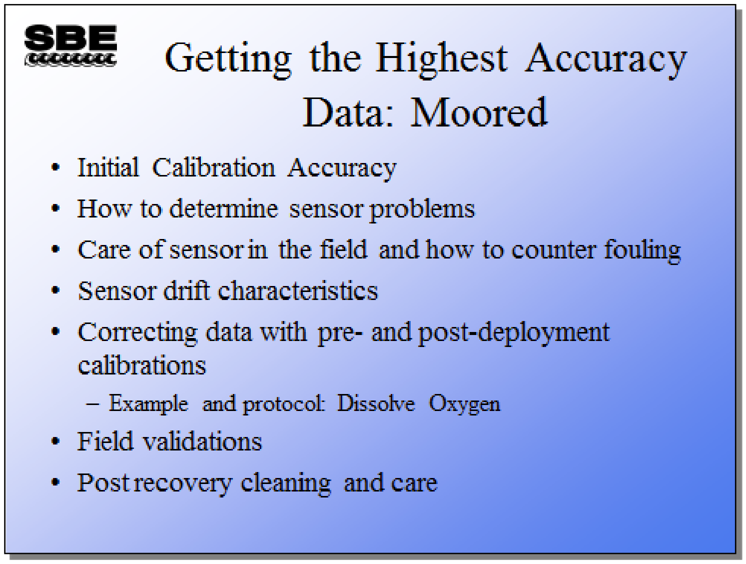
Module 12

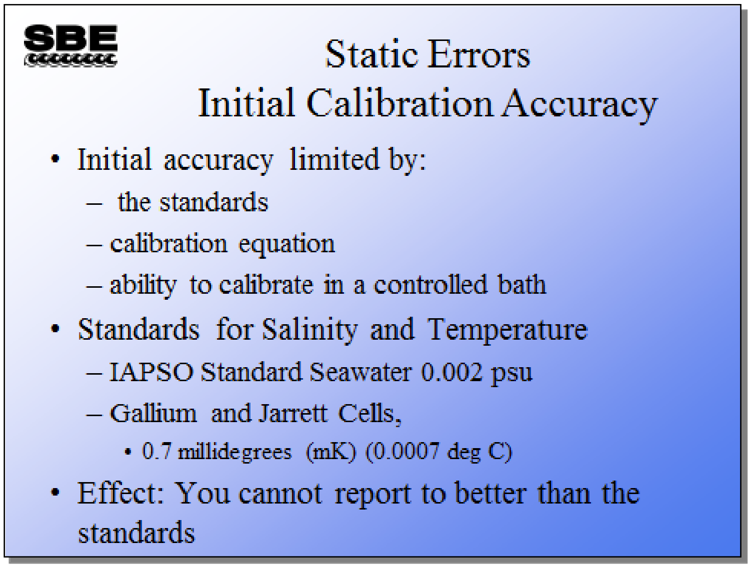
Getting the Highest Accuracy Data from Moored Instruments

Overview

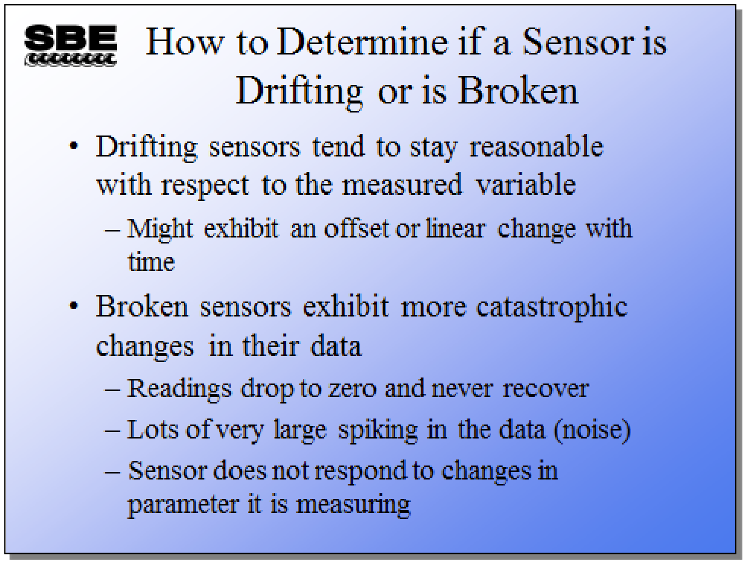


In the module we will discuss the means to get the highest accuracy in your moored measurements. This includes care of sensors in the field and understanding sensor drift characteristics. Moored instruments can exhibit unexpected drift in conductivity. Topics covered include pre- and post-deployment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

Static Errors

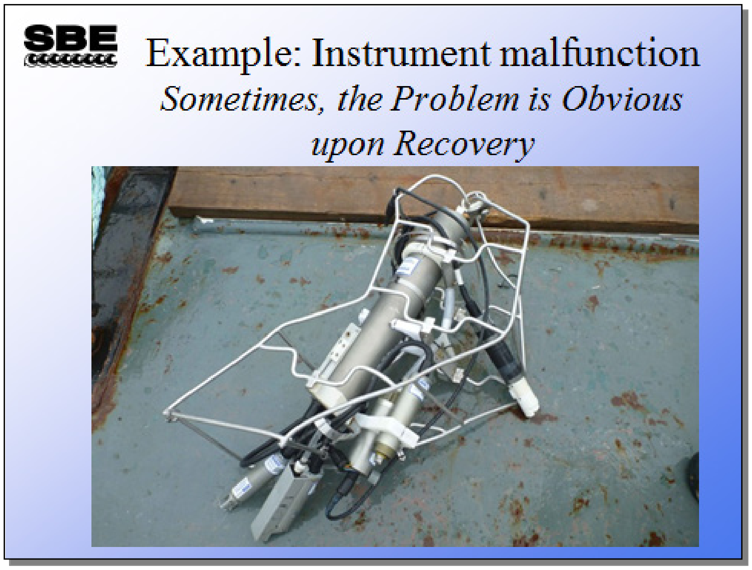


Static Errors (*continued*)

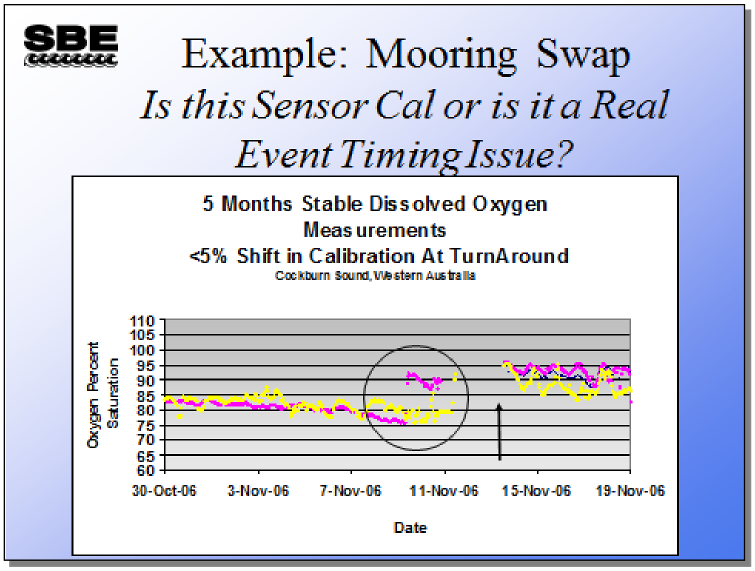


Fouling

Instrument Malfunction

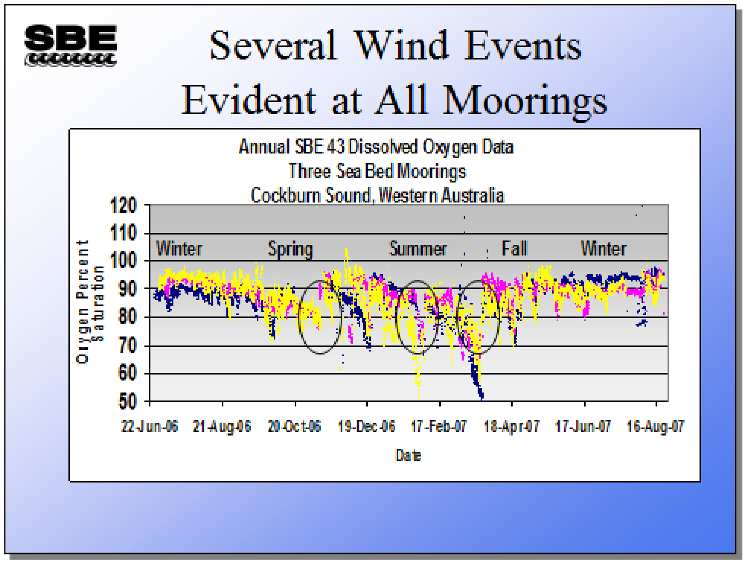


Instrument Malfunction (*continued*)



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.

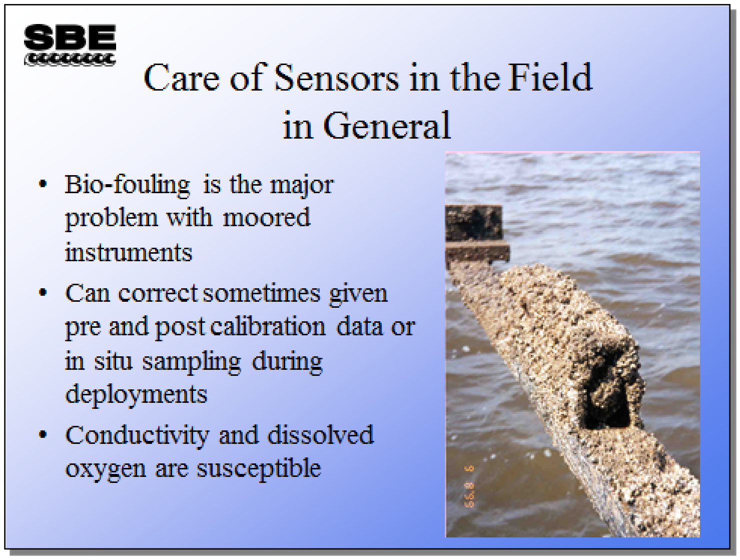
Instrument Malfunction (*continued*)



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.

