Nutrient and CO_2 dynamics in the northern Benguela

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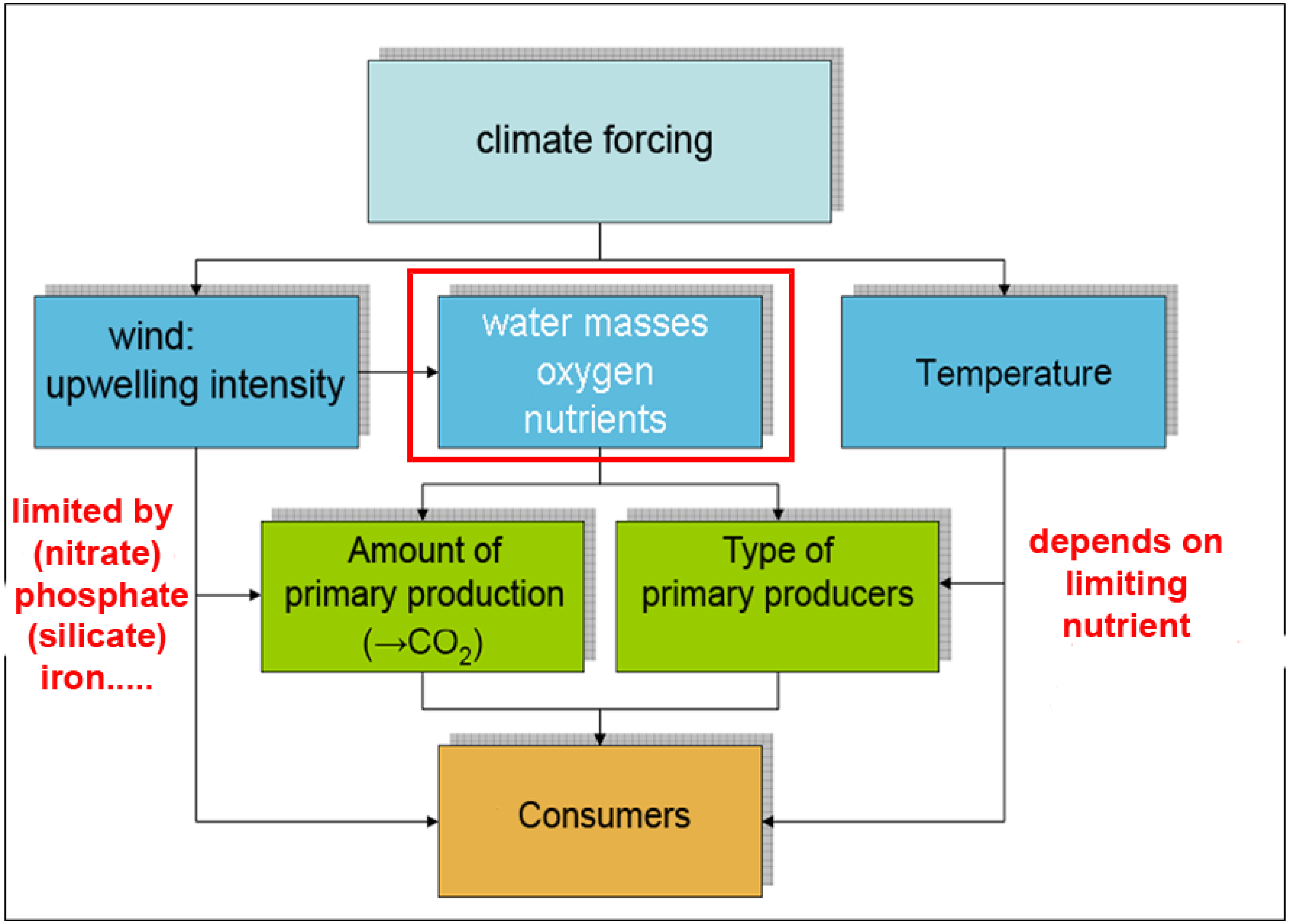
GENUS hypotheses



Changes in the biogeochemical regime (oxic-suboxic-anoxic) are direct consequences of climatic forcing via changes in water mass origin and properties.

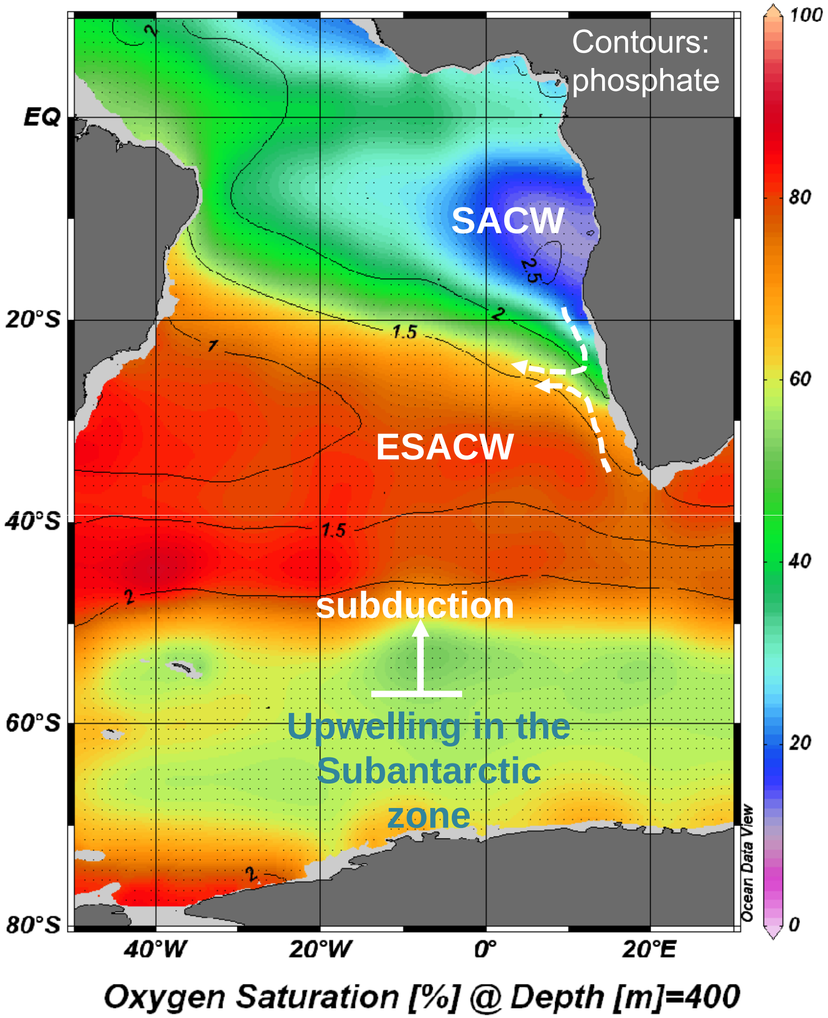
Changes in the nutrient mass and ratios (qualitative and quantitative) cause changes at the base of the food chain, in the CO_2 balance, and in the composition of higher trophic levels.

