



Introduction, Course Plan, and Syllabus
Sea-Bird Scientific University



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Introduction to
Data Collection in the Ocean
Sea-Bird Scientific University
Module 0



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SBE Training Introduction



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.

Modules

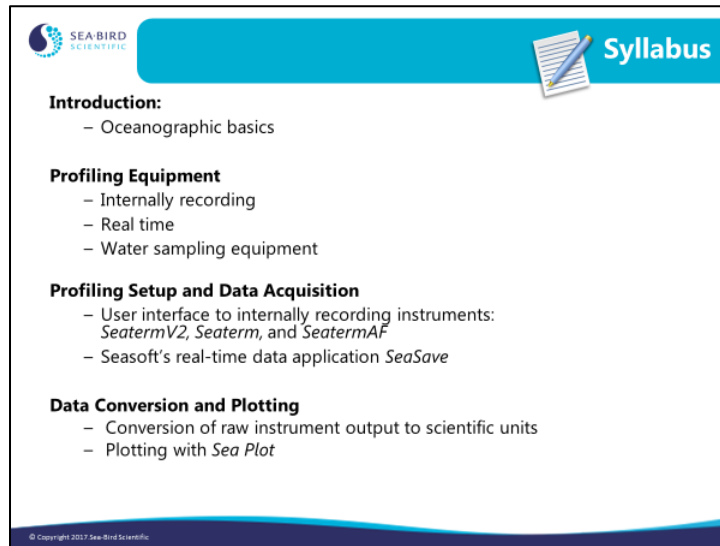
SEA-BIRD SCIENTIFIC		Modules by the Numbers	
0.	Introduction	16.	Moored Software
1.	Profiling Equipment	17.	Moored Hardware
2.	Internally Recording Profiling Instruments	18.	Moored Data Accuracy
3.	Real-Time Profiling Systems	19.	Waves and Tides: Theory
4.	Data Processing, Conversion and Plotting	20.	Wave and Tides: Data
5.	Water Sampling	21.	Troubleshooting
6.	Miscellaneous Applications	22.	The Cruise: Before, During and After
7.	Thermosalinographs	23.	Maintenance
8.	Making Measurements in the Ocean	24.	Biogeochemical Equipment
9.	CTD care and Calibrations	25.	Acquiring Biogeochemical Data
10.	Field Calibrations	26.	Care of Biogeochemical Sensors
11.	Advanced Data Processing: Dynamic Errors	27.	Biogeochemical Data Processing
12.	Advanced Data Processing: Dynamic Corrections	28.	Advanced Biogeochemical Data Processing
13.	Advanced Data Processing: Ship Heave	29.	Servicing
14.	Advanced Data Processing: Batch Processing		
15.	Moored Equipment		

 The Module Number is highlighted on every slide 

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Modules 13 and 14 cover Sea-Bird's wave and tide instruments. These modules are included in your binder, but will not be covered in class.

Topics We Will Cover



The slide features a blue header with the SEA-BIRD SCIENTIFIC logo on the left and the word 'Syllabus' next to a notepad icon on the right. The main content is organized into four sections with bolded titles and bulleted items. A small copyright notice is visible at the bottom left of the slide.

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Syllabus

Introduction:

- Oceanographic basics

Profiling Equipment

- Internally recording
- Real time
- Water sampling equipment

Profiling Setup and Data Acquisition

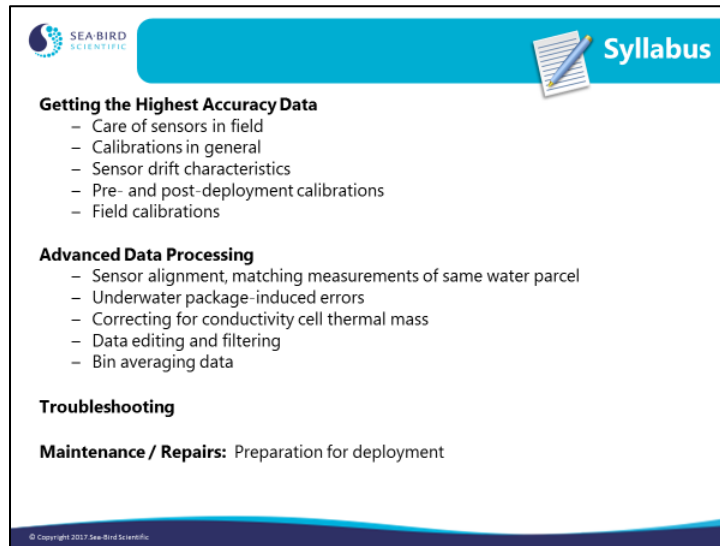
- User interface to internally recording instruments: *SeatermV2*, *Seaterm*, and *SeatermAF*
- Seasoft's real-time data application *SeaSave*

Data Conversion and Plotting

- Conversion of raw instrument output to scientific units
- Plotting with *Sea Plot*

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Topics We Will Cover (*continued*)



The slide features the SEA-BIRD Scientific logo in the top left corner, a blue header bar with a notepad icon and the word "Syllabus" in white, and a blue wavy footer bar with a small copyright notice.

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Syllabus

Getting the Highest Accuracy Data

- Care of sensors in field
- Calibrations in general
- Sensor drift characteristics
- Pre- and post-deployment calibrations
- Field calibrations

Advanced Data Processing

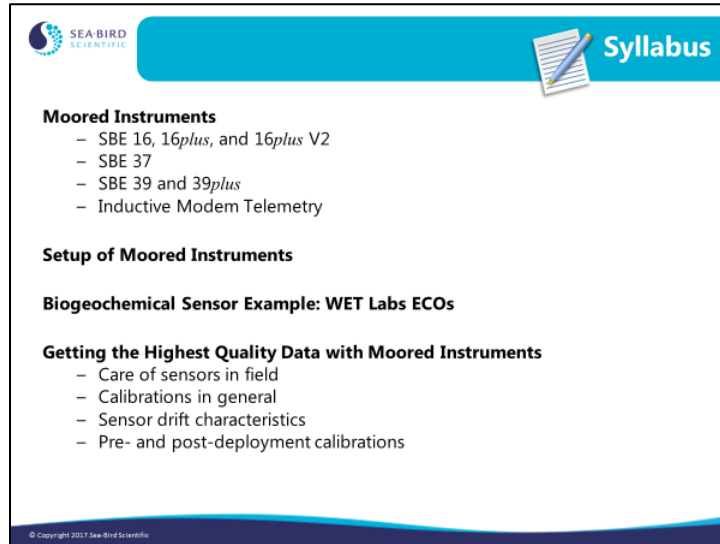
- Sensor alignment, matching measurements of same water parcel
- Underwater package-induced errors
- Correcting for conductivity cell thermal mass
- Data editing and filtering
- Bin averaging data

Troubleshooting

Maintenance / Repairs: Preparation for deployment

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Topics We Will Cover (*continued*)



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Syllabus

Moored Instruments

- SBE 16, 16*plus*, and 16*plus* V2
- SBE 37
- SBE 39 and 39*plus*
- Inductive Modem Telemetry

Setup of Moored Instruments

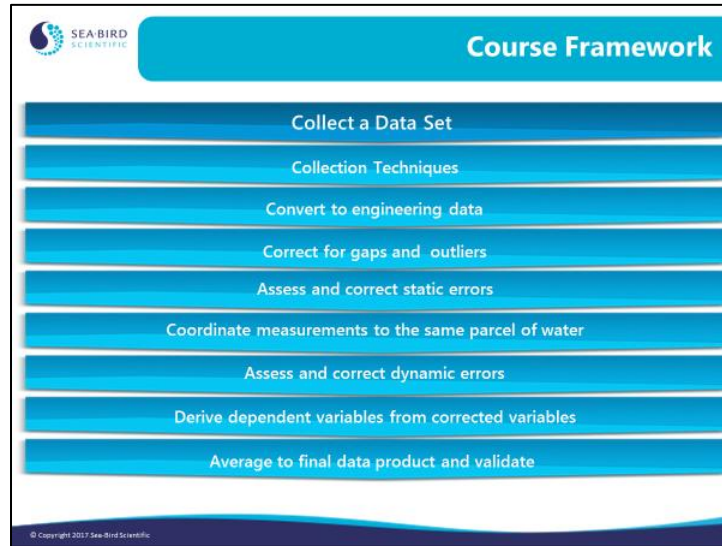
Biogeochemical Sensor Example: WET Labs ECOs

