

Guidelines for determination of salinity and temperature using CTD

1. Background

1.1 Introduction

Salinity

Measurements based on electrical conductivity have since the 1960s replaced measurements of chlorinity. The Practical Salinity Scale of 1978 (PSS-78) presently used, has been defined to maintain a continuity with older scales and methods. The scale is based on conductivity of a reference solution prepared from potassium chloride. Practical Salinity (S_p) is calculated from the ratio of conductivity between sample and reference solution.

Since the scale is based on a ratio, no unit is assigned to it. Despite this, salinity data are sometimes presented with the units ‰ or psu. The equations used in calculation of Practical Salinity from conductivity are valid for practical salinity ranging from 2 to 42.

A new standard for the properties of seawater was introduced in 2010; the thermodynamic equation of seawater 2010 (TEOS-10). This standard also includes a new scale, called the Absolute Salinity scale. Absolute Salinity (S_A) is expressed as a mass fraction, in grams per kilogram of solution.

While Absolute Salinity is the variable needed to calculate density and other properties of seawater, Practical Salinity is still the variable measured, reported and archived in marine environmental monitoring.

Temperature

Temperature sensors are calibrated to the ITS 90 scale.

1.2 Purpose and aims

Although not HELCOM Core Indicators, salinity and temperature are essential supporting parameters in marine monitoring. CTD profiles should always be recorded when water is sampled for monitoring purposes.

A CTD cast gives vital information about the present characteristics of the water column. The data and information obtained from a CTD cast can be used for identifying water masses by its salinity and temperature, finding the depth for the onset of hypoxia and anoxia, view the phytoplankton distribution and other oceanographic phenomena depending on which additional sensors that are used together with the CTD. If the CTD data undergoes basic quality controls onboard it can also be made available in near-real time for example to be assimilated into ocean models (Baltic Operational Oceanographic System, www.boos.org).

The parameters obtained from the CTD could be used for assessment of water quality and/or as supporting parameters. To ensure that CTD data of high quality is collected there is a need to follow standard protocols for CTD sampling, data processing, documentation, quality control, sensor control, calibration and maintenance, data reporting and data storage.

2. Monitoring methods

2.1 Monitoring features

2.1.1 CTD

CTDs are equipped with conductivity and temperature sensors for *in situ* measurements. Additional instruments, such as sensors for dissolved oxygen, turbidity, fluorescence and light transmission can also be attached.

2.1.2 Bench salinometers

Water samples are collected from discrete depths, and analysed. A well-established method for determination using bench salinometer is available. Bottle samples are first and foremost collected as reference samples for *in situ* measurements.

2.2 Time and area

CTD casts shall be performed, if possible, at all monitoring stations visited.

Additional CTD casts should be performed during exceptional events, for example to follow major inflow to the Baltic Sea or when other special phenomena are observed.

Normally, CTD casts are also performed after or before other marine sampling activities, or when moored oceanographic instruments are deployed or recovered.

2.3 Monitoring procedure

2.3.1 Monitoring strategy

Salinity and temperature data are primarily obtained from CTD measurements. Salinity data from bench salinometers are still relevant as reference for *in situ* measurements.

Sampling methods and equipment

CTD

CTD should preferably be equipped with dual sensors for salinity and temperature, to prevent loss of data and provide a first instance of quality control.

For stratified waters such as the Baltic Sea, CTDs should preferably have a sampling rate of 12 Hz or higher.

A CTD equipped with a rosette for water samplers is preferred to individual sampling flasks clamped to a wire.

It is recommended that the CTD is mounted vertically within the frame of the rosette frame to avoid fouling of sensors by debris or bubbles, and promote free flow of water.

Reference instruments for temperature

Reference data for temperature is obtained from reversing thermometers, mounted on the rosette frame.

In-house calibration of thermometers used in sampling requires a reference instruments with a traceable calibration.

Reference samples for bench salinometers

Samples are collected from sampling bottles attached to the CTD-rosette. It is recommended that reference samples are collected in triplicates.

For general requirements for sampling, preservation, handling, transport and storage of water samples, see EN ISO 5667-3.

