dbar)}$$

Temperature

The CTD temperatures were checked against measurements from calibrated SIS digital reversing thermometers that were attached to one or more of the water bottles. These were found to agree within 0.003°C. Consequently no temperature calibration has been applied.

Salinity

Salinity was calibrated against water bottle samples measured on the Guideline 55358 AutoLab Salinometer during the cruise.

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction applied for this cruise was:

$$S_{corr} = S + 0.027 \qquad \text{(standard deviation 0.003)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 supplied by RVS.

Upwelling (#2): PAR (W m^{-2}) = exp (-4.97*volts + 6.878)/100
Downwelling (#1): PAR (W m^{-2}) = exp (-4.90*volts + 7.237)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into µE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.622V). The manufacturer's voltage for the instrument used (SN103D) was 4.758V.

Reports were received from UNW that the clear water attenuance values measured by the transmissometer used on this cruise were anomalously high. A careful investigation was initiated to look at this problem. This involved examination of clear water attenuance values from casts deeper than 500 m and an inter-comparison of the surface attenuance values with contemporaneous data from the underway transmissometer. It must be stressed that this exercise was comparative, looking at differences in the relationship between the CTD and underway instruments. No attempt was made to render both data sets numerically identical as experience has shown that the mechanical effects of the pump on the suspended particulate material modify the attenuance of the water in the non-toxic supply.

The exercise worked well and the following corrections were derived and have been applied to the data:

Casts CP77 to CP102	$Atten_{corr}$ = Atten –0.06
Casts CP103 to CP109	$Atten_{corr}$ = Atten –0.10
Casts CP128 to CP131	$Atten_{corr}$ = Atten –0.04
Casts CP142 to CP147	$Atten_{corr}$ = Atten –0.05
Casts CP156 to CP175	$Atten_{corr}$ = Atten –0.04

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368 \times \text{Atten}) - 0.801 \quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including cruise Charles Darwin CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

200 ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. 224 extracted chlorophyll concentrations (range 0.09 to 0.42 mg m^{-3}) were regressed against the corresponding fluorometer voltages. The following relationship was found between extracted chlorophyll levels and corresponding fluorometer voltages:

$$\text{Chlorophyll (mg m}^{-3}\text{)} = \exp(1.55 \times \text{volts} - 4.2) \quad (R^2 = 72.4\%, n = 224)$$

Dissolved Oxygen

Dissolved oxygen concentrations were determined by micro-Winkler titration of seawater samples taken from a range of depths on several CTD casts. These values were compared with oxygen readings derived from the oxygen sensor membrane current, oxygen sensor temperature, sea temperature and salinity values recorded by the CTD on the upcast. Hilary Wilson (University of Wales, Bangor) carried out this work, under the supervision of Dr. Paul Tett. The following equation was supplied to BODC and the coefficients A and B were applied to the data:

$$[O_2] = (A*C + B)* S' \text{ ml l}^{-1}$$

where A = 2.229,

C = oxygen sensor current (µA)

B = -0.1819,

S'= oxygen saturation concentration (a function of water temperature and salinity).

Finally, the data were converted to µM by multiplication by 44.66.

Considerable manipulation of the oxygen data, such as the substitution of downcast data by isopycnal-matched upcast data, was required to produce the oxygen data channel in the final data set. This, combined with the uncertainties involved in the calibration of oxygen data, might mean that some users would wish to re-examine the oxygen processing. To facilitate this, BODC have systematically archived the raw data (including oxygen current and temperature) from both upcasts and downcasts. These data are available on request.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

Oxygen saturation has been computed using the algorithm of Benson and Krause (1984).

4) Data Warnings

None.

5) References

Benson B.B. and Krause D. jnr. 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.

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** 44.