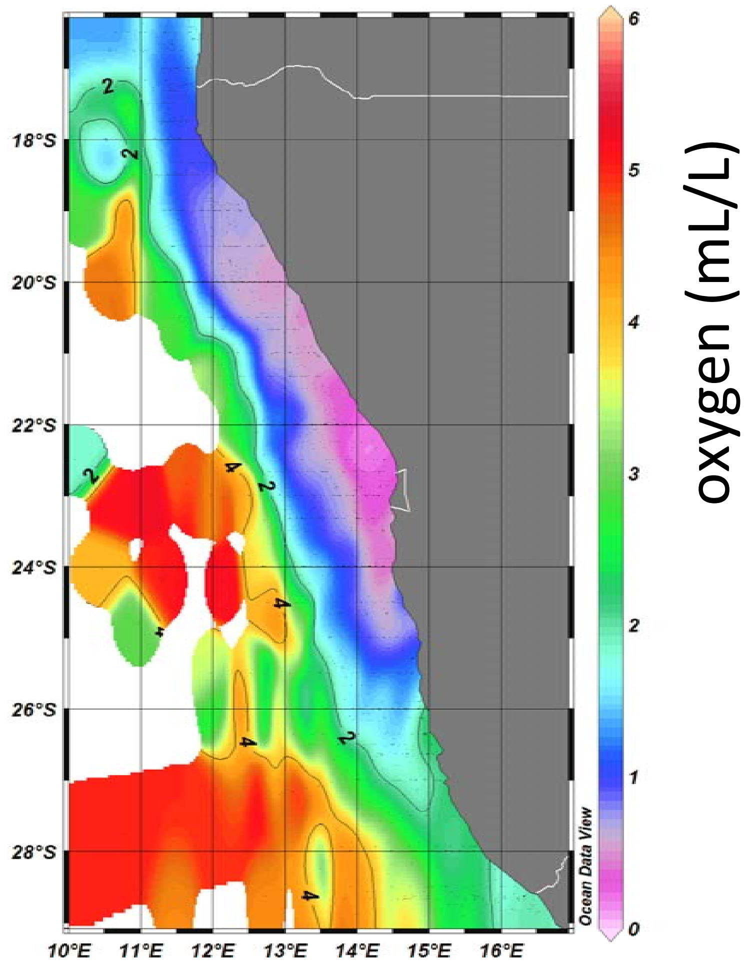
Such changes are communicated to the adjacent epipelagic or mesopelagic ocean.

Nutrient sources, turnover, and sinks in the upwelling system

CO_2 sources and sinks, and relation to water masses

The role of intermediate (=source) water masses





Upwelling feed waters derive from the Subantarctic and lose O_2/gain CO_2 and nutrients on the way. They are O_2 to start with (light limitation in the Subantarctic) and have an excess of phosphate. SACW has taken a longer route, has more nutrients and CO_2, and less oxygen

In the northern BUS, oxygen is lost through oxidation of organic matter produced in the surface layer, advected organic matter, oxidation of gases/ reduced components, and of organic matter in sediments.

Online measurements (FerryBox)

RV Meteor:
Cruise M 76-2

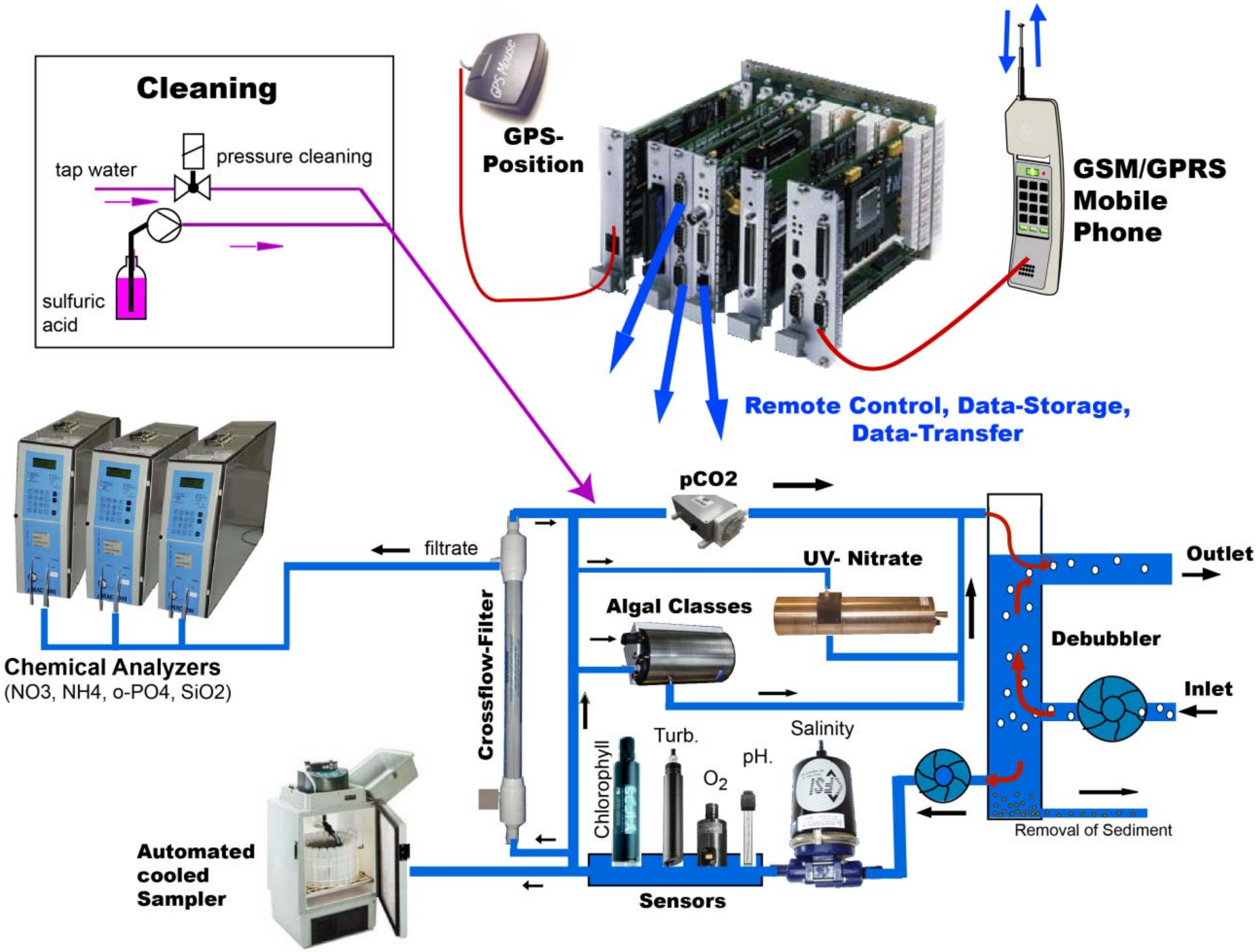
May 2008
(moderate upwelling)