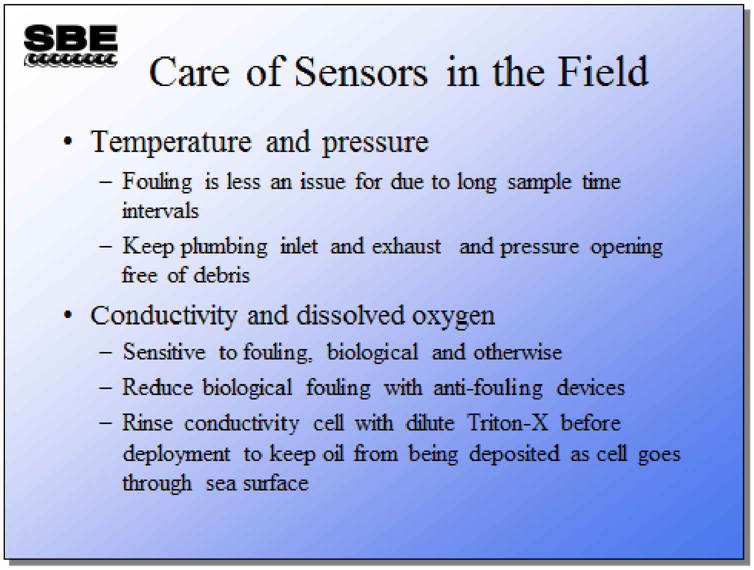
When all the nearby mooring data were analyzed, it became clear that the sensor swap occurred during a wind event, and that the bulk of the 5% shift observed on the previous slide was probably caused by a natural occurring event, rather than indicative of a sensor problem or drift.

Care of Sensors in the Field



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*)



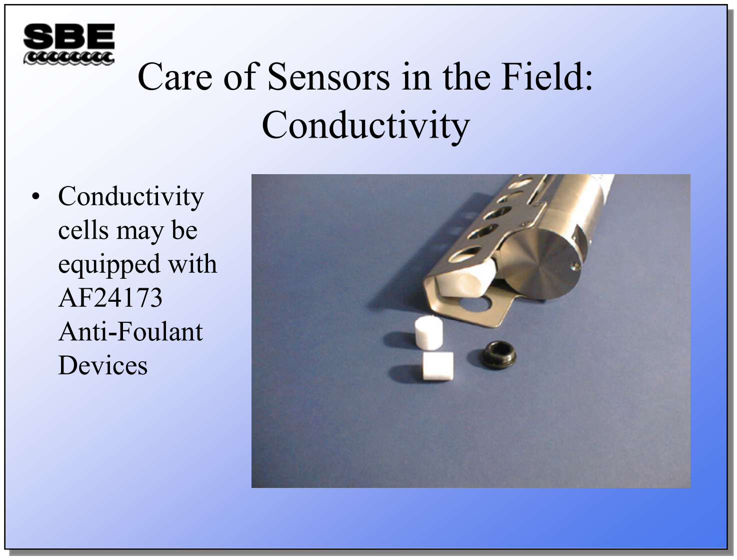
As we have discussed, thermometers are very robust. In moored applications, the sampling interval is much longer than the time constant of the thermometer, so except in extreme conditions fouling does not affect thermometers.

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.

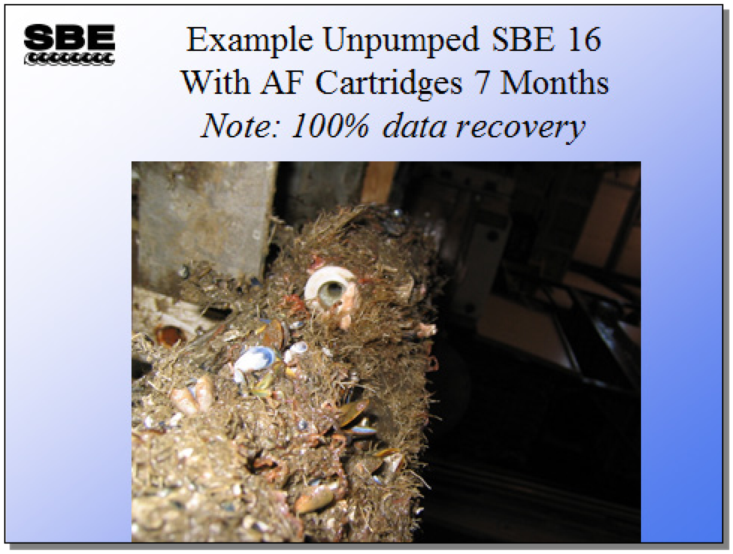
We'll talk more about conductivity sensors and dissolved oxygen sensors.

Care of Sensors in the Field: Conductivity

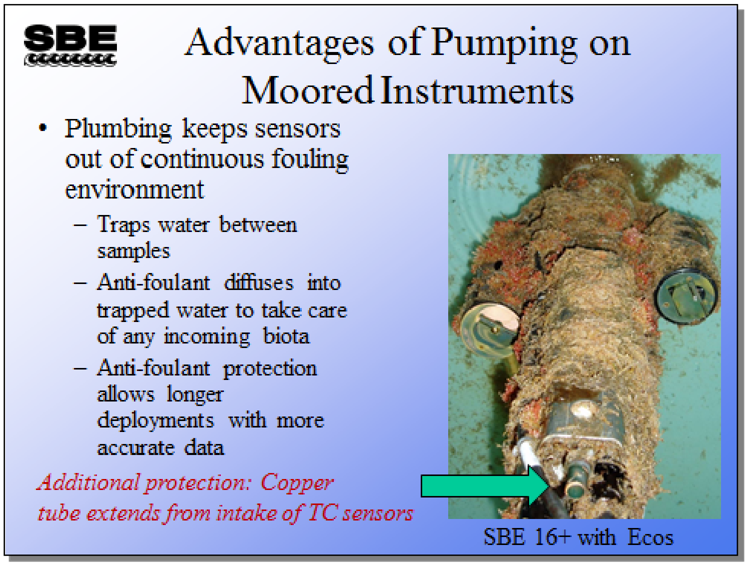


On conductivity sensors, a very thin coating can change the cell geometry, having a large effect on the conductivity measurement.

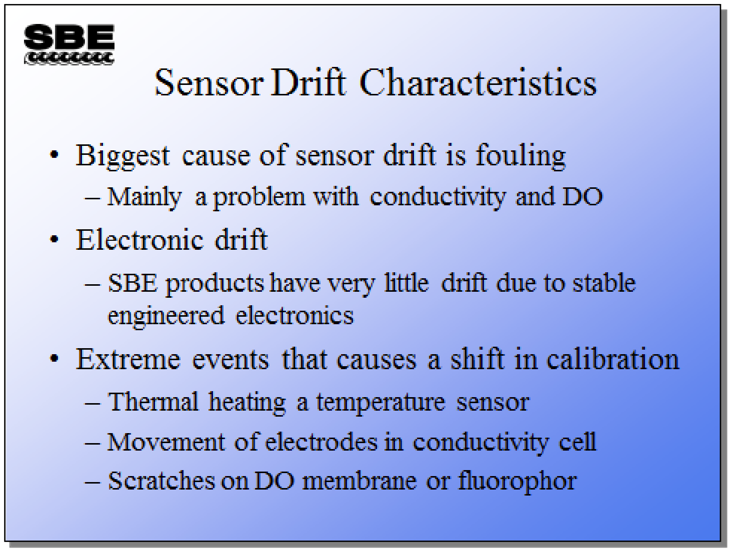
Care of Sensors in the Field: Conductivity (*continued*)



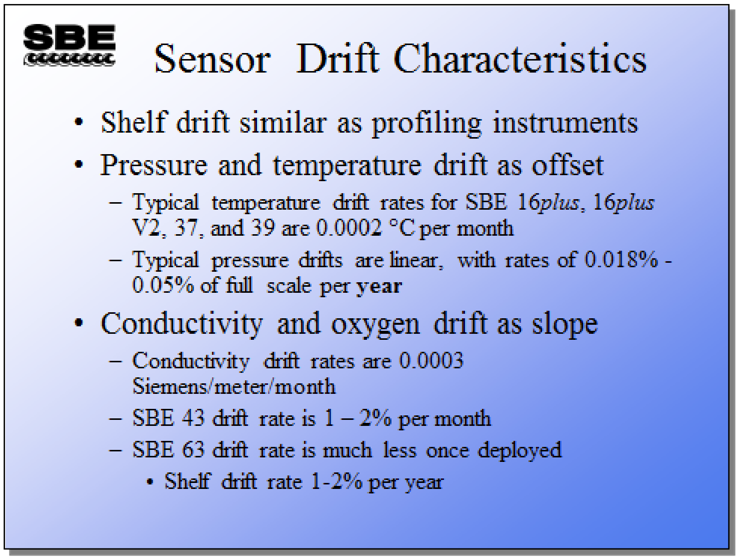
Care of Sensors in the Field: Conductivity (*continued*)