CTD Data for Cruise Challenger CH126A
(11th April to 26th April 1996)

1) Components of the CTD data set

The CTD data set for cruise CH126A consists of 45 vertical profiles containing the parameters temperature, salinity, upwelling and downwelling irradiance (on some casts), chlorophyll, and optical attenuance.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor. The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre Niskin bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml l^{-1} to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer's specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{Attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

<u>Pressure</u>

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). A consistent air reading was exhibited and the following correction applied:

$$P_{corr} = P - 2.91 \qquad \text{(standard deviation 0.17 dbar)}$$

<u>Temperature</u>

The CTD temperature was compared with the digital reversing thermometers attached to the water bottles. The two instruments were found to agree within 0.001°C. Hence no correction has been applied to the CTD temperature data.

Salinity

Salinity was calibrated against water bottle samples measured on the Guildline 55358 AutoLab Salinometer during the cruise.

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction applied for this cruise was:

$$S_{corr} = S + 0.027 \text{ (standard deviation 0.003)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 supplied by RVS.

Upwelling (#2): PAR (W m^{-2}) = exp (-4.97*volts + 6.878)/100
Downwelling (#1): PAR (W m^{-2}) = exp (-4.90*volts + 7.237)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into μE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during cruise Challenger CH125B (4.622V). The Challenger CH125B value was used as no air readings were taken during this cruise. The manufacturer's voltage for the instrument used (SN103D) was 4.758V.

Reports were received from UWB that the clear water attenuance values measured by SN103D were anomalously high. A careful investigation was initiated to look at this problem. This involved examination of clear water attenuance values from casts deeper than 500 m and an inter-comparison of the surface attenuance values with contemporaneous data from the underway transmissometer. It must be stressed that this exercise was comparative, looking at differences in the relationship between the CTD and underway instruments. No attempt was made to render both data sets numerically identical as experience has shown that the mechanical effects of the pump on the suspended particulate material modify the attenuance of water in the non-toxic supply.

Further information on the pattern of corrections required was obtained by examination of the superimposed attenuance profiles from groups of series on a graphics editor.

As a result, the following corrections were derived and have been applied to the data:

Casts CP1 to CP17	-0.133 per metre
Casts CP26 to CP27	-0.064 per metre
Casts CP38 to CP45	-0.097 per metre

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$SPM\ (mg/l) = (2.368*Atten) - 0.801\quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including cruise Charles Darwin CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

200 ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. The sample data set for calibration purposes comprised 94 values in the range 0.01 to 3.92 mg m^{-3}. The following relationship was found between extracted chlorophyll levels and corresponding fluorometer voltages:

$$Chlorophyll\ (mg/m^3) = \exp(1.11*volts - 2.96)\quad (R^2 = 86\%, n = 94)$$

Dissolved Oxygen

No Winkler titration data were available from this cruise for the calibration of the dissolved oxygen sensor. Consequently, no dissolved oxygen channel has been included in the final version of the data set.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

None.

5) Reference

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** 44.

CTD Data for Cruise Challenger CH126B
(27th April to 12th May 1996)

1) Components of the CTD data set

The CTD data set for cruise CH126B consists of 157 vertical profiles containing the parameters temperature, salinity, upwelling and downwelling irradiance, chlorophyll, dissolved oxygen and optical attenuance.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor. Water was pumped over the oxygen membrane using a SeaBird pump. The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre Niskin water bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The dataset was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen (nominal calibration applied) was converted from ml l^{-1} to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer's specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational DataBase Management System.

For this cruise, the RVS Neil Brown Mk 3B CTD system was equipped with a SeaBird pump, which sent water at a constant rate through the housing containing the existing Beckman oxygen electrode. Problems associated with the plumbing of the pump to the oxygen probe resulted in many profiles only recording good oxygen data on upcasts. To overcome this, the upcast data for oxygen, temperature and salinity channels were flagged to remove any spikes. The downcast oxygen values loaded into ORACLE were then replaced where necessary by upcast oxygen data using isopycnal (rather than pressure) matching to determine the replacement values to be used.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

<u>Pressure</u>

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). A consistent air reading was exhibited and the following correction applied:

$$P_{corr} = P - 3.06 \qquad \text{(standard deviation 0.22 dbar)}$$

Temperature

The CTD temperature was compared with the calibrated digital reversing thermometers attached to the instrument frame. There were six suspect comparisons in a data set of 132 CTD temperature readings. Ignoring the suspect data the two instruments were found to agree within 0.003°C. Hence, no temperature correction was applied to the CTD data.

