Observation of Net Community and Export Production from Autonomous Platforms

Todd Martz

OCB Floats and Gliders Workshop Moss Landing 2009

Collaborators
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Steve Riser (UW)
Mike DeGrandpre (U. Montana)

TOPICS

Production

- Fluorescence
  - Perry et al. 2008 ◘
  - Davis et al. 2008 ◘
  - Boss et al. 2008 ◘
  - Niewiadomska et al. 2008 ◘
- Oxygen
  - Kortzinger et al. 2004
  - Riser and Johnson 2008
  - Nicholson et al. 2008 ◘

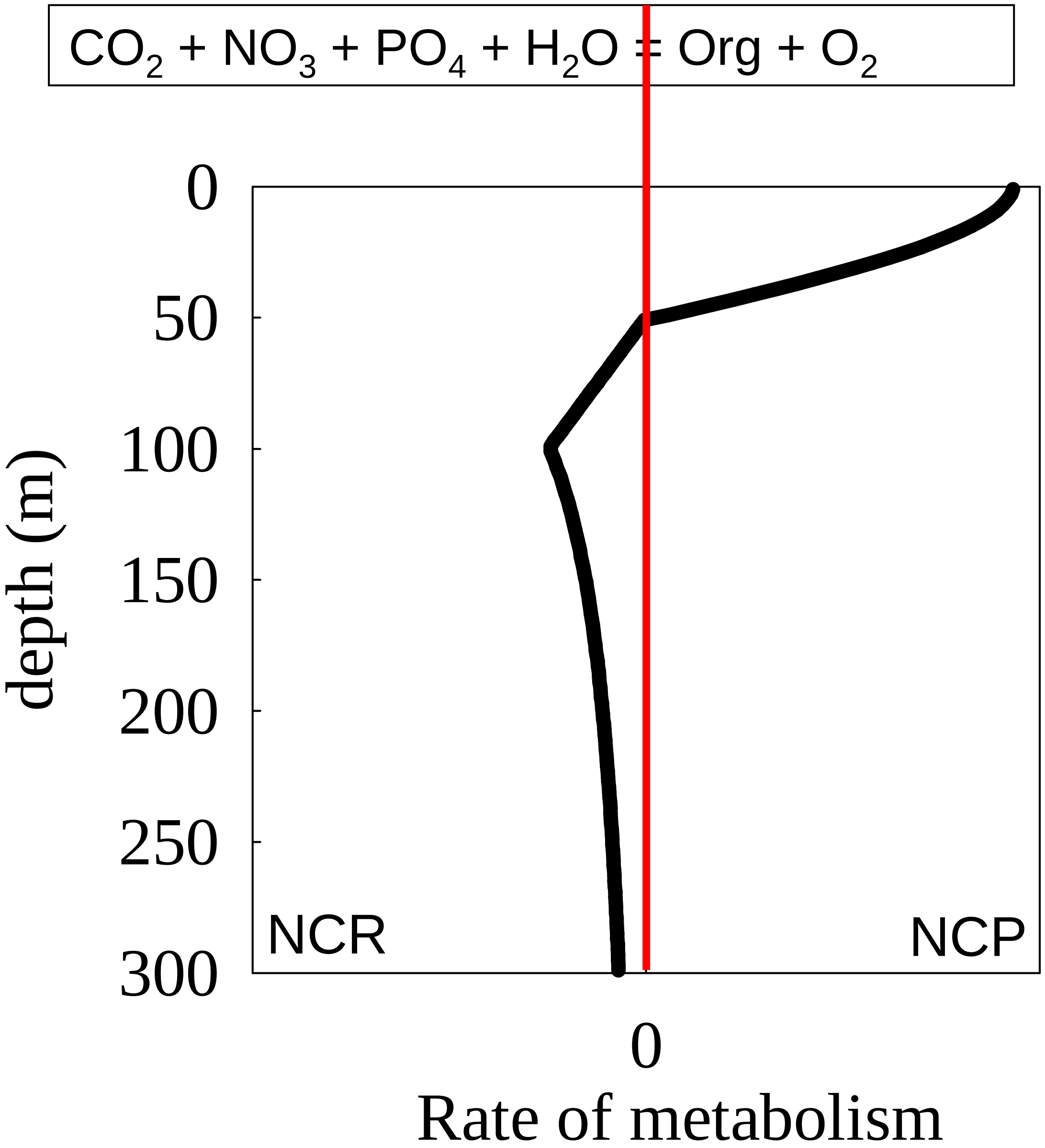
Export

- Beam attenuation / OBS
  - Bishop et al. 2002, 2004, 2009;
  - Boss et al. 2008 ◘
- Oxygen (OUR)
  - Martz, Riser Johnson, 2008◘

◘ L&O 53 (5, part 2) Special Issue on ALPS

Optical properties
Chemical properties

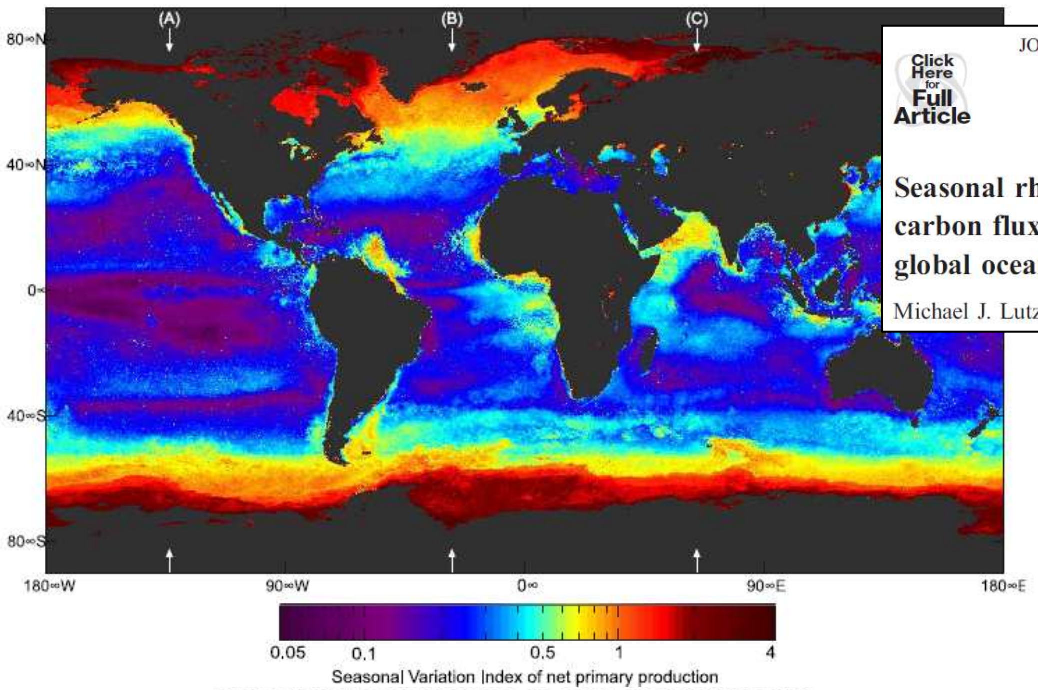
Production, Respiration & Export



Observation of a reactant or product required to estimate rates of Net Community Metabolism & Export.

We have poor spatial coverage of NCP and Export

C10011 LUTZ ET AL.: SEASONALITY OF THE BIOLOGICAL PUMP C10011

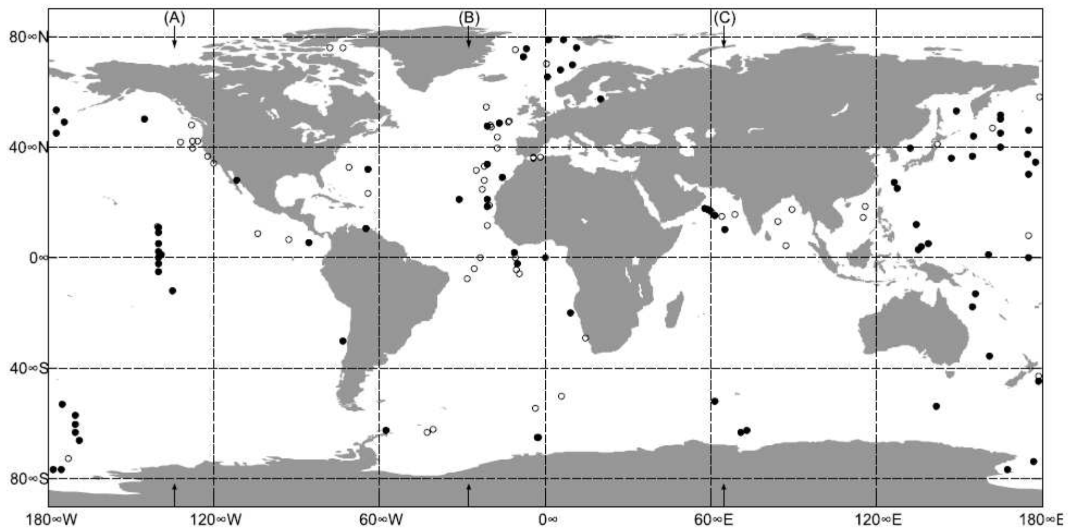


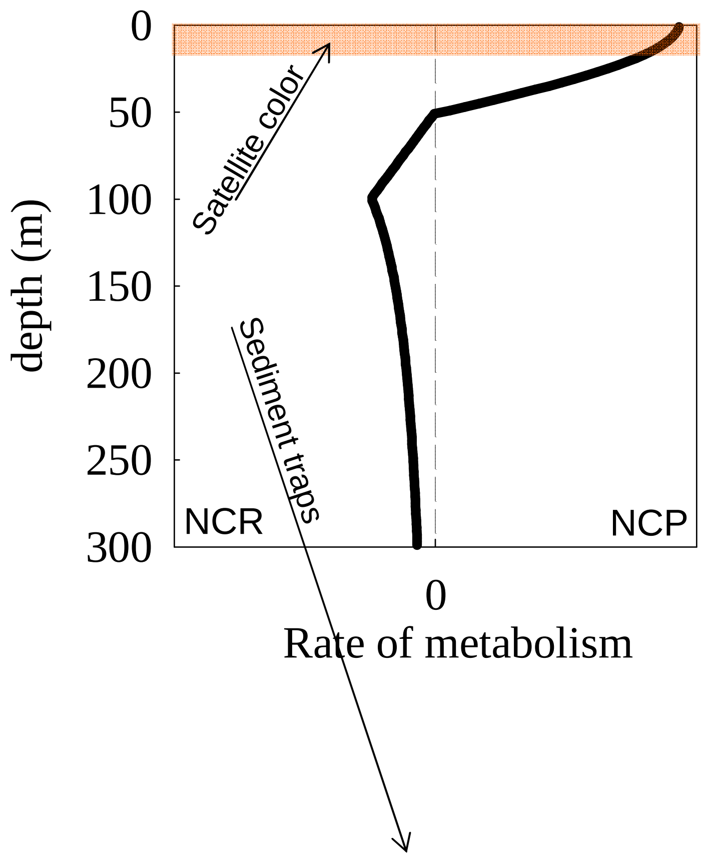
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, C10011, doi:10.1029/2006JC003706, 2007

Click Here for Full Article

Seasonal rhythms of net primary production and particulate organic carbon flux to depth describe the efficiency of biological pump in the global ocean

Michael J. Lutz,[1] Ken Caldeira,[2] Robert B. Dunbar,[1] and Michael J. Behrenfeld[3]





NATURE|Vol 458|12 March 2009

NEWS & VIEWS

CARBON CYCLE

Fickle trends in the ocean

Nicolas Gruber

A model analysis of the uptake of carbon dioxide in the North Atlantic carries with it a cautionary reminder about interpreting what may be short-term trends as signals of long-term climate change.

