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Using oxygen species to measure marine production in Drake Passage

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Marine biological production is key to understanding the global carbon cycle, particularly the role of the Southern Ocean as a sink of CO_2. Measurements of oxygen in the surface ocean allow quantifying marine biological productivity, since CO_2 and O_2 are linked via photosynthesis and respiration.

Measurements of O_2/Ar ratios and dissolved O_2 isotopologues, together with wind-speed gas exchange parameterizations, give estimates of biological oxygen air-sea fluxes (F_{bio}) and gross photosynthetic production (G) in the mixed layer (z_{mix}). In the absence of vertical mixing, F_{bio} can be used as a proxy for net community production (N).

O_2/Ar ratios and O_2 concentrations were measured continuously in the uncontaminated seawater supply on board the *RRS James Clark Ross* along two sections across Drake Passage (DP). The DP1 section (southbound, 27 February–3 March 2007) represented mid-summer; DP2 represented early autumn (northbound, 12–15 April, 2007). The time difference between the two transects was 40 days. Weighted average gas exchange rates were calculated using the WOCE-NODC ocean mixed layer depth climatology and ECMWF wind speeds over 60 days prior to sample collection.

The WOCE-NODC climatology shows a deepening of the z_{mix} by on average 46 m within 40 days. The sea surface temperature decreased about 2.4 ºC from DP1 to DP2. This reflects the seasonal transition from late summer to early autumn.

In agreement with previous observations, we observed a strong north-south gradient of biological oxygen production in the DP. Our results also show high temporal variability over the course of 40 days. During late summer, the physical supersaturation contributes to about 3.6% of the total O_2 supersaturation (ΔO_2) for the Subantarctic and Polar Frontal Zones (SAZ and PFZ, respectively). In the other hand, the biological O_2 supersaturation (ΔO_2/Ar) showed mainly positive and homogeneous values ($\sim$1%) along the Antarctic Zone and Southern Antarctic Circumpolar Current Zone (AZ and SACCZ, respectively). This observation reflects predominantly a biological O_2 production, associated with a shallow summer z_{mix} (66 m), rather than due to physical processes (average F_{bio} of 9 mmol m^{-2} d^{-1} and G of 28 mmol m^{-2} d^{-1}).

The situation is inverted 40 days later during early autumn, when sea ice begins to form and z_{mix} deepens (112 m). In AZ and SACCZ, F_{bio} and G decreased to -7 mmol m^{-2} d^{-1} and 10 mmol m^{-2} d^{-1}, respectively. It is unclear whether net heterotrophy, upwelling of O_2 subsaturated waters or increased of z_{mix} and entrainment of low oxygen waters are responsible for the negative biological oxygen flux observed in during late summer in SAZ and PFZ, and in early autumn for AZ and SACCZ.

We found a higher correlation between F_{bio} and z_{mix} for the DP2 section than for DP1 (R^2=0.61 and 0.08, respectively). Therefore, the increase of the z_{mix} also plays an important role for the F_{bio} and G pattern in the DP, suggesting the entrainment of subsurface O_2 depleted waters to the upper water column at the end of the growing season. Based on our observations, we argue that seasonal variations in z_{mix} can potentially explain part of the meridional gradients found in the DP.