Salinity

During graphical examination of the data, a number of salinity offsets were observed that clearly affected the density profiles. These have been attributed to conductivity cell fouling and have been eliminated by the application of the following corrections:

CP97	0.0075 PSU added between 18 db and 57.5 db
CP101	0.005 PSU added between 63 db and 87 db
CP103	0.005 PSU added between 37 db and 56.1 db.
CP134	0.010 PSU added between 188 db and 199 db
CP134	0.025 PSU added between 204 db and 221 db
CP143	0.010 PSU added between 84 db and 96.5 db
CP149	0.010 PSU added between 76 db and 106 db
CP157	0.010 PSU added between 24 db and 41.1 db
CP157	0.005 PSU added between 41.2 db and 56 db
CP159	0.027 PSU added between 0 db and 120 db

Salinity was then calibrated against water bottle samples measured on the Guildline 55358 AutoLab Salinometer during the cruise.

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction applied for this cruise was:

$$S_{corr} = S + 0.034 \qquad \text{(standard deviation 0.004)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 supplied by RVS.

Upwelling (#2): $\quad$ PAR (W m^{-2}) = exp (-4.97*volts + 6.878)/100

Casts CP46 to CP135:

Downwelling (#1): PAR (W m^{-2}) = exp (-4.90*volts + 7.237)/100

Casts CP136 to CP202:

Downwelling (#8): PAR (W m^{-2}) = exp (-4.97*volts + 6.426)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into μE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

Two different transmissometers were used during cruise CH126B. For casts CP46 to CP72 the instrument used (SN103D) had a manufacturer's voltage of 4.758V. The air correction applied for these casts was obtained from an air reading during cruise Challenger CH125B (4.622V). The Challenger CH125B value was used as no air readings were taken during this part of the cruise.

For casts CP73 to CP202 the instrument used (SN125D) had a manufacturer's voltage of 4.789V. The air correction applied for this instrument was based on an air reading obtained during this section of the cruise (4.690V).

Reports were received from UWB that the clear water attenuance values measured by SN103D were anomalously high. A careful investigation was initiated to look at this problem. This involved examination of clear water attenuance values from casts deeper than 500 m and an inter-comparison of the surface attenuance values with contemporaneous data from the underway transmissometer. It must be stressed that this exercise was comparative, looking at differences in the relationship between the CTD and underway instruments. No attempt was made to render both data sets numerically identical as experience has shown that the mechanical effects of the pump on the suspended particulate material modify the attenuance of water in the non-toxic supply.

Further information on the pattern of corrections required was obtained by examination of the superimposed attenuance profiles from groups of series on a graphics editor.

As a result, the following corrections were derived and have been applied to the data:

$Atten_{corr}$ = Atten –0.19 (SD = 0.02) Casts CP46 to CP52 only

$Atten_{corr}$ = Atten –0.10 (SD = 0.03) Casts CP53 to CP72 only

These corrections produce a minimum attenuance value of 0.34, which is lower than expected for deep water in the SES field area. The attenuance data for casts CP46 to CP72 should therefore be used with a degree of caution.

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368*\text{Atten}) - 0.801 \quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including cruise Charles Darwin CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

200 ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. There were 309 CTD chlorophyll values used in the calibration (range 0.08 to 6.23 mg m^{-3}). The following relationship was found between extracted chlorophyll levels and corresponding fluorometer voltages:

$$\text{Chlorophyll (mg/m}^3\text{)} = \exp(0.85*\text{volts} - 2.22) \quad (R^2 = 69\%, n = 309)$$

Dissolved Oxygen

Dissolved oxygen concentrations were determined by micro-Winkler titration of seawater samples taken from a range of depths on several CTD casts. These values were compared with oxygen readings derived from the oxygen sensor membrane current, oxygen sensor temperature, sea temperature and salinity values recorded by the CTD on the upcast. Hilary Wilson (University of Wales, Bangor), under the supervision of Dr. Paul Tett, carried out this work. The following equation was supplied to BODC and the coefficients A and B were applied to the data:

$$[O_2] = (A*C + B)*S' \text{ ml/l}$$

where A = 2.3625023

C = oxygen sensor current (μA)
B = -0.0057156
S'= oxygen saturation concentration (a function of water temperature and salinity).