Getting the Highest Quality Data with Moored Instruments

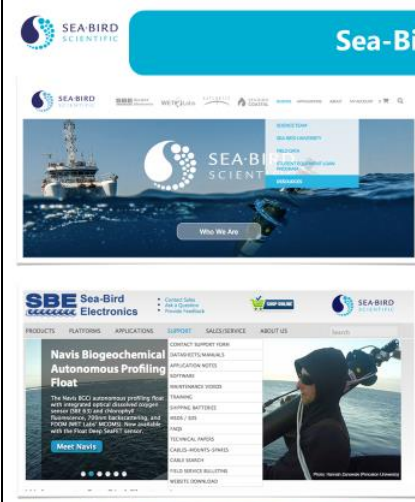
- Care of sensors in field
- Calibrations in general
- Sensor drift characteristics
- Pre- and post-deployment calibrations

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Topics We Will Cover (*continued*)




Resources



The screenshot shows the Sea-Bird Scientific website. At the top, there is a blue header with the company logo and the text "Sea-Bird Website Resources". Below this, the main website interface is visible, featuring a navigation menu with links for "HOME", "PRODUCTS", "SUPPORT", "SALES/SERVICE", and "ABOUT US". A search bar is also present. The main content area highlights a featured article titled "Navis Biogeochemical Autonomous Profiling Float" with a "Meet Navis" button. A sidebar on the right contains a list of links including "CONTACT SUPPORT", "DATA FITS/MANUALS", "APPLICATION NOTES", "SOFTWARE", "TRAINING", "SUPPORT BATTERIES", "PUMP / BIR", "HELP", "TECHNICAL PAPERS", "CABLES/HEADS/SPARES", "CASE STUDIES", "FIELD SERVICE BULLETIN", and "WEB TO GO/APP/DRS".

sea-birdscientific.com
Offers a wide variety of resources:
Conference Posters
Peer Reviewed Articles

For additional information, go to
www.seabird.com



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Resources (*continued*)

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Resources on seabird.com

Manuals:

- Instrument and Software manuals

95+ Application Notes, by topic/sensor type

FAQs – commonly asked questions

Software – upload from website

Customer Service

- Support staff can answer questions regarding instrument problems and data processing
- Online RMA forms for service, email contacts

Technical Papers and Presentations



- Sourced literature relevant to SBE products
- SBE presentations, papers, and course materials

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Introduction to Data Collection in the Ocean




Introduction to Data Collection in the Ocean



Oceanographic Basics

This module covers the following:

- Nomenclature
 - Sensors vs. Instruments vs. Systems
 - What is a Profile?
 - Oceanographic terms
- Oceanographic Parameters
 - What are we trying to measure?
 - Standards and conventions
 - Ranges in the real ocean


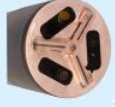



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Sensors, Instruments, and Systems

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Sensors vs. Instruments vs. Systems

Sensor	Instrument	System
The measurement system	The physical package that includes the data and power systems	Incorporates multiple sensors and instruments
 SBE 3 Temperature Sensor	One or more sensors  ECO Triplet-w	 SBE 9plus

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Nomenclature



Nomenclature

Profile


- Measurement methodology that collects data and samples by lowering and raising an instrument to a depth:
- Primary sampling mode is with respect to depth (z):

$d\text{Property}/dz$

Mooring


- Measurement methodology that collects data and samples by deploying an instrument on a fixed platform in the water column:
- Primary sampling mode is with respect to time (t):

$d\text{Property}/dt$



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Ocean Profiling




What is a Profile?