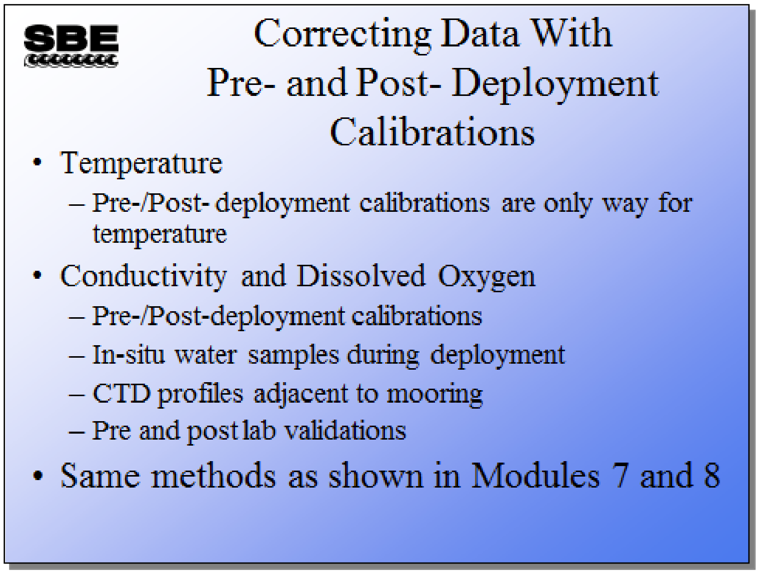
Sensor Drift Characteristics



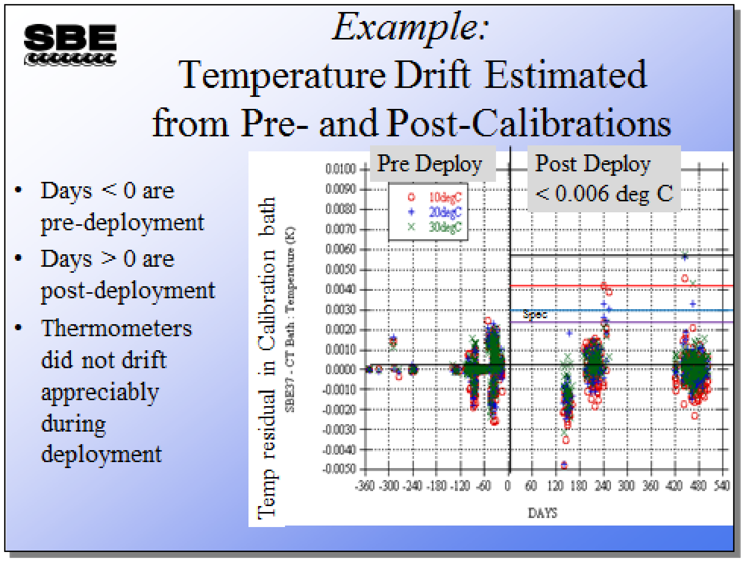
Sensor Drift Characteristics (*continued*)



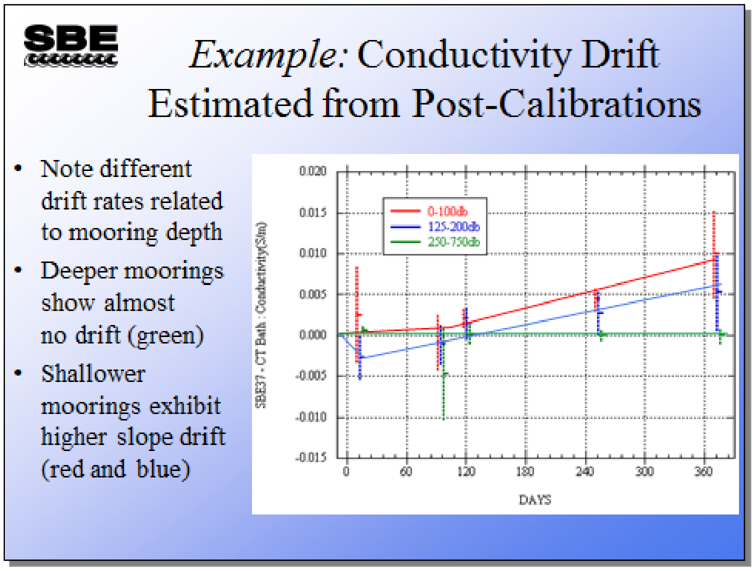
Correcting Data with Pre- and Post-Deployment Calibrations



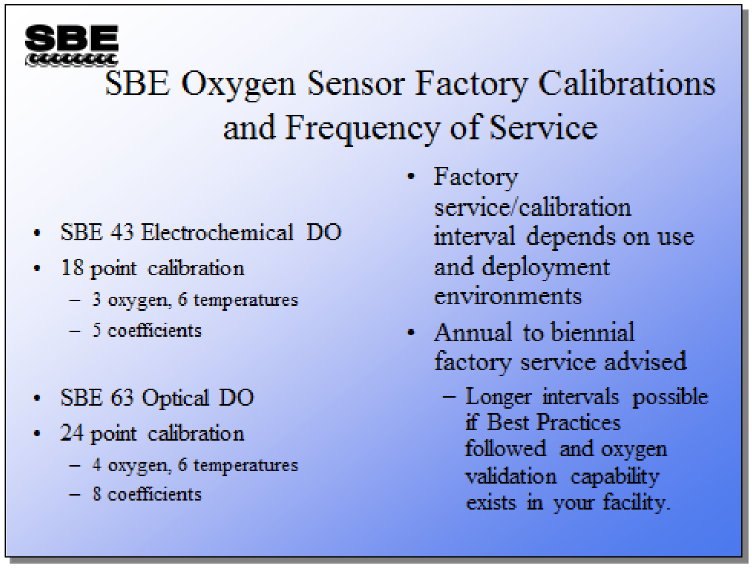
Correcting Data with Pre- and Post-Deployment Calibrations (*continued*)



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

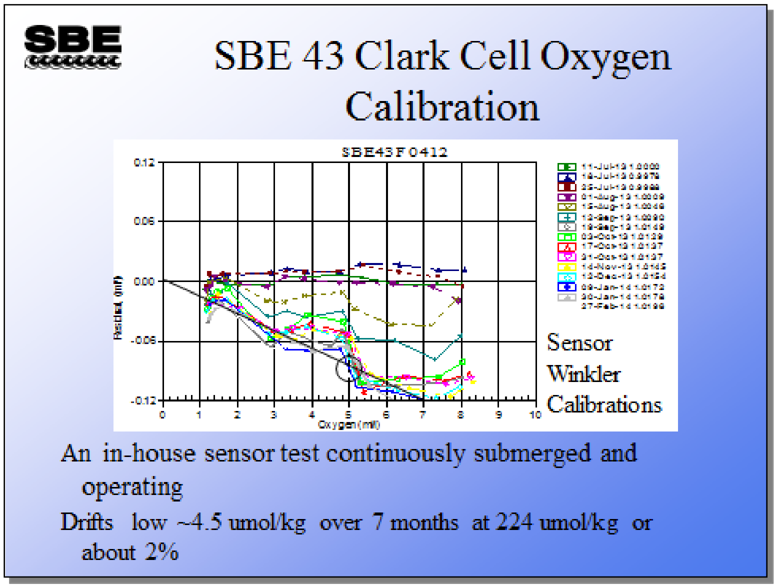


Care of Sensors in the Field: Dissolved Oxygen



Each SBE 43 and SBE 63 is calibrated individually in a temperature-controlled bath. Bath temperatures are varied at each of 3 to 4 oxygen values, providing a comprehensive 18 to 24-point calibration. Two reference sensors in each bath are standardized against Winkler titrations weekly and monitored with high-quality controlled wet chemistry standards. Response time tests are conducted on each sensor, using gas. Salinity and pressure impacts on sensor response are each checked at two separate points.

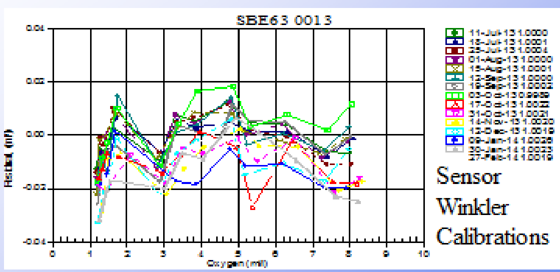
Care of Sensors in the Field: Dissolved Oxygen (*continued*)



Plot indicates a slope drift of < 0.1 ml/L (~4.5 umol/kg) over seven months at saturation.

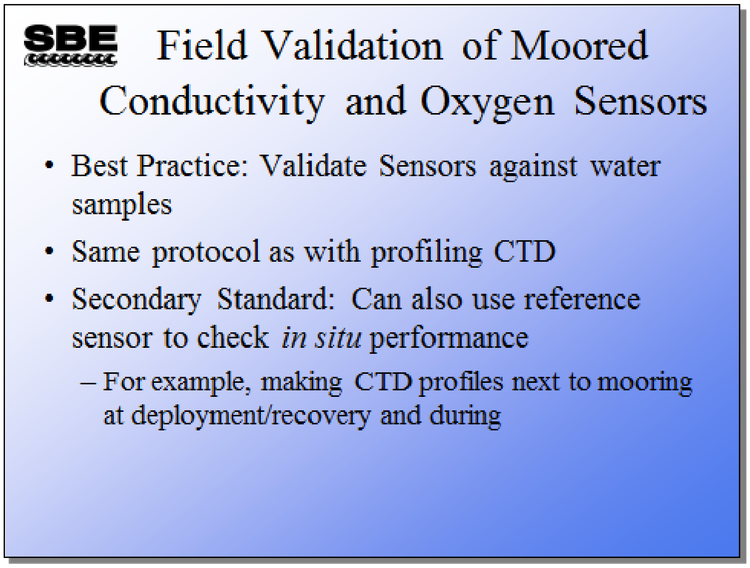
Care of Sensors in the Field: Dissolved Oxygen (*continued*)

SBE 63 Optical Oxygen Calibration

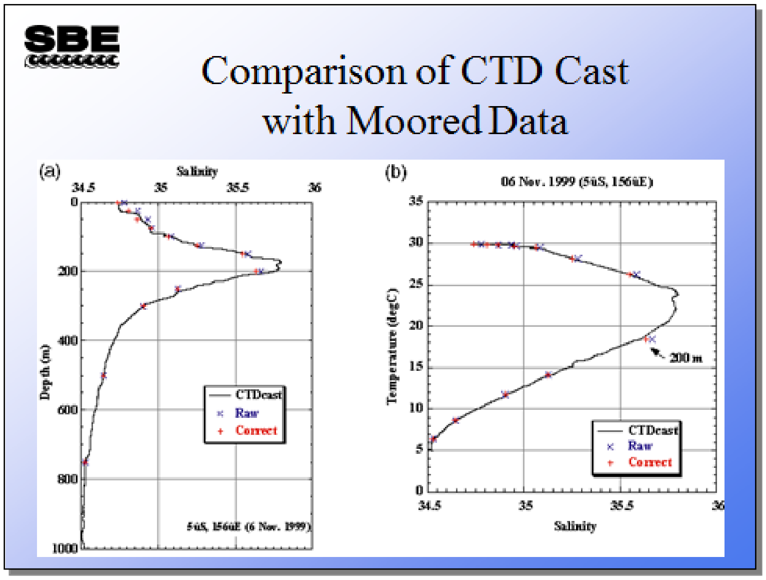


- An in-house sensor test continuously submerged and operating
  - Stable at +/- 1 umol/kg over 7 months
- Calibration spread is bath and standard, not sensor repeatability
- Dry storage can introduce drift ~1% over 6 months

