Benguela Upwelling System: A sink or source of CO_2 to the atmosphere?

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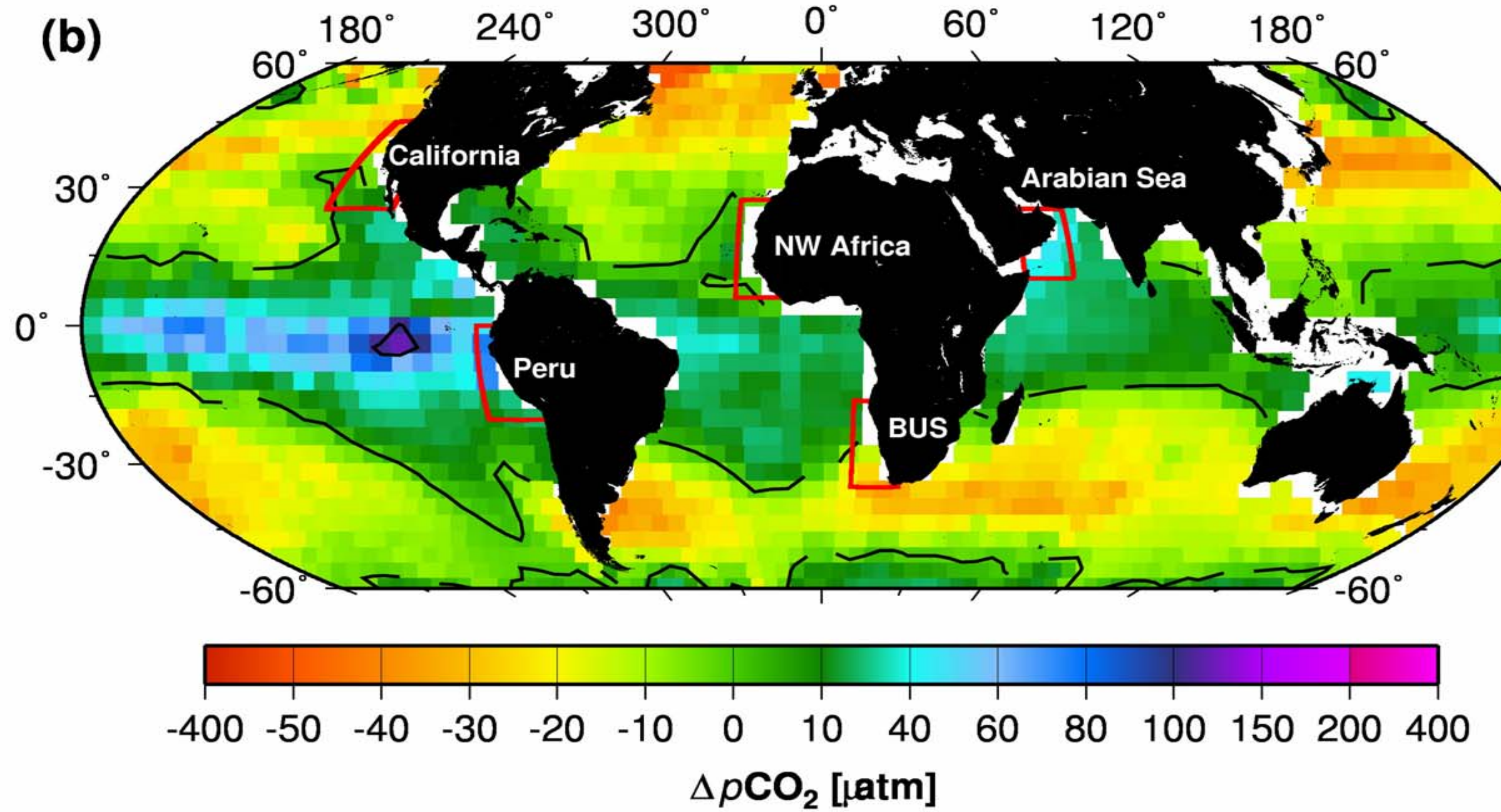
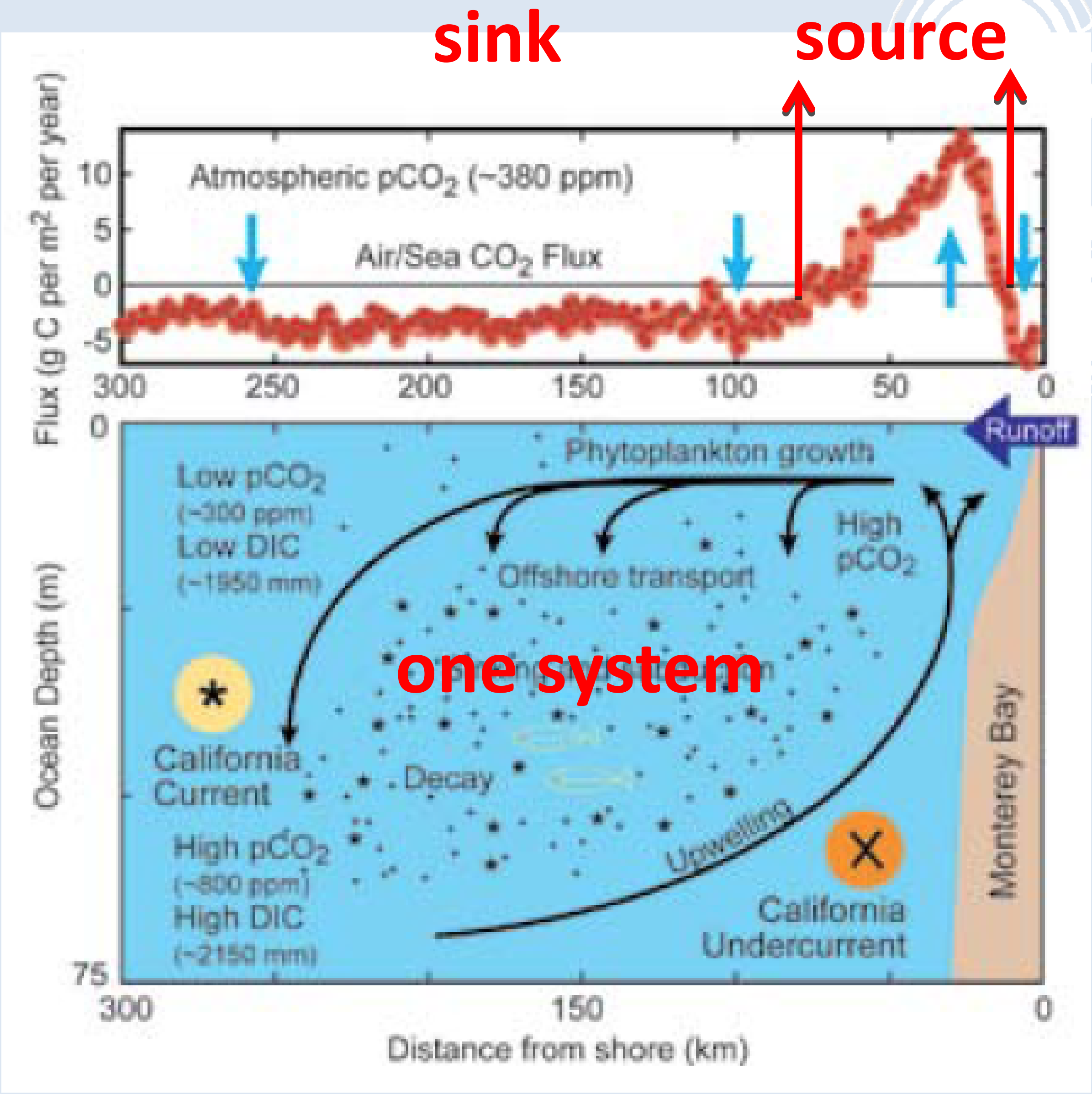
What is a sink and a source?

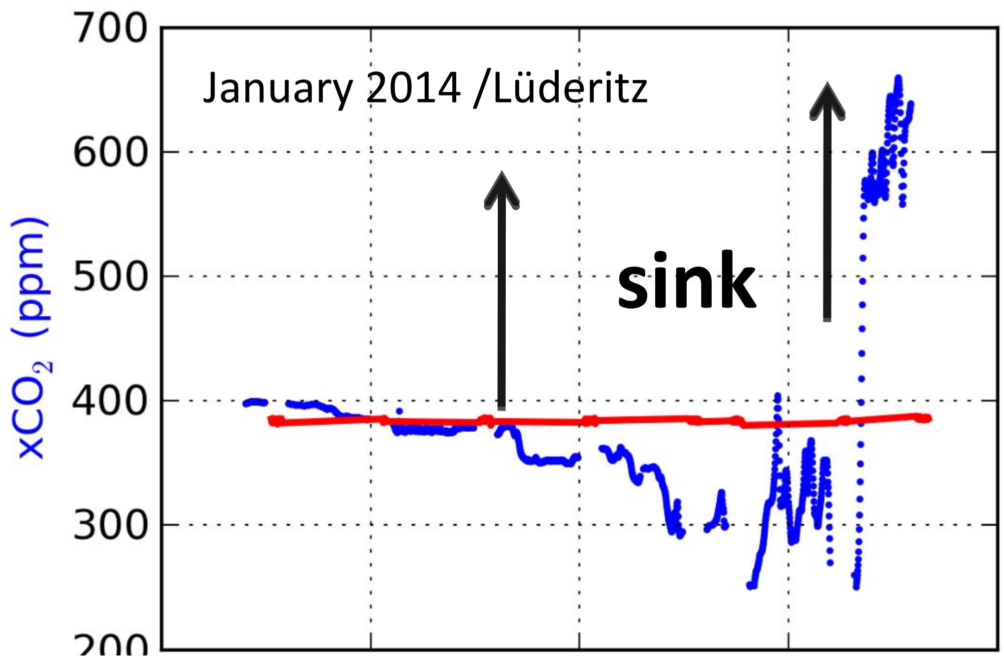


Data: Takahashi, et al., *Deep Sea Research Part II: Topical Studies in Oceanography 56 (8-10), 554 (2009).*

