CTD data series for cruise Challenger CH140 (22 October to 9 November 1998)

Cruise Principal Scientist

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Data Originators

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Research Vessel Services, SOC, Southampton, UK.

Content of data series

Parameter	Unit	Parameter code	Number of stations	Comments
Pressure	db	PRESPR01	60	none
Salinity	PSU-78	PSALST01	60	none
Temperature	deg. C	TEMPST01	60	none
Potential temperature (UNESCO)	deg. C	POTMCV01	60	none
Sigma-theta (UNESCO SVAN)	kg m^{-3}	SIGTPR01	60	none
Chlorophyll *a*	µg l^{-1}	CPHLPR01	42	calibrated from fluorometer voltages caution (see text)
Raw fluorometer voltages	volts	FVLTAQ01	60	none
Optical attenuance	m^{-1}	ATTNMR01	60	none
Total suspended sediment	mg l^{-1}	TSEDTR01	60	calibrated from attenuance caution (see text)
Dissolved oxygen	µmol l^{-1}	DOXYPR01	31	caution (see text)
Oxygen saturation	percent	OXYSBB01	31	caution (see text)
Downwelling PAR	µE m^{-2} s^{-1}	IRRDPP01	60	none
Upwelling PAR	µE m^{-2} s^{-1}	IRRUPP01	60	none
Lightmeter voltages (downwelling irradiance)	volts	LVLTPD01	60	none
Lightmeter voltages (upwelling irradiance)	volts	LVLTPU01	60	none

Instrumentation and data processing by originator

CTD unit and auxiliary sensors:
RVS Neil Brown Mk3B CTD incorporating a pressure sensor, a conductivity cell, a platinum resistence thermometer, a 20 cm pathlength SeaTech transmissometer (660 nm), a Mk II Aquatracka fluorometer, two 2PI PAR light meters for upwelling and downwelling irradiance and a Beckman dissolved oxygen sensor fed by a Seabird 5T submersible pump.

Changes of sensors during the cruise:
- the transmissometer T-1022D was spiking intermittently and moisture in the slip ring assembly was suspected. It was replaced by transmissometer T-1019D for cast 03 but the noise persisted. T-1022D was re-installed on the CTD frame. Further attempts to resolve the problem were unsuccessful.
- the fluorometer SA-226 was replaced by fluorometer SA3-254 between casts 04 and 05 because of the presence of unusually high noise and spikes in the fluorescence profiles.

Data acquisition:
The CTD was first lowered down to a depth of approx. 10 m where it was left for a few minutes before being brought back to just below sea surface. This was necessary to activate the SeaBird pump. It was then lowered continuously at 0.5 to 1 m s^{-1} to the closest comfortable proximity to the sea floor. The

upcast was done in stages between bottle firing depths.

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

On-board data processing:
The raw data (ADC counts) were converted into engineering units (volts for PAR meters, for fluorometers and transmissometers; 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 & 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). PAR volts were converted to µWatts cm^{-2}

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.

Sampling device:
The CTD unit was protected by a metallic frame. A General Oceanic rosette sampler equipped with twelve 30-litre Niskin water bottles was fitted above the frame. The base of the bottles was at 0.75 metres above the pressure head and their tops at 1.55 m above it. One bottle was fitted with a holder for twin digital reversing thermometers mounted 1.40 metres above the CTD temperature sensor.

Above the rosette was a PML 2PI PAR (photosynthetically available radiation) sensor pointing upwards to measure downwelling irradiance. A second 2PI PAR sensor, pointing downwards, was fitted to the bottom of the cage to measure upwelling irradiance.

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

BODC post-cruise processing and screening

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

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

- transmissometer voltages were corrected to the manufacturer's specified voltage ratio by using transmissometer air readings taken during the cruise (see details in "Calibration" paragraph). The voltages were then converted to percentage transmission by multiplying them by a factor of 20. Conversion to attenuance was made using the following algorithms:

$$\% \text{ transmission} = \text{Volts} * 20 * Va / Vb \quad (1)$$

$$\text{attenuance } (m^{-1}) = -1 / PL * \log_e (\% \text{ transmission} / 100) \quad (2)$$

where Va is the manufacturer's air reading for this instrument, Vb is the average of the air readings carried out during the cruise and PL is the transmissometer pathlength in metres (0.20 m).

