

**Marine Alliance for Science and Technology for Scotland (MASTS)  
Visiting Fellowship 2025 - Final Report**

**Improving the biological relevance of open ocean monitoring – enhancing  
quality-controlled oxygen measurements in the North and South Atlantic**

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## **Summary**

One of the main purposes of this research visit was to exchange knowledge for calibration methodologies and analyses of moored oxygen measurements, combined with historical mooring and hydrographic data including Biogeochemical Argo floats. This built up on experience and lessons learned from the Ellett Array led by SAMS, a component of the OSNAP overturning monitoring system in the North Atlantic. Comparisons were performed with calibration methodologies for oxygen optodes used in other similar programmes leading to methodology improvements. During the research visit the visiting fellow gave a seminar at SAMS, visited the School of GeoSciences at the University of Edinburgh, and gave a talk at the MASTS Annual Science Meeting. All these activities provided many inspiring and fruitful opportunities to interact with researchers from MASTS institutions to explore further collaborations.

## Background and Objectives

Studying the variability of biogeochemical properties in the ocean is important for climate assessments, and analyzing changes in productivity, carbon draw-down and ecosystems. In particular, dissolved oxygen is crucial to sustain the health of marine resources. Hydrographic observations during the past 50 years have revealed oxygen declines mainly as a result of warming and increased stratification (e.g., Breitburg et al. 2018; Garcia-Soto et al. 2021). In particular the Southwestern South Atlantic has been identified as a hypoxic region (Breitburg et al. 2018) with potentially large implications for marine ecosystems and resources. Despite the importance of understanding patterns and drivers of dissolved oxygen variability, measurements from moored oxygen sensors are still relatively novel with best practices to calibrate and process the data still being refined (e.g. Berx et al. 2019; Miller et al. 2024).

The Atlantic Meridional Overturning Circulation (AMOC) is a system of ocean currents that play a key role in redistributing biogeochemical parameters such as nutrients and dissolved oxygen as well as heat, salt and mass. Thereby, the AMOC influences weather, climate, sea level, and marine resources. While *in situ* observations of AMOC-related physical parameters are more abundant, biogeochemical measurements are less well established, particularly in the South Atlantic where observations are scarce. Recent efforts have aimed at increasing the number of biogeochemical sensors deployed on existent AMOC moored arrays including in the South Atlantic. Dissolved oxygen sensors have been deployed on moorings in the eastern Overturning in the Subpolar North Atlantic Program OSNAP Array since 2017 (by SAMS; Johnson et al. 2024) while sensors were deployed for the first time on a tall mooring in the western portion of the South Atlantic MOC Basin-wide Array (SAMBAs) at the shelf break in the SW South Atlantic in 2022 funded by the EU 2020 iAtlantic project (2019-2024). However, procedures for calibrating moored dissolved oxygen sensors are not yet standardized within the global oceanographic community and are still evolving. In particular, considerable effort is required to calibrate the moored sensors to ensure the highest climate quality timeseries possible.

The main objectives of this research visit were:

1. Examine methods developed by SAMS to calibrate moored optode dissolved oxygen sensors. Compare these to any other published methodology. Apply these to existing OSNAP data.
2. Search for publically available dissolved oxygen data e.g. World Ocean Database, Biogeochemical ARGO, GLODAP. Assess the quality of these. Perform a preliminary analysis of oxygen variability at selected sites in the South Atlantic.
3. Give seminars at MASTS institutions and interact with staff and students to promote future collaborations.

## Activities

### 1. Examine methods developed by SAMS to calibrate moored dissolved oxygen sensors. Compare these to any other published methodology.

From the experience from the OSNAP Ellett Array in the eastern subpolar North Atlantic led by scientists at SAMS, we examined methods developed by Dr. Clare Johnson (Johnson et al. 2024) to calibrate moored dissolved oxygen (DO) from optode sensors applied to already existing OSNAP Ellet Array data. The existing methodology follows several processing steps: identifying and removing any pressure-related reversible drift, and correcting for irreversible storage and deployment drift by calibrating to nearby calibration casts. The pressure-related drift is a fast (hours-days) and slower (months) exponential drift which is fitted to the oxygen record with temperature-related variability removed. This typically is only seen in instruments deployed deeper than 1000 dbar. Calibration is done to nearby post-deployment and pre-recovery Conductivity Temperature Depth Oxygen (CTD-DO) casts. Ideally, it is necessary to perform a nearby CTD-DO cast after deployment and before recovery of the mooring to account for any storage drift and any in situ drift, respectively. For the two end-point calibration casts, an offset between the Winkler-calibrated CTD-DO sensor and the uncalibrated moored DO sensor is calculated in density and time space. A linear correction between these two offset is then applied to the moored optode DO sensor.

