


**Module 0**

**Introduction to Sea-Bird  
Electronics Training  
for Data Collection  
in the Ocean**

## SBE Training Introduction




**Sea-Bird Electronics Training for  
Data Collection in the Ocean**

- Monday and Tuesday
  - Measurement of Ocean Profiles
  - Sea-Bird Tour
- Wednesday
  - Troubleshooting / Maintenance and Repairs
- Thursday
  - Time Series Measurements with Moored Instruments

Welcome to Sea-Bird Electronics training course. The next few slides will show you what we are going to cover in a little more detail.

## Topics We Will Cover



**SBE**  
seatech

### Topics We Will Cover

- Introduction
  - Oceanographic basics
- Profiling Equipment
  - Internally recording
  - Real time
  - Water sampling equipment
- Profiling Setup and Data Acquisition
  - User interface to internally recording instruments:  
*SeatermV2, Seaterm, and SeatermAF*
  - Seasoft's real-time data application *Seasave*

## Topics We Will Cover (*continued*)



- Data Conversion and Plotting
  - Conversion of raw instrument output to scientific units
  - Plotting with *Sea Plot*
- Water Sampling and Deployment
  - Sampling equipment
  - User interface
  - Deployment issues
- Miscellaneous Applications
  - Adding Latitude and Longitude to your data
  - Fresh water applications
  - Thermosalinographs

## Topics We Will Cover (*continued*)

**SBE**  
*seawater*

- Making Measurements in the Ocean
  - Sampling theory and sensor characteristics
  - Coordinating measurements in space and time
  - Comparison of sampling for different instruments
- Getting the Highest Accuracy Data
  - Care of sensors in field
  - Calibrations in general
  - Sensor drift characteristics
  - Pre- and post-deployment calibrations
  - Field calibrations

## Topics We Will Cover (*continued*)

**SBE**  
*oceanic*

- Advanced Data Processing
  - Sensor alignment, matching measurements of same water parcel
  - Underwater package-induced errors
  - Correcting for conductivity cell thermal mass
  - Data editing and filtering
  - Bin averaging data
- Troubleshooting
- Maintenance / Repairs
  - Preparation for deployment

---

## Topics We Will Cover (*continued*)


**SBE**  


- Moored Instruments
  - SBE 16, 16*plus*, and 16*plus* V2
  - SBE 37
  - SBE 39
  - Inductive modem telemetry
- Setup of Moored Instruments
- Auxiliary Sensors (WetLABS ECOs and FLNTU)
- Getting the Highest Quality Data with Moored Instruments
  - Care of sensors in field
  - Calibrations in general
  - Sensor drift characteristics
  - Pre- and post-deployment calibrations

## Introduction: Ocean Profiling

**SBE** *What is a *Profile* and Why Do We Want One?*

- *Profiling* means lowering an instrument from surface of ocean to some depth
- Instrument measures environmental parameters (e.g., pressure and temperature) as it is lowered
- Relationship between measured parameters is used for scientific purposes
  - For example: Prediction of ocean currents



A profile is a set of data for one or more environmental measurements, such as temperature and salinity, taken at a regular interval over the ocean depth. In the beginning, there were few options for obtaining ocean data. The most common means were:

- Hydrocasts
 

Oceanographers hung water samplers on a cable lowered into the ocean, then dropped a weight down the cable to close the sample bottle and capture a water sample, released another weight to trigger the next sample bottle, and so on. Once the samples were retrieved, discrete samples could be analyzed for temperature and salinity. Accuracy was poor by modern standards, and only 12 – 24 data points were obtained for the whole water column. They yearned for more data points.
- Bathythermograph
 