- light units were re-converted from µWatts cm^{-2} to Volts to allow for the application of BODC's calibration software.

Screening:
Reformatted CTD data were transferred onto a high-speed graphics workstation. Using custom in-house graphics editor SERPLO, downcasts and upcasts were differentiated and the limits of the downcasts and upcasts were manually flagged. If present, spikes and suspicious data 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 to 'M' for suspicious values and 'N' for null.

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.

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

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.

- Pressure: the pressure offset was determined by looking at the pressure values recorded when the CTD was logging in the air (readily apparent from the conductivity channel). Only casts with no spike in the pressure channel were considered for the determination of the pressure offset. The following correction was applied:

$P_{corr} = P - 1.13$ (standard deviation 0.36 db)

- Temperature: the CTD temperature was compared with readings from the digital reversing thermometers attached to the water bottles (data originator: J. Benson, RVS, Southampton, UK). A significant offset was observed between the Neil Brown CTD thermometer and the temperature readings from the two digital thermometers. Since this offset was consistent throughout the cruise, the following correction was applied:

$T_{corr} = T + 0.022$ (standard deviation 0.002)

- Salinity: salinity was calibrated against water bottle samples measured on the Guildline 55358 AutoLab Salinometer during the cruise (data originator: J. Benson, RVS, UK). 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 laboratory containing the salinometer before analysis.

A significant offset in the difference between CTD salinity and salinometer salinity was observed between the first leg (24-28 Oct.) and second leg (1-7 Nov.) of the cruise. As a result two different corrections have been applied to the following groups of CTD casts:

CTD01 to CTD18: $S_{corr} = S - 0.030$ (standard deviation 0.003)
CTD19 to CTD60: $S_{corr} = S - 0.039$ (standard deviation 0.002)

Upwelling and downwelling irradiance: the PAR voltages were converted to W m^{-2} using the following equations determined in August 1995 and supplied by RVS:

Downwelling (#12): PAR (W m^{-2}) = exp (-4.92*volts + 6.506)/100
Upwelling (#11): PAR (W m^{-2}) = exp (-5.00*volts + 6.536)/100

The data were then converted from W m^{-2} into µE m^{-2} s^{-1} (22/12/1998) by applying a multiplication factor of 3.75. This factor is derived from an empirical calibration of the 2PI PAR sensors.

- Optical attenuance and suspended matter: the air correction applied was based on the averaged air readings obtained during the cruise and on the manufacturer's air reading for the instrument used. The readings associated with the two transmissometers used during the cruise were as follows:

T-1022-D (all casts except CTD03):
manufacturer's air reading = 4.662 volts
air reading = 4.656 volts
blocked light path reading = 0.000 volts

T-1019-D (CTD03):
manufacturer's air reading = 4.682 volts
air reading not available (used manufacturer's air reading)
blocked light path reading = 0.002 volts

The air correction was applied during the transfer of the ASCII data into PXF (see above). The data stored in the database are therefore calibrated.

- Total suspended particulate matter concentration (TSED) was estimated at the University of Wales, Bangor, by linear regression of the concentration of total suspended particulate matter as measured on water samples by gravimetry and attenuance (ATTN) as measured by the CTD transmissometer at the time of sample collection. The resulting calibration equation is:

TSED (mg l^{-1}) = (ATTN - 0.39557) / 0.46891, R^2=0.373, n=62

- Chlorophyll: the voltage of the CTD fluorometer was very unstable during this cruise. During screening it became obvious that the data could be distributed into three groups:

- a first group of 24 profiles characterised by a low voltage signal (casts 04-05, 13-15, 17-19, 21, 28, 30-32, 37-38, 43, 47-48, 50, 52-56).