RRS Discovey:
Cruise D-356

September 2010
(strong upwelling)

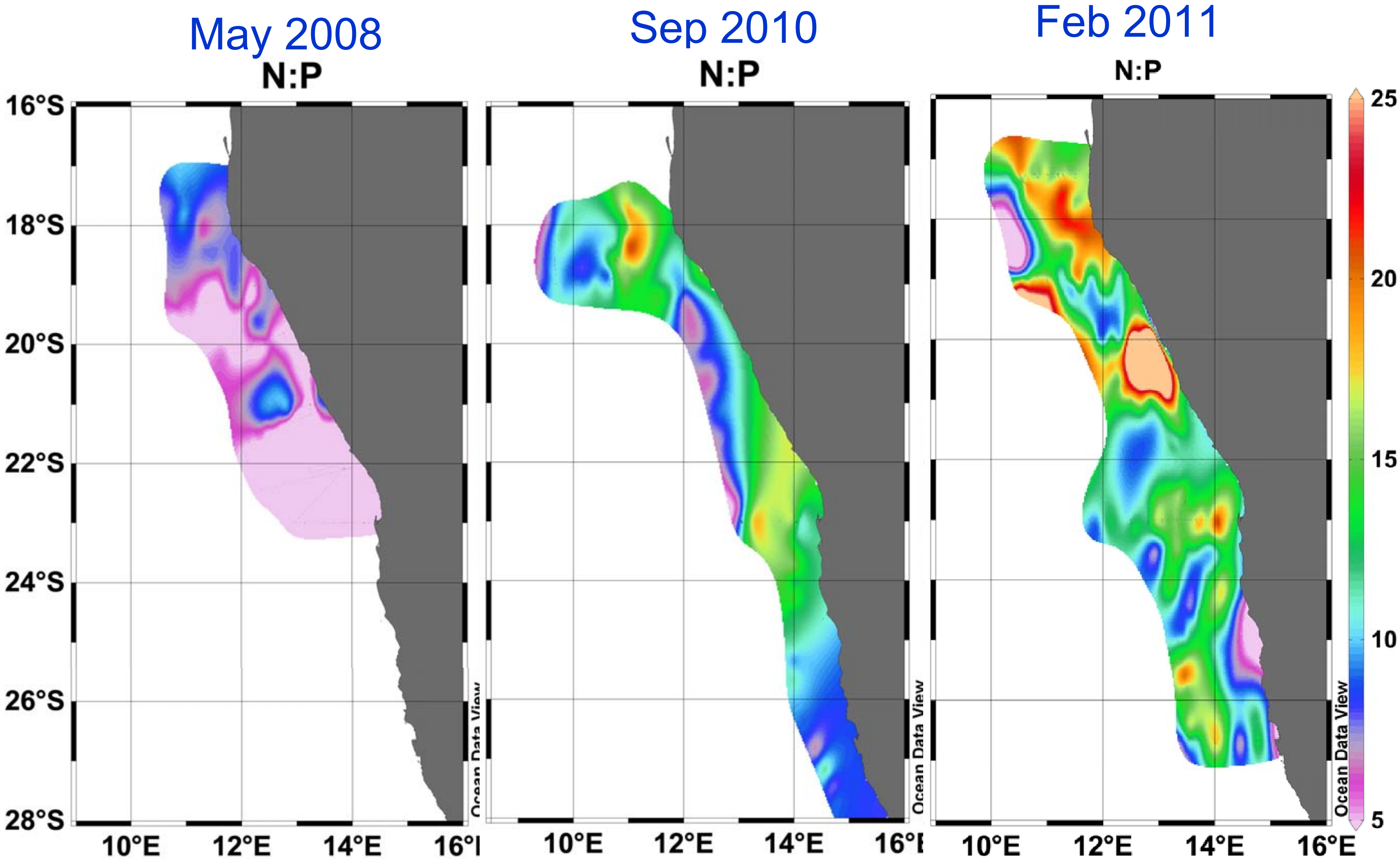
RV Maria S. Merian:
Cruise MSM 17-3

February 2011
(weak upwelling)



