


Module 8

Getting the Highest Accuracy Data, Continued

Overview



Getting the Highest Accuracy Data: Profiling (continued)


- Field calibrations
 - Pressure
 - Temperature
 - Conductivity
 - Dissolved O₂
- As good as it gets: autonomous profilers

We are going to continue our discussion of methods to ensure the accuracy of profiling equipment, and then we will discuss data from autonomous profilers. We will see that the human influence on conductivity sensors is the greatest obstacle to good conductivity data.

At the end of this module, you should be able to:

- Field calibrate your CTD and Dissolved O₂ sensors.
- Have heightened awareness about the handling of your conductivity sensor.

Field Calibrations




Field Calibrations

- Pressure
 - Slope and offset, typically use offset only
 - Best practice, measured in the lab against a barometer
 - In a pinch, on deck (We know where sea level is, right?)
- Temperature
 - Slope and offset, typically use offset only
 - Reversing thermometers
 - SBE 35 reference thermometer
- Conductivity
 - Slope and offset, typically use slope only
 - Discrete salinity samples
- Dissolved oxygen
 - Calibration equation contains slope and offset
 - Discrete samples

The *.con* file has entries for *slope* and *offset* for all standard sensor types except dissolved oxygen. These entries are the means to make adjustments in the sensor calibration by using field observations.

The *.con* file does not have *slope* and *offset* entries for dissolved oxygen sensors. For the SBE 43, the calibration coefficients *Soc* and *Voffset* are adjusted through comparison to Winkler titrations of discrete samples. For older oxygen sensors, *Soc* and *Boc* are adjusted.

Field Calibrations: Pressure



Pressure Offset, in the Lab or Field

- Physically locate the instrument in the orientation that it will have when deployed
- Make your offset measurement in a constant temperature environment, with the instrument temperature the same as the environment
- Measure your offset
 - **Best practice**, measure your offset against a barometer
 - In a pinch, measure your offset against sea level
- Maintain a log to observe pressure sensor drift

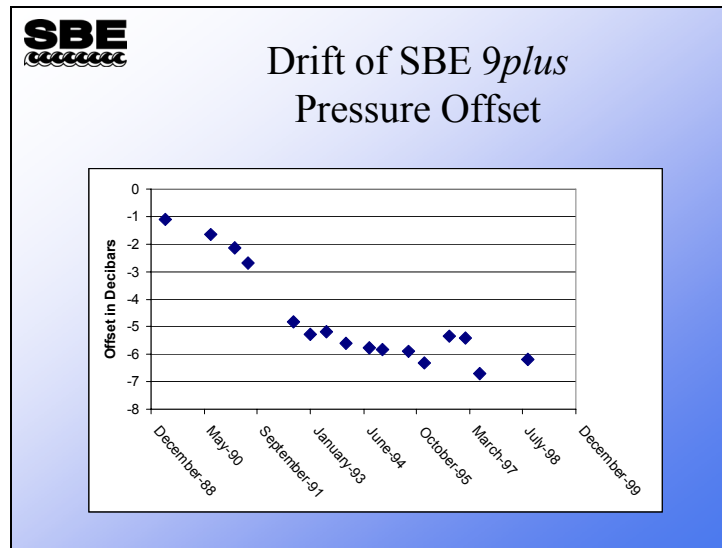
This discussion is primarily intended as a guide for the SBE *9plus* with a Digiquartz pressure sensor. However, the technique is sound for all pressure sensor types regardless of sensitivity.

All pressure sensors are sensitive to their orientation, primarily because of gravity's pull on the fluids that fill their capillaries. To correct for this orientation effect, determine the offset with the instrument in the same orientation that it will have when you deploy it.

Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature. Sea-Bird instruments are constructed to minimize this by thermally decoupling the sensor from the body of the instrument. There is still some residual effect, and the instrument should be allowed to equilibrate in a reasonably constant temperature environment.

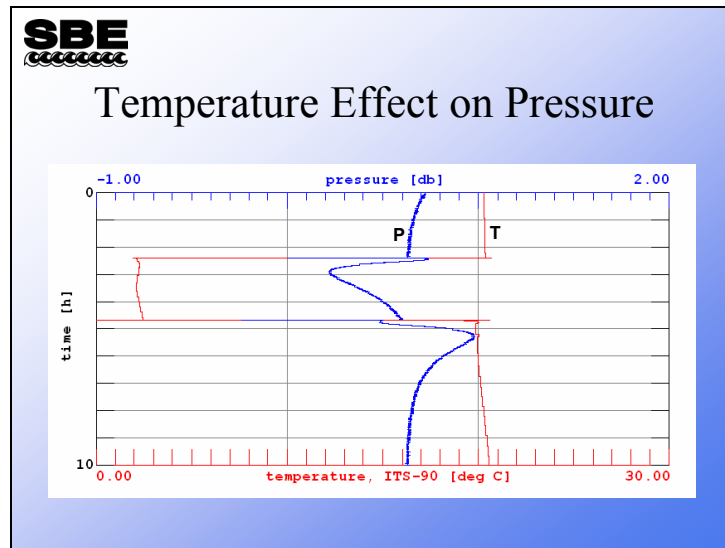
Measure the offset required to zero the pressure sensor with a barometer and convert to decibars for the entry in the *.con* file. As the next slide shows, a log of these offsets can provide good confirmation about the drift rate and show when the sensor needs maintenance.

