Near-Surface Temperature, Salinity, and Bathymetry Measurements

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1. Introduction

Measurements of near-surface temperature and salinity with reliable thermosalinographs (TSG) and digital bathymetry with Narrow Beam Sonars (NBS) in combination with GPS/NAVSTAR navigation receivers should be possible and are recommended to be made on a routine basis between ports on all research vessels participating in the WHP. Accuracies which may be achieved for the above components depend strongly on in situ calibration of TSGs on board and careful error detection and analysis of NBS and positioning data. Accuracies of 10 mK, 0.02 PSU, 0.5% in bathymetry and ±100 m (1 σ) in positioning at 1-minute recording intervals are realistic tasks and achievable goals for the WHP.

On Voluntary Observing Ships (VOS), NBS bathymetry generally will not be available, and thus bathymetric data from these ships are not adequate and should not be used for WOCE. On the other hand, TSGs in combination with GPS/NAVSTAR receivers are easily installed and run on such ships and could provide valuable data sets. Since qualified staff will usually not be available for *in situ*, on-board calibration of TSGs, near-surface temperature and salinity measurements will be less accurate than on research vessels. Accuracy will depend crucially on sampling during cruises and on after cruise service and calibration in ports. For logistical reasons, in many cases these services will have to be done by nearby local research institutions under the guidance of the principal investigator. With this in mind, accuracies of 10 mK and 0.01 to 0.02 PSU may be realistic values for TSGs on VOS. Positioning and recording intervals are as before.

An accurate time basis in each component is essential to merge the data from the navigational system with the TSG and the NBS if this cannot be done on-line. Detailed requirements are outlined in the following paragraphs.

2. Positioning

GPS/NAVSTAR with C/A-Code receivers allow positioning with standard deviation ±100 in (1 σ,). Only discrete and corrected coordinates (latitude and longitude) with appropriate time assignment are useful. For quality checks of GPS positions, the registration

of the position dilution of precision (PDOP) is recommended. Whenever possible, spikes and erroneous measurements should be identified and deleted during the cruise.

Digital data files should contain the following information:

- Year, month, day, time:
  year YYYY, month MM, day of month DD, time in UTC HH, minutes MM.M
- Geographical position in latitude (positive north) and longitude (positive east), with minutes to at least two decimals, *i.e.*, ±DD MM.MM latitude, ±DDD MM.MM longitude.
- Geodetic reference system (ellipsoid) used for positioning, *i.e.*, World Geodetic System WGS 72 or WGS 84, European Datum (ED), North American Datum (NAD).
- Fix indicator when using integrated navigation systems to mark TRANSIT satellite fixes.
- Position quality indicator: One character flag to specify whether the position quality is suspect=:'s', acceptable='a' or unspecified=' '
- Minor and major axis of error ellipse derived from PDOP values when using GPS.

3. Near-Surface Temperature and Salinity

Modern thermosalinographs (TSG) provide 10 mK and 0.01 PSU resolution for temperature and salinity, respectively, and digital data output. Laboratory calibration of TSGs is recommended between cruises - at least once a year. Once installed on a ship, recalibration in a laboratory may turn out to be difficult, both because the system has to be dismounted, which can be a complicated procedure, and because home port calls are usually short. Therefore, calibration of temperature as well as salinity measurements will essentially depend on *in situ* data, and the procedures of these and the system's maintenance strongly influence the final accuracy.

Before each leg or cruise the housing containing the conductivity cell should be cleaned. This usually should not be done during a cruise or leg to avoid sudden jumps in the cell's calibration. If possible, a laboratory calibration should be conducted.

During a cruise, *in situ* calibration values should be taken for both temperature and salinity as often as possible, at least once a day. Temperature calibration with in situ data is easy on research vessels, where calibrated CTD temperatures from the TSG's sensor's depth axe available on stations and may serve as reference. For VOS measurements, usually no such valuable reference will be available, and the TSG's final accuracy in temperature measurements totally depends on its last laboratory calibration.

Bottle samples may serve for *in situ* salinity calibration. Samples used for calibration should either be taken while on station or from regions with weak horizontal gradients, i.e., out of frontal regions because of the long flushing times of TSGs. On research vessels, trained

personnel is available to take the samples and to analyze them for salinity on-board with the same high accuracy as required for *in situ* CTD calibration. For VOS measurements, it may be hard to get any *in situ* reference values. Nevertheless, one should try to define and train a VOS crew member to take one sample per day. These samples then have to be analysed later by experienced staff in a laboratory close to the port called by the VOS. If this is not possible, air freighting (with all the risks) of the samples to the principal investigator's laboratory has to be considered.

All VOS data sets must be checked carefully by the responsible scientist especially for systematic errors before distribution. Check values axe to be documented.

With the above procedures in mind, we expect the following accuracies possible for TSG measurements: 10 mK and 0.02 PSU for measurements on research vessels; and 10 mK and 0.05 to PSU for VOS measurements, the latter depending crucially on the last temperature calibration in a laboratory and on available samples for salinity calibration.

The following information must accompany a TSG data file:

- Ship, cruise, originator, *etc.*
- Type of TSG, resolution and expected accuracies of measurements, corrections already applied to source data including algorithms.
- Depth of temperature sensor mounted on the ship's hull and depth of the water inlet.
- Laboratory and *in situ* calibration information (algorithms with coefficients, number and range of calibration points, standard deviation of calibration, *etc*).
- Information about positioning as above.

After removing spikes and erroneous values and calibration, the data file should contain, together with positioning data, near-surface temperatures and salinities with a resolution of 1 mK and 0.001 PSU at 1-minute intervals.

4. Digital Bathymetry

Narrow Beam Sonars (NBS) allow precise depth measurements, and such systems are recommended to acquire bathymetric data during WOCE in combination with positioning systems described above.

Spikes and erroneous measurements should be identified and removed before applying a low pass filter to smooth the raw data. To reduce the amount of processing, this should be done quasi on line. As for positioning, the recording interval should be at 1-minute intervals. Final accuracy after using sound correction tables can then be 0.5% of depth.

To guarantee successful map compilation with bathymetric data collected by different research vessels, the following information must be provided by the originator and accompany the data:

- General information about the ship/cruise, *etc.*
- Nature of sounding equipment used, quality of its calibration and its accuracy, corrections already applied for instrumental, hydrological and other factors. If corrections were already applied, uncorrected sounding depths must remain in the data files (see below) and should be marked as such.
- Information about positioning as above.

Depth data should be stored in the following way together with positioning data:

- Sounding depths based on 1500 m/s sound velocity instead of two-way travelling times. It is strongly recommended that no corrections shall be applied to avoid later confusion.
- The actual depth of the transducers and, in shallow waters, also the state of the tide to correct the soundings.
- The quality indicator of bathymetric measurements can be given with one character, *i.e.*, unspecified=' ', acceptable='a', and suspect='s'.

5. Data Formats

WOCE data sets should be supplied in the General Format, GF3. For other purposes than WOCE, bathymetric data can be also provided in the Marine Geophysical Data Exchange Format, MGD77.

Complete format descriptions of both, GF3 and MGD77, can be obtained from: Marine Information and Advisory Service (MIAS), Institute of Oceanographic Sciences, Bidston Observatory, Data Banking Service, Birkenhead, Merseyside L437RA, United Kingdom.