Module 0

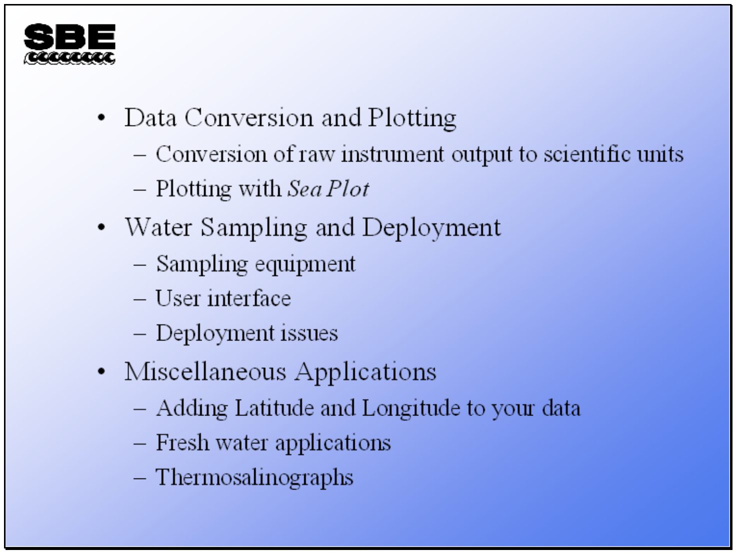
Introduction to Sea-Bird Electronics Training for Data Collection in the Ocean

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.

Topics We Will Cover

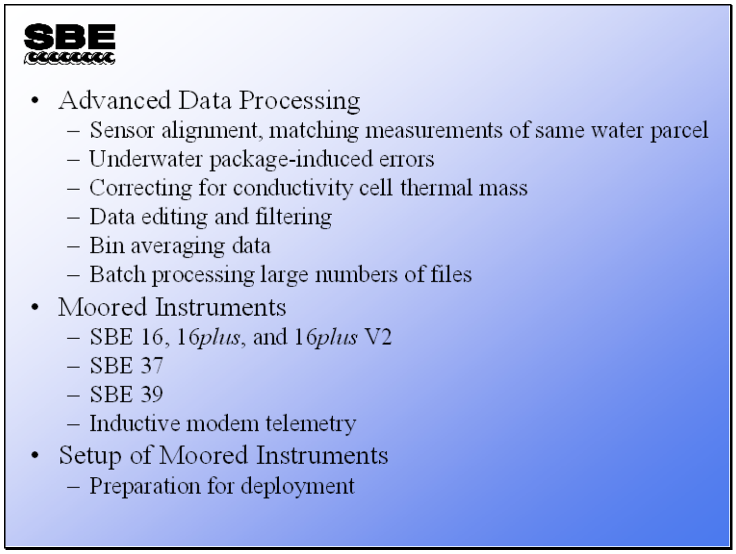
Topics We Will Cover (*continued*)



Topics We Will Cover (*continued*)

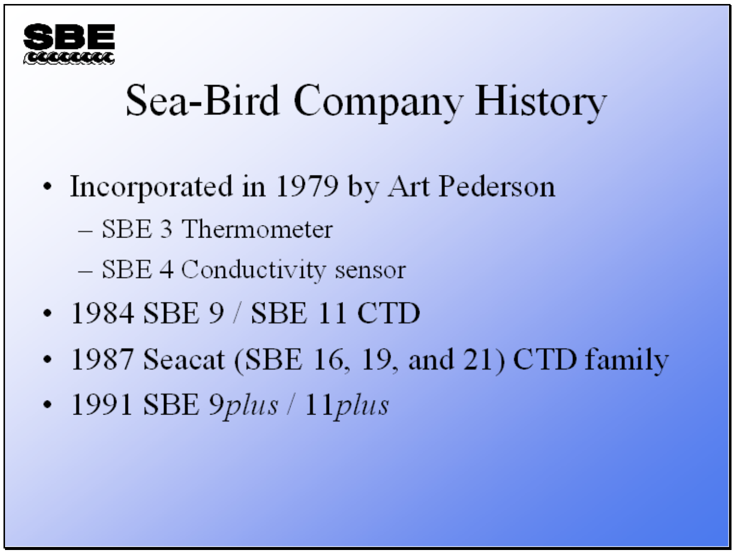
- Making Measurements in the Ocean
  - Sampling theory and sensor characteristics
  - Coordinating measurements in space and time
  - Comparison of sampling for different instruments
  - Conversion of instrument output to scientific units
- Getting the Highest Accuracy Data
  - Care of sensors in field
  - Calibrations in general
  - Sensor drift characteristics
  - Pre- and post-deployment calibrations
  - Field calibrations
  - As good as it gets: autonomous profilers