Field Calibrations: Pressure (*continued*)



This sensor shows a typical drift until October 1995, when it begins to change in a more random manner. The random behavior indicates that it is time for a calibration and test by the factory.

Field Calibrations: Pressure (*continued*)



As we mentioned earlier, the SBE *9plus* pressure sensor exhibits small pressure excursions in response to rapid changes in temperature. If you are attempting to determine an offset for the pressure sensor in the field, you must take care that the instrument is equilibrated in temperature with its environment. As the plot shows, if you pull the instrument up from a very cold depth, it can take 4 to 5 hours for the pressure sensor to completely equilibrate. It is for this reason that Sea-Bird recommends a laboratory determination of offset in relation to a barometer.

Field Calibrations: Pressure (*continued*)



Pressure Offset in the Lab

- With offset in *.con* file set to 0.0, pressure measured by CTD should equal barometric pressure
- Calculate offset (db) = barometer reading – CTD reading
 - Conversion of psia to decibars: decibars = (psia - 14.7) * 0.6894759
- Enter calculated offset in *.con* file
- Example:
 - CTD reads -2.5 dbars
 - Barometer reads 14.65 psia. Converting to decibars, barometer reads $(14.65 - 14.7) * 0.6894759 = -0.034$ dbars
 - offset (db) = barometer reading – CTD reading = $-0.034 - (-2.5) = 2.466$

Field Calibrations: Pressure (*continued*)


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Entering Pressure Offset

- Pressure offset is entered with the calibration coefficients

Parameter	Value
Serial number	02446
Calibration date	951013
C1	-5.101973e+004
C2	6.660125e-001
C3	1.395839e-002
D1	3.342009e-002
D2	0.000000e+000
T1	2.879507e+001
T2	-7.653596e-005
T3	3.919516e-006
T4	0.000000e+000
T5	0.000000e+000
Slope	0.99978890
Offset	5.72000
AD590M	1.147000e-002
AD590B	-8.563950e+000

Field Calibrations: Temperature



Field Calibrations, Temperature

- Mercury deep sea reversing thermometers have an accuracy of ± 0.002 °C
- Electronic deep sea reversing thermometers have an accuracy of ± 0.002 °C, but can be read to ± 0.001 °C
- SBE 3 has an accuracy of ± 0.001 °C
- SBE 35 has an accuracy of > 0.001 °C


Traditional mercury deep-sea reversing thermometers are not capable of resolving temperature accurately enough to field calibrate the SBE 3. Nor do electronic deep-sea reversing thermometers have the accuracy for field calibrations. Sea-Bird markets a deep-sea standards thermometer, the SBE 35, which has the physical configuration to allow calibration in a triple point cell or a gallium melt cell.

However, you have to be very careful making field calibrations of deep-sea thermometers, because the distance between the two thermometers can make a great difference in the water they measure. Additionally, the part of the ocean used for comparison must change temperature very slowly, to avoid artifacts due to location on the sampling package and time constants.

A further difficulty is that the part of the ocean that changes most slowly is the deepest and coldest part. This means that field calibrations may be carried out over a small part of the temperature range of interest. The paper cited below discusses the authors' experiences and the issues discussed above.

It is best to use pre- and post-cruise calibrations for correction of temperature data.

Field Calibrations: Conductivity and Dissolved Oxygen



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Field Calibrations, Conductivity
and Dissolved Oxygen


- These require water samples
 - Laboratory determinations of salinity
 - Winkler titrations of dissolved oxygen

Field Calibrations: Discrete Sampling

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ocean

Field Calibrations: Discrete Samples


- You must take your samples in parts of water column where change in parameter of interest is small compared to size of underwater package
- Important point: sometimes water sample bottles leak!



Most instrument packages are more than a meter tall. If you take your samples for field calibrations in a part of the water column where the salinity or oxygen concentration is changing rapidly, you will not get a good sample for calibrating. Not only is there mixing of the water inside the water sampler, but you will be comparing a large mixed sample with a virtual point sample from the sensors.

Often the surface of the ocean is well mixed and provides good field calibrations for one end of the scale. And the deep ocean offers plenty of water where salinity and oxygen is changing very slowly for the other end of the scale.