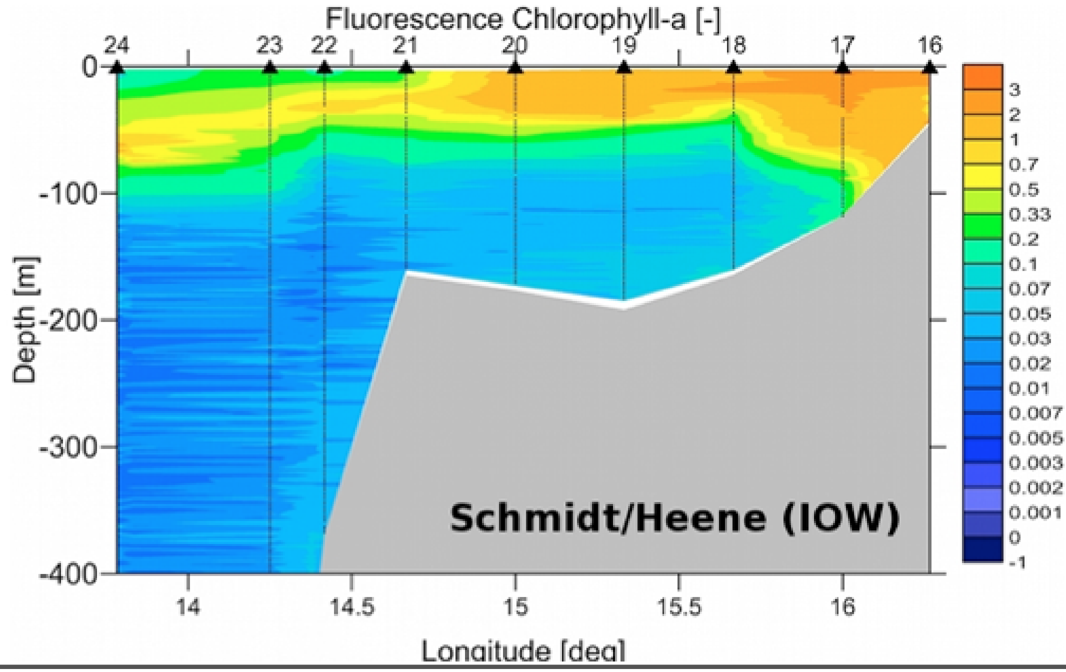


Chavez et al. 2007

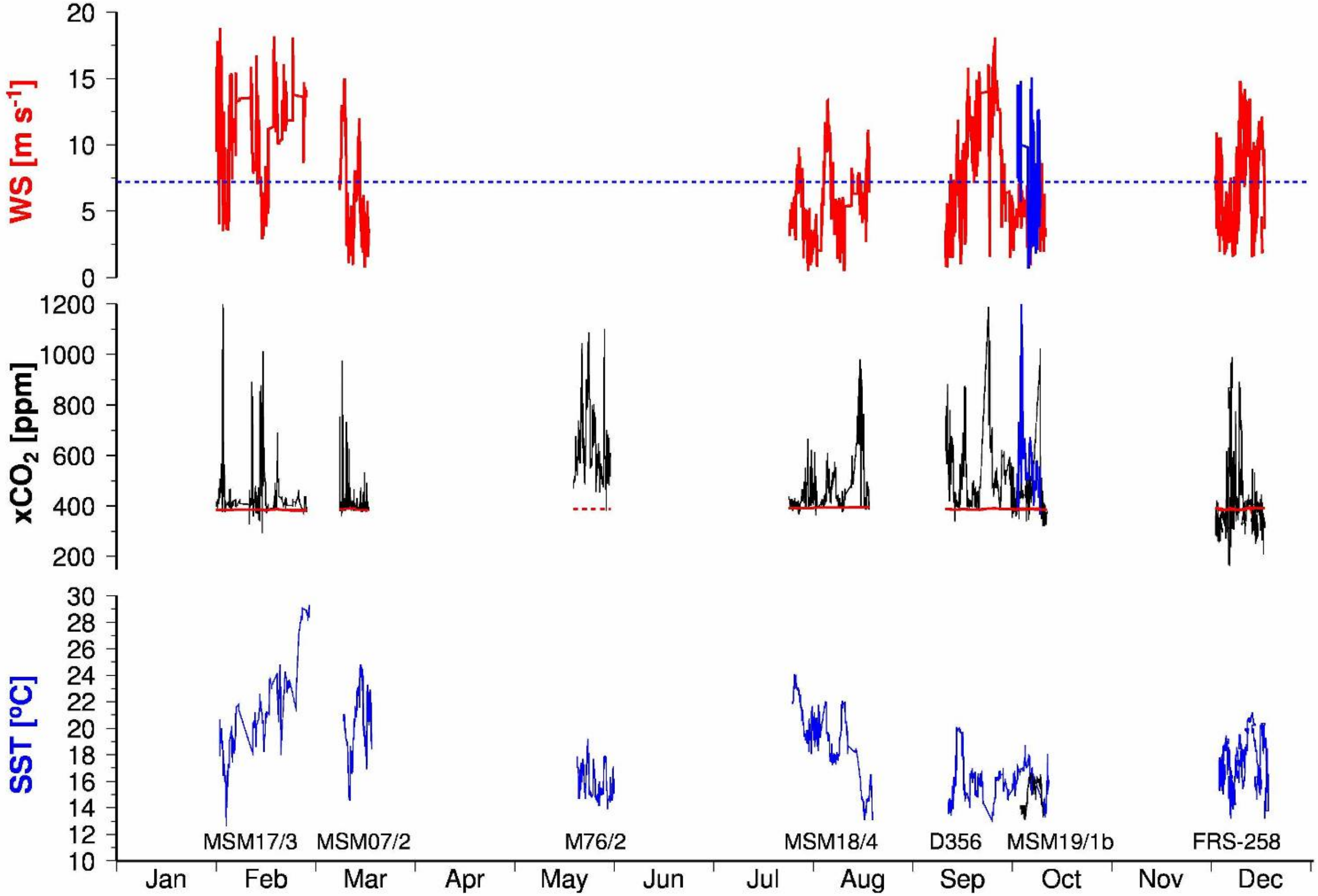
Seven cruises

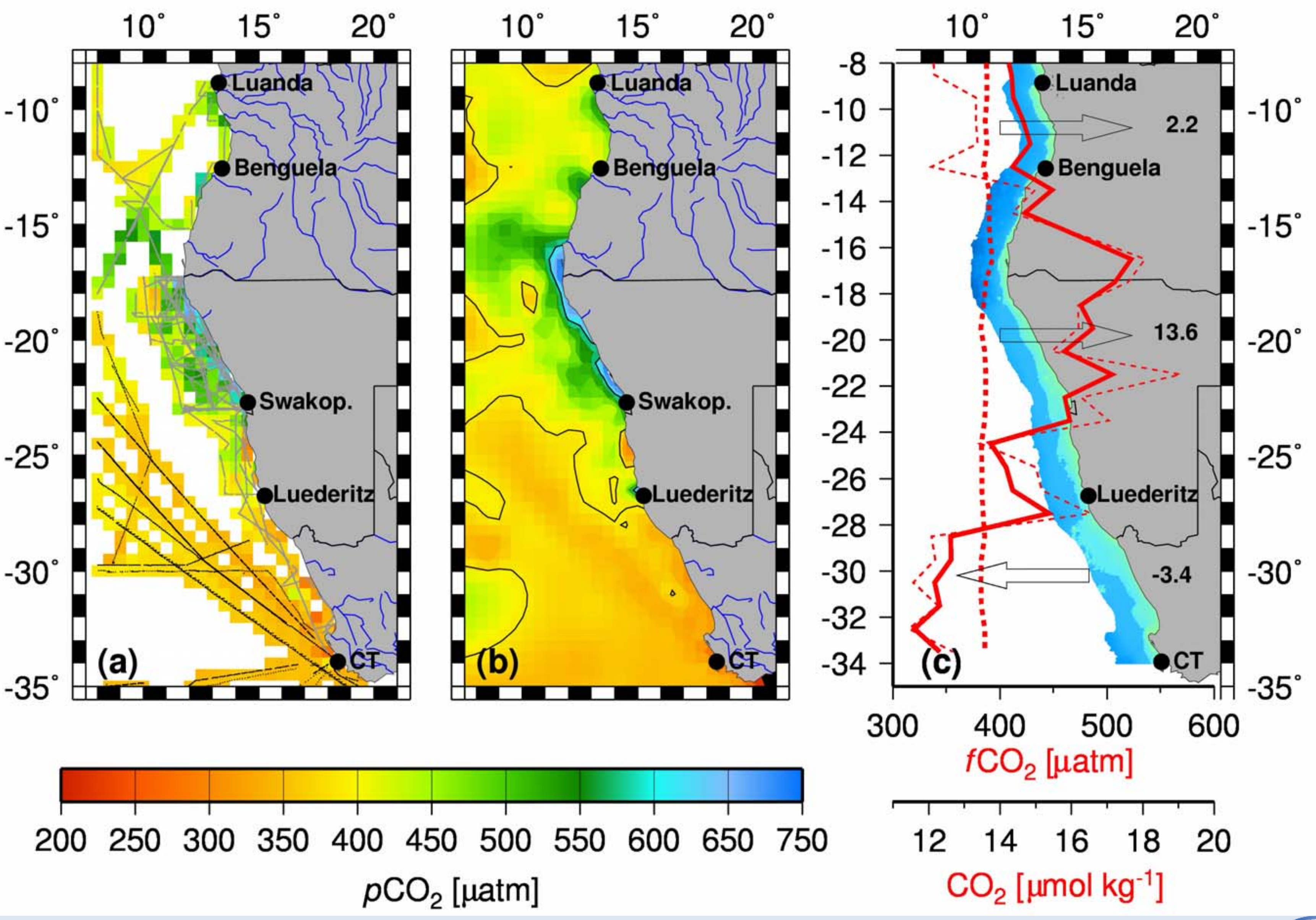

January 2014 /Lüderitz
sink
xCO$_2$ (ppm)
700
600
500
400
300
200

source

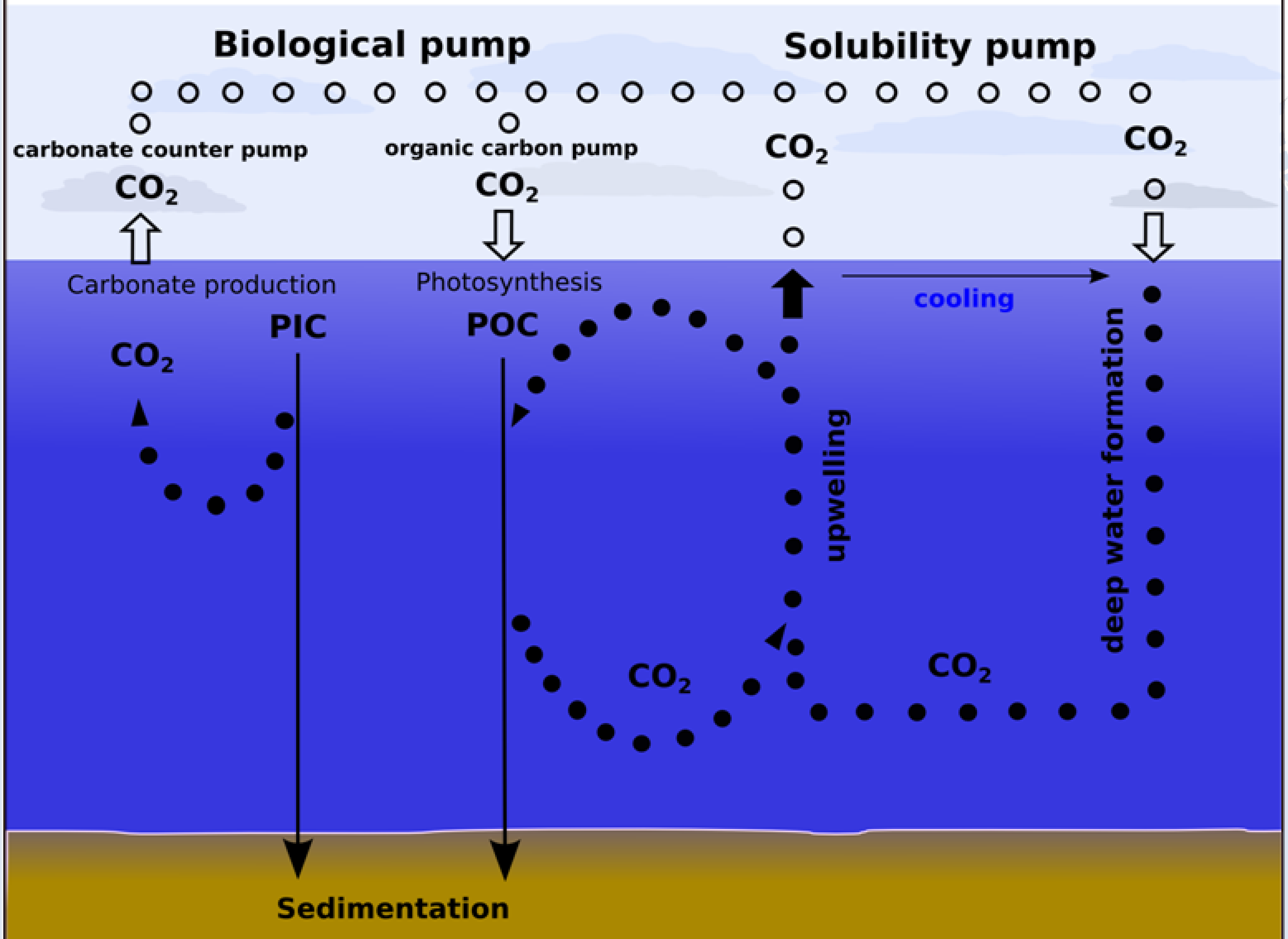

Fluorescence Chlorophyll-a [-]
24
23
22
21
20
19
18
17
16
Depth [m]
0
-100
-200
-300
-400
14
14.5
15
15.5
16
Longitude [deg]
Schmidt/Heene (IOW)
3
2
1
0.7
0.5
0.33
0.2
0.1
0.07
0.05
0.03
0.02
0.01
0.007
0.005
0.003
0.002
0.001
0
-1

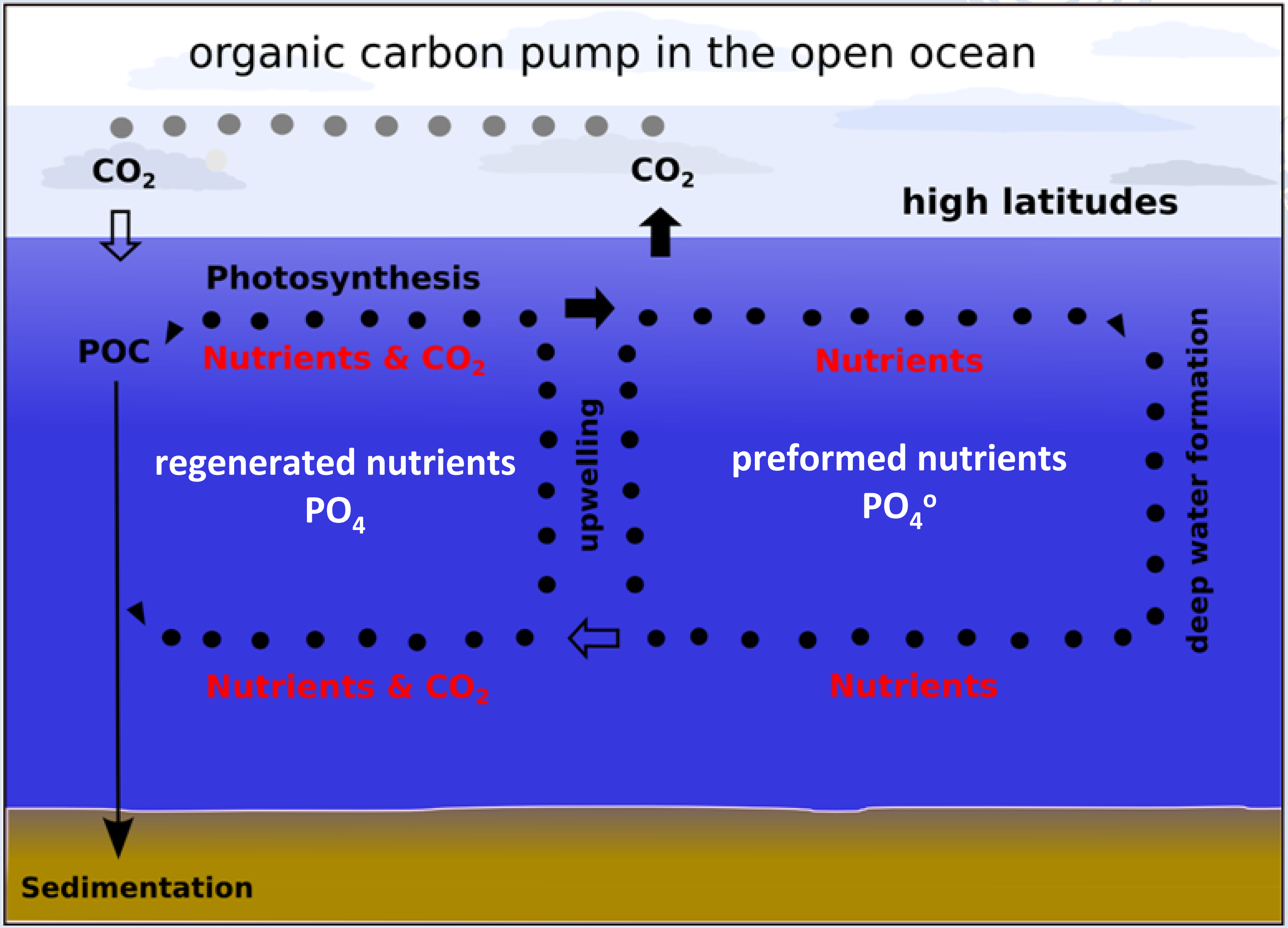
Seven cruises