Field Validation



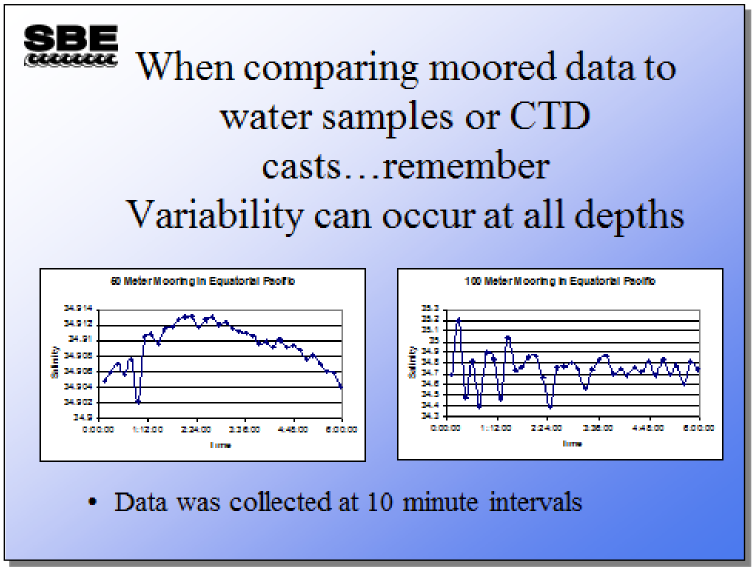
Correcting Conductivity and Temperature Data: Example



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.

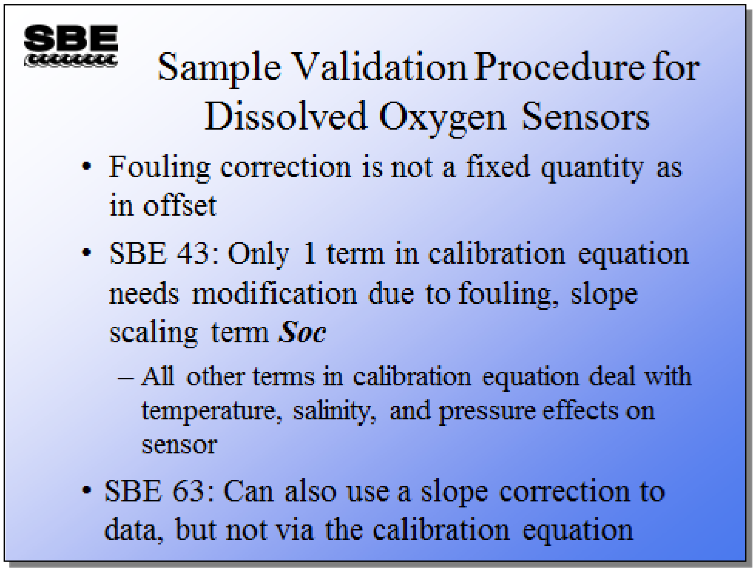
When choosing locations to make corrections, consider the position of the thermocline and other variables that can add error to reference samples (Winklers or CTD comparisons). Also, be aware that pressure sensors on moored instruments need to be checked, as pressure is an important variable in the salinity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

Correcting Conductivity and Temperature Data: Example

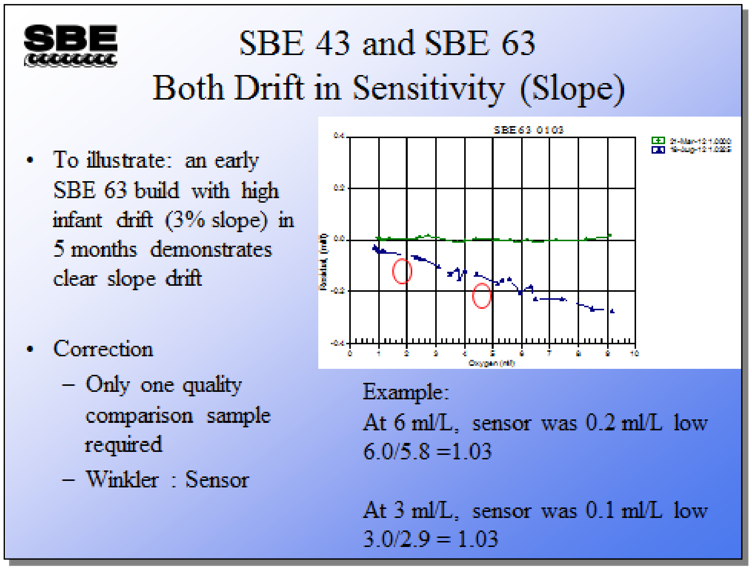


When comparing data collected by moored instruments with data collected in a CTD profile, it is important to keep in mind that even though the mooring is fixed in place, the ocean moves around it. There can be substantial variability over a fairly small time interval. Most of the time there is little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

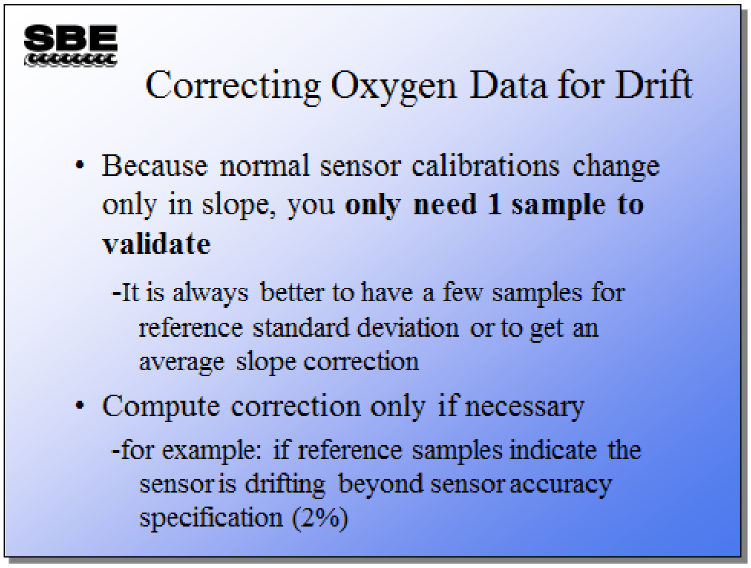
Correcting Oxygen Data



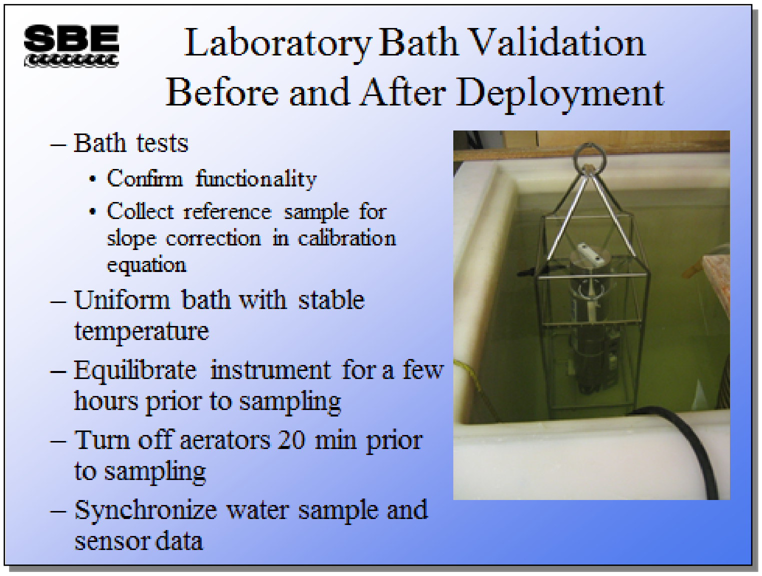
Correcting Oxygen Data (*continued*)



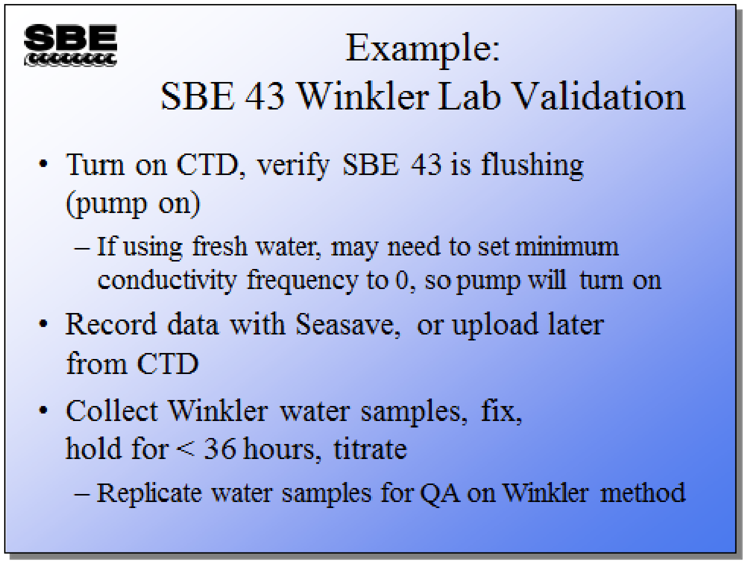
Correcting Oxygen Data (*continued*)



Correcting Oxygen Data (*continued*)



