



Getting the Highest Accuracy Data:  
Moored Applications  
Sea-Bird Scientific University Module 18



## Overview

**SEA-BIRD SCIENTIFIC** **Getting the Highest Accuracy Data: Moored Applications**

This module covers the following:

- Static errors and initial calibrations
- Diagnosing sensor problems
- Care of sensor in the field and how to counter fouling
- Sensor drift characteristics
- Correcting data with pre- and post-deployment calibrations
- Lab validations

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In the module we will discuss the means to get the highest accuracy in your moored measurements. This includes care of sensors in the field and understanding sensor drift characteristics. Moored instruments can exhibit unexpected drift in conductivity. Topics covered include pre- and post-deployment calibrations, field calibrations, and bio-fouling.

## Static Errors



**Static Errors:  
Initial Calibration Accuracy**

- Initial accuracy limited by:
  - standards
  - calibration equation
  - ability to calibrate in a controlled bath
- Standards for Salinity and Temperature
  - IAPSO Standard Seawater 0.002 psu
  - Gallium and Jarrett Cells,
    - 0.7 millidegrees (mK) (0.0007 deg C)
- Effect: You cannot report to better than the standards

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## Static Errors (*continued*)




How to Determine if a Sensor is Drifting or is Broken

- Drifting sensors tend to stay reasonable with respect to the measured variable
  - Might exhibit an offset or linear change with time
- Broken sensors exhibit more catastrophic changes in their data
  - Readings drop to zero and never recover
  - Lots of very large spiking in the data (noise)
  - Sensor does not respond to changes in parameter it is measuring




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## Instrument Malfunction

 **Example: Instrument malfunction**

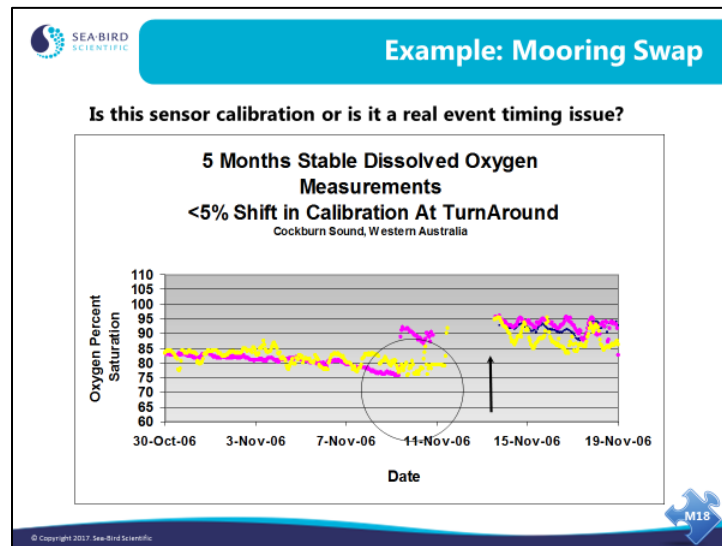
**Sometimes, the problem is obvious upon recovery!**



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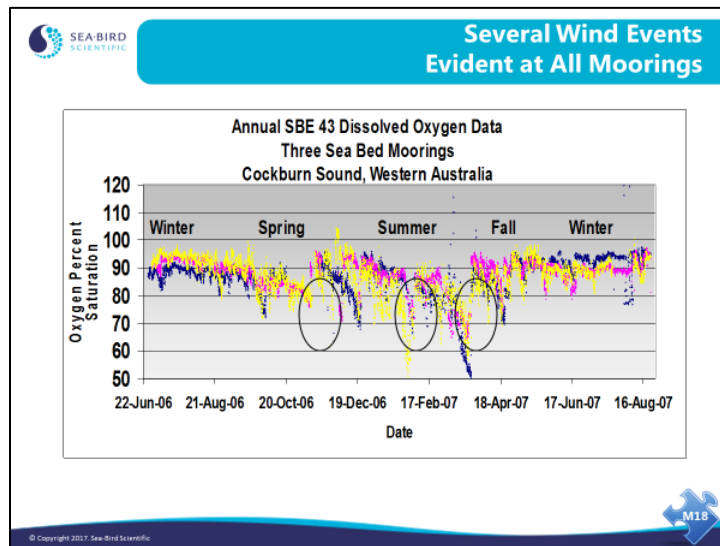


## Instrument Malfunction (*continued*)



In this example, the customer saw a rapid decline in oxygen. They assumed the sensor was going bad so planned to recover it. They recovered the sensor, and swapped it a few days later with a newly calibrated sensor. They observed a large shift in oxygen (~5%) and complained that the sensors were not working.