Finally, the data were converted to μM by multiplication by 44.66.

The calibration coefficients used were derived using the pooled data from the profiles from which bottle oxygen samples were taken. Individual calibrations were derived for each of these profiles. These are included below for reference. However, please note that the whole cruise coefficients given above were applied to all profiles in the database.

CP51	2.11479085	0.05078459
CP69	2.31819552	-0.0174178
CP90	2.40072982	-0.041451
CP117	1.80121762	0.35455168
CP140	2.47991271	-0.0731599
CP150	2.49382778	-0.0637023
CP174	2.64767402	-0.1367603
CP183	2.52620942	-0.1129443
CP188	2.57519571	-0.1201767

Considerable manipulation of the oxygen data, such as the substitution of downcast data by isopycnal-matched upcast data, was required to produce the oxygen data channel in the final data set. This, combined with the uncertainties involved in the calibration of oxygen data, might mean that some users would wish to re-examine the oxygen processing. To facilitate this, BODC have systematically archived the raw data (including oxygen current and temperature) from both upcasts and downcasts. These data are available on request.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

Oxygen saturation has been computed using the algorithm of Benson and Krause (1984).

4) Data Warnings

The transmissometer used for part of this cruise had an intermittent fault that caused variation in the signal baseline. Data from a number of the casts using this instrument have been rejected totally or for a significant proportion of the profile. An empirical calibration, based on intercalibration with the underway instrument, has been applied but resulted in a lower than expected clear water attenuance for the handful of deep casts taken before the transmissometer was swapped. Attenuance data from these casts (CP46-CP72) should be used with a degree of caution.

5) References

Benson B.B. and Krause D. jnr. 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.

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** 44.

CTD Data for Cruise Challenger CH128A
(10th July to 25th July 1996)

1) Components of the CTD data set

The CTD data set for cruise CH128A consists of 88 vertical profiles. The data parameters are temperature, salinity, upwelling and downwelling irradiance, dissolved oxygen, chlorophyll and optical attenuance.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor. Water was forced over the oxygen membrane by a SeaBird submersible pump. The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre Niskin water bottles. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling scalar irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling scalar irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 ms^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml/l for oxygen; mmho/cm for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml/l to μM by multiplying the values by 44.66.
- Transmissometer voltages were corrected to the manufacturer's specified voltage by ratio using transmissometer air readings taken during the cruise.
- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.
- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using a custom in-house graphics editor, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, clusters of points recorded while the CTD was held stationary were used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

For this cruise, the RVS Neil Brown Mk 3B CTD system was equipped with a SeaBird pump, which sent water at a constant rate through the housing containing the existing Beckman oxygen electrode. Problems associated with the plumbing of the pump to the oxygen probe resulted in many profiles only recording good oxygen data on upcasts. To overcome this, the upcast data for oxygen, temperature and salinity channels were flagged to remove any spikes. The downcast oxygen values loaded into ORACLE were then replaced where necessary by upcast oxygen data using isopycnal (rather than pressure) matching to determine the replacement values to be used.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data except for the calibration to express attenuance in terms of suspended matter concentration.

Pressure

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). The following correction was calculated from 14 values:

$$P_{corr} = P - 0.16$$

Temperature

The CTD temperature was compared with readings from the digital reversing thermometers attached to the water bottles. Normal BODC practice is to use this comparison as a check to ensure against CTD malfunction rather than a calibration because the Neil Brown CTD thermometer is considered more accurate than the SIS digital reversing thermometers.

