Monitoring Dissolved Oxygen: Best Practices, Calibration and Validation

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Topic I: Best Practices

- Sea-Bird Scientific Sensor Offering
  - Fundamental feature of each kind of sensing technology
- Pumping sensors
  - Anti-fouling approach using SBE sensors
- Protocols and reference materials
  - Online manuals
  - Online application notes
  - SBE Training Modules Handbook
- Pre/Post-Deployment Validation
- Sensor Storage

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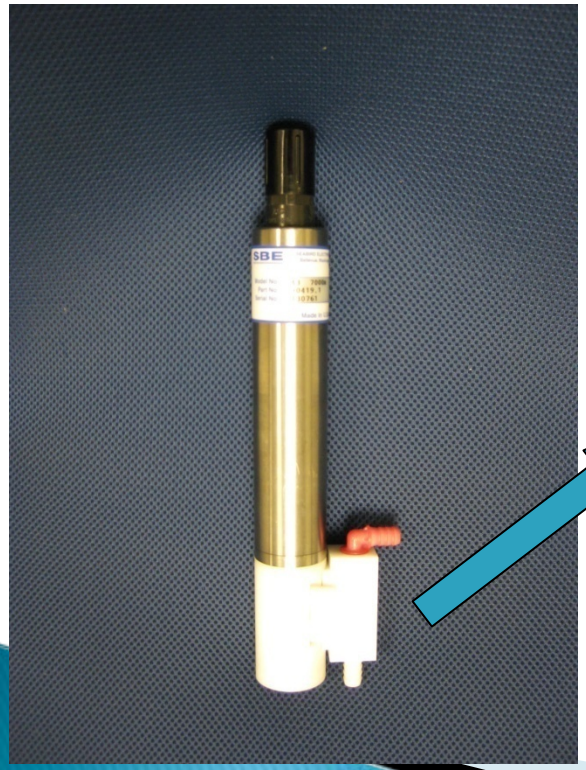
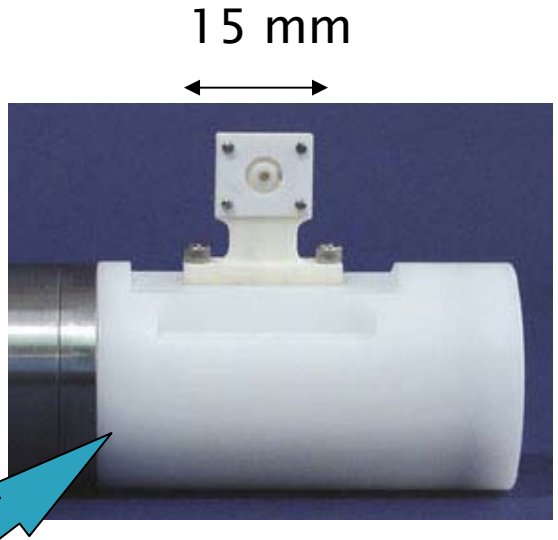
Electrochemical Sensor SBE 43: A Complete Redesign of the Clark Cell





SBE 43
Without the pump plenum

- Designed for fast profiling
  - [moored applications]
- Fast response time (1-5 s)
- Reduced electrochemical drift
- Not sensitive to H_2S poisoning
- Pumping reduces need for stirring and Bio-wipers

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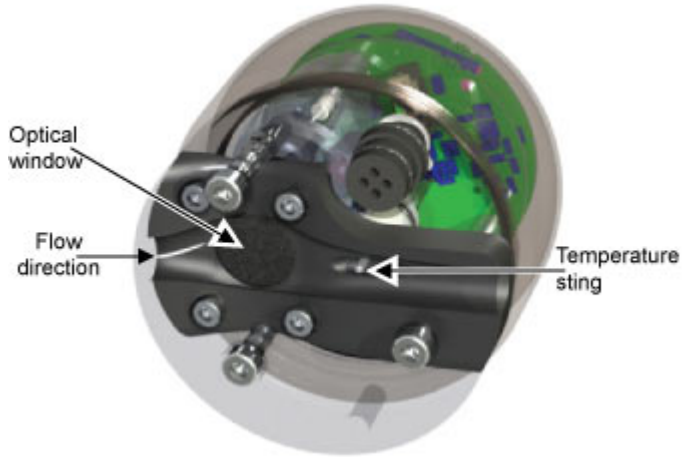
Optical Oxygen Sensor SBE 63

- Designed for moored and slow profiling applications
- Onboard temperature measured near sensing window
- Currently available as an integrated sensor
  - SBE 41 Argo CTD
  - SBE 37 Microcat
- Add on
  - SBE 16+V2 Seacat




Argo CTD


SBE 37 ODO

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Both DO Sensors are Plumbed and Pumped along with CTD sensors

Profiling and Towing

- A constant pumped flow ensures adequate flow past the sensor under variety of descent/ascent rates and towed speeds for consistent response
- Water sampling **time alignment** is possible with other CTD sensors and produces more accurate data in thermocline
  - Important for derived quantities like DO which depend on T, S, and P

Moorings

- Plumbed system traps water between samples and protects sensor from continuous exposure to the fouling environment
- Adding anti-foulant cartridges to plumbing reduces bio-growth for all plumbed sensors along with conductivity
- Water in plumbing goes to low oxygen state between samples
  - Electrolyte consumption minimized for SBE 43
- Plumbing and black plenums prevent *in situ* fouling and eliminates light interference (optical sensor)

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The Advantage of Plumbing Sensors…

Sensors continuously exposed to external environment do not perform well for long