Several observational studies have suggested

in the 1960s, a long-term trend towards very

They point out that most of the observations were made after the early 1990s, a period during which the NAO changed from very positive to near normal values. Their model indicates that normal to negative phases of the NAO are associated with a lower oceanic uptake of CO_2; so the trend towards lower NAO states since the early 1990s could explain the tendency of the North Atlantic to take up less CO_2 than expected during this period. Thomas *et al.* also speculate that the North Atlantic carbon sink will probably rebound in the coming years,

GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 22, GB4027, doi:10.1029/2007GB003167, 2008

Click Here for Full Article

Changes in the North Atlantic Oscillation influence CO_2 uptake in the North Atlantic over the past 2 decades

Helmuth Thomas,[1] A. E. Friederike Prowe,[1,2] Ivan D. Lima,[3] Scott C. Doney,[3] Rik Wanninkhof,[4] Richard J. Greatbatch,[1,5] Ute Schuster,[6] and Antoine Corbière[7]

Received 12 December 2007; revised 1 August 2008; accepted 11 August 2008; published 31 December 2008.

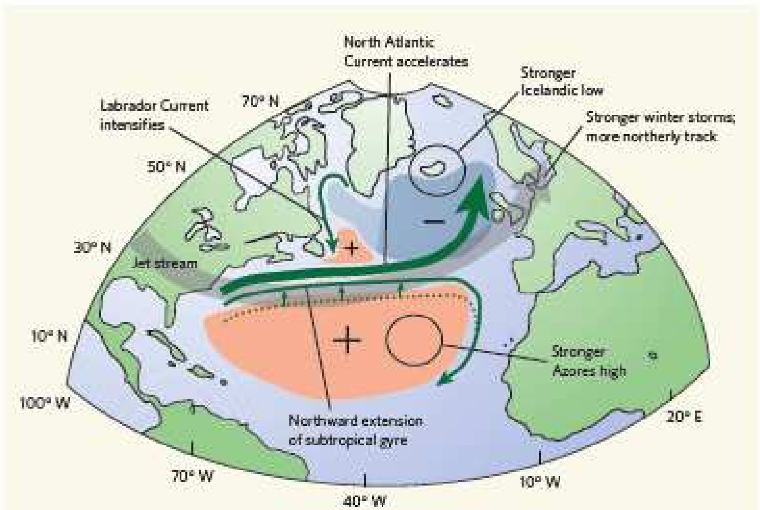
in the past[2]. One modelling study[3], for example, has suggested that the oceanic sink, which has removed about 30% of the global anthropogenic emissions over the past 250 years or so[4], might be stalling. Some of the best observational evidence comes from the North Atlantic Ocean, where long-term measurements of the surface ocean's partial pressure of CO_2 (pCO_2) indicate that its carbon uptake from the atmosphere has decreased in recent decades, perhaps owing to climate change[5,6]. Thomas *et al.*[1] challenge this interpretation.

The North Atlantic is the largest ocean sink for atmospheric CO_2 in the Northern Hemisphere, with half of the flux in the North Atlantic being driven by the uptake of anthropogenic CO_2 (ref. 7). The detection of long-term changes in this sink is challenging, however, because the sink varies substantially from year to year. That variation is largely associated with the North Atlantic Oscillation (NAO)[8], which is the dominant mode of climate variability in this region.

The NAO is a large-scale seesaw in atmospheric mass between a subtropical high-

to put analyses of relatively short-term observational trends[5,6] into a longer-term context.

What about carbon sinks in other parts of the global ocean? With a few notable exceptions[9],



Resolving the global carbon budget

"The first task is to ensure that appropriate observational systems are put in place to permit accurate quantification of the oceanic carbon sinks and detect changes reliably"
-N. Gruber

We need reliable sensors operating on autonomous platforms!

Lagrangian measurement of Export

NBSTs avoid sampling bias and allow shallower deployments

Ship required for recovery and subsequent analysis of particles

Journal of Marine Research, 65, 345–416, 2007

An assessment of the use of sediment traps for estimating upper ocean particle fluxes

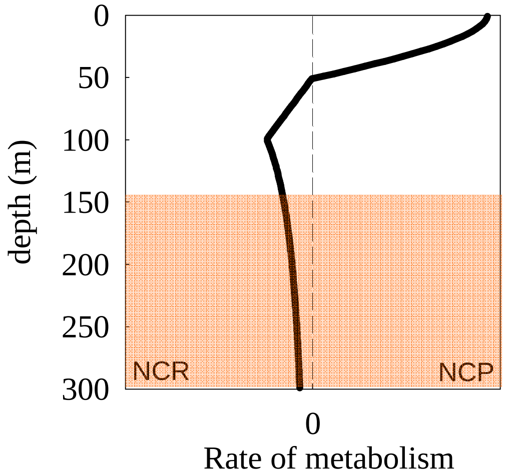
by Ken O. Buesseler[1], Avan N. Antia[2], Min Chen[3], Scott W. Fowler[4,5], Wilford D. Gardner[6], Orjan Gustafsson[7], Koh Harada[8], Anthony F. Michaels[9], Michiel Rutgers van der Loeff[10], Manmohan Sarin[11], Deborah K. Steinberg,[12] and Thomas Trull[13]

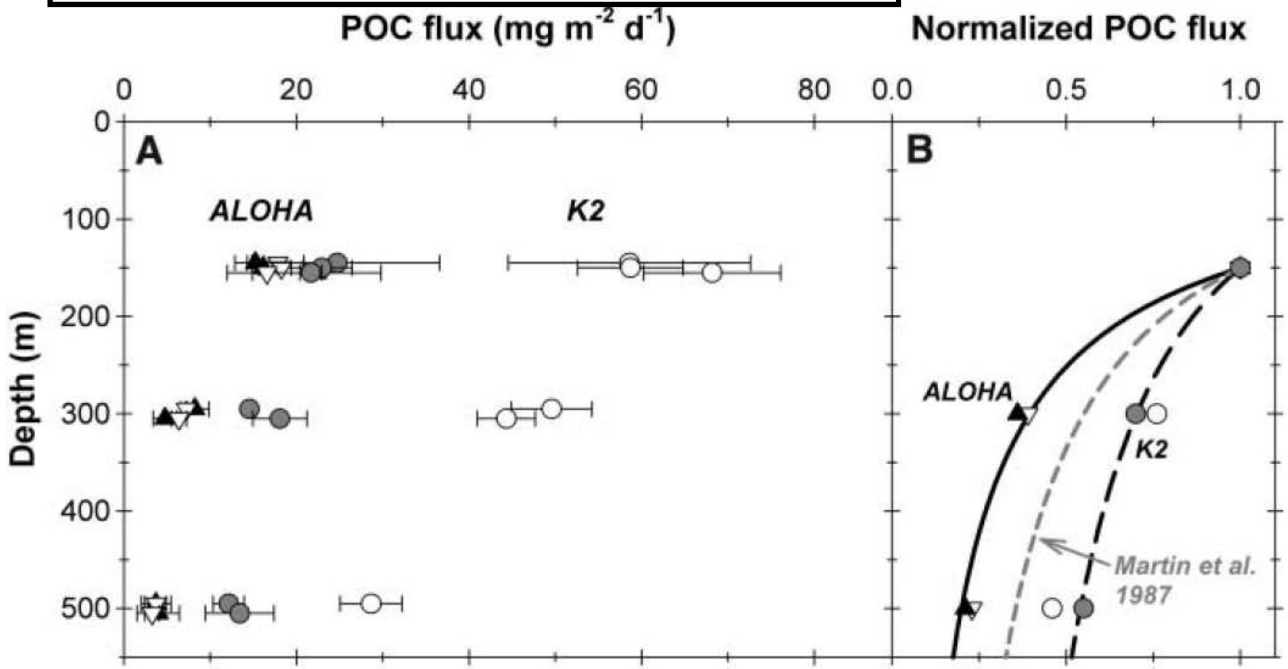
www.sciencemag.org SCIENCE VOL 316 27 APRIL 2007

Revisiting Carbon Flux Through the Ocean's Twilight Zone

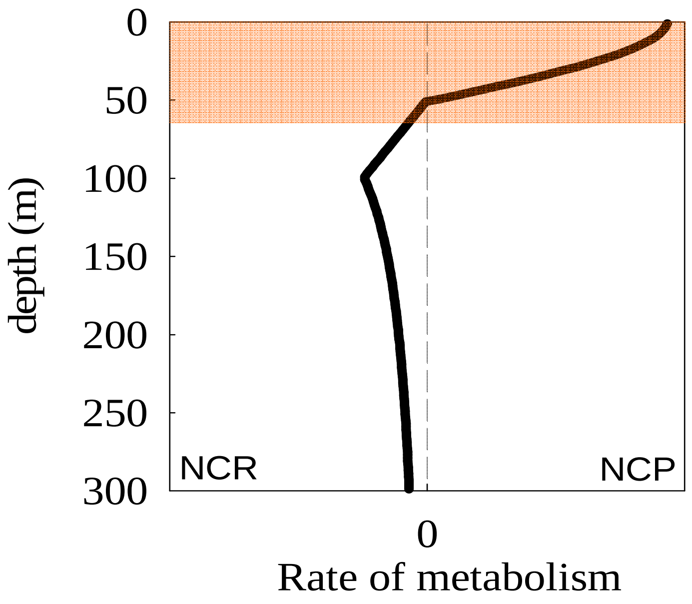
Ken O. Buesseler,[1]* Carl H. Lamborg,[1] Philip W. Boyd,[2] Phoebe J. Lam,[1] Thomas W. Trull,[3] Robert R. Bidigare,[4] James K. B. Bishop,[5,6] Karen L. Casciotti,[1] Frank Dehairs,[7] Marc Elskens,[7] Makio Honda,[8] David M. Karl,[4] David A. Siegel,[9] Mary W. Silver,[10] Deborah K. Steinberg,[11] Jim Valdes,[12] Benjamin Van Mooy,[1] Stephanie Wilson[11]