Data acquisition: every 30 seconds,
>90,000 measurements

Ferrybox results - nitrate:phosphate ratios surface waters

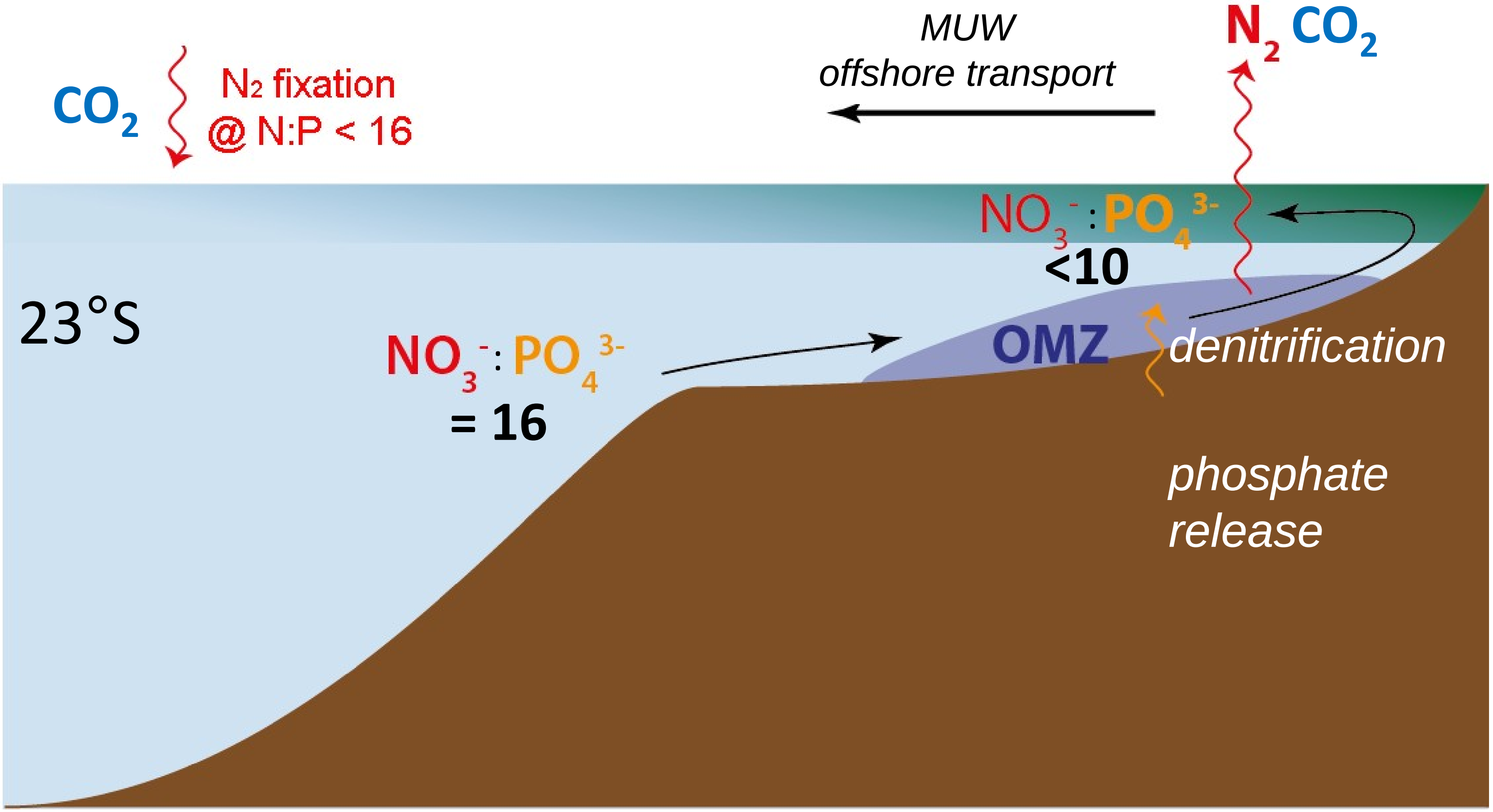


High temporal and spatial variability

N-deficit estimated to between 1.5 to 2.5 Tg N/a (Tg = 10^{12} g N)

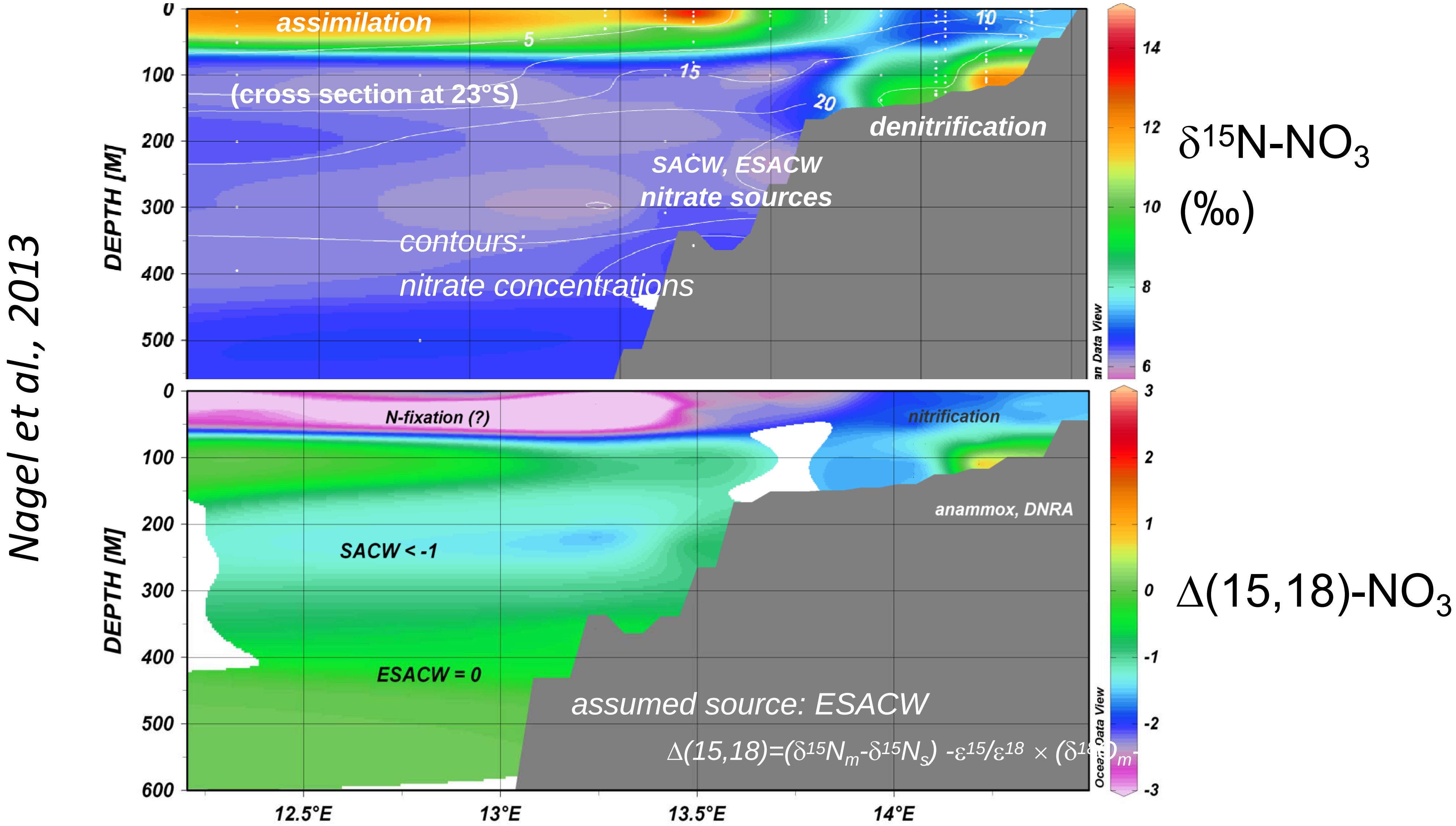
N-deficit could also be P-gain from sediment reflux