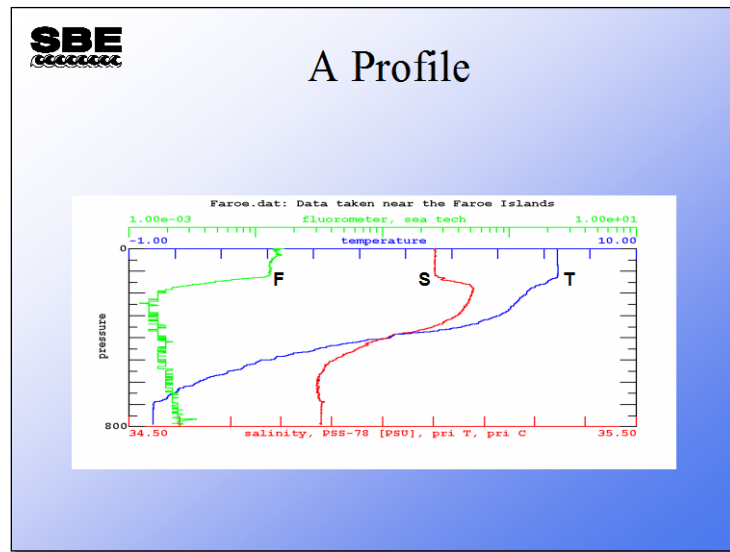
The bathythermograph was towed from a ship as it was lowered on a cable. It scratched a trace of the temperature versus depth on a coated glass slide. This provided more points, but only for temperature and only for relatively shallow depths. People still yearned for more data.
- Modern sensors and profiling equipment
 

Equipment that could make measurements and telemeter these measurements from the end of a conducting cable back to the ship was invented; now there were more points, and life was good. However, there was room for improvement. There has been steady refinement in profiling equipment, data is telemetered digitally, sensors are improved, water sampling equipment is attached to the measurement package, and samplers capture their water on command from the computer on the ship. There are sensors available to measure a wider variety of parameters.

What do we do with our profile? We estimate deep ocean currents based on density profiles. We look for sharp density changes to investigate the interesting chemical and biological processes that go on there. We look for the boundaries of surface ocean currents. We look for the movements of different water masses near shore that indicate upwelling or currents that move sediment along the shore. We measure a sound velocity profile so we can refine our acoustic investigation of the ocean bottom. We discover the depth at which a basin becomes anoxic. We are only limited by our imagination.

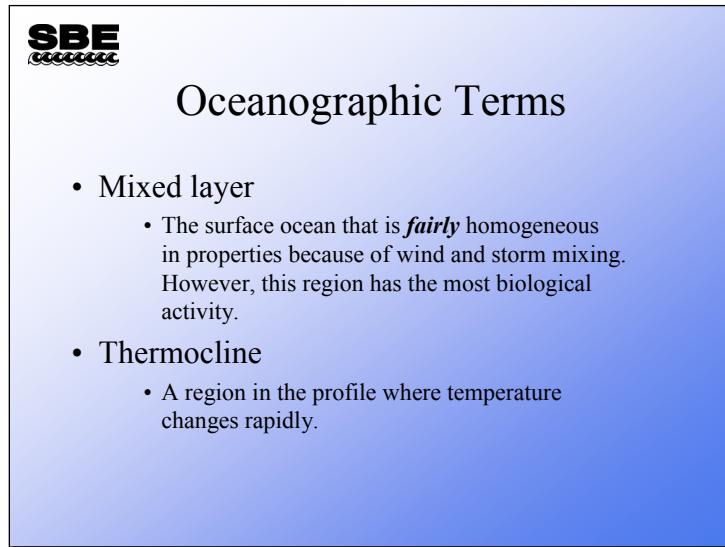


## Introduction: Ocean Profiling



This profile was collected with an SBE 911*plus* system near the Faroe Islands.

## Introduction: Oceanographic Terms



**SBE**  
cccccc

### Oceanographic Terms

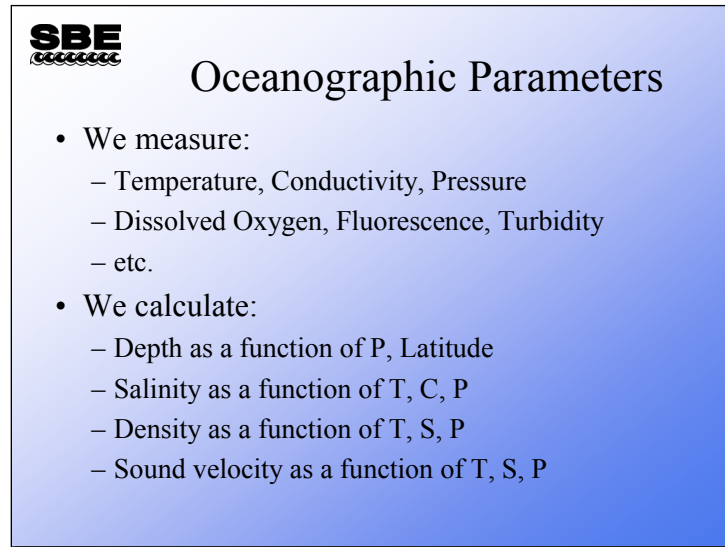
- Mixed layer
  - The surface ocean that is *fairly* homogeneous in properties because of wind and storm mixing. However, this region has the most biological activity.
- Thermocline
  - A region in the profile where temperature changes rapidly.