Topics We Will Cover (*continued*)



Topics We Will Cover (*continued*)

Sea-Bird Electronics Company History



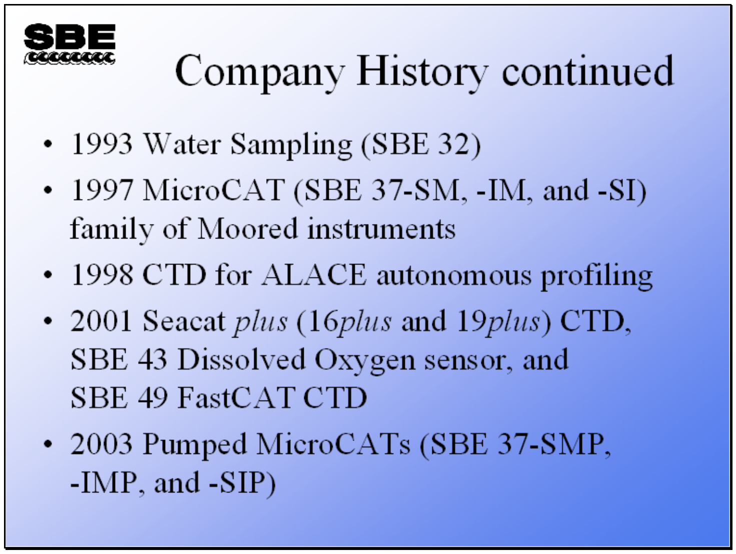
Art Pederson developed Sea-Bird's first products for an autonomous vehicle at the University of Washington's Applied Physics Laboratory in 1961. These first products later became the SBE 3 ocean thermometer and SBE 4 conductivity sensor. Pederson incorporated Sea-Bird Electronics in 1979 with these two sensor products.

From there, the product line expanded to include real-time ocean profiling instruments with the SBE 9 / SBE 11 acquisition/telemetry equipment and stored data profiling instruments with the Seacat product line.

Later improvements yielded the SBE 9*plus* CTD/ 11*plus* Deck Unit:

- Water sampler control
- More power for auxiliary sensors
- Any 9*plus* will work with any 11*plus*
- Improved telemetry

Sea-Bird Electronics Company History (*continued*)



- SBE 32 Carousel:
  - Improved reliability
  - Bottle closure in any order
  - Easier preparation for deployment
  - Mechanical compatibility with existing equipment
- Seacat *plus* enhancements:
  - Simultaneous P, T, and C sampling
  - Higher resolution for auxiliary sensors
  - More power available for auxiliary sensors
  - Ducted T and C
- SBE 43 DO sensor:
  - Calibration stability, improved temperature response, continuous polarization, reduced hysteresis
- SBE 49 FastCAT CTD:
  - Fast sampling, low cost CTD with no internal power or memory, no auxiliary sensors – ideal for use with ROVs, AUVs, etc.
- Pumped MicroCATs:
  - Improved anti-foul protection and conductivity response

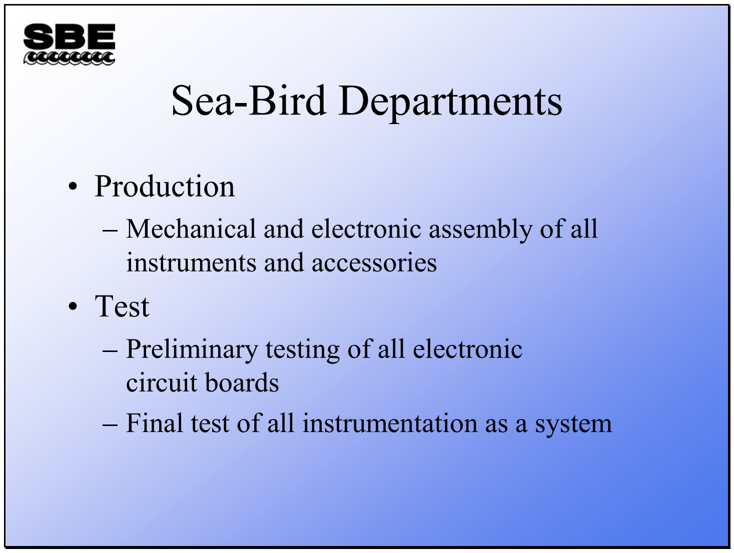
Sea-Bird Electronics Company History (*continued*)

