Supplementary online material

Background: Basis of NCP measurements

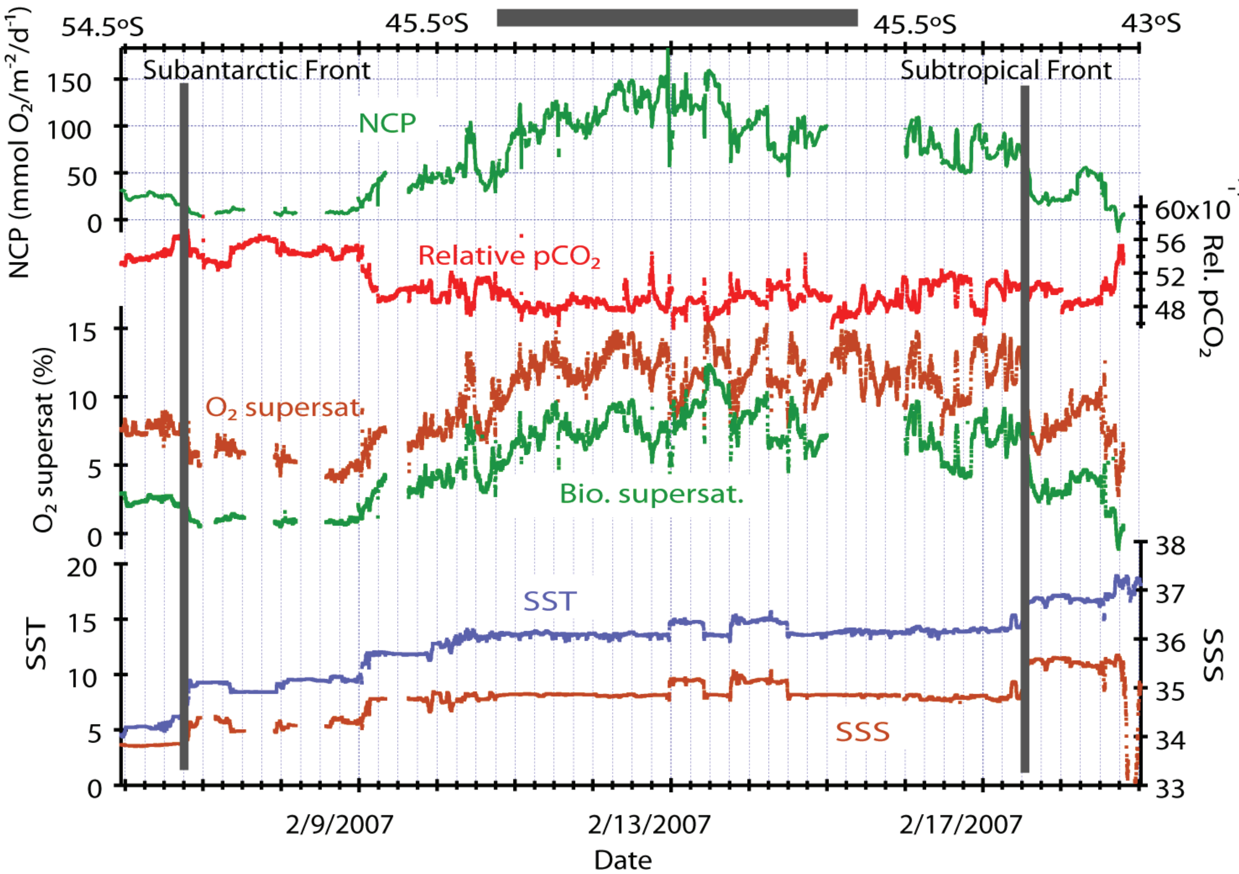
Within the ocean mixed layer, net community productivity (NCP) is a function of photosynthesis and community respiration according to the following approximate stoichiometry (Redfield et al., 1963),

$$106CO_2 + 16HNO_3 + H_3PO_4 + 122H_2O \underset{\text{Respiration}}{\overset{\text{Photosynthesis}}{\rightleftarrows}} (CH_2O)_{106}(NH_3)_{16}H_3PO_4 + 138O_2 \quad (1)$$