All of these non-pumped sensors were moored for 1-month in an estuary

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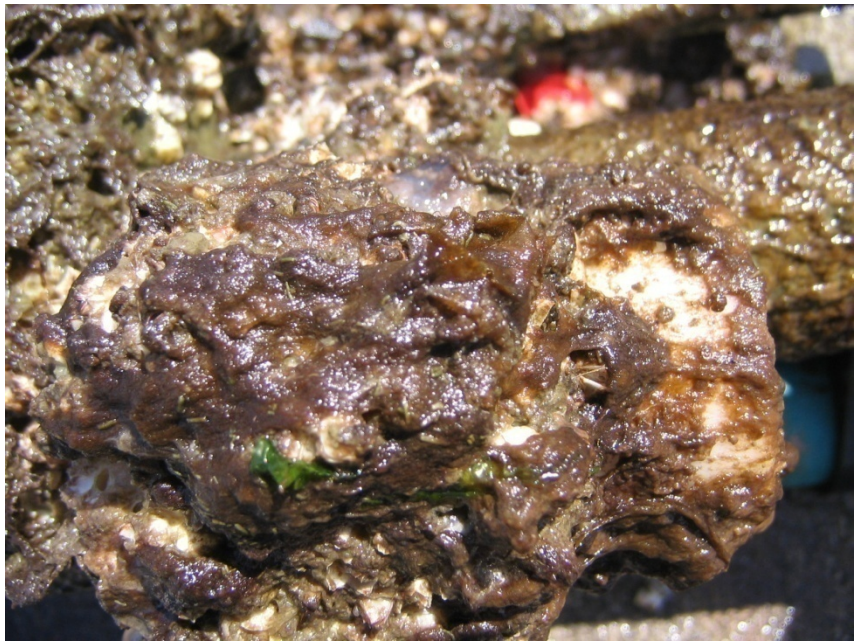
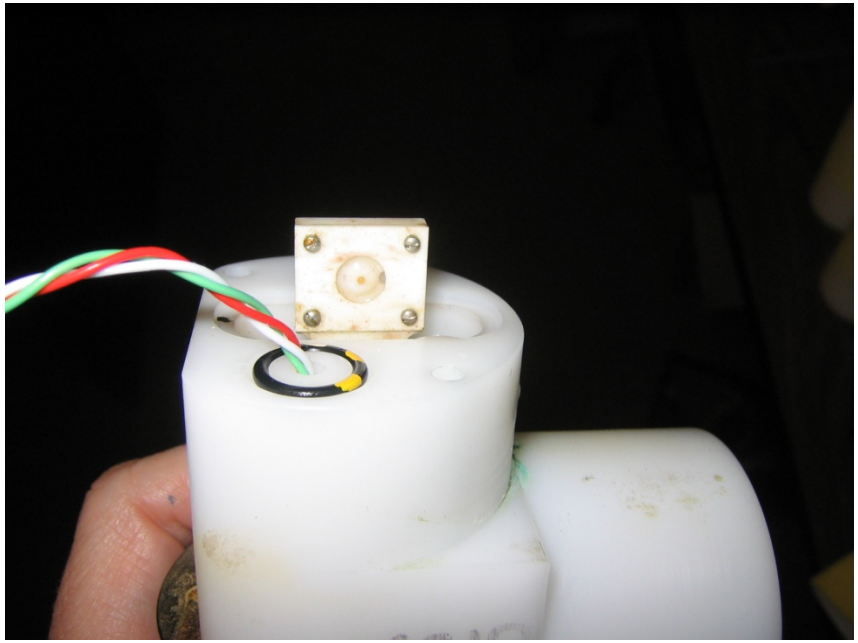
…Plumbing Reduces Fouling of the Sensor Itself

…and eliminates light interference on surface moorings for optical sensors



External fouling on instrument does Not impair interior



Interior of same SBE 43 with clean DO sensor

After 5 months in coastal marina

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Best Practice Includes Following Set Protocols Pre and Post-Deployment

- SOPs in online materials
- http://www.seabird.com/application_notes/ANcategories.htm
  - SBE 43 Application-Note 64 Series
- http://www.seabird.com/pdf_documents/manuals/63_008.pdf
  - SBE 63
- http://www.seabird.com/training/TrainingHandouts.htm
  - Training Modules for all SBE products

- **Validate** sensor before deployment, and after cleaning and prior to redeployment
  - Test Bath
  - Field validation

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Store Sensors Clean to Prevent Fouling and Drift

SBE 43

BEST: Store dry with moist sponge in Tygon loop

SBE 63

BEST: Store wet in cool dark environment

Practical: Store dry if necessary

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Topic II: Calibration

- Difference between calibration and validation
- Sensor stability characteristics
- Sensor drift characteristics
  - Easy to adjust calibration slope in-field validation

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Oxygen Calibration

- A true calibration is measuring how a sensor performs in a tightly controlled environment against a known standard across all sensitivities (DO, T, P, S)
- At Sea-Bird, we calibrate at multiple oxygen, temperature and pressure points to characterize the sensor output.

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SBE Sensors Include Complete Calibration with Purchase and Servicing

- SBE 43 Electrochemical DO
- 18 point calibration
  - 3 oxygen, 6 temperatures
  - 5 coefficients

- SBE 63 Optical DO
- 24 point calibration
  - 4 oxygen, 6 temperatures
  - 8 coefficients

- Factory service/calibration interval depends on use and deployment environments
- Annual to biennial factory service advised
  - Longer intervals possible if Best Practices followed and oxygen validation capability exists in your facility.

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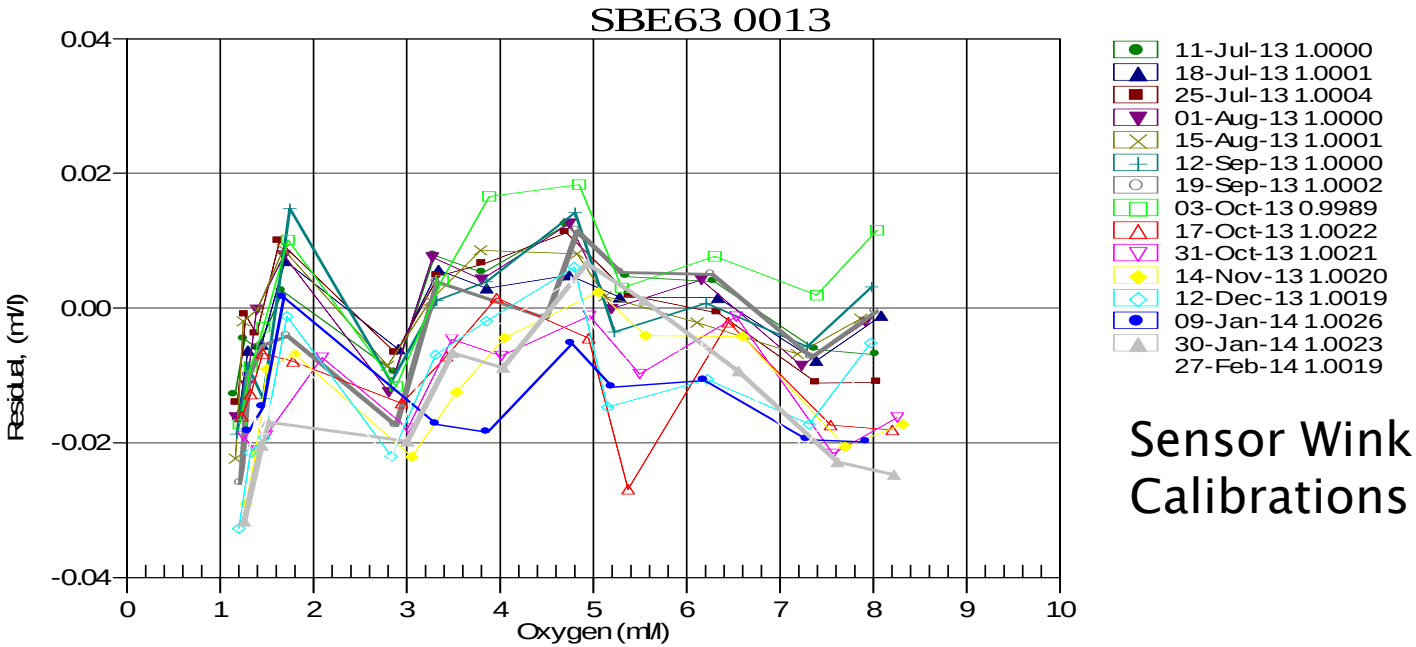
SBE 63 Optical Oxygen Calibration