- SBE 26*plus*:
  - Real-time tide data, wave data, and wave statistics, and internal recording
  - Sampling flexibility, large memory, low power consumption
- SBE 39-IM Temperature Recorder:
  - Inductive modem version of high accuracy SBE 39
- SBE 53 BPR Bottom Pressure Recorder:
  - Full ocean depth water level with extremely high resolution, accuracy, and stability
- SBE 55 ECO Water Sampler:
  - Small (3- or 6-bottle) water sampler for depths to 600 meters, for real-time or autonomous sampling

Sea-Bird Electronics Company History (*continued*)

- SBE 37 IDO MicroCAT
  - MicroCATs (C-T-optional P) with Integrated Dissolved Oxygen (IDO)
- Glider Payload CTD (GPCTD)
  - C-T-P and optional DO for autonomous gliders
- Underwater Inductive Modem Module (UIMM)
  - For integration of RS-232 instruments with real-time moorings using Sea-Bird's Inductive modem (IM) telemetry
- SBE 56 Temperature Logger
  - Low-cost, high-accuracy, small, easy-to-use temperature recorder with USB interface
- Satlantic acquisition in January 2011

Sea-Bird Electronics Organization



Sea-Bird's departments are:

- Production
- Test
- Customer Service
- Calibration
- Sales

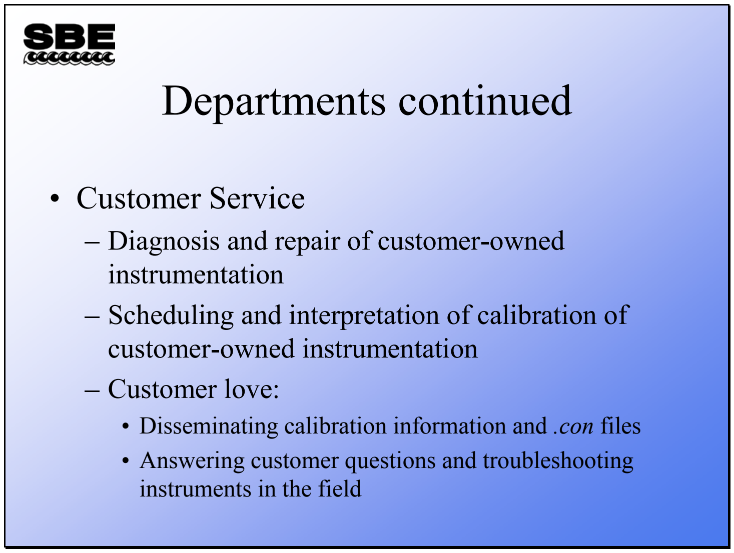
Production

The production department does all product assembly, from Carousels to conductivity cells. To support product assembly, printed circuit boards are populated with electronic components either at Sea-Bird or off site. Mechanical components are machined, coated, and labeled as appropriate. Sea-Bird performs all bonding of plastic to glass or metal.

Test

The test department performs preliminary acceptance testing on all printed circuit boards and final testing on each instrument system. Sea-Bird tests products by collecting data from each instrument while immersing it in one of the cold salt-water baths maintained for this purpose. The bath testing serves two purposes: to provide an operation check for the entire system and to ensure the instrument's ruggedness by exposing it to the shock of being plunged into a bath at approximately 2 – 3 ºC.

Sea-Bird Electronics Organization (*continued*)

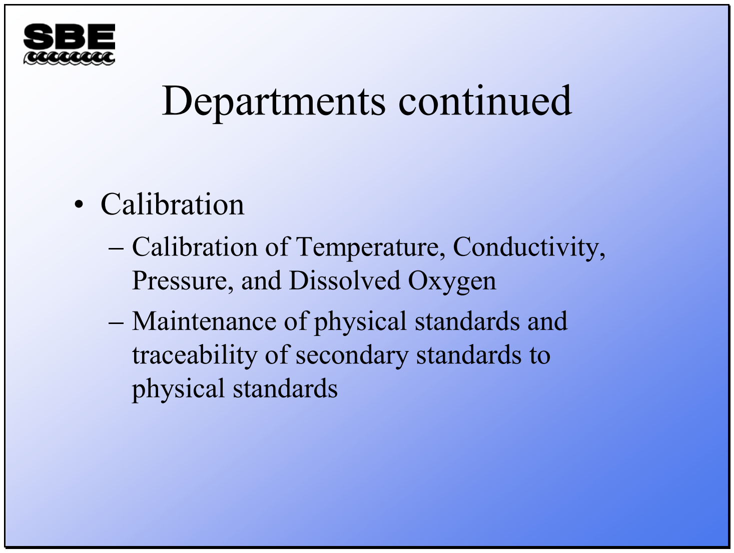


Customer Service

Customer service has the broadest set of responsibilities at Sea-Bird. Their activities include:

- Receiving equipment for maintenance and repair.
- Scheduling maintenance and repair activities with customers.
- Responding to customer requests for help with instrument operation.
- Interpreting and disseminating calibration information.
- Performing final checkout of all instruments that have been repaired or recalibrated.

