The 2008 North Atlantic Bloom Experiment

Calibration Report #10

Calibration of the Optode Oxygen Sensors on Seagliders
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Summary
Oxygen data from the optodes on the 4 NAB seagliders was corrected for time lags in oxygen and temperature and by a gain and offset in oxygen. Values of these parameters were chosen to minimize the difference between oxygen on up and down casts, to minimize the difference in oxygen between different gliders and between gliders and float 48 on 40 nearby profiles and to minimize to difference in oxygen between gliders and Winkler bottle data on 4 glider calibration casts made from the R.V. Knorr. The resulting oxygen has an error of ±2 µMol kg⁻¹.

1. Oxygen Sensors, Mission and Errors
The four seagliders used in NAB08 each carried an Aanderaa 3830 optode. Seagliders [140 141 142 143] carried serial numbers [769 016 013 014] with foil batches [50005 1707 1707 1707] respectively. The optodes were mounted near the tail of the vehicle as shown in Fig. 1. The sampling interval varied from 5s to 85s, decreasing with depth, with the optodes turned off between 600dbar and 900 dbar starting on day 116. The gliders profiled to about 980 dbar.

Data from data release 2.2 was used in this analysis. The optode computes dissolved oxygen from measurements of ‘bphase’ and temperature. Since the optode temperature is inferior to that measured by the Seabird sensors, dissolved oxygen is recomputed in the basic processing using the Seabird oxygen. All analysis here was done using this recomputed oxygen, variable aanderaa3830_dissolved_oxygen from data release v2.2;
3. Optode Calibration formula

Optode errors are due both to calibration errors in the sensor and to time lags in its oxygen and temperature responses. The optode is adjusted using the formula

\[ [O_2]_{cal} = A + B \cdot [O_2] + \tau \frac{d[O_2]}{dt} + C \frac{dT}{dt} \]  

Note that this is somewhat different than the formula used to adjust the float optode in NAB report #3. This may represent the greater importance of time lags in the glider data, since gliders move faster than floats, the different errors of the different sensors, or differing arbitrary empirical choices in the calibration processes.

4. Lag Correction (*updown2.m*)

The constants \( \tau \) and \( C \) correct for the time response of the optode. They are computed by minimizing the difference between the up and down values of oxygen in the same glider dive using a straightforward least-squares minimization on the depth range of 0-100m. Using the full depth range does not change the answer significantly. Fig. 2 shows the result for glider 140. Results for the other gliders are shown in Appendix 1. The value of \( \tau \) varies from 19s to 25s between gliders; the value of \( C \) varies by \( \pm 12\% \).

![Fig. 2. Smoothed difference between up and down values of oxygen measured by the optode on glider 140. Left) Before lag correction. Right) After lag correction. RMS value, printed on plot, is decreased.](image)

5. Calibration

The constants \( A \) and \( B \) are computed by minimizing the differences between optode oxygen on nearby gliders, between optode oxygen on gliders and calibrated oxygen on float 48 and between optode oxygen on gliders and Winkler bottle samples taken from the *R.V. Knorr*. The values were adjusted manually and included in the function *CorrectGliderOptode.m* listed below. The results after adjustment are shown here.

Intercomparison was done on 40 pairs of profiles in which two gliders or a float and glider were closer than 2 km. For each profile the mean and median differences between the oxygen values were computed in a depth range of 50-500m. A sample profile-profile intercomparison is shown in Fig. 3; the entire set is shown in Appendix 2.
The differences for all profile pairs are shown in Fig. 4. The depth-averaged differences between profiles is almost always less than $\pm 2 \mu$Mol kg$^{-1}$.

Fig. 3. Sample intercomparison cast between Seagliders 141 (green) and 143 (black). Upper Left: Depths of two gliders against time and colored by time. Lower Left: Positions of two gliders colored by time. Upper Right: Profiles of oxygen against depth. Lower Right: Profiles of oxygen against potential temperature. For this pair, the mean difference is 1.0 $\mu$Mol kg$^{-1}$. 
Fig. 4. Average profile differences A-B colored by pair type. Inside symbol indicates profile A; outside indicates B. Colors [red, green, blue, black, magenta] correspond to [gliders 140, 141, 142, 143, and float 48].