Low oxygen effects



- incoming Redfield-Ratio: N/P~16
- phosphate release from sediments and denitrification in OMZ reduce the ratio in upwelling to <10, CO_2 degassing
- compensated by N_2 fixation and CO_2 uptake offshore?

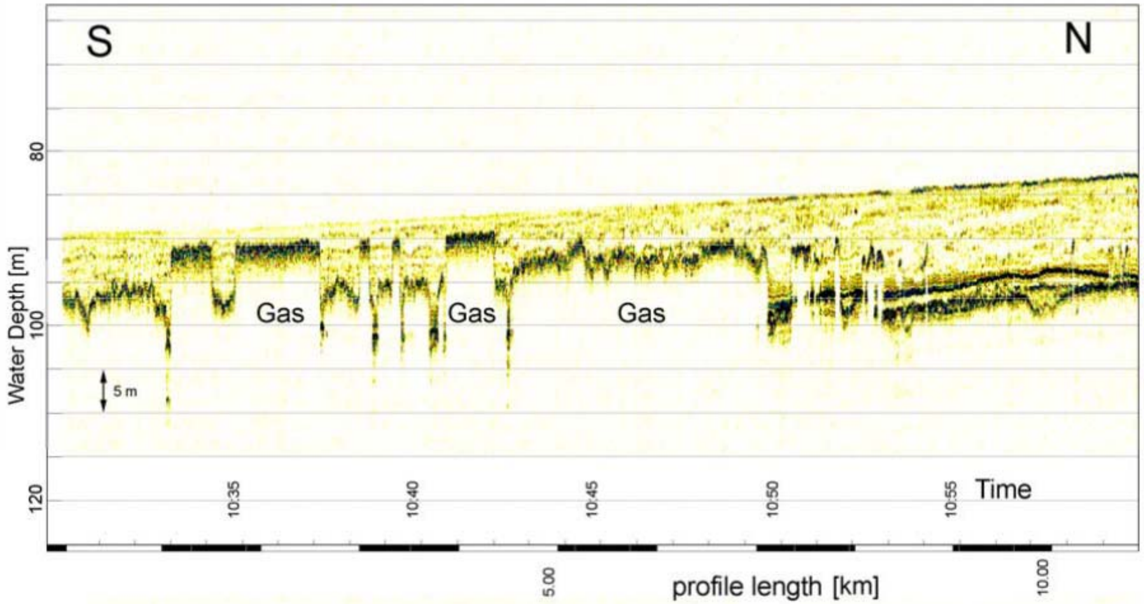
Estimate of denitrification/ nitrate isotopes



N loss due to denitrification estimated to 0.38 to 0.54 Tg (10^{12}g) N per year

at a water residence time on the shelf of 80 days and suboxic conditions for 9 months per year