Profiling means lowering an instrument from the surface of the ocean to some depth.

The instrument measures environmental parameters as it is lowered.

Profiling data is the core data for most oceanographic research cruises and programs.



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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

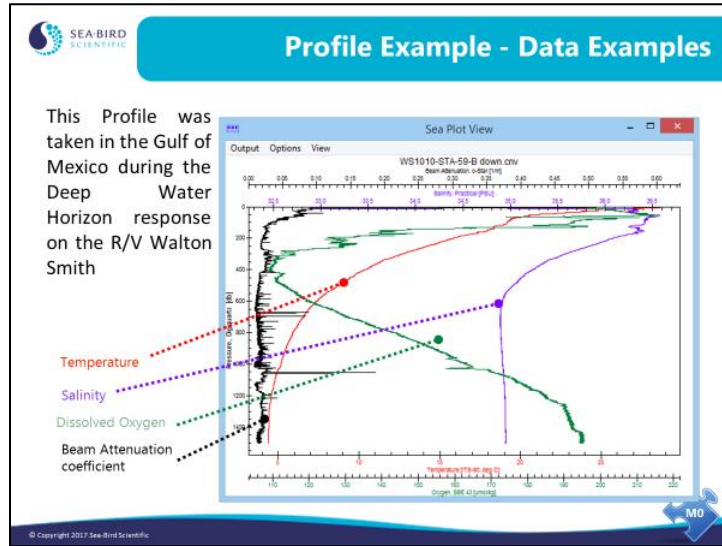
The bathythermograph was towed from a ship as it was lowered on a cable. It scratched a trace of the temperature versus depth on a coated glass slide. This provided more points, but only for temperature and only for relatively shallow depths. People still yearned for more data.

- 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.

Ocean Profiling (continued)



Oceanographic Terms




Oceanographic Terms

- **cline**: A layer where a property exhibits rapid change over a depth range:

- Thermocline (temperature)
- Halocline (salinity)
- Chemocline (chemical component, such as nutrients)

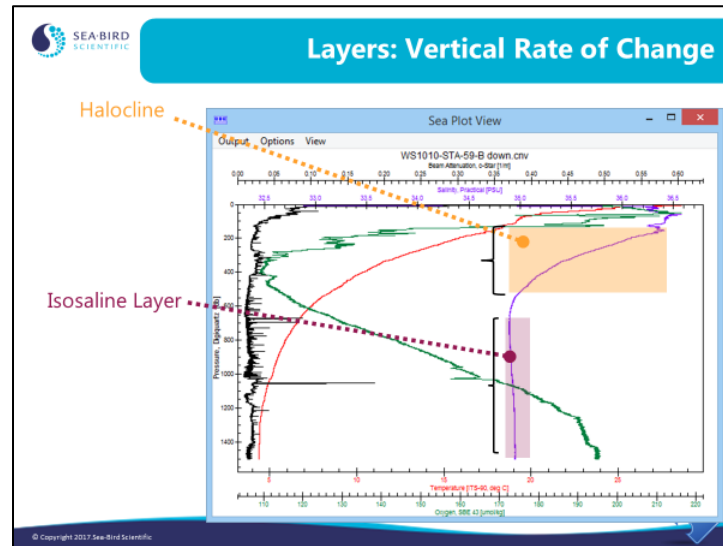
Iso - : A layer where a property exhibits very little or no change over a depth range:

- Isopycnal (density)
- Isothermal (temperature)
- Isosaline (salinity)