## Instrument Malfunction (*continued*)



In this example, there is an apparent slow mean drift in sensor output with time. However, the large wind-driven events in the oxygen data are not sensor related and occur on regular 2-10 day time scales. This is observed at all moorings in this bay. Furthermore, the mix-down occurs very quickly (over the course of several hours to a day), so removing without an immediate sensor replacement during an event will cause a missed natural occurrence, and mislead the data.

When all the nearby mooring data were analyzed, it became clear that the sensor swap occurred during a wind event, and that the bulk of the 5% shift observed on the previous slide was probably caused by a natural occurring event, rather than indicative of a sensor problem or drift.

## Care of Sensors in the Field

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### Care of Sensors in the Field

- Bio-fouling is the major problem with moored instruments
- Can correct sometimes given pre and post calibration data or in situ sampling during deployments
- Conductivity and dissolved oxygen are susceptible

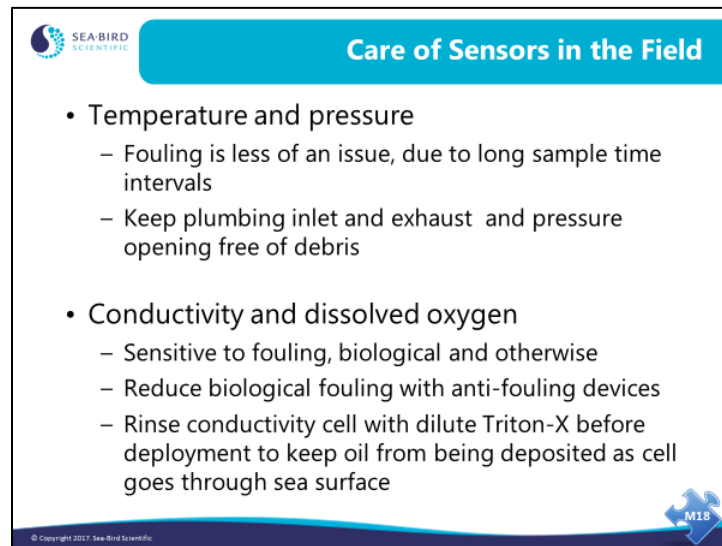
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This SBE 37 is deployed in the tide waters of Georgia. Biological activity surges when the water temperature exceeds 20 °C. The researcher uses extra bio-fouling protection on each end of the conductivity cell and protects the pressure housing of the instrument with packing tape and silicon grease.



## Care of Sensors in the Field (*continued*)



**Care of Sensors in the Field**

- Temperature and pressure
  - Fouling is less of an issue, due to long sample time intervals
  - Keep plumbing inlet and exhaust and pressure opening free of debris
- Conductivity and dissolved oxygen
  - Sensitive to fouling, biological and otherwise
  - Reduce biological fouling with anti-fouling devices
  - Rinse conductivity cell with dilute Triton-X before deployment to keep oil from being deposited as cell goes through sea surface

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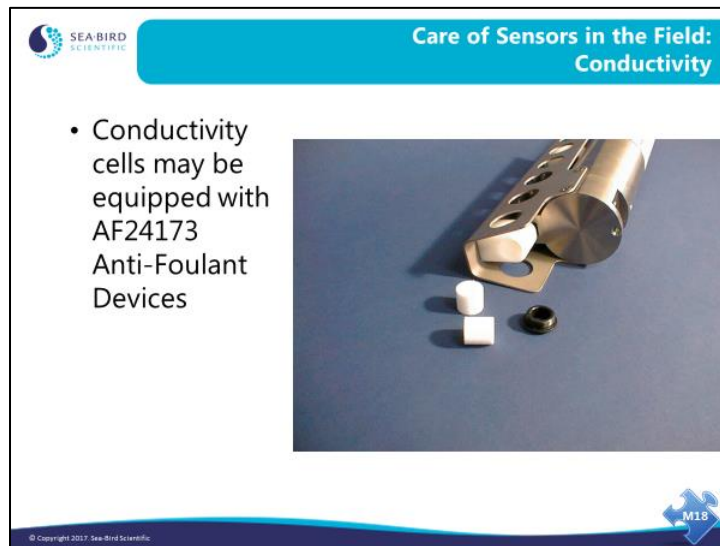
As we have discussed, thermometers are very robust. In moored applications, the sampling interval is much longer than the time constant of the thermometer, so except in extreme conditions fouling does not affect thermometers.