Sediments on the shelf: diatomaceous muds

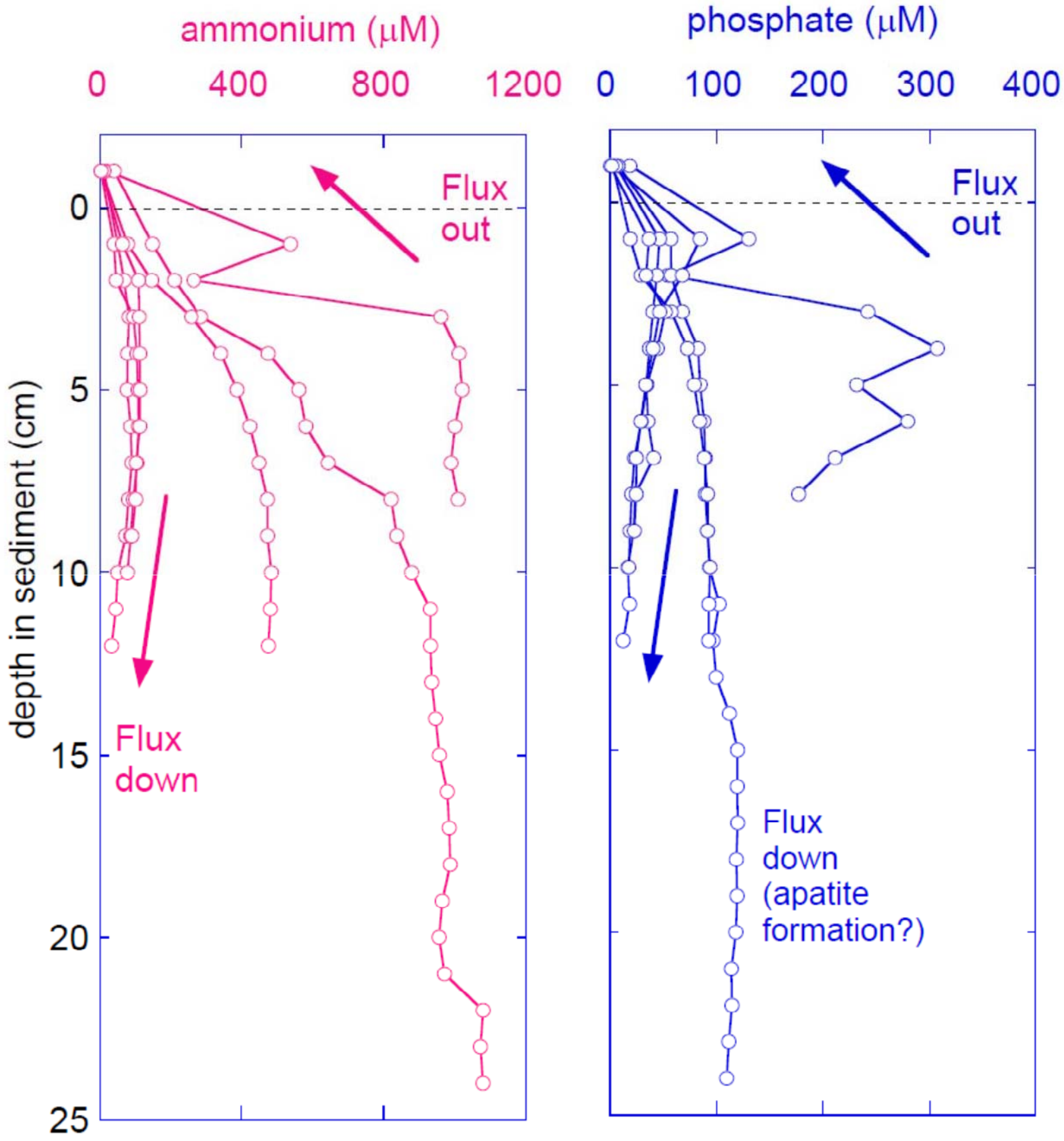


Up to 14 m thick, anoxic, filled with gas,

settled by bacteria

water content > 90%,
~10% organic carbon!

Pore water data (MSM17-3)



34 stations from 17°S to 27°S

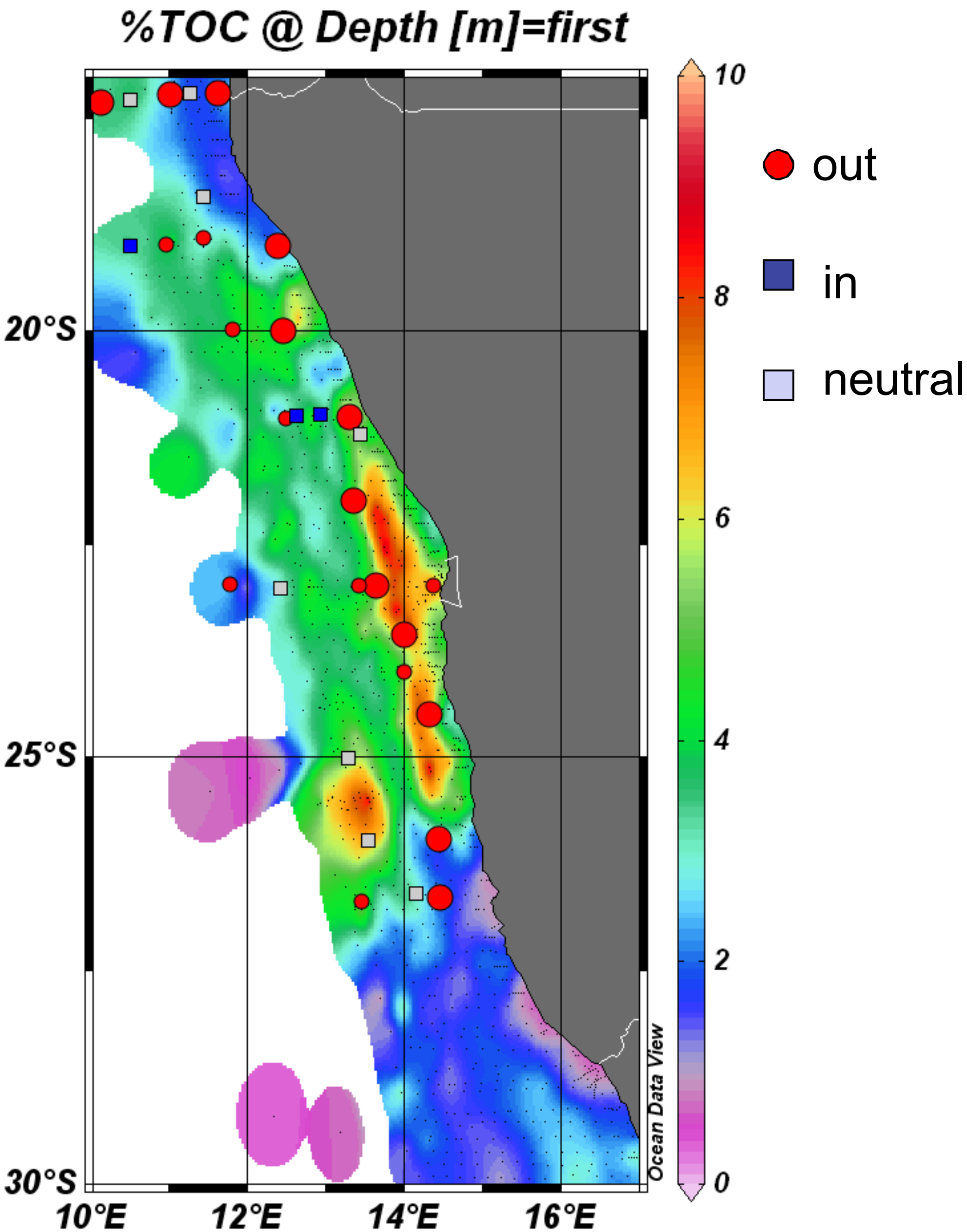
phosphate flux from
+3.3 μM m^{-2}d^{-1} (in, n=6)
-1,350 μM m^{-2}d^{-1}(out, n=28)

