



Advanced Data Processing:
Dynamic errors in CTDs
Sea-Bird Scientific University Module 11



Overview

SEA-BIRD SCIENTIFIC **Advanced Data Processing**


This module covers the following:

- The importance of accurate data
- Potential errors in CTD data
- How Sea-Bird instruments are designed to minimize errors

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The advanced data processing sections are the final topics about profiling CTDs. This section will explain small artifacts caused by frequency counting, plumbing, and sensor physics. Understanding these topics will help explain most of the peculiar things that you might observe in your data if you look closely.


Why worry about absolute accuracy?



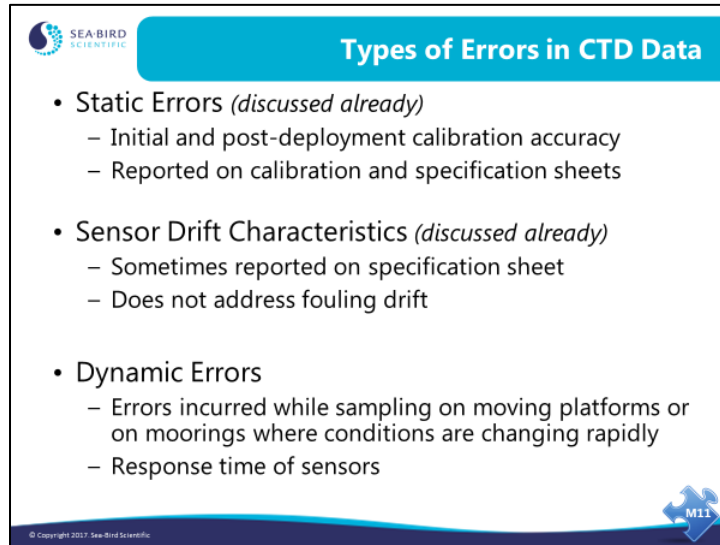
Why worry about Absolute Accuracy in Sensors?

- In oceanography, we measure physical quantities to calculate many parameters necessary to analyze the ocean
 - Thermodynamic properties are needed in ocean/climate models
- Calculated parameters (salinity) rely on accurate measurement of temperature, conductivity, and pressure
- **Small errors in original measurements can lead to large errors in calculated parameters**
 - **These small errors can lead to big errors in data analysis and interpretations**

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Errors in CTD Data




Types of Errors in CTD Data

- **Static Errors** (*discussed already*)
 - Initial and post-deployment calibration accuracy
 - Reported on calibration and specification sheets
- **Sensor Drift Characteristics** (*discussed already*)
 - Sometimes reported on specification sheet
 - Does not address fouling drift
- **Dynamic Errors**
 - Errors incurred while sampling on moving platforms or on moorings where conditions are changing rapidly
 - Response time of sensors

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In this module, we discuss how to process and improve data for Dynamic Errors.

Dependent versus Independent Variables




Converting Dependent Quantities vs. Raw Independent Quantities

- Salinity and Oxygen are computed quantities
 - They are what we call *Dependent Variables* as they rely on Independent Variables (T,C, P, OXVOLTS)
- For successful computation of Dependent Variables, inputs need to be accurately measured AND accurately coordinated on a point in space, and secondarily coordinated in time response
- If these Independent Variables are measured or coordinated incorrectly, this will have ripple effect in other computed quantities
 - density, buoyancy frequency, etc.




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Dependent versus Independent Variables (*continued*)





For Example:
How to get salinity with only 10% of signal

- Electrical measurement of conductivity
 - 90% of signal from temperature
 - 10% from salinity based on conducting ion content of seawater
- 1% error in Temperature causes 10% error in Salinity
- **Always compute Salinity AFTER processing Temperature, Conductivity, and Pressure**




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Dynamic Errors in Temperature

