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Supplementary Materials for

The North Atlantic Biological Pump

INSIGHTS FROM THE OCEAN OBSERVATORIES INITIATIVE IRMINGER SEA ARRAY

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Data Sources, Processing, and Calibration

All Ocean Observatories Initiative (OOI) data, including those used in this paper, are publicly available from the OOI Data Portal (https://ooinet.oceanobservatories.org) and the Raw Data Archive (https://rawdata.oceanobservatories.org/files). All glider data used in this study were downloaded from the Raw Data Archive on September 16, 2016. All Apex Profiler Mooring data were downloaded from the OOI Data Portal on March 6, 2017. Dissolved oxygen data and CTD data from the flanking moorings and the Apex Surface Mooring were downloaded from the OOI Data Portal on March 22, 2017. All chlorophyll *a* data were downloaded from the OOI Data Portal on July 12, 2017.

Detailed information about all Array platforms and sensors is available at http://oceanobservatories.org/array/global-irminger-sea.

TEMPERATURE AND SALINITY

Mixed layer temperature and salinity data are from Sea-Bird SBE 37 CTDs on Flanking Mooring A (~30 m) and on the Star Engineering ASIMET Bulk Meteorology Instrument Package on the surface buoy of the Apex Surface Mooring. High-frequency noise was removed using a one-dimensional median filter with a 200-measurement (~20 minute) filter window. Flanking mooring measurements collected from July 15, 2015–October 15, 2015, and after May 10, 2016, were excluded from analysis of mixed layer properties, as variability in these data indicated that the mixed layer was shallower than the depth of the flanking mooring measurements at times during these periods.

Temperature and salinity data at depth are from the Sea-Bird SBE 52 CTD on the Apex Profiler Mooring (profiling range specified as 240–2,400 m, but with data available from ~200–2,550 m). Data from each profile were gridded onto regular 5 m intervals prior to interpretation.

CHLOROPHYLL *a*

Chlorophyll *a* data are from WET Labs ECO Triplet-w three-wavelength fluorometers on Flanking Mooring A (~30 m depth) and the near-surface instrument frame of the Apex Surface Mooring (~12 m depth). Chlorophyll *a* was calculated from fluorescence using the original factory calibration. Data collected during daylight hours (from two hours before sunrise to two hours after sunset) were excluded to remove bias caused by photochemical quenching, and data from Flanking Mooring A were excluded during periods when the mooring fluorometer was below the mixed layer.

OXYGEN

Dissolved oxygen data are from Aanderaa Optode 4831 oxygen sensors on Flanking Moorings A and B (~30 m), the surface buoy (~1 m depth) and the near-surface instrument frame (~12 m depth) of the Apex Surface Mooring, global profiling gliders transiting the array triangle (profiling from the surface to 1,000 m), and the Apex Profiler Mooring (profiling range specified as 240–2,400 m depth, but with data available from ~200–2,550 m). All raw optode data were corrected for salinity and depth compensation following the equations from the Aanderaa operating manual.

Oxygen data from each glider profile and the profiler mooring were interpolated onto regular gridded depths (10 m interval for gliders and 5 m interval for the profiling mooring) prior to interpretation. For the profiler mooring, paired upward and downward profiles were merged to a single mean to remove aliasing due to sensor response times. This pairing was not applied to the gliders because they generally only collect data on upward profiles, and are less influenced by sensor lag due to their slower ascent rate. For the fixed depth sensors on the flanking moorings and the Apex Surface Mooring, high-frequency noise was removed using a one-dimensional median filter with a 20-measurement (15 minute or shorter) filter window, and data collected during daylight hours (from two hours before sunrise to two hours after sunset) were excluded to remove bias caused by light interference with the optical sensor.