More recently Miller et al. (2024) re-examined calibration methodologies for DO optodes on ocean moorings and provided recommendations for deployment and *in situ* calibration as the result of experience of optodes deployed as part of the Gases in the Overturning and Horizontal circulation of the Subpolar North Atlantic Program (GOHSNAP). The methodology is thoroughly described in Miller et al. (2024), here we briefly describe the most important innovations compare to the previous methodology. As in the Johnson methodology, drift is divided into: (i) an irreversible, time dependent drift that occurs during both optode storage and deployment and a (ii) a reversible and pressure-and-time dependent drift that is detectable in some optodes deployed at depths greater than 1,000 m. Where the Miller et al. (2024) method deviates from that of Johnson, is on how to correct for the irreversible time dependent drift. The Johnson method uses nearby calibration casts to calculate the difference between the calibrated CTD-DO sensor and the moored DO sensor (equation 1).

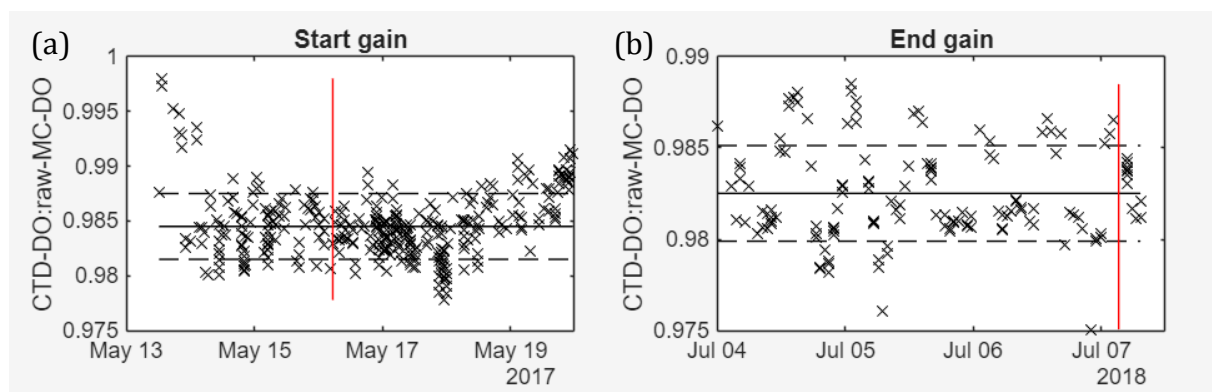
$$\text{correction} = \text{CTD-DO} - \text{optode-DO} \quad (1)$$

In contrast, the Miller et al. (2024) method uses a ratio between the Winkler-calibrated CTD-DO and moored DO (called gain). Additionally, instead of using a single crossover point in time and density space, Miller et al. (2024) use multiple crossover points identified by identifying similar water in temperature-salinity-time space. These individual gains are then averaged to create a mean gain (G) for the start and end calibration casts (equation 2).

$$G = \text{mean}(\text{CTD-DO} / \text{optode-DO}) \quad (2)$$

Both the Johnson and Miller et al. methods apply a linear correction between the start offset / gain and the end offset / gain.

The Miller et al. (2024) method requires decisions on the temperature, salinity and time limits used to create the start and end crossover points. Miller et al. (2024) recommend limits of 0.005 °C, 0.005, 100 dbar and 5 days for temperature, practical salinity, pressure and time respectively. These were chosen to ensure a good match between the water masses sampled by the optode-DO and by the CTD-DO and should result in a standard deviation in the ratio of CTD-DO to optode-DO of less than 0.01. We did tests to see whether these limits were applicable in the Northeast Atlantic, in particular whether the 5 day crossover period was appropriate. The gain was found to be fairly stable for at least 2 days either side of the calibration casts (Figure 1) although this is likely to vary geographically and also with depth.