2007] *Buesseler et al.:*

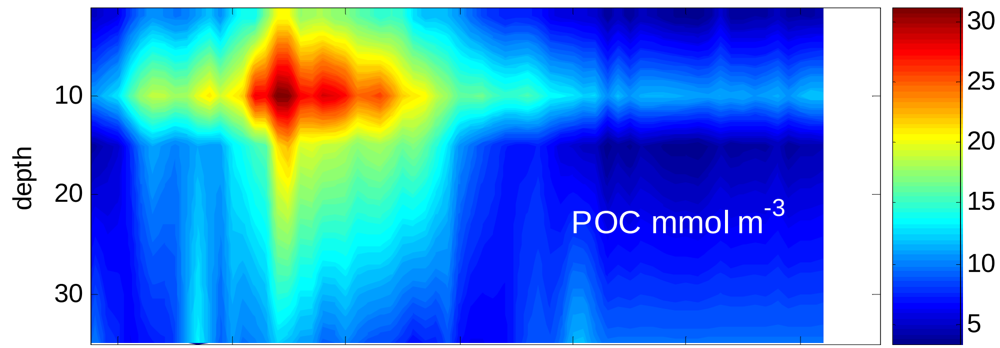


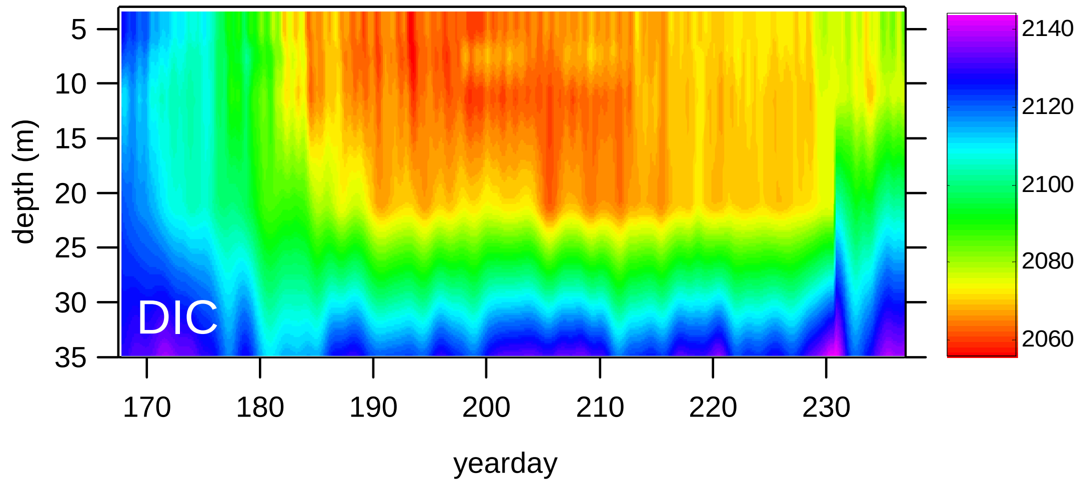


Autonomous measurement of NCP & export



Martz, DeGrandpre, Strutton, McGillis, Drennan. 2009. Sea surface pCO_2 and carbon export during the Labrador Sea spring-summer bloom: an in situ mass balance approach, *JGR Oceans*, accepted.





$$CO_2 + NO_3 + PO_4 + H_2O = Org + O_2$$

Labrador Sea Carbon Budget

Assumptions/simplifications

<u>ΔDOC:NCP = 0.1</u>

Hansell & Carlson (1998)

Teira et al. (2001)

<u>PIC:POC = 0.025</u>

Milliman et al. (1999)

<u>Fadv = 0</u>

C mass balance

ΔDIC

+ ΔPOC_{sus}

+ ΔDOC

+ ΔPIC

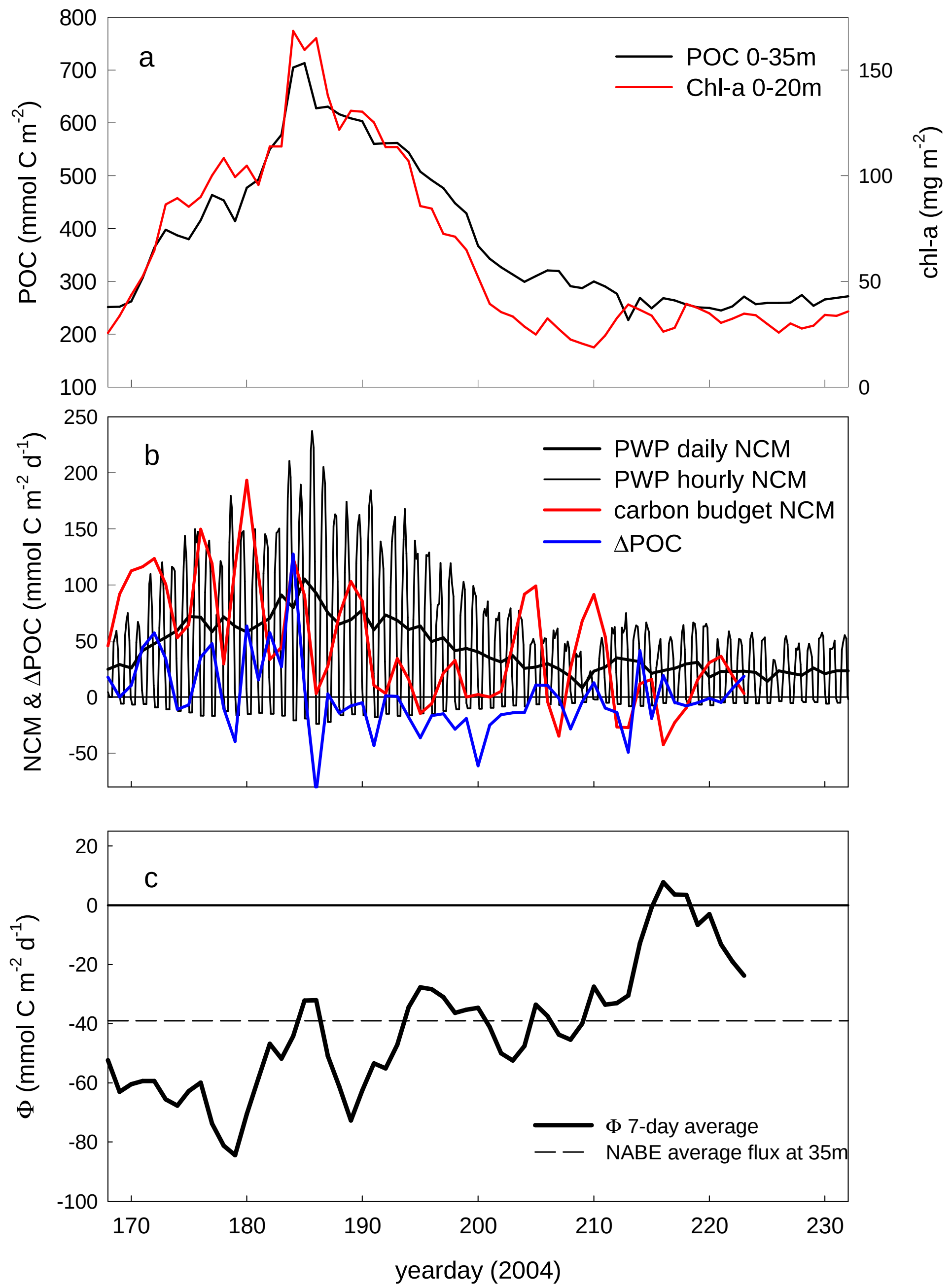
+ ΦPOC

+ Fgas

+ Fent

+ Fadv

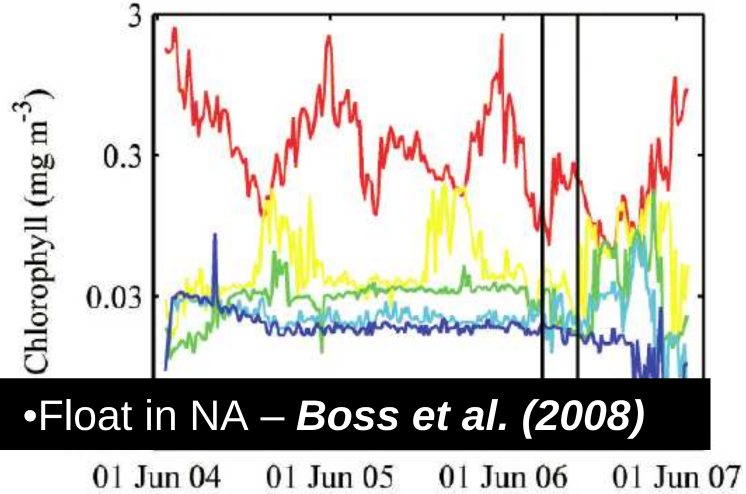
= 0



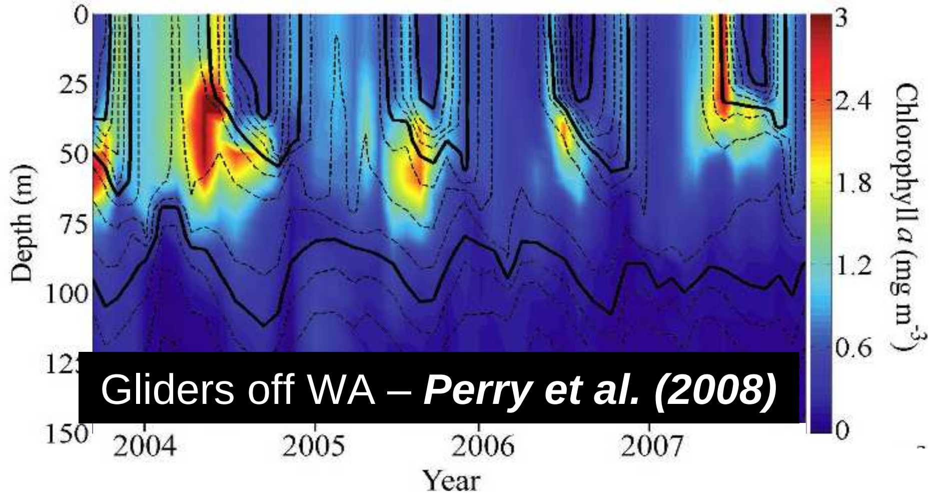
Several other examples of mooring-based work…rest of talk focuses on ALPS

Observations of Fluorescence from ALPS

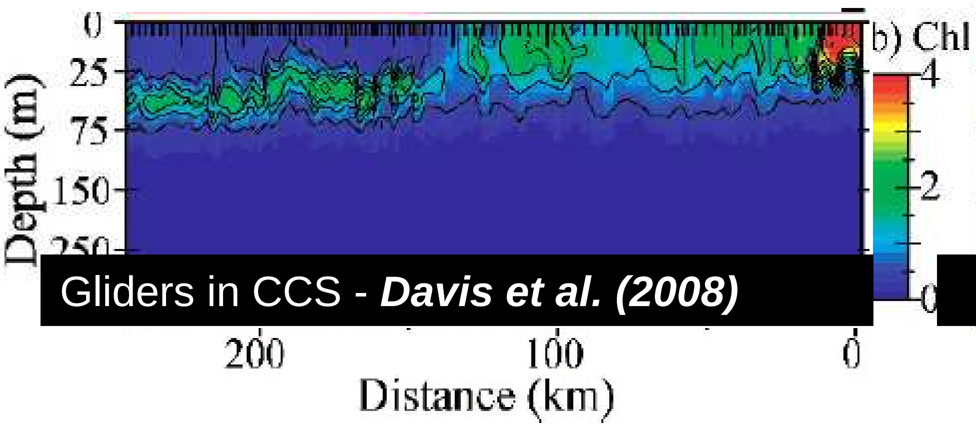
•Excellent for: establishing bloom timing, extent, intensity, duration; Ground truthing and filling in gaps in satellite data; identifying spatial patterns due to e.g. fronts/eddies.
•Conversion of data into quantitative rates of NCP still elusive.