Sea-Bird Electronics Organization (*continued*)

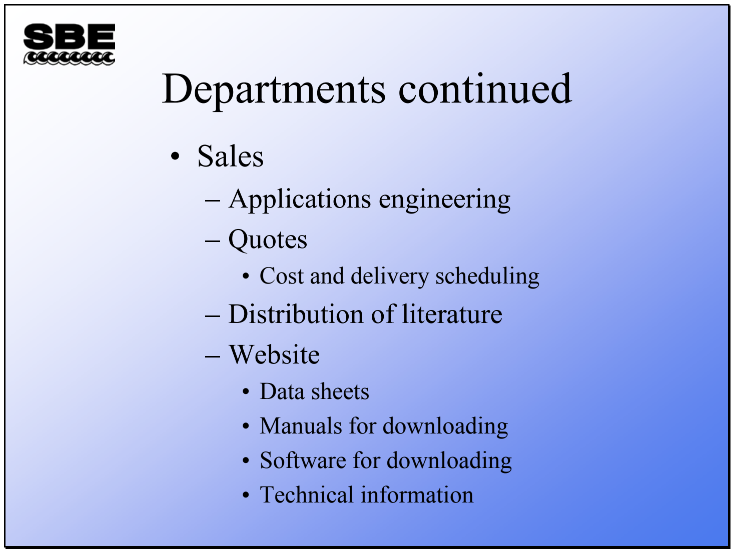


Calibration

The calibration department:

- Calibrates new sensors and re-calibrates sensors returned from the field.
- Maintains calibration histories for all sensors.
- Monitors new sensors being held at Sea-Bird until a sensor history, adequate for the precision specified for the sensor, exists.
- Maintains physical standards that allow temperature calibrations to be traced to the triple point of water and the melting point of gallium.
- Operates the Guildline Autosal laboratory salinometer as a conductivity standard.
- Picks out and maintains some very precise pressure sensors to use for verification of other sensors.

Sea-Bird Electronics Organization (*continued*)



Sales

Sea-Bird's sales department acts as our ambassador to the oceanographic community in addition to:

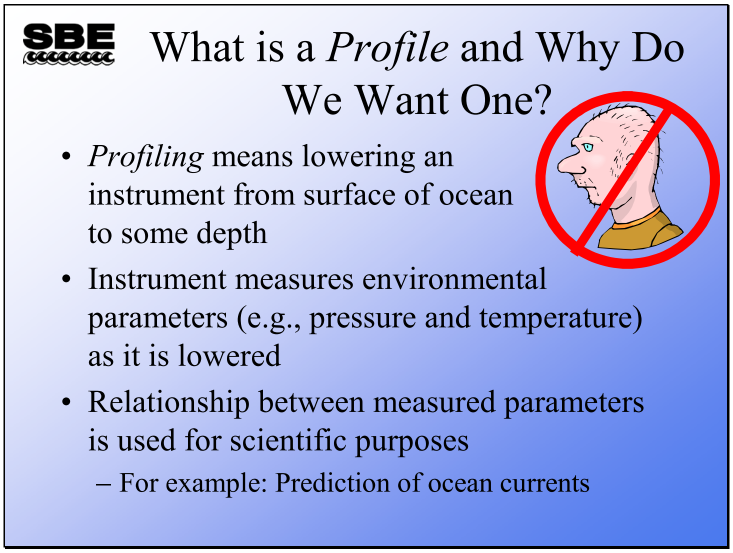
- Providing application engineering

  Applications engineering means the customer describes their project and Sea-Bird makes recommendations for the equipment package to best suit their needs.

- Creating datasheets, manuals, and application notes.
- Maintaining the Sea-Bird website.
  All information available is available electronically on www.seabird.com.

TIP: Sea-Bird's web site is the best source of up-to-date software and documentation.