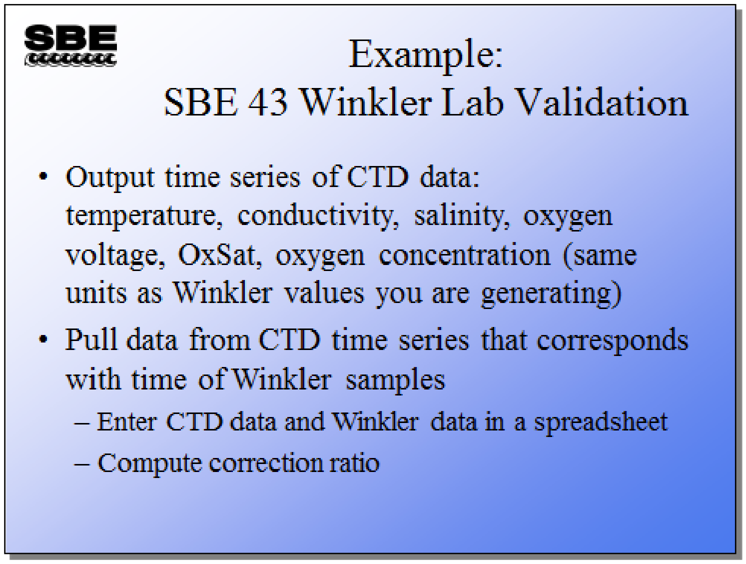
Correcting Oxygen Data: Lab Validation



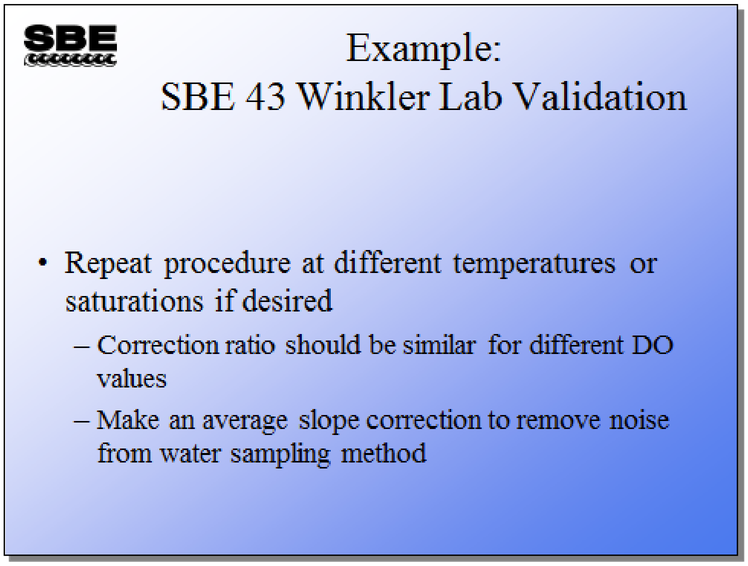
Note for SBE 9*plus* CTD -

Minimum conductivity frequency cannot be set by the user for an SBE 9*plus* CTD. It is factory set (hard wired) to approximately 3500 Hz. An SBE 9*plus* with custom modifications allows you to manually turn the pump on and off, which can be useful for fresh water applications (or for testing in the lab).

Correcting Oxygen Data: Lab Validation (*continued*)



Correcting Oxygen Data: Lab Validation (*continued*)



Correcting Oxygen Data: Field Validation

SBE

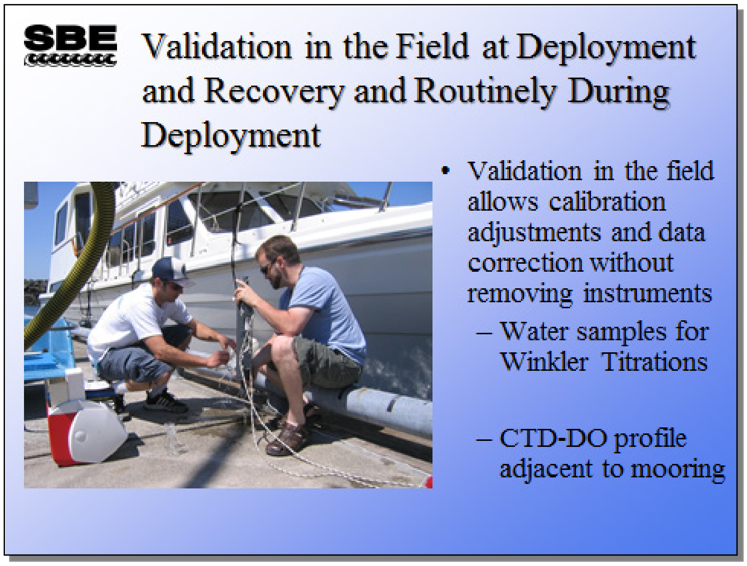
Example:
SBE 43 Winkler Field Validation

- Follow similar procedure for validation in field
- Choose depth of CTD and Winkler water sample comparisons where D.O. is not changing much
  - Collect replicate field samples if possible, and use average or "best of"
- If replication not possible, collect samples at multiple locations to get idea of sampling variability and to be sure you do not have a bad sample

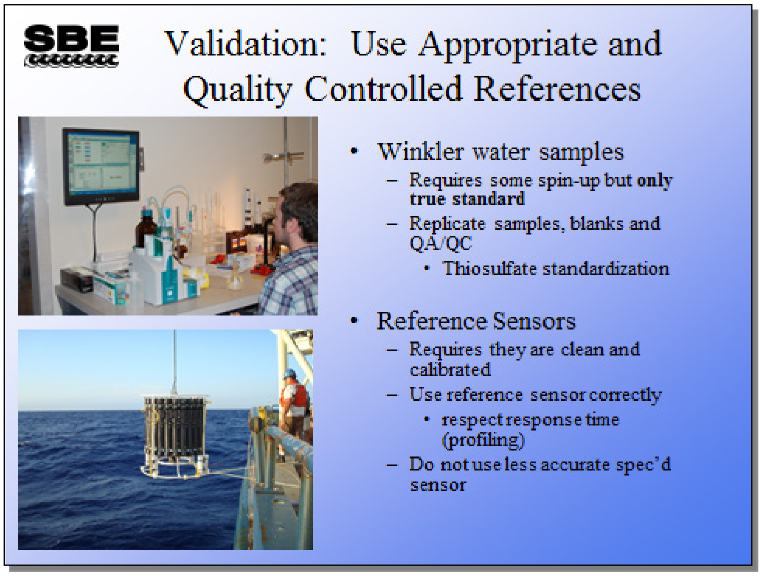
Field validations must be carefully executed!

For additional information on SBE 43 data and corrections, see **Application Notes 64, 64-1, and 64-2** on our website.

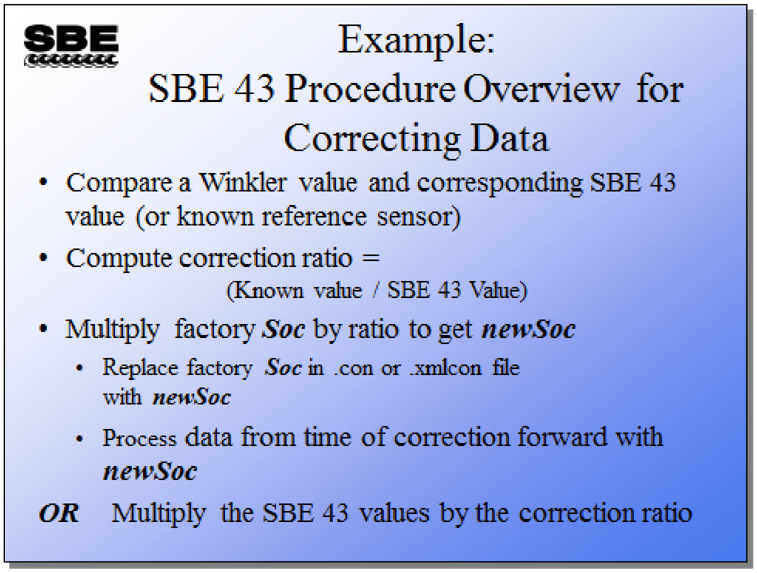
Correcting Oxygen Data: Field Validation (*continued*)



Correcting Oxygen Data: Field Validation (*continued*)



Correcting Oxygen Data



The correction ratio is typically greater than 1.0 if the sensor is fouling.

See **Application Note 64-2** (www.seabird.com/application_notes/AN64-2.htm).

Activity: Compute Correction Factor for *Soc*

SBE

Activity:
Compute Correction Factor for *Soc*

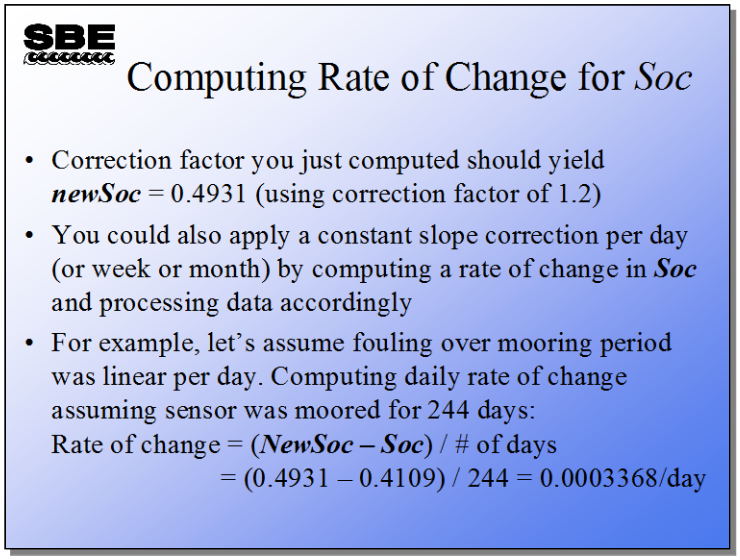
Winkler (ml/l)	SBE 43 (ml/l)	Offset = Difference (SBE 43 – Winkler)	Correction Factor (Winkler/SBE 43)
6.8	5.8		
4.2	3.6		
1.2	1.0		

- If factory ***Soc*** was 0.4109, calculate ***newSoc***

Note that the Offset (difference between SBE 43 readings and Winkler readings) is not constant, indicating that the SBE 43 is drifting by slope, not offset.

The new ***Soc*** (***newSoc***) is entered in the configuration (.con or .xmlcon) file in SBE Data Processing. The modified configuration file is used for processing measurements made after the date corresponding to the Winkler water samples.

