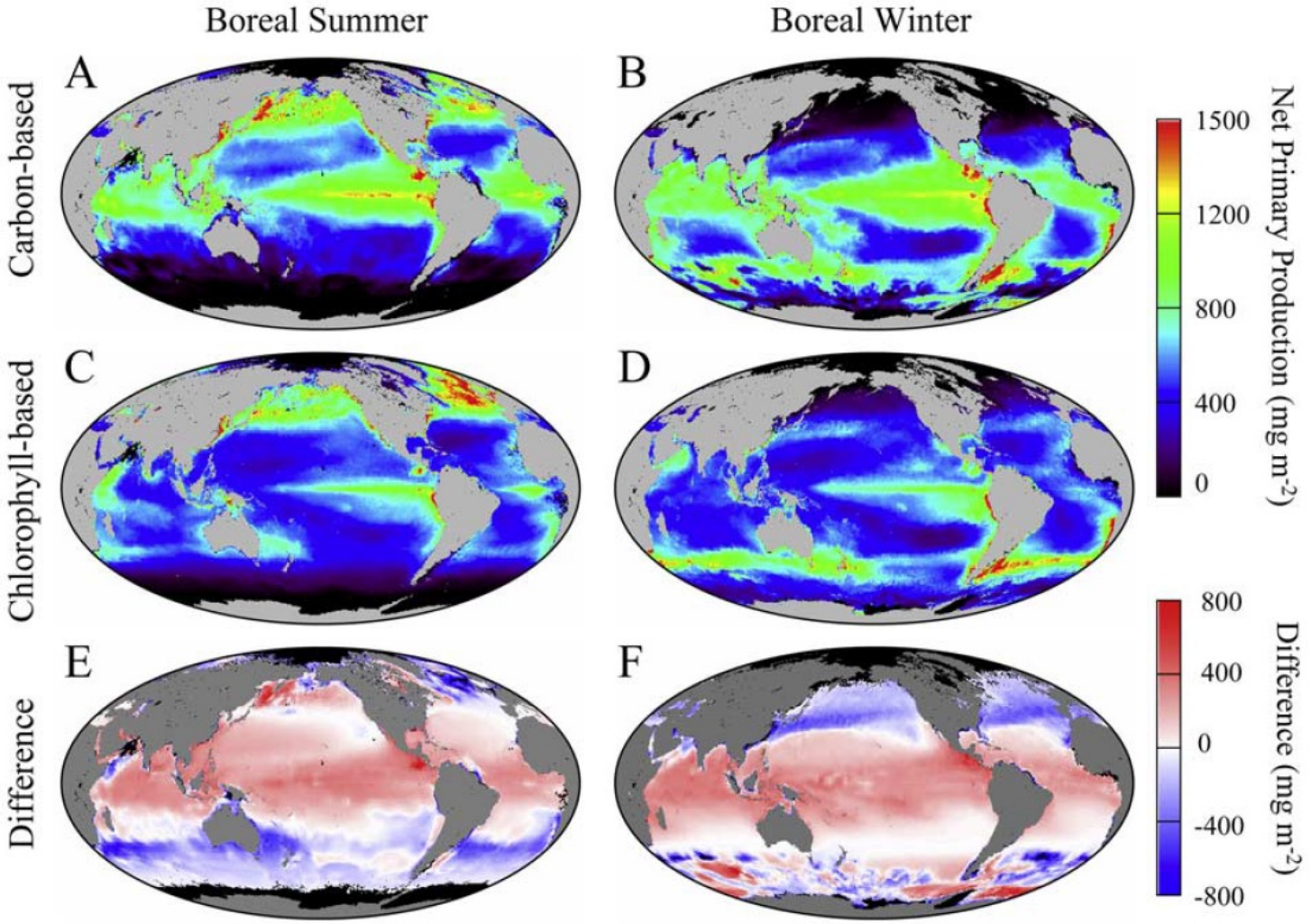
Quantification of the biological pump and nutrient export

- Complete annual cycles
- Global scale

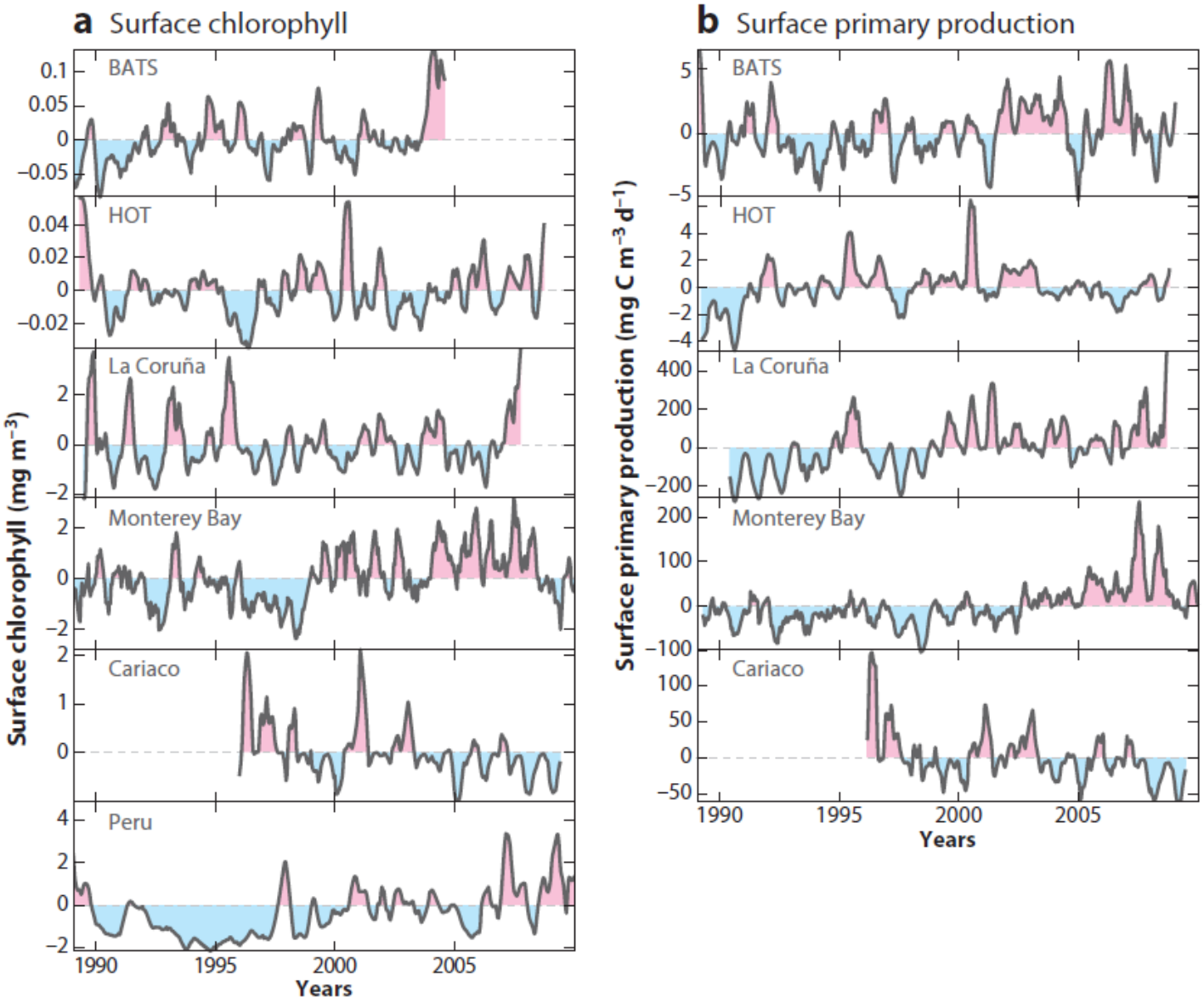
Ken Johnson
MBARI

why not satellite primary production???

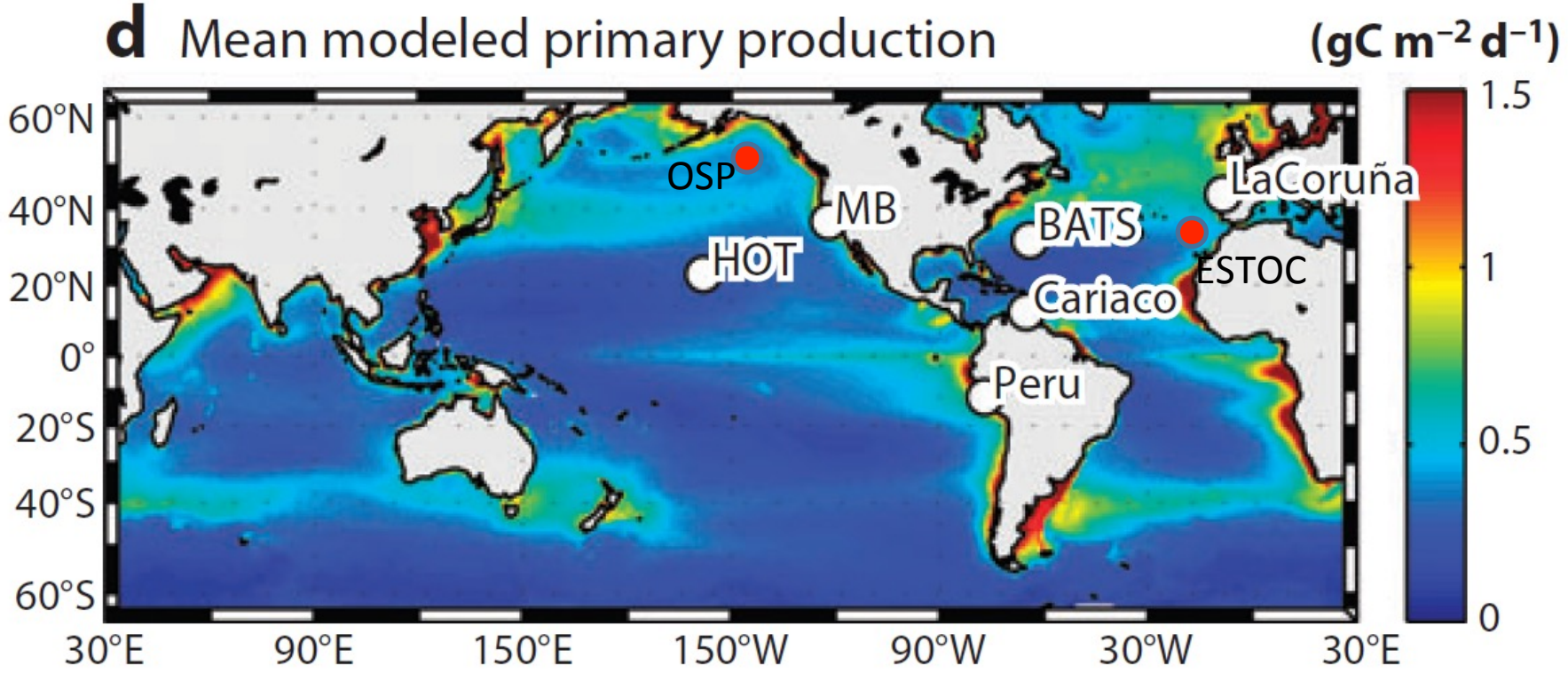
- Pri. Prod. is a rate and there is nothing in the satellite observations that are rate measurements.



