O_2 optodes

Autonomous platforms (Argo and gliders): known issues, recommendations for implementation and qualification

Henry Bittig

IOW, Baltic Sea Research Institute Warnemünde

Workshop on Interoperability Technologies and Best Practices in Environmental Monitoring - Brest, 10-12 October 2018

Known issues?

Best practice:

If you want to put your sensor in a given environment, know the behaviour of your probe beforehand (or know how to check).

What characterization?

(Equilibrium) response to O_2, to T, and to P (two-fold effect*)

→ Quite well known or 'straightforward' to obtain

Time delay τ?

O_2 time response (reasonably-well known), no relevant pressure hysteresis

Change with time Δt? If yes, in which way?

O_2 (strong 'storage' drift, small 'in-situ' drift, known), T (no evidence), P (possibly, not proven)

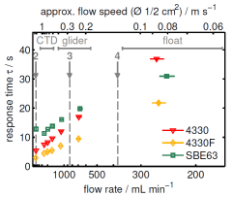
*Bittig et al. (2015) Pressure Response of Aanderaa and Sea-Bird Oxygen Optodes, JAOT

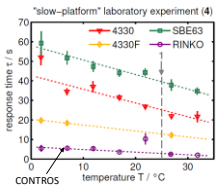
O_2 time response issue

Characterized in lab experiments: Step response O_2/N_2-bubbled baths

(a) Changing flow at constant temperature

(b) Constant flow with changing temperature





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Characterized in lab experiments: Step response O_2/N_2-bubbled baths

(a) Changing flow at constant temperature

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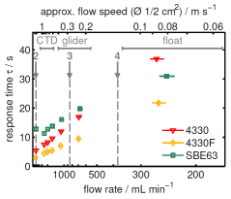
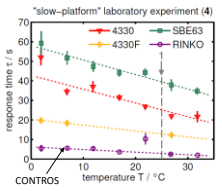
→ Two-layer stagnant film model to explain O_2 time response:

(a) Flow determines liquid layer thickness l_L

(b) Temperature-dependent diffusivities/solubilities modify τ(T)

→ look up-table for $\tau = f(l_L,T)$





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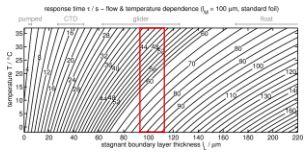

Bittig et al. (2014) Time response of oxygen optodes on profiling platforms and its dependence on flow speed and temperature. Limnol. Oceanogr. Methods

Bittig and Körtzinger (2017) Technical note: Update on response times, in-air measurements, ... Ocean Sci.

O_2 time response issue

Transfer to field deployments:

→ velocity – l_L parameterization depending on platform & attachment

e.g., from dual-O_2 float (fast & slow O_2 optode on same float), dual-O_2 CTD, dual-O_2 glider, ...

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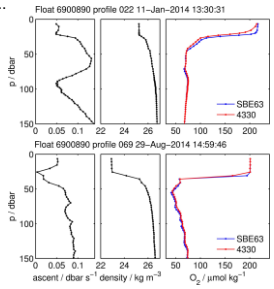

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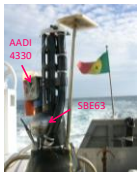

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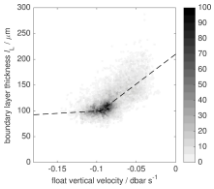

Henry Bittig, Réunion Oxygène France, Brest, 12. Oct. 2018

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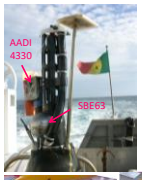

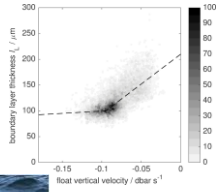

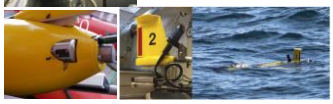

Similar?

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(2) Any deployment needs some way of referencing.

Linear with pO_2, small (often negligible) zero intercept.

(3) Adjust with a ***slope only*** (or a slope and very small offset).

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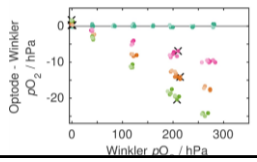
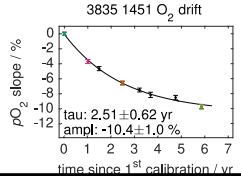
3835 1451 calibration data



3835 1451 O_2 drift



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O_2 response 'in-situ' drift

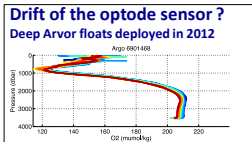
From multi-year float deployments, e.g.,

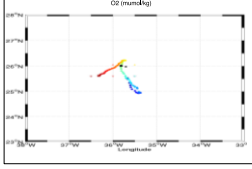
- Change in deep O_2 (believed to be stable)

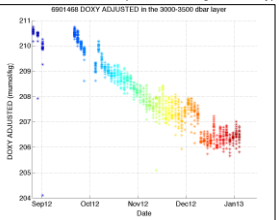
(Slide from Virginie Thierry)

Drift of the optode sensor ?