Computing Rate of Change for *Soc*



Activity: Compute Rate of Change for *Soc*

Activity:
Compute Rate of Change for *Soc*

- With ***Soc*** = 0.4109 and ***newSoc*** = 0.4931:
  - Assume fouling was linear **per day**, and sensor was moored for 1 year (365 days).
    What is rate of change in ***Soc*** per day?
  - Assume fouling was linear **per week**, and sensor was moored for 8 months (35 weeks).
    What is rate of change in ***Soc*** per week?

Correcting Oxygen Data: Example

SBE

Example: Shilshole Marina

Date (2007)	Winkler 1	Winkler 2	Winkler 3	Average	Standard Dev
3/12	(Calibration date)				
3/23 17:10	6.123	6.165	6.239	**6.176**	**0.059**
3/30 11:10	7.077	7.084	7.111	**7.091**	**0.018**
4/19 12:20	7.324	7.328	Dud	**7.326**	**0.003**
5/04 13:10	7.552	7.579	7.569	**7.567**	**0.014**
5/04 14:10	7.643	7.742	7.765	**7.717**	**0.065**
5/17 13:10	8.239	8.250	8.248	**8.246**	**0.006**
5/30 12:40	9.025	9.184	9.146	**9.118**	**0.083**
6/05 15:20	8.517	8.509	8.488	**8.505**	**0.015**

Sea-Bird deployed an SBE 43 on a CTD at Shilshole Marina in Seattle from March 23 to June 5, 2007, and performed periodic water sampling at various times during the deployment period. The table above summarizes the Winkler results from the water samples.

Note that 3 water samples were drawn and analyzed from the bottle collected on each water sampling date. We will use the average Winkler value on each date to perform the corrections. The standard deviation in the Winklers gives an estimate on method draw and lab errors. It does not account for co-sampling (location/timing) errors with respect to the oxygen sensor.

Correcting Oxygen Data: Example (*continued)*

Example: Shilshole Marina

Date (2007)	SBE 43 **	Difference (Winkler – SBE 43)	Ratio (Winkler / SBE 43)	newSoc	Corrected SBE 43
3/12	Calibration Date, ***Soc*** = 0.00012913				
3/23 17:10	6.028	0.148	1.024	0.00013223	**6.176**
3/30 11:10	6.789	0.302	1.044	0.00013481	**7.091**
4/19 12:20	6.885	0.441	1.064	0.00013739	**7.326**
5/04 13:10	7.236	0.331	1.045	0.00013494	**7.567**
5/04 14:10	7.319	0.398	1.054	0.00013610	**7.717**
5/17 13:10	7.740	0.506	1.065	0.00013752	**8.246**
5/30 12:40	8.470	0.648	1.077	0.00013907	**9.118**
6/05 15:20	7.789	0.716	1.092	0.00014101	**8.505**

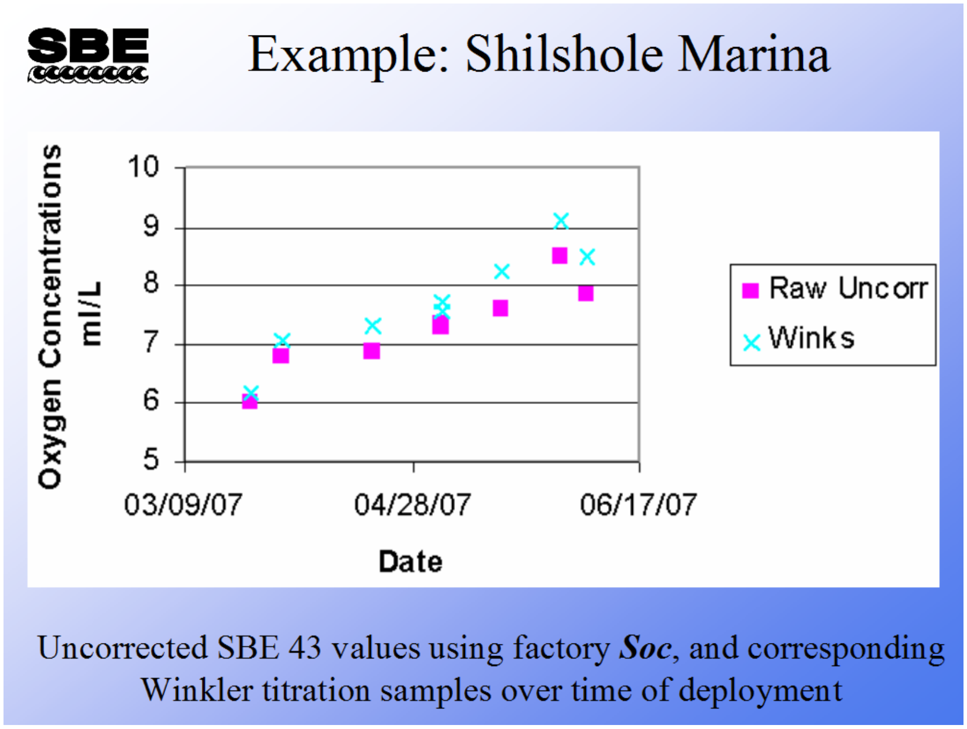
** Using original ***Soc*** (= 0.00012913)

Looking at these data, the percent change in ***Soc*** from beginning of deployment to end of deployment (3/23 to 6/5, approximately 2.5 months) is 7%.

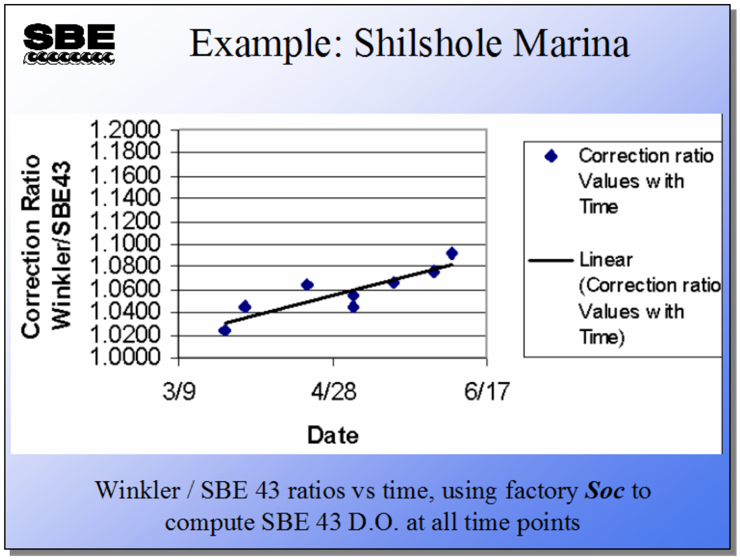
Note the following:

- The corrections would be small (< 4%) through 5/17.
- Have an idea what level of data accuracy you expect.
- Look for outliers - they could indicate a problem in your calculations, or that the sensor and water samples do not agree (for example, co-sampling errors and time of sample with sensor mismatches).
- There are many ways to implement corrections. For examples, see our website.
- Tracking data can help identify instrument or coefficient problems.
- It is not normal for the ratios and resulting ***Soc*** values to decrease with time.
  1) Verify calibration coefficients are entered in the configuration (.con) file correctly.
  2) Contact customer service with a sample of the problem you are seeing.
  3) Return the SBE 43 to the factory for assessment if the problem is not resolved.
- Sea-Bird recommends factory servicing when the ***Soc*** correction ratio factor ~ 1.2 (equivalent to 15 - 20% drift from factory calibration), **and** it is not corrected by sensor cleaning.

Correcting Oxygen Data: Example (*continued*)



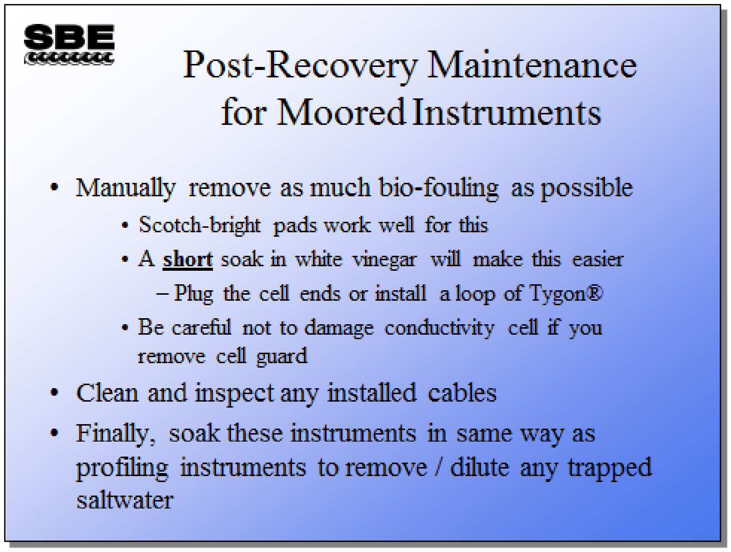
Correcting Oxygen Data: Example (*continued)*



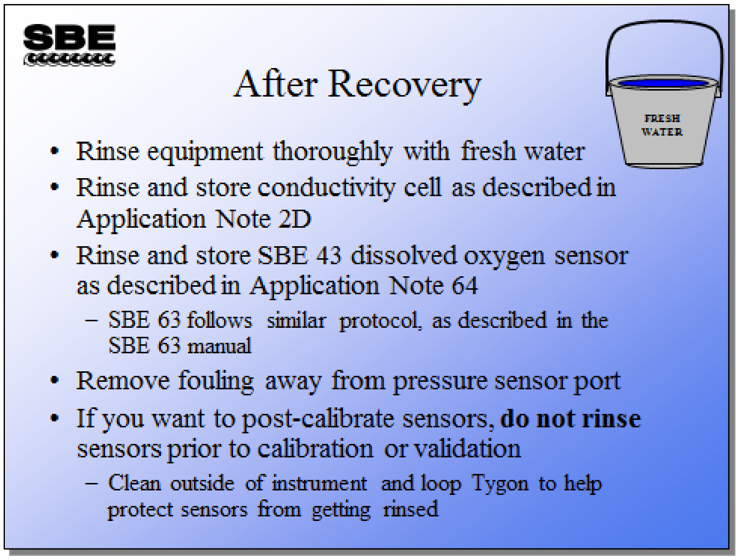
This plot shows the Winkler / SBE 43 ratios versus time, using the original factory calibration value to compute the SBE 43 D.O. at all time points.