However, the CTD used on this cruise had not been accurately calibrated by RVS and the temperature data supplied to BODC were based on a nominal calibration. Consequently, the reversing thermometer data were used to recalibrate the CTD temperature data and the following correction has been applied:

$$T_{corr} = T - 0.032 \quad \text{(standard deviation 0.006)}$$

Salinity

During screening an offset was noted in the salinity trace. This was attributed to the conductivity cell contamination. The following correction has been applied:

CP57 0.041 PSU added between 158.0 db and 355.6 db

Salinity was calibrated against water bottle samples measured on the Guildline 55358 AutoLab Salinometer during the cruise. Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction determined for this cruise was:

$$S_{corr} = S + 0.088 \quad \text{(standard deviation 0.003)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 supplied by RVS.

Upwelling (#10): PAR ($W\ m^{-2}$) = exp (-4.98*volts + 6.565)/100.0
Downwelling (#12): PAR ($W\ m^{-2}$) = exp (-4.92*volts + 6.506)/100.0

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into $\mu E/m^2/s$, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.736V). The manufacturer's voltage for the instrument used (SN079D) was 4.744V.

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

SPM (mg/l) = (2.368*Atten) - 0.801 (R^2 = 79%)

This calibration is valid for all SES cruises after and including cruise Charles Darwin CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

200ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. A relatively small number of samples were taken on CH128B. Consequently, the data from both legs of CH128 were pooled for the calibration.

The extracted chlorophyll concentrations (range 0.1 to 2.94 mg m^{-3}) were regressed against the corresponding fluorometer voltages, giving the following calibration which has been applied to the data:

Chlorophyll (mg m^{-3}) = exp (1.33 * volts - 2.75) (R^2 = 56.7%, n = 176)

Dissolved Oxygen

Dissolved oxygen concentrations were determined by micro-Winkler titration of seawater samples taken from a range of depths on several CTD casts. These values were compared with oxygen readings derived from the oxygen sensor membrane current, oxygen sensor temperature, sea temperature and salinity values recorded by the CTD on the upcast. Hilary Wilson (University of Wales, Bangor), under the supervision of Dr. Paul Tett, carried out this work. The following equation was supplied to BODC and the coefficients A and B were applied to the data:

$$[O_2] = (A*C + B)* S' \text{ ml/l}$$

where A = 2.1507689 (casts CP1-CP80) or 3.39847069 (casts CP81-CP90)
C = oxygen sensor current (µA)
B = -0.1448435 (casts CP1-CP80) or –1.2152591 (casts CP81-CP90)
S'= oxygen saturation concentration (a function of water temperature and salinity).

Finally, the data were converted to µM by multiplication by 44.66.

The calibration coefficients used for casts CP1-CP80 were derived using the pooled data from 4 of the profiles from which bottle oxygen samples were taken. The calibration for CP81-CP90 was based on data from cast CP81. Individual calibrations were derived for each of these profiles. These are included below for reference. However, please note that the whole cruise coefficients given above were applied to all profiles in the database.

CP5	2.33219833	-0.2623257
CP64	2.15424386	-0.1062559
CP65	2.34197522	-0.2343615
CP69	2.03641103	-0.0567426
CP81	3.39847069	–1.2152591

Considerable manipulation of the oxygen data, such as the substitution of downcast data by isopycnal-matched upcast data, was required to produce the oxygen data channel in the final data set. This, combined with the uncertainties involved in the calibration of oxygen data, might mean that some users would wish to re-examine the oxygen processing. To facilitate this, BODC have systematically archived the raw data (including oxygen current and temperature) from both upcasts and downcasts. These data are available on request.

During the visual inspection of the oxygen data from this cruise it was noticed that there was a significant difference between the downcast and upcast data (sometimes 1-200 µM different at the surface). This difference was far greater than other SES cruises and was present, though it diminished in magnitude with depth, for the whole cast. Consequently, all the data in the final data set have been derived from the upcast rather than the odd 'patch' as in CH121B and CH126B. Looking at the data leaves a nagging doubt that the oxygen sensor was being very slow to equilibrate and there is no concrete evidence that it had reached equilibrium by the start of the upcast. Users are therefore recommended to use the CTD oxygen data from this cruise with a degree of caution.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

Oxygen saturation has been computed using the algorithm of Benson and Krause (1984).