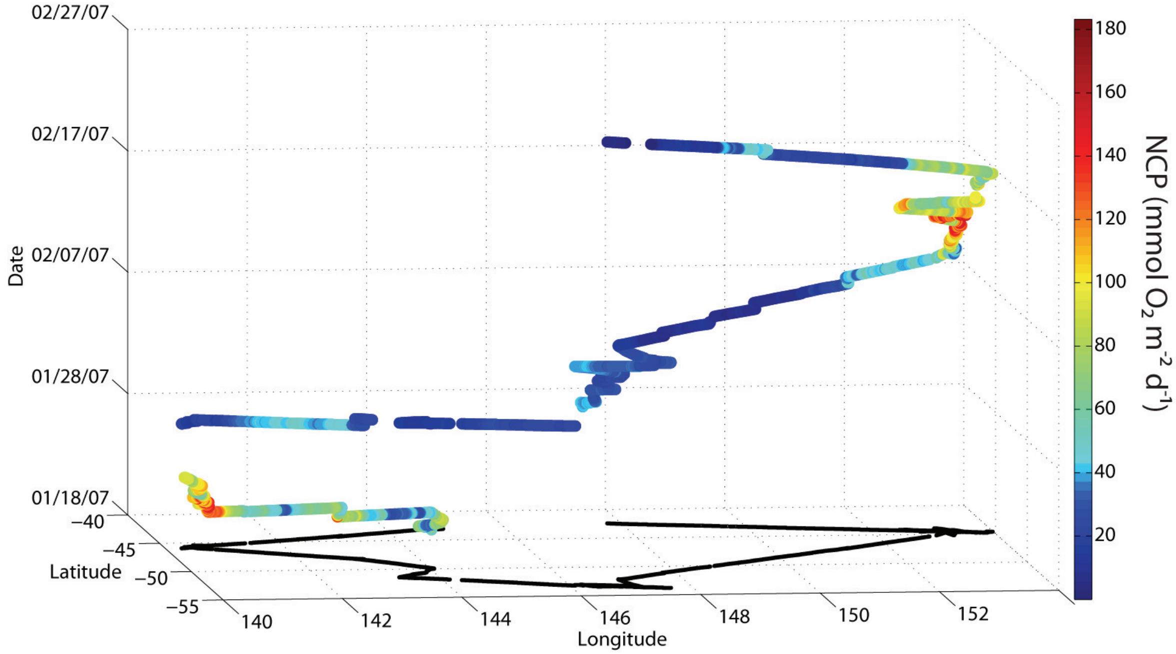
NCP can therefore be estimated from net changes in the inventories of several upper ocean properties; notably oxygen, organic and inorganic carbon, nitrogen and phosphorus. In equation (1), if the forward reaction (photosynthesis) exceeds the reverse reaction (respiration), the system is net autotrophic, which leads to an increase in $[O_2]$ and a decrease in dissolved inorganic carbon (DIC) within the mixed layer. This net autotrophy is characterized by a net accumulation and sinking of organic carbon, in the form of particulate and dissolved organic carbon (POC and DOC). In contrast, if heterotrophy exceeds autotrophy within the mixed layer, oxygen decreases and dissolved inorganic carbon increases. Given that oxygen and inorganic carbon have a gaseous component, a gas exchange flux component must be included in their mass budgets.