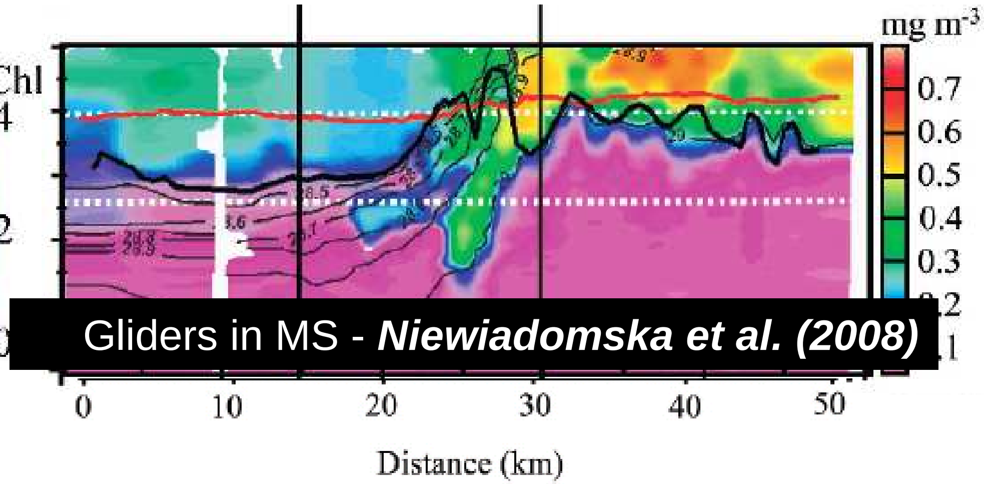
•Float in NA – ***Boss et al. (2008)***



Gliders off WA – ***Perry et al. (2008)***

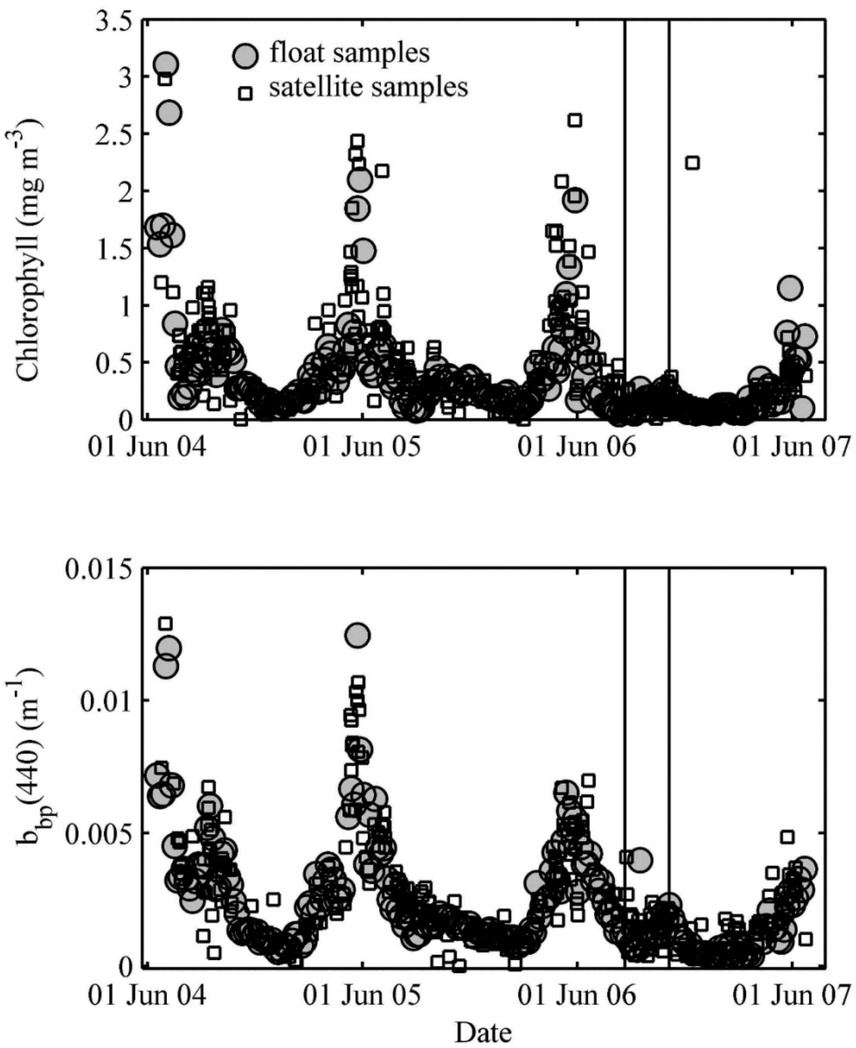


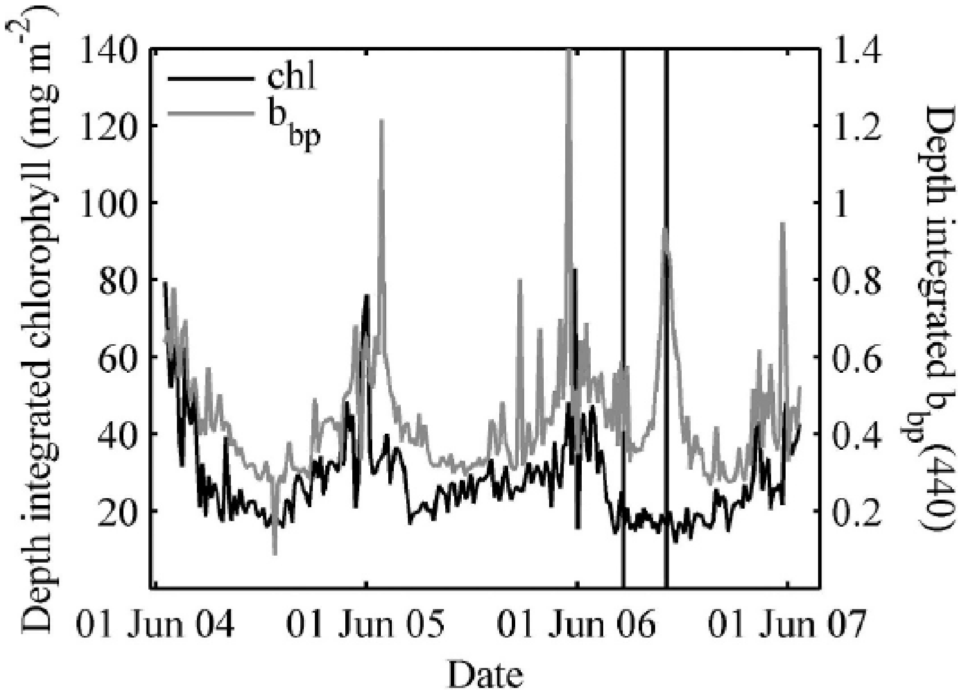
Gliders in CCS - ***Davis et al. (2008)***



Gliders in MS - ***Niewiadomska et al. (2008)***

Bio-optical observations of export from floats





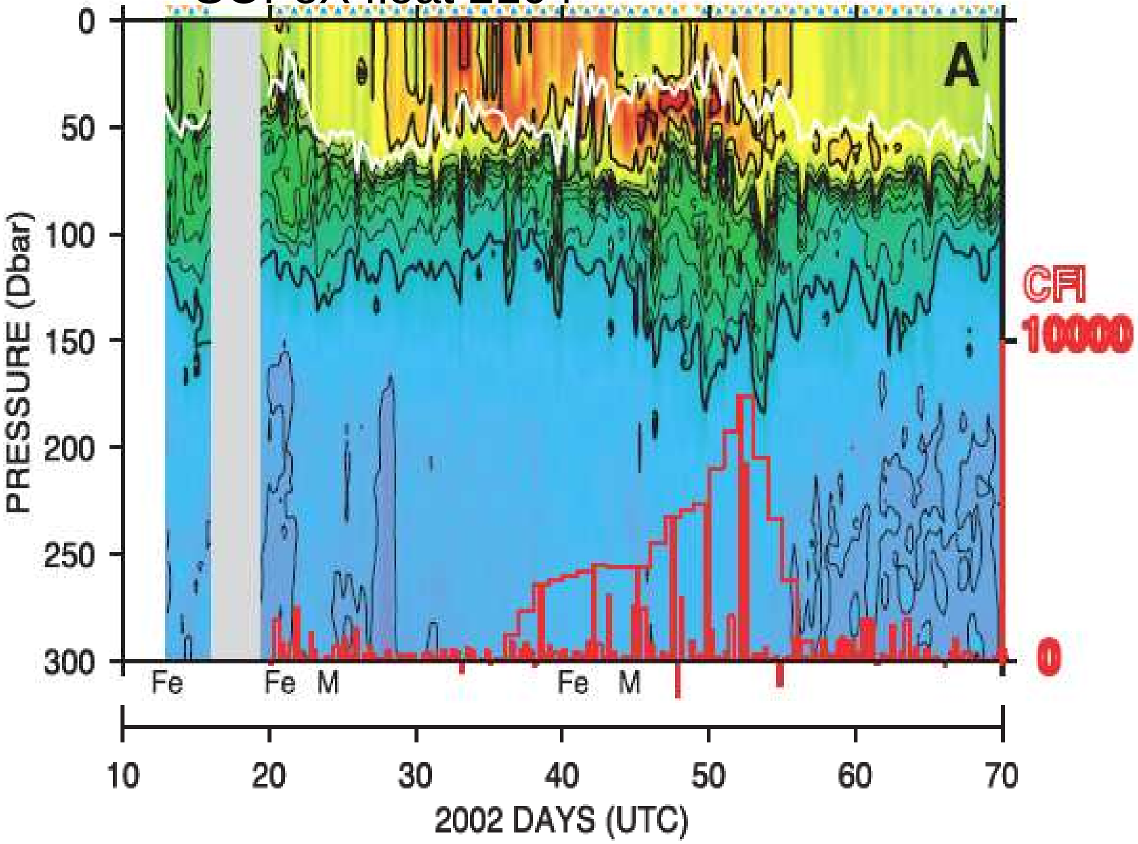
Light side scattering sensor (POC proxy)
Boss et al. (2008)

Export observed in eddy using integrated LSS – not found in fluorescence from satellite or float.