Introduction: Ocean Profiling



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

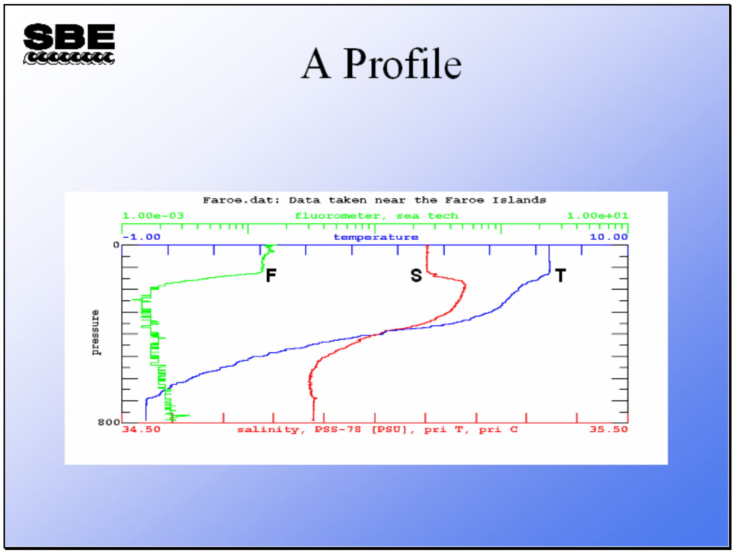
  The bathythermograph was towed from a ship as it was lowered on a cable. It scratched a trace of the temperature versus depth on a coated glass slide. This provided more points, but only for temperature and only for relatively shallow depths. People still yearned for more data.

- 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.

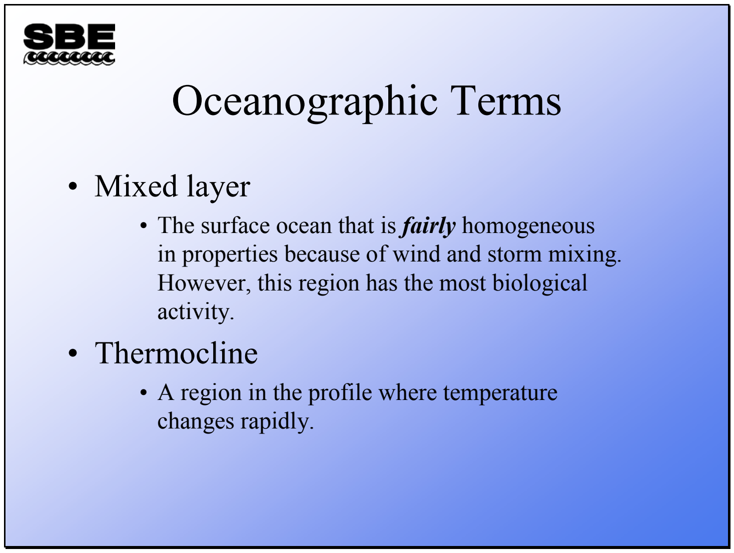
What do we do with our profile? We estimate deep ocean currents based on density profiles. We look for sharp density changes to investigate the interesting chemical and biological processes that go on there. We look for the boundaries of surface ocean currents. We look for the movements of different 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



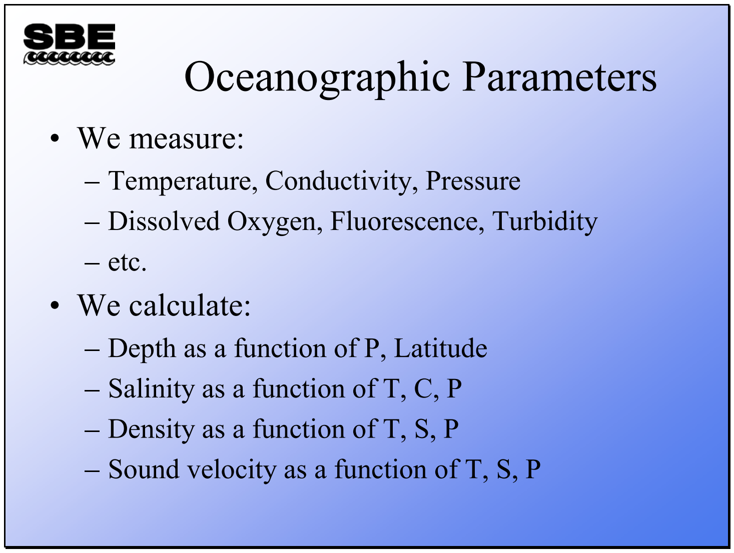
This profile was collected with an SBE 911*plus* system near the Faroe Islands.

