ICES Guidelines
for CTD Data

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CTD (conductivity, temperature and depth) instruments were introduced to the oceanography community in the late 1960's. Since then, the electronic measurement of conductivity, temperature and pressure provided by the CTD has become the backbone of hydrography measurements in the ocean.

CTDs typically consist of an array of sensors that measure the frequency or voltage response that represents changes in an ocean parameter. Beyond the typical conductivity and temperature sensors, CTDs may also have attached sensors for light transmission, fluorescence, oxygen content, optical backscatter and turbidity. For details regarding the use of CTDs, see the attached training annex.

1.0 RECEIVING DATA

The Data Centres require the following information to be supplied by the data supplier together with the data. When receiving data, the Data Centres of the ICES community shall strive to meet the following guidelines.

1.1 Data Standard

All stations from a cruise can be in the same file (recommended), or one file can be used for each station.

It is recommended that the header information, the configuration file and the raw data file be included in the same file. If this is not possible, then it is acceptable to include the header information in a separate (master) file. In this case, an unambiguous index connecting the header with the data file must be used. This index should preferably be a construction of a station/cast number and should be part of the data file name.

The files must be homogeneous. For the headers, that means that each piece of information must always be in the same place in the file or each data element should be terminated with a field separator. For the data, this means that all of the files (for one cruise) must have the same parameters in the same order. If the data file does not include a definition statement of what data are following in what order then certain rules must be followed. In particular even if one parameter is not measured at one particular station, it can be replaced by its null value, in order to have a fixed number of columns for files of the same cruise. The null value, which must not be confused with valid data, may be a large negative number (e.g. -99.999).

Only the down casts of the station should be provided except if only the upcast is available. If water samples have been collected, discrete upcast CTD values (discrete refers to CTD values collected at the time of bottle trip) should be provided as well.

The file needs to contain the measured parameters, in situ temperature (not potential temperature), pressure (not depth), salinity, etc.

The recommended pressure interval is 1 decibar

All parameters must be clearly specified and described. If parameter codes are to be used, then the source data dictionary must be specified. Parameter units must be clearly stated. Parameter scales must be noted where applicable. If computed values are included, the equations used in the computations should be stated.

All relevant calibrations should be applied to the data including laboratory and field calibrations. The data should be fully checked for quality and flagged for erroneous values such as spikes, gaps, etc. Laboratory suspect flags – different organizations have different approaches to suspect flags for example CEFAS (UK) denotes suspect data with a '1'. This system isn't necessarily used by other organisations or ICES. An explicit statement should be made of the checks and edits applied to the data.

If a cruise/data report is available describing the data collection and processing, this can be referenced. If possible a copy of the calibration record and Roscop form should be supplied with the data.

1.2 Format Description

Data should be supplied in a fully documented ASCII format although the preferred method of transport is ftp. Any large submissions should be compressed using a winzip compatible compression routine. Data Centres are capable of handling CTD data in a wide variety of user-defined and project formats (e.g., WOCE). If in doubt about the suitability of any particular format, advice from the Data Centre should be sought.

Individual fields, units, etc. should be clearly defined and time zone stated. Time reported in UTC is strongly recommended. Ideally all of the data from the instrument should be stored in a single file. The contents of the data and ancillary information should adhere to the Formatting Guidelines for Oceanographic Data Exchange (http://www.ices.dk/ocean/formats/getade_guide.htm) prepared by the IOC's Group of Experts on the Technical Aspects of Data Exchange (GETADE) and available from RNODC Formats.

1.3 Collection Details

The collection of quality CTD data requires considerable training and care. For this reason, we provide here a training annex for those new to CTD operations.

Pertinent information to be included in the data transfer to the Data Centre includes:

- Project, platform, cruise identifier

- Country, organization
- Station number, Site,
- Date and time of the start and end of the sampling
- Position (latitude and longitude degrees and minutes or decimal degrees can be used. Explicitly state which format is being used. It is recommended that N, S, E and W labels are used instead of plus and minus signs.)
- Description of operational procedures including sampling method, sampling rate, sensor resolutions, methods of position fixing (e.g. GPS, DGPS)
- Details of the instrument and sensors (e.g. manufacturer, model number, serial number, and sampling rate)
- Station depth and sample depth should be included for each station. The method and assumptions of determining the sounding should be included.

Any additional information of use to secondary users which may have affected the data or have a bearing on its subsequent use.

2.0 VALUE ADDED SERVICE

When processing and quality controlling data, the Data Centres of the ICES community shall strive to meet the following guidelines.