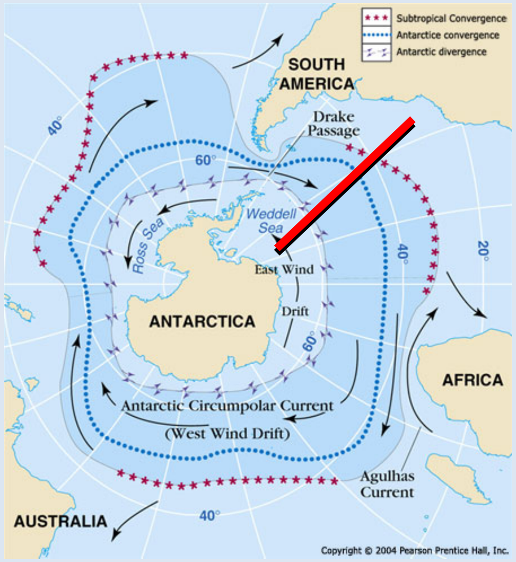

10° 15° 20°
-10° -15° -20° -25° -30° -35°
Luanda
Benguela
Swakop.
Luederitz
CT
(a)
(b)
(c)
2.2
13.6
-3.4
-8 -10 -12 -14 -16 -18 -20 -22 -24 -26 -28 -30 -32 -34
300 400 500 600
fCO2 [µatm]
12 14 16 18 20
CO2 [µmol kg-1]
200 250 300 350 400 450 500 550 600 650 750
pCO2 [µatm]

CO_2 pumps in the open ocean





organic carbon pump in the open ocean
CO2
CO2
high latitudes
Photosynthesis
POC
Nutrients & CO2
Nutrients
upwelling
deep water formation
regenerated nutrients
PO4
preformed nutrients
PO4o
Nutrients & CO2
Nutrients
Sedimentation