Field Calibrations: Discrete Sampling (*continued*)

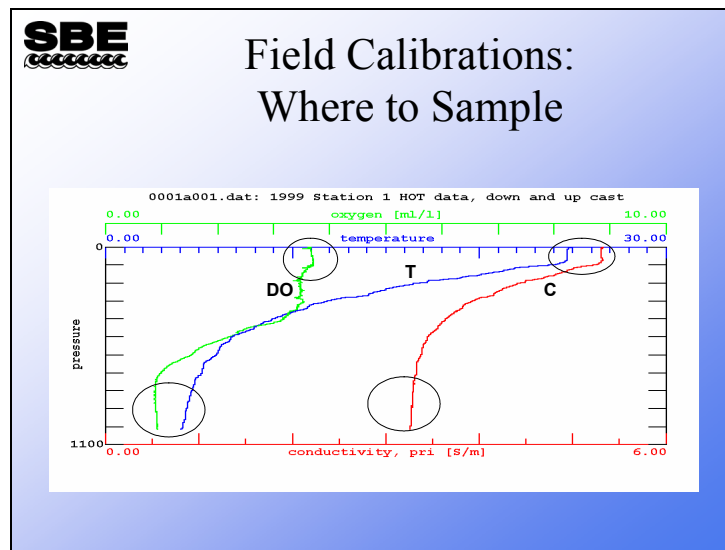


Field Calibrations:
Checking for Leaks

- Run underwater package down deep to nice, uniform water
- Close all water bottles
- Run salinities on each water bottle
- Compare salinities, fix leakers, and repeat

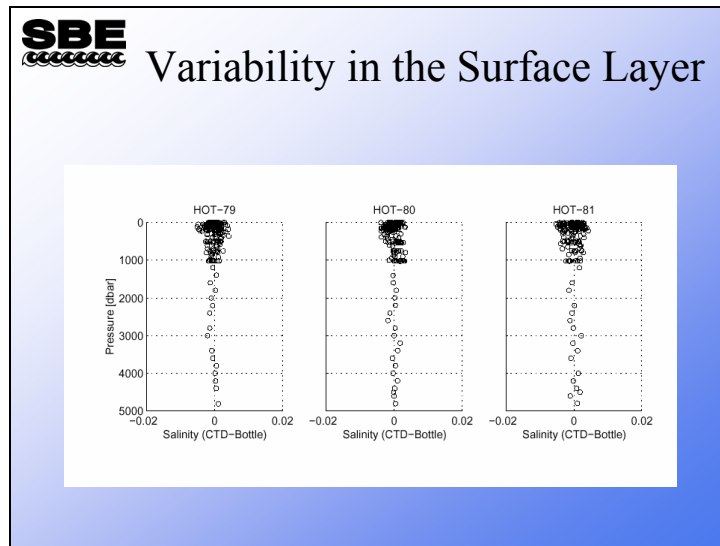
A water bottle consists of a plastic tube with top and bottom caps. The caps are sealed with o-rings and held in place with a spring or elastic tube. Consider that the instrument package moves through the water column on average at 1 meter per second, and faster when the ship heaves. Leaky o-rings or weak springs can allow an exchange of water between the captured sample and the ocean as the instrument package is brought to the surface. It is good practice to take the instrument package down to a depth where the salinity is changing very slowly, and then close all the sample bottles. Using this method, any leakers will be obvious when the laboratory salinity samples are run. Repair or replace any bottles that leak, or only use bottles that have been shown not to leak in field calibrations.

Field Calibrations: Discrete Sampling (*continued*)



Use samples from depths showing the most uniformity in the parameter you are most interested in.

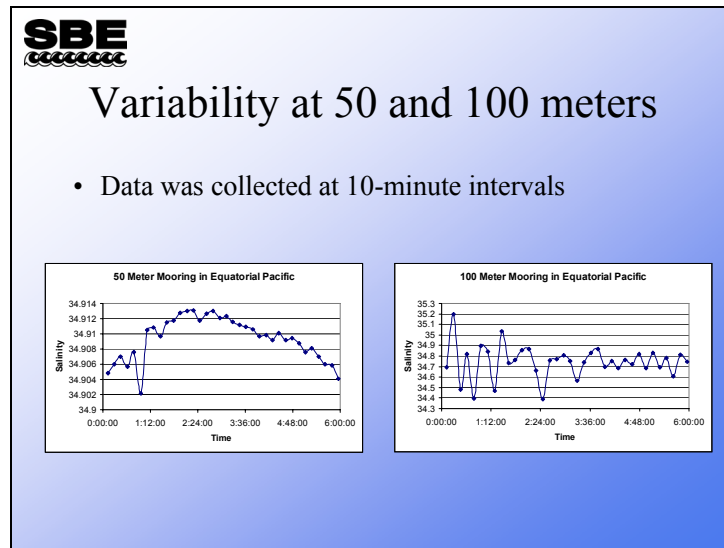
Field Calibrations: Conductivity



These data are taken from 3 cruises off Hawaii. The problem with using the surface layer to correct CTD conductivity is obvious.

L. Tupas, et al., Hawaii Ocean Time-series Data Report 9, 1997. University of Hawaii, School of Ocean and Earth Science and Technology. page 21


Field Calibrations: Conductivity (*continued*)



This slide shows data from a mooring near the equator. The 50-meter mooring data shows a change in salinity that might be from tidal influence. The change observed here is of similar magnitude to the correction that might be applied to CTD data based on the difference between discrete samples and the CTD.