Sensor Winkler Calibrations

- An in-house sensor test continuously submerged and operating
  - Stable at +/- 1 umol/kg over 7 months
- Calibration spread is bath and standard, not sensor repeatability
- Dry storage introduces drift ~1% over 6 months

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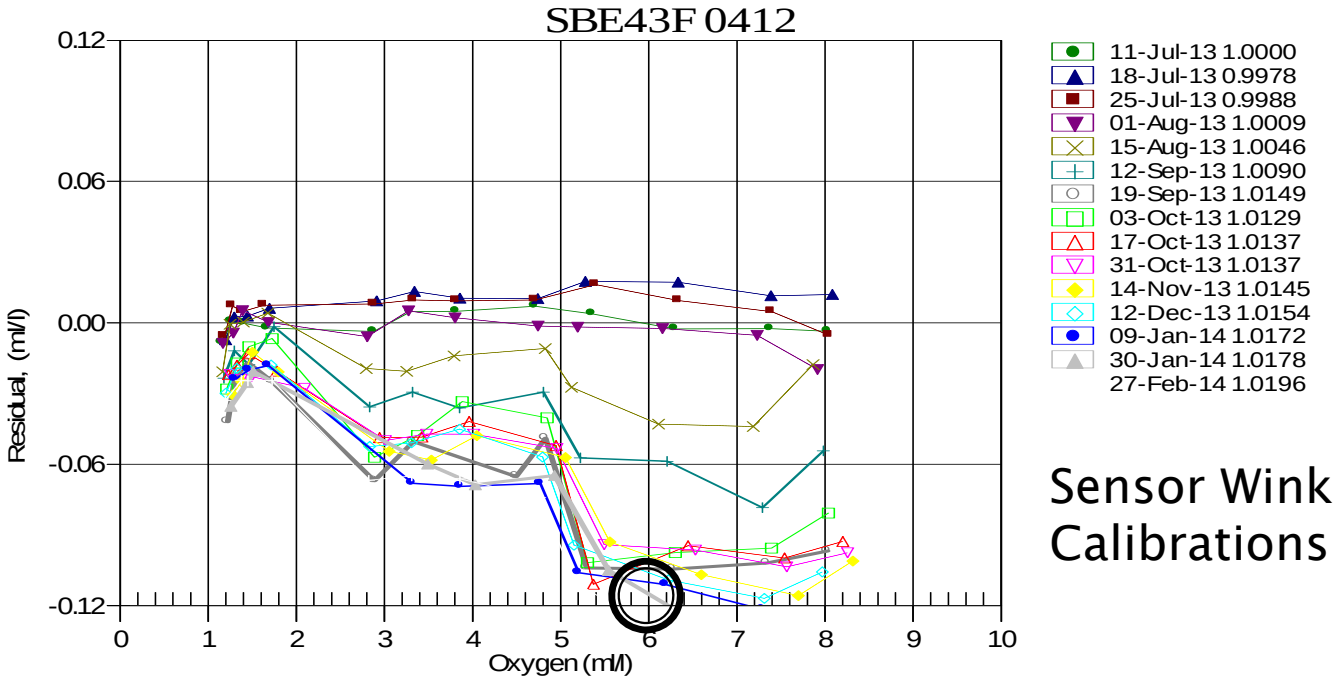
SBE 43 Clark Cell Oxygen Calibration



Sensor Winkler Calibrations

- An in-house sensor test continuously submerged and operating
  - Drifts low ~5 umol/kg over 7 months at 264 um/kg

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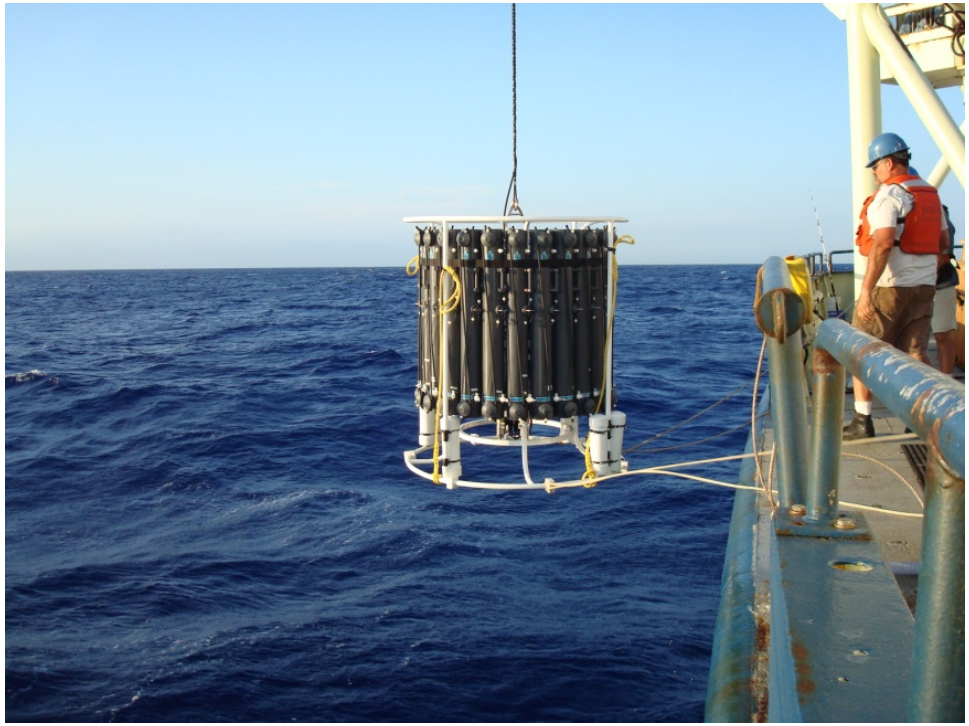
Topic III: Laboratory and Field Validation