Shipboard time series can nicely resolve annual cycles:



But shipboard time series don't scale to the globe.



Marine Primary Production in Relation to Climate Variability and Change

Francisco P. Chavez, Monique Messié, and J. Timothy Pennington

Annu. Rev. Mar. Sci. 2011. 3:227–60

Limnol. Oceanogr., 46(6), 2001, 1287–1297

Global net community production estimated from the annual cycle of surface water total dissolved inorganic carbon

Kitack Lee[1]

Cannot detect inter-annual variability.

Data very (very) sparse in winter.

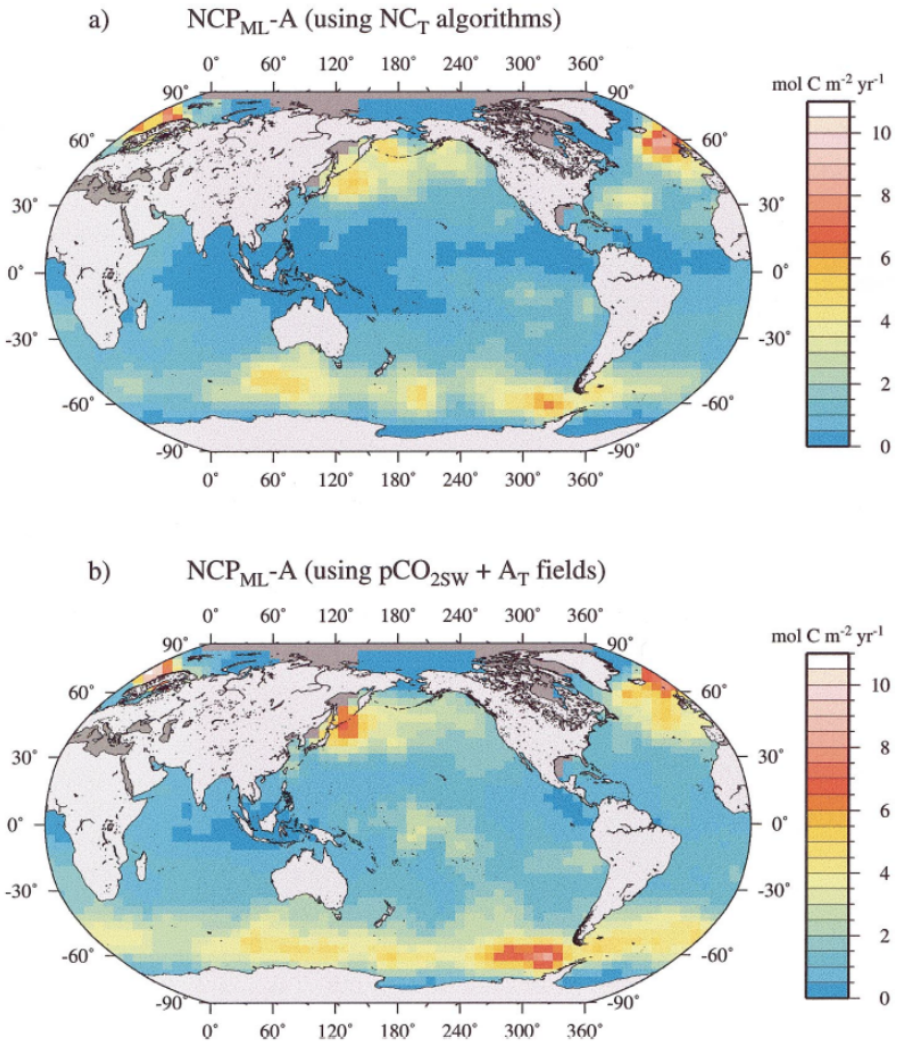


Fig. 3. Annual rates of net community production integrated from the surface to the base of the mixed layer as derived from the cumulative NC_T decrease that is calculated from (a) regional NC_T/SST/NO_3^- algorithms along with seasonal mean SST and NO_3^- fields, and from (b) the pCO_{2SW} and A_T fields using thermodynamic relationships. Values are expressed as mol C m^{-2} yr^{-1}. Globally integrated net community production estimates for (a) and (b) are 9.1 (Lee-1) and 10.8 Gt C yr^{-1} (Lee-2), respectively. Global records of seasonal mean mixed layer depth are interpolated to a 4° × 5° gird cell to match with the grid size used in the pCO_{2SW} climatology.

PERGAMON

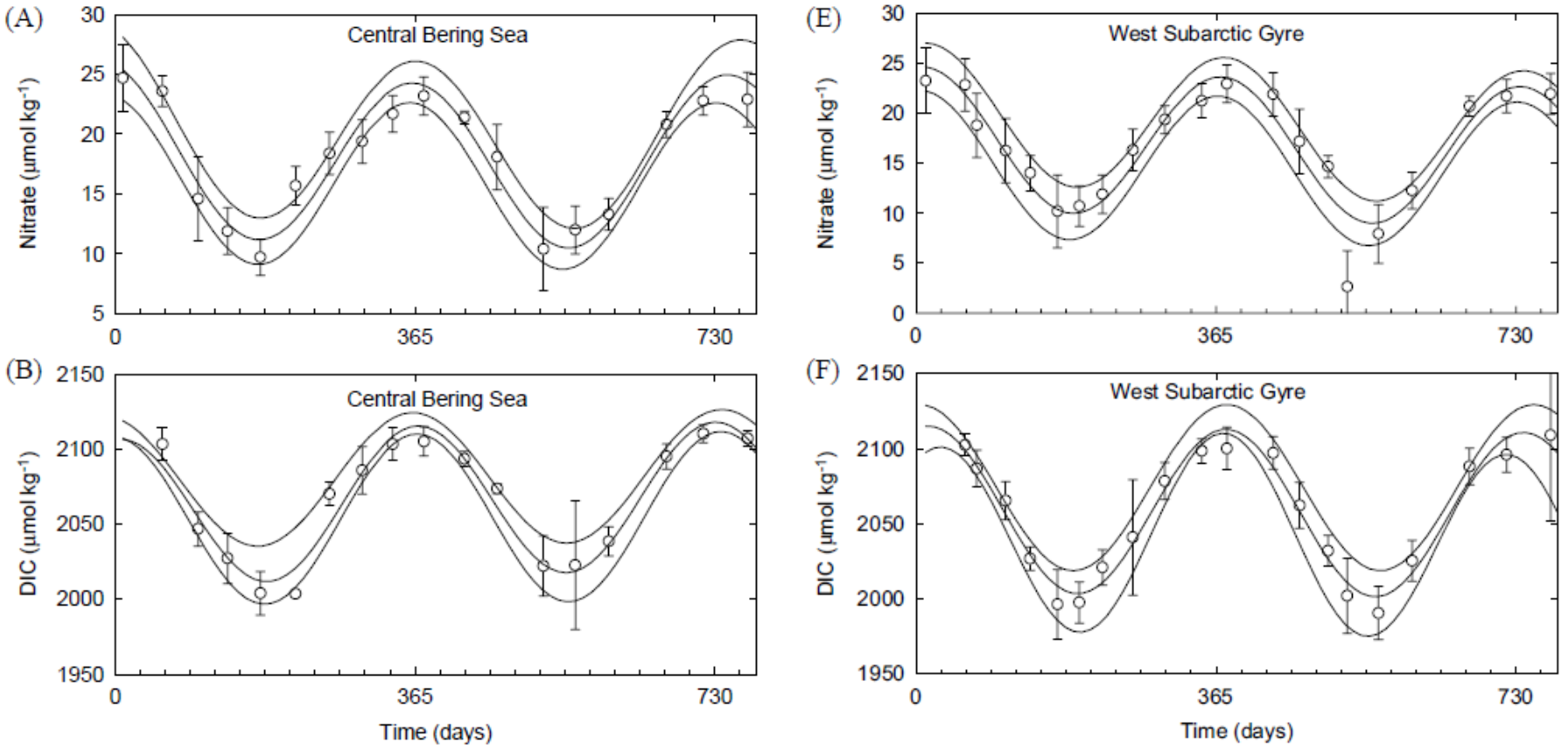
Deep-Sea Research II 49 (2002) 5317–5338