The ocean is often spoken of as a two-layer system: a mixed or surface layer and a deep layer. The mixed layer or surface layer is as it sounds, at the surface of the ocean and well mixed by wind and waves. The deep layer is separated from the surface by a region of rapidly changing temperature referred to as the thermocline. Because density is a strong function of temperature, the water in this area also changes sharply in density. The change in density makes it difficult for water in the deep ocean to mix with water in the surface ocean, effectively separating the deep layer from the mixed layer.

**Definitions of many other oceanographic terms and parameters are available in the Glossary that is at the back of your binder.**

---

## Introduction: Oceanographic Parameters


A blue gradient rectangular box containing the SBE logo and a list of oceanographic parameters. The logo is in the top left, followed by the title 'Oceanographic Parameters'. Below the title is a bulleted list with two main categories: 'We measure' and 'We calculate', each with several sub-items.

**SBE**  
Oceanographic Parameters

- We measure:
  - Temperature, Conductivity, Pressure
  - Dissolved Oxygen, Fluorescence, Turbidity
  - etc.
- We calculate:
  - Depth as a function of P, Latitude
  - Salinity as a function of T, C, P
  - Density as a function of T, S, P
  - Sound velocity as a function of T, S, P

We measure physical quantities with Sea-Bird instruments. These quantities are then used to calculate the many parameters that are found in the analysis of oceanographic data. Because the calculated parameters rely on accurate measurement of the physical quantities, a small error in the original measurement can result in a large error in data analysis.

## Introduction: Oceanographic Parameters (*continued*)




**Which Temperature Should I Use?**

- The International Temperature Scale is agreed upon by a committee of scientists.
- They agreed in 1968, producing the IPTS-68 temperature scale.
- Based on improved data they agreed again in 1990, producing ITS-90.
- Oceanographic temperatures are reported in ITS-90
- Over the oceanographic range:  
$$\text{IPTS68} = \text{ITS90} * 1.00024$$

The calculation of the parameters mentioned on the previous slide is made with equations of the physical parameters. These equations were derived by gathering data in a laboratory relating T, P, and C to the parameter of interest, and statistically fitting the data to high order polynomials. The coefficients of the polynomials were determined using the 1968 temperature scale. So, to use these high-order polynomials, we must convert to the 1968 temperature scale for these calculations.

---

## Introduction: Oceanographic Parameters (*continued*)



### What is Salinity?

- Salinity was defined in 1902 as the amount of salts in 1 kg of seawater. Major salts are:
  - NaCl, MgCl<sub>2</sub>, MgSO<sub>4</sub>, CaSO<sub>4</sub>
- As an approximation, 35 grams of salts dissolved in 1 liter of water equals 35 PSU salinity (1 liter fresh water weighs 1 kg)
- The relative proportions of the salts in seawater are (*almost*) always the same
- Conductivity is a function of temperature (90%) and salinity (10%)
- Water of a given salinity at a given temperature will have the same salinity if taken to a different temperature

The basis of the PSU calculations is the assumption that the relative proportion of each salt in seawater remains constant all over the ocean. This means that if we compare a kg of seawater at 35.000 PSU with a kg of seawater at 20.000 PSU, only the proportion of water in each is different. This does not hold true in areas of freshwater influence, such as river estuaries, or at high Latitudes when the ice is melting. Similarly it does not hold true in brines, either those formed by evaporation of seawater or from dissolution of salt domes or formed via volcanic influence.