Subtropical Convergence
Antarctice convergence
Antarctic divergence
SOUTH AMERICA
Drake Passage
Weddell Sea
Ross Sea
East Wind
Drift
ANTARCTICA
AFRICA
Antarctic Circumpolar Current
(West Wind Drift)
Agulhas Current
AUSTRALIA
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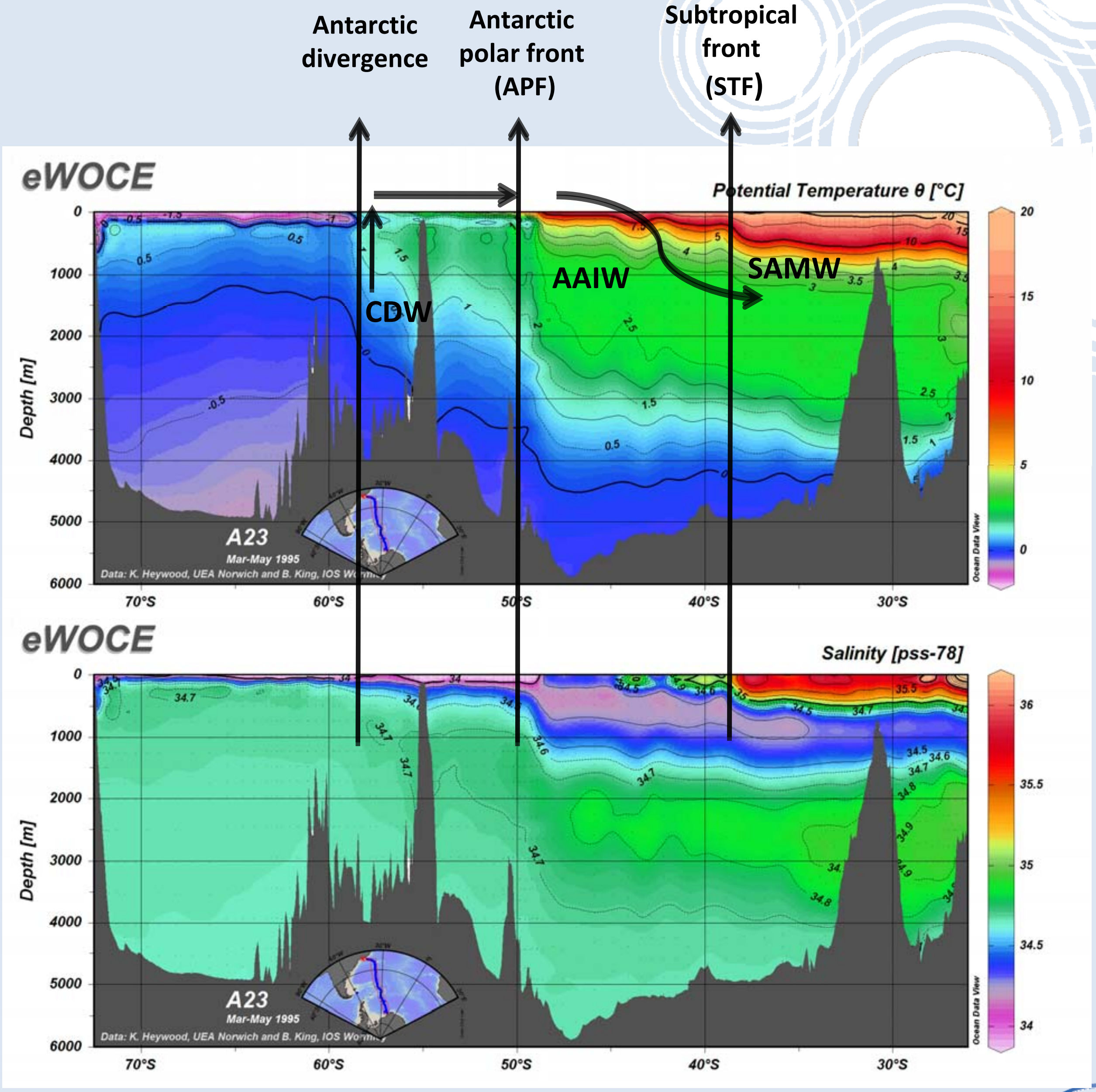
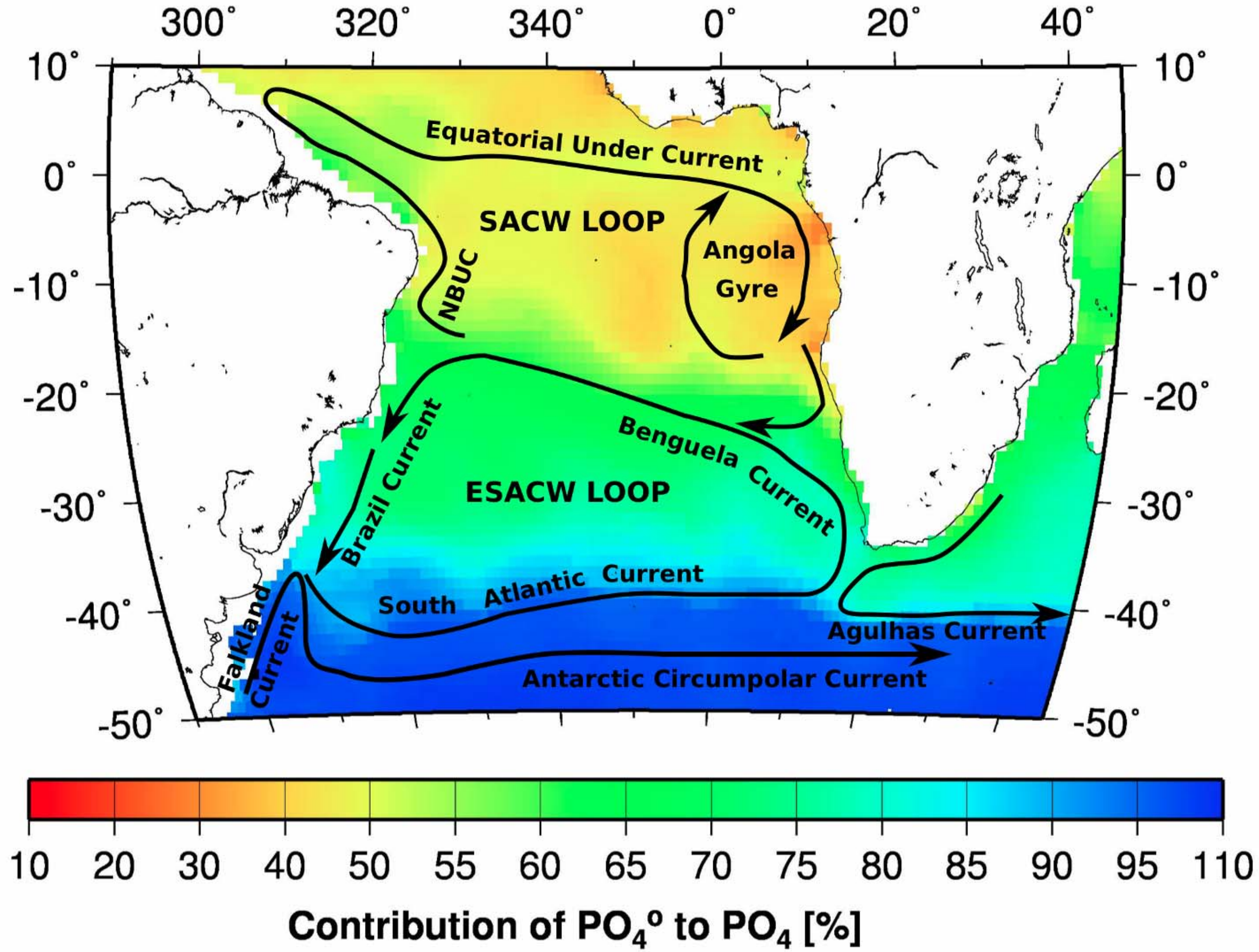
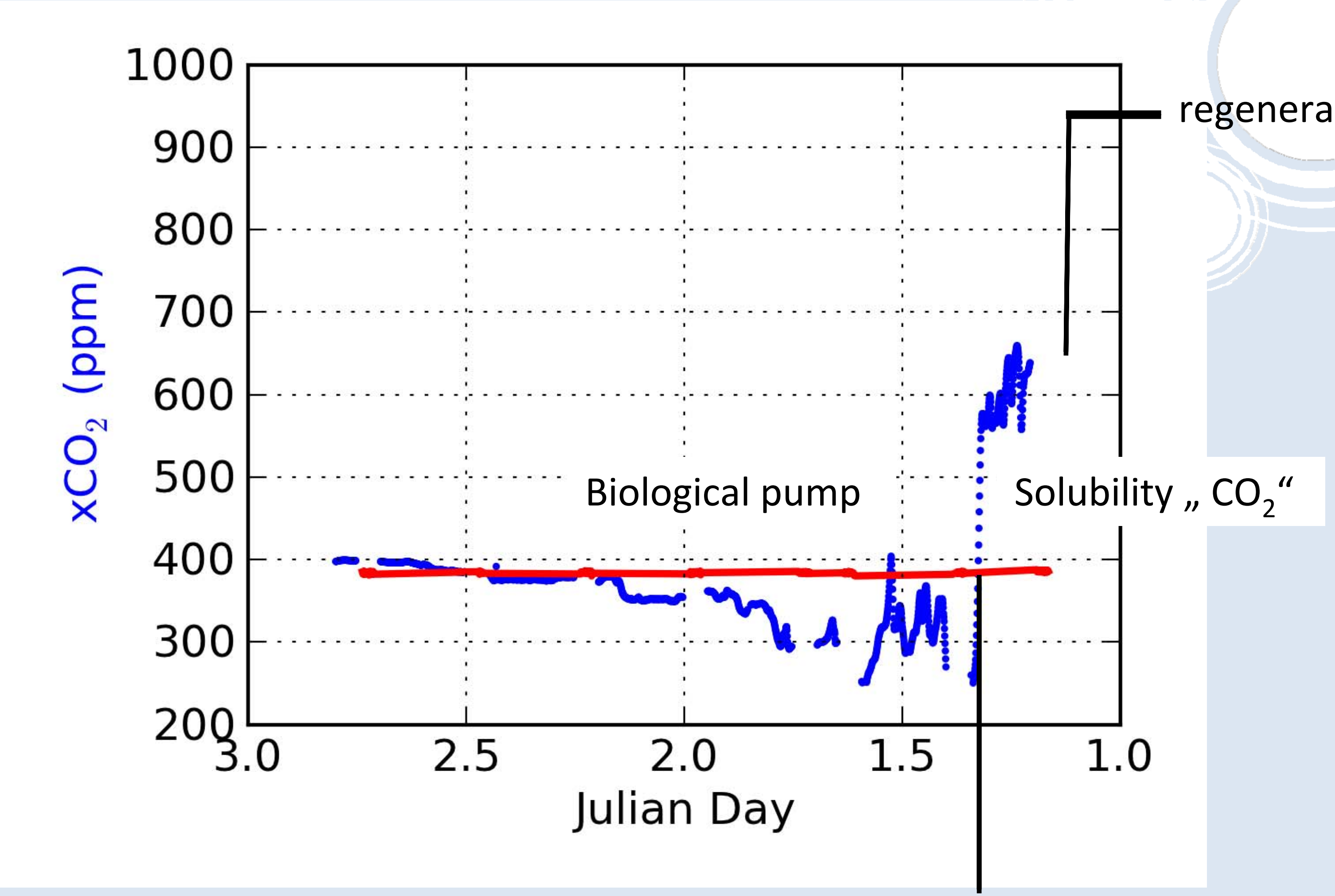
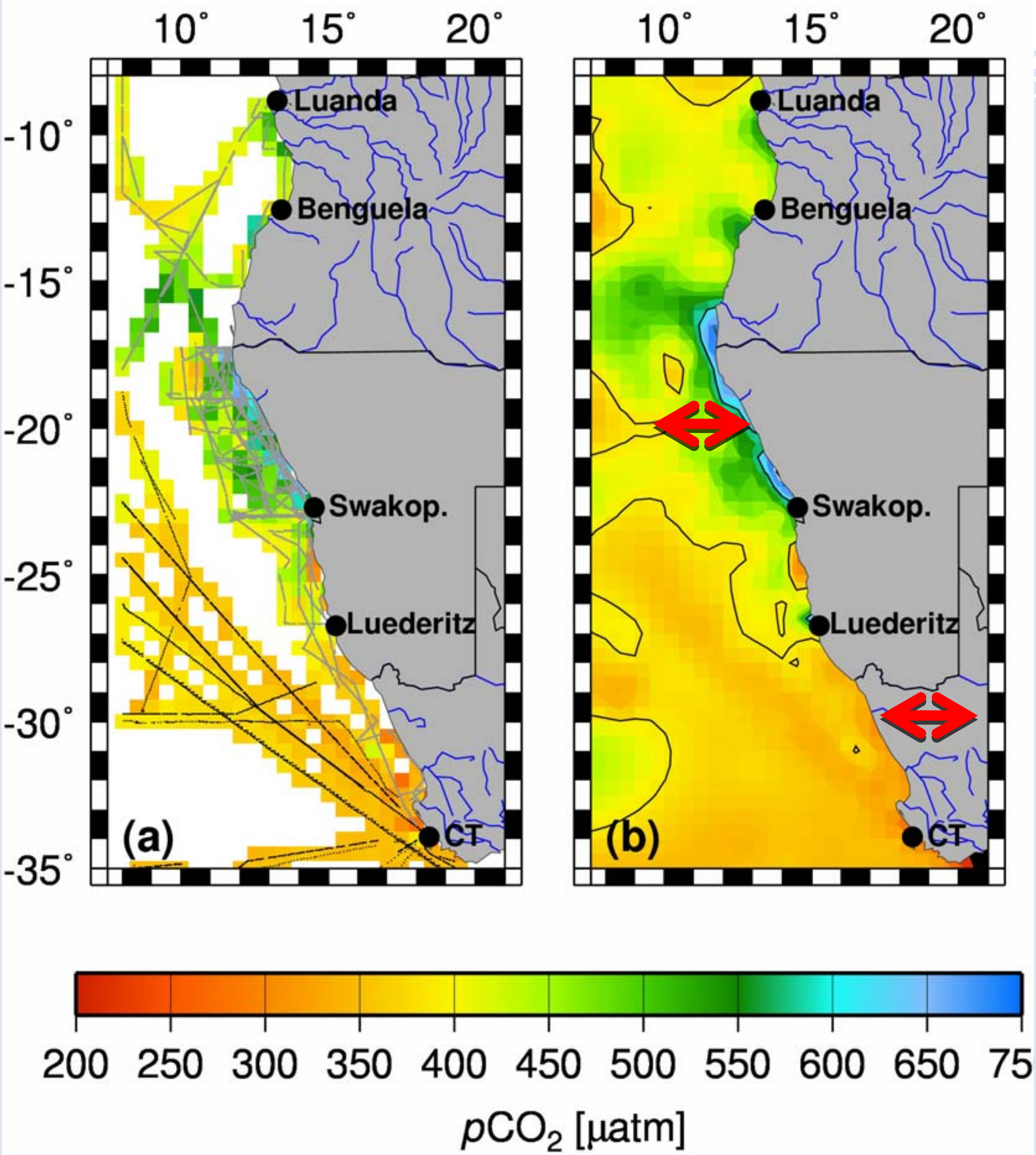
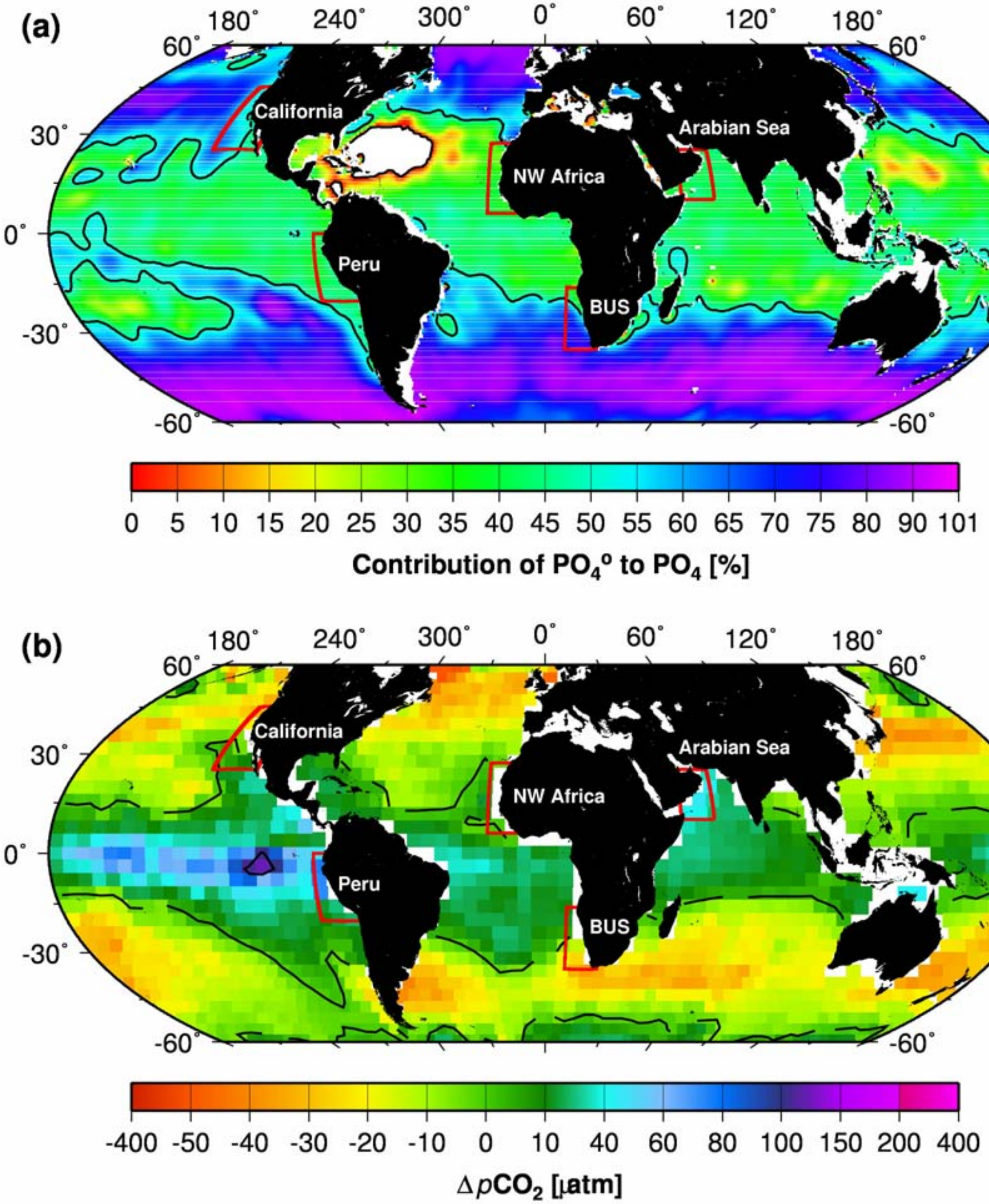