All oxygen data were calibrated both for pre-deployment drift from the original factory optode calibration (using an initial gain correction) and for in situ post-deployment drift. Gain corrections for the profiling mooring and gliders were made using Winkler dissolved oxygen measurements from multiple depths through the water column (example in Figure S1). Gain corrections were calculated using Winkler measurements from deployment cruise casts within 30 km of the glider/profiler mooring, paired with the optode profile data most closely aligned in depth and time (number of available calibration points varied from n = 5 to n = 20). For fixed-depth sensors on the Apex Surface Mooring and flanking

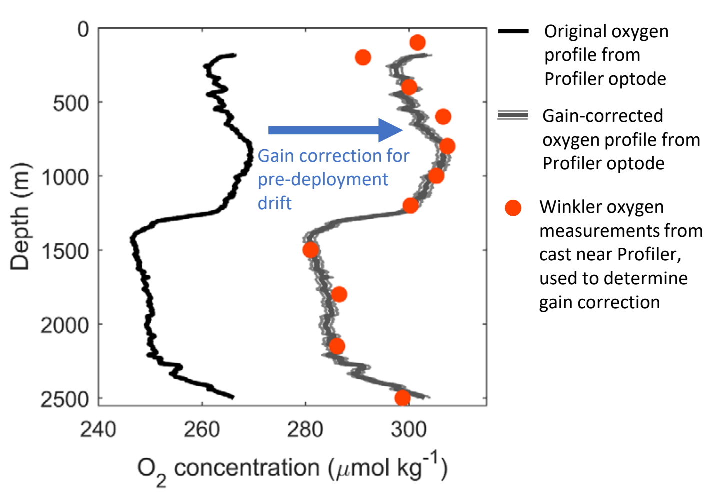

FIGURE S1. Example of a gain correction for pre-deployment drift from the factory optode calibration. Data shown is from the Year 2 deployment of the Apex Profiler Mooring in July 2015.

moorings, gain corrections were limited by only having a single discrete sample to compare with the sensor measurements, so gain corrections were made by calibrating the fixed-depth sensors with corrected glider measurements (applied after corrections for post-deployment drift described below) when the gliders profiled alongside the moorings. Table S1 presents sensor-specific uncertainty in the gain corrections.

Correction for post-deployment (in situ) drift requires regular measurement of water (or air) with a stable oxygen concentration. Oxygen trends in the deep ocean have previously been used as a proxy for sensor drift, due to the expected stability of oxygen concentrations in the deep ocean (Takeshita et al., 2013). Profiler mooring oxygen measurements on isotherms well below the deepest winter ventilation depths (Figure S2) show oxygen decrease rates that significantly exceed expected rates of deep ocean respiration (on the order of ~0.1–1 μmol kg^{-1} yr^{-1}; Sarmiento and Gruber, 2006), indicating that in situ drift dominates the observed signal. We correct for drift based on the assumption that deep ocean respiration at depths >2,000 m is negligible and that the observed drift entirely reflects changing sensor sensitivity over time. This is a conservative choice with regard to estimating the seasonal thermocline respiration rate; if some of the observed oxygen trend on deep isotherms were due to respiration rather than drift, we would have then overcorrected for drift in the thermocline and underestimated the contribution of respiration.

Table S2 presents drift rates for all oxygen optodes used in this analysis. Drift rates for the profiler mooring are determined based on oxygen decrease rates observed on deep isotherms (Figure S2). Drift rates for other assets that do not sample depths with stable oxygen measurements were determined by intercomparison of gliders with the profiling mooring to determine glider drift rates and intercomparison of fixed depth mooring sensors with the gliders to determine surface mooring sensor drift (in both cases considering glider profiles for intercomparison with mooring assets when at a distance of <10 km). The glider and surface mooring drift rates are greater than from Argo floats (usually ~2 μmol kg^{-1} yr^{-1}, but extending up to 6 μmol kg^{-1} yr^{-1}; Takeshita et al., 2013; Bushinsky et al., 2016), likely reflecting the fact that these optodes collect oxygen data at much higher frequency than Argo floats, photo-bleaching the sensor foil more rapidly.

TABLE S1. Sensor-specific uncertainty in the initial gain correction applied to account for pre-deployment drift from the original factory optode calibration. For the Profiler Mooring and gliders, uncertainty represents the standard error of the mean (2σ/√n) for gain corrections determined from multiple Winkler measurements used for calibration. Uncertainty in the gain correction for the fixed depth sensors (Flanking Moorings and Apex Surface Mooring) was determined by propagating error from the intercalibration between the fixed-depth sensor and the glider measurements and from the uncertainty in the original glider gain corrections.

