MARINE PRODUCTIVITY ESTIMATES FROM O_2/AR RATIOS AND OXYGEN ISOTOPES IN THE EQUATORIAL PACIFIC

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ABSTRACT

Upwelling of high-nutrient waters in the equatorial Pacific gives rise to a band of enhanced primary production around the equator that stretches from Peru almost to Indonesia. It has been suggested that this oceanic region accounts for a large part of global net production. The equatorial Pacific is also thought to be the largest oceanic CO_2 source and makes an important contribution to the atmospheric CO_2 budget.

In order to better constrain photosynthesis and respiration in this part of the world ocean, we use simultaneous O_2/Ar ratio measurements and the triple oxygen isotope composition of dissolved O_2. Dissolved O_2/Ar ratios are indicative of net community production (the difference of photosynthesis and respiration), because O_2 and Ar share similar solubility properties, but only O_2 is biologically influenced. Moreover, photosynthesis diminishes the ^{17}O isotope anomaly of atmospheric O_2, which derives from stratospheric isotope exchange reactions. Combination of both measurements with suitable wind speed-gas exchange parameterizations allows estimating net and gross production rates of oceanic ecosystems at larger scales and with higher resolution than possible by traditional approaches.

We have recently achieved a significant advance for the O_2/Ar method by building a membrane inlet mass spectrometer (MIMS) [*Kaiser et al.*, 2005] that allows continuous shipboard analysis of O_2, Ar, N_2, and eventually CO_2 and other gases. It was successfully deployed in the equatorial Pacific between 110ºW and 95ºW (October/November 2003) and between 170ºW and 125ºW (June–September 2004). The MIMS measurements were accompanied by discrete O_2/Ar and triple oxygen isotope measurements, along with continuous O_2 concentration measurements. A short-term reproducibility of 0.05% was achieved for the O_2/Ar ratio, with a sampling frequency greater than twice per minute. Meridional and zonal gradients and local phenomena were clearly resolved (Fig. 1). The results also allow us to compute absolute Ar supersaturations, which may provide insight into the origin of physical supersaturations.

The results of this study are a first order picture of the distribution of net community production and the net/gross production ratio away from the equatorial upwelling, together with estimates of the air-sea flux of O_2, in the eastern half of the equatorial Pacific basin at the time of sampling.

METHODS

The O_2/Ar method [*Craig and Hayward*, 1987] is based on the similar solubility characteristics of O_2 and Ar with respect to temperature and pressure changes as well as bubble-mediated gas exchange. One can define an O_2/Ar supersaturation, $\Delta O_2/Ar$, as:

$$\Delta O_2/Ar = \frac{c(O_2)}{c(Ar)} \Big/ \frac{c_{sat}(O_2)}{c_{sat}(Ar)} - 1$$

$\Delta O_2/Ar$ essentially records the difference between photosynthetic O_2 production and respiration. c is the dissolved gas concentration and c_{sat} is the saturation concentration. c_{sat} is a function of temperature, pressure and salinity. Our newly developed MIMS method allows continuous underway measurements of the O_2/Ar ratio, extending earlier oceanographic MIMS applications [*Kana et al.*, 1994; *Tortell*, 2005]. The combination of $\Delta O_2/Ar$ measurements with $^{17}O/^{16}O$ and $^{18}O/^{16}O$ isotope ratios of dissolved O_2 allows deriving ratios of net to gross production and gross production to gas exchange [*Luz and Barkan*, 2000].