Antarctic divergence
Antarctic polar front (APF)
Subtropical front (STF)
CDW
AAIW
SAMW
eWOCE
Potential Temperature θ [°C]
Depth [m]
A23
Mar-May 1995
Data: K. Heywood, UEA Norwich and B. King, IOS Wormley
70°S
60°S
50°S
40°S
30°S
Ocean Data View
eWOCE
Salinity [pss-78]

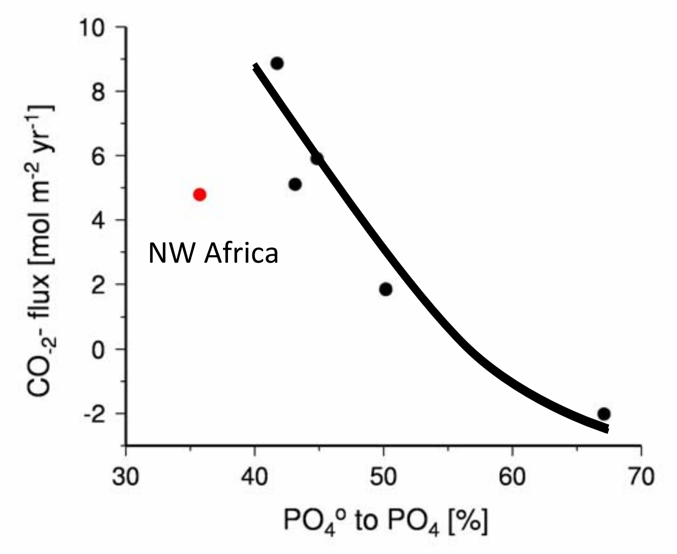

300°
320°
340°
0°
20°
40°
10°
0°
-10°
-20°
-30°
-40°
-50°
Equatorial Under Current
SACW LOOP
Angola
Gyre
NBUC
Benguela Current
Brazil Current
ESACW LOOP
South Atlantic Current
Agulhas Current
Falkland Current
Antarctic Circumpolar Current
10
20
30
40
50
55
60
65
70
75
80
85
90
95
110
Contribution of PO_4^o to PO_4 [%]



further offshore


10°
15°
20°
-10°
-15°
-20°
-25°
-30°
-35°
Luanda
Benguela
Swakop.
Luederitz
CT
(a)
(b)
200
250
300
350
400
450
500
550
600
650
75
pCO2 [µatm]





	CO_2-flux mol m^{-2} yr^{-1}	Period	
California	1,85	1998-1999	Friederich et al. 2002
Peru	5,10	2004-2006	Friederich et al. 2008
NW Africa	4,79	2005	Steinhoff et al. 2012
S-BUS	-2,01	2008-2011	
N-BUS	5,91	2008-2011	
Arabian Sea	8,87	1995	Rixen et al. 2006

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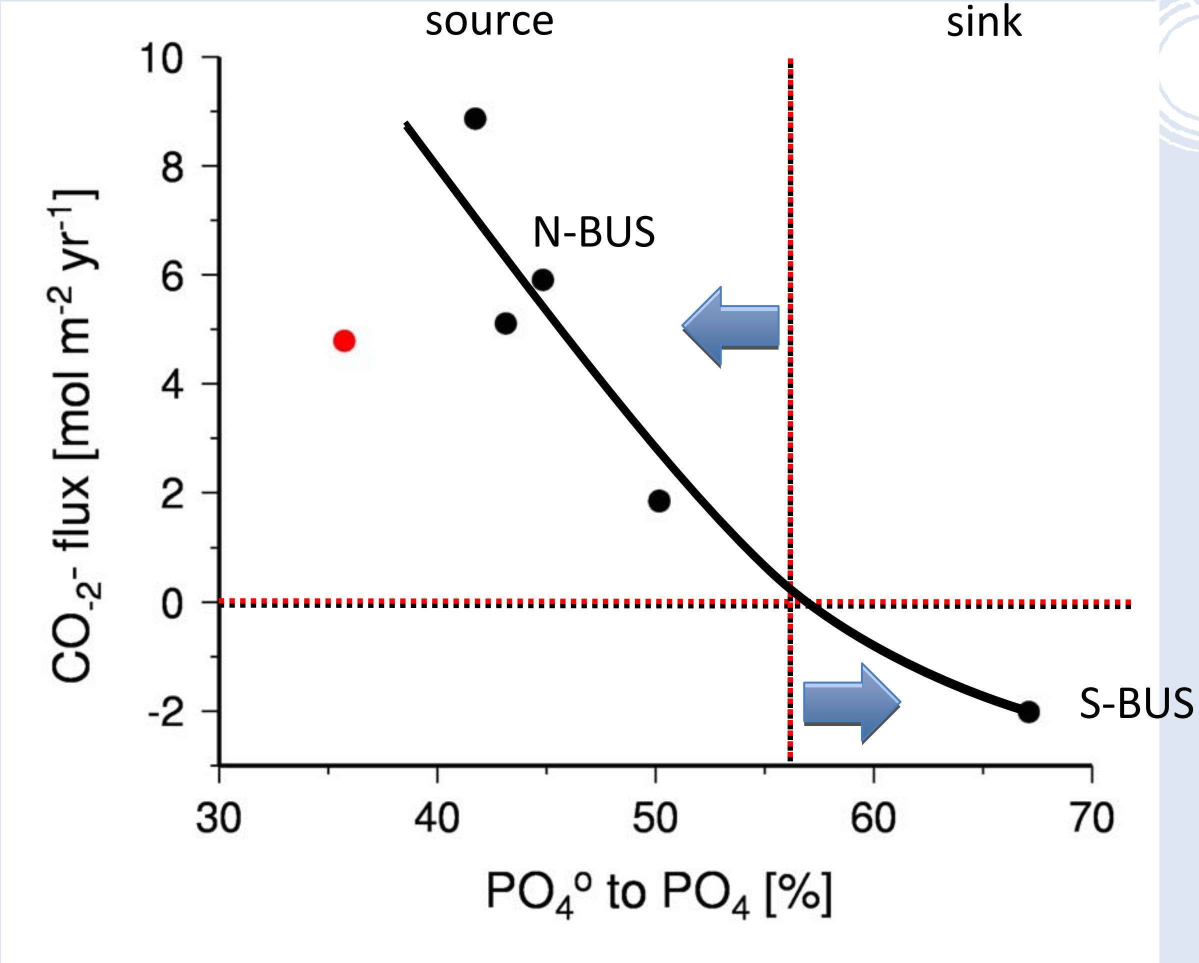
A sink or source of CO_2 to the atmosphere?



Conclusion:

A. The organic carbon pump takes up CO_2 in the N- and S-BUS because in both systems preformed nutrients are utilized.

B. A sink or source of CO_2 to the atmosphere?

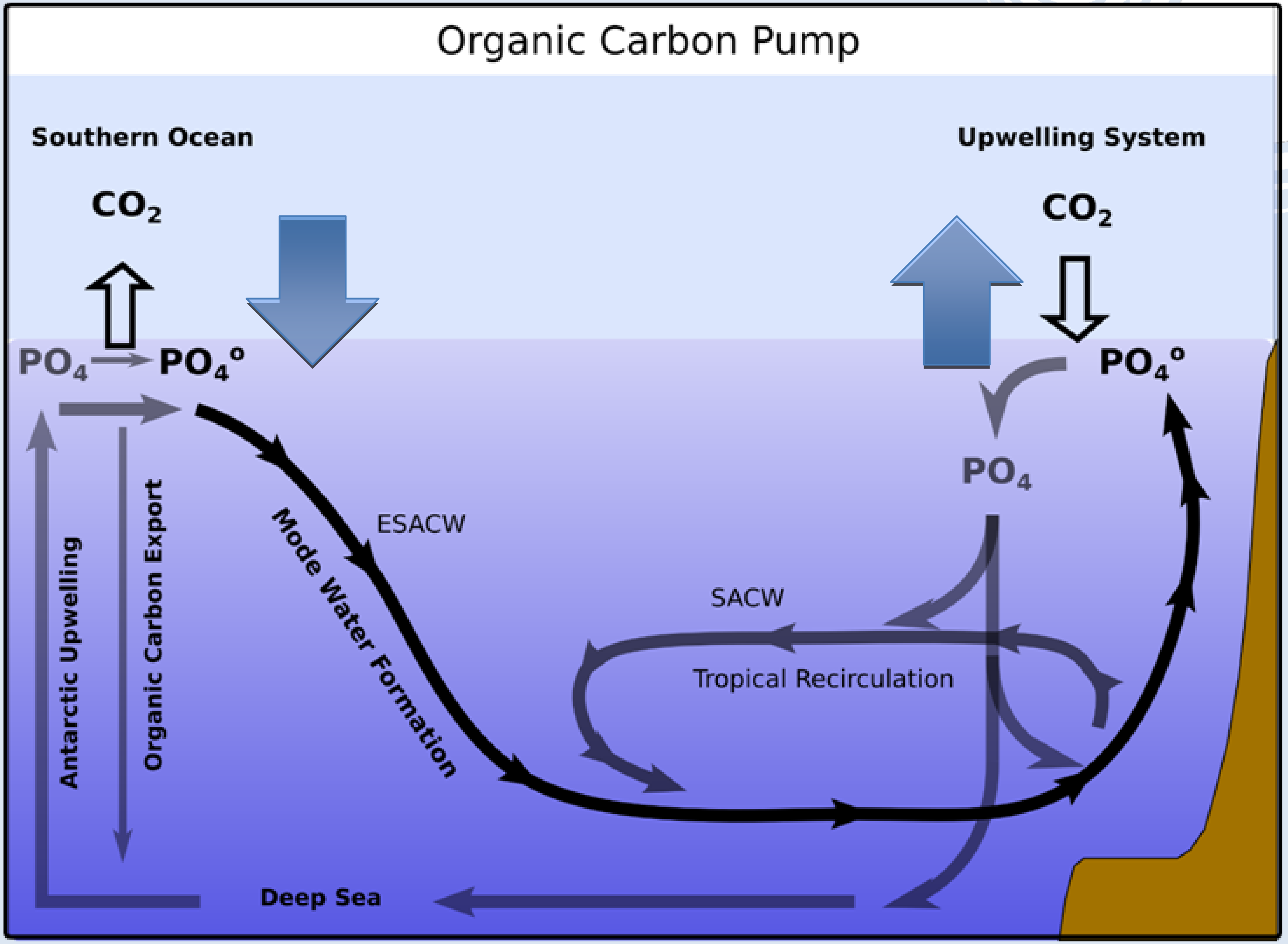
The S and (N)-BUS are sinks.

because: organic carbon pump solubility pump

C. Upwelling system on the on shelf

1. The N-BUS is source
2. The S-BUS is a sink

Benguela System:



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www.biogeosciences.net/9/1797/2012/
doi:10.5194/bg-9-1797-2012

Biogeosciences

Preformed and regenerated phosphate in ocean general circulation models: can right total concentrations be wrong?