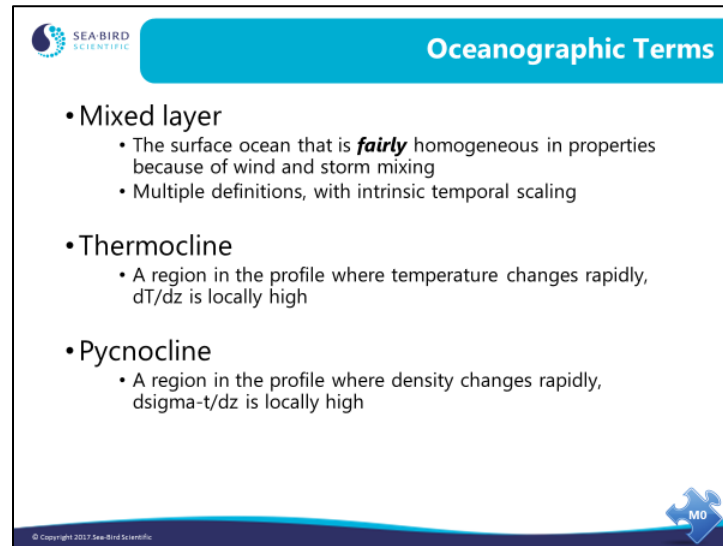
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Oceanographic Terms (*continued*)



Halocline (layer with rapid change over depth in salinity): In the Arctic, a halocline is present between the colder fresher water that exchanges between the annual ice melting and freezing cycle and the warmer water from the Atlantic that fills the deep basins. The halocline is formed from high salinity water from the shelf that sinks off the shelf and spreads laterally through the Arctic Ocean. The halocline layer is an important impediment to vertical mixing in the Arctic.

Oceanographic Terms (*continued*)



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Oceanographic Terms


- **Mixed layer**
 - The surface ocean that is *fairly* homogeneous in properties because of wind and storm mixing
 - Multiple definitions, with intrinsic temporal scaling
- **Thermocline**
 - A region in the profile where temperature changes rapidly, dT/dz is locally high
- **Pycnocline**
 - A region in the profile where density changes rapidly, $d\sigma_t/dz$ is locally high

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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.

Oceanographic Terms (*continued*)



Oceanographic Terms


Photic Zone
The near surface layer where there is more than enough light to drive plant growth

Oxygen Minimum Zone
A subsurface layer where the dissolved oxygen saturation is at a local minimum

Nepheloid Layer
A region in the profile with elevated particle concentration

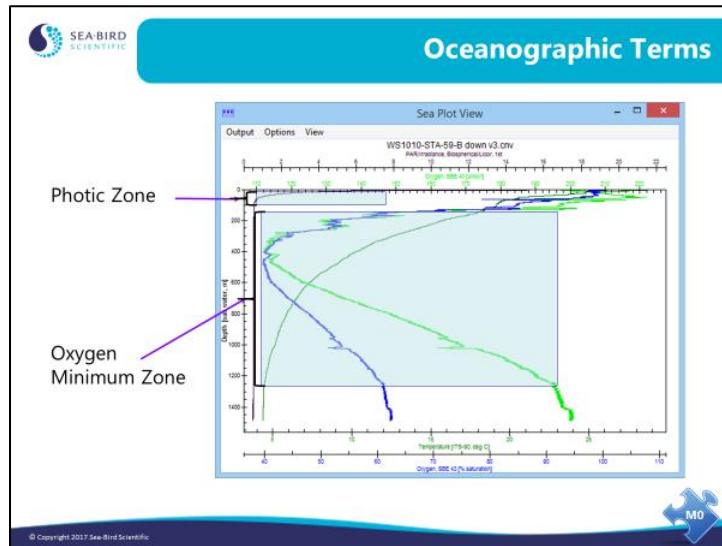
- Bottom Nepheloid Layer
- Intermediate Nepheloid Layer

