Documentation of CTD Data from RV Sonne Cruise No. 118 (27.04.98)

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1. General information

The Data on RV Sonne cruise No. 118 were collected during the German BIGSET Program. The cruise took place in the Arabian Sea from the 31.03.1997 until 11.05.1997, chief scientist was Dr. Olaf Pfannkuche, GEOMAR Institute.

The Data were collected and provided by:

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2. Standard Processing

The data were processed with the SEABIRD standard software by the German JGOFS Data Manager (T. Mitzka). The common parameter proposed by Seabird were used to process these data. **Neither a Salinity nor a Temperature calibration was applied onto the data because of missing reference values.** For accuracy refer to the sections 3.1 and 3.2.

The following routines and parameters were used:

- **DATCNV** converts the raw data to pressure, temperature and salinity
- **ALIGNCTD** Advance oxygen 1 to 5 seconds relative to pressure (5 seconds were used)
- **CELLTM** Conductivity cell thermal mass correction. Typical values are alpha = 0.03 and 1/beta = 7.0. (These standard values were used).
- **FILTER** Low pass filter pressure with a time constantof 0.15 seconds to increase pressure resolution.
- **LOOPEDIT** Mark scans where the CTD moves less than the minimum velocity or travelling backwards due to ship roll. (0.3 m/s was used)
- **DERIVE** Compute oxygen
- **BINAVG** Average data into 1db pressure bins.

- **DERIVE** compute salinity, Theta, Sigma-theta

3. Description of Sensors (SBE 9/II)

3.1 Conductivity Sensor SBE 4

SBE 4 series conductivity sensors are modular, self contained instruments that measure conductivity from 0 to 7 S/m (Siemens/meter) thus covering the full range of lake and oceanic applications. Using an upgraded electronic technique (Version 2; S/N 2000 and higher), these new sensors have electrically-isolated power circuits and optically-coupled outputs to eliminate any possibility of noise and corrosion caused by ground loops. Interfacing is also simplified by the square-wave variable frequency output signal (nominally 2.5 to 7.5 kHz corresponding to 0 - 7 S/m). The sensors offer improved temperature compensation, smaller fit residuals, and faster turn-on stabilization times. Supply voltage range has been increased to 6 - 24 volts.

The SBE 4C is a primary sensor for Sea-Bird's SBE 9 CTD Underwater Unit and SBE 25 Sealogger CTD. Available in 6800 m aluminium or 10500 m titanium housings, the 4C has a quick-disconnect for plumbing to the CTD pump. Supplied without the quick-disconnect fitting, the SBE 4M is also available with a low-corrosion 6061 aluminium 3400 m housing for long-term moored deployments.

The sensing element is a cylindrical flow-through borosilicate glass cell with three internal platinum electrodes. The electrode arrangement offer distinct advantages over inductive or "open" external field cells. Because the outer electrodes are connected together, electric fields are confined inside the cell, making the measured resistance (and instrument calibration) independent of the calibration bath size or proximity to protective cages or other objects. In particular, the internal field permits effective antifoul protection using toxic "gatekeepers" positioned at the cell ends. The cell resistance controls the output frequency of a Wien Bridge oscillator circuit. A unique Sea-Bird design feature introduces a fixed conductivity offset, permitting the instrument to measure conductivity down to 0 for "fresh" water work.

APPLICATION:
Because of the SBE 4's low noise characteristics, hybrid frequency measuring techniques (used in Sea-Bird's CTD instruments) may be used to obtain rapid sampling with very high temporal and spatial resolution. The SBE 4 is ideally suited for obtaining horizontal data with towed systems or vertical data with lowered systems. Because of its small size, it is especially useful for moorings, portable CTD systems, or through-the-ice work. In moored applications, anti-foulant attachments (PN 24012) may be used to protect the cell from biological growth. After a 5 month mooring at depths of 80 to 290 meters, four SBE4s with anti-foulant protection showed drifts of <0.0015 S/m over a year's interval between calibrations. The anti-foul is effective for 6 to 12 months in areas of high biological activity.

