Supplemental Material

1 Model performance for dissolved oxygen

Accurate representation of dissolved oxygen in the 1-D model depends on modeling air-sea gas exchange processes, the biological production of oxygen due to net community production, as well as transport of oxygen due to mixing, entrainment and other physical processes. Here we present simulated oxygen fields at BATS and HOT for the upper water column (Fig S1) and for the mixed layer (Fig S2) using default net community production (NCP) rates of 2.5 mol O_2 m^{-2} y^{-1} for both BATS and HOT, which previously have been determined to have annual NCP near this value [*Emerson et al.*, 2008; *Keeling et al.*, 2004]. Highest ΔO_2 accumulates where photosynthesis is active but below the mixed layer and capped from gas exchange. These same regions have low values for $\delta^{18}O$ (Fig S3). $\delta^{18}O$ is higher in the thermocline where respiration dominates.

Several processes where important to accurately simulating O_2 distributions in our 1-D model. Air-sea bubble fluxes were added using a wind-speed based parameterization [*Stanley et al.* 2009], which increase O_2 saturation by roughly 1 percent. Coefficients for both complete (A_C) and partially (A_P) trapped bubble fluxes were set to values of $A_C = 2.3 \times 10^{-11}$ s^2 m^2 and $A_P = 5.8 \times 10^{-4}$ s^2 m^2. A_C and A_P where proportionally scaled down from published values to better match O_2 observations. For oxygen, completely collapsing bubbles contribute about 2/3 of the bubble flux with the remaining 1/3 due to partially collapsing bubbles. To simulate ventilation of the deeper thermocline, oxygen was weakly restored below 500 m towards equilibrium with a timescale based on the ventilation age/depth relationship determined from tritium-helium dating [*Jenkins et al.*, 1988] at BATS and CFC ages at HOT [*Sonnerup et al.*, 1999]. A restoring O_2 flux is necessary in 1-D models to prevent a long term downward drift in thermocline O_2. Oxygen isotopomers are restored proportionally to O_2 and all restoring occurs at depths (500-1000 m) well below the area of interest for $^{17}\Delta_{dis}$ based calculations of primary productivity. Overall RMS error was 2.3% of saturation at BATS and 3.5% at HOT. For the mixed layer, RMS error was 1.1% at both BATS and HOT.

Another important aspect controlling the oxygen supersaturation often observed in the mixed layer depends on the magnitude of NCP. Changing annual NCP from 0 to 5 mol O_2 m^{-2} y^{-1} alters oxygen saturation by a few percent. The effect of such uncertainty in net oxygen evolution has an impact of changing $^{17}\Delta_{dis}$ also by a few percent (Fig S4), an amount much less than uncertainty due to other concerns, such as gas exchange rates and entrainment. Thus large changes in NCP have only a minor impact on simulated $^{17}\Delta_{dis}$ which is primarily sensitive to gross oxygen production (P) and quite weakly sensitive to NCP. Our conclusions and rates regarding P would not be significantly influenced by modest errors in NCP parameterization.

2 Captions

Figure S1: Simulated dissolved oxygen saturation (%) in the upper 150 meters at BATS and HOT. Circles show observations from time-series measurements. NCP is set to the default value of 2.5 mol O_2 m^{-2} y^{-1}.

Figure S2: Simulated dissolved oxygen saturation (%) in the mixed layer at BATS and HOT (blue lines) for base case, and upper and lower limits of NCP = 0 and 5 mol O_2 m^{-2} y^{-1}. Red circles show observations from BATS and HOT time-series measurements.

Figure S3: δ^{18}O for the default case run in the upper 150 meters. Values are near equilibrium in the mixed layer, more positive where respiration dominates, and negative where photosynthetic O_2 accumulates.

Figure S4: Sensitivity of calculated $^{17}\Delta_{dis}$ to changes in the magnitude of NCP. Annual NCP was set to 2.5 mol O_2 m^{-2} y^{-1} at each site in the default case. The effect on mixed layer $^{17}\Delta_{dis}$ of doubling NCP to 5 mol O_2 m^{-2} y^{-1} (red) or reducing NCP to zero (blue) is shown for BATS and HOT below. On average, doubling NCP increased $^{17}\Delta_{dis}$ by 1.7 per meg and 1.4 per meg for BATS and HOT, respectively. Setting NCP to zero decreased $^{17}\Delta_{dis}$ by 2.5 per meg and 1.7 per meg. Therefore, error introduced due to uncertainty in NCP is less than analytical uncertaintly in measuring $^{17}\Delta_{dis}$ as well as much less than caused by uncertainties in gas transfer rates.

References

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