Occasionally, when a Sea-Bird instrument with a Druck pressure sensor is deployed in a muddy and/or biologically productive environment, the pressure port may partially fill with sediment or the pressure port plug vent hole may be covered with biological growth. Either of these occurrences can cause a delay in the pressure response, or in extreme cases can completely block the pressure signal. Sea-Bird developed a high-head pressure port plug for these types of deployments. See **Application Note 84** on our website for details.

**Note:** Newer pumped SBE 37 MicroCATs (SMP, IMP, SIP) and all IDO and ODO SBE 37 MicroCATs (SMP-IDO, IMP-IDO, SIP-IDO, SMP-ODO, IMP-ODO, SIP-ODO) are not compatible with the high-head pressure port plug.

We'll talk more about conductivity sensors and dissolved oxygen sensors.

## Care of Sensors in the Field: Conductivity




The slide features a blue header with the SEA-BIRD SCIENTIFIC logo on the left and the title 'Care of Sensors in the Field: Conductivity' on the right. Below the header, a bulleted list on the left states: '• Conductivity cells may be equipped with AF24173 Anti-Foulant Devices'. To the right of the text is a photograph of a cylindrical conductivity cell with a white anti-foulant device partially inserted into its top. Below the cell, two more white anti-foulant devices and a small black cap are visible on a dark blue surface. In the bottom right corner of the slide, there is a blue diamond icon with the number '18' inside. At the bottom left, there is a small copyright notice: '© Copyright 2017, Sea-Bird Scientific'.


- Conductivity cells may be equipped with AF24173 Anti-Foulant Devices


On conductivity sensors, a very thin coating can change the cell geometry, having a large effect on the conductivity measurement.

## Care of Sensors in the Field: Conductivity (*continued*)

 **Example: Unpumped SBE 16 with AF Cartridges, 7 Months**


**Note: 100% data recovery!**






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## Care of Sensors in the Field: Conductivity (*continued*)


 **Advantages of Pumping on Moored Instruments**

- Plumbing keeps sensors out of continuous fouling environment
  - Traps water between samples
  - Anti-foulant diffuses into trapped water to take care of any incoming biota
  - Anti-foulant protection allows longer deployments with more accurate data


*Additional protection: Copper tube extends from intake of TC sensors*

 SBE 16*plus* with ECOs

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## Sensor Drift Characteristics




### Sensor Drift Characteristics

- Biggest cause of sensor drift is fouling
  - Mainly a problem with conductivity and DO
- Electronic drift
  - Sea-Bird products have very little drift due to stable engineered electronics
- Extreme events that causes a shift in calibration
  - Thermal heating a temperature sensor
  - Movement of electrodes in conductivity cell
  - Scratches on DO membrane or fluorophor

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## Sensor Drift Characteristics (*continued*)



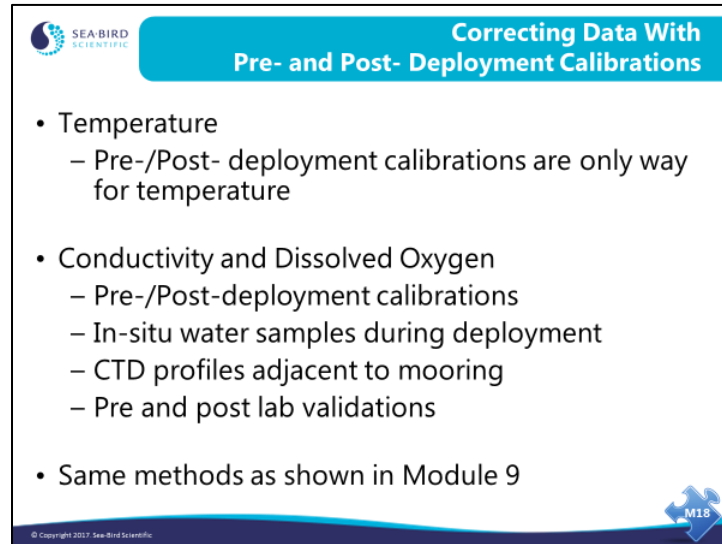
### Sensor Drift Characteristics

- Shelf drift similar as profiling instruments
- Pressure and temperature drift as offset
  - Typical temperature drift rates for SBE 16*plus*, 16*plus* V2, 37, 39, and 39*plus* are 0.0002 °C per month
  - Typical pressure drifts are linear, with rates of 0.018% - 0.05% of full scale per **year**
- Conductivity and oxygen drift as slope
  - Conductivity drift rates are 0.0003 Siemens/meter/month
  - SBE 43 drift rate is 1 – 2% per month
  - SBE 63 drift rate is much less once deployed
    - Shelf drift rate 1-2% per year