## Introduction: Oceanographic Parameters (*continued*)



### How Do We Calculate Practical Salinity From Conductivity?

- A committee of scientists commissioned work to create an equation that relates salinity to conductivity.
- The Practical Salinity Scale of 1978 was born (PSS 78).
- PSS 78 uses the 1968 temperature scale!
- To calculate Practical Salinity, we must convert our ITS-90 temperatures to IPTS-68.

Salinity is calculated from several polynomials that characterize seawater's thermodynamic behavior in terms of conductivity, temperature, and pressure. The calculation is based on the ratio of the seawater sample conductivity to the conductivity of standard seawater. The polynomials were determined by statistically fitting the coefficients of these equations to laboratory results. The Practical Salinity Scale of 1978 is only valid when used with the temperature scale of 1968 over a temperature range of -2 °C to 35 °C, and it is only valid for seawater that has salinity between 2 and 42 practical salinity units (PSU).

Note that Sea-Bird calibrates temperature sensors using the ITS-90 scale. In our real-time data acquisition software and data processing software, the ITS-90 temperatures are automatically converted to IPTS-68 temperatures before input to the salinity equation.

## Introduction: Oceanographic Parameters (*continued*)

**SBE** Absolute Salinity and TEOS-10

- New Thermodynamic Equation of State of Seawater TEOS-10 (see Application Note 90)
  - Thermodynamic properties of seawater influenced by total mass of dissolved constituents
  - Dissolved constituents regionally variable, not always accurately represented when using conductivity measurements
  - Algorithm estimates Absolute Salinity, based on Practical Salinity
- SeaCalc (seawater calculator in SBE Data Processing) allows for calculation of Absolute Salinity for 1 user-input data scan
- Derive TEOS-10 (module in SBE Data Processing) calculates TEOS-10 variables when processing data sets
- For rest of course, when we talk about *Salinity* we are talking about *Practical Salinity*

IAPSO recommends that only Practical Salinity be stored in data repositories:

- Absolute Salinity derived from a combination of C, T, P as well as other measurements and corrections that are not yet well established.
- Important to not create confusion in national data bases with a change in reporting of salinity.
- Algorithm for determining Absolute Salinity is immature, and will likely change.

In 2013, Sea-Bird released SBE Data processing version 7.23.1, which includes:

- SeaCalc III (seawater calculator module that computes a number of derived variables from one user-input data scan), , and
- Derive TEOS-10, which allows you to calculate most relevant TEOS-10 variables when processing data sets.

Application Note 90 on our website ([www.seabird.com/application\\_notes/AN90.htm](http://www.seabird.com/application_notes/AN90.htm)) provides more details.

## Introduction: Oceanographic Parameters (*continued*)

**SBE**  
Seabird Electronics

### Oceanographic Density

- By definition, the density of fresh water is 1.0000 kilogram/liter
- The density of seawater might be 1.0250 kilograms/liter
- Oceanographers report density as a “sigma” value, which is (density -1) \* 1000 (in our example, 25.000)
- Further, “sigma” is referenced to pressure, sigma-t being at the surface, sigma-theta being at *in-situ* pressure and sigma-1000, sigma-2000, etc. being referenced to 1000 decibars, 2000 decibars, etc.

Parameter	Units	Definition	Additional Information
$\rho(t, s, p)$	kg/m <sup>3</sup>	Density as a function of temperature, salinity, and pressure	<ul style="list-style-type: none"> <li>• Relationship with T and S nonlinear (more so for T)</li> <li>• Less sensitive to T at low T</li> </ul>
$\sigma(t, s, p)$	-	$\text{Sigma} = \rho(t, s, p) - 1000$	<ul style="list-style-type: none"> <li>• Used because variations in oceanic density are very small</li> <li>• Includes pressure effect on density</li> <li>• Pressure effect on T and S not accounted for</li> <li>• Most variations in density due to direct effects of pressure; however, dynamically important changes are not due to pressure, so this parameter is less commonly used</li> </ul>
$\sigma_t(t, s, 0)$	-	$\text{Sigma-t} = \rho(t, s, 0) - 1000$	<ul style="list-style-type: none"> <li>• Sigma at atmospheric pressure</li> </ul>
$\sigma_\theta(\theta, s, 0)$	-	$\text{Sigma-theta} = \rho(\theta, s, 0) - 1000$	<ul style="list-style-type: none"> <li>• Removes effect on density caused by adiabatic cooling / heating</li> <li>• Removes pressure effect on density</li> </ul>



