Quality Control of Profiling Float Oxygen Data

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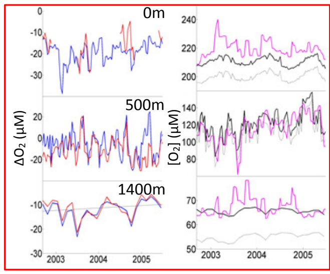
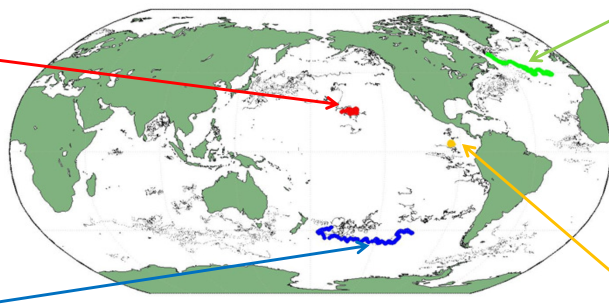
Introduction

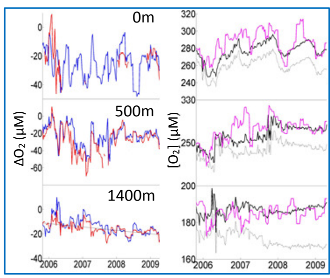
Profiling floats provide a near-ideal platform for monitoring the seasonal evolution of both physical and chemical processes at the regional, basin, and global scale. Although temperature, salinity, and pressure data must pass well-defined Quality Control protocols at Global Data Assembly Centers, no such protocol exists for chemical data (oxygen and nitrate) now being measured on 348 "Argo Equivalents" (of which ~150 are still active) within the ~3200 float array. With the number of chemical measurements returned from the rapidly growing Argo array, it is important to develop and evaluate new QC procedures for these data in order to use the chemical Argo dataset for quantitative descriptions of oceanic biogeochemical processes. We compared the float oxygen dataset (reported since 2002) to the World Ocean Atlas 2009 in order to compute sensor drift and sensor offset, relative to the atlas. Here, we discuss the correction terms, separated by sensor type (Aanderaa Optode vs. Seabird43), and present the resulting global float oxygen dataset.

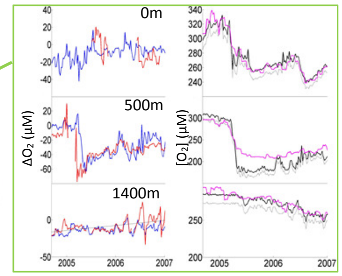
World Ocean Atlas 2009

WOA09 provides a monthly climatology on a one-degree latitude-longitude grid from the surface to 1500m at 24 standard depths. The climatology was created from over 800,000 scientifically quality controlled discrete oxygen measurements that exist in the World Ocean Data Base 2009. Only the measurements made using the Winkler Titration method using visual, amperometric, or photometric end point detection techniques were included in the climatology. The data went through further quality control by means of range checks as a function of depth and ocean region, statistical checks, and subjective flagging of data by the authors of the climatology. For further details, refer to Garcia et al. 2009.









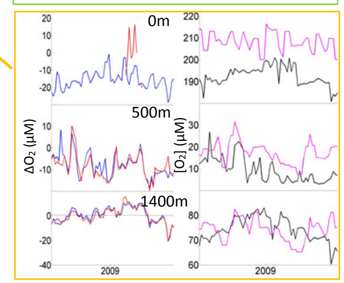


Figure 1. Float profiles used in the analysis (black dots, n=14,533). Four profiling floats (4900093 (red), 4900608 (green), 5900966 (blue), and 5901457 (orange)) are shown in the panels in order to demonstrate the basic steps taken in the analysis. In each panel the left column (blue and red lines) represents a time series of ΔO_2 (ΔO_{2depth} and $\Delta O_{2isopyc}$), and the right column shows a time series of the oxygen concentration of the WOA09 climatology(magenta), corrected float oxygen (Solid Black), and uncorrected float oxygen (Dashed Black).

Methods

Profiling Float data were downloaded from the USGODAE website in June 2010. After visual inspection, approximately 120 floats were eliminated from the dataset due to lack of data, sparseness of data (Antarctic deployments), and evident sensor failure due to unreasonable T, S, or O_2 values, leaving 163 floats for further analysis (Table 1). Outliers that caused spikes in the profiles were removed during this process as well. Whenever available, delayed mode data were used. The ΔO_2, defined as $\Delta O_2 = [O_2]_{float} - [O_2]_{WOA}$ was calculated using the climatology values from the grid point closest to each profile at the 24 standard depths (ΔO_{2depth}), and isopycnal surfaces corresponding to these depths ($\Delta O_{2isopyc}$); the average density calculated from float T, S, and P data at the standard depths was used as the isopycnal to calculate $\Delta O_{2isopyc}$.

Sensor Drift: Rates of change in ΔO_{2depth} and $\Delta O_{2isopyc}$ were calculated using linear least squares regression. In most cases, the standard deviation of residuals from the fit for $d\Delta O_2/dt$ was smaller when it was calculated on isopycnal surfaces than at constant depths. Thus, the rate of change of $d\Delta O_{2isopyc}/dt$ was used to determine sensor drift. The sensor drift was determined as the average of the six "deep" slopes (1000m-1500m in 100m intervals).