*Figure 1. Gains (CTD-DO:optode-DO) for (a) the deployment calibration cast and (b) the recovery calibration cast against time for an optode-DO deployed in the Northeast Atlantic. The red line indicates the timing of the calibration cast. The black crosses show each individual gain, whilst the solid black line shows the mean gain and the dashed lines  $\pm$  one standard deviation.*

We also compared optode-DO calibrated using the two methodologies. Results (Figures 2 and 3) show that the two methods agree within expected errors of the instrument (approx. 3  $\mu\text{mol/kg}$ ).

Overall, the corrections applied by Miller et al. (2024) method give more accurate calibration of moored optode-DO as it is reliant on multiple crossover points rather than the single crossover point of the Johnson method. Additionally, the Miller et al. (2024) method gives increased flexibility as the calibration casts can be within  $\pm$  2 days of the mooring deployment / recovery rather than needing to be whilst the mooring is in the water. We recommend that in the future, the Miller et al. 2024 method is used and will introduce this method in both the work at SAMS and in the South Atlantic array. As the recovery of the mooring in the South Atlantic originally scheduled for 2023 was delayed due to circumstances outside the Fellow's control, all tests were carried out on data from the Northeast Atlantic. However, when the South Atlantic optodes are recovered, Johnson and Chidichimo will be in contact to ensure that the optodes are calibrated to the highest quality possible.

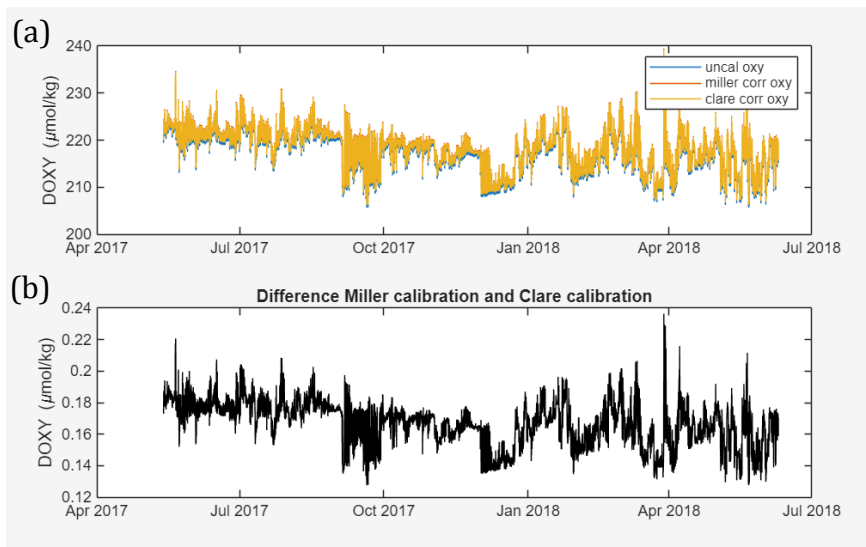


Figure 2. Comparison of the two difference calibration methods an optode (S/N 14987) deployed in the Northeast Atlantic. (a) shows timeseries of: the uncalibrated data (blue), data calibrated using the Miller et al., 2024 method (orange) and data calibrated using the Johnson method (yellow). (b) shows the difference between the records calibrated using the Miller and Johnson methods.

