

MicroCAT/SeaCAT Sensor Calibration and Data Quality Control: Lessons Learned from 10 Years of WHOTS Mooring Deployments



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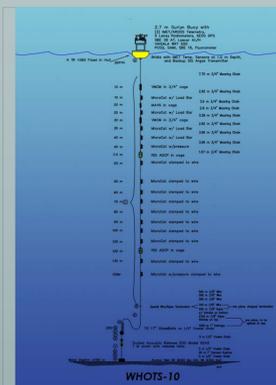
Introduction

The WHOI-Hawaii Ocean Time-Series Site (WHOTS) surface mooring has been measuring atmospheric surface forcing and upper ocean variability at Station ALOHA (22° 45'N, 158°W) with high temporal resolution since mid-2004. The subsurface instrumentation has included Sea-Bird SeaCATs (SBE-16) and MicroCATs (SBE-37) measuring temperature (T), conductivity (C) and pressure (P) in the upper 155 m. The mooring is replaced every year, and visited during near-monthly Hawaii Ocean Time-series (HOT) cruises. A compilation of the best practices for sensor calibration and data quality control are presented here based on data processing from 10 annual deployments.



Data

The WHOTS mooring includes SeaCATs and/or MicroCATs at nominal depths of 1.5, 15, 25, 35, 40, 45, 50, 55, 65, 75, 85, 95, 105, 120, 135 and 155 m and 37 m above bottom, sampling between 1-10 minute intervals. A pool of 15 SeaCATs and 35 MicroCATs have been used for annual deployments. The instruments are deployed with an antifoulant device, and are calibrated at Sea-Bird after each deployment. 200 m shipboard CTD (Sea-Bird 911-plus) yo-yo profiles are regularly conducted during HOT cruises 200 to 500 m from the mooring to provide comparisons with the mooring instruments. In addition, CTD single or yo-yo profiles are obtained near the mooring after its deployment and before its recovery during the mooring turnaround cruises.



WHOTS-10 mooring design



MicroCAT ready for deployment (left), and after recovery, covered with barnacles (right).



Internal Clock Inspection and Missing Samples

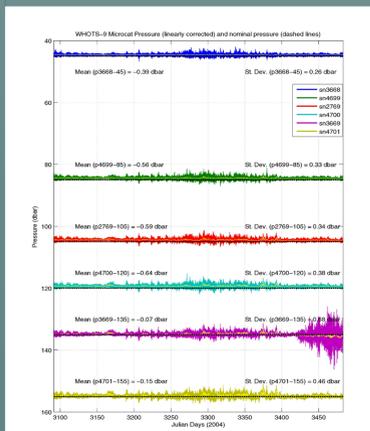
To check the instrument's clock, a temperature spike is generated in the instrument's data before deployment and after recovery by placing an ice bag on top of the thermistor. The time of the spike is matched with the time recorded in the data for this event. For all the instruments in the 10 deployments, the time of the spike has matched the instrument clock time (within the sampling interval of each instrument), indicating insignificant clock drift in all the instruments. Also, there were no missing samples in all the deployments.

Pressure Drift Correction

Some of the MicroCATs used in the mooring were outfitted with pressure sensors. A surface pressure offset is determined for each instrument from the

on-deck pressure readings before deployment and after recovery, and used to determine sensor drift. This drift is removed from the data with a linear fit between the initial and final on-deck pressure offsets. The pressure drift has been near zero for most of the deployments (more than 50). Only 4 instruments showed annual drift between 0.8 and 2 dbar, and 3 instruments failed during deployment (e.g. see Fig. 1).

Figure 1. Pressure data for MicroCATs during the WHOTS-9 deployment, nominal depth (dashed), and 7 hour running mean (yellow). Sensor at 135m failed near the end of the deployment.



Conductivity Calibration

Post-deployment conductivity calibrations at Sea-Bird indicate that most of the SeaCAT and MicroCAT sensors experienced a drift during deployment. This is confirmed by comparisons of the mooring data against CTD profiles. The causes of the conductivity drifts are not clear and may be multiple. Comparisons against CTD profiles showed that some of the instruments had a drift offset at the beginning of the deployment, although the most did not start drifting until after they were deployed.

Negative Conductivity drift

Conductivity drifting towards lower values (fresher salinities) is typical of cell fouling. This is commonly observed in shallow instruments after the antifoulant has been depleted (Figs 2, 3). This drift is often non-linear in time, and it may be combined with sudden offsets apparently caused by blockages of the cell (Fig. 3). CTD casts conducted during each deployment were used to determine the onset and magnitude of the drift (Fig. 2), and the conductivities were corrected.