Notice the small positive trend in the correction with time. Sea-Bird recommends a factory service when the correction ratio reaches 1.2 and is not corrected with cleaning.

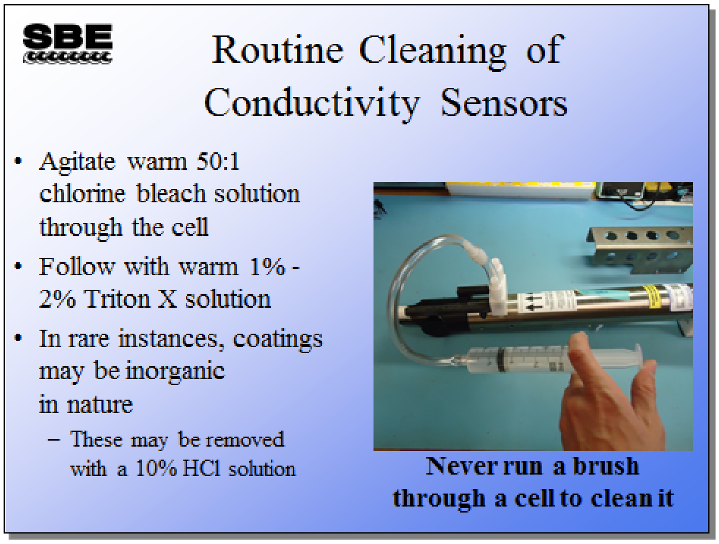
Post-Recovery Maintenance



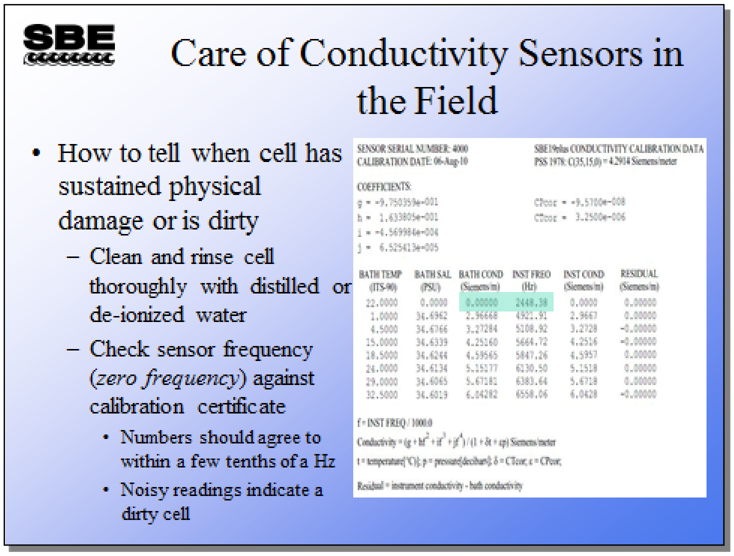
Post-Recovery Maintenance (*continued*)



Post-Recovery Maintenance (*continued*)



Post-Recovery Maintenance (*continued*)



Activity: Validations

Activity: How to Enable Real-Time Output for both Zero Conductivity Checks and Validations

In SeatermV2 Command window, type:

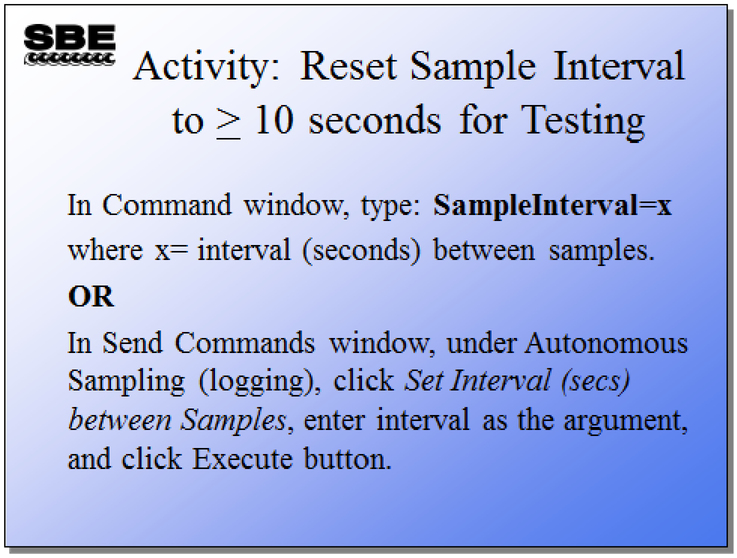
TxRealTime=y

(Output real-time data while sampling autonomously or in serial line sync mode. **Note, you cannot sample faster than 10 seconds for real time output.**)

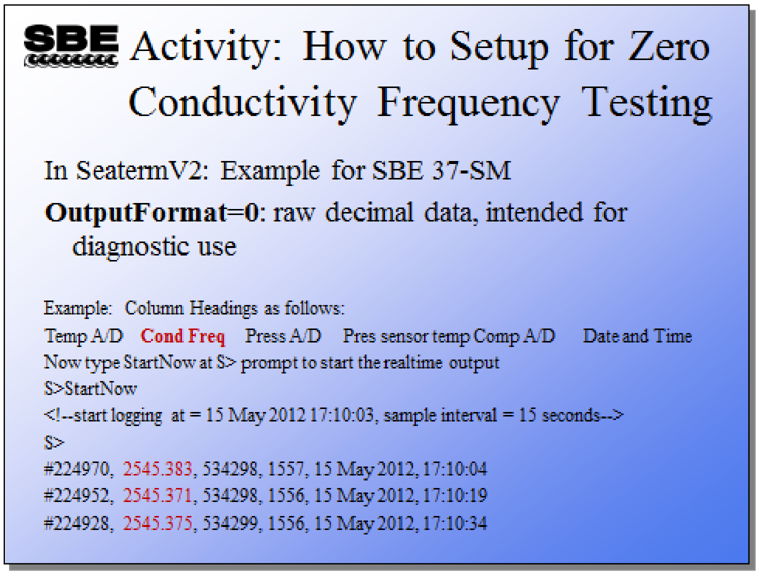
OR

In Send Commands window, under General Setup, click *Enable Output of Real-Time data*, select *Yes* as the argument, and click Execute button.

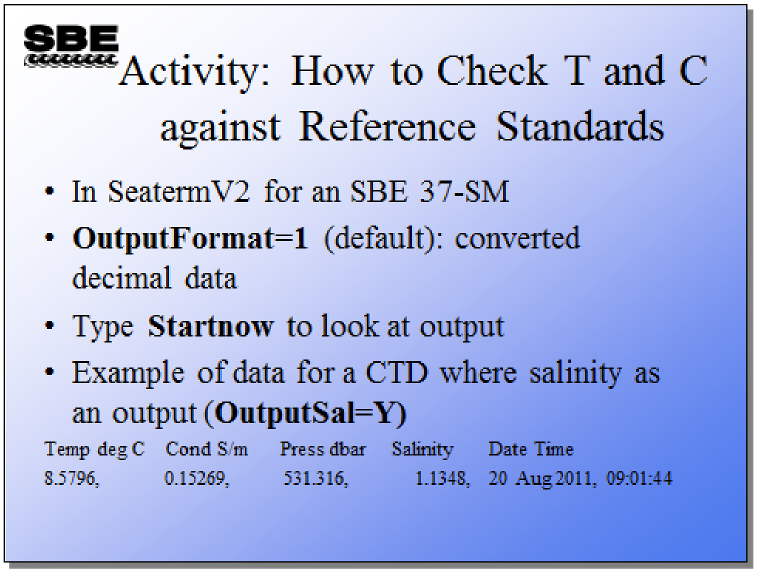
Activity: Validations (*continued*)



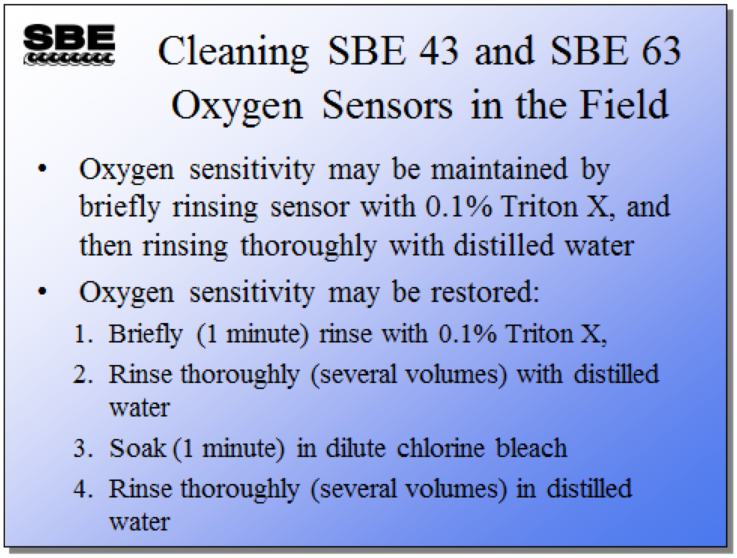
Activity: Validations (*continued*)



Activity: Validations (*continued*)