4) Data Warnings

There is strong evidence that the oxygen sensor was exceptionally slow to equilibrate. Although the data presented in the final data set have been taken from the upcast, users are recommended to use the oxygen data from this cruise with caution.

5) References

Benson B.B. and Krause D. jnr. 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.

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater***. UNESCO Technical Papers in Marine Science*** 44.

CTD Data for Cruise Challenger CH128B
(27th July to 6th August 1996)

1) Components of the CTD data set

The CTD data set for cruise CH128B consists of 36 vertical profiles of the parameters temperature, salinity, upwelling and downwelling irradiance, optical attenuance and chlorophyll.

2) Data Acquisition and On-Board Processing

2.1) Instrumentation

The CTD profiles were taken with an RVS Neil Brown Mk3B CTD incorporating a pressure sensor, conductivity cell, platinum resistance thermometer and a Beckmann dissolved oxygen sensor (fed by a SeaBird pump). The CTD unit was mounted vertically in the centre of a protective cage approximately 1.5m square. Attached to the bars of the frame were a Chelsea Instruments Aquatracka fluorometer and a SeaTech red light (661 nm) transmissometer with a 25cm path length.

Above the frame was a General Oceanics rosette sampler fitted with twelve 10-litre water bottles. These comprised a mixture of Niskin and ultra-clean teflon lined Go-Flo bottles as dictated by sampling requirements. The bases of the bottles were 0.75 metres above the pressure head and their tops 1.55 metres above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.38 metres above the CTD temperature sensor.

Above the rosette was a PML 2π PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2π PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance. It should be noted that these sensors were vertically separated by 2 metres with the upwelling sensor 0.2 metres below the pressure head and the downwelling sensor 1.75 metres above it.

No account has been taken of rig geometry in the compilation of the CTD data set. However, all water bottle sampling depths have been corrected for rig geometry and represent the true position of the midpoint of the water bottle in the water column.

2.2) Data Acquisition

On each cast, the CTD was lowered continuously at 0.5 to 1.0 m s^{-1} to the closest comfortable proximity to the sea floor. The upcast was done in stages between the bottle firing depths.

Data were logged by the RVS ABC data logging system. Output channels from the deck unit were logged at 32 Hz by a microprocessor interface (the Level A) which passed time-stamped averaged cycles at 1 Hz to a Sun workstation (the Level C) via a buffering system (the Level B).

2.3) On-Board Data Processing

The raw data comprised ADC counts. These were converted into engineering units (volts for PAR meters, fluorometer and transmissometer; ml l^{-1} for oxygen; mmho cm^{-1} for conductivity; °C for temperature; decibars for pressure) by the application of laboratory determined calibrations. Salinity (Practical Salinity Units as defined in Fofonoff and Millard, 1983) was calculated from the conductivity ratios (conductivity/42.914) and a time lagged temperature using the function described in UNESCO Report 37 (1981).

The data set was submitted to BODC in this form on Quarter Inch Cartridge tapes in RVS internal format for post-cruise processing and data banking.

3) Post-Cruise Processing and Calibration at BODC

3.1) Reformatting

The data were converted into the BODC internal format (PXF) to allow the use of in-house software tools, notably the workstation graphics editor. In addition to reformatting, the transfer program applied the following modifications to the data:

- Dissolved oxygen was converted from ml/l to µM by multiplying the values by 44.66.

- Transmissometer voltages were corrected to the manufacturer's specified voltage by ratio using transmissometer air readings taken during the cruise.

- Transmissometer voltages were converted to percentage transmission by multiplying them by a factor of 20.

- The transmissometer data were converted to attenuance using the algorithm:-

$$\text{Attenuance } (m^{-1}) = -4 \log_e (\% \text{ transmission}/100)$$

3.2) Editing

Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editors, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged.

Spikes on all the downcast channels were manually flagged. No data values were edited or deleted; flagging was achieved by modification of the associated quality control flag.