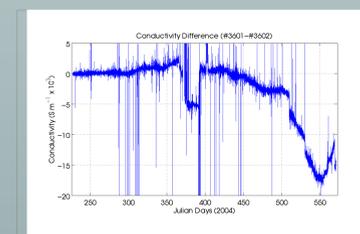
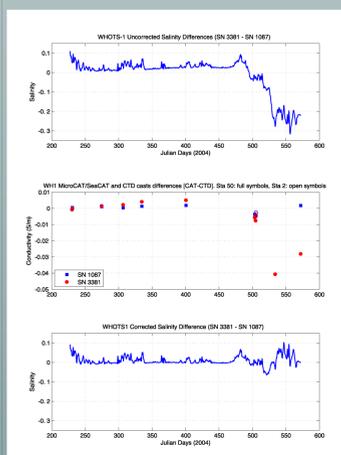


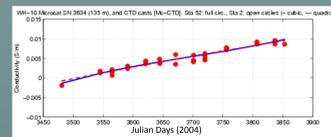
Figure 3 Conductivity difference between two MicroCATs at 1.5 m showing a temporary blockage after day 350.

Figure 2. Conductivity differences between instruments at 35 and 40 m before (top) and after drift correction (bottom) using CTD data (middle).

Positive Conductivity drift

Most of our instruments showed a positive conductivity drift (e.g. Fig. 4). The cause of this drift was originally attributed to scouring of the cell by diatoms flowing through during mooring heaving. However, statistics from Argo float deployments indicate a correlation between positive conductivity drift and instruments deployed at low latitudes. The possible mechanism is that at lower latitudes the warmer waters accelerate changes in the electrical properties of the materials that make up the conductivity cell.

Figure 4. Conductivity differences between sensor MicroCAT at 135 m during WHOTS-10 and CTD casts (dots) as a function of time.



Experimental MicroCATs were installed on the WHOTS mooring in July 2015 to try to understand and control the positive conductivity drift. The instruments will be recovered in June 2016.

Conductivity correction using pre-and post-deployment calibrations

We used pre- and post-deployment conductivity calibrations to find the drift of some of the WHOTS mooring instruments (Sea-Bird's Application Note 31), and compared it with the drift obtained using nearby CTD profiles. We selected 44 instruments in which the CTD-calculated drift was nearly linear (e.g., Fig. 4). The comparison between the two methods yielded annual drift differences in the ± 0.0035 S/m/year range, with a standard deviation of 0.0016 S/m/year (Fig. 5). The corresponding differences in salinity drift have a range of ± 0.025 g/kg/year, with a standard deviation of 0.012 g /kg/yr.

Conductivity drift differences between pre- / post-deployment calibrations and CTD casts

Possible reasons: The C-sensor had an offset at the beginning of the deployment, and/or the post-recovery calibration was not adequate to estimate the *in situ* sensor drift.

An inadequate post-recovery calibration may be caused by the handling of the instrument after recovery, as there is no method that can preserve the conductivity cell in a state identical to that which it had before recovery (Freitag et al., 1999). Allowing the cell to dry after recovery allows evaporative deposits and desiccation of the biota, which changes the cell geometry. Keeping the cell in fresh water would prevent these cell changes, however doing this for long periods would probably allow further biological fouling and chemical deposition to occur. Thus, *in situ* calibration before mooring recovery is critical to obtaining the best drift estimates and highest quality salinity data.

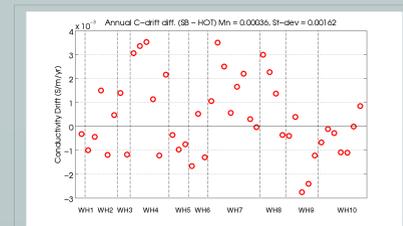


Figure 5. Conductivity drift differences between the two methods discussed in the text, for WHOTS instruments.

Conclusions

- The inspection of the internal clock and temperature data from instruments in more than 160 year-long deployments (and pressure data from more than 50) confirmed the stability and reliability of these sensors
- Comparisons with HOT CTD profiles showed that the majority of the WHOTS conductivity sensors had positive drifts that are not well understood at this point.
- Near-surface instruments had negative (and often non-linear) drift due to fouling when antifoulant plugs were exhausted.

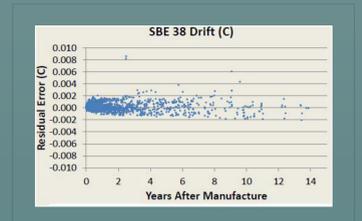
Recommendations

- Conduct CTD casts near the mooring before recovery for SeaCAT/MicroCAT conductivity calibration – Because post-deployment Sea-Bird calibration may not be sufficient to evaluate sensor drift.
- Conduct CTD casts near the mooring after deployment for conductivity calibration – Because sensors may have drifted before being deployed (or during deployment).
- Conduct CTD casts near the mooring while deployed for conductivity calibration – Because sensor drift may be non-linear due to fouling.

Temperature Sensor Stability

Sea-Bird calibration history of 411 SBE-38 temperature sensors (used in SBE-37 and SBE-16 instruments), show the stability of the sensors over the years after manufacture (Fig. 6).

Figure 6. Residual error due to drift of SBE-38 temperature sensors as a function of time.



Sea-Bird's evaluation of the WHOTS temperature sensors' drift from post-recovery calibrations was used to calculate the temperature offsets for the duration of each deployment. These values turned out to be not higher than 0.0025 °C. Comparisons between the HOT CTD and SeaCAT/MicroCAT data confirmed that the temperature drift of the moored instruments was insignificant.