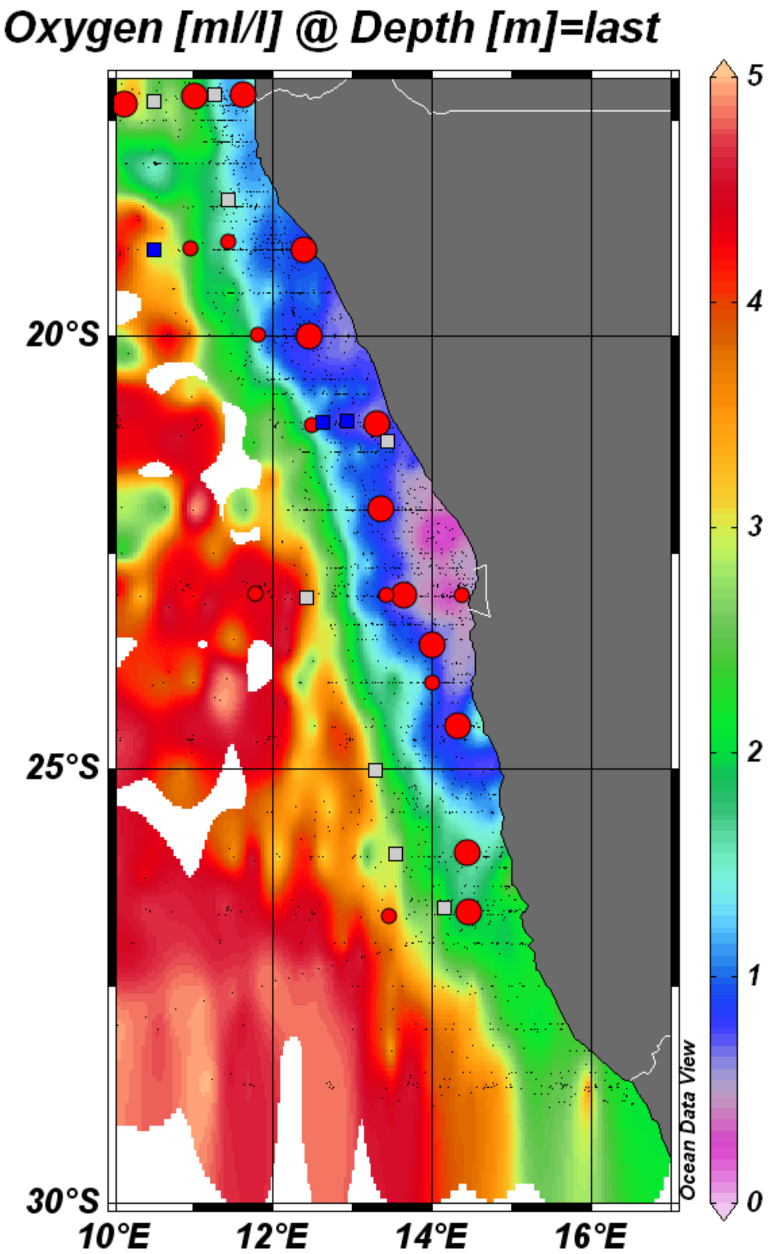
ammonium flux from
+171 μM m^{-2}d^{-1} (in)
-2,640 μM m^{-2}d^{-1}(out)

average N:P ratio outflux ~5

Neumann et al., in prep.

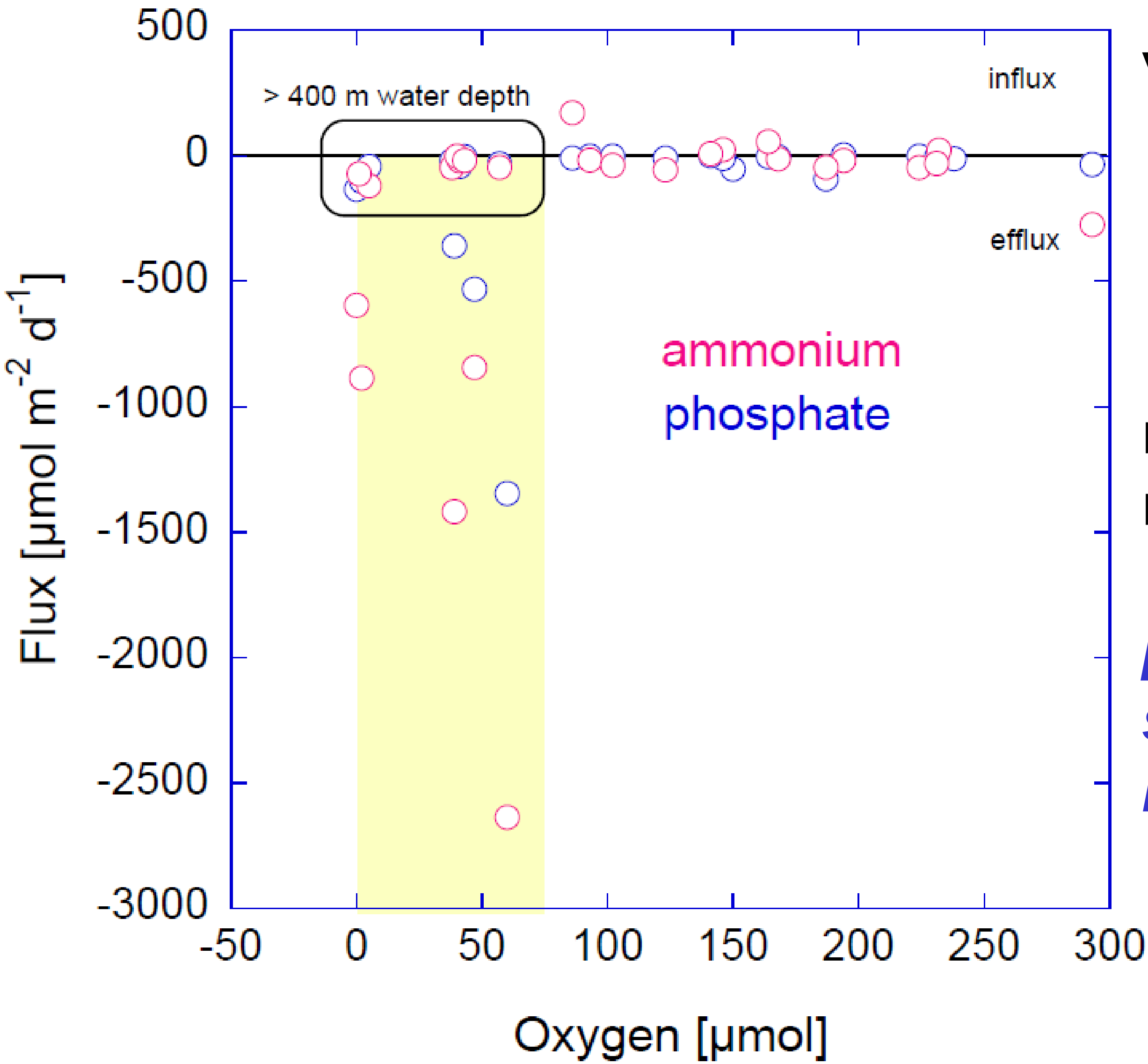
Fluxes across sediment water interface





Neumann et al., in prep.