Benthic Mixed Layer
Near bottom region where shear produces a well mixed layer

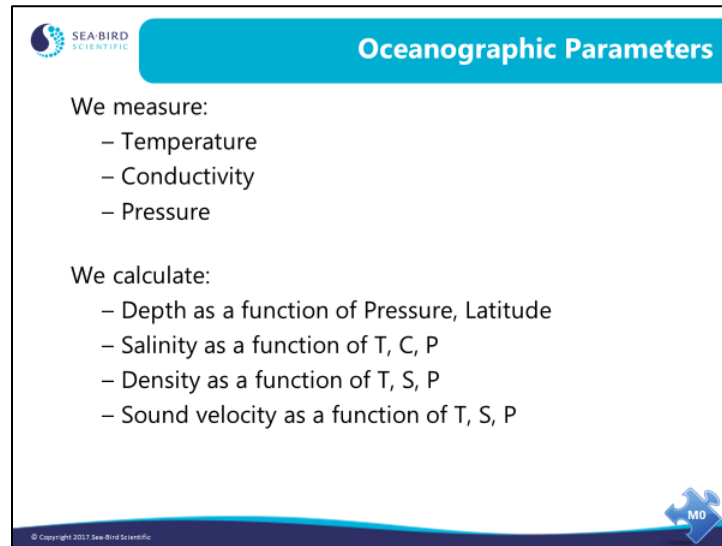


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Oceanographic Terms (*continued*)



Oceanographic Parameters



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Oceanographic Parameters

We measure:

- Temperature
- Conductivity
- Pressure

We calculate:


- Depth as a function of Pressure, 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

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MO

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.

Oceanographic Parameters (*continued*)




Temperature and Salinity Standards

Standards determine what is 1 °C and what is 1 practical salinity unit.

There are two standards for temperature:

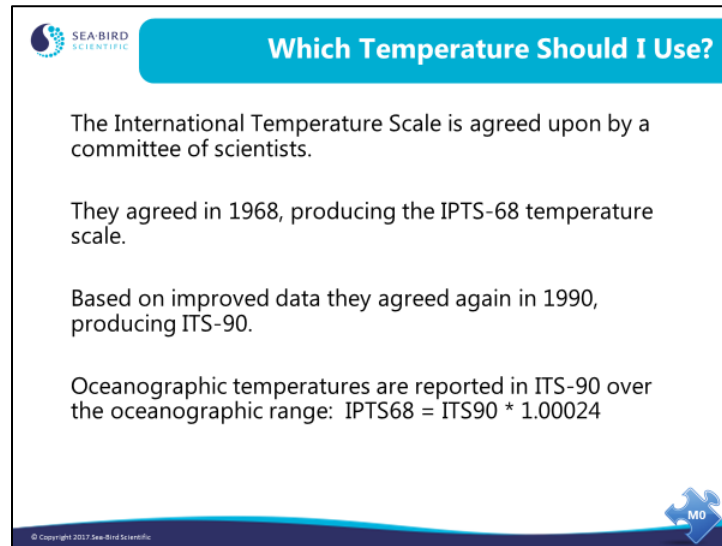
- International Practical Temperature Scale of 1978 (IPTS-68)
- International Temperature Scale of 1990 (ITS-90)

And one standard for salinity:
Practical salinity scale of 1978 (PSS-78)



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Oceanographic Parameters (*continued*)



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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: $IPTS68 = ITS90 * 1.00024$

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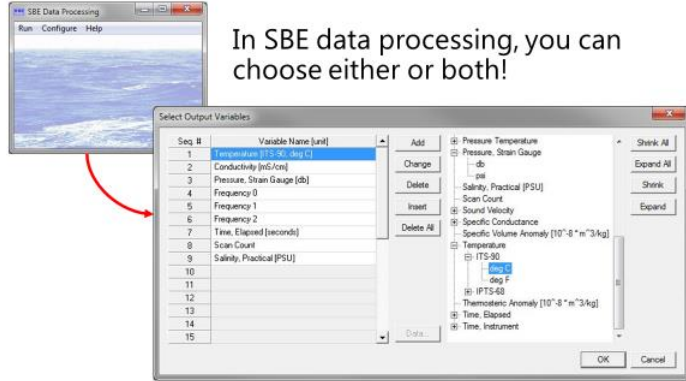
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The calculation of the parameters mentioned on the previous slide is made with equations of the physical parameters. These equations were derived by gathering data in a laboratory relating T, P, and C to the parameter of interest, and statistically 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.