## Introduction: Oceanographic Parameters (*continued*)


**SBE**  
Seabird Electronics

### More Oceanographic Parameters

- Potential temperature is temperature a parcel of water would have at surface
- Specific volume is inverse of density, provides a convenient way to look at density variations in deep ocean
- Specific volume anomaly
- Thermosteric anomaly

Parameter	Units	Definition	Additional Information
$\theta$	deg C	Potential temperature = Temperature of sample brought adiabatically to surface (no heat exchange with surrounding water as raised)	<ul style="list-style-type: none"> <li>• Temperature parcel of water would have at surface</li> <li>• Used to compare waters at significantly different depths, and used for describing vertical motions over large depth ranges</li> </ul>
$\alpha(t, s, p)$	m <sup>3</sup> /kg	Specific volume = $1/\rho(t, s, p)$	<ul style="list-style-type: none"> <li>• Convenient way to look at density variations in deep ocean</li> </ul>
$\alpha(0, 35, p)$	m <sup>3</sup> /kg	$1/\rho(0, 35, p)$	<ul style="list-style-type: none"> <li>• Specific volume of arbitrary seawater standard (0 deg C, 35 PSU) at depth of sample</li> </ul>
$\delta$	m <sup>3</sup> /kg	Specific volume anomaly = $\alpha(t, s, p) - \alpha(0, 35, p) = \delta_s + \delta_t + \delta_{s,t} + \delta_{s,p} + \delta_{t,p} + \delta_{s,t,p}$	<ul style="list-style-type: none"> <li>• Sum of 6 anomalies of specific volume due to t, s, p</li> </ul>
$\Delta_{s,t}$	m <sup>3</sup> /kg	Thermosteric anomaly = $\delta_s + \delta_t + \delta_{s,t}$	<ul style="list-style-type: none"> <li>• Accounts for most of the density effect due to t, s</li> <li>• <math>\delta_{s,t,p}</math> is quite small, so is usually ignored</li> </ul>

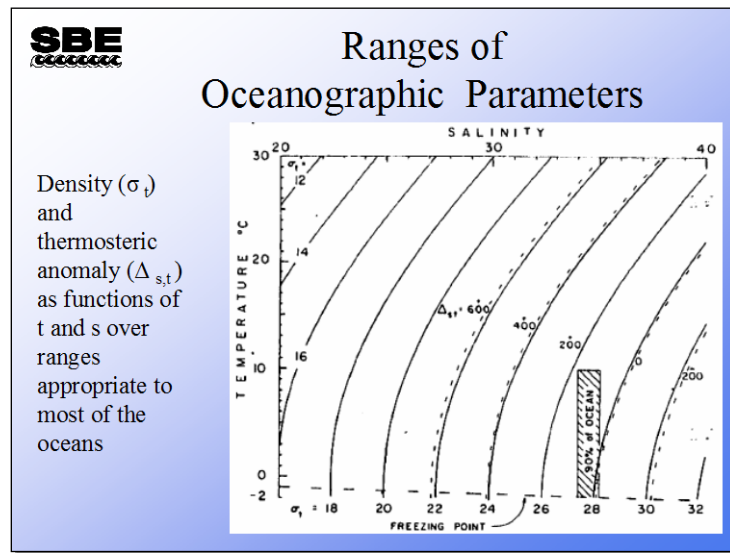
## Introduction: Oceanographic Parameters (*continued*)



Ranges of  
Oceanographic Parameters

- Temperature: -2 to 35 °C
  - Best accuracy:  $\pm 0.001$  °C
- Conductivity: 0.0 to 7.5 Siemens/meter
  - Best accuracy:  $\pm 0.0003$  S/m
  - SBE 19+V2s range 0-9.0 S/m
  - Some CTDs can be modified for higher conductivity
- Salinity: 2 to 42 PSU
  - Best accuracy:  $\pm 0.002$  PSU

## Introduction: Oceanographic Parameters (*continued*)



Approximately 90% of the world ocean has temperature and salinity values within the shaded rectangle.

*Graph is from Introductory Dynamical Oceanography, Pond & Pickard, 1983, 2<sup>nd</sup> Edition.*