O. Duteil[1], W. Koeve[1], A. Oschlies[1], O. Aumont[2], D. Bianchi[3], L. Bopp[4], E. Galbraith[5], R. Matear[6], J. K. Moore[7], J. L. Sarmiento[3], and J. Segschneider[8]

Table 1. General description of the models used in this study.

Model	OPA-PISCES	MPIOM-HAMOCC	CCSM3-BEC	UVIC	om1p7-BLINGv0	CSIRO	MOM-P2A
Ref.	Aumont and Bopp (2006)	Maier-Reimer et al. (2005)	Krishnamurty et al. (2009)	Oschlies et al. (2008)	Galbraith et al. (2010)	Matear and Hirst (2003)	Gnanadesikan et al. (2004)

Are Upwelling Zones Sources or Sinks of CO_2?

A.J. WATSON
Plymouth Marine Laboratory, Prospect Place, West Hoe, GB–Plymouth PL1 3DH, U.K.

Upwelling in the Ocean: Modern Processes and Ancient Records
Edited by C.P. Summerhayes, K.-C. Emeis, M.V. Angel, R.L. Smith, and B. Zeitzschel © 1995 John Wiley & Sons Ltd.

What is a sink and a source?

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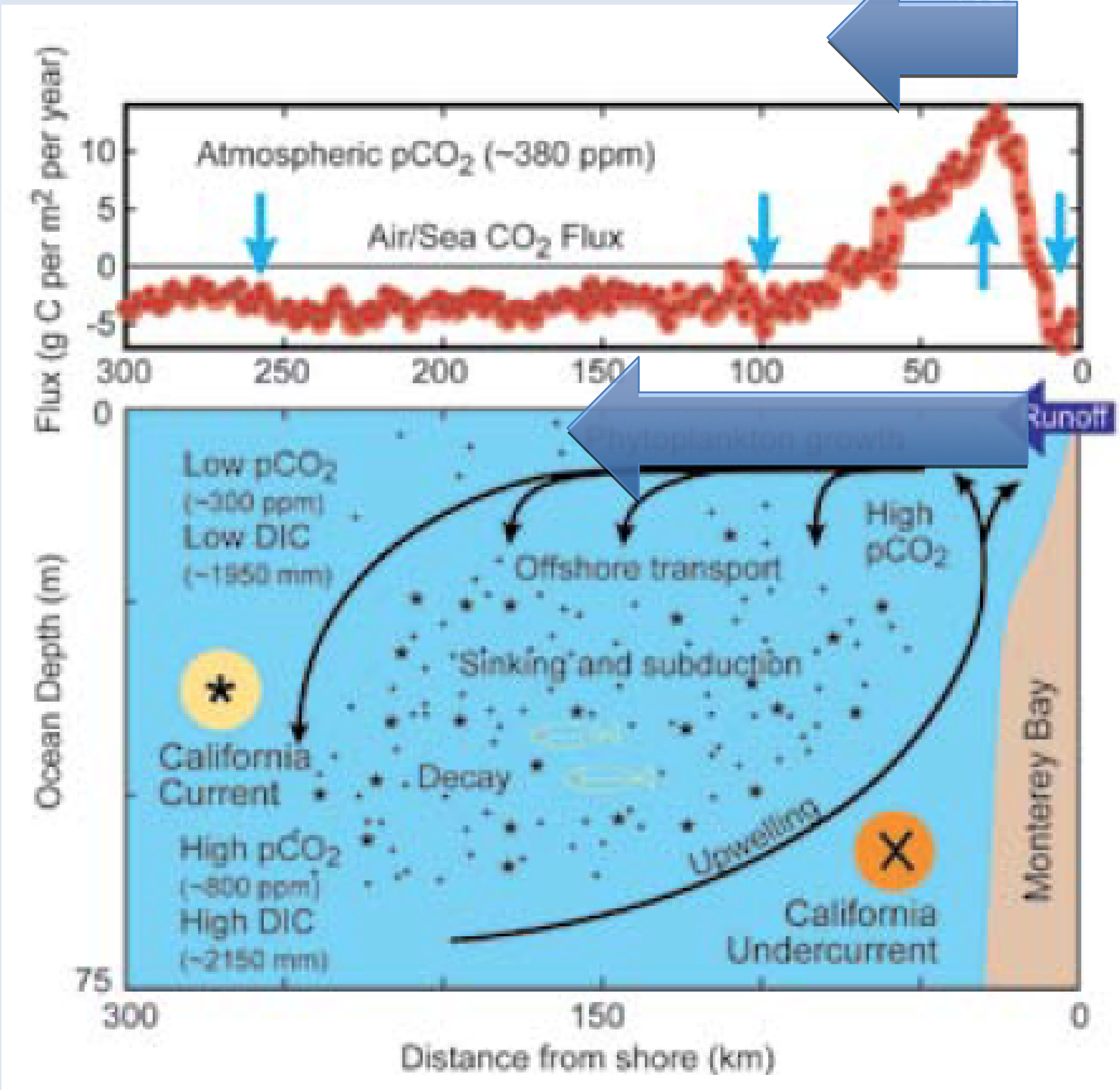
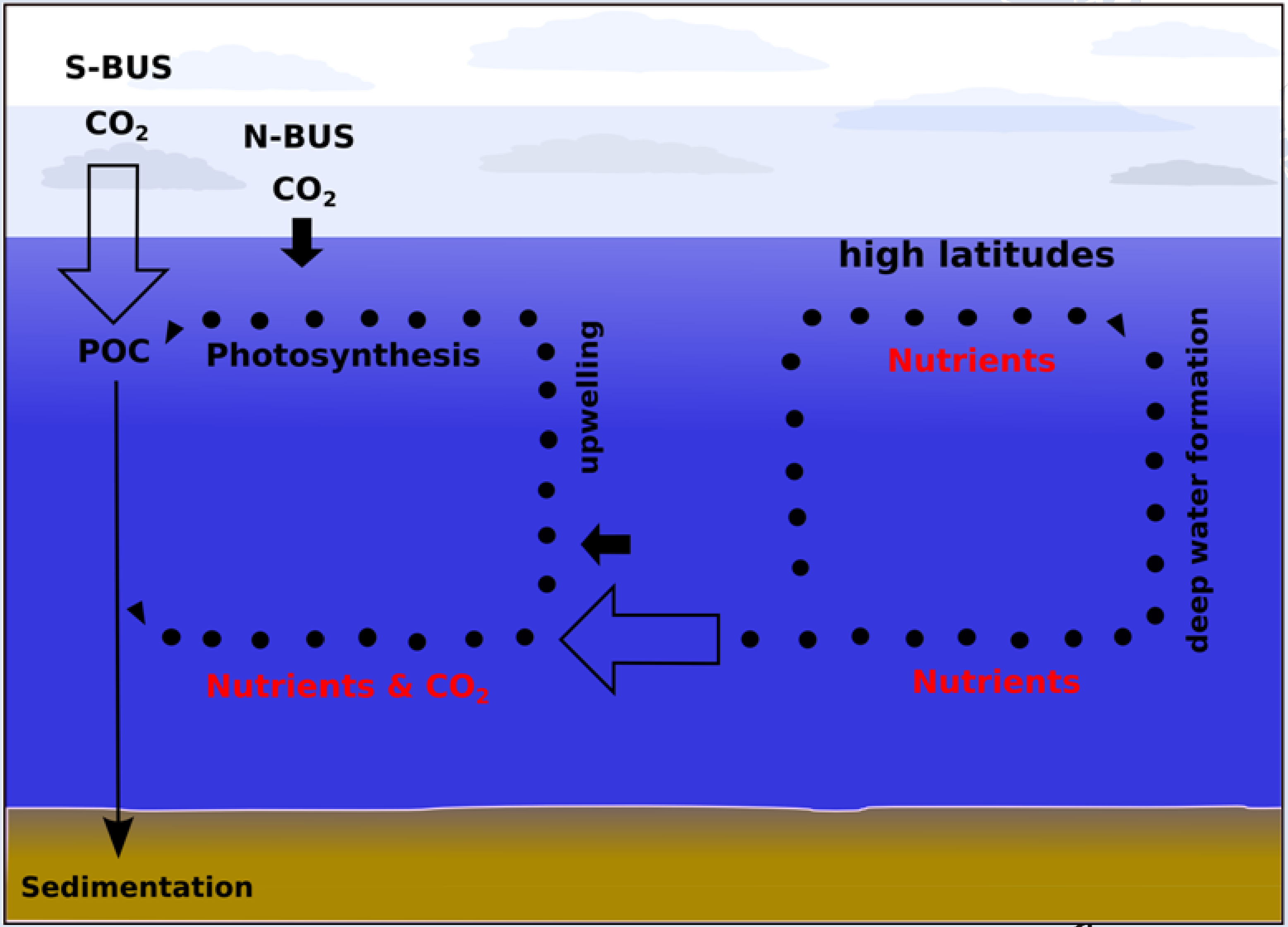
What is a sink and a source?