www.elsevier.com/locate/dsr2

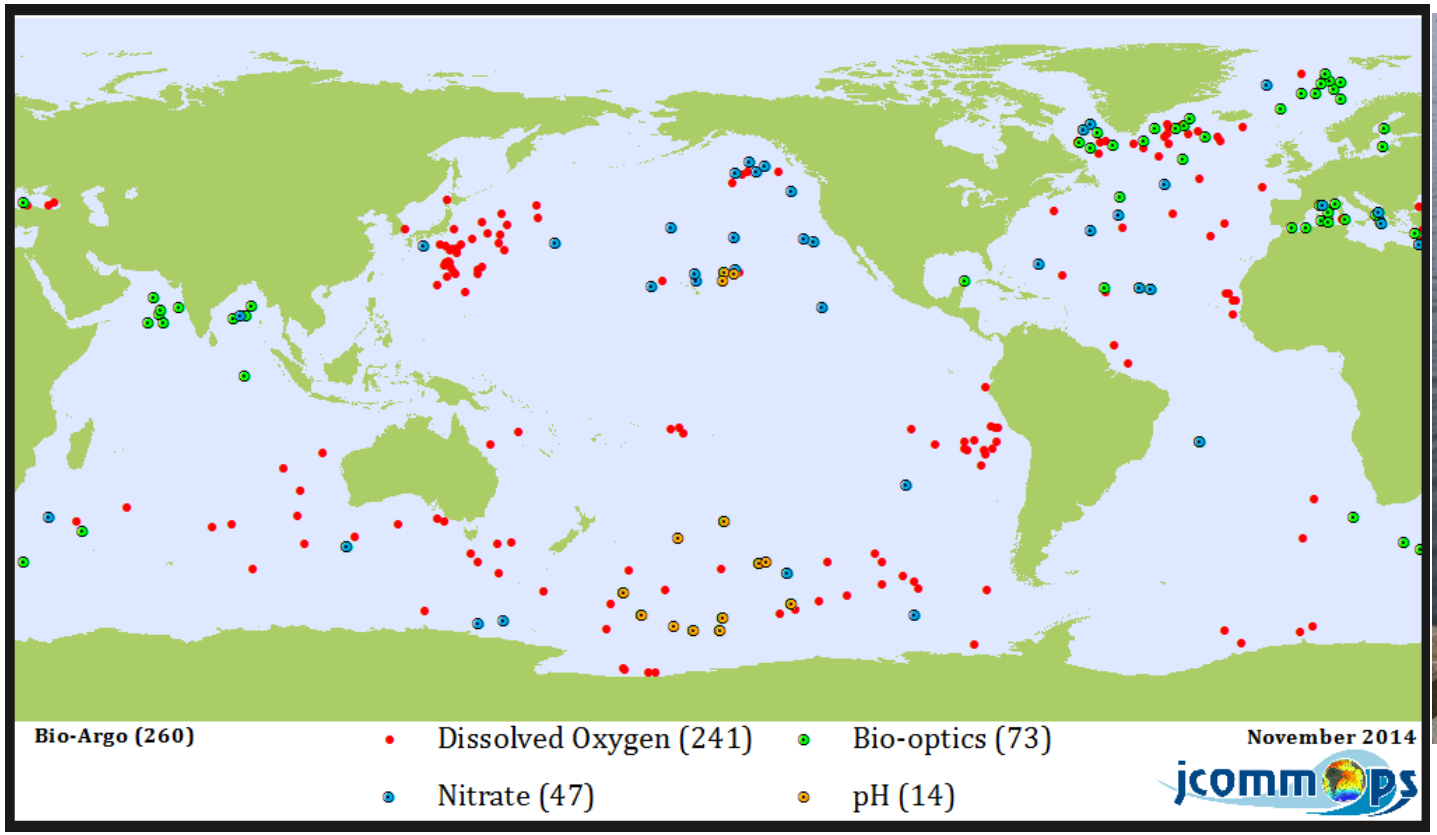
Seasonal cycles of nutrients and dissolved inorganic carbon at high and mid latitudes in the North Pacific Ocean during the *Skaugran* cruises: determination of new production and nutrient uptake ratios

C.S. Wong[a,*], N.A.D. Waser[b], Y. Nojiri[c], F.A. Whitney[a], J.S. Page[a], J. Zeng[d]

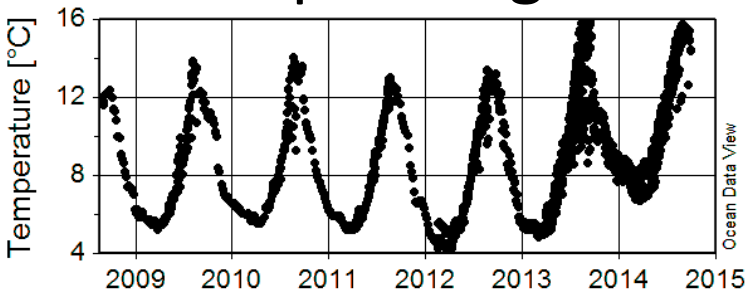
Volunteer Observing Ships: Super, but don't resolve depth, not quite global. Relatively expensive.

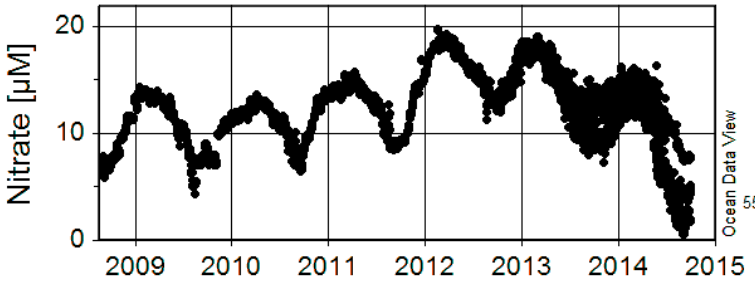


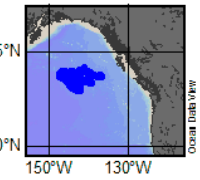
Profiling floats with chemical sensors:
A global, biogeochemical Argo array is self-assembling.
Life cycle cost relatively low because little labor required for ~5 year lifetime after launch.

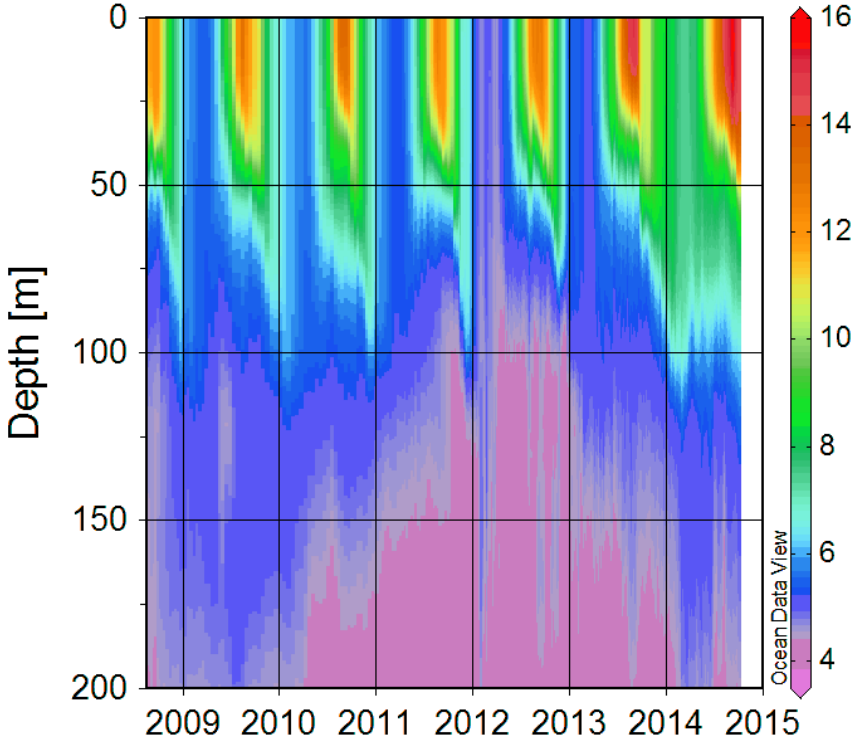


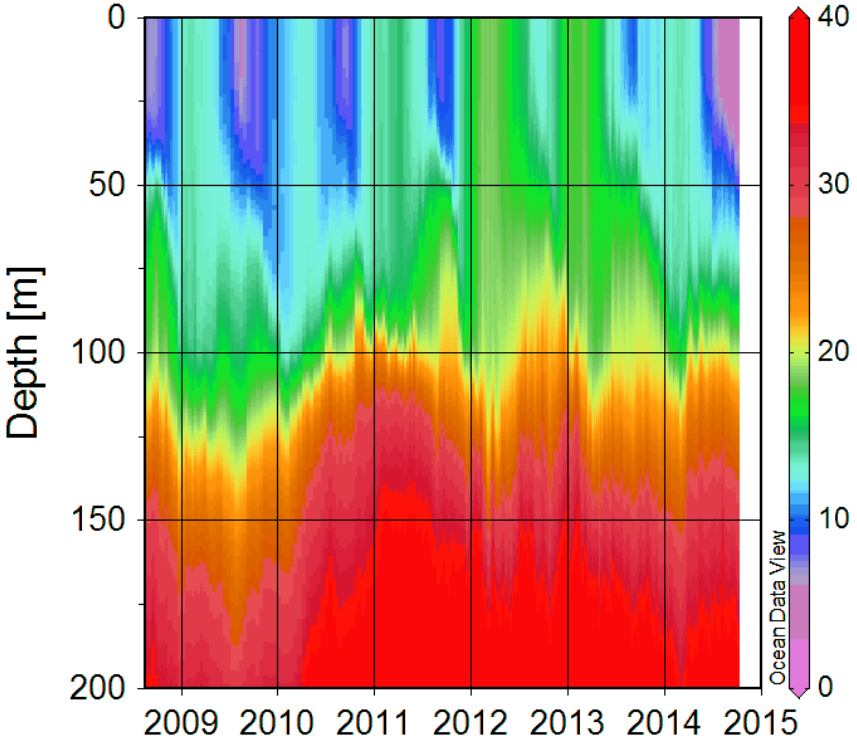
Six years of nitrate sensor data from UW/MBARI profiling floats at Ocean Station Papa











MBARI ISUS Nitrate Sensor (Johnson et al., 2013 JAOT)