The 100-meter mooring data shows changes in salinity that might be caused by internal waves in the thermocline. Changes of this magnitude over this time interval will cause a large and real difference between the upcast and downcast.

Field Calibrations: Conductivity (*continued*)



**Field Calibrations
of Conductivity**

- Correct pressure and temperature first
- Correct conductivity, not salinity!
- 0 – 10% of salinity error is due to pressure error
- 10 - 30% of salinity error is due to temperature error

Because the equation that converts the conductivity sensor output from frequency to conductivity includes pressure and temperature as well as frequency, it is necessary to correct pressure and temperature before correcting conductivity. The usual reason for collecting conductivity data is to calculate salinity. Examining the salinity equation, up to 10% of a possible salinity error could be in the pressure term, 10 – 30% in the temperature term, and the remainder in the conductivity term. It is well worth correcting pressure and temperature in addition to conductivity.

Field Calibrations: Conductivity (*continued*)

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ocean

Field Calibrations of Conductivity

- As with pre/post-cruise calibrations, correct conductivity with slope:

$$slope = \frac{\sum_{i=1}^n \alpha_i \beta_i}{\sum_{i=1}^n \alpha_i \alpha_i}$$

– Where

- n = number of samples
- α = CTD conductivity
- β = true (bottle sample) conductivity

The summation symbol, Sigma (\sum), denotes the addition of a series of values. The script on the bottom of the \sum is the index of the starting value, the script on the top is the ending value. We wish to use all suitable samples so we will start with one and end with n, the total number of samples.

Example:

Suppose we had 2 salinity samples to go with our CTD cast. The conductivity of these water samples is determined by a laboratory salinometer and paired with CTD data from the corresponding depths.

CTD Conductivity	Salinometer Conductivity
2.1234	2.1244
4.1234	4.1244

$$slope = \frac{(2.1234 * 2.1244) + (4.1234 * 4.1244)}{(2.1234 * 2.1234) + (4.1234 * 4.1234)}$$

$$slope = 1.00029$$

Field Calibrations: Conductivity (*continued*)

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Example Conductivity Correction

- Raw data is shown below
- Note that CTD temperature shown is ITS-90

CTD pressure	CTD temperature	CTD conductivity	CTD salinity	Bottle salinity
202.7	18.3880	4.63421	34.9705	34.9770
1008.8	3.9831	3.25349	34.4634	34.4710
4064.1	1.4524	3.16777	34.6778	34.6850

This example is a slight variation of the example in Application Note 31. You would find the CTD data in your *.ros* file, which is created by the Data Conversion module.

Field Calibrations: Conductivity (*continued*)



Step One: Conductivity Correction

- Correct P for +0.5 dbar error
- Correct T for +0.0015 °C error
- Recalculate CTD salinity for comparison to Bottle salinity

Corrected CTD pressure	Corrected CTD temperature	CTD conductivity	CTD salinity (T, P corrected)	Bottle salinity
202.2	18.3865	4.63421	34.9719	34.9770
1008.3	3.9816	3.25349	34.4653	34.4710
4063.6	1.4509	3.16777	34.6795	34.6850

Temperature and pressure are corrected first. CTD salinity is recalculated only for comparison to the bottle salinity. We will be correcting conductivity, not salinity.

Field Calibrations: Conductivity (*continued*)

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SeacaleW

Step Two: Conductivity Correction

- Bottle conductivity is calculated at CTD corrected T and P using SeacaleW
- Note slope shown in CTD – Bottle conductivity

CTD conductivity	Bottle conductivity	CTD – Bottle conductivity
4.63421	4.63481	-0.00060
3.25349	3.25398	-0.00049
3.16777	3.16822	-0.00045

The numbers in the column labeled *CTD – Bottle conductivity* are not constant. Rather, they have the slope we have been harping on.

Let's look at calculating the slope:

$$slope = \frac{\sum_{i=1}^n \alpha_i \beta_i}{\sum_{i=1}^n \alpha_i \alpha_i}$$

Slope =

$$\frac{(4.63421 * 4.63481) + (3.25349 * 3.25398) + (3.16777 * 3.16822)}{(4.63421 * 4.63421) + (3.25349 * 3.25349) + (3.16777 * 3.16777)}$$

$$= 1.000138$$

Field Calibrations: Conductivity (*continued*)

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Step Three: Conductivity Correction


- Slope calculated from previous slide is 1.000138
- Place slope in slope entry of conductivity calibration coefficients; Corrected CTD conductivity = CTD conductivity * slope
- Corrected CTD salinity is calculated from corrected CTD conductivity shown here, and corrected temperature and pressure from Step 1

Corrected CTD conductivity	Corrected CTD salinity	Bottle Salinity
4.63485	34.9773	34.9770
3.25394	34.4706	34.4710
3.16821	34.6849	34.6850

The correction puts the CTD salinities much closer to the bottle salinities. You may be wondering what to do if you collect bottle salinities with every cast and have many casts in a cruise. It would be a bit onerous to make this calculation for every cast and process each cast with a different offset. Usually, making this calculation and changing the slope value in the conductivity sensor's calibration coefficients each week is sufficient.

