CO_2 Drawdown During Southern Ocean GasEx: A Preliminary Assessment of the Role of Phytoplankton

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ABSTRACT

Our objective was to determine the size of the CO_2 sink contributed by phytoplankton photosynthesis, during the Southern Ocean GasEx experiment. A patch of water at ca. 51.7° S, 37° W was infused with tracer (SF_6 & ^3H) and its biogeochemical properties were analyzed for a 15-day period. We performed daily measurements of CO_2 uptake by phytoplankton using a combination of simulated *in-situ* incubations and photosynthesis-irradiance experiments, using ^{14}C-CO_2 as tracer. Greater than 95% of the plant biomass and CO_2 uptake by phytoplankton was observed in the surface isothermal layer (the putative mixing layer) in the upper 55 m. The isothermal layer was also coincident with the depth of the euphotic zone. We observed 3-to-4-fold variations in daily CO_2 drawdown during the 15-day period. Total CO_2 removal by plant photosynthesis is estimated at 439 mmol C m^{-2} and was confined to the surface mixed layer during the 15-day period.

METHODS

Study Site:). Upper mixed layer (~upper 55 m) was tagged with SF_6 and ^3H on YD 77 and water mass was tracked for 15 days (Mar 21 – Apr 5, 2008) during which evolution of chemical and biological properties was measured.

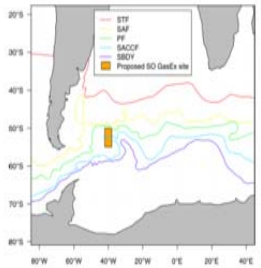

Figure 1. SO GasEx study site was located at approx 51.7°S, 37°W. The research vessel was the *NOAA ship Ronald H. Brown.*

Photosynthesis-Irradiance [PE] Experiments: Seawater was collected during 11 am CTD casts from 8 depths from the surface (z=5m) to beneath the 1% surface light depth (~ 45 m), which was approximately equal to the upper mixing depth. Thirteen 50 ml samples were spiked with 10 μCi C14-bicarbonate and incubated in a light gradient at constant ambient temperatures (± 4°C) in a radial photosynthetron for 1.5 to 2 h. Particulates were collected on Gf/f filters, acidified, and assimilated C14-CO_2 measured using a liquid scintillation counter the following day. Daily production values at each depth were calculated at 15-minute intervals with PAR irradiance at the each depth (15 min averages), using the PE model of Webb et al (1974) or Platt et al. (1980) if photoinhibition was present. The Ed(z) was calculated using a constant Kpar value of 0.12, based on measured submarine PAR made in the upper mixed layer on the same day.

On-deck Productivity Experiments: Seawater samples (280 ml) were collected from 6 depths from surface to 50 m, inoculated with 14C-CO_2 and incubated in on-deck incubator cooled with flowing surface seawater at simulated *in situ* light levels. Incubation times were 12 and/or 24 hours. Following incubations, particles were collected on Gf/f filters and treated as with PE samples above.

Surface Light Measurements: Downwelling PAR irradiance was monitored continuously using two LiCor cosine sensors mounted on the aft end of the ship on top of the lab van located on the main deck. To minimize effect of ship shadow, the maximum reading of the two was used.

Chlorophyll a Concentration: Following standard fluorometric procedure using methanol extraction.

RESULTS

Point #1: Upper water column was isothermal from surface to ca. 55 m, with chlorophyll well distributed throughout. Primary productivity was highest near the surface (z= 5m) and decreased with light intensity to bottom of isothermal layer.

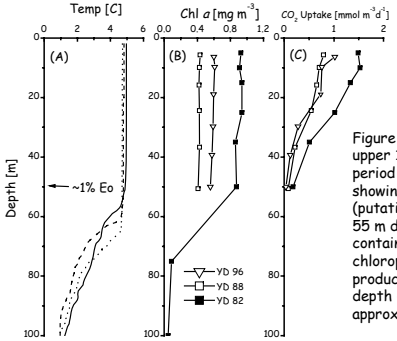

Figure 2. Three profiles from upper 100 m, spanning time period of patch occupation, showing isothermal layers (putative mixing layer) to ca. 55 m depth (A), which contained most of the chlorophyll a (B), and primary production (C). Euphotic depth (1% Eo) was approximately 50 m

Point #2: CO_2 uptake kinetics were highly conserved during the period of observations (with exception of one station on YD 30). CO_2 uptake kinetics by phytoplankton at light saturation (P^b_{max}) and light limitation (α^b) showed greatest variability in the upper 20 m, suggesting that vertical mixing was slower than the phytoplankton's rate of photoadaptation.

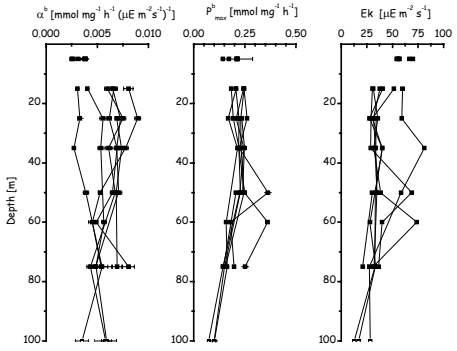

Figure 3. CO_2 uptake kinetics profiles for YD 87 thru 95. P^b_{max} and α^b are normalized to chlorophyll *a* concentration (units of mg). E_k is calculated as P^b_{max}/α^b.

RESULTS (con't)

Point #3: Daily primary production modeled from PE kinetics parameters (top graph, red symbols) was in excellent agreement with daily production measured by simulated *in-situ* on-deck incubations (black symbols). Daily CO_2 drawdown rates by phytoplankton varied between ca. 12 and 40 mmol m^{-2}. Total CO_2 drawdown during 15-day period is estimated at 439 mmol m^{-2}.

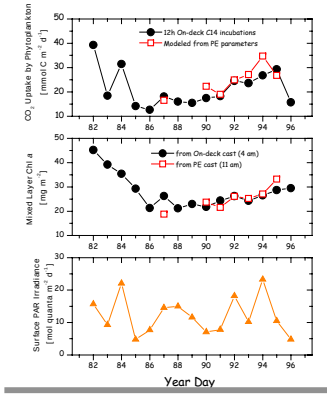

Figure 4. Daily (12-hr) mixed layer (50 m) CO_2 uptake (a) and Chl *a* (b) and surface PAR irradiance (c) during the 15-day period of patch occupation. Seawater samples for on-deck 12-h and PE incubations and Chl a estimations were collected from CTD casts spaced ca. 7 hours apart, but within the same water mass.

Point #4: Good agreement between daily CO_2 drawdown and product of surface Chl a & daily surface light, shows potential utility of light-biomass models of primary productivity for this region.

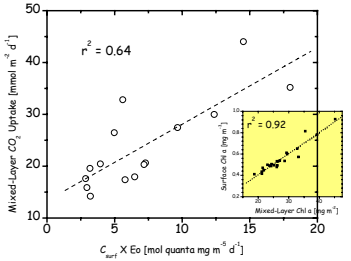

Figure 5. Daily (12-hr) mixed layer CO_2 uptake plotted against product of surface Chl *a* and surface PAR irradiance. Inset graph shows strong agreement between surface (z=5m) and ML Chl a, as expected in a well-mixed environment.

References

Webb, W.L., M. Newton and D. Starr. 1974. Carbon dioxide exchange of Alnus rubra: a mathematical model. Oecologia 17: 281-291.

Platt, T., C.L. Gallegos, & W.G. Harrison. 1982. Photoinhibition of photosynthesis in natural assemblages of marine phytoplankton. J. Mar. Res. 38: 687-701.