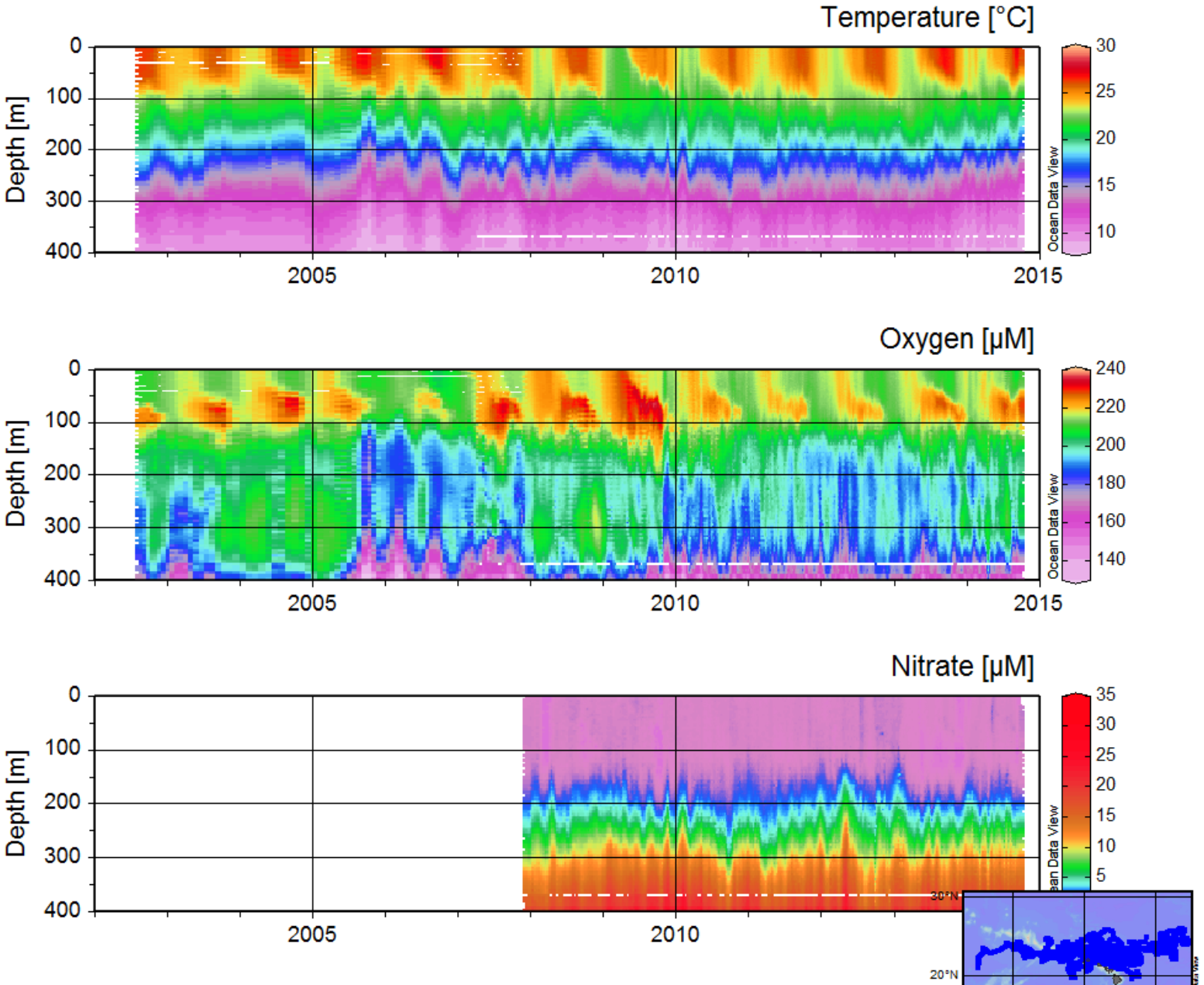
	Float Nitrate based NCP at OSP					
	2009	2010	2011	2012	2013	
	mol C/m2/y					
	2.1	0.8	1.3	1.2	3.6	
				1.2	3.0	
					3.2	
Mean	2.1	0.8	1.3	1.2	3.3	2.1
SD						1.1

Emerson et al (2008) OSP mean 2.3 mol C/m2/y

NCP = Net Community Production = Primary Production – Respiration at all Trophic Levels

A 12 year record of oxygen from profiling floats near Hawaii.
100's now deployed globally (UW & UW/MBARI floats).

Riser & Johnson, Nature 2008; Johnson et al., Nature 2010



Deep-Sea Research I 57 (2010) 1255–1265

Contents lists available at ScienceDirect

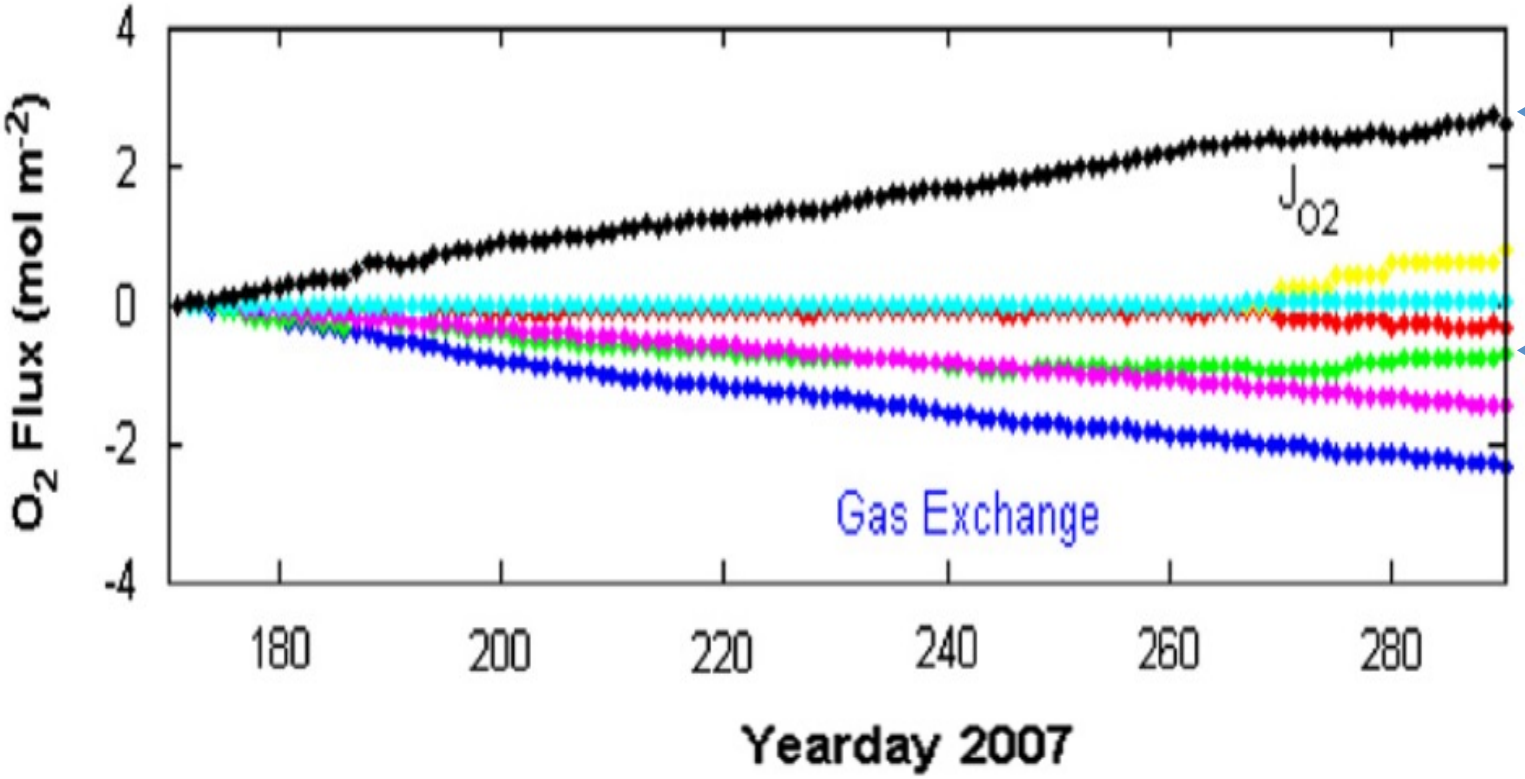
Deep-Sea Research I

journal homepage: www.elsevier.com/locate/dsri

Net biological oxygen production in the ocean—II: Remote in situ measurements of O_2 and N_2 in subarctic pacific surface waters

Steven Emerson *, Charles Stump

A



3. Sum is the NCP

1. Measure this (dO_2/dt)

2. Estimate this

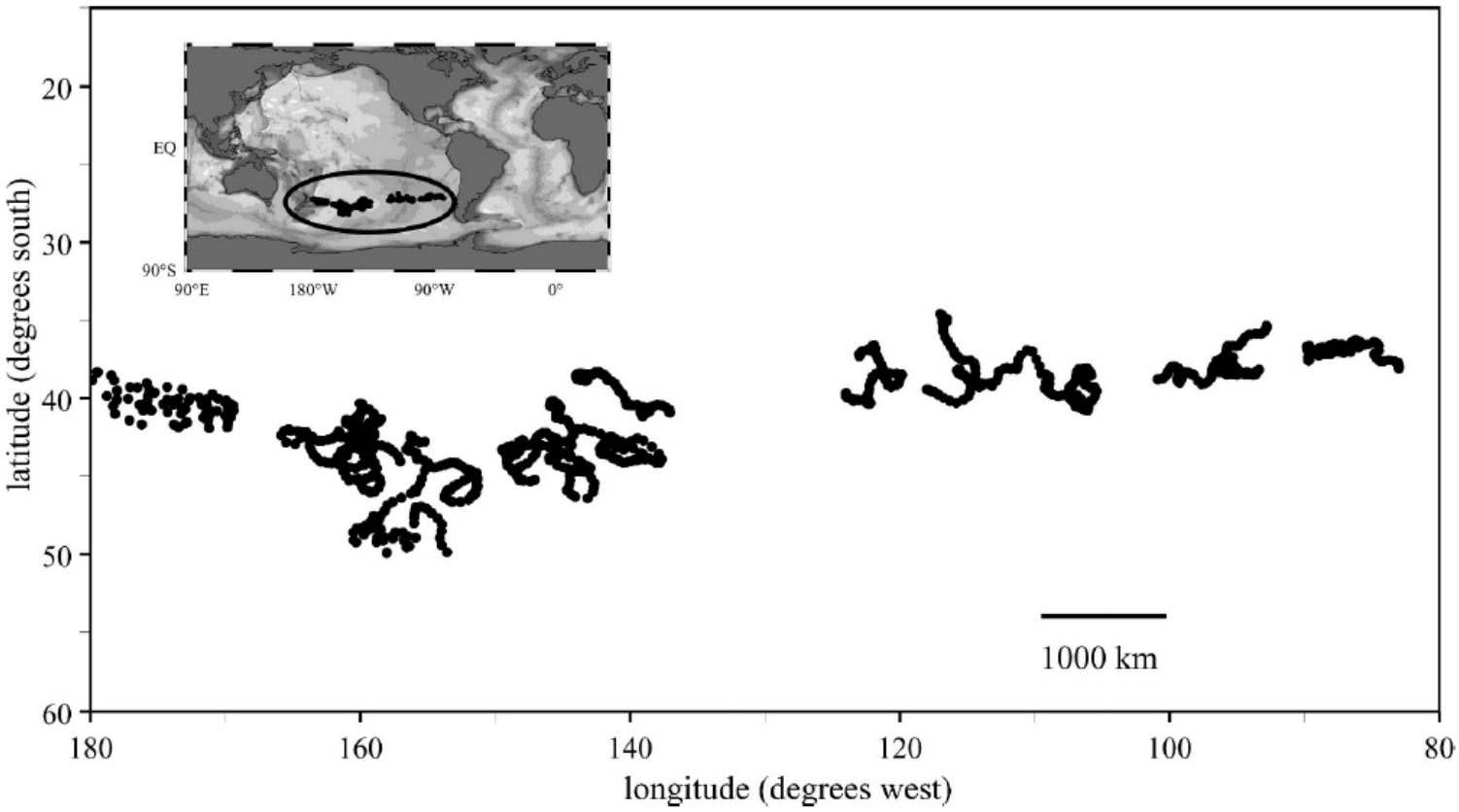
The sensor must be exquisitely well calibrated to get the Gas Exchange flux. Most aren't. BUT:

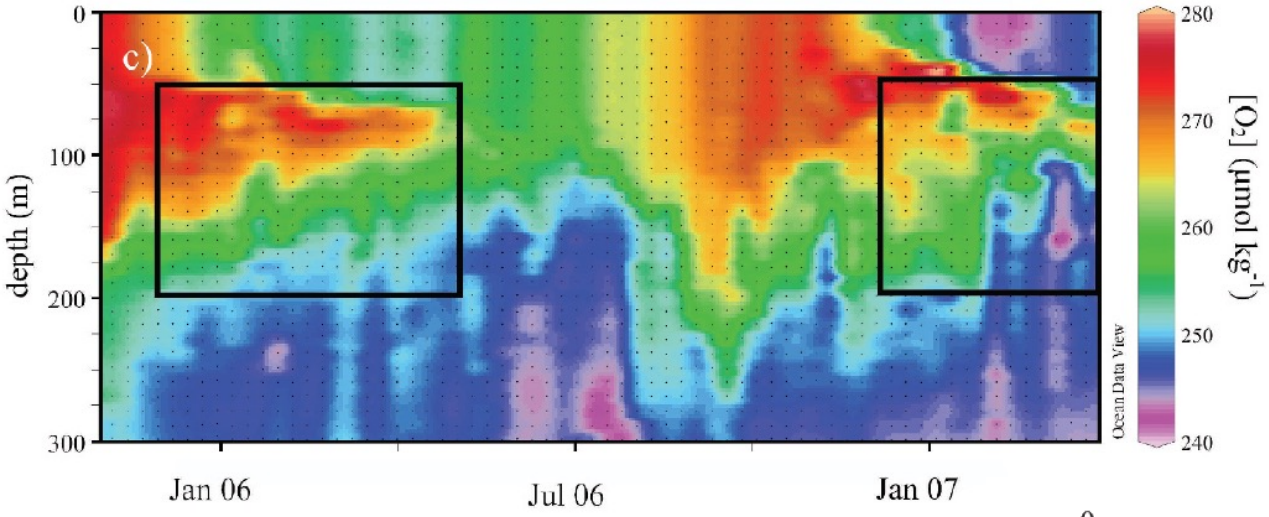
Limnol. Oceanogr., 53(5, part 2), 2008, 2094–2111

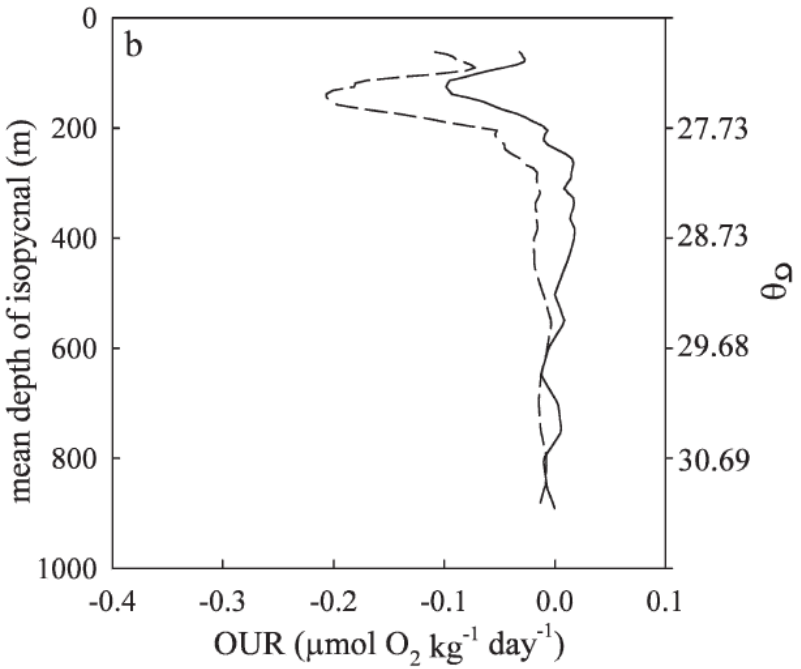
Ocean metabolism observed with oxygen sensors on profiling floats in the South Pacific

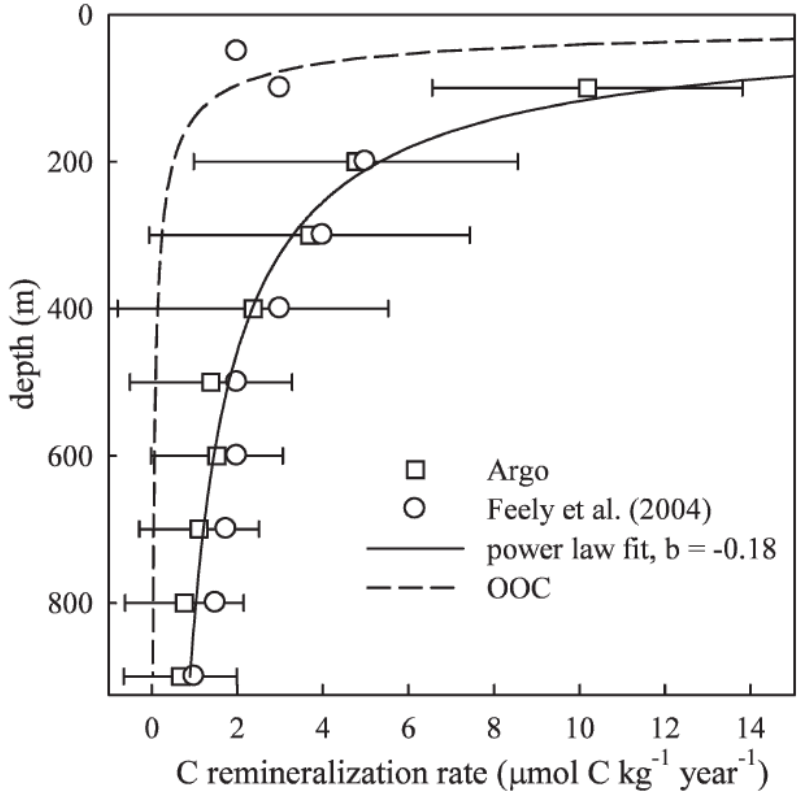
Todd R. Martz and Kenneth S. Johnson
Monterey Bay Aquarium Research Institute, Moss Landing, California 95039

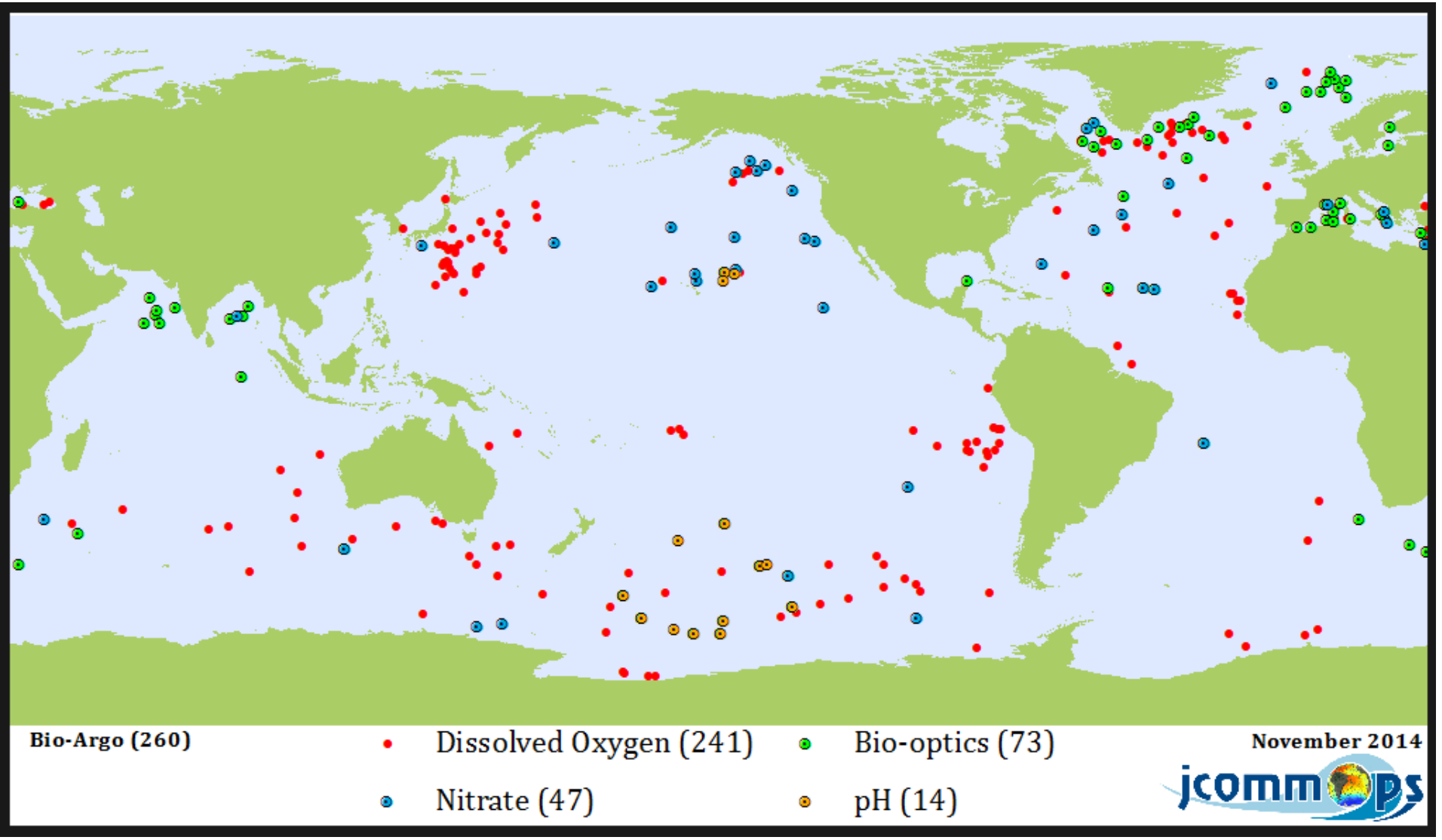
Stephen C. Riser
School of Oceanography, University of Washington, Seattle, Washington 98195