- Pre-deployment checks
- Sensor field drift characteristics
  - Slope drift
- Field validation methods
- Appropriate validation references



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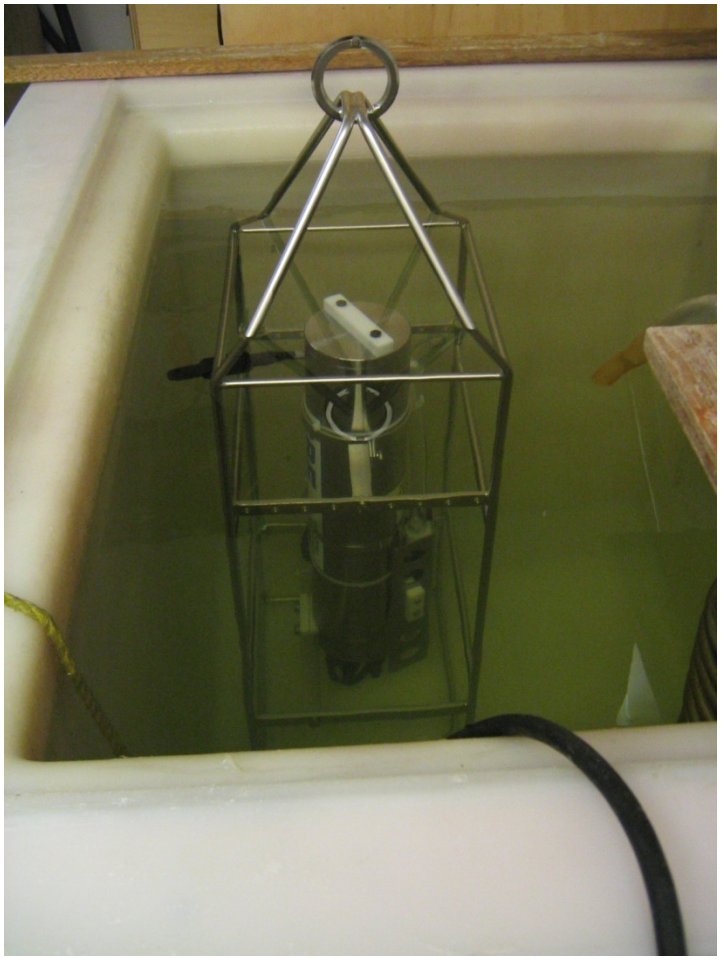
Laboratory Bath Validation Before and After Deployment

- Bath tests
  - Confirm functionality
  - Collect reference sample for slope correction in calibration equation
- Uniform bath with stable temperature
- Equilibrate instrument prior to sampling
- Turn off aerators 20 mins prior to sampling
- Synchronize water sample and sensor data



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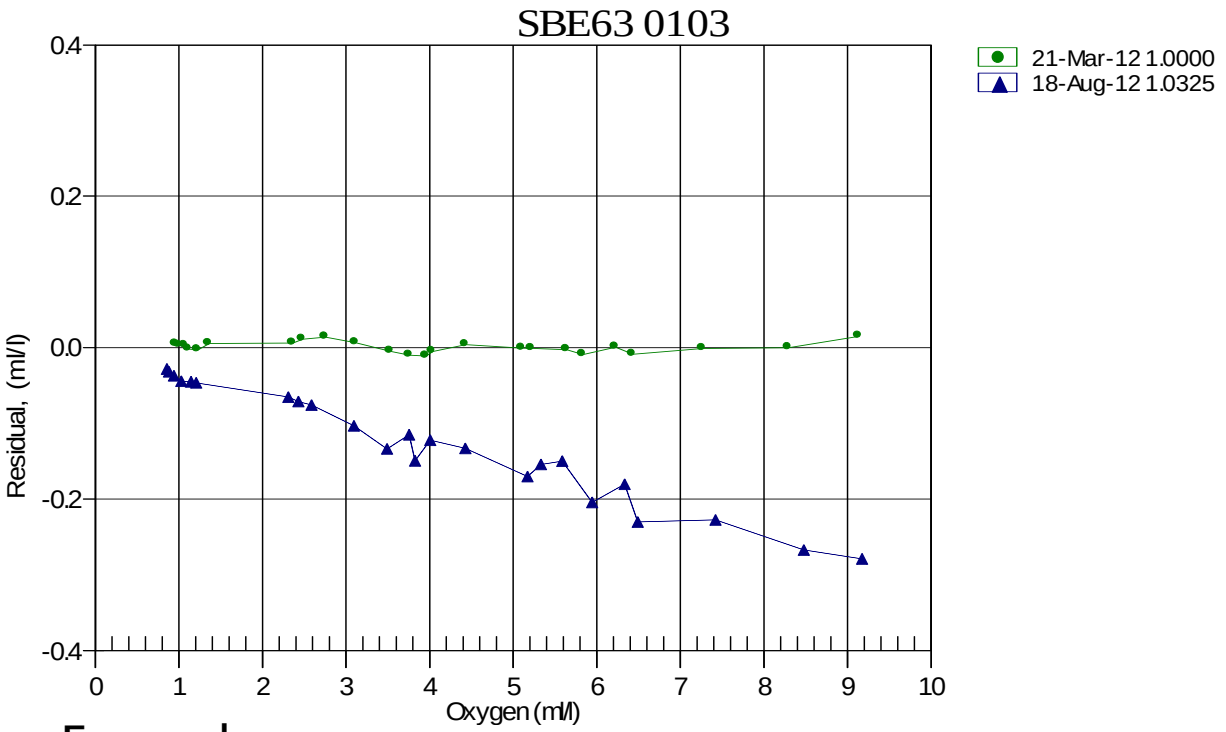
SBE 43 and SBE 63 Both Drift in Sensitivity (Slope) -- Easy Calibration Adjustment