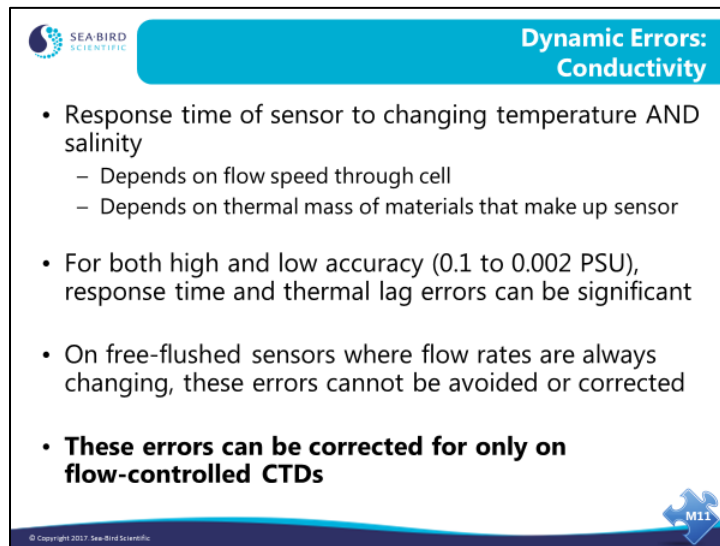


- Response time of sensor to changing condition
- Temperature response time largely determined by physical size and construction.
 - Response time for profiling CTDs
 - 0.070 sec (SBE 911*plus*, 25, and 25*plus*)
 - 0.5 sec (SBE 19*plus* and 19*plus* V2)
 - Response time for moored CTDs 0.5 sec




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Dynamic Errors in Conductivity



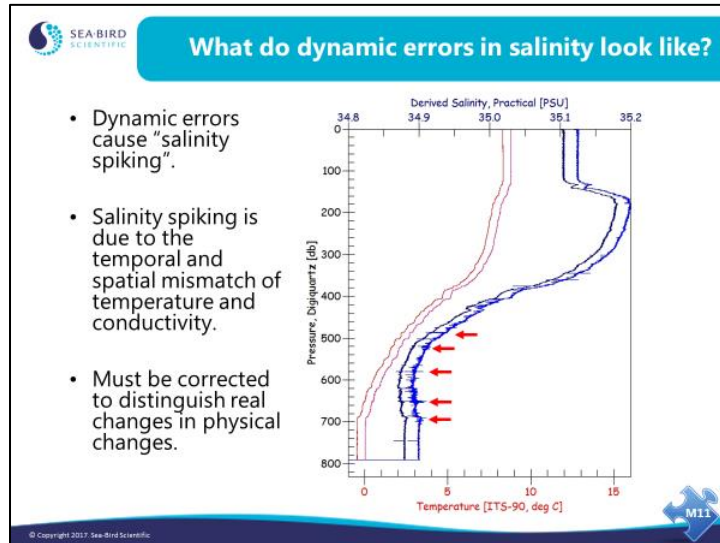
SEA-BIRD SCIENTIFIC **Dynamic Errors: Conductivity**

- Response time of sensor to changing temperature AND salinity
 - Depends on flow speed through cell
 - Depends on thermal mass of materials that make up sensor
- For both high and low accuracy (0.1 to 0.002 PSU), response time and thermal lag errors can be significant
- On free-flushed sensors where flow rates are always changing, these errors cannot be avoided or corrected
- **These errors can be corrected for only on flow-controlled CTDs**

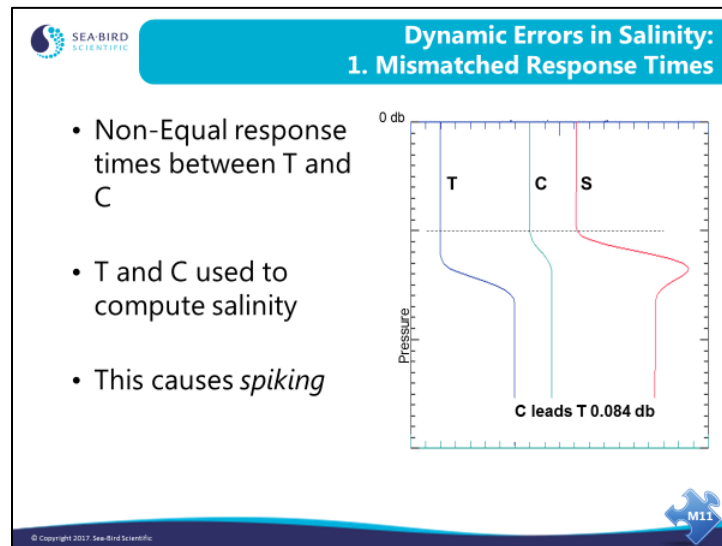
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In these examples, the temperature and conductivity sensors are not sampling the same water parcel. This will lead to errors in computed salinity and density.

Dynamic Errors in Salinity (*continued*)



Dynamic Errors in Salinity (*continued*)



In this example, the conductivity sensor responds to a change faster than the temperature sensor. This causes the salinity to *spike* high of correct.