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## Correcting Data with Pre- and Post-Deployment Calibrations



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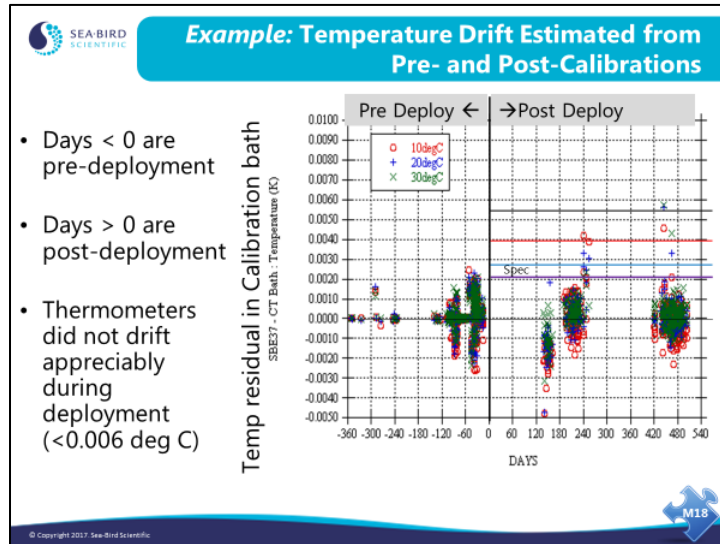
### Correcting Data With Pre- and Post- Deployment Calibrations

- Temperature
  - Pre-/Post- deployment calibrations are only way for temperature
- Conductivity and Dissolved Oxygen
  - Pre-/Post-deployment calibrations
  - In-situ water samples during deployment
  - CTD profiles adjacent to mooring
  - Pre and post lab validations
- Same methods as shown in Module 9

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## Temperature Drift from Pre- and Post-Deployment Calibrations






## Field Validation of Conductivity



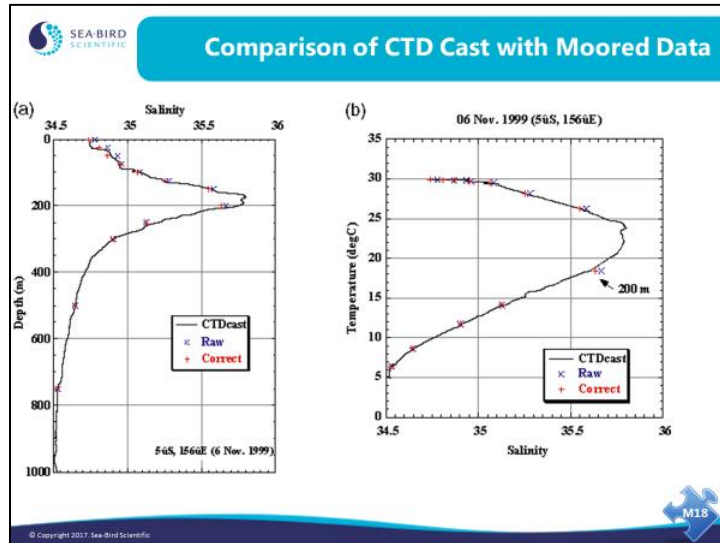
### Field Validation of Moored Conductivity and Oxygen Sensors

- Best Practice: Validate Sensors against water samples
- Same protocol as with profiling CTD
- Secondary Standard: Can also use reference sensor to check *in situ* performance
  - For example, making CTD profiles next to mooring at deployment/recovery and during

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## Correcting Conductivity and Temperature Data: Example