Introduction: Oceanographic Terms



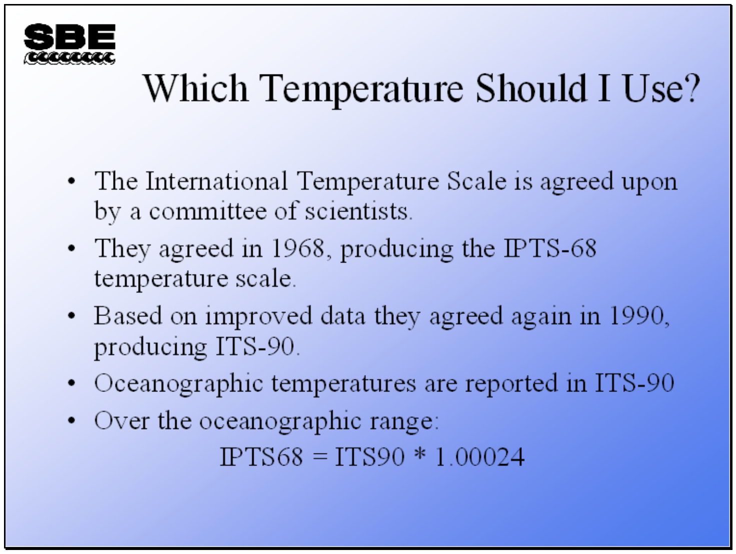
The ocean is often spoken of as a two-layer system: a mixed or surface layer and a deep layer. The mixed layer or surface layer is as it sounds, at the surface of the ocean and well mixed by wind and waves. The deep layer is separated from the surface by a region of rapidly changing temperature referred 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.

Introduction: Oceanographic Parameters



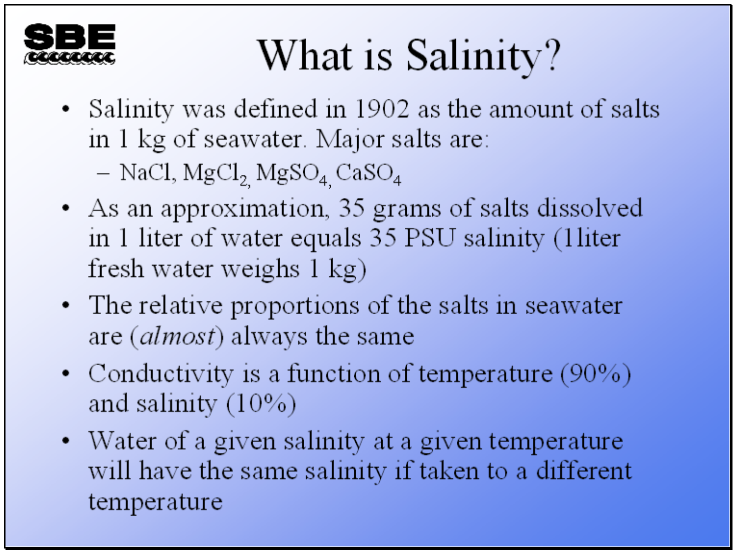
We measure physical quantities with Sea-Bird instruments. These quantities are then used to calculate the many parameters that are found in the analysis of oceanographic data. Because the calculated parameters rely on accurate measurement of the physical quantities, a small error in the original measurement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

Introduction: Oceanographic Parameters (*continued*)



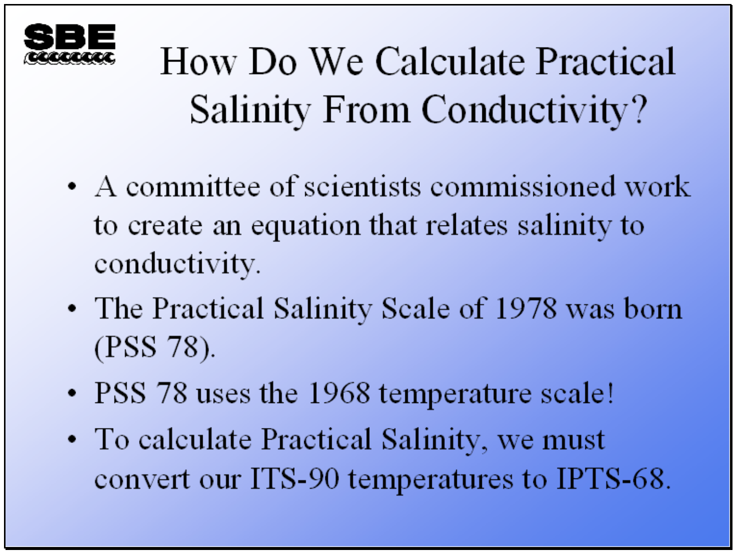
The calculation of the parameters mentioned on the previous slide is made with equations of the physical parameters. These equations were derived by gathering data in a laboratory relating T, P, and C to the parameter of interest, and statistically fitting the data to high order polynomials. The coefficients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



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.