The implications of variable fluorescence measurements

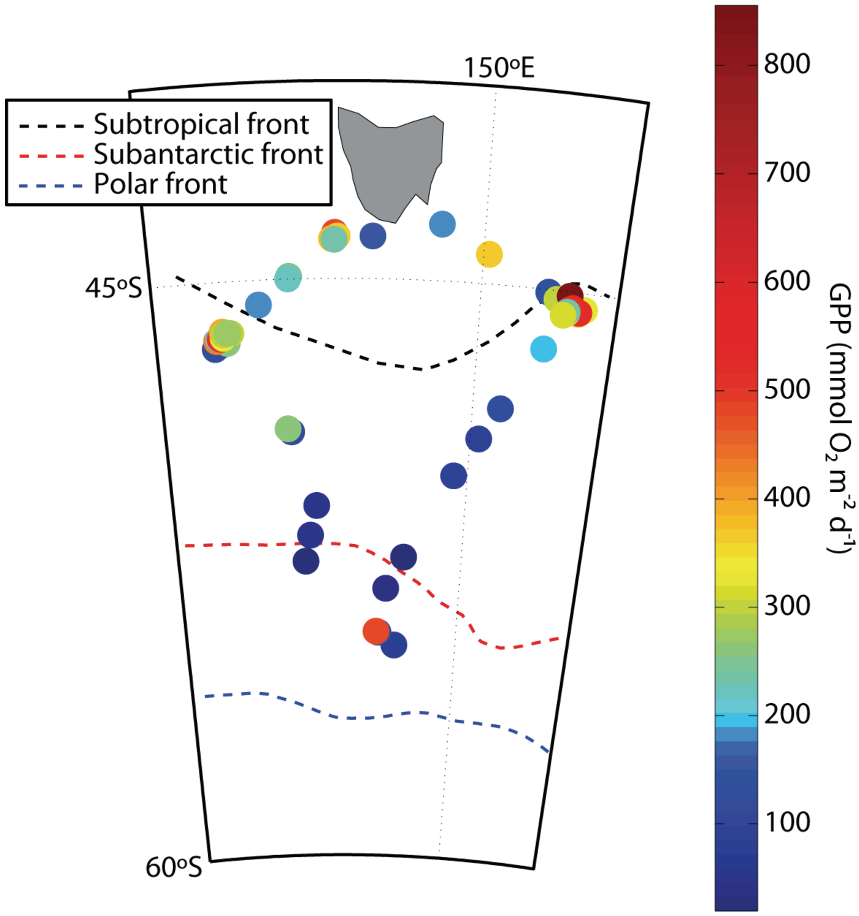
Because NCP is proportional to the net primary productivity (NPP) minus heterotrophic respiration integrated over the mixed layer, where NPP is a function of the autotrophic biomass and specific growth rate (d^{-1}), a comparison of F_v/F_m may also shed light into the influence of growth rate on NCP. A linear relationship, albeit variable, between ^{14}C NPP (Nielsen, 1951) and F_v/F_m has been reported in numerous studies (Kolber and Falkowski, 1993; Boyd et al., 1997; Suggett et al., 2001; Melrose et al., 2006). The relationship should be stronger with oxygen derived productivity because oxygen evolution occurs at PSII sites, and not all electrons generated at PSII are utilized for carbon fixation. Comparison of F_v/F_m to NCP therefore gives insight into the dependence of NCP on PSII dynamics, oxygen evolution and autotrophic growth rate, and physiological stress due to iron limitation.