Oceanographic Parameters (*continued*)



Which Temperature Should I Use?




In SBE data processing, you can choose either or both!



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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, MgCl₂, MgSO₄, CaSO₄

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



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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.

Oceanographic Parameters (*continued*)

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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

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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 $-2\text{ }^{\circ}\text{C}$ to $35\text{ }^{\circ}\text{C}$, 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.

Oceanographic Parameters (*continued*)

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Absolute Salinity and TEOS-10

Thermodynamic Equation of State of Seawater TEOS-10
(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

More info: www.teos-10.org

For rest of course, when we talk about **Salinity**,
We are talking about **Practical Salinity**

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Thermodynamic properties of seawater are influenced by the total mass of dissolved constituents. Dissolved constituents are regionally variable, and are not always accurately represented when using conductivity measurements. The TEOS-10 algorithm estimates Absolute Salinity, based on Practical Salinity and latitude and longitude.

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 provides more details

(www.seabird.com/document/an90-absolute-salinity-and-teos-10-sea-birds-implementation).

Oceanographic Parameters (*continued*)




Oceanographic Density

- By definition, the density of fresh water is 1.0000 kg/l
- The density of seawater might be 1.0250 kg/l
- Oceanographers report density as a "sigma" value, which is **(density - 1) * 1000** (in our example, 25.000)
- Sigma (σ) is the in situ density of seawater and a function of salinity, temperature and pressure.
- Sigma-t (σ_t) is the potential density of seawater when a parcel of seawater has been brought to the surface and the effect of pressure has been removed.
- Sigma-theta (σ_θ) is the potential density of seawater when seawater has been adiabatically brought to the surface and is a function of salinity, pressure and potential temperature (θ).

For example:

	sigma-t	depth	Density	depth
	20.5213	3.248	1.0205213	3.248
	20.522	3.216	1.020522	3.216
	20.5303	3.216	1.0205303	3.216
	20.5316	3.16	1.0205316	3.16
	20.5302	3.16	1.0205302	3.16


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“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 ³	Density as a function of temperature, salinity, and pressure	<ul style="list-style-type: none"> Relationship with T and S nonlinear (more so for T) Less sensitive to T at low T
$\sigma(t, s, p)$	-	$\text{Sigma} = \rho(t, s, p) - 1000$	<ul style="list-style-type: none"> Used because variations in oceanic density are very small Includes pressure effect on density Pressure effect on T and S not accounted for 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
$\sigma_t(t, s, 0)$	-	$\text{Sigma-t} = \rho(t, s, 0) - 1000$	<ul style="list-style-type: none"> Sigma at atmospheric pressure
$\sigma_\theta(\theta, s, 0)$	-	$\text{Sigma-theta} = \rho(\theta, s, 0) - 1000$	<ul style="list-style-type: none"> Removes effect on density caused by adiabatic cooling / heating Removes pressure effect on density

Oceanographic Parameters (*continued*)




More Oceanographic Parameters

Potential temperature (θ) 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



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Parameter	Units	Definition	Additional Information
θ	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"> • Temperature parcel of water would have at surface • Used to compare waters at significantly different depths, and used for describing vertical motions over large depth ranges
$\alpha(t, s, p)$	m ³ /kg	Specific volume = $1/\rho(t, s, p)$	<ul style="list-style-type: none"> • Convenient way to look at density variations in deep ocean
$\alpha(0, 35, p)$	m ³ /kg	$1/\rho(0, 35, p)$	<ul style="list-style-type: none"> • Specific volume of arbitrary seawater standard (0 deg C, 35 PSU) at depth of sample
δ	m ³ /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"> • Sum of 6 anomalies of specific volume due to t, s, p
$\Delta_{s,t}$	m ³ /kg	Thermosteric anomaly = $\delta_s + \delta_t + \delta_{s,t}$	<ul style="list-style-type: none"> • Accounts for most of the density effect due to t, s • $\delta_{s,t,p}$ is quite small, so is usually ignored