- Early SBE 63 build with high infant drift (3% slope) in 5-months demonstrates slope change



- Correction
  - Only one quality comparison sample required
  - Winkler : Sensor

Example:
At 6 ml/L, sensor was 0.2 ml/L low
6.0/5.8 =1.03

At 3 ml/L, sensor was 0.1 ml/L low
3.0/2.9 = 1.03

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Validation in the Field at Deployment and Recovery and Routinely During Deployment

- Validation in the field allows calibration adjustments and data correction without removing instruments
  - Water samples for Winkler Titrations
  - CTD-DO profile adjacent to mooring

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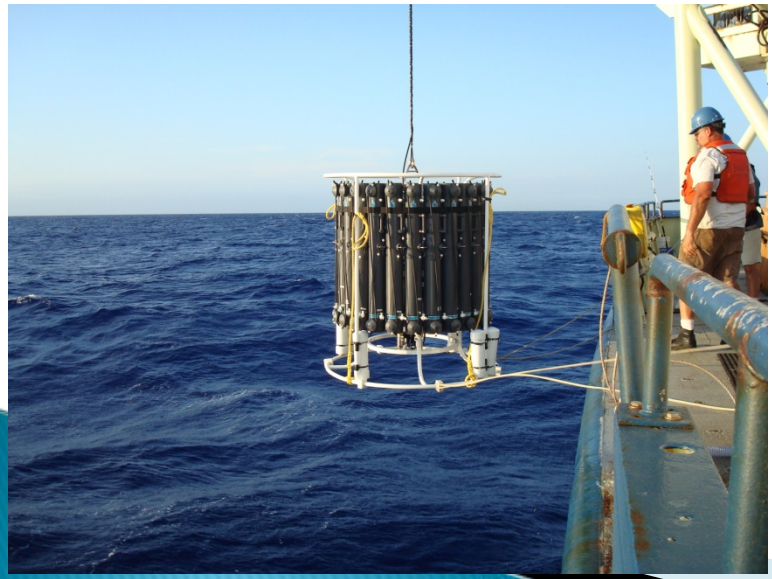
Validation: Use Appropriate and Quality Controlled References



- Winkler water samples
  - Requires some spin-up but **only true standard**
  - Replicate samples, blanks and QA/QC
    - Thiosulfate standardization
- Reference Sensors
  - Requires they are clean and calibrated
  - Use reference sensor correctly
    - respect response time (profiling)
  - Do not use less accurate spec'd sensor

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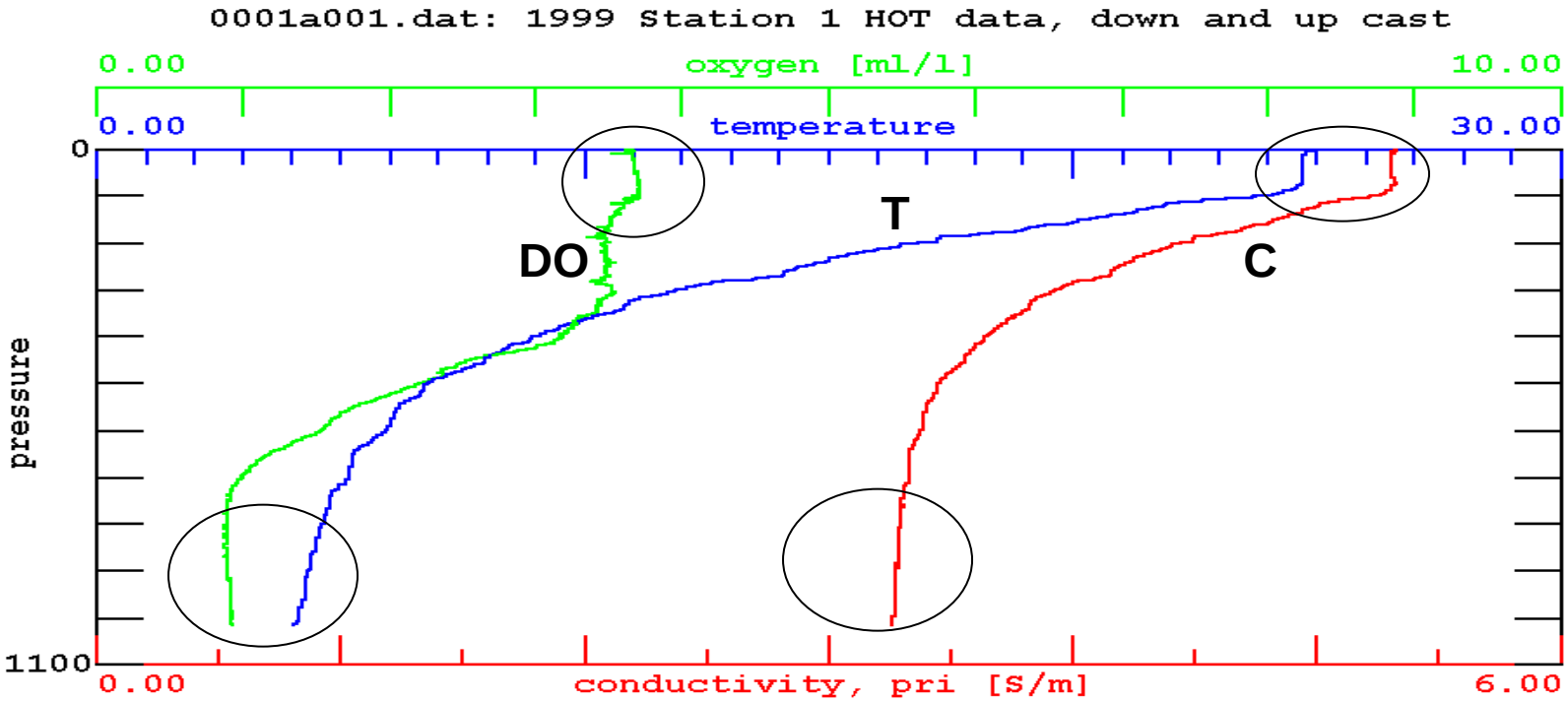
Field Validation: Where to Collect Water Samples for Calibration CTD-DO profilers