Samples for determination of salinity are subsampled into glass bottles with tight fitting caps. Bottles with a plastic screw cap and a disposable plastic insert are preferred.

A large sample volume (>200 ml) decreases the risk of contamination during subsampling and handling, and provides enough sample for thorough rinsing of the measuring cell. Bottles should be rinsed with sample water before filling. Fill the bottle leaving enough headspace to allow for thermal expansion. The rim of the bottle, and the cap, must be dry before sealing to prevent formation of salt crystals in the threads of the bottle.

Rinse bottles and crates with fresh water when the caps are sealed to prevent formation of salt crystals on the outside of the bottle during storage.

2.3.2 Data acquisition

There are many protocols for CTD measurements (WOCE 1991, UNESCO 1994, UNESCO, 1988 and previous COMBINE guidelines). Starting from what is suggested by the previous protocols and taking into account the field experience the following protocol is proposed:

1. Follow the manufacturer's recommendations on preparations of the CTD and rosette sampler. If the CTD has not been used for a long time, e.g. the first cast of the cruise, problems with bottles leaking may occur since the O-rings for the bottles caps are dehydrated. If this is known to happen, it can be prevented by rinsing and filling all bottles with freshwater for at least 1 hour before sampling.
2. When the CTD is on deck start the system and note the CTD pressure and temperature in the log book.
3. The CTD must be lowered below the sea surface for at least 1 minute before starting the measurements. This gives time for all sensors to acclimatize and air bubbles have time to be flushed out by the pump.
4. Bring the CTD back to the surface and the measurement of the profile starts. If the sea state is rough it is recommended to start the downcast from a few meters below the sea surface to prevent bubbles from breaking waves entering the sensors.
5. Care must be taken to keep the lowering speed as constant as possible, and around 0.5 m/s. If an Active Heave Compensation (AHC) system is available, a slower speed (0.3 m/s) can be used.
6. Lower the CTD as close to the bottom as possible, though without risking bottom contact. Note the bottom depth and all the other information required by the CTD log or monitoring protocol.
7. The rosette bottles should preferably be fired at selected standard depths during the up-cast in order to obtain an undisturbed CTD profile during the down-cast and undisturbed water samples on the way up. If the winch is maneuvered manually between each sampling depth, attention must be paid to approach the set depth as gentle as possible to reduce the disturbance of the water profile. This is especially important in stratified waters.
8. At each sampling depth the sampling bottles should have time to acclimatize and the effect of dragging water from deeper depth should be avoided. Wait at least 1 minute before the sampling bottles to be fired. If the CTD values still are not stable wait another 3 minutes before firing. If the bottles are equipped with reference sensors do not forget to wait the appropriate time for the sensors to measure after firing the bottle.
However, if the CTD and rosette is equipped and prepared for free-flow sampling bottles, it can be configured to fire water samples on predefined standard depths during the down-cast. Note that samples near the surface should be collected during up-cast to avoid trapping air bubbles mixed into the water by breaking waves and turbulence when the CTD is lowered.
9. When the CTD is back on deck, note the pressure and temperature in the CTD log. The pressure value must be approximately the same as that read before the cast; differences are due to thermal and mechanical hysteresis of the pressure sensor. Do not use deck pressure as offsets to correct pressure. Deck pressure should only be used as consistency check against laboratory measured historical drift.
10. Note if there is any leakage or malfunction to the CTD, water sampler or water bottles. Questionable sensor readouts should also be noted. Note also all particular events that happened during the cast. Follow manufacturer's instructions for cleaning the CTD after each cast.
11. Between casts and after the cruise; store the CTD and rosette in a way to prevent contamination. All sensors should be treated and stored according to the manufactures recommendations.

2.3.3 Sample handling and analysis

Reference samples for bench salinometers

When stored in suitable bottles, samples are stable for several months. Allow samples to equilibrate to the temperature of the laboratory and the salinometer before analysis.

Use IAPSO Standard Sea Water for standardization of salinometer. The standard seawater for standardization normally has a salinity of 35 or slightly below. For use in the Baltic region, a standard with a salinity of 10 can be used for linearity check.