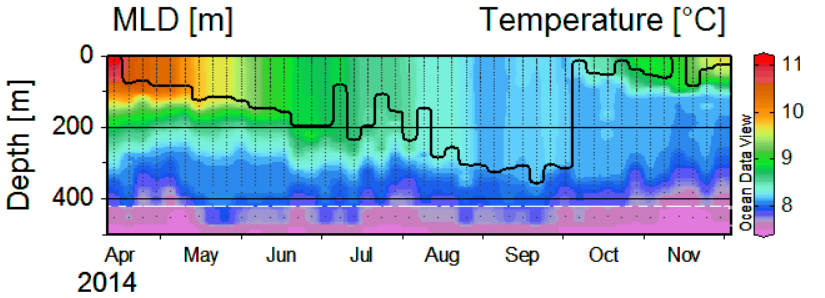


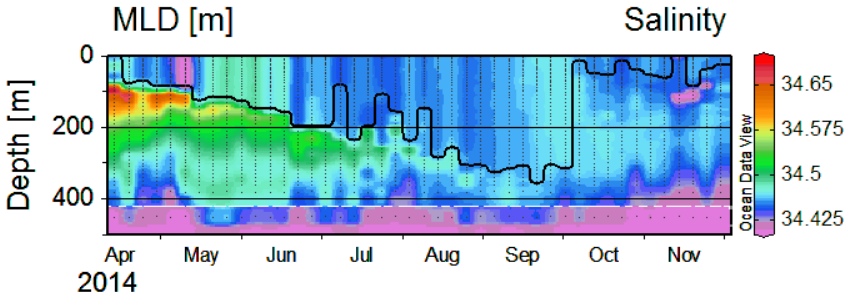

c)
depth (m)
0
100
200
300
Jan 06
Jul 06
Jan 07
280
270
260
250
240
[O2] (µmol kg-1)
Ocean Data View

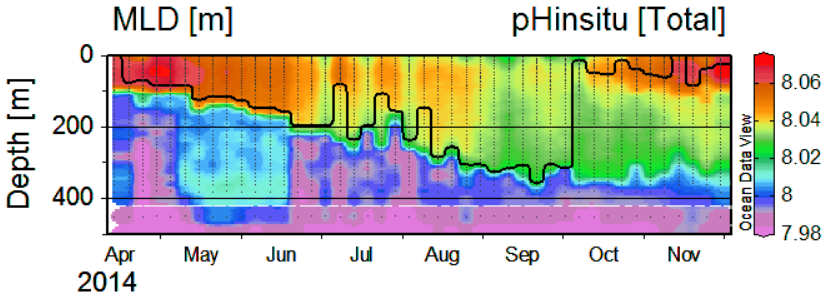

b
mean depth of isopycnal (m)
0
200
400
600
800
1000
27.73
28.73
29.68
30.69
σθ
-0.4
-0.3
-0.2
-0.1
0.0
0.1
OUR (µmol O2 kg-1 day-1)

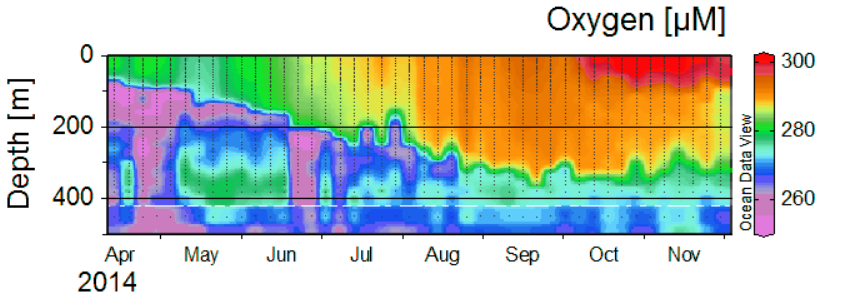

depth (m)
0
200
400
600
800
Argo
Feely et al. (2004)
power law fit, b = -0.18
OOC
0
2
4
6
8
10
12
14
C remineralization rate (µmol C kg-1 year-1)

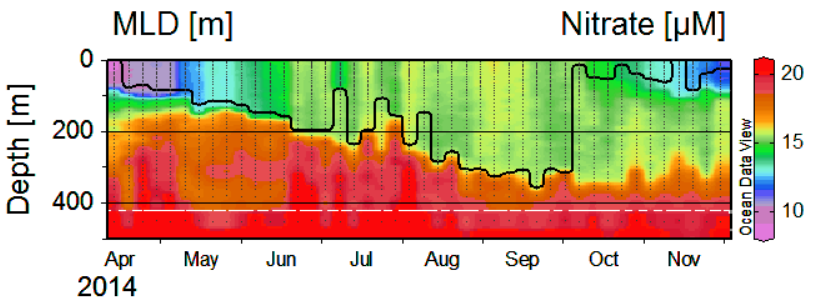

Bio-Argo (260)
Dissolved Oxygen (241)
Bio-optics (73)
Nitrate (47)
pH (14)
November 2014
jcommops