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Summary

- Start with a stable and well characterized sensor for the given application
  - A complete calibration that captures the sensor's full character is critical for out of box accuracy
- Best Practices
  - Follow manufacturer's guidance on maintenance and storage
  - Validate with appropriate and accurate references
  - Simple pre and post-deployment check lists and validations
    - Document conditions before and after deployment
  - Establish Laboratory and In-Field Validation Procedures based on specification of data accuracy that is needed

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Extra Slides

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Sometimes, it is not the Sensor
Look at Your Data and All Systems

Problem

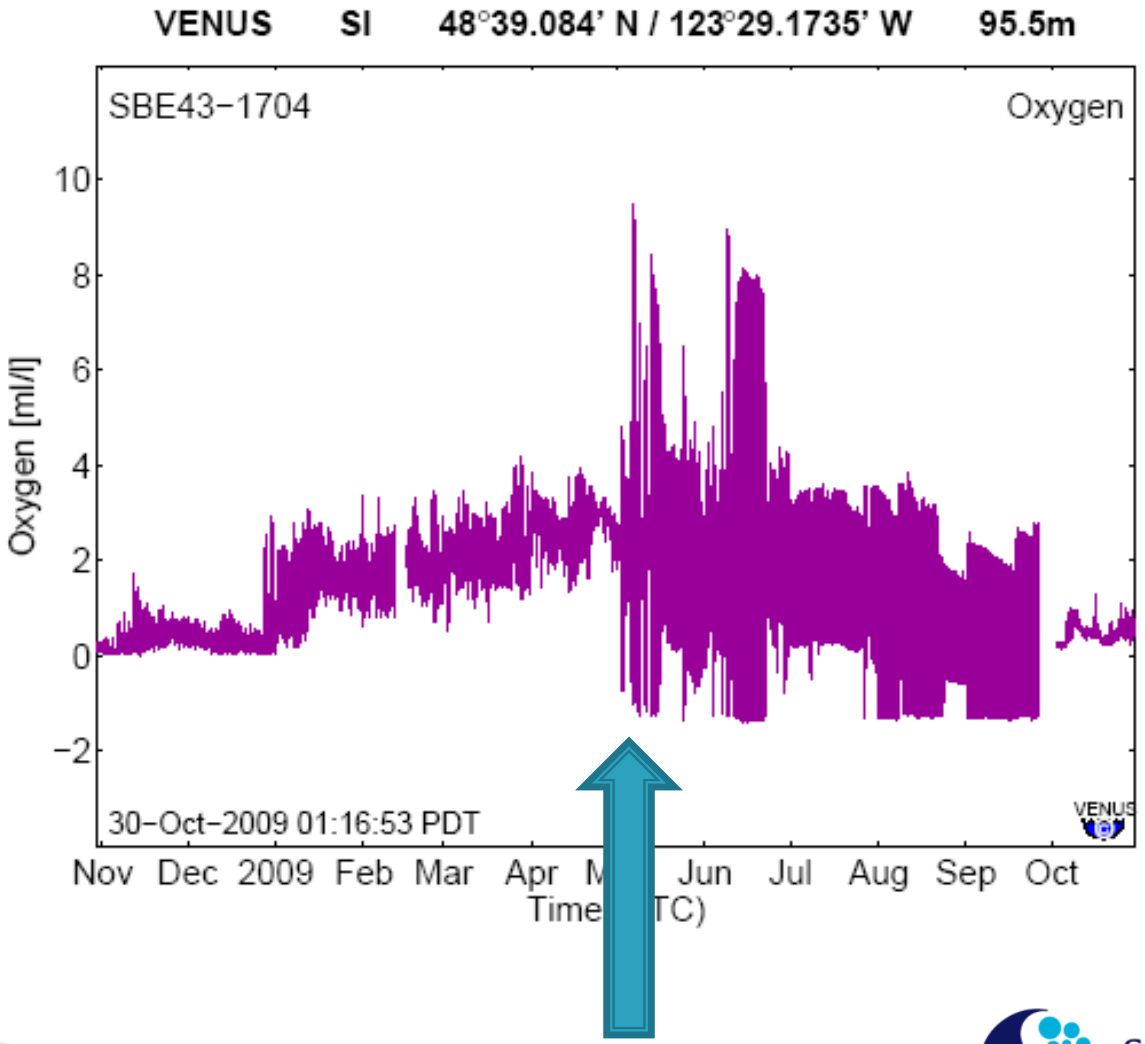
Erratic Data

Intermittant

Trending correct

Clog?
Fouling?

Cables?
Electrical?



Problem first noticed

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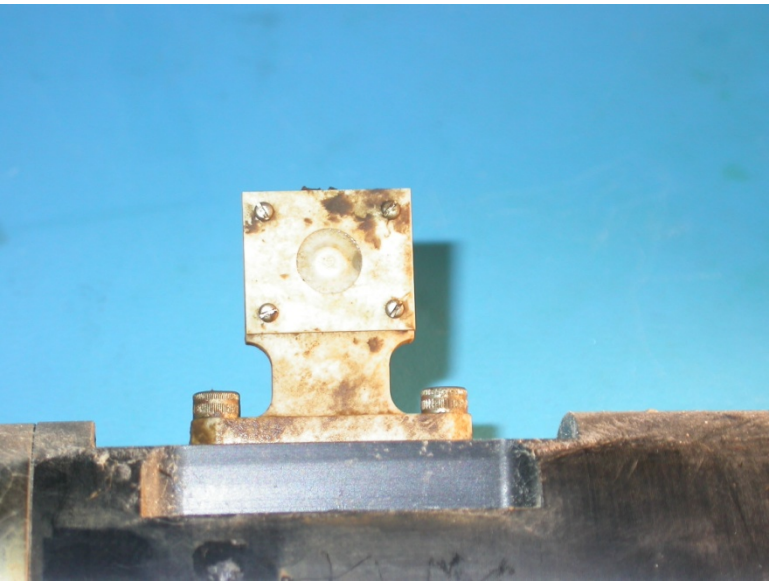
When Sensor Returned Plumbing was clear and Sensor Drifted < 5% /year



Light fouling

Post-Calibrated well after 20 months of deployment (nearly two years!)