Fig. 5. As in Fig. 3 but comparing a Seaglider profile with a nearby R.V. Knorr CTD cast. Circles show Winkler bottle samples; horizontal bar is ±2μMol kg⁻¹.
Oxygen profiles at each of the 4 glider calibration casts from the *R.V. Knorr* were compared to Winkler oxygen samples taken on these casts. An example is shown in Fig. 4; all 4 casts are shown in Appendix 3. Most of the Winkler samples are within ±2µMol kg⁻¹ of the glider measurement. The cast for glider 140 has significantly more error. This could easily be due to the presence of a sharp water mass gradient in this vicinity, as can be seen, for example, in many of the other calibration casts in NAB report #3.

### 6. Deep Oxygen Values

Figure 5 compares the deep glider oxygen values with data from 4 WOCE cruises. At the coldest temperatures, the gliders are consistent to better than ±2µMol. All of the WOCE data collapses to a small region at potential temperatures near 3.5°C. Although the glider data does not reach these cold temperatures, it clearly trends toward this point. These data indicate that there are no gross errors in the glider oxygen at the greatest depths.

![Fig. 5. Comparison of glider data (small dots color coded as in Fig. 3) with data from 4 WOCE cruises in this region (large circles). Data is plotted in potential temperature/oxygen coordinates.](image-url)
7. Conclusion

The following function brings the 4 glider optode oxygen sensors into agreement with each other and with the Winklers during the Knorr cruise to about 2 μMol/kg. These corrections are applied to release 3 of the glider data. The new oxygen variables are:

- **oxyca0** – Oxygen concentration computed from release 2.2
- **oxyca1** – time lags have been applied oxyca0
- **oxyca2** – Slope and offset have been applied to oxyca1
- **oxy** - **Best glider oxygen.** Equals oxyca2 in this release

```matlab
function [oxyca0 oxyca1 oxyca2]=CorrectGliderOptodeNaN(num,oxy,S,T,P,yd)
% Correct oxygen values from NAB08 glider optodes to be consistent with CTD Winkler, calibrated float and historical data
% Input:
%   num - glider number  140, 141, 142 or 143
%   oxy - optode oxygen computed. Same as variable '
aanderaa3830_dissolved_oxygen'
% % in data release 2.2
%   S,T,P - Salinity, Temperature (not potential) and Pressure on same timebase
%   yd -yearday
%
% Output: calibrated oxygen
%   oxyca0 - original oxygen values
%   oxyca1 - lags removed
%   oxyca2 - lags removed and calibrated
%
% Notes:
%   Gaps (NaNs) in the original oxy data are preserved, and oxy values over 500 are removed (replaced with NaNs).
%
% EAD - October 2010
% graya - 21 Oct 2010

if num==140
  O2off=4.0;Poff=0;Toff=0;Ogain=0.09;Cfix=[315  21.8];
elseif num==141
  O2off= 0.2;Poff=0;Toff=0;Ogain=5/270;Cfix=[416  19.1];
elseif num==142
  O2off=1;Poff=0;Toff=0;Ogain=12/270;Cfix=[349  25.2];
elseif num==143
  O2off=8.5;Poff=0;Toff=0;Ogain= 0/270;Cfix=[383  19.6];
else
  error('No such glider %d',num);
end
```
g = find(~isnan(oxy+T+S) & oxy<500);
b = find(isnan(oxy+T+S) | oxy>=500);

oxy(b) = NaN;
oxycal0 = oxy;

% perform calculations on the good values only
yd=yd(g);P=P(g);S=S(g);T=T(g);oxy=oxy(g);

% oxycal1: Optode lag correct
der = [-1 0 1]';
dTdt = conv2(T,der,'same')./conv2(yd*86400,der,'same');  % Temp change rate
dOdt = conv2(oxy,der,'same')./conv2(yd*86400,der,'same');  % Oxygen change rate
oxy = oxy+dTdt*Cfix(1)+dOdt*Cfix(2);  % Corrected data

oxycal1 = NaN*ones(size(oxycal0));
oxycal1(g) = oxy;

% oxycal2: Optode calibration
oxy = oxy+O2off;
oxxy = oxy+(500-P)/480*Poff;  % Pressure correction
oxy = oxy+Toff*(T-9.5);  % Temperature correction
oxy = oxy+Ogain*oxy;  % Oxygen gain

oxycal2 = NaN*ones(size(oxycal0));
oxycal2(g) = oxy;
APPENDIX 1 – Time Lag Corrections
APPENDIX 2 – Glider-Glider and Glider-Float Intercalibrations
Cast A - B  mean-o median-s (Outside=A, Inside=B, [rgbkm]=[140:143 float])
Appendix 3 – Glider-Winkler Comparisons