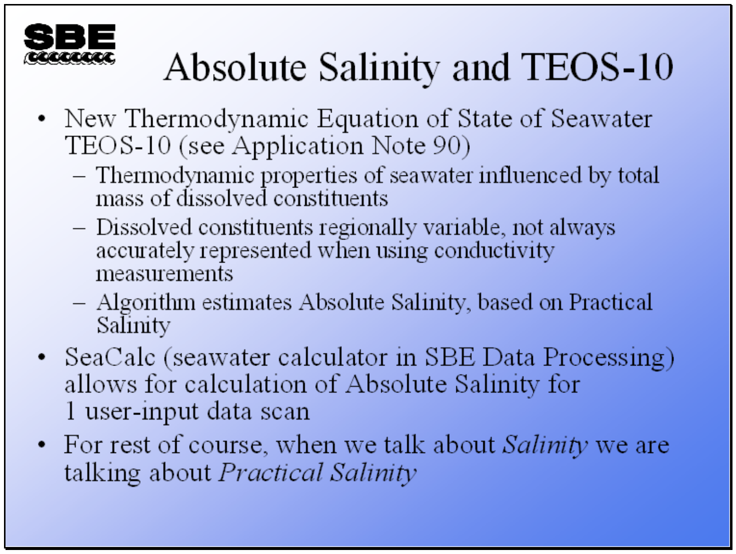
Introduction: Oceanographic Parameters (*continued*)



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*)



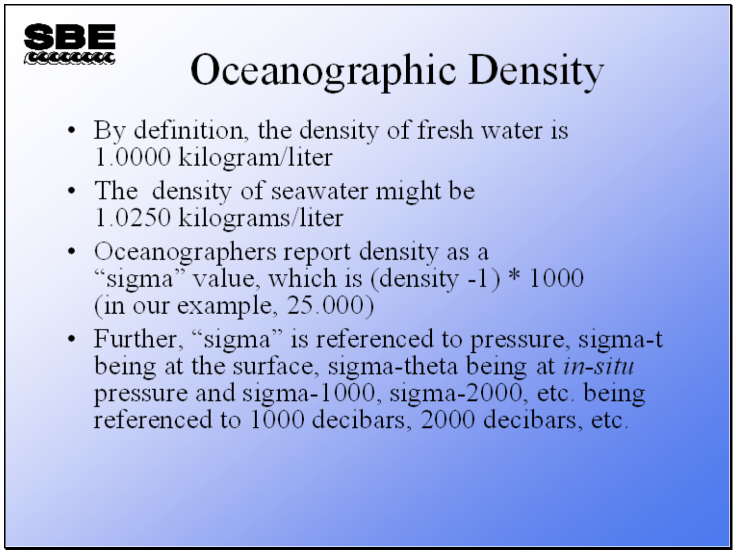
IAPSO recommends that only Practical Salinity be stored in data repositories:

- 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.

Consistent with the recommendations of IAPSO that only Practical Salinity should be stored in databases, at this time Sea-Bird continues to offer only Practical Salinity calculations in our computational software for analyzing data sets (Seasave and SBE Data Processing). However, we implemented the Absolute Salinity calculation as an option in SeaCalc (seawater calculator module in SBE Data Processing that computes a number of derived variables from one user-input data scan), to enable scientists to become familiar with Absolute Salinity.

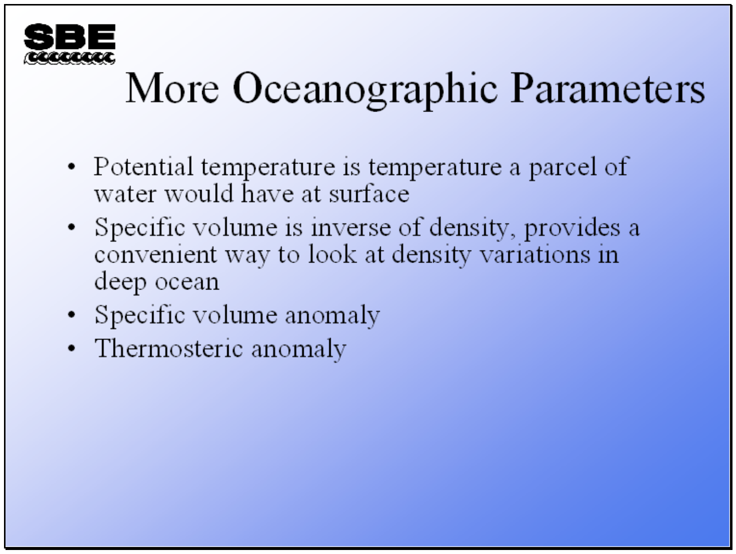
Application Note 90 on our website (www.seabird.com/application_notes/AN90.htm) provides more details.