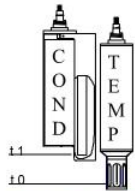
Dynamic Errors in Salinity (*continued*)

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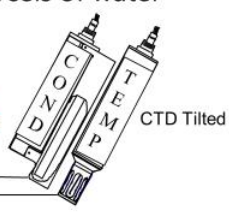
Dynamic Errors in Salinity: 2. Not Sampling Same Water Parcel

- T and C sensors measuring different parcels of water

Examples of Non-plumbed Sea-Bird sensors




Physical Misalignment



CTD Tilted

Other Company's T and C sensors



COND

TEMP

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Dynamic Errors in Salinity (*continued*)

**Dynamic Errors in Salinity:
3. Conductivity Cell Thermal Mass**

Small errors in conductivity cell temperature cause large errors in salinity.

Conductivity measurement is very sensitive to thermal mass of the cell

- 90% of Conductivity signal is dependent on Temperature

Time it takes to change temperature to new value is *thermal mass lag*

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The slide features a blue header with the title 'Dynamic Errors in Salinity: 3. Conductivity Cell Thermal Mass'. Below the header, a bolded sentence states 'Small errors in conductivity cell temperature cause large errors in salinity.' To the left, three mugs are shown in a row: a black mug with 'OLD' on it, a white mug with 'ND HO' on it, and a white mug with 'HO' on it. Below the mugs is the caption 'Image of a cold cup that changes color after putting hot coffee into it'. To the right of the mugs, text explains that conductivity measurement is very sensitive to the thermal mass of the cell and that 90% of the conductivity signal is dependent on temperature. At the bottom, a red bolded sentence states 'Time it takes to change temperature to new value is thermal mass lag'. The slide also includes the Sea-Bird Scientific logo in the top left, a copyright notice at the bottom left, and a blue arrow icon with 'M11' in the bottom right.

All materials can be heated up, some more easily than others. For example, a cast iron pan will get hotter than an aluminum pan when heated for the same length of time. A ceramic cup full of hot tea can be comfortably held, but a metal cup full of hot tea would be too hot to hold.

Different materials have different capacities for heat. The amount of heat that any given amount of material can hold is either called that material's thermal capacity or its **thermal mass**. The lower its heat capacity, the less energy it needs to raise its temperature. If it has a high heat capacity, it can store a lot of energy at any given temperature.

Since sensors are made of thermally conductive materials, we should understand how the sensor body materials affect the thermal mass, hence the measurement.

Dynamic Errors in Salinity (*continued*)



Rough Seas Can Affect Data Quality



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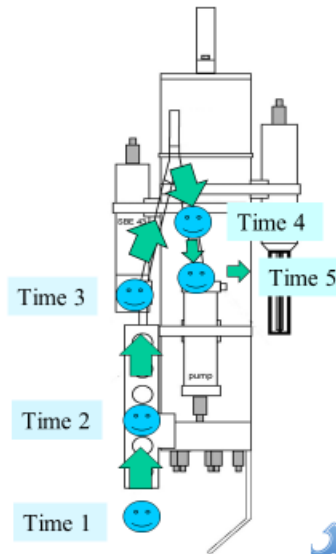
The error caused by ship motions, known as ship heave, comes from the instrument package disturbing the water that it is trying to sample. Because of this, there is no numerical solution for the problem. SBE Data Processing has an editor that will mark (flag) the offending data, so that it is not used in your final calculations. As winch technology improves, we can expect to see vessels equipped with motion compensation capability, which will greatly reduce this problem. Until that is available, you may want to profile a bit more quickly to reduce the effect of ship heave in rough water.

Reducing Dynamic Errors



Sea-Bird Solution to Reducing Dynamic Errors

1. Make measurements on the same water parcel at stations along a pump-controlled flow path
2. This allows us to post-process data to significantly reduce dynamic errors



Reducing Dynamic Errors (*continued*)



Flow Control

- Forces sensors to measure same water parcel, but at different times
- Can correct for differences in time each sensor takes its reading, because we have constant flow (speed) and sample rate
- Provides constant response time for sensors that are flow dependent (conductivity and oxygen)
- Constant flow and sample rate allows for response time adjustments between sensors (similar to time of sample adjustment)
- Reduces thermal mass amplitude and lag PLUS allows us to correct for it
- Can separate alignment issues from ship heave
- By adjusting flow speed, we can better match response times of sensors (T and C) on SBE 9plus
 - Lag is fixed and can be removed with high precision (SBE 19*plus*, 19*plus* V2, 25, 25*plus*)