The pressure ranges over which the bottle samples had been collected were logged by manual interaction with the software. Usually, the marked reaction of the oxygen sensor to the bottle firing sequence was used to determine this. These pressure ranges were subsequently used, in conjunction with a geometrical correction for the position of the water bottles with respect to the CTD pressure transducer, to determine the pressure range of data to be averaged for calibration values.

Once screened on the workstation, the CTD downcasts were loaded into a database under the ORACLE Relational Database Management System.

3.3) Calibration

With the exception of pressure, calibrations were done by comparison of CTD data against measurements made on water bottle samples or from the reversing thermometers mounted on the water bottles as in the case of temperature. In general, values were averaged from the CTD downcasts but where visual inspection of the data showed significant hysteresis values were manually extracted from the CTD upcasts.

All calibrations described here have been applied to the data.

<u>Pressure</u>

The pressure offset was determined by looking at the pressures recorded when the CTD was clearly logging in air (readily apparent from the conductivity channel). The following correction was applied:

$$P_{corr} = P - 0.12 \qquad \text{(standard deviation 0.30)}$$

<u>Temperature</u>

The CTD temperature was compared with readings from the digital reversing thermometers attached to the water bottles. Normal BODC practice is to use this comparison as a check to ensure against CTD malfunction rather than a calibration because the Neil Brown CTD thermometer is considered more accurate than the SIS digital reversing thermometers.

However, the CTD used on this cruise had not been accurately calibrated by RVS and the temperature data supplied to BODC were based on a nominal calibration. Consequently, the reversing thermometer data were used to recalibrate the CTD temperature data and the following correction has been applied:

$$T_{corr} = T - 0.031 \qquad \text{(standard deviation 0.003)}$$

Salinity

Salinity was calibrated against water bottle samples measured on the Guildline 55358 AutoLab Salinometer during the cruise.

Samples were collected in glass bottles filled to just below the neck and sealed with plastic stoppers. Batches of samples were left for at least 24 hours to reach thermal equilibrium in the lab containing the salinometer before analysis.

The correction determined for this cruise was:

$$S_{corr} = S + 0.092 \quad \text{(standard deviation 0.005)}$$

Upwelling and Downwelling Irradiance

The PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 supplied by RVS.

Upwelling (#10): PAR (W m^{-2}) = exp (-4.98*volts + 6.565)/100
Downwelling (#12): PAR (W m^{-2}) = exp (-4.92*volts + 6.506)/100

Note that these sensors have been empirically calibrated to obtain a conversion from W/m^2 into μE/m^2/s, which may be effected by multiplying the data given by 3.75.

Optical Attenuance and Suspended Particulate Matter

The air correction applied for this cruise was based on an air reading obtained during the cruise (4.736V). The manufacturer's voltage for the instrument used (SN079D) was 4.744V.

Large volume samples were taken for gravimetric analysis of the suspended particulate matter concentration. These were used to generate calibrations that expressed attenuance in terms of suspended particulate matter concentrations.

Robin McCandliss (University of Wales, Bangor) undertook this work, under the supervision of Sarah Jones. The optimal approach developed was to base the calibration on samples taken from near the seabed (i.e. those with the minimum content of fluorescent material). The data from all SES cruises where SPM samples were taken were pooled to derive the calibration equation:

$$\text{SPM (mg/l)} = (2.368 * \text{Atten}) - 0.801 \quad (R^2 = 79\%)$$

This calibration is valid for all SES cruises after and including cruise Charles Darwin CD93A. The clear water attenuance predicted by the equation is 0.336 per m, which agrees well with literature values.

No attempt has been made to replace attenuance by SPM concentration in the final data set. However, users may use the equation above to compute an estimated SPM channel from attenuance when required.

Chlorophyll

200ml of seawater collected at several depths on each cast were filtered and the papers frozen for acetone extraction and fluorometric analysis on land. A relatively small number of samples were taken on CH128B. Consequently, the data from both legs of CH128 were pooled for the calibration.