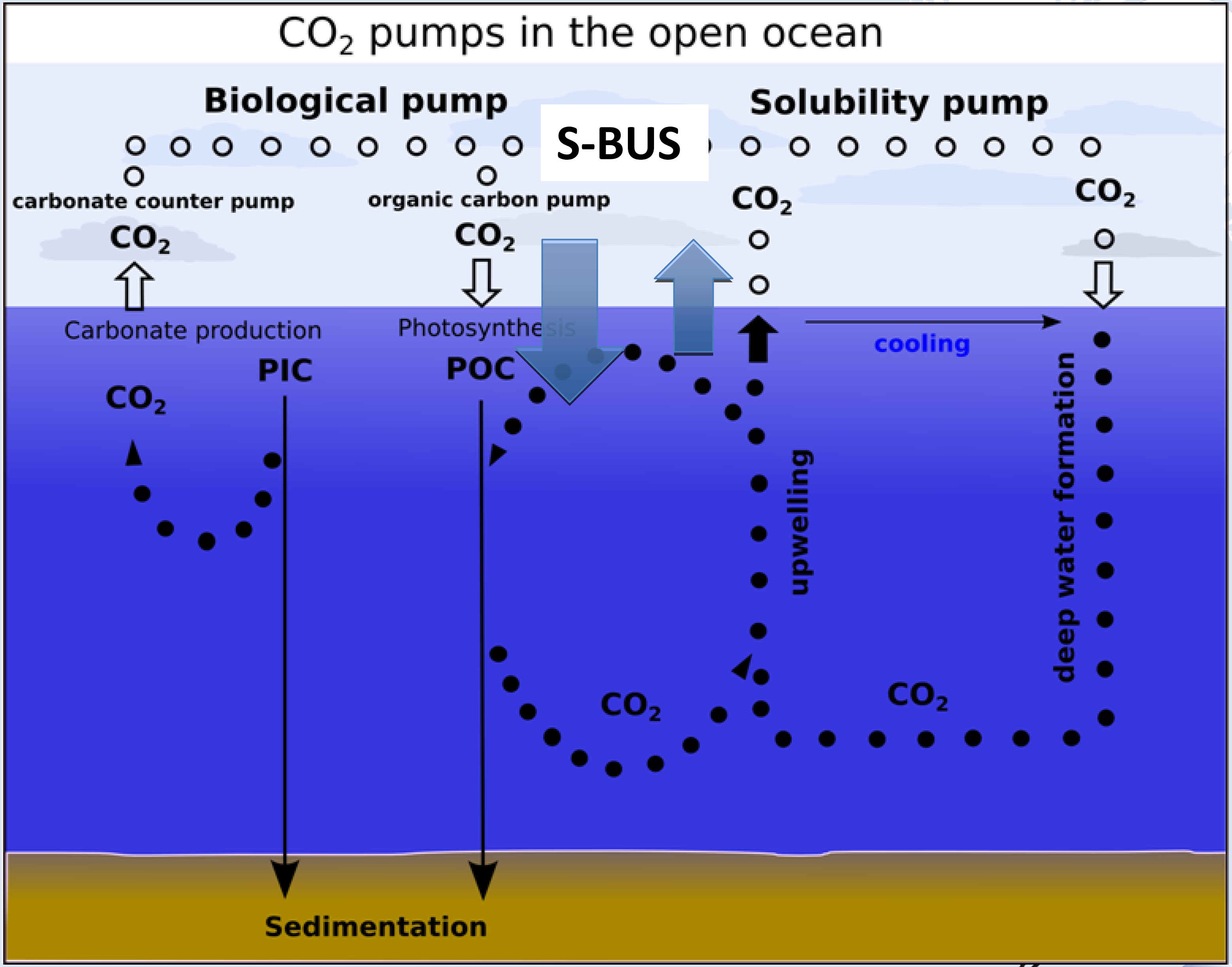
		Eastern Boundary Upwelling Systems						
		California	Peru	NW Africa	S-BUS	N-BUS	Arabian Sea	
Area	m^2	1,61E+11	1,73E+11	1,53E+11	1,39E+11	1,92E+11	3,57E+11	Messie et al. 2009
Duration	s	31536000	31536000	31536000	31536000	31536000	10368000	Messie et al. 2009
Upwelling								
a) at the coast	$10^6\ m^3\ s^{-1}$	**0,90**	**1,58**	**1,30**	**0,61**	**1,69**	**10,00**	Messie et al. 2009
b) shelf/slope	$10^6\ m^3\ s^{-1}$	**0,27**	**0,72**	**0,44**	**0,20**	**0,51**	**3,57**	Messie et al. 2009
Nutrients								
a) Nitarte concentration /coast	$mmol\ m^{-3}$	**17,20**	**17,00**	**19,20**	18,10	**18,10**	16,20	Messie et al. 2009
b) Nitarte concentration/shelf	$mmol\ m^{-3}$	**14,90**	**16,80**	**19,00**	16,90	**16,90**	16,20	Messie et al. 2009
Supply								
Nitrate	$mmol\ s^{-1}\ m^{-1}$	19,51	38,87	33,21	14,52	39,23	219,77	
	$mol\ N\ yr^{-1}$	**6,15E+11**	**1,23E+12**	**1,05E+12**	**4,58E+11**	**1,24E+12**	**2,28E+12**	
N/P ratio		10,39	8,90	15,17	11,49	12,73	11,15	WOA 2009
CPPC	%	50,17	43,12	35,72	67,09	44,82	41,72	WOA 2009
Phosphate	$mol\ P\ yr^{-1}$	5,92E+10	1,38E+11	6,90E+10	3,98E+10	9,72E+10	2,04E+11	
PO4o	$mol\ P\ yr^{-1}$	2,97E+10	5,94E+10	2,47E+10	2,67E+10	4,36E+10	8,53E+10	
CO2 uptake	$Tg\ C\ yr^{-1}$	37,78	75,55	31,36	34,00	55,41	108,45	
							342,55	

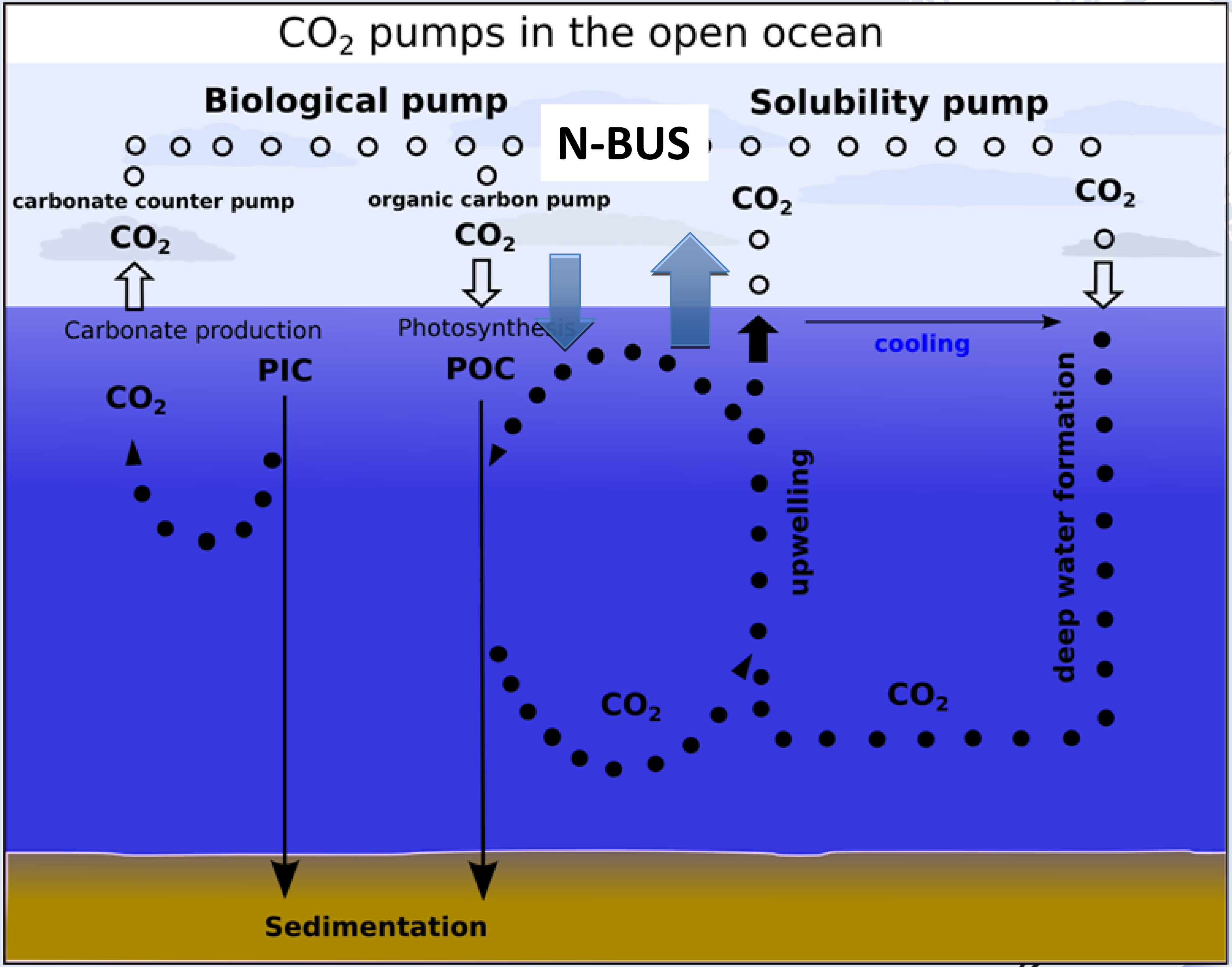


Flux (g C per m² per year)
Atmospheric pCO2 (~380 ppm)
Air/Sea CO2 Flux
10
5
0
-5
300
250
200
150
100
50
0
Runoff
Phytoplankton growth
Ocean Depth (m)
0
75
Low pCO2
(~300 ppm)
Low DIC
(~1950 mm)
Offshore transport
High
pCO2
Sinking and subduction
California
Current
Decay
Upwelling
High pCO2
(~800 ppm)
High DIC
(~2150 mm)
California
Undercurrent
Monterey Bay
300
150
0
Distance from shore (km)

organic carbon pump in the open ocean




CO2 pumps in the open ocean
Biological pump
Solubility pump
S-BUS
carbonate counter pump
organic carbon pump
CO2
CO2
CO2
CO2
Carbonate production
Photosynthesis
cooling
PIC
POC
CO2
upwelling
deep water formation
CO2
CO2
Sedimentation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