Bio-optical observations of export from floats

Bean attenuation (POC proxy, CFI – carbon flux index)
Bishop et al. 2002, 2004, 2009 in press

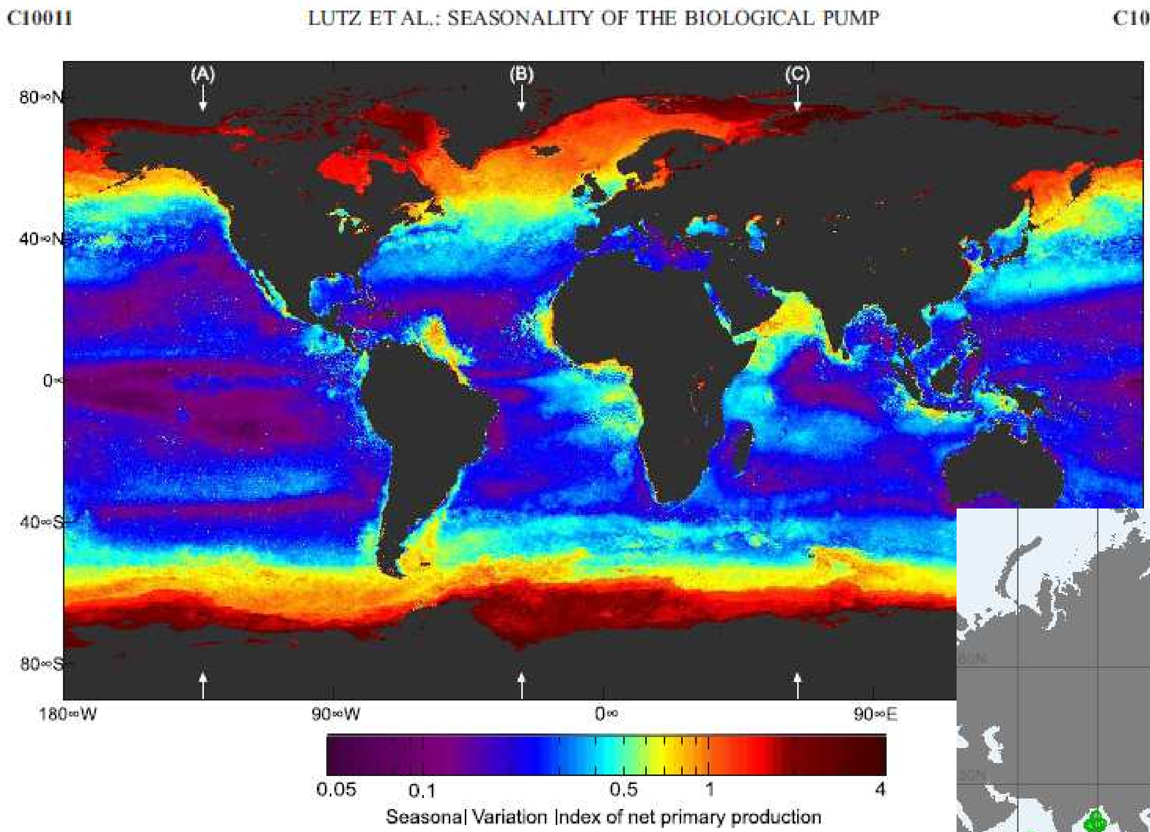
Figure 2A from Bishop et al. 2004
SOFeX float 2104



- During bloom, 2 µM → 9 µM POC and deepening of 1 µM contour clearly indicate growth and export.
- Possible to estimate export flux from CFI or changes in integrated POC standing stocks.

Autonomous measurements of NCP and Export using oxygen sensors on floats and gliders

$CO_2 + NO_3 + PO_4 + H_2O = Org + O_2$



Riser & Johnson (2008)

Nicholson et al (2008)

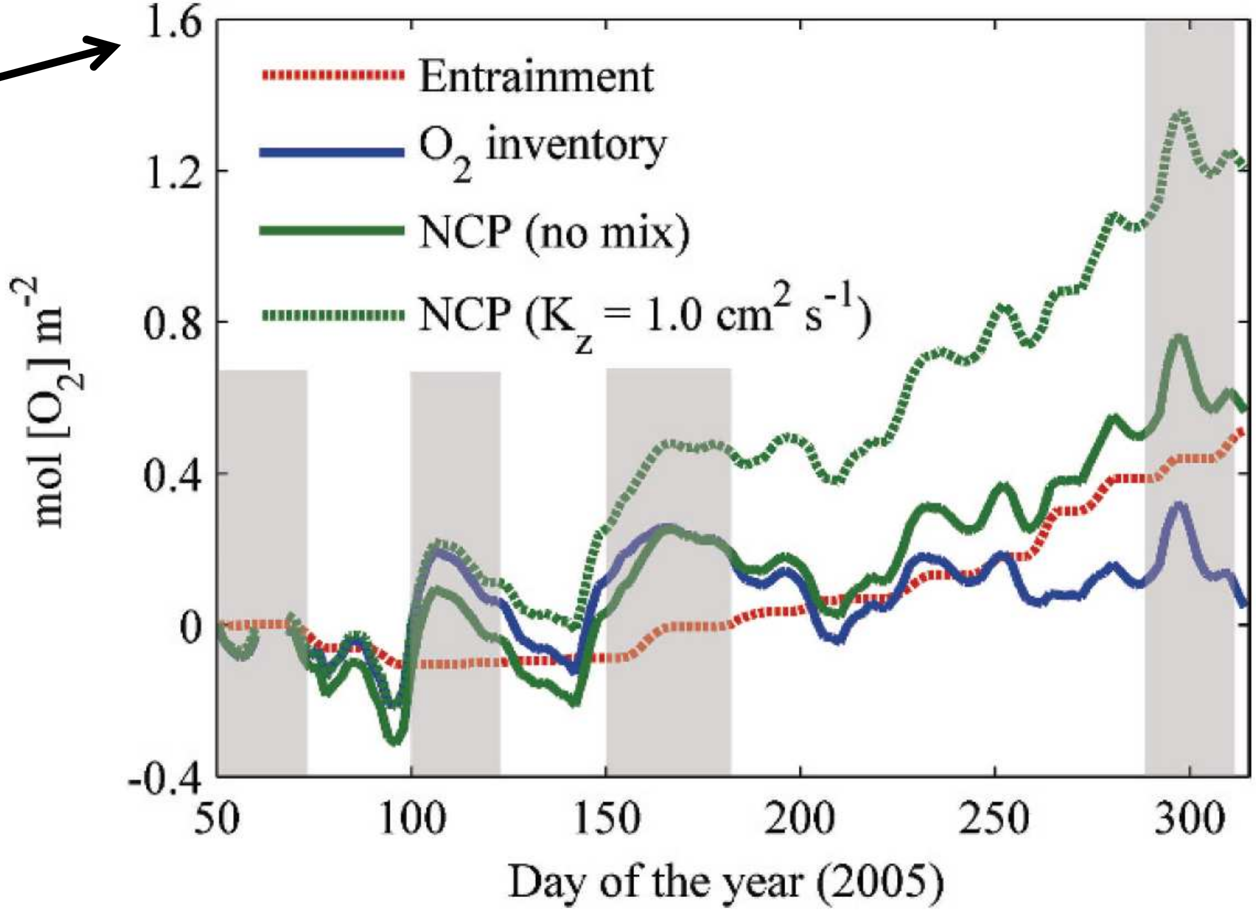
Martz, Johnson & Riser (2008)

NCP from O_2 on gliders

- Data collected near the Hawaii Ocean Time Series on autonomous platforms observe oxygen production in the deep euphotic zone.
- Mass balance calculations used to calculate NCP agree reasonably well with historical data.

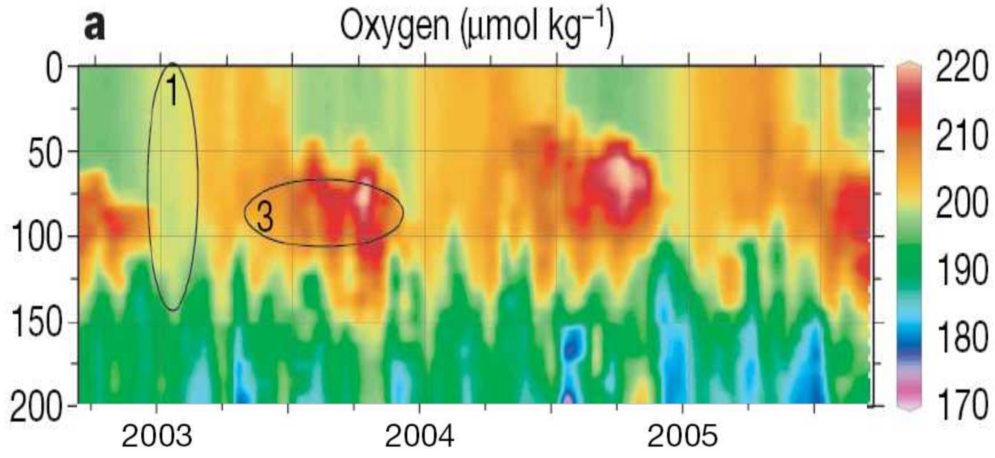
Glider data from Nicholson et al. (2008) 0.6-1 mol C m^{-2} yr^{-1} (DEZ)

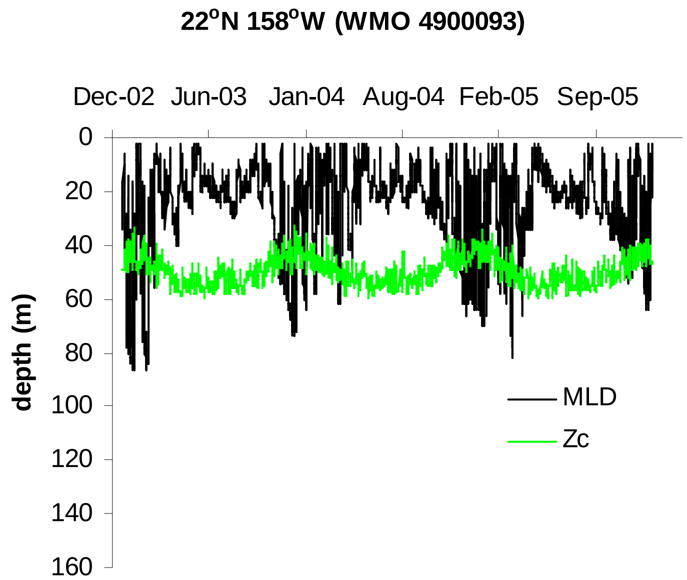
Profiling float data from Riser and Johnson (2008) <u>1.6 mol C m^{2-} yr^{-1}</u> (EZ)