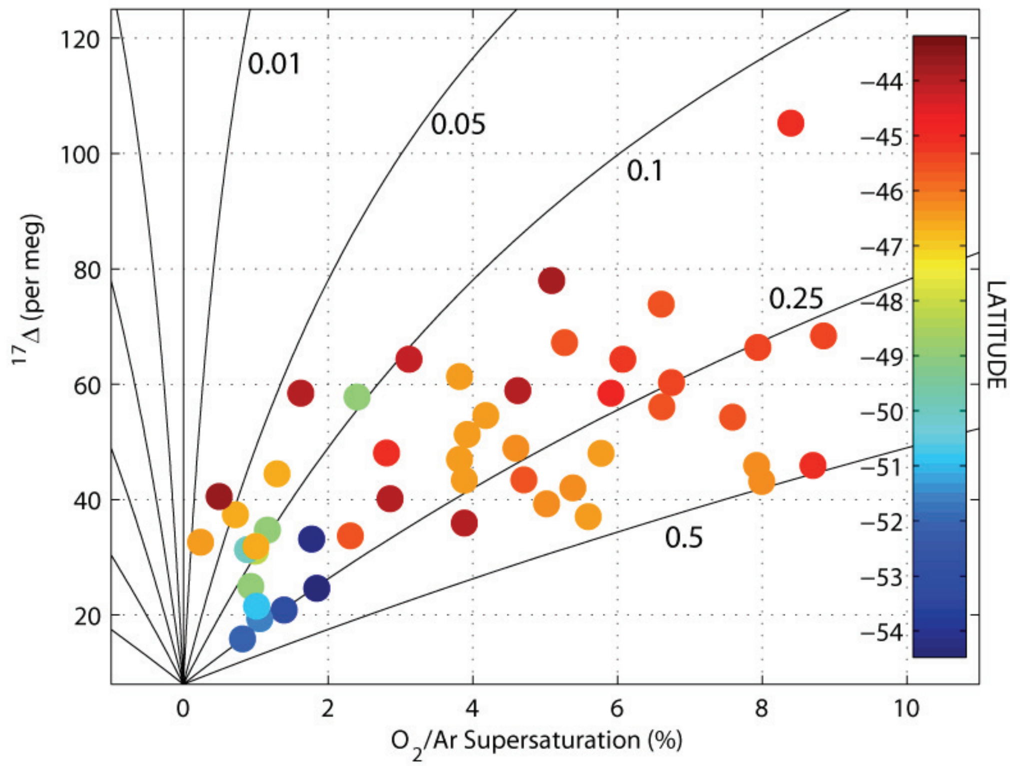
Supplementary Material Figure 1. SAZ-Sense North-bound transect NCP (from in situ O_2/Ar), uncalibrated pCO_2 (from EIMS mass 44 measurements), total (optode) and biological (EIMS) oxygen supersaturation, and sea surface temperature (SST) and salinity (SSS). Approximate position of fronts is also represented.



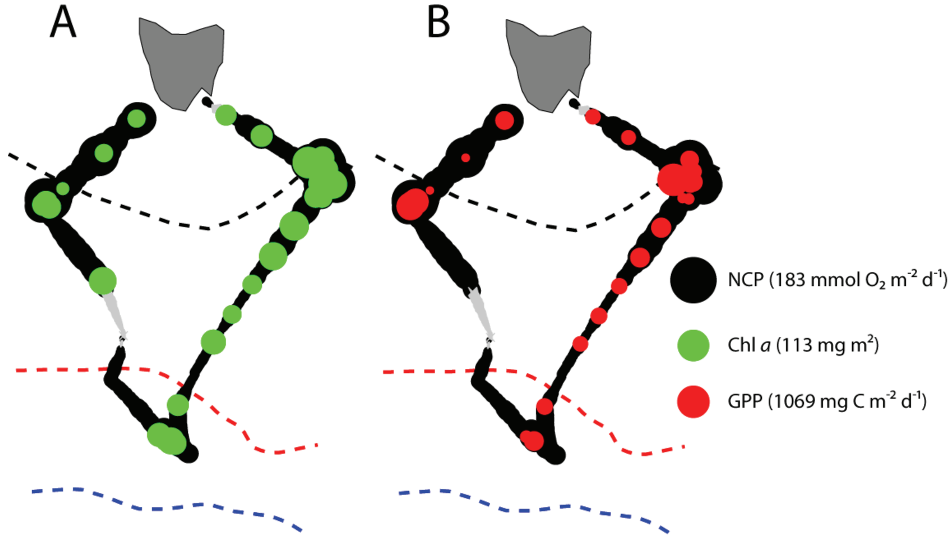
Supplementary Material Figure 2. SAZ-Sense NCP (mmol O_2 m^{-2} d^{-1}) as a function of geographical position and time. Only positive NCP measurements are illustrated.