2.1 Quality Control

A range of checks are carried out on the data to ensure that they have been imported into the Data Centre s format correctly and without any loss of information. For CTD data, these should include:

- Check header details (vessel, cruise number, station numbers, date/time, latitude/longitude (start and end), instrument number and type, station depth, cast (up or down)), data type/no. of data points)
- Plot station positions to check not on land
- Check ship speed between stations to look for incorrect position or date/time
- Automatic range checking of each parameter
- Check units of parameters supplied
- Check pressure increasing
- Check no data points below bottom depth
- Check depths against echo sounder
- Plot profiles (individually, in groups, etc)
- Check for spikes
- Check for vertical stability/inversions
- Plot temperature vs. salinity
- Check profiles vs. climatology for the region
- Check calibration information available

2.2 Problem Resolution

The quality control procedures followed by the Data Centres will typically identify problems with the data and/or metadata. The Data Centre will resolve these problems through consultation with the originating Principal Investigator (PI) or data supplier. Other experts in the field or other Data Centres may also be consulted.

2.3 History Documentation

All quality control procedures applied to a dataset are fully documented by the Data Centre. As well, all quality control applied to a dataset should accompany that dataset. All problems and resulting resolutions will also be documented with the aim to help all parties involved; the Collectors, Data Centre, and Users. A history record will be produced detailing any data changes (including dates of the changes) that the Data Centre may make.

3.0 PROVIDING DATA AND INFORMATION PRODUCTS

When addressing a request for information and/or data from the User Community, the Data Centres of the ICES community shall strive to provide well-defined data and products. To meet this objective, the Data Centres will follow these guidelines.

3.1 Data Description

The Data Centre shall aim to provide well-defined data or products to its clients. If digital data are provided, the Data Centre will provide sufficient self-explanatory information and documentation to accompany the data so that they are adequately qualified and can be used with confidence by scientists/engineers other than those responsible for their original collection, processing and quality control. This is described in more detail below:

- A data format description fully detailing the format in which the data will be supplied
- Parameter and unit definitions, and scales of reference
- Definition of flagging scheme, if flags are used Relevant information included in the data file (e.g. ship, cruise, project, start and end dates, etc.)
- Data history document (as described in 3.2 below)

3.2 Data History

A data history document will be supplied with the data to include the following:

- A description of data collection and processing procedures as supplied by the data collector (as specified in Section 1.1 and 1.3)
- Quality control procedures used to check the data (as specified in Section 2.1)
- Any problems encountered with the data and their resolution Any changes made to the data and the date of the change

- Any additional information of use to secondary users which may have affected the data or have a bearing on its subsequent use should also be included.

3.3 Referral Service

ICES member research and operational data centres produce a variety of data analysis products and referral services. By dividing ocean areas into regions of responsibility, and by developing mutually agreed guidelines on the format, data quality and content of the products, better coverage is obtained. By having the scientific experts work in ocean areas with which they are familiar, the necessary local knowledge finds its way into the products. Data and information products are disseminated as widely as possible and via a number of media including mail, electronic mail and bulletin boards.

If the Data Centre is unable to fulfil the client s needs, it will endeavour to provide the client with the name of an organisation and/or person who may be able to assist. In particular, assistance from the network of Data Centres within the ICES Community will be sought.

ICES CTD Training Annex

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CTD instruments are capable of measuring conductivity, temperature and pressure to a high accuracy provided they are used correctly. This requires all staff collecting CTD data to receive basic training in how the instrument works and what its capabilities are, how to calibrate the instrument, how to deploy the instrument at sea and successfully log the measurements using instrumentation software, and if necessary, how to subsequently process the profile. In order to achieve accurate measurements considerable care has to be taken, especially in the derivation and application of sensor calibrations, and users should be made aware of potential problems. Guidelines may be useful, but an **understanding of the instrument and procedures to be adopted** is better than following instructions while not appreciating the reasoning behind them. Proper training must be emphasised.

The following outlines the key points to collecting quality CTD data.

A.1 USE CAREFULLY DRAFTED LOGSHEETS

Logsheets are an important requirement when CTD data are being collected and the need for correctly completed logsheets should be emphasised when training those new to collecting CTD data. The logsheets should be drafted while at sea so that any problems or queries arising from any stations can be dealt with promptly.
These sheets go further than recording the station position, time, etc. and if carefully drafted they will prompt users to record much of the relevant information that is needed. This includes for example, the serial number of the instrument, the identity of reversing thermometers used to compare with the CTD temperature sensor, and the identity of the persons who worked the station, read the thermometers and collected the water samples for example, salinity and nutrient analysis. Users should be encouraged to record as much relevant information as possible on the logsheet (further comments box), especially any unusual features such as indications of sensor malfunctions and large wire angles.