However as we have discussed, fouling is often *an event*. This being the case, careful scrutiny of your data is warranted to ensure that you catch these events and change the slope correction accordingly.

Field Calibrations: Dissolved Oxygen




Field Calibrations:
Correcting Dissolved O₂

- Dissolved oxygen sensors drift in slope, like conductivity
- The *Soc* and *Voffset* coefficients are adjusted to account for the drift
- The means of field correction is similar in concept to corrections for conductivity

There are two mechanisms at work in oxygen sensor drift. Since the electrode remains polarized throughout its life, the electrolyte gets used up and there is some diminishing of the sensitivity of the electrode itself. There is also fouling, which can be *an event* like in the conductivity example. Check your oxygen data with bottle samples and make corrections to *Soc* at your discretion.

Field Calibrations: Dissolved Oxygen (*continued*)



Field Calibrations: Correcting Dissolved O₂

- Dissolved oxygen equation (ml/l) from Owens-Millard (1985):


$$\text{Oxygen}(ml/l) = \left\{ Soc * \left(V + V_{offset} + \tau * \frac{\partial V}{\partial t} \right) + Boc * e^{(-0.03 * T)} \right\} * O_{xsat}(T,S) * e^{(tcor * T)} * e^{(pcor * P)}$$

- Where:
 - V = SBE 43 output voltage signal (volts)
 - dV/dt = time derivative of SBE 43 output signal (volts / second)
 - T = CTD temperature in (°C)
 - S = CTD salinity (psu)
 - P = CTD pressure (dbars)
 - $O_{xsat}(T,S)$ = oxygen saturation (ml / l)
 - Soc , Boc , V_{offset} , τ , $tcor$, and $pcor$ are calibration coefficients

The basis for calculating dissolved oxygen is work done by Owens and Millard (1985). This equation includes a blank or zero oxygen term, Boc , and a term that is proportional to the first derivative of the oxygen sensor output voltage, $\tau * \delta V / \delta t$. The Boc term is redundant for the SBE 43, because the sensor output is offset by a V_{offset} term which takes the place of Boc .

The term that is proportional to the first derivative of the sensor output was introduced to sharpen the response of the sensor to rapid changes in oxygen concentration. The SBE 43 was designed for profiling applications and does not suffer the poor response times of previous sensors. In consideration of this, the derivative term is left out of the equation used to calculate oxygen concentration from output voltage for the SBE 43.

Field Calibrations: Dissolved Oxygen (*continued*)



Field Calibrations: Correcting Dissolved O₂


- For the SBE 43, set *Boc* and τ to zero:

$$\text{Oxygen}(ml/l) = \{Soc * (V + Voffset)\} * Oxsat(T,S) * e^{(tcor * T)} * e^{(pcor * P)}$$

- SBE 43 produces an output voltage linear with respect to Oxygen partial pressure
- *SOC* is the slope term, and will change as the sensor loses sensitivity
- *tcor* and *pcor* correct for small secondary responses to temperature and pressure: these change very slowly over time.

The SBE 43 is expected to provide an output voltage that is linear with respect to oxygen concentration. Normal calibration drift manifests itself as a loss of sensitivity and is evident as a change of slope and offset in the linear relationship between oxygen concentration and voltage output. The coefficients *tcor* and *pcor* correct for small secondary responses to temperature and pressure. Because these coefficients change very slowly over time, the values given on the SBE 43 calibration certificate will be used in this analysis.

Field Calibrations: Dissolved Oxygen (*continued*)



Field Calibrations:
Correcting Dissolved O₂

- For a field correction we will rearrange the previous equation into a linear form, let:


$$\phi = e^{(tcor*T)} * Oxsat(T,S) * e^{(pcor*P)}$$

- Oxygen equation reduces to:

$$oxygen(ml/l) = Soc * (V + Voffset) * \phi$$

Our goal is to rearrange the equation into a linear form that we can use in a linear regression of Winkler titration dissolved oxygen versus SBE 43 voltage output. To simplify this we will collect terms and express oxygen saturation and the corrections for pressure and temperature as *phi*.

Field Calibrations: Dissolved Oxygen (*continued*)