Always homogenize samples by shaking prior to analysis to eliminate any gradient formed in bottles during storage. Rinse the measuring cell thoroughly with sample water to avoid contamination from previous sample.

Avoid air bubbles in the cell during measurements. Any debris in the bottles must be left to sediment or be removed by filtration. Follow the manufacturer's recommendations for handling and maintenance of the salinometer.

2.4 Data analysis

The CTD data should be processed and quality controlled according to ICES Guidelines for CTD Data.

3. Data reporting and storage

3.1.1 CTD data

The national data centre or designated oceanographic data centre is responsible for storage of master data collected within the national monitoring programs to contribute to the HELCOM monitoring programme. The data centres obligations are to store all raw data, metadata and processed CTD data in a long term and secure way and to report data and/or changes in data to ICES. The data centre should also make sure that sufficient, confident, and traceable documentation of the samples and measurements is available for further data handling.

The CTD data format, preferably a simple ASCII-format should include all metadata, all processed data and quality flags for each scan and parameter. However, the data centre should follow the direction given by ICES when reporting data yearly; hence data could be submitted in any format as long as it is well described and structured consistently. In order to ensure that all data has been converted correctly a statistical summary should be added to the submission, including range of each parameter. All other relevant information and documentation of methods and special circumstances should be submitted and if available a cruise summary report for each cruise.

The data centre should also make preliminary data available as soon as possible after the cruise, preferably, at a searchable website. Since the data centres have the master data storage and all changes and new data are available here first, access to data could be made via a web service. Then, any data user can access data as soon as the national data centre publishes the data by harvesting of new or changed data from the web service.

3.1.2 Salinity data from bench salinometers

Salinity data should be expressed according to the PSS 78 scale, and reported with 3 decimals.

Data is reported annually to the HELCOM COMBINE database, hosted by ICES.

4. Quality control

4.1 Quality control of methods

Contracting parties should follow the HELCOM monitoring guideline but minor deviations from this are acceptable if the method achieves comparable results. Validation of the adopted method needs to be performed on the relevant matrix and concentration range e.g. by taking part in intercomparison studies or proficiency testing schemes.

4.1.1 CTD

Laboratory calibration the CTD sensors need to be performed with regular intervals. Manufacturers normally provide calibration services for pressure, temperature and salinity sensors. However, it should be noted that not all manufacturers can provide a traceable calibration.

In between calibrations, performance of the CTD conductivity and temperature sensors is monitored by comparison to data from reference samples/reference instruments produced as described in 2.3.2 and 2.3.4.

The pressure sensor of the CTD can be calibrated on a dead weight tester. Performance during cruises can be monitored with reversing pressure meters, mounted on the rosette frame.

Reference instruments for temperature

Reference thermometers must have a traceable calibration, performed in-house, or by manufacturer or another accredited contractor.

4.1.2 Bench salinometers

Laboratories should have established a quality management system according to EN ISO/IEC 17025.

A certified reference material (independent of IAPSO Standard Seawater) should be analysed regularly.

Temperature within the laboratory where conductivity measurements are performed must be maintained and monitored, since they are dependent of constant temperature.

4.2 Quality control of data and reporting

The CTD data should be quality controlled according to ICES Guidelines for CTD Data.

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.

Measurement uncertainty should be estimated using ISO 11352. Estimation should be based on within-laboratory reproducibility, data from proficiency testings, IRM, and, when available, CRM.

Data must be flagged if normal QA routines cannot be followed.

5. Contacts and references

5.1 Contact persons

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5.2 References

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EN ISO 5667-3*: Water quality – Sampling – Part 3: Preservation and handling of water samples

EN ISO 11352*: Water quality – Estimation of measurement uncertainty based on validation and quality control data

EN ISO/IEC 17025*: General requirements for the competence of testing and calibration laboratories

ICES Guidelines for CTD Data:

https://www.ices.dk/sites/pub/Publication%20Reports/Data%20Guidelines/Data_Guidelines_CTD_%20v7_revised_2006.pdf

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5.3 Additional literature

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