Controls on fluxes across sediment water interface



Very rough flux estimate
@ 9 months/year
suboxic area of mud belt
~ 15.000 km^2 :

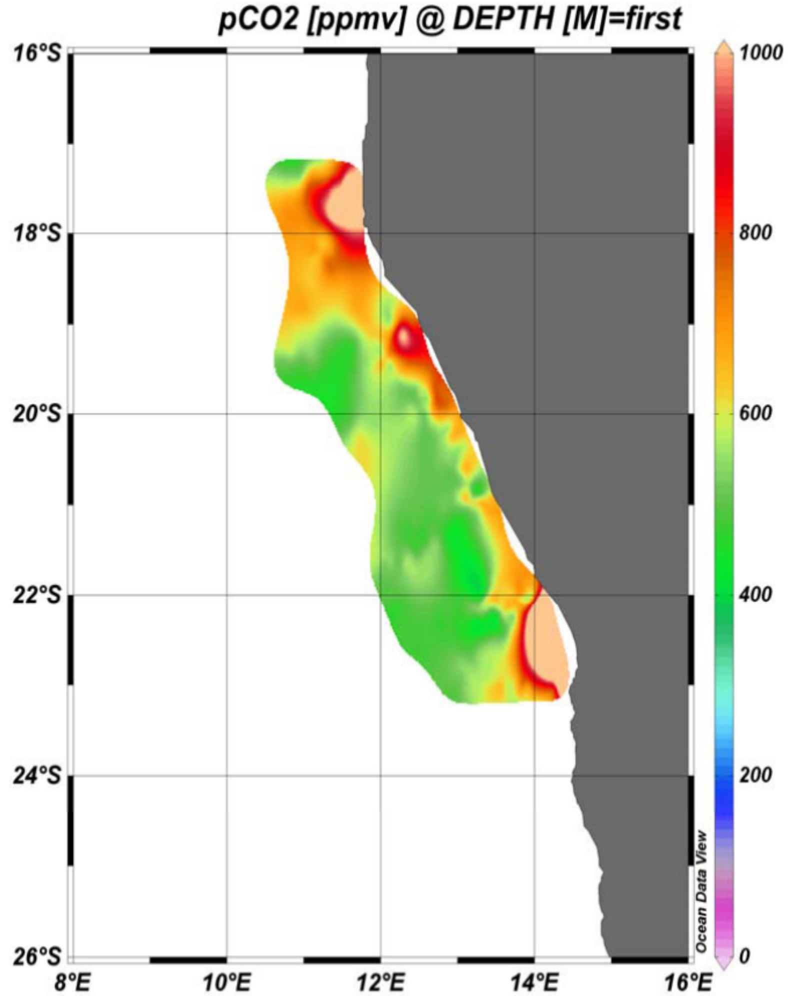
reflux ammonia: ~0.05 Tg N
reflux phosphate: ~ 0.05 Tg P

phosphate reflux from sediments explains N-deficit remaining after denitrification!

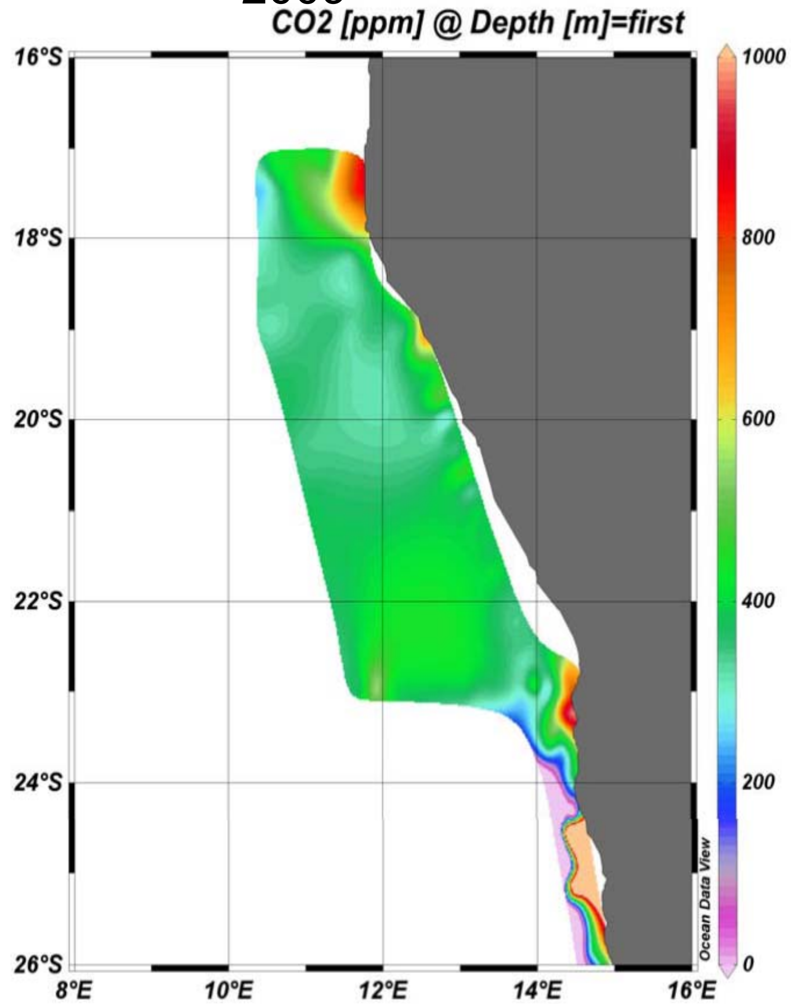
oxygen <70 µM, <400 m water depth:
median ammonium -660 ± 800 µM m^{-2} d^{-1}
median phosphate -140 ± 350 µM m^{-2} d^{-1}, median N:median P: 4.8 (M/M)

pCO_2 underway observations by FerryBox

M-76/2 May
2008