The extracted chlorophyll concentrations (range 0.1 to 2.94 mg m^{-3}) were regressed against the corresponding fluorometer voltages, giving the following calibration which has been applied to the data:

$$\text{Chlorophyll (mg } m^{-3}) = \exp(1.33 * \text{volts} - 2.75) \quad (R^2 = 56.7\%, n = 176)$$

Dissolved Oxygen

No Winkler titration data were available from this cruise for the calibration of the dissolved oxygen sensor. Consequently, no dissolved oxygen channel has been included in the final version of the data set.

3.4) Data Reduction

Once all screening and calibration procedures were completed, the data set was binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

None.

5) Reference

Fofonoff N.P., and Millard Jr., R.C. 1982. Algorithms for Computation of Fundamental Properties of Seawater. ***UNESCO Technical Papers in Marine Science*** 44.

CTD Data for HNLMS Tydeman Cruise
(2^{nd} to 7^{th} September 1995)

1) Components of the CTD data set

The CTD data set for the HNLMS Tydeman cruise consists of 31 vertical profiles of temperature and salinity. The data were collected as part of the Defence Evaluation and Research Agency (DERA) SESAME project that was co-located both in space and time with the LOIS Shelf Edge Project.

2) Data Acquisition and On-Board Processing

The data were supplied to BODC as fully worked up data. No details are known of the instrumentation used or the processing and calibration protocols applied.

3) Post-Cruise Processing and Calibration at BODC

The data were converted into the BODC internal format and inspected using an interactive graphical editor on a UNIX workstation. Any suspect data points were flagged and checks were made to ensure that the data values were consistent with those obtained during SES. No additional calibrations were applied.

The screened downcasts were loaded into a database under the ORACLE Relational Database Management System and binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

CTD Data for RV Colonel Templer Cruise CT01
(10th August to 9th September 1995)

1) Components of the CTD data set

The CTD data set for RV Colonel Templer cruise CT01 (sometimes known as SESAME1 or SESAME95) consists of 31 vertical profiles of temperature and salinity. The data were collected as part of the Defence Evaluation and Research Agency (DERA) SESAME project that was co-located both in space and time with the LOIS Shelf Edge Project.

2) Data Acquisition and On-Board Processing

The data were supplied to BODC as fully worked up data. No details are known of the instrumentation used or the processing and calibration protocols applied.

3) Post-Cruise Processing and Calibration at BODC

The data were converted into the BODC internal format and inspected using an interactive graphical editor on a UNIX workstation. Any suspect data points were flagged and checks were made to ensure that the data values were consistent with those obtained during SES. No additional calibrations were applied.

The screened downcasts were loaded into a database under the ORACLE Relational Database Management System and binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

CTD Data for RV Colonel Templer Cruise CT02
(26th July to 29th August 1996)

1) Components of the CTD data set

The CTD data set for RV Colonel Templer cruise CT02 (sometimes known as SESAME2 or SESAME96) consists of 71 vertical profiles of temperature and salinity. The data were collected as part of the Defence Evaluation and Research Agency (DERA) SESAME project that was co-located both in space and time with the LOIS Shelf Edge Project.

2) Data Acquisition and On-Board Processing

The data were supplied to BODC as fully worked up data. No details are known of the instrumentation used or the processing and calibration protocols applied.

3) Post-Cruise Processing and Calibration at BODC

The data were converted into the BODC internal format and inspected using an interactive graphical editor on a UNIX workstation. Any suspect data points were flagged and checks were made to ensure that the data values were consistent with those obtained during SES. No additional calibrations were applied.

During screening, it was observed that the data, particularly salinity, were exceptionally noisy and heavy flagging of the data were required. All salinities outside the range 35.35 to 35.45 were flagged suspect.

The screened downcasts were loaded into a database under the ORACLE Relational Database Management System and binned to 2 db (casts deeper than 100 db) or 1 db (casts shallower than 100 db). The binning algorithm excluded any data points flagged suspect and attempted linear interpolation over gaps up to 3 bins wide. If any gaps larger than this were encountered, the data in the gaps were set null.

4) Data Warnings

The data, particularly salinity, were very noisy. The level of noise in the final data set has been significantly reduced during screening at BODC. Even so, it is recommended that the data be used with caution.