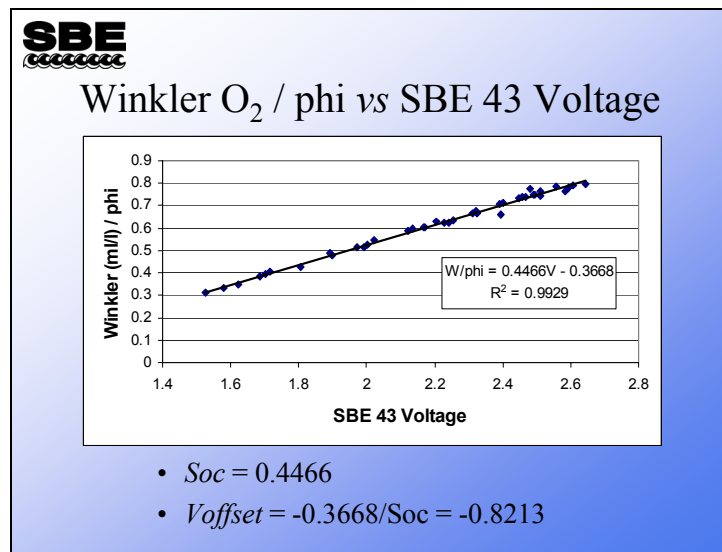


Field Calibrations:
Correcting Dissolved O₂

- The previous equation may be expressed in linear form as:
$$\frac{\text{oxygen}(ml/l)}{\phi} = Soc * (V + Voffset) = M * V + B$$
- Where:
 - $Soc = M$
 - $Voffset = B / M$

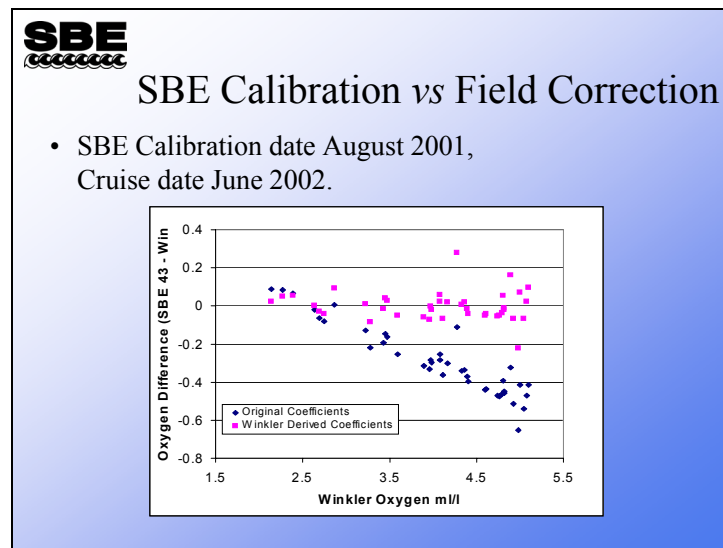
Finally, Winkler titration values divided by *phi* is the independent variable and SBE 43 output voltage is the dependent variable. Note that *Soc* and *Voffset* are constants, so the right side of the equation is expressed as a slope (*Soc*) multiplied by a variable voltage plus a constant offset (*Voffset*).

Field Calibrations: Dissolved Oxygen (*continued*)



Here is a plot and regression of some data gathered in Puget Sound. Even though Puget Sound is not a well-mixed environment, there is a very strong relationship between Winkler O₂ / *phi* and SBE 43 Voltage.

Field Calibrations: Dissolved Oxygen (*continued*)



This plot shows the improvement in agreement between the Winkler titrations of dissolved oxygen and the SBE 43 measurement of dissolved oxygen after application of the Winkler-derived *Soc* and *Voffset*. The blue diamonds are the difference between the Winkler values and the SBE 43 values using *Soc* and *Voffset* from the most recent calibration. The pink squares are the difference between the Winkler values and the SBE43 values using the derived *Soc* and *Voffset*.

Field Calibrations: Dissolved Oxygen (*continued*)

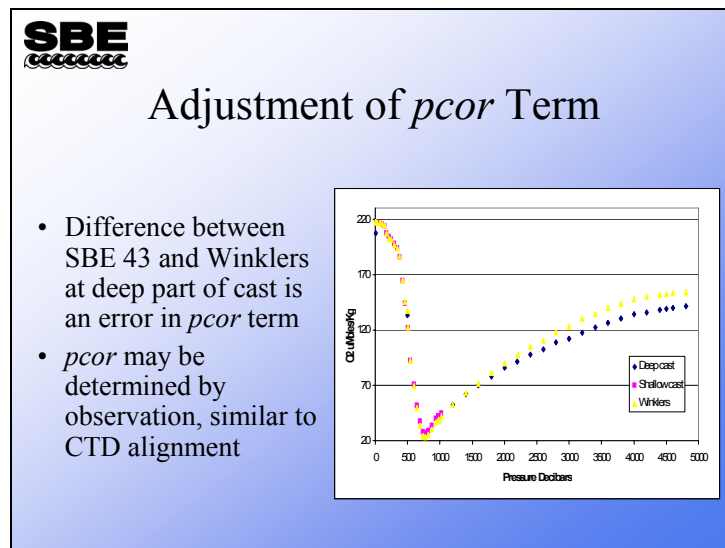
SBE Dissolved Oxygen Measurement
in Deep Water

$$\text{Oxygen}(ml/l) = \{Soc * (V + Voffset)\} * Oxsat(T,S) * e^{(tcor * T)} * e^{(pcor * P)}$$

- The function $Oxsat(T,S)$ calculates the maximum partial pressure of oxygen that will not out gas from water of a given salinity and temperature
- Soc scales the sensor output to a fraction of oxygen saturation
- Terms containing $tcor$ and $pcor$ correct for secondary effects of temperature and pressure

Recall the dissolved oxygen equation; basically it is a scaling of oxygen saturation based on sensor output with a correction for temperature sensitivity and for pressure sensitivity. In the following discussion we will explore the pressure correction and learn how to fine tune it with adjustments to $pcor$.