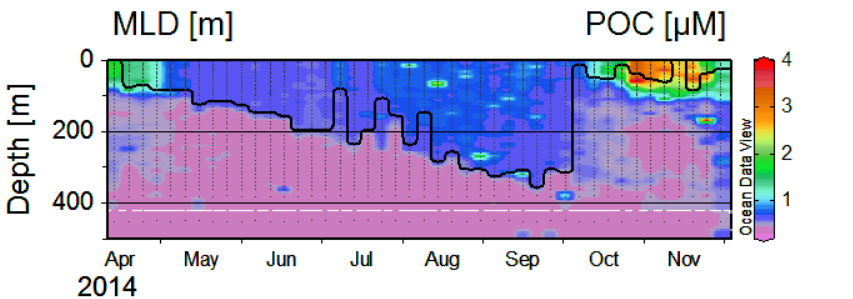


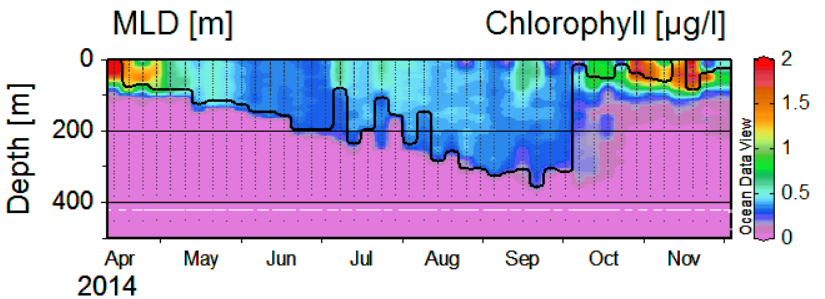


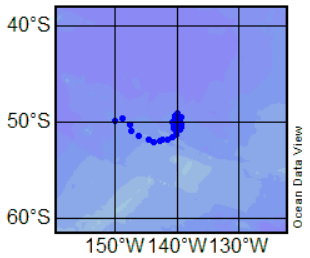






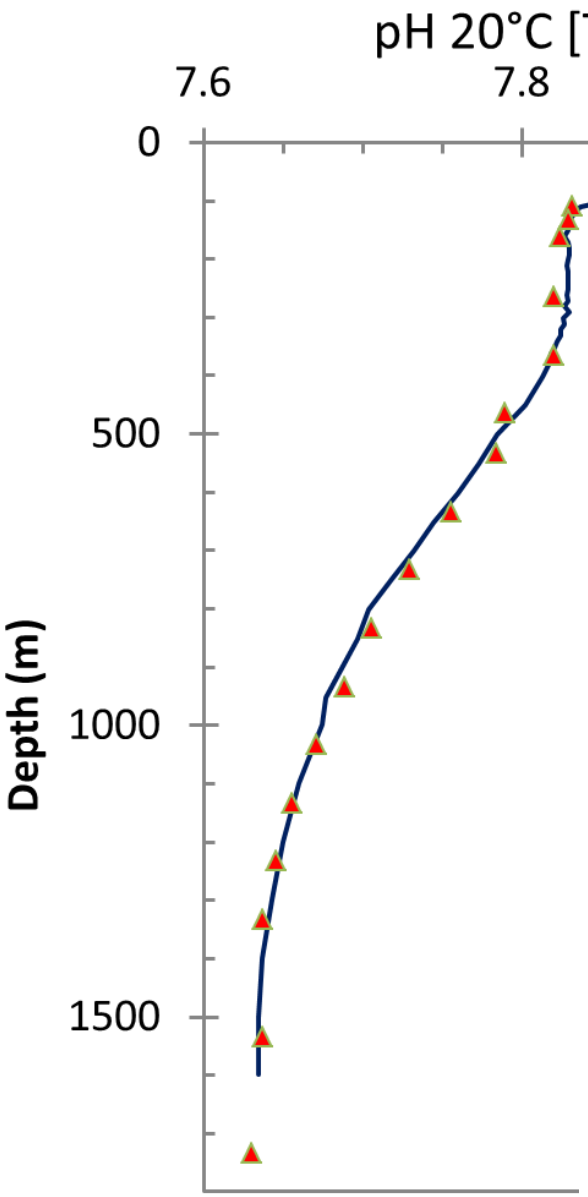


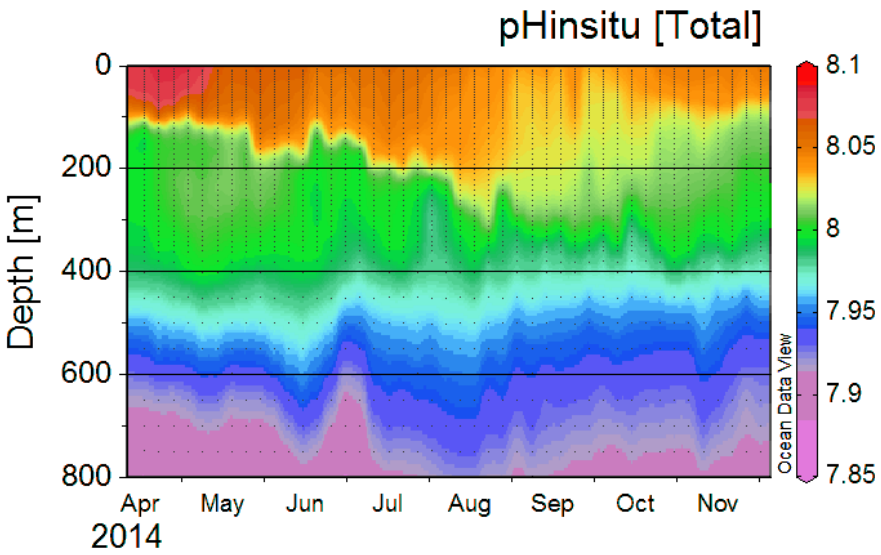


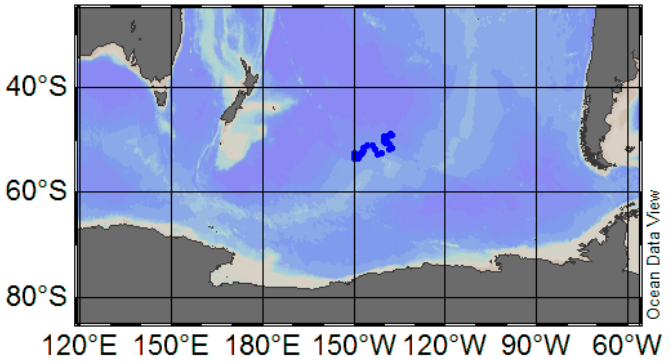


Float 9095

SOCCOM

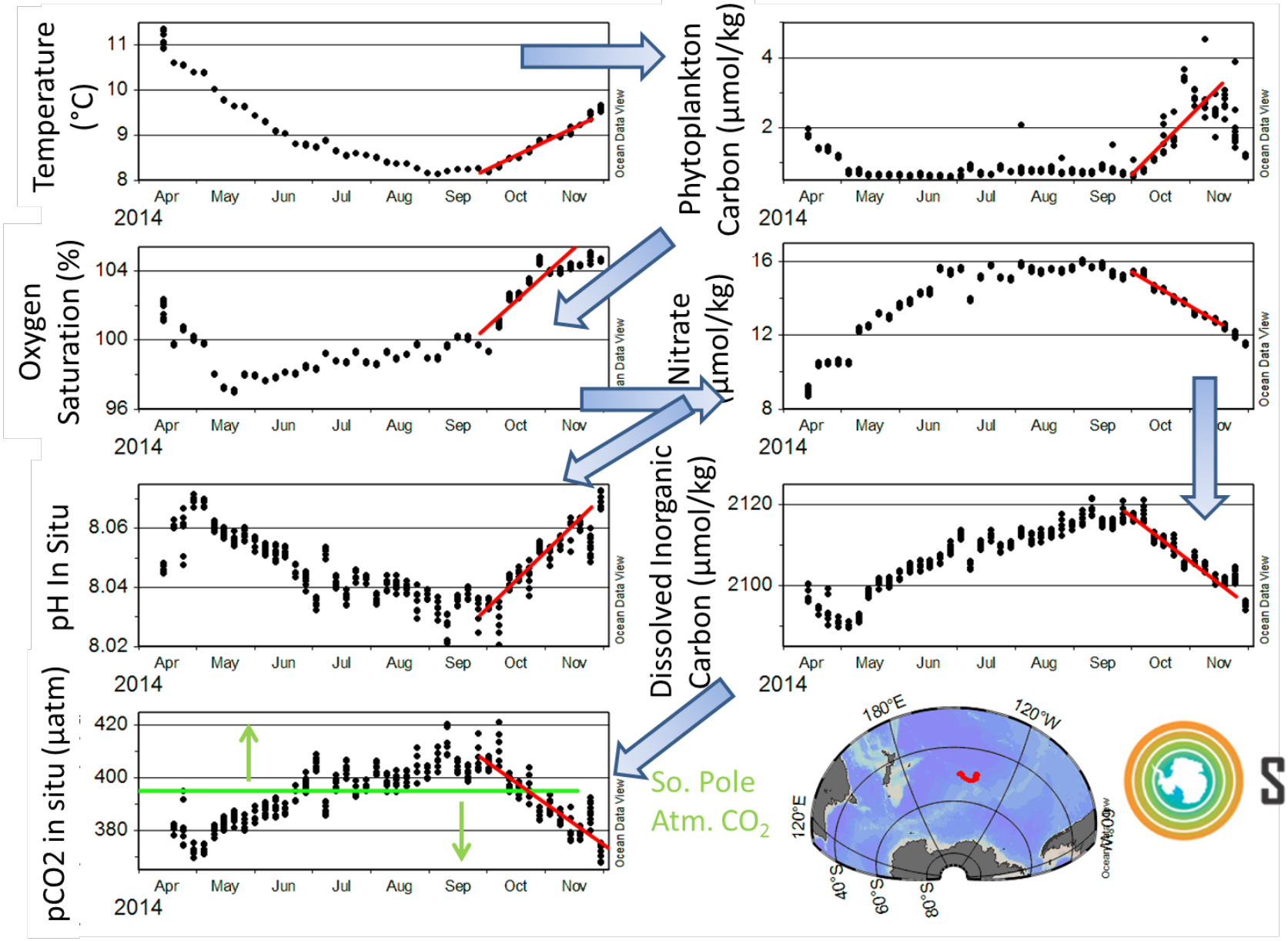

pH 20°C [Total]
7.6
7.8
8.0
0
500
1000
1500
Depth (m)


pHinsitu [Total]
0
200
400
600
800
Depth [m]
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2014
8.1
8.05
8
7.95
7.9
7.85
Ocean Data View

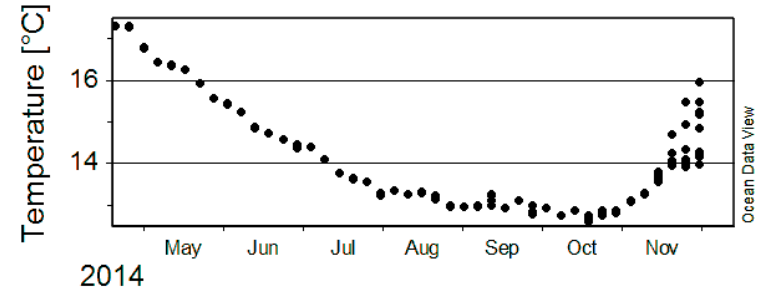

40°S
60°S
80°S
120°E
150°E
180°E
150°W
120°W
90°W
60°W
Ocean Data View

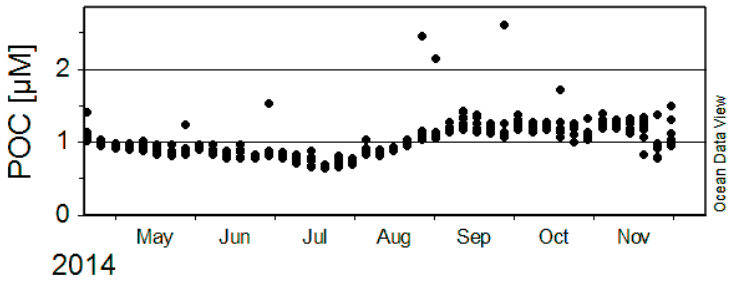
SOCCOM

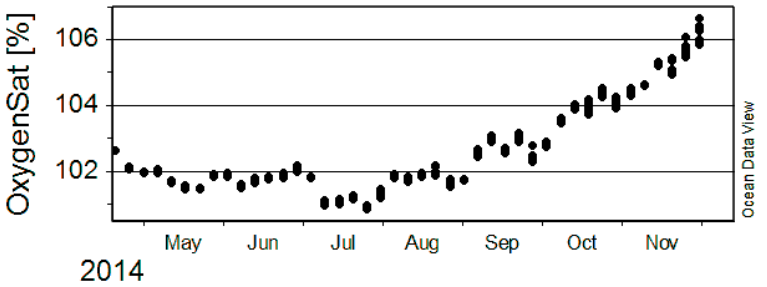
The spring bloom changes the ocean from a CO_2 source to the atmosphere in winter to a CO_2 sink (SOCCOM float 9095 50 South)