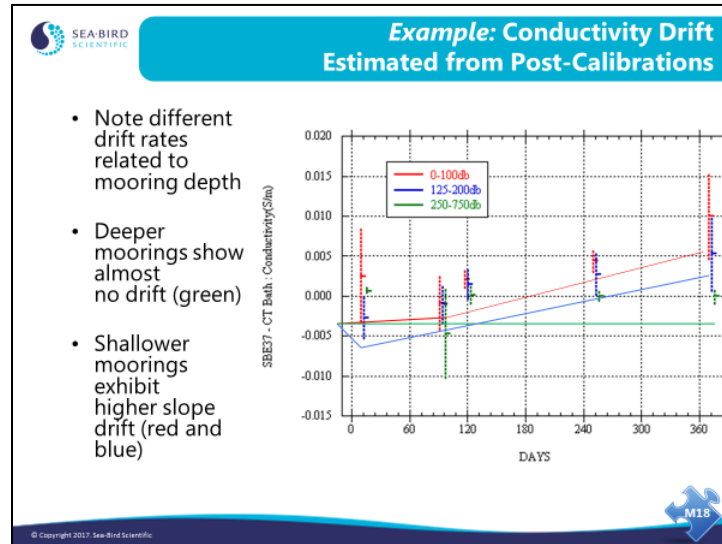


Here is a plot of a CTD cast with the mooring data overplotted on it. Raw and corrected values are shown. Although the scale is rather coarse, the correction improved the agreement between the instruments.


When comparing data collected by moored instruments with data collected in a CTD profile, it is important to keep in mind that even though the mooring is fixed in place, the ocean moves around it. There can be substantial variability over a fairly small time interval. Most of the time there is little hope of having the CTD in place at the moment the moored instrument is taking a measurement.

When choosing locations to make corrections, consider the position of the thermocline and other variables that can add error to reference samples (Winklers or CTD comparisons). Also, be aware that pressure sensors on moored instruments need to be checked, as pressure is an important variable in the salinity calculation. Large errors in pressure can create large errors in salinity.

## Correcting Data with Pre- and Post-Deployment Calibrations (*continued*)





## Lab Validation




### Laboratory Bath Validation Before and After Deployment

- Bath tests
  - Confirm functionality
  - Collect reference sample for slope correction in calibration equation
- Uniform bath with stable temperature
- Equilibrate instrument for a few hours prior to sampling
- Turn off aerators 20 minutes prior to sampling
- Synchronize water sample and sensor data



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## Activity: Validate T and C against Reference Standards



**Activity: Check T and C  
against Reference Standards**

- In Seaterm V2 for an SBE 37-SM
  - Type **OutputFormat=1** (default; converted decimal data)
  - Type **StartNow** (to look at output)
- Example of data for a CTD where salinity is an output (**OutputSal=Y**)

Temp deg C	Cond S/m	Press dbar	Salinity	Date Time
8.5796,	0.15269,	531.316,	1.1348,	20 Aug 2011, 09:01:44



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### Recommended Format for C and T Validations using bottled Standards and References

**OutputFormat=1** (default): converted decimal data

tttt.tttt,ccc.ccccc,ppppp.ppp,ssss.ssss,vvvvv.vvv, dd mmm yyyy, hh:mm:ss

where

tttt.tttt = temperature (°C, ITS-90).

ccc.ccccc = conductivity (S/m).

ppppp.ppp = pressure (decibars); sent only if optional pressure sensor installed.

ssss.ssss= salinity (psu); sent only if **OutputSal=Y**.

vvvvv.vvv = sound velocity (meters/second); sent only if **OutputSV=Y**.

dd mmm yyyy = day, month, year.

hh:mm:ss = hour, minute, second.

Example of data from a DIFFERENT CTD (not one above), with salinity as an output.

Temp deg C	Cond S/m	Press dbar	Salinity	Date Time
8.5796,	0.15269,	531.316,	1.1348,	20 Aug 2011, 09:01:44

**To get salinity as an output (Recommended):**

**Type OutputSal=Y in Command Line Window.**

**OR**

**In Send Commands Window, under Output Format Setup, Click on Set Data Output Format, select 1 in the Argument for Command box below, and Execute.**

Note: You may have to hit Return (Enter key) in the Command Line Window first if this does not execute right away as instrument might have gone into quiescent mode.

After you set **OutputFormat =1**, click on Enable Output of Salinity, and Execute.

Click Capture button on Menu bar to create .cap capture file.

Type **StartNow** to look at data real-time on the screen.

Type **Stop** to stop the logging.

Click Capture button on Menu bar to close .cap file you just created.

Look at .cap file; you will see that you saved all testing information for your QA/QC.