CALIBRATION:
Sea-Bird calibrates the sensors over the range of approximately 3 to 6 S/m in computer controlled baths using natural seawater; a water sample at each point is compared to IAPSO seawater using a Guildline AutoSal. A least squares fitting technique (also including a zero conductivity point in air) yields calibration coefficients for use in the following equation:

Conductivity [S/m] = g + hf2 + if3 + jf4 / 10 (1 + dt + ep) where f is the instrument frequency [kHz], t is temperature [℃], p is pressure [decibars], d represents the bulk compressibility (-9.57e-08) and e the thermal coefficient of expansion (3.25e-06) of the borosilicate cell. The resulting coefficients g, h, i, & j are listed on the calibration certificate. Residuals are typically less than 0.0002 S/m.

3.2 SBE 3 Temperature Sensor Calibration

SBE 3 sensors are calibrated to ITS-90 temperature using Sea-Bird's computer-controlled calibration bath. Extremely well insulated, the baths provide a uniform toroidal circulation yielding an overall transfer accuracy against an SPRT within 0.0002℃. Repeatability at each of twelve individually mapped sensor positions is better than 0.0001℃. Sea-Bird's metrology laboratory underpins the new temperature calibration baths. Following consultation with the U.S. National Institute of Standards and Technology, the met lab was configured to achieve temperature precision of 50 µK and accuracy of 0.0005 ℃. To obtain this performance, premium primary references including four Jarrett water triple-point cells (with maintenance bath) and an Isotech gallium melt cell are operated in conjunction with two YSI 8163 standards-grade platinum resistance thermometers and an ASL F18 Automatic Temperature Bridge.

Calibration Equation:

The calibration yields four coefficients (g, h, i, j) that are used in the following equation (Bennett):

$$T = [1 / (g + h\ln(fo/f) + i\ln^2(fo/f) + j\ln^3(fo/f))] - 273.15, [℃]$$

where T is temperature [℃.] and ln is the natural lo g function, and f is the SBE 3 output frequency in Hz. Note that fo, an arbitrary scaling term used for purposes of computational efficiency, was historically chosen as the lowest sensor frequency generated during calibration. For all calibration results expressed in terms of ITS-90 temperatures, the fo term is set to 1000. Calibration fit residuals are typically less than 0.0001℃.

4. Documentation of CTD sampling during SONNE cruise No. 118 (by. R. Luff)

4.1 Introduction

In spring the northern part of the Indian ocean is dominated by the change of the wind and pressure system of the Monsoon. The North-East Monsoon which dominates the region between November and March has already lost its influence, while the South-West Monsoon has not taken the predominance yet. The shift from one Monsoon to the other happens relatively rapidly, occurring over a period of 4-6 weeks. This Intermonsoon period is dominated by very calm winds. The general flow structure with a westward-flowing 'North Equatorial Current' and a southward current on the west side of the Arabian Sea breaks into a series of cold and warm mesoscale eddies which eventually transition into the reversed ocean circulation with a eastward 'North Equatorial Current' in the South-West Monsoon (PICKARD & EMERY 1990). During the South-west Monsoon the circulation in the northern Indian Ocean is dominated by a strong westerly boundary current, the 'Somali' current.

4.2 Methodology and description of the work carried out

During the cruise SO118, 31 CTD-measurements where carried out at the five main stations with the ship owned Sea-Bird SBE 911+ CTD-Profiler in combination with a 24x10 litre bottle rosette. The CTD had sensors for conductivity, temperature and oxygen. On the shallow profiles (up to 600m) the CTD was additionally equipped with a "Dr. Haardt" flurometer.

The combination of the Seabird software and the CTD/rosette works very well. All necessary software for the data manipulation of the CTD-data was included in Seabird software package. Therefore it was not necessary to use the installed, but for this type of cruise to complex program "REISE" from the IOW for the data management and station report.