Oxygen optode location	Uncertainty in gain corrections for pre-deployment drift	
	2014–2015	2015–2016
Profiler Mooring	± 5.2 μmol kg^{-1} (1.7%)	± 1.1 μmol kg^{-1} (0.4%)
Glider 002	± 9.3 μmol kg^{-1} (3.2%)	± 3.2 μmol kg^{-1} (1.1%)
Glider 003	–	± 3.9 μmol kg^{-1} (1.4%)
Flanking Mooring A	± 9.9 μmol kg^{-1} (3.3%)	± 4.5 μmol kg^{-1} (1.5%)
Flanking Mooring B	± 9.9 μmol kg^{-1} (3.3%)	–
Apex Surface Mooring Buoy, ~1 m	± 9.6 μmol kg^{-1} (3.2%)	± 4.4 μmol kg^{-1} (1.4%)
Apex Surface Mooring Instrument Frame, ~12 m	–	± 4.4 μmol kg^{-1} (1.4%)

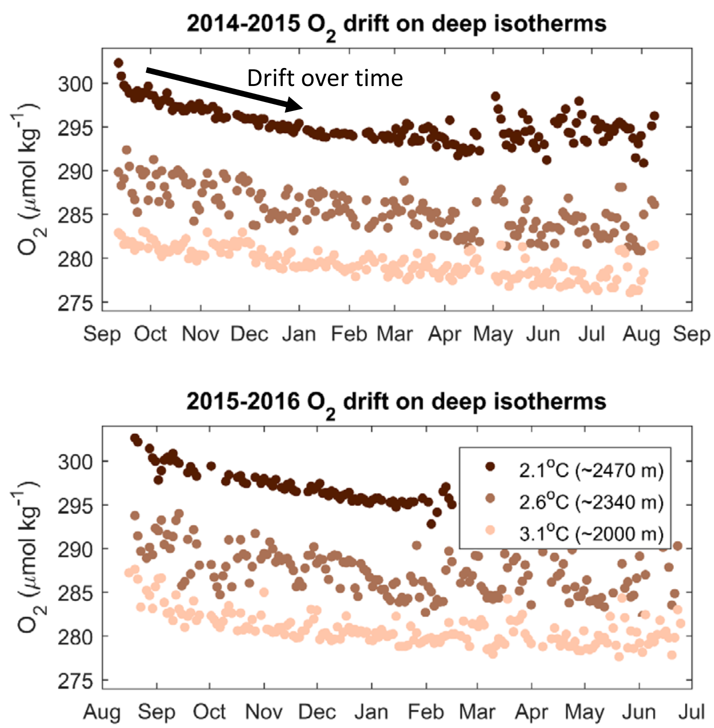

FIGURE S2. Post-deployment (in situ) drift in optode oxygen measurements on deep isotherms sampled by the Apex Profiler Mooring in Years 1-2 of the OOI Irminger Sea Array deployments. Optode measurements have been calibrated using a gain correction based on Winkler titrations from deployment casts (as illustrated in Figure S1).

TABLE S2. Sensor-specific corrections for post-deployment (in situ) drift in dissolved oxygen measurement sensitivity. Drift rates for the Profiler Mooring are based on observed oxygen trends on deep isotherms (Figure S2). Drift rates for the gliders are determined based on intercomparison with the Profiler Mooring and drift rates for the Flanking and Apex Surface Moorings are determined based on intercomparison with the gliders.

Oxygen optode location	Drift rate (μmol kg^{-1} yr^{-1})	
	2014–2015	2015–2016
Profiler Mooring	−5.0 ±0.7	−3.7 ±0.9
Glider 002	−26 ±3	−18 ±2
Glider 003	–	−23 ±2
Flanking Mooring A	+11 ±3	−21 ±4
Flanking Mooring B	+13 ±3	–
Apex Surface Mooring Buoy, ~1 m	−22 ±2	−33 ±2
Apex Surface Mooring Instrument Frame, ~12 m	–	−33 ±2

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