Oceanographic Parameters (*continued*)



Ranges of Oceanographic Parameters

Temperature: -2 to 35 °C

- Best accuracy: ± 0.001 °C


Conductivity: 0.0 to 7.5 Siemens/meter

- Best accuracy: ± 0.0003 S/m
- SBE 19plus V2s range 0-9.0 S/m
- Some CTDs can be modified for higher conductivity

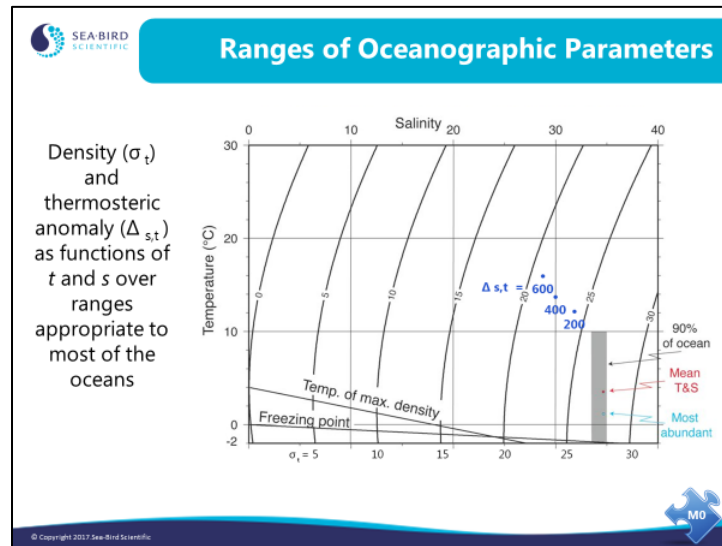
Salinity: 2 to 42 PSU

- Best accuracy: ± 0.003 PSU

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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, 2nd Edition.

Activity: Install Seasoft and Course Data

1. Insert Training CD / memory stick into laptop.
2. Install Seasoft: double click on **SeasoftV2.exe**.
 - **SeasoftV2.exe** installs programs intended for use with CTDs, including: SeatermV2 and Seaterm (terminal programs), and SeatermAF (terminal program for auto-fire water sampling systems); Seasave V7 and Seasave-Win32 (real-time data acquisition programs); and SBE Data Processing (post-processing program).
 - The installation program contains two versions of our main terminal program Seaterm. **We will be using SeatermV2 in the course instead of the older Seaterm.**
 - The installation program contains two versions of our real-time data acquisition program Seasave. **We will be using Seasave V7 in the course instead of the older Seasave-Win32.**
3. Create shortcuts on your desktop for SeatermV2, Seasave V7, and SBE Data Processing, to make it easier to access the software during the class.
4. Copy **Data** folder to C:\ drive to make it easier for you to access the files for the class activities.
 - Data folder contains data we will use in exercises for this class.
 - When you finish, you should see the Data folder on your local disk (C:) in the Explorer window.
5. (Optional) Install Seasoft for Waves: double click on **SeasoftWaves_Vn_nn.exe** (*n_nn* is software version).
 - Seasoft for Waves is intended for use with our wave and tide gauge products, which we will not discuss during class (covered in Modules 13 and 14 in your binder).

Additional setup notes:

If the Explorer window does not show file extensions (.con, .dat, .hex, etc.) and/or does not show the full path in the address bar, we suggest you change the settings to make your life easier for this course. Follow these directions (written for Windows XP Professional) to change settings:

1. Select Start / Control Panel.
2. Select Folder Options.
3. Click the View tab.
 - A. **Unclick** *Hide extensions for known file types*.
 - B. Click *Display the full path in the address bar*.
 - C. Click Apply.
 - D. Click OK.

Activity: Install Seasoft and Course Data