Minor problems with the CTD occured only at two stations because of a leak in the sampling unit of the rosette. The problem was fixed by the WTD immediately. Because of the extreme uncertain information from the CTD´s bottom sensor a pinger was used to estimate the depth above the bottom. This combination works very precisely, so that it was possible to get water samples from exactly 5-4m above the bottom. The last CTD-station (CTD-32) at WAST-PLAIN was cancelled, because of major problems with the ship's winch. The CTD-profile of station 31 at WAST-PLAIN was taken 3 hours prior so that at least the data acquisition was not influenced by this problem.

The depth of each individual CTD-profile depended on the depth of the water samples required by the different groups. Samples were taken for the calibration of satellite data for A. Boetius on the surface and in the depth of 60m, for chemical analyses from O. Pfannkuche, R. Turnewitsch, and K. Wallmann and for biological and particle analysis from P. Schäfer, B. Springer and C. Petry in depth between 5m above the ground up to the sea surface. For the zooplankton analyses from F. Kurbjeweit the samples were taken in depth between 2500m to the surface just before the multinet stations. The deepest profiles of temperature, salinity and oxygen from the stations: WAST-Plain, SAST, CAST and NAST are shown in the figures 1 to 3. From the shallower station WAST-Top the temperature, salinity, oxygen and sigma profiles are shown in the figure 4.

4.3 Results

The salinity at the surface of the Arabian Sea reaches high values up to 36.5 due to effective evaporation in combination with very less river runoff into it. The sea surface temperature reaches values up to 30°C due to very low mixing because of the lack of strong wind during the Intermonsoon. The strong solar radiation and the low wind is responsible for the temperature difference between the air and the sea surface of about 3°.
The thermocline is in a depth of about 250m-300m, while the halocline is in a depth of about 150m-200m. A significant mixed layer with a uniform temperature and salinity distribution is not present.

Below the surface layer and north of 10°S the 'Indian Equatorial Water' can be found (WYRTKI, 1973). This water has a relatively uniform salinity of 34.9 to 35.5. Some of it is formed in the Arabian Sea but there are also components from the Red Sea and the Persian Gulf with values up to 36.3. This watermass has a strong influence of the water in a depth of about 100m at the German JGOFS mooring station SAST(10°01.94N, 64°59.92E). Because of the very high salinity at the surface this watermass is difficult to identify.

Below of this watermass, the layer of intermediate water is easy to identify by the oxygen minimum zone. Below 200m at mooring station CAST(14°24.96N, 64°34.00E) and NAST(19°59.99N, 65°34.99E), below 350m at WAST(16°13.00N, 60°15.96E) and below 500m at SAST oxygen concentrations from 0.2 mg/l to 0.7 mg/l where measured. This watermass is part of the Indian Central Water. The local oxygen minimum in 200m at the mooring stations SAST and CAST is connected to the Red Sea outflow water described above. The influence of this watermass at the other stations seems to be very weak.

The intermediate, deep and bottom waters of the Indian Ocean are of Atlantic/Antarctic origin with a relatively uniform temperature and salinity (PICKARD & EMERY, 1990) of 1.2°C and 34.72 PSU at the bottom. The oxygen concentration at the bottom reaches relatively high values at SAST with 5.28 mmol/l at 4410m and relative low values at NAST with 3.8 mmol/l at 3180m. This depletion represents the different age with the oldest water of the same watermass in the north-east of the Indic Ocean prognosted by a deep ocean circulation model by STOMMEL (1958).

The CTD-data is online available for the BIGSET project at: http://www.geomar.de/sci_dpmt/umwelt/bigset_7/bigset.html

4.4 Literature

PICKARD, G.L. & W.J. EMERY, 1990: „Descriptive Physical Oceanograpy An Introduction“, Pergamon Press, Oxford, London, New York, Paris, Frankfurt, 5th Edition.
STOMMEL H., 1958: „The abyssal circulation“, Deep Sea Research, 5, 80-82
WYRTKI, K., 1973: „Pysical Oceanography of the Indian Ocean“, in: The Biology of the Indian Ocean, Springer Verlag, 18-36.