Corrosion on bulkhead pins of SBE 43

More severe in cable connector

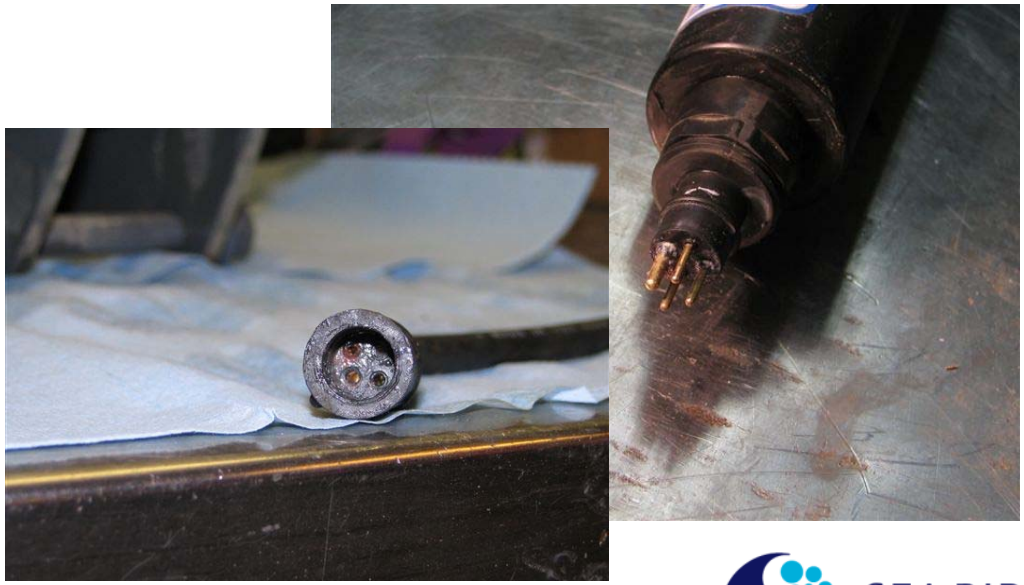


Photo: Courtesy of Paul Macoun from UVIC

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Sensor was fine…
The Cable connecting SBE 43 to Data Logging CTD Leaked!

Photo: Courtesy of Paul Macoun from UVIC

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Calibration and Metrology At Sea-Bird

27 CTD and DO calibration baths;
more than 38,000 calibrations/year

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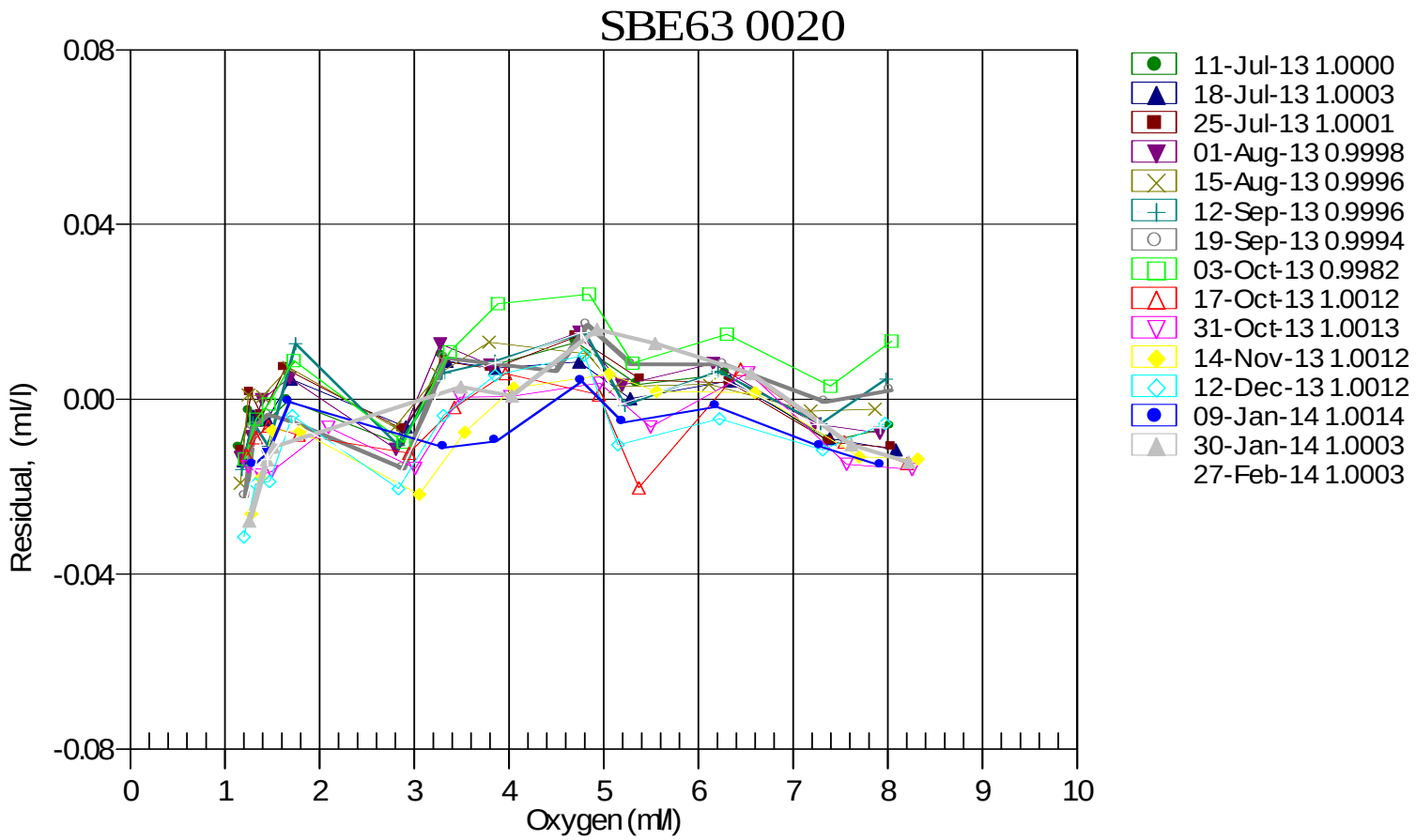
SBE 63 Reference Sensor 0020