Deep Arvor floats deployed in 2012







This floats stayed during 5 months in a very small area

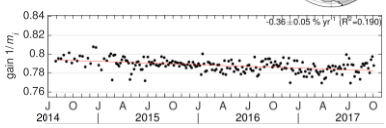
Apparent drift of about 4 µmol/kg over 5 months

O_2 response 'in-situ' drift

6902549 / Norway

From multi-year float deployments, e.g.,

- Change in deep O_2 (believed to be stable)
- Direct observations at surface 'in-air'



Order of O(0.5 % / year) magnitude smaller than 'storage' drift (O(5 %/year))

(7) Long-term deployments need long-term way of referencing.
e.g. regular in-air measurements!

O_2 response 'in-situ' drift – In-air observations

On floats: Established, becoming standard.

Bittig and Körtzinger (2015), Johnson et al. (2015), Bushinsky et al. (2016), SCOR WG 142 (2015)

Unclear fleet tendency (15 floats with multipoint calibration: slightly negative; 52 floats with batch calibration: both negative and positive),
but individual ones drift significantly (correction needed) Bittig et al. (2018)

On gliders: Proven, but rare?

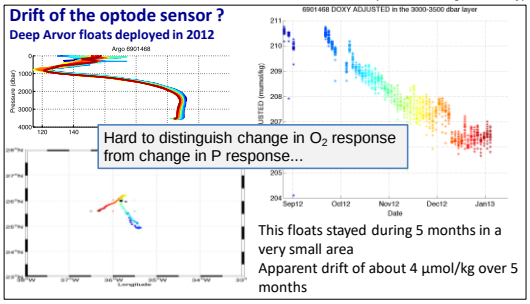
Pressure response drift

vs.

From multi-year float deployments, e.g.,

- change in deep O_2 (believed to be stable)

(Slide from Virginie Thierry)



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Pressure response drift/conditioning

Surface O_2 drift only linear vs. deep O_2 drift curved – mismatch?
Pressure conditioning through pressure cycling?
But no hard clues. Still... watch out!

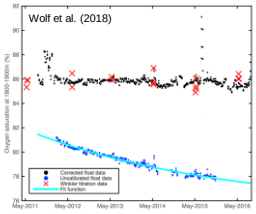

Figure 2. Float 1901210 corrected oxygen saturation (%) at 1,800 to 1,900 m (black dots) compared to the uncalibrated float data for the same depths used for the fit calculation (blue dots). The exponentially decaying fit function (light blue line) is calculated from equation (2). Winkler titration data from annual May surveys of the AR7W hydrographic line are shown in red "x". All floats shown in Figure 52.

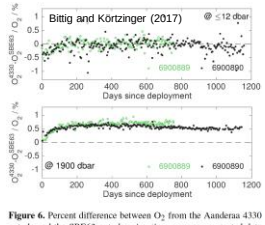

Figure 6. Percent difference between O_2 from the Aanderaa 4330 optode and the SBE63 optode using time response corrected data (top) near the surface and (bottom) at depth for floats 6900889 (green) and 6900890 (black). There seems to be a conditioning effect on either one or both optodes during the first half-year / ≈ 40 profiles, after which differences between optodes are stable.

Summary

Two-fold pressure response, on luminophore and on quenching process.
(0) Pressure correction should be done in two steps.
Strong 'storage' O_2 sensitivity loss (O(5 % / year)), i.e.,
(1) Not recently calibrated optodes should be regarded as uncalibrated!
(2) Any deployment needs some way of referencing
Linear with pO_2, small (often negligible) zero intercept.
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(5) Requires lab multipoint O_2-T calibration at some point; Batch-adjusted often distorted-linear and not recommended.
Drift becomes less intense in older optodes / foils.
(6) Don't change foils unless mechanically damaged.
Smaller but significant in-situ drift (O(0.5 % / year))
(7) Long-term deployments need long-term way of referencing.
(e.g., in-air if profiling or surface mooring)

Further reading :-)

ORIGINAL RESEARCH ARTICLE
Front. Mar. Sci., 24 January 2018 | https://doi.org/10.3389/fmars.2017.00429

Oxygen Optode Sensors: Principle, Characterization, Calibration, and Application in the Ocean

Henry C. Bittig[1*], Arne Körtzinger[2,3], Craig Neill[4], Eikbert van Ooijen[4], Joshua N. Plant[5], Johannes Hahn[2], Kenneth S. Johnson[5], Bo Yang[6] and Steven R. Emerson[6]

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[3]Christian-Albrechts-Universität zu Kiel, Kiel, Germany
[4]CSIRO Oceans and Atmosphere, Hobart, Australia
[5]Monterey Bay Aquarium Research Institute, Moss Landing, CA, United States
[6]School of Oceanography, University of Washington, Seattle, WA, United States