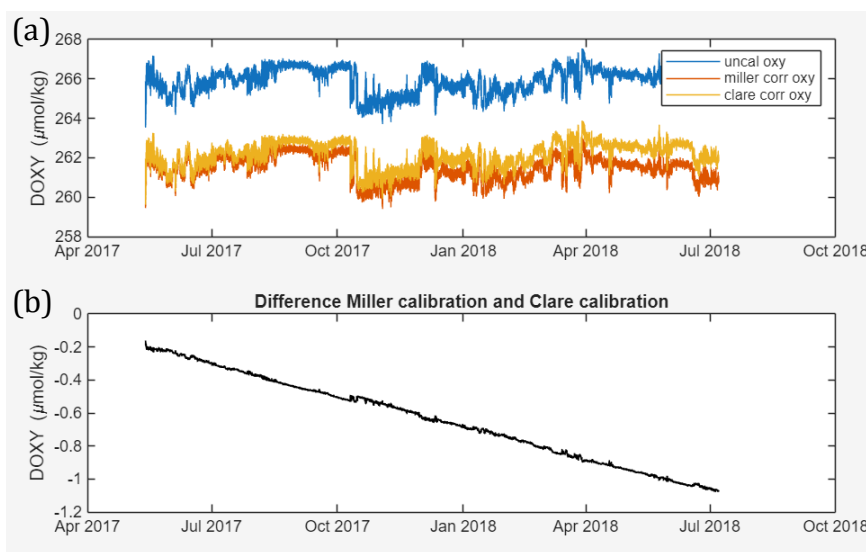
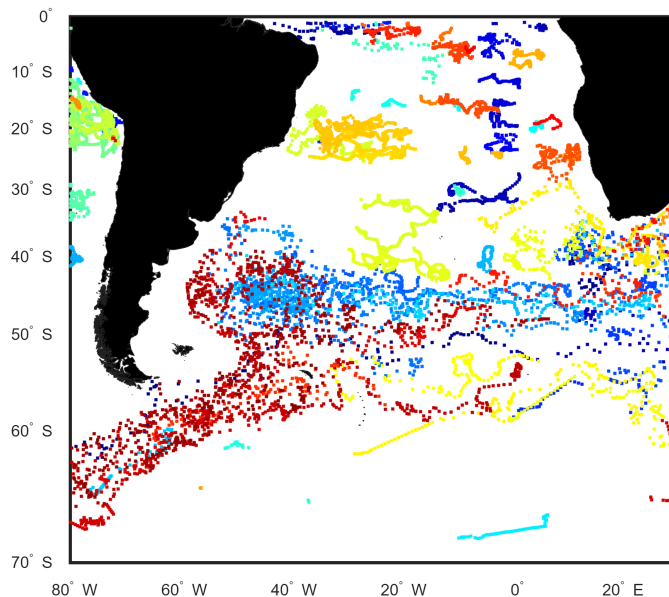


Figure 3. Same as for Figure 2 but for optode S/N 15298.

**2. Search for publically available dissolved oxygen data e.g. World Ocean Database, Biogeochemical ARGO, GLODAP. Assess the quality of these. Perform a preliminary analysis of oxygen variability at selected sites in the South Atlantic.**

The analyses above are complemented using publicly available data from hydrographic sections and global databases (e.g., World Ocean Database, GLODAP), and Biogeochemical Argo floats to perform preliminary analyses of oxygen variability at selected regions in the South Atlantic. For example, these datasets can be used to provide a larger geographic context as well as providing independent points to assess the quality of optode calibrations. Given time

constraints, during the visit data from Biogeochemical ARGO floats in the South Atlantic were extracted with a preliminary analysis focussing on the SW Atlantic region (Figure 4). Additionally, guidance on the ARGO data file formats, which variables to use to ensure high-quality data and ARGO-DO sensor calibration techniques were provided. All these analyses will continue beyond the fellowship and Johnson and Chidichimo will maintain contact via email and teams.



*Figure 4. Plot showing the trajectories (colours) of all Biogeochemical ARGO floats with oxygen data within the South Atlantic, extracted as of November 2025.*

### **3. Exchange activities**

- During 4-6<sup>th</sup> November the visiting fellow together with SAMS members participated in online sessions of the CONNECT Workshop, organized by the National Oceanography Centre, Southampton, UK. The workshop aimed to foster new collaborations between the North and South Atlantic AMOC scientific communities.
- On 11<sup>th</sup> November the visiting fellow visited the School of GeoSciences at the University of Edinburgh hosted by Prof. Murray Roberts, where she had meetings with Prof. Murray Roberts, Prof. Sebastian Hennige, Prof. Channing Prend, Prof. Andy Sweetman, and Dr. Simone D'Alessandro, with additional time for *ad hoc* discussions of collaborations, and participated in a lunch with the Atlantic oceanography community.
- During her stay at SAMS, the visiting fellow had many opportunities to meet and discuss her research with several members of SAMS and also participated in social activities. On 13<sup>th</sup> November, the visiting fellow gave a Seminar at SAMS where she presented her current research on ocean circulation variability in the South Atlantic, which provided an additional opportunity to discuss research interests with SAMS members.
- During 18-19<sup>th</sup> November, the visiting fellow attended the MASTS Annual Science Meeting 2025, held at the Technology & Innovation Centre (TIC) of University of

Strathclyde, Glasgow, UK, where she interacted with researchers, students and project managers from several MASTS institutions, and gave a talk entitled “Ocean Circulation Variability in the Southwestern Atlantic” (19 November, MASTS General Science Session 4).