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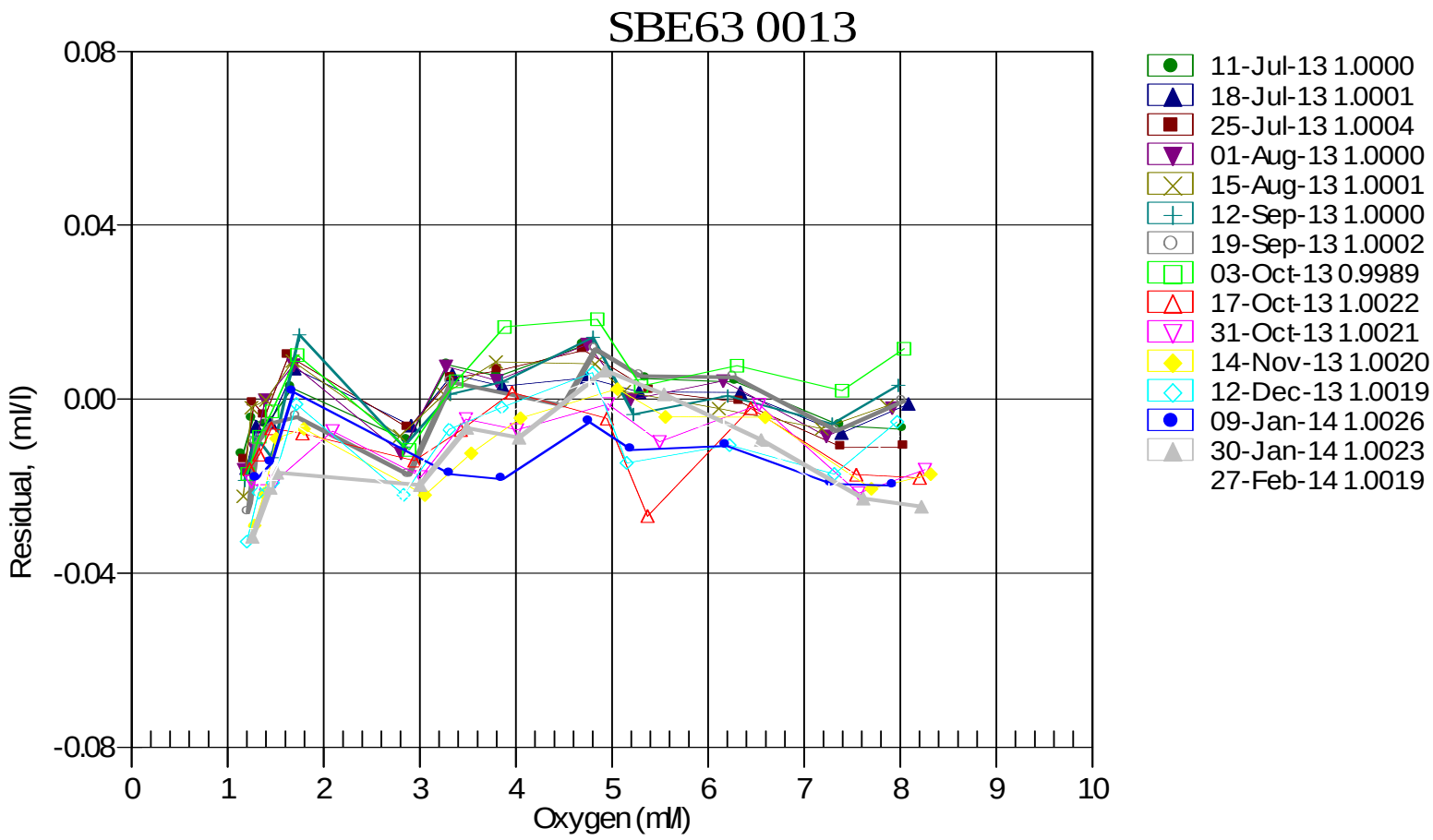
SBE 63 Reference Sensor 0013



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Best Practice, Sensor Validation and Data Correction: SBE Website

SBE 43 Application-Note 64 Series for Oxygen (cleaning, sensor performance, validation, data corrections). Follow similar protocols for SBE 63.
http://www.seabird.com/application_notes/ANcategories.htm

SBE 63 Manual (Care, operation, and data processing)
http://www.seabird.com/pdf_documents/manuals/63_008.pdf

Training Modules for SBE Instruments (Modules 8 and 12 cover oxygen best practices and validation protocols)
http://www.seabird.com/training/TrainingHandouts.htm

Technical Papers and Topics (several papers on SBE 43 applications, data validation and best practices)
http://www.seabird.com/pdf_documents/manuals/63_008.pdf

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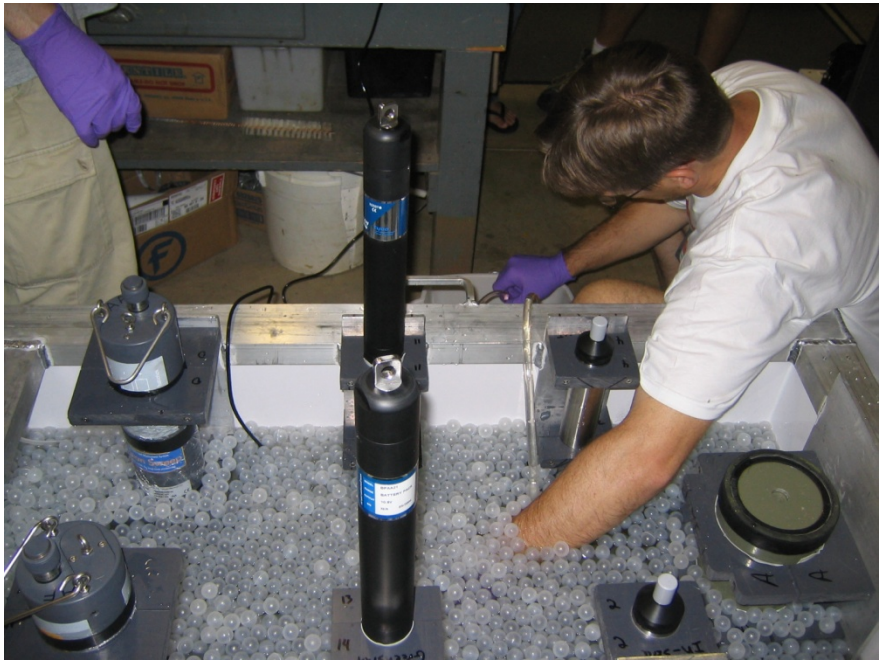
Pre-Deployment Checks and Suggestions

- Always a good idea
  - After shipment
  - Before deployment
  - After recovery
  - After cleaning
- With multiple sensors, test together in a known environment
  - Stable portion of the water column, strap together for in-field tests and comparisons before deployment



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