Sensor Offset: After applying a drift correction to sensor data at all depths, ΔO_2 was recalculated. The ΔO_2 at each depth was averaged over all profiles to create a single profile of the average ΔO_{2depth} for every float (Fig. 4). The ΔO_{2depth} between 1000m and 1500m from this profile was averaged and this value was applied to all float data as the sensor offset (i.e. Average Deep ΔO_2 in Fig 3). 13 floats did not exceed 1000m, and could not be corrected in this manner, reducing the final inventory to 150 floats.

Conclusions

- **The optode exhibited lower drift than the SBE43.**
- **Slow response time of the optode may be responsible for larger deviations from the WOA near the oxycline suggesting that an "advance time" correction may improve optode data (Uchida et al., 2008)**
- **The accuracy of the oxygen measurements does not seem to be improving with time for either sensor.**
- **Poor documentation of metadata (e.g. sensor type, oxygen concentration units, post-deployment calibration) increases the uncertainty involved in using the float oxygen dataset.**
- **Applying an offset correction based on deep ΔO_2 shifts the average surface oxygen % saturation towards 100% (96±10% to 101±7%).**

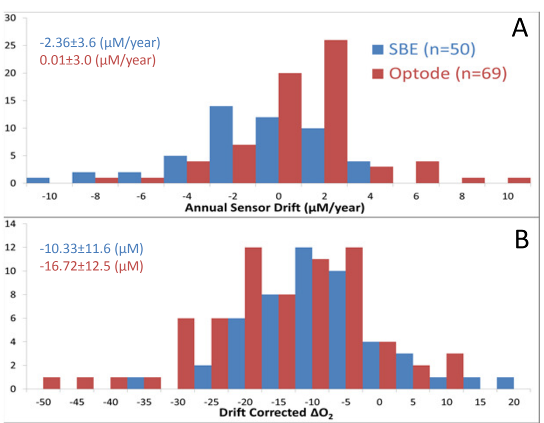


Figure 2. Histogram of sensor drift (A) and the Drift Corrected Average Deep ΔO_2 (B) for the two different types of oxygen sensors. The mean±std. dev. is labeled on the plot with its corresponding color.

Sensor Comparison

All oxygen profiling floats are equipped with either an Aanderaa Optode or a Sea-Bird SBE43. Sensor performance was evaluated by comparing the annual sensor drift (Fig. 2), Average Deep ΔO_2 (Fig. 2), and the Average Deep ΔO_2 as a function of deployment date (Fig. 3). Sensor type was not listed in the metadata for 30 of the 149 floats examined (Table 1), therefore the comparison in Figures 2 and 3 are for 119 floats.

Table 1: Summary of float elimination previous to analysis. Numbers are floats remaining (eliminated)

USGODAE Archive	298 (0)
No Oxygen Data	227(71)
Sensor Failure	206 (21)
Antarctic Deployment	185 (22)
<1000m Floats	163 (14)
Dataset Used	149 (128)

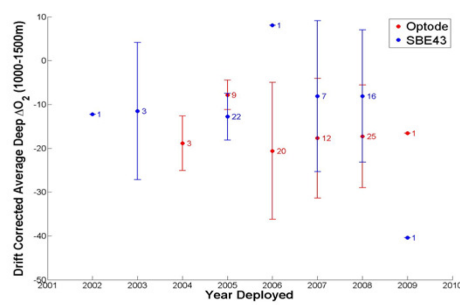


Figure 3. Drift Corrected Average Deep ΔO_2 as a function of deployment date. The dots represent the mean, and the error bars are ± 1SD.

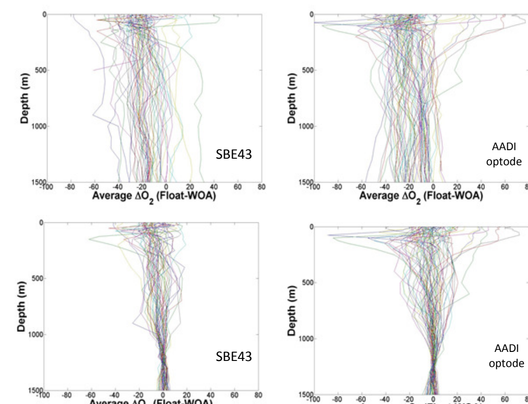


Figure4. Compiled uncorrected (top) and corrected (bottom) depth profiles of the average ΔO_2 for SBE43 (n = 50) and Optode (n = 69) ; each line represents averages of all profiles available for a single profiling float.

References

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Garcia, H. E., R. A. Locarnini, T. P. Boyer, J. I. Antonov, O. K. Baranova, M. M. Zweng, and D. R. Johnson, 2010. *World Ocean Atlas 2009 Volume 3: Dissolved Oxygen, Apparent Oxygen Utilization, and Oxygen Saturation*. S. Levitus, Ed., NOAA Atlas NESDIS 70, U.S. Government Printing Office, Washington, D.C., 344 pp.

Uchida H., T. Kawano, I. Kaneko, and M. Fukaswa, 2008. *In Situ Calibration of Optode-Based Oxygen Sensors.* J. Atm. Ocean. Technol. **25**: 12. 2271-2281