A.2 PRE-DEPLOYMENT CHECKS

It is wise to complete an examination of the CTD sensors prior to deployment to check that:

- No fouling of sensors and any protective coverings have been removed
- Lenses of optical sensors are clean
- Thermometers are correctly set (if fitted)
- Bottles are correctly set and taps closed (if used)
- Any additional battery supplies are switched on
- With the instrument switched on observe the values displayed by the sensors to confirm that they are functioning correctly and record the value displayed by the

pressure and temperature sensors whilst the CTD is on deck. This can be used to correct the logged pressure.

To avoid confusion, it is helpful if each team adopts an agreed procedure, so that each member will complete the same checks at each station. An itemised check list is useful.

A.3 SENSOR CALIBRATION

To obtain the highest quality data, corrections need to be applied to the CTD sensors. Calibration procedures will vary from one laboratory to another, but it is generally accepted that whilst the pressure and temperature sensors can be subject to pre- and post-cruise calibrations in the laboratory, the conductivity sensor is best calibrated by comparison with samples collected for salinity analysis. A pressure correction for each station can be determined by noting the pressure when the instrument is on deck, but some pressure sensors are temperature sensitive and a further correction may be necessary. A dead-weight tester is often used to obtain a pressure calibration in the laboratory and the results from this should be in good agreement with the observed 'on deck' value.

In the laboratory, a temperature sensor is readily calibrated by comparing its readings with temperatures from a platinum resistance thermometer and this gives a more accurate calibration than can be achieved with reversing thermometers. However, a thermometer will provide a check on the CTD temperature and may indicate the presence of a temperature 'jump'. Thermometers are also useful to identify rosette misfires.

Care is needed when taking samples for salinity analysis to compare with the CTD conductivity. A standard operating procedure document for this process is recommended. For the highest quality salinity (or conductivity) data corrections, it is recommended that water sample salinity replicates be drawn. Replicates not satisfying some pre-set criteria (e.g. difference of 0.002) may be rejected. It is also very important that the salinometer being used for salinity samples be maintained to a high standard.

Care is also required when using reversing thermometers for comparison with the CTD temperature estimates. Those depths where temperature (or salinity) gradients are known to exist should be avoided. If samples have to be collected from such depths the logsheet should be clearly marked to this effect and it is probably advisable not to include them in the calibration computation. If it is required to sample in the thermocline (or halocline) then it would be wiser to add additional sampling depths suitable for calibration. The operator has to be vigilant when the samples are being collected. If thermometers are being used sufficient time must be allowed for equilibrium (at least five minutes for mercury-in-glass thermometers). See also Karl (1996), UNESCO (1988) and UNESCO (1991).

Throughout this time the operator should be viewing the values displayed by the CTD and if they are variable this should be clearly recorded on the logsheet and preferably not used to determine the calibration coefficients. Many CTD users have the instrument mounted in a multisampler rosette that accommodates bottles, perhaps fitted with reversing thermometers. These bottles are closed in pairs at selected depths to collect the sample for salinity analysis that is eventually compared with the derived CTD estimate. Care has to be exercised when using this data to identify rosette misfires (i.e. when a bottle does not fire at the selected depth). Sometimes a bottle does not respond to the triggering signal or two (or more) bottles close simultaneously. Often, if a misfire takes place all subsequent samples collected during the cast will not be from the intended depth. The actual sampling depths need to be established when deriving the calibration coefficients. That a misfire has occurred is not always obvious when the CTD is returned to the surface, but all users should be made aware that this can (and does) happen and that they must look closely at the data to check for this.

A.4 SENSOR RESPONSE

An important feature of the CTD instrument that causes problems is the mismatch in temperature and conductivity signals due to the time response and physical offset between the sensors. If improperly accounted for in the processing, these differences result in salinity 'spikes'. All users should be aware of this problem and if necessary a procedure for removing them needs to be adopted. The report of the SCOR WG 51 discusses this in detail.

Software packages are now available, often purchased with the instrument, which purport to remedy this problem. It is recommended that a careful appraisal of such packages is made before deciding whether to use them. Local conditions can also influence data quality (e.g. the response of the conductivity sensor in waters with a large sediment load may be impaired).

A.5 POST PROCESSING

It is recommended that some processing of the data be completed at sea, preferably soon after the CTD station is complete. A database can be used for this purpose where all general details, niskin information, digital thermometer, salinity bottles numbers are recorded for each station. This is often the only way of detecting an instrument malfunction (e.g. a noisy sensor) and a comparison between CTD and thermometer temperatures, CTD and salinometer salinity estimates should be made regularly during the cruise. The data from other sensors being logged should also be examined. This 'first look' offers an opportunity to identify samples unsuitable for use in derivation of the sensor calibration coefficients (e.g. varying estimates). It is useful to have the pre-cruise calibration data at sea so that checks on performance can be compared with the most recent laboratory calibrations during the cruise.

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