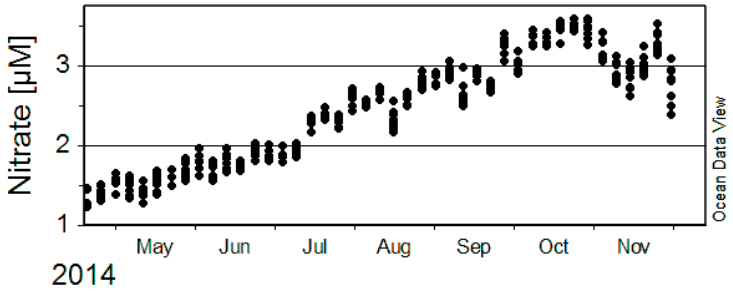


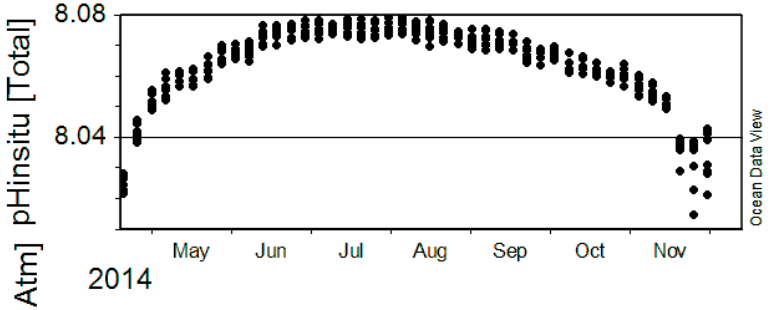
SOCCOM Float 9254 near 40 South

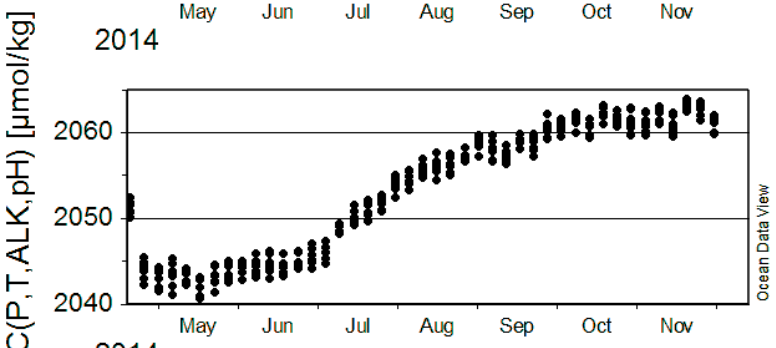


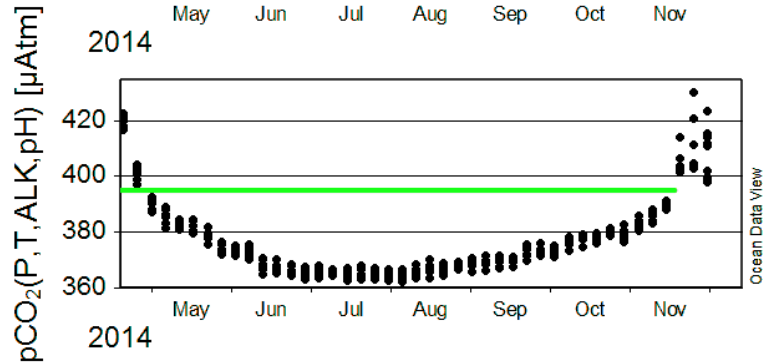


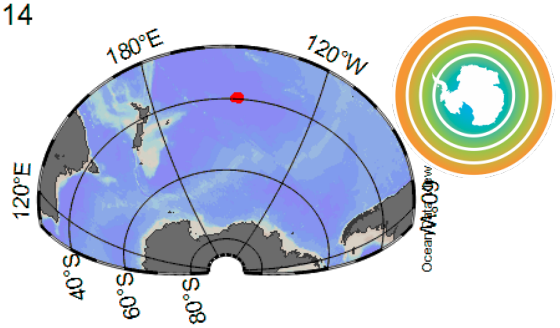












SOCCOM

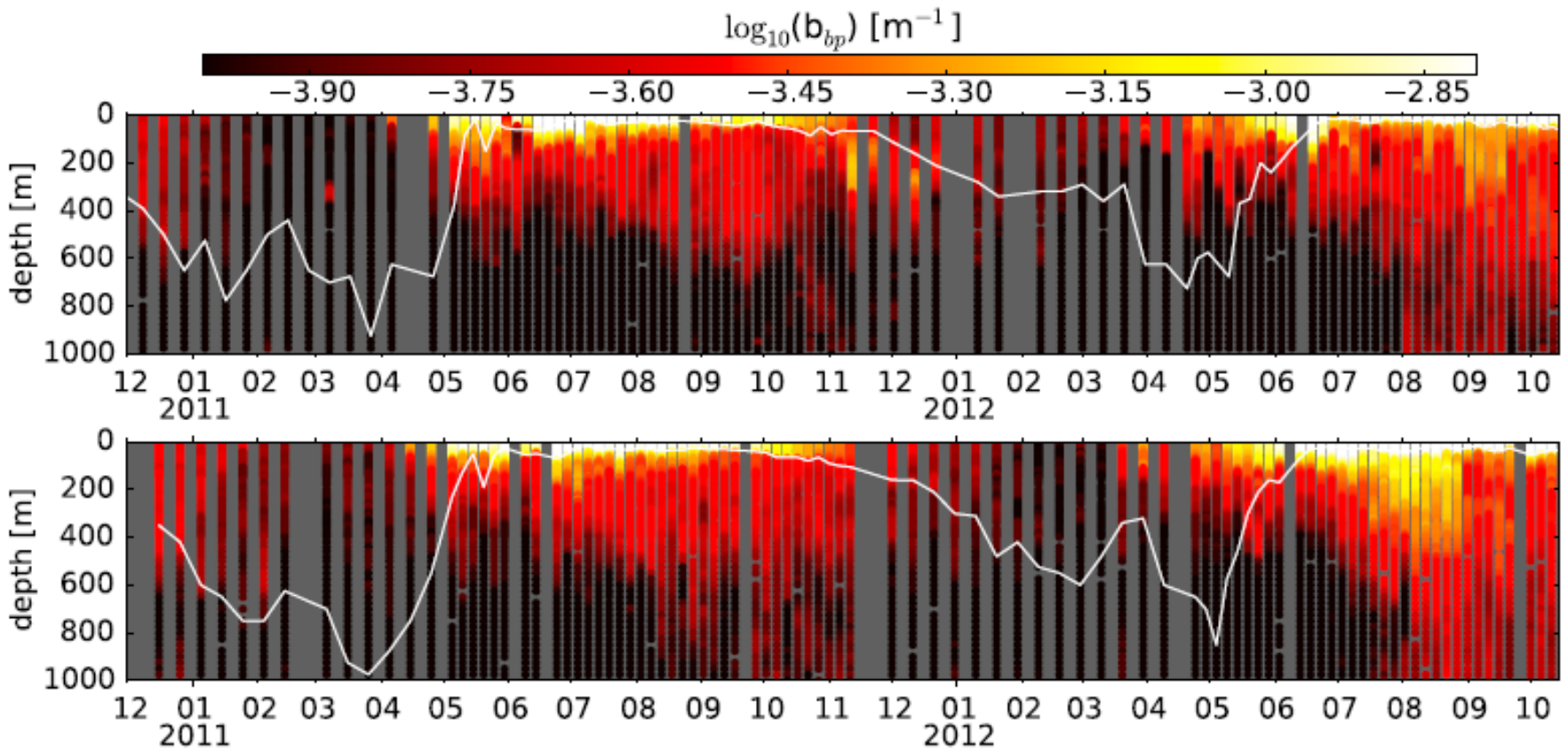
Geophysical Research Letters

RESEARCH LETTER

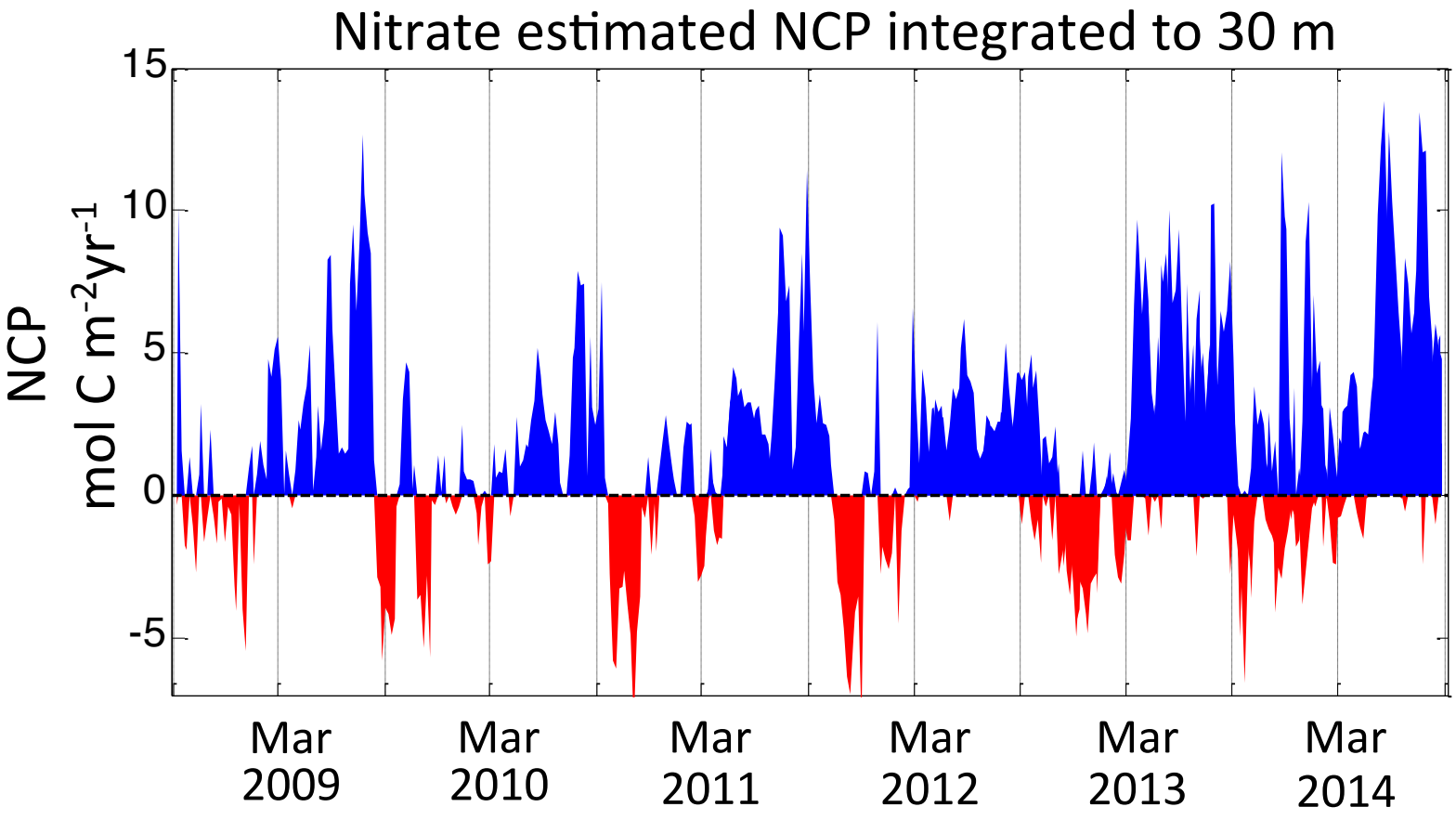
10.1002/2014GL059244

Carbon export by small particles in the Norwegian Sea

Giorgio Dall'Olmo[1,2] and Kjell Arne Mork[3,4]



Carbon export by small particles ~0.8 mol C/m2/y


Nitrate estimated NCP integrated to 30 m
NCP
mol C m-2yr-1
15
10
5
0
-5
Mar
2009
Mar
2010
Mar
2011
Mar
2012
Mar
2013
Mar
2014

The sensors easily resolve sub-mixed layer O_2 cycles and calibration is not a problem.