FIGURE

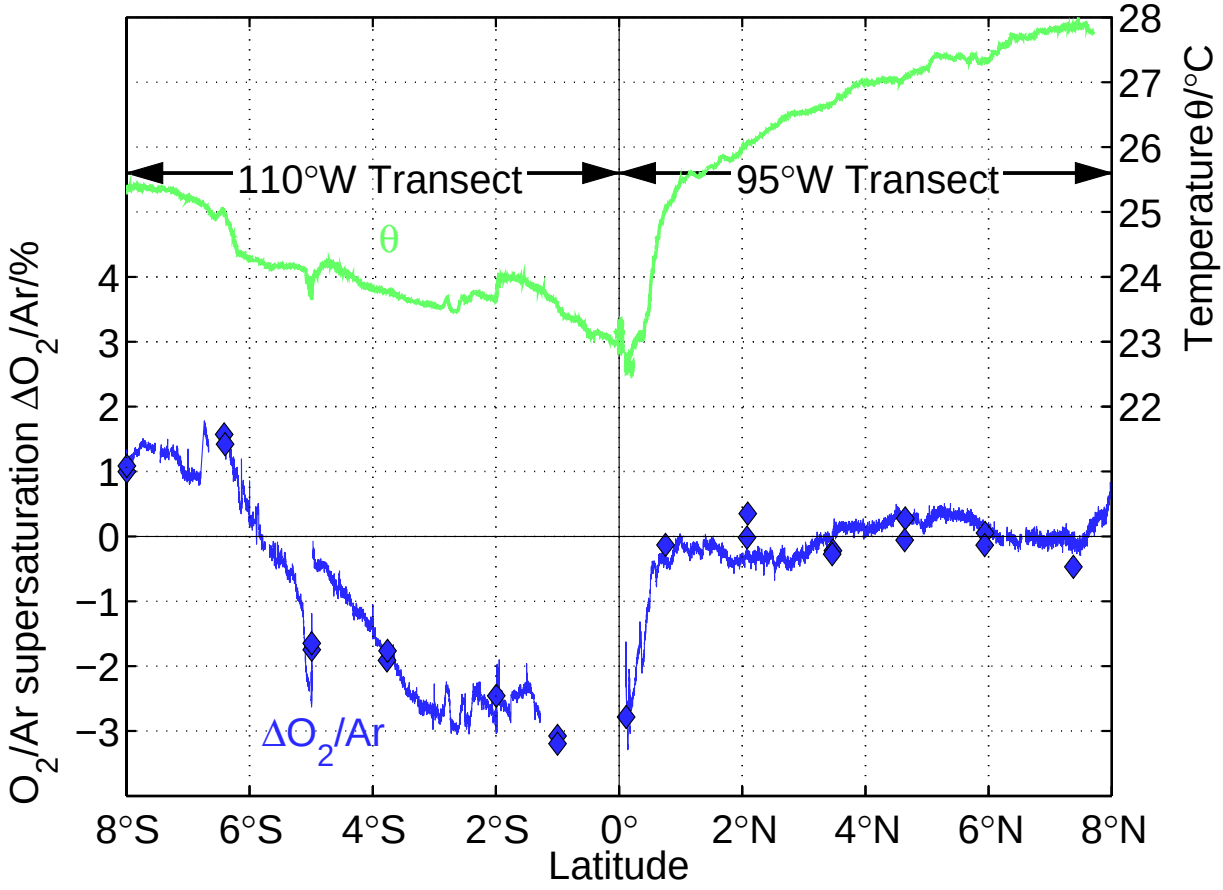

Fig. 1. O_2/Ar supersaturation (ΔO_2/Ar) and sea surface temperature (θ) for the southern part of the 110ºW transect and the northern part of the 95ºW transect. Continuous lines represent underway measurements, solid symbols correspond to discrete O_2/Ar measurements from headspace-equilibrated samples. The good agreement between discrete and continuous measurements illustrates the success of the calibration. Reproducibility (about 0.05%) and spatiotemporal resolution of the MIMS measurements (about 150 m in the horizontal direction at a cruise speed of 12 kn) offer unprecedented insight into rapid changes at fronts and other small-scale features. Over larger scales, one can discern the influence of O_2-undersaturated water from equatorial upwelling between 6ºS and 1ºN, but also the higher biological supersaturation at 8ºS than at 8ºN, indicating higher net community production.

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