Introduction: Oceanographic Parameters (*continued*)



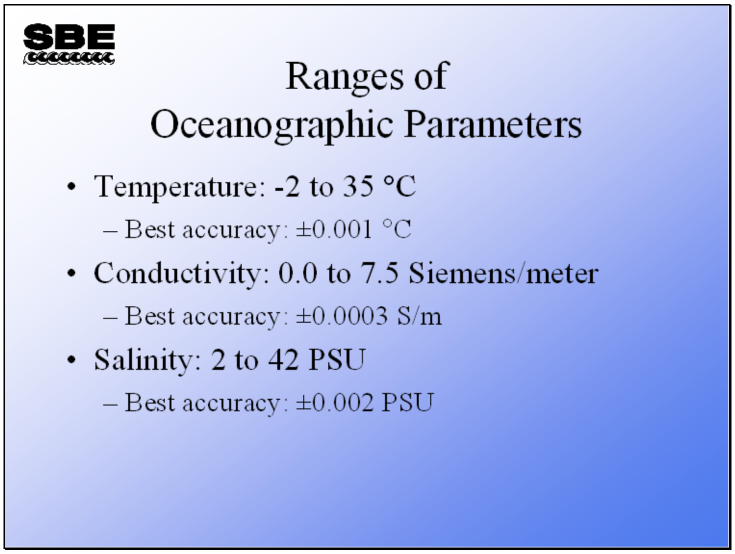
Parameter	Units	Definition	Additional Information
ρ (t, s, p)	kg/m^3	Density as a function of temperature, salinity, and pressure	• Relationship with T and S nonlinear (more so for T) • Less sensitive to T at low T
σ (t, s, p)	-	Sigma = ρ (t, s, p) - 1000	• Used because variations in oceanic density 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
σ_t (t, s, 0)	-	Sigma-t = ρ (t, s, 0) - 1000	• Sigma at atmospheric pressure
σ_θ (θ, s, 0)	-	Sigma-theta = ρ (θ, s, 0) - 1000	• Removes effect on density caused by adiabatic cooling / heating • Removes pressure effect on density

Introduction: Oceanographic Parameters (*continued*)

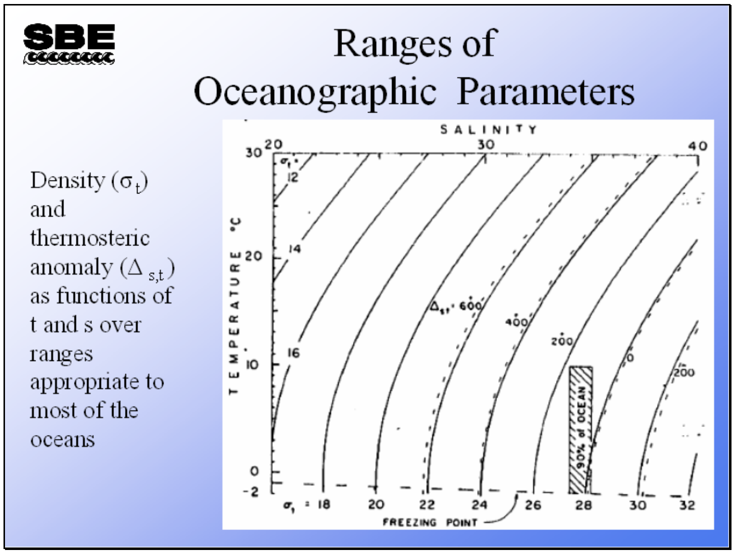


Parameter	Units	Definition	Additional Information
θ	deg C	Potential temperature = Temperature of sample brought adiabatically to surface (no heat exchange with surrounding water as raised)	• Temperature parcel of water would have at surface • Used to compare waters at significantly different depths, and used for describing vertical motions over large depth ranges
α (t, s, p)	m^3/kg	Specific volume = $1/\ \rho$ (t, s, p)	• Convenient way to look at density variations in deep ocean
α (0, 35, p)	m^3/kg	$1/\ \rho$ (0, 35, p)	• Specific volume of arbitrary seawater standard (0 deg C, 35 PSU) at depth of sample
δ	m^3/kg	Specific volume anomaly = α (t, s, p) - α (0, 35, p) = $\delta_s + \delta_t + \delta_{s,t} + \delta_{s,p} + \delta_{t,p} + \delta_{s,t,p}$	• Sum of 6 anomalies of specific volume due to t, s, p
$\Delta_{s,t}$	m^3/kg	Thermosteric anomaly = $\delta_s + \delta_t + \delta_{s,t}$	• Accounts for most of the density effect due to t, s • $\delta_{s,t,p}$ is quite small, so is usually ignored

Introduction: Oceanographic Parameters (*continued*)



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, 2nd Edition.