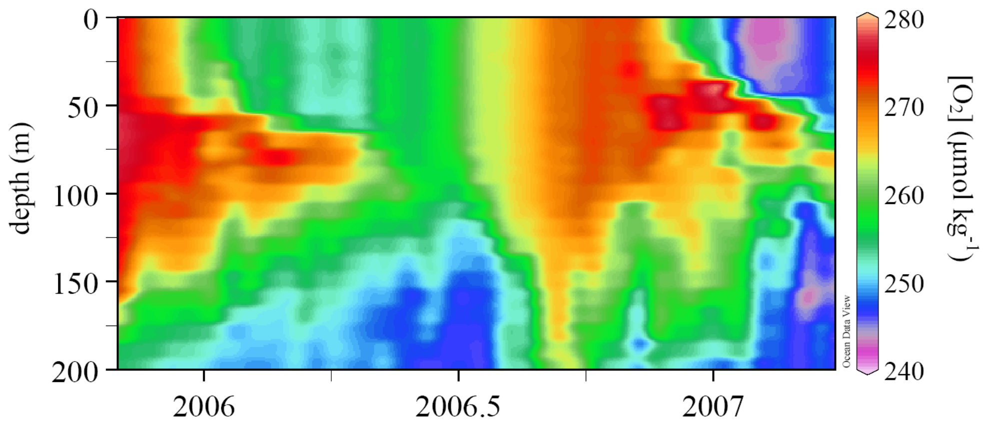
NCP and export from O_2 on floats

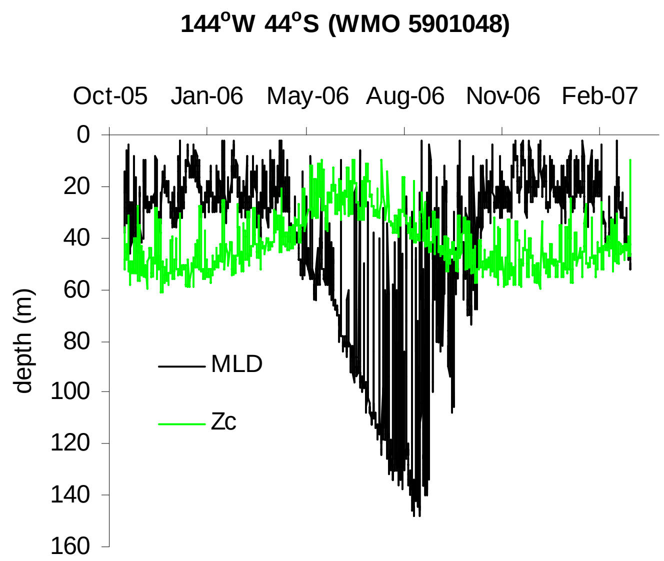
Production zone SOM at 22ºN



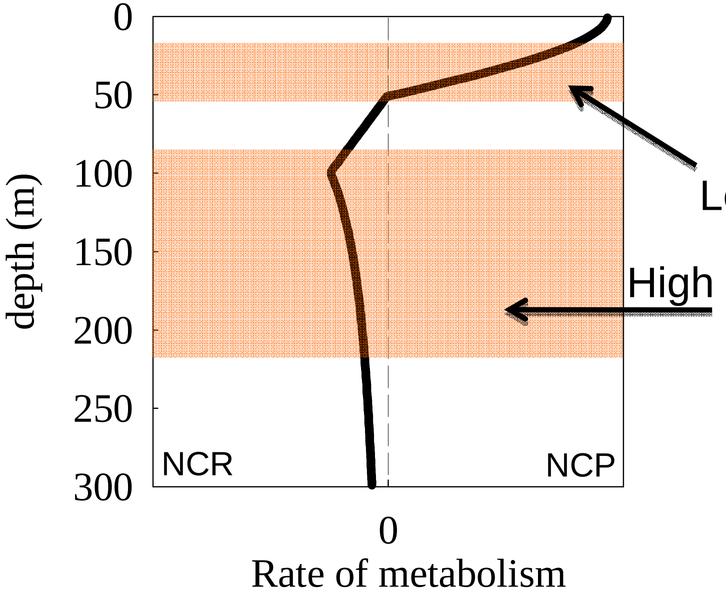


Consumption zone SOM at 43ºS





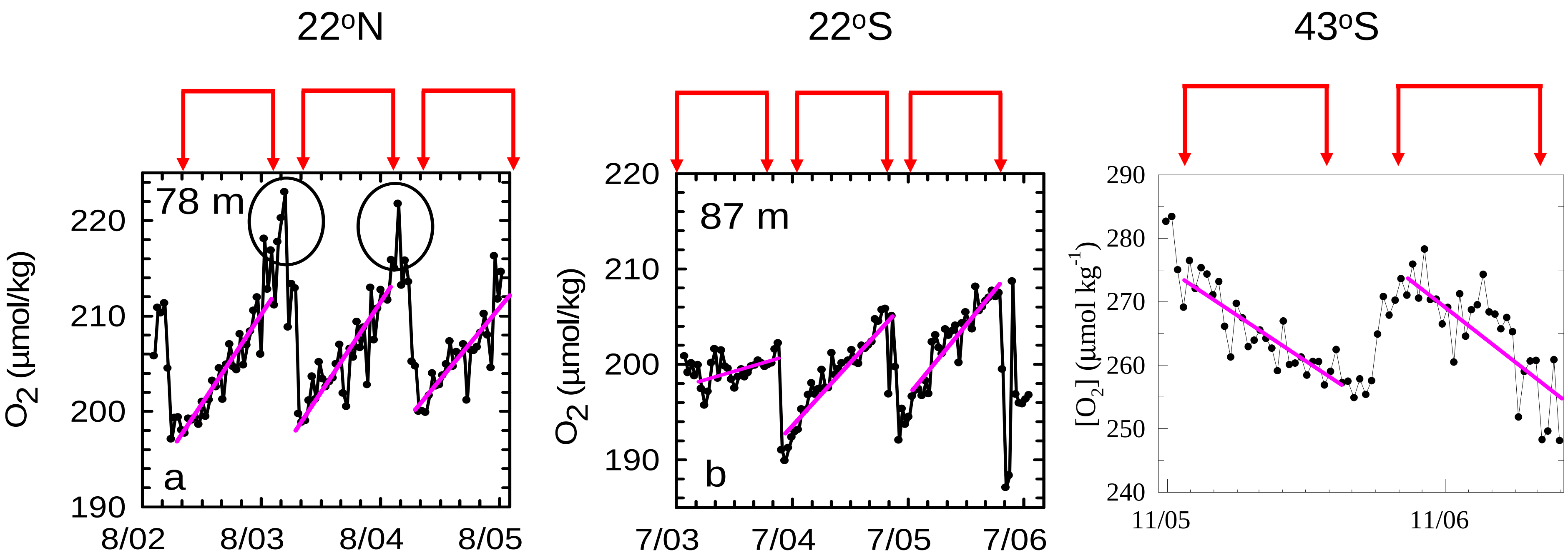
Seasonal observations O_2



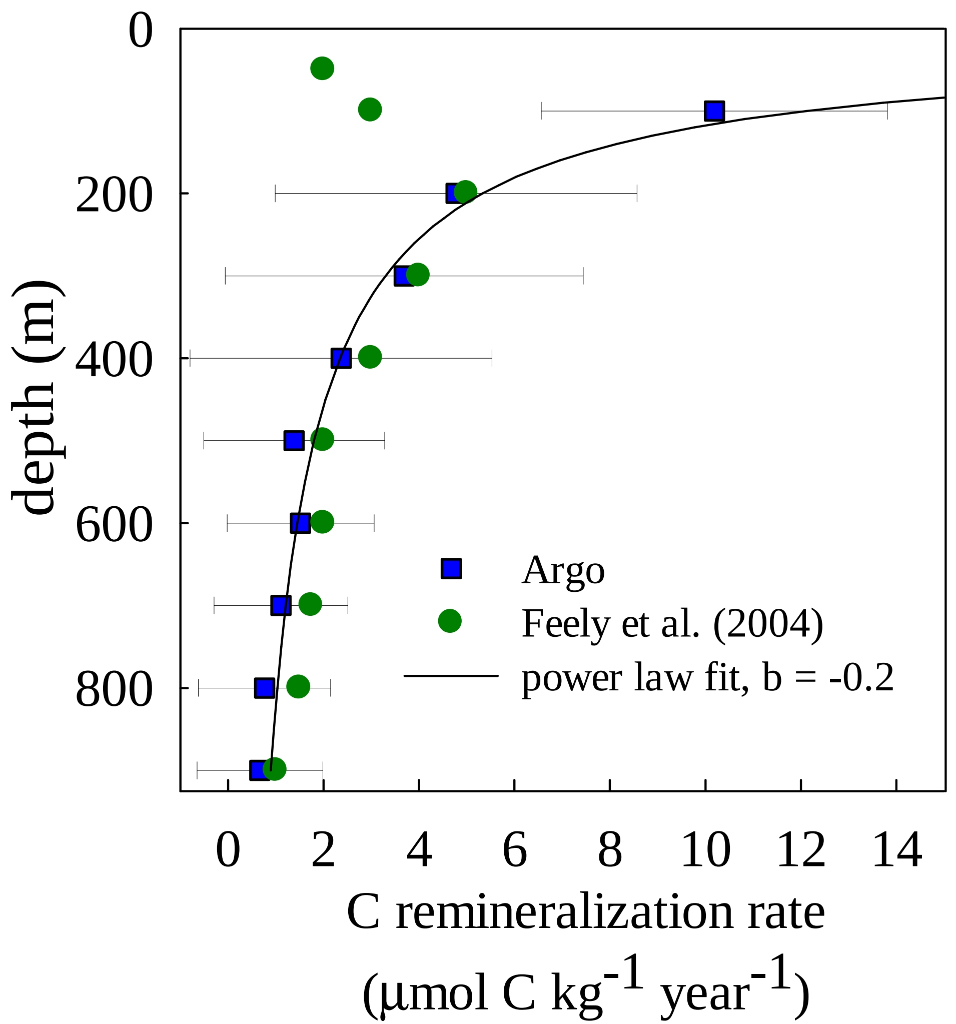
Low latitude NCP partially observed (Riser & Johnson, 2008)

High latitude EP partially observed (Martz, Riser & Johnson, 2008)

- Annual pattern changes with latitude
- Observe some NCP at low latitude
- Observe some EP at high latitude



Remineralization rates at 43ºS



Derivative of the particle flux attenuation function

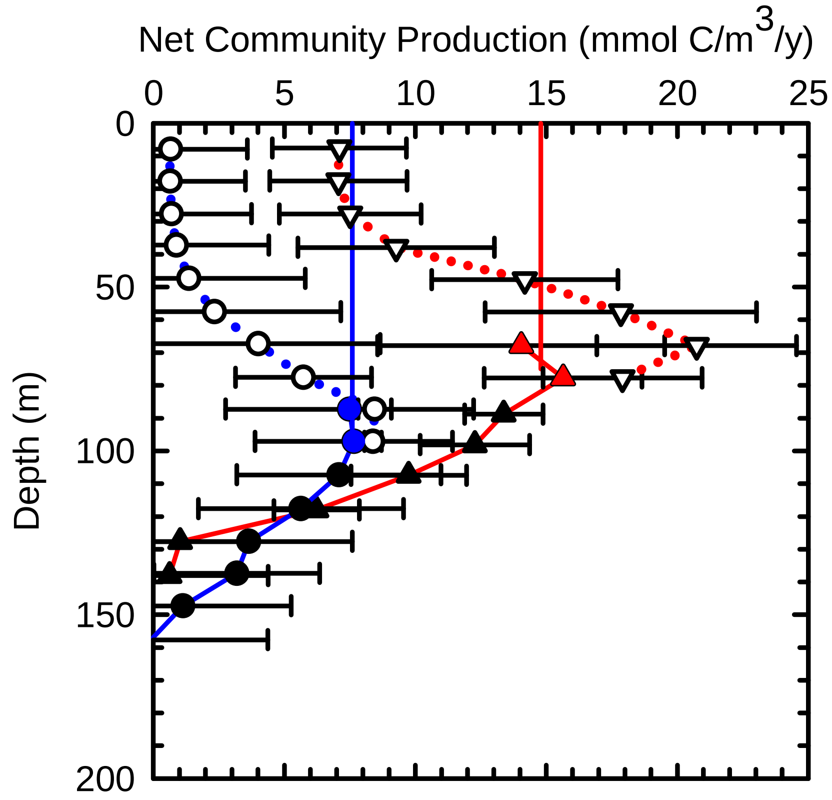
$$R_z \approx \frac{\partial F}{\partial z} = R_{100}\left(\frac{z}{100}\right)^{b-1}$$

Martin et al. (1987)

Martin ‘b’ exponent found using binned oxygen rates appears to be larger than trap-based values (usually -1.3 to -0.6).