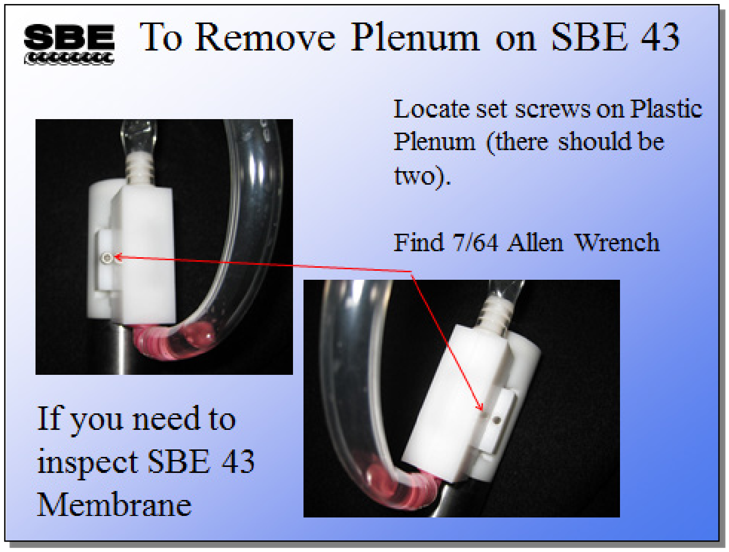


Dissolved Oxygen Sensor Field Care



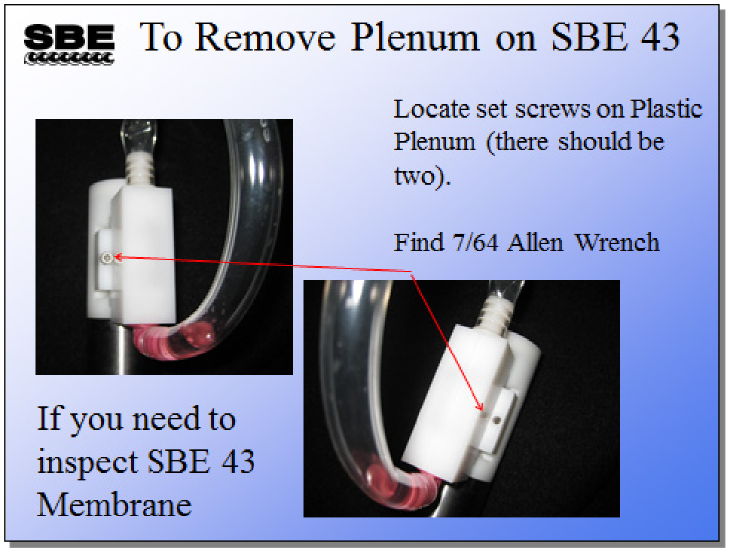
Dissolved Oxygen Sensor Field Care (*continued*)

Dissolved Oxygen Sensor Field Care (*continued*)

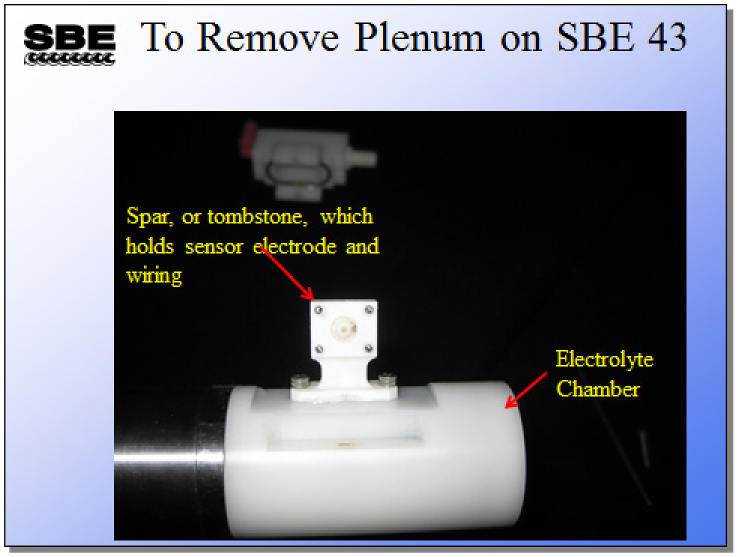


Dissolved Oxygen Sensor Field Care (*continued*)

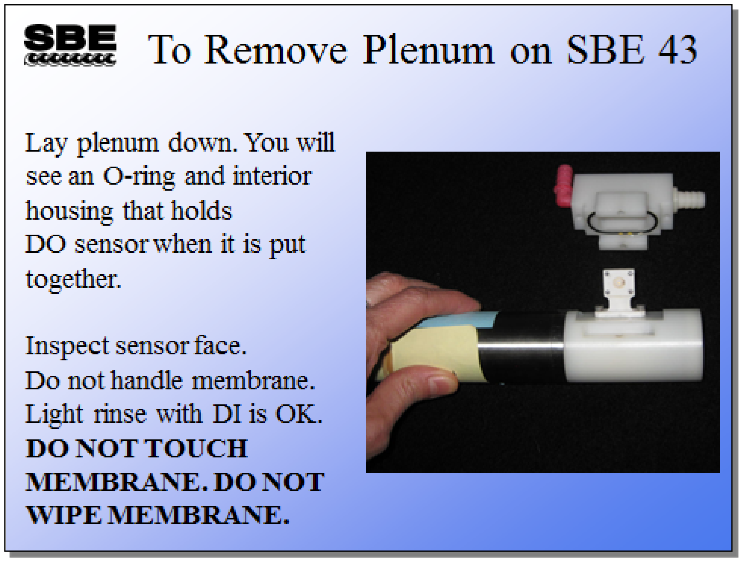
Dissolved Oxygen Sensor Field Care (*continued*)



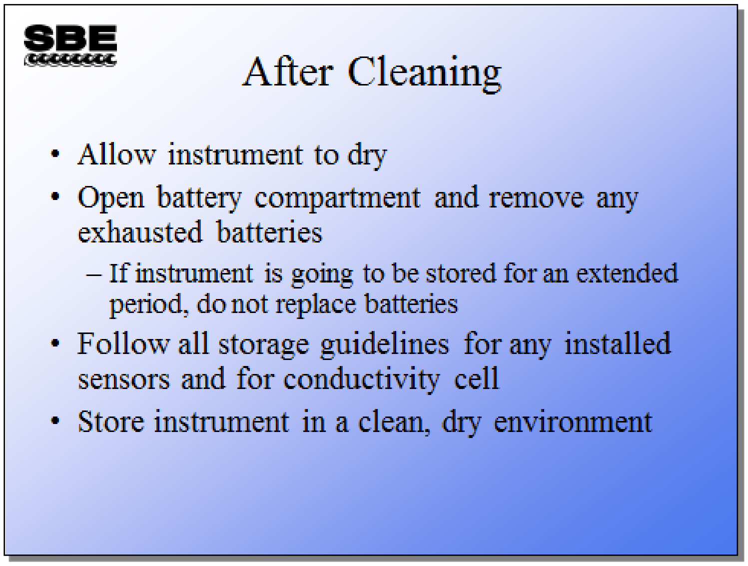
Dissolved Oxygen Sensor Field Care (*continued*)



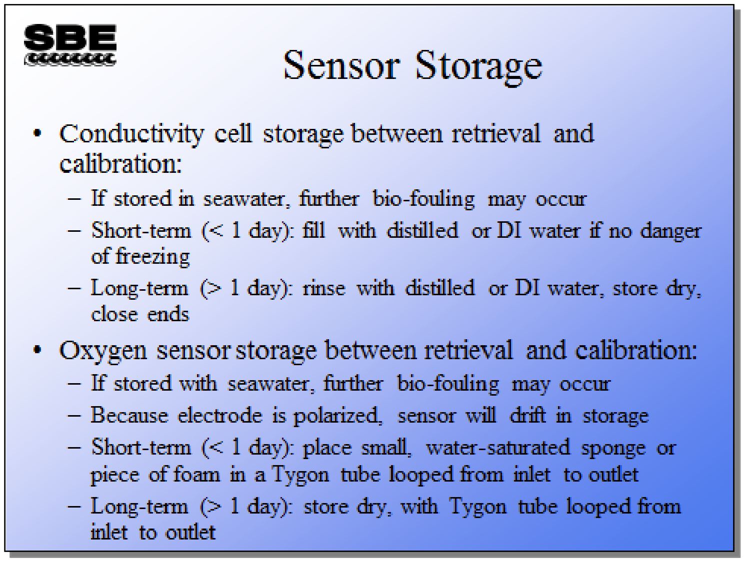
Dissolved Oxygen Sensor Field Care (*continued*)



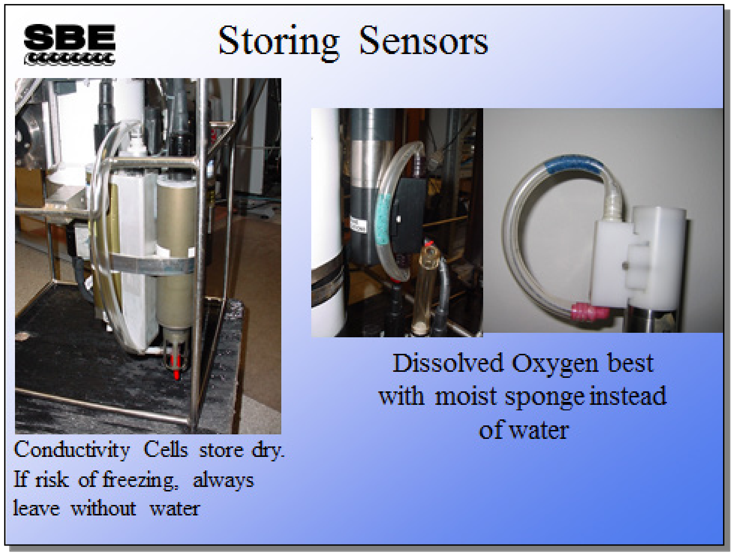
Sensor Storage



Sensor Storage (*continued*)



Sensor Storage (*continued*)



Conductivity cell (See **Application Note 2D** for details.):

- Short-term storage: If there is no danger of freezing, store the conductivity cell with distilled or de-ionized water in Tygon tubing looped around the cell. If there is danger of freezing, store the conductivity cell dry, with Tygon tubing looped around the cell.
- Long-term storage: Since conditions of transport and long-term storage are not always under the control of the user, we recommend storing the conductivity cell dry, with Tygon tubing looped around the cell ends. Dry storage eliminates the possibility of damage due to unforeseen freezing, as well as the possibility of bio-organism growth inside the cell.

Oxygen sensor (See **Application Note 64** for details.):

- Short-term storage: If there is no danger of freezing, place a small piece of clean sponge, *slightly dampened* with fresh, clean water, in the center of the tubing (not near the membrane). If there is danger of freezing, store the oxygen sensor dry, with Tygon tubing looped from inlet to outlet.
- Long-term storage: Since conditions of transport and long-term storage are not always under the control of the user, we recommend storing the oxygen sensor dry, with Tygon tubing looped from inlet to outlet. Dry storage eliminates the possibility of damage due to unforeseen freezing, as well as the possibility of bio-organism growth inside the cell.