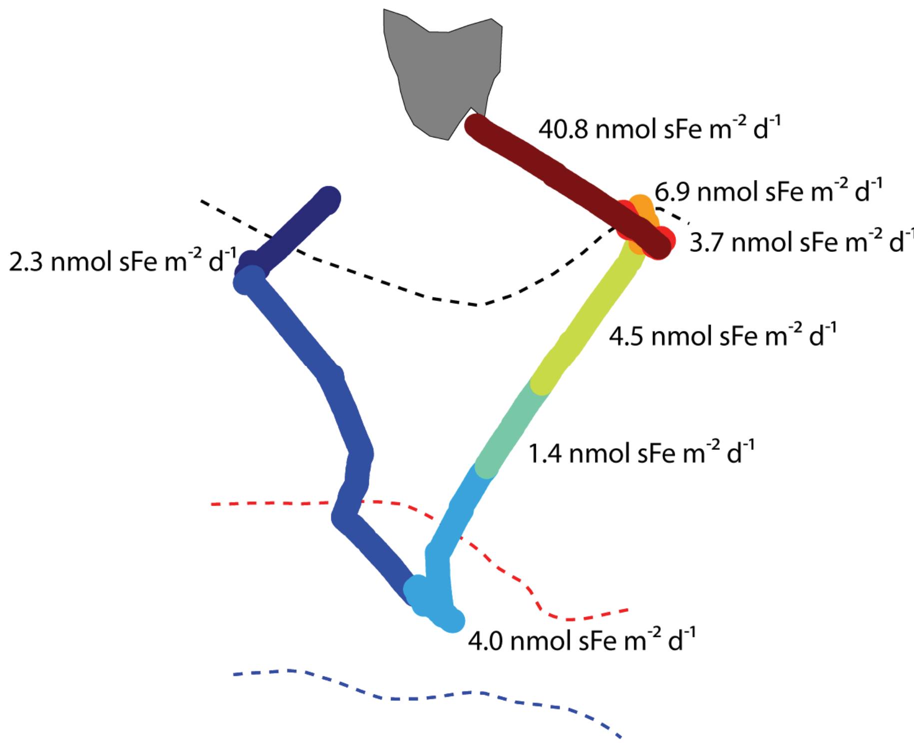
Supplementary Material Figure 3. GPP estimates based on triple isotopic composition of dissolved oxygen. Oxygen in the surface ocean has two main sources: air and photosynthetic splitting of water. These sources have distinct isotopic signatures. Atmospheric O_2 has a characteristic isotopic signature derived from a stratospheric reaction with a mass independent fractionation between O_2 and CO_2 (Luz et al., 1999; Boering et al., 2000; Thiemens, 2001; Lammerzahl et al., 2002; Luz and Barkan, 2005). Mass-independent fractionation is manifested in a non-zero value of $^{17}\Delta$, where $^{17}\Delta = \ln\left(0.001*\delta^{17}O+1\right)-0.516*\ln\left(0.001*\delta^{18}O+1\right) \sim \delta^{17}O-0.516*\delta^{18}O$. The overall isotopic signature of O_2 in the surface ocean thus depends on the relative abundance of atmospheric and photosynthetic O_2. The sinks for dissolved O_2 in the surface ocean are respiration and gas exchange. These processes fractionate O_2 mass dependently and therefore do not change $^{17}\Delta$. GPP is the rate of photosynthetic O_2 production required to maintain the observed departure of $^{17}\Delta$ from atmospheric equilibrium against the equilibrating effect of gas exchange(Luz and Barkan, 2000).



Supplementary Material Figure 4. $^{17}\Delta$ of O_2 (per meg) vs. biological O_2 supersaturation (%). Solid lines represent isopleths of constant NCP/GPP. The relation between the two properties defines NCP/GPP, which, when multiplied by a factor of ~2 to account for stoichiometry (Bender, 1999) is comparable to the "f" export ratio.



Supplementary Material Figure 5. Mixed-Layer NCP vs. (A) Chl *a* (green) (B) depth integrated ^{14}C primary production (red). The diameter of the filled red and green circles indicates the magnitude of the ^{14}C production and Chl a values. Legend shows the largest corresponding values. Positive and negative NCPs are represented by black and grey symbols, respectively, such that the thickness of the band in each figure is proportional to the continuous NCP measurement. Negative NCP values could result from vertical mixing of O_2 undersaturated waters. The black, red, and blue dashed lines represent the climatological positions (Orsi et al., 1995) of the Subtropical, Subantarctic, and Polar fronts, respectively.