## **Achievements and Prospects**

This fellowship enabled knowledge exchange with scientists at SAMS, University of Edinburgh, and other MASTS institutions. The proposed 3-week collaboration had specific objectives that were initiated or completed during the fellowship. The methods developed by SAMS to calibrate moored dissolved oxygen sensors were compared to other published methodology with the updated methodology being used from now on. This work will continue beyond the fellowship to contribute to sharing best practices and exchange knowledge for the use and calibration of moored biogeochemical sensors in the North and South Atlantic. Additionally, the fellowship served to set basis for future collaborations expanding the analyses utilizing data gathered in the South Atlantic Ocean to better align observations across the Atlantic and to perform analyses of biogeochemical properties in the South Atlantic using publicly available data sets. Future comparison of moored oxygen timeseries in the North and South Atlantic could improve our understanding of exchanges at sensitive gateways.

A key objective of this visit was to strengthen and establish scientific excellence and collaboration with MASTS institutions, which continue beyond the fellowship. The research visit was very productive and also very enjoyable. SAMS provided a very special and unique environment to interact with leading physical oceanography researchers and with researchers and students from different disciplines. The visit to the University of Edinburgh provided an excellent and inspiring opportunity to consolidate existing research networks and discuss new collaborations across the Atlantic Ocean community. Attending the MASTS Annual Science Meeting 2025 was a very enriching experience to learn about many projects and marine research activities being carried out in Scotland, and to interact with researchers across MASTS partner institutions. This was also a venue to follow up with researchers from both SAMS and the University of Edinburgh and to meet other researchers from other institutions to discuss common research interests and new collaborations.

Dr. Chidichimo expresses her deepest gratitude to Dr. Clare Johnson for her kind hospitality and work together during the research visit at SAMS, which was very fruitful and also greatly enjoyable. Dr. Chidichimo expresses her deep appreciation to MASTS and to the authorities at SAMS for the opportunity to do this research visit, and to all the staff at SAMS who were very friendly and welcoming. Dr. Chidichimo also expresses her deepest gratitude to Prof. Stuart Cunningham for the long-standing kindness and collaboration since her PhD studies at MPI-M in Hamburg years ago and to Prof. Murray Roberts for his great generosity, support and continued collaborations.

## References

- Berx, B. et al. (2019), The observational potential of the transport mooring arrays: Assessment of the impact of upper-ocean measurements and of coherent integration of O<sub>2</sub> measurements for transport and fluxes in the Atlantic TMAs and synergies with the wider Atlantic observing system, Rep., 35 pp, <https://ec.europa.eu/research/participants/documents/downloadPublic?documentId=080166e5c3cd9ebc&appId=PPGMS>
- Breitburg, D. et al. (2018), Declining oxygen in the global ocean and coastal waters. *Science*, 359, <https://www.science.org/doi/10.1126/science.aam7240>
- Garcia-Soto, C. et al. (2021), An Overview of Ocean Climate Change Indicators: Sea Surface Temperature, Ocean Heat Content, Ocean pH, Dissolved Oxygen Concentration, Arctic Sea Ice Extent, Thickness and Volume, Sea Level and Strength of the AMOC (Atlantic Meridional Overturning Circulation), *Frontiers in Marine Science*, 8, <https://doi.org/10.3389/fmars.2021.642372>
- Johnson, C. et al. (2024), Biogeochemical properties and transports in the North East Atlantic. *Journal of Geophysical Research: Oceans*, 129, <https://doi.org/10.1029/2023JC020427>
- Miller UK, Fogaren KE, Atamanchuk D, Johnson C, Koelling J, Le Bras I, Lindeman M, Nagao H, Nicholson DP, Palevsky H, Park E, Yoder M and Palter JB (2024). Oxygen optodes on oceanographic moorings: recommendations for deployment and in situ calibration. *Front. Mar. Sci.* 11:1441976. doi: 10.3389/fmars.2024.1441976