Field Calibrations: Dissolved Oxygen (*continued*)



As you might imagine, the term in the equation that corrects for pressure effects has little effect in the upper part of the profile. The slide above illustrates that as the pressure increases, the response of the instrument deviates from the Winkler titrations. We can improve the agreement of the SBE 43 and the Winkler titrations by adjusting $pcor$.

Field Calibrations: Dissolved Oxygen (*continued*)

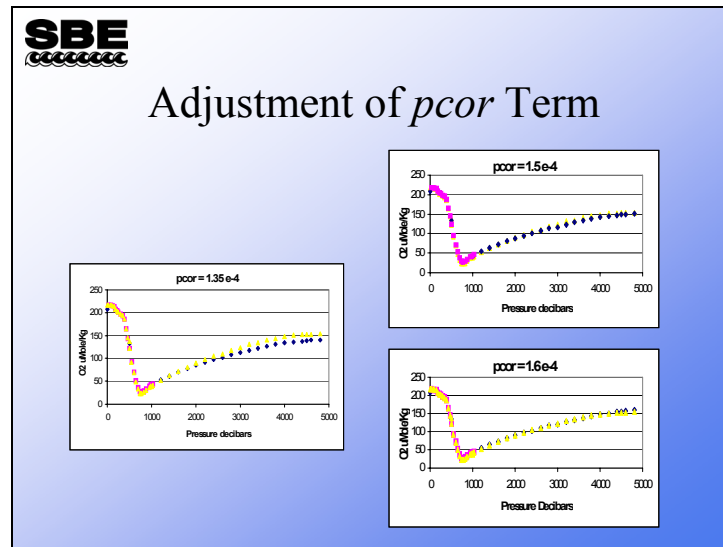
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Adjustment of *pcor* Term

The image shows two overlapping software windows from SBE. The background window is titled 'Configuration for the SBE 911/917 plus CTD'. It features a table for channel configuration with columns for Channel, Sense, and Menu. Channel 11 is highlighted in blue and is labeled 'Dxygen, SBE 43'. Other channels include Temperature, Conductivity, and various sensors. The foreground window is titled 'Dxygen, SBE 43' and contains calibration parameters for the oxygen sensor. The parameters are as follows:

Parameter	Value
Serial number	0124
Calibration date	08-Jan-02
Soc	3.1390e-001
Boc	0.0000
Voffset	-0.5791
Tcor	0.002000
Pcor	1.50e-004
Tau	0.0

Field Calibrations: Dissolved Oxygen (*continued*)



We can make the adjustment to $pcor$ empirically. The plots above show the discrepancy between the SBE 43 calculated oxygen and the Winkler titrations with a series of $pcor$ values. Clearly, the middle value of 1.5×10^{-4} gives the best agreement.

PALACE Float: No Conductivity Drift (almost)



High Accuracy Data: As Good as it Gets

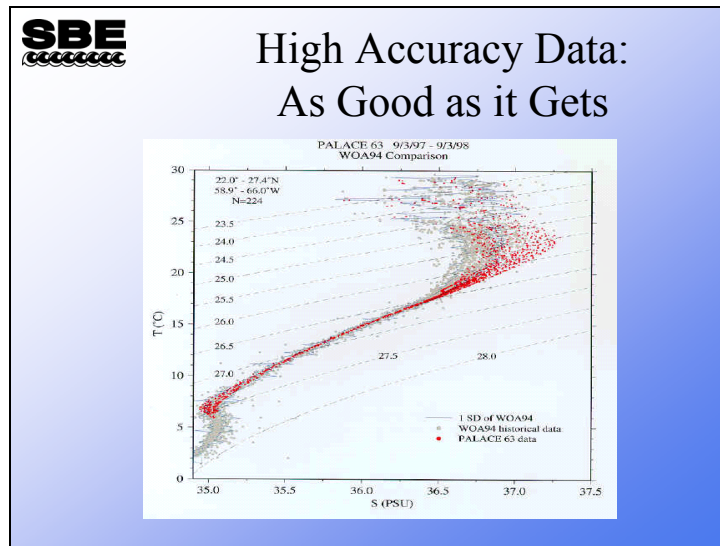
- Autonomous profiling instruments:
 - Get placed in ocean,
 - Sink to a pre-programmed depth,
 - Wait at depth, and
 - Then surface, collecting data as they rise
- Data is transmitted to an ARGO satellite
- Instrument receives no handling after deployment



These CTDs have a significant advantage over the usual deployments with regard to conductivity drift. They are deployed from ships with their conductivity cells full of de-ionized water, and have no contact with ships or humans for the remainder of their lives. They are never exposed to the sea surface near a ship with its oil film. Finally, their cells are never allowed to dry, so the electrodes are always stored in biology-resistant water.