Supplementary Material Figure 6. Spatial extent of aeolian soluble Fe deposition fluxes. Each color represents a filter measurement integrated over a section of the cruise track. Full details are contained in Bowie et al. (Bowie et al., 2009).

Supplementary Material References

Bender, M., J. Orchardo, M.-L. Dickson, R. Barber, and S. Lindley: In vitro O_2 fluxes compared with ^{14}C production and other rate terms during the JGOFS equatorial Pacific experiment, Deep Sea Res., 46, 637-654, 1999.

Boering, K. A., Jackson, T., Thiemens, M. H., Bender, M., and Atlas, E.: Anomalous fractionation of oxygen isotopes in stratospheric carbon dioxide: From ozone production and transport to global biospheric productivity., Abstracts of Papers of the American Chemical Society, 219, U308-U308, 2000.

Bowie, A. R., Lannuzel, D., Remenyi, T. A., Wagener, T., Lam, P. J., Boyd, P. W., Guieu, C., Townsend, A. T., and Trull, T. W.: Biogeochemical iron budgets of the Southern Ocean south of Australia: summertime supply decouples iron and nutrient cycles in the subantarctic zone, Global Biogeochem. Cycles, doi:10.1029/2009GB003500, 2009.

Boyd, P. W., Aiken, J., and Kolber, Z.: Comparison of radiocarbon and fluorescence based (pump and probe) measurements of phytoplankton photosynthetic characteristics in the Northeast Atlantic Ocean, Mar Ecol-Prog Ser, 149, 215-226, 1997.

Kolber, Z., and Falkowski, P. G.: Use of active fluorescence to estimate phytoplankton photosynthesis in situ, Limnol. Oceanogr., 38, 1646-1665, 1993.

Lammerzahl, P., Rockmann, T., Brenninkmeijer, C. A. M., Krankowsky, D., and Mauersberger, K.: Oxygen isotope composition of stratospheric carbon dioxide, Geophys. Res. Lett., 29, -, 2002.

Luz, B., Barkan, E., Bender, M. L., Thiemens, M. H., and Boering, K. A.: Triple-isotope composition of atmospheric oxygen as a tracer of biosphere productivity, Nature, 400, 547-550, 1999.

Luz, B., and Barkan, E.: Assessment of oceanic productivity with the triple-isotope composition of dissolved oxygen, Science, 288, 2028-2031, 2000.

Luz, B., and Barkan, E.: The isotopic ratios O^{17}/O^{16} and O^{18}/O^{16} in molecular oxygen and their significance in biogeochemistry, Geochim. Cosmochim. Acta, 69, 1099-1110, 2005.

Melrose, D. C., Oviatt, C. A., O'Reilly, J. E., and Berman, M. S.: Comparisons of fast repetition rate fluorescence estimated primary production and C14 uptake by phytoplankton, Marine Ecology-Progress Series, 311, 37-46, 2006.

Nielsen, E. S.: Measurement of the production of organic matter in the sea by means of carbon-14, Nature, 167, 684-685, 1951.

Orsi, A. H., Whitworth, T., and Nowlin, W. D.: On the meridional extent and fronts of the Antarctic circumpolar current, Deep-Sea Research Part I-Oceanographic Research Papers, 42, 641-673, 1995.

Redfield, A. C., Ketchum, B. H., and Richards, F. A.: The influence of organisms on the composition of seawater, in: The sea, v.2., edited by: Hill, M. N., Interscience, 1963.

Suggett, D., Kraay, G., Holligan, P., Davey, M., Aiken, J., and Geider, R.: Assessment of photosynthesis in a spring cyanobacterial bloom by use of a fast repetition rate fluorometer, Limnol. Oceanogr., 46, 802-810, 2001.

Thiemens, M. H.: Atmospheric science - The mass-independent ozone isotope effect, Science, 293, 226-226, 2001.