- a second group of 18 profiles characterised by a high voltage signal (casts 06-12, 25, 34, 36, 39, 41-42, 45, 49, 58-60).

- a third group of 18 profiles during which the signal jumped from low to high voltage (casts 01-03, 16, 20, 22-24, 26-27, 29, 33, 35, 40, 44, 46, 51, 57).

For the third group the noise in the data was such that it was deemed impossible to calibrate the data. The whole fluorescence profile was therefore flagged suspect and no chlorophyll concentration was derived.

For the remaining profiles, the calibration dataset was composed of 49 measurements of extracted chlorophyll (data originator: K. Jones, DML, UK) of which 28 were associated with low voltages fluorometer output and 21 with high voltages fluorometer output. The range of chlorophyll concentration was quite low in both groups ranging from 0 to 0.54 µg l^{-1} in the low voltage group and 0 to 0.57 µg l^{-1} in the high voltage group. The calibration equations applied are as follows:

Low voltage group: Chl = exp (12.59 FV – 10.54), R^2=0.278, n=15
High voltage group: Chl = exp (5.72 FV – 10.02), R^2=0.744, n=14

where Chl = predicted chlorophyll *a* concentration in µg l^{-1} and FV= CTD fluorometer voltage. Note that null values for chlorophyll concentration had to be excluded in order to calculate the logarithmic fit. Residuals from the regressions ranged from –0.25 to +0.29 µg l^{-1} for the first group and from –0.23 to +0.25 µg l^{-1} for the second. Both residuals and predicted values were examined graphically for skewness. The distribution of the regression residuals were also examined against sample depths and *in situ* irradiance but no significant trends were observed.

- Oxygen: problems were observed with the oxygen record on a number of profiles probably due to a malfunction of the oxygen pump. Good, reliable data were only observed from casts 04 to 13. For casts 01 to 03 the records were very unstable and the entire profiles were flagged as suspect. For casts 14 to 18 the entire profile was null. After cast 18 the oxygen pump functioned very sporadically and a number of profiles were eliminated: casts 20-21, 25-30, 34-36, 40-49, 52, 54, 58-60. For the other profiles, although the relative changes in oxygen concentration with depth look real, the oxygen concentration and oxygen staturation values were unrealistically high. Oxygen profiles for the following casts were therefore flagged as suspect: 19, 22-24, 31-32, 37-38, 50-51, 53, 55-57.

Oxygen concentration measurements by Winkler titration were performed on samples taken from eight depths on casts 02, 05 and 14 (data originator: K. Jones, DML, UK). Because of the problems encountered with the CTD oxygen probe on casts 02 and 14 calibration could only be derived using data from cast 05. The calibration equation derived is as follows:

Oxygen= 4.20 CTD_oxygen – 227.70, R^2= 0.889, n=8

Considering that this calibration was derived from one profile only, users are advised to use the calibrated oxygen CTD data with caution.

Comments on data quality

- Salinity: suspect flags were applied to spikes observed on the pycnocline and to loops associated with the ship's motion. Malfunction of the conductivity cell for casts 01 and 03 resulted in bad salinity values being recorded on the downcast (salinity offset between downcast and upcast values was 1.5 PSU for cast 01 and 0.5 PSU for casts 03). A correction was applied to the banked salinity data based on values observed during the upcast. These data were flagged 'R'.

- Fluorometer: as detailed above the fluorometer malfunctioned during the cruise and full calibration procedure was only carried out on 42 of the 60 casts.

- Oxygen probe: the oxygen probe functioned intermittently during the cruise: 29 profiles were disgarded because the probe recorded either wrong data or showed no signal. Oxygen profiles for casts 21 to 60 were generally of poor quality and post-calibration concentrations and saturation values tended to be unrealistically high. These data should be treated with extreme caution. On the other hand, oxygen profiles from casts 04 to 13 were of better quality and post-calibration values compared well with oxygen concentration measured on water samples.