The consequence of this is that their conductivity sensors drift negligibly or not at all.

PALACE Float: Compared to Historical Data



Note the low scatter in the mid-region compared to historical CTD data. Also, note the shift in surface values, PALACE being saltier than historical data.

Activity: Correct CTD Conductivity with Water Samples

Pressure db	CTD Temp	CTD Cond	Uncorrected CTD Salinity	Water Bottle Salinity	Water Bottle Cond	Corrected CTD Temp	Corrected CTD Cond	Corrected CTD Salinity	Corrected CTD Salinity-Water Bottle Salinity
4.9	24.0798	5.23638	35.1885	35.2055		24.0798			
519	6.6922	3.43991	34.0769	34.0848		6.6922			
850.6	4.4142	3.27659	34.3667	34.3738		4.4142			
1000.8	4.003	3.25475	34.4616	34.472		4.003			
1202.3	3.5221	3.22482	34.5083	34.5148		3.5221			
1401	3.039	3.19378	34.5452	34.5503		3.039			
1599.6	2.6724	3.1719	34.5692	34.5769		2.6724			
1999.1	2.1309	3.1445	34.6131	34.6194		2.1309			
2400.2	1.7884	3.13273	34.6392	34.6463		1.7884			
2798.9	1.5911	3.13234	34.6563	34.6645		1.5911			
3200.1	1.4927	3.1397	34.6674	34.676		1.4927			
3600.3	1.4587	3.15175	34.6737	34.6829		1.4587			
4001.5	1.4537	3.16568	34.6772	34.6853		1.4537			
4401.9	1.4766	3.18142	34.6790	34.6871		1.4766			
4500.7	1.4868	3.18558	34.6788	34.6883		1.4868			
4600.8	1.4969	3.18976	34.6789	34.6883		1.4969			
4809.4	1.5119	3.19792	34.6795	34.6884		1.5119			

1. What temperature scale is CTD temperature reported in? What temperature scale is used to calculate conductivity?
2. Use SeaCalcW to calculate “Water Bottle Conductivity” using “Corrected CTD Temp” and “Water Bottle Salinity”.
3. Calculate a conductivity correction slope based on the shaded portion of the table. We are using 3 data rows in class as a quick exercise. Normally, how much of the table would you use? Recall pages 17 and 20.

CTD Conductivity Corrected With Water Samples

Pressure db	CTD Temp	CTD Cond	Uncorrected CTD Salinity	Water Bottle Salinity	Water Bottle Cond	Corrected CTD Temp	Corrected CTD Cond	Corrected CTD Salinity	Corrected CTD Salinity-Water Bottle Salinity
4.9	24.0798	5.23638	35.1885	35.2055	5.23862	24.0798	5.23763	35.1980	-0.0075
519	6.6922	3.43991	34.0769	34.0848	3.44062	6.6922	3.44073	34.0861	0.0013
850.6	4.4142	3.27659	34.3667	34.3738	3.27720	4.4142	3.27737	34.3758	0.0020
1000.8	4.003	3.25475	34.4616	34.472	3.25563	4.003	3.25553	34.4708	-0.0012
1202.3	3.5221	3.22482	34.5083	34.5148	3.22537	3.5221	3.22559	34.5175	0.0027
1401	3.039	3.19378	34.5452	34.5503	3.19420	3.039	3.19454	34.5544	0.0041
1599.6	2.6724	3.1719	34.5692	34.5769	3.17253	2.6724	3.17266	34.5785	0.0016
1999.1	2.1309	3.1445	34.6131	34.6194	3.14502	2.1309	3.14525	34.6223	0.0029
2400.2	1.7884	3.13273	34.6392	34.6463	3.13331	1.7884	3.13348	34.6484	0.0021
2798.9	1.5911	3.13234	34.6563	34.6645	3.13301	1.5911	3.13309	34.6655	0.0010
3200.1	1.4927	3.1397	34.6674	34.676	3.14039	1.4927	3.14045	34.6767	0.0007
3600.3	1.4587	3.15175	34.6737	34.6829	3.15250	1.4587	3.15250	34.6829	0.0000
4001.5	1.4537	3.16568	34.6772	34.6853	3.16634	1.4537	3.16644	34.6864	0.0011
4401.9	1.4766	3.18142	34.6790	34.6871	3.18208	1.4766	3.18218	34.6883	0.0012
4500.7	1.4868	3.18558	34.6788	34.6883	3.18636	1.4868	3.18634	34.6881	-0.0002
4600.8	1.4969	3.18976	34.6789	34.6883	3.19054	1.4969	3.19052	34.6881	-0.0002
4809.4	1.5119	3.19792	34.6795	34.6884	3.19865	1.5119	3.19868	34.6888	0.0004

Note: For Shaded section of table:

Sum of CTD conductivity * Water Sample conductivity = 30.55649

Sum of CTD conductivity * CTD conductivity = 30.54918

Ratio used to correct CTD conductivity = 1.000239