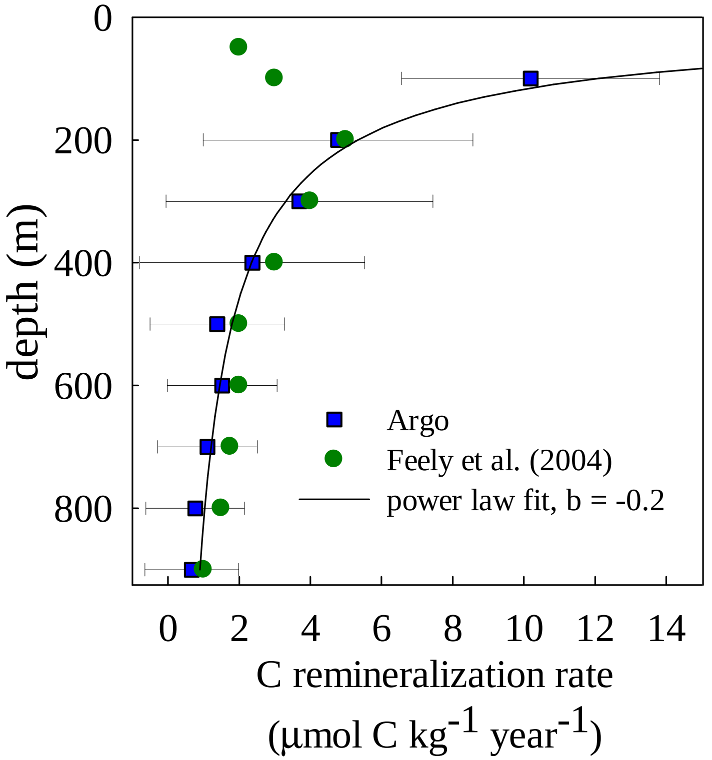
This can be reconciled by: oxygen gradients, trapping efficiency, active transport.

Summary of rates calculated



Low productivity STG

Intense SOM allows estimates of NCP above Z_c

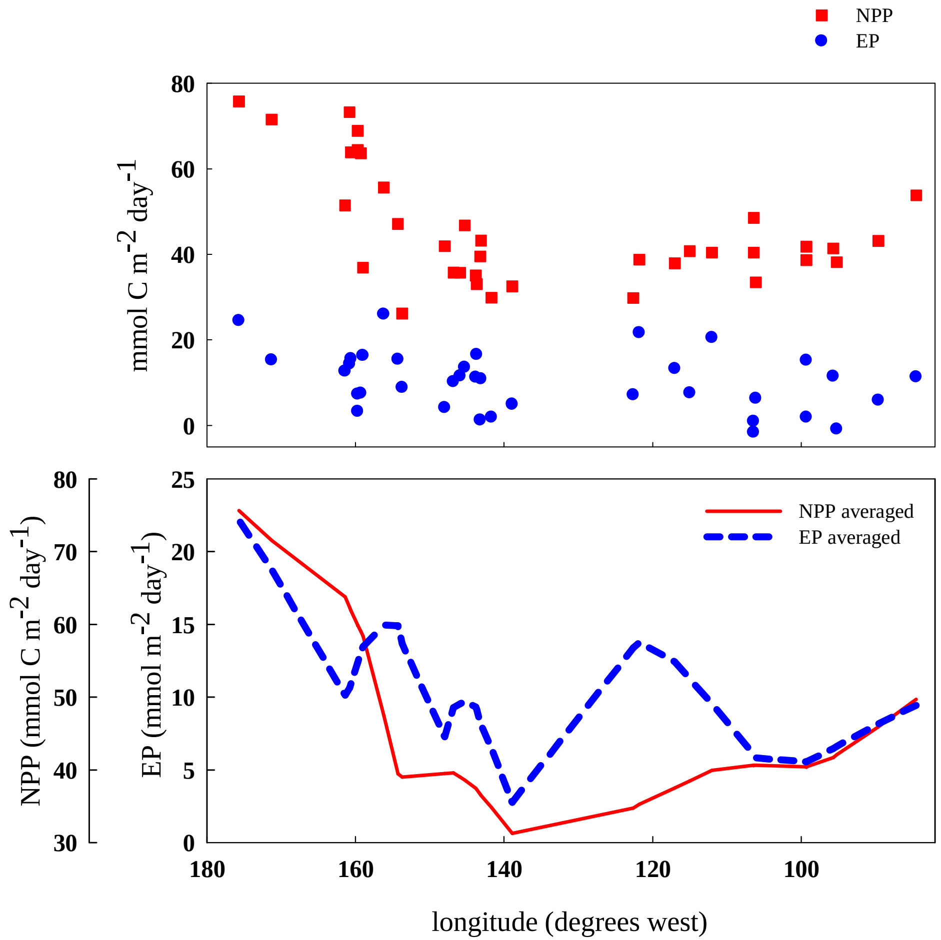


Higher productivity region (STF)

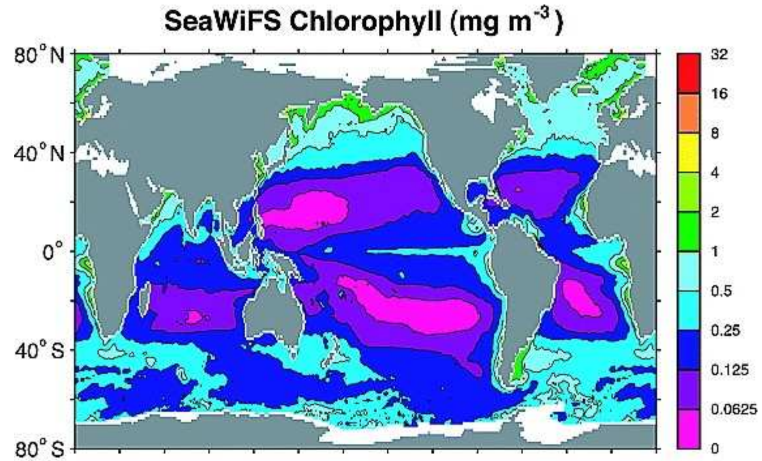
Substantial vertical export/transport of organic matter allows estimates of EP below Z_c

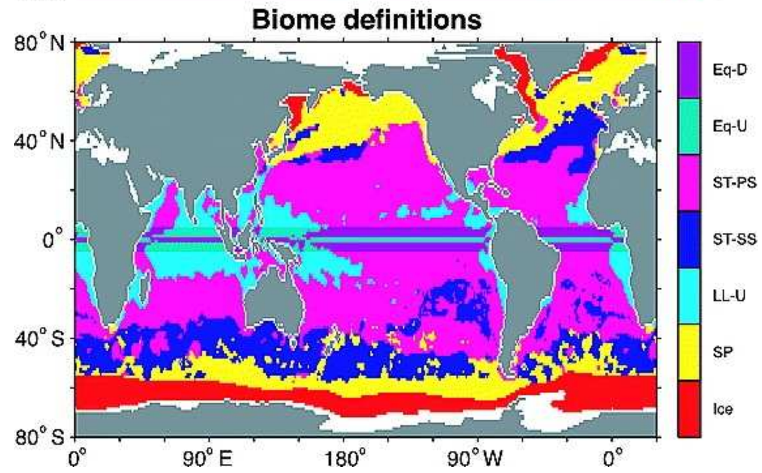
Spatial trends at 42ºS

Floats are located in a transition region between the permanently stratified, oligotrophic South Pacific subtropical gyre and the seasonally stratified, mesotrophic South Pacific



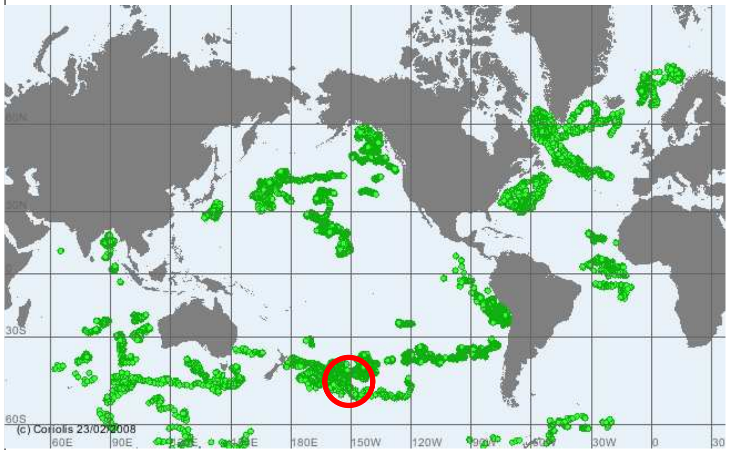
Sarmiento, J. L.; R. Slater, R. Barber, L. Bopp, S. C. Doney, A. C. Hirst, J. Kleypas, R. Matear, U. Mikolajewicz, P. Monfray, V. Soldatov, S. A. Spall, and R. Stouffer. 2004. Response of ocean ecosystems to climate warming. Global Biogeochem. Cycles. **18**: GB3003, doi:10.1029/2003GB002134.

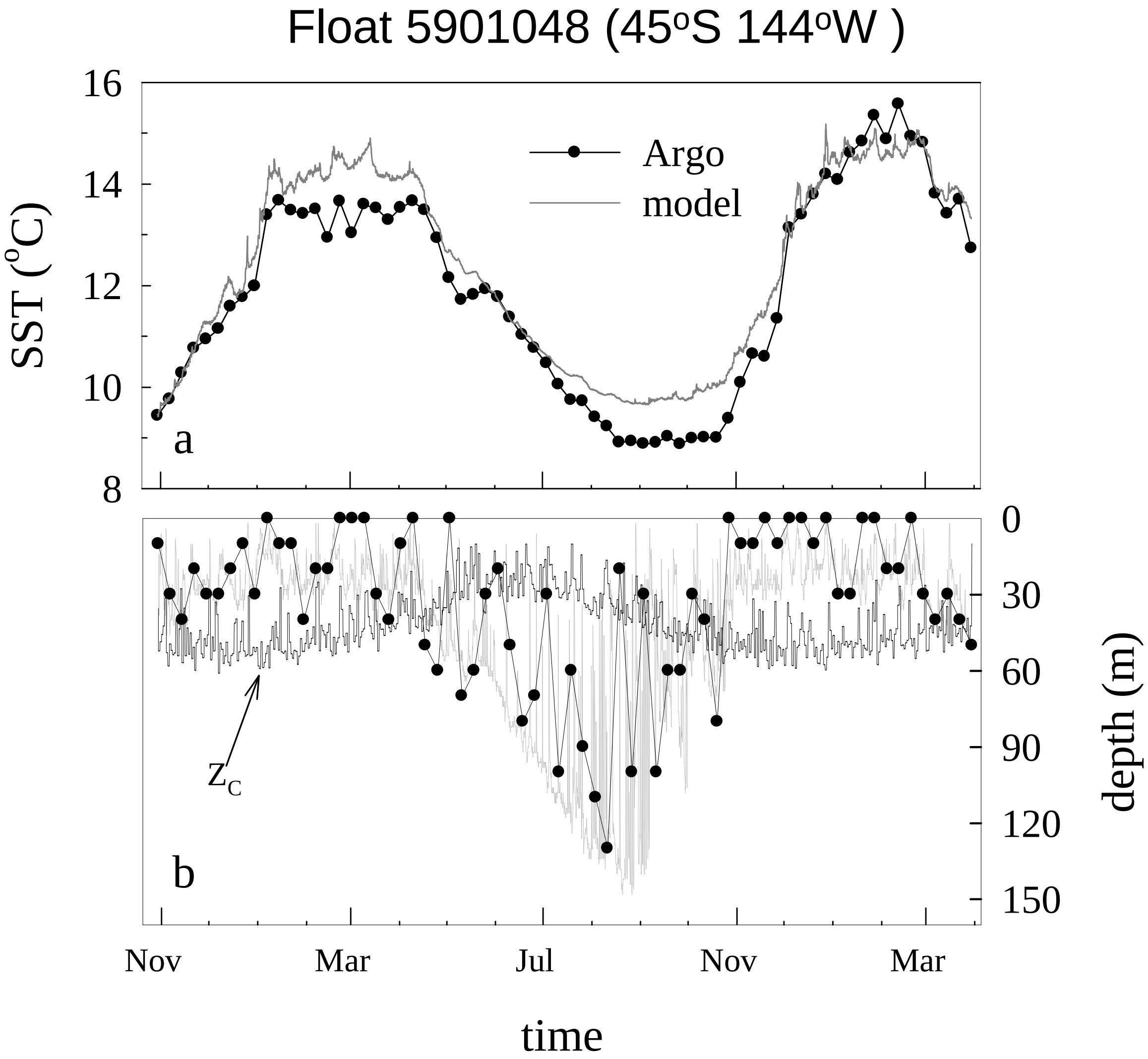




Pacific Profiling Float: Physical model

•PWP model of mixed layer physics with biology added (Musgrave et al., 1988).
•NCP constrained by measured data (model solves for NCP using a least squares fit).





•PWP does a reasonable job of reproducing the annual temperature and mixed layer depth

•Compensation depth, Z_c, is calculated from the I_c of Siegel et al. (2002) and the incident radiation from NCEP

Float 1D Model

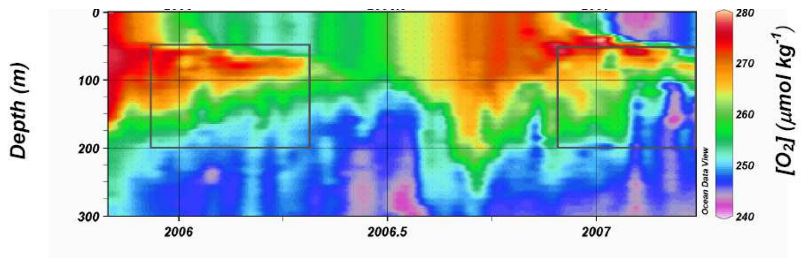
Model NCP = 2.1 mol C m^{-2} yr^{-1}

$EP_{50\text{-}900}$ for float 5901048:

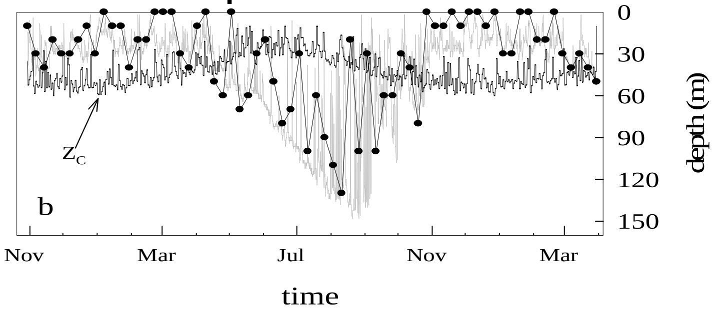
year 1 = 2.0 mol C m^{-2} yr^{-1}

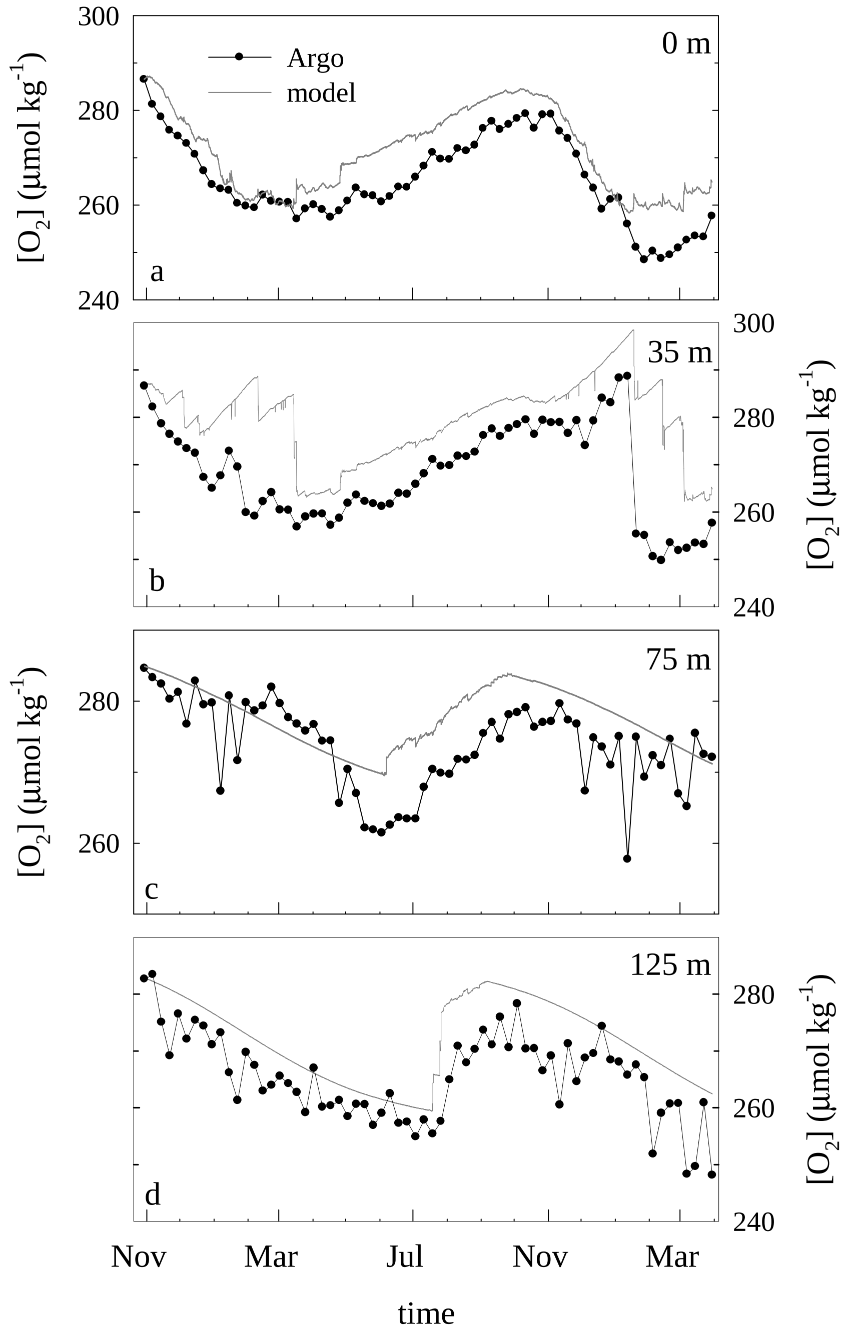
year 2 = 3.0 mol C m^{-2} yr^{-1})

Model explains erosion of SOM due to MLD-Zc proximity

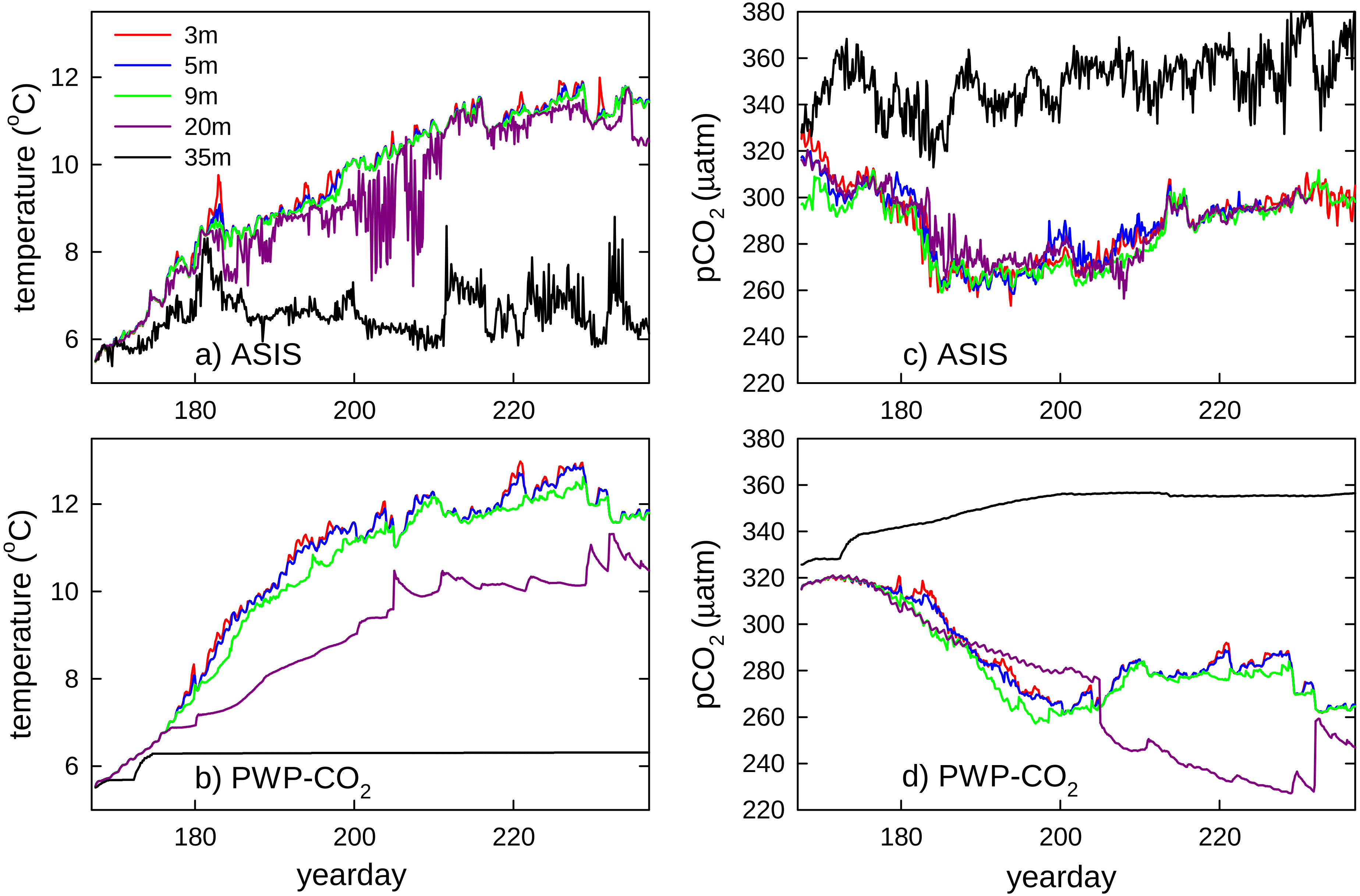


Consumption zone SOM





PWP model adapted to CO_2 for Labrador Sea ASIS



What Next?

$$CO_2 + NO_3 + PO_4 + H_2O = Org + O_2$$

ISFET ISUS

Expect: Increased number of optical and chemical (O_2, NO_3^-, pH) sensors on floats and other autonomous platforms.

What should be done?

-Quality control of chemical data at Argo data centers is not currently supported…

-Modelers need to begin thinking about integrating float data into regional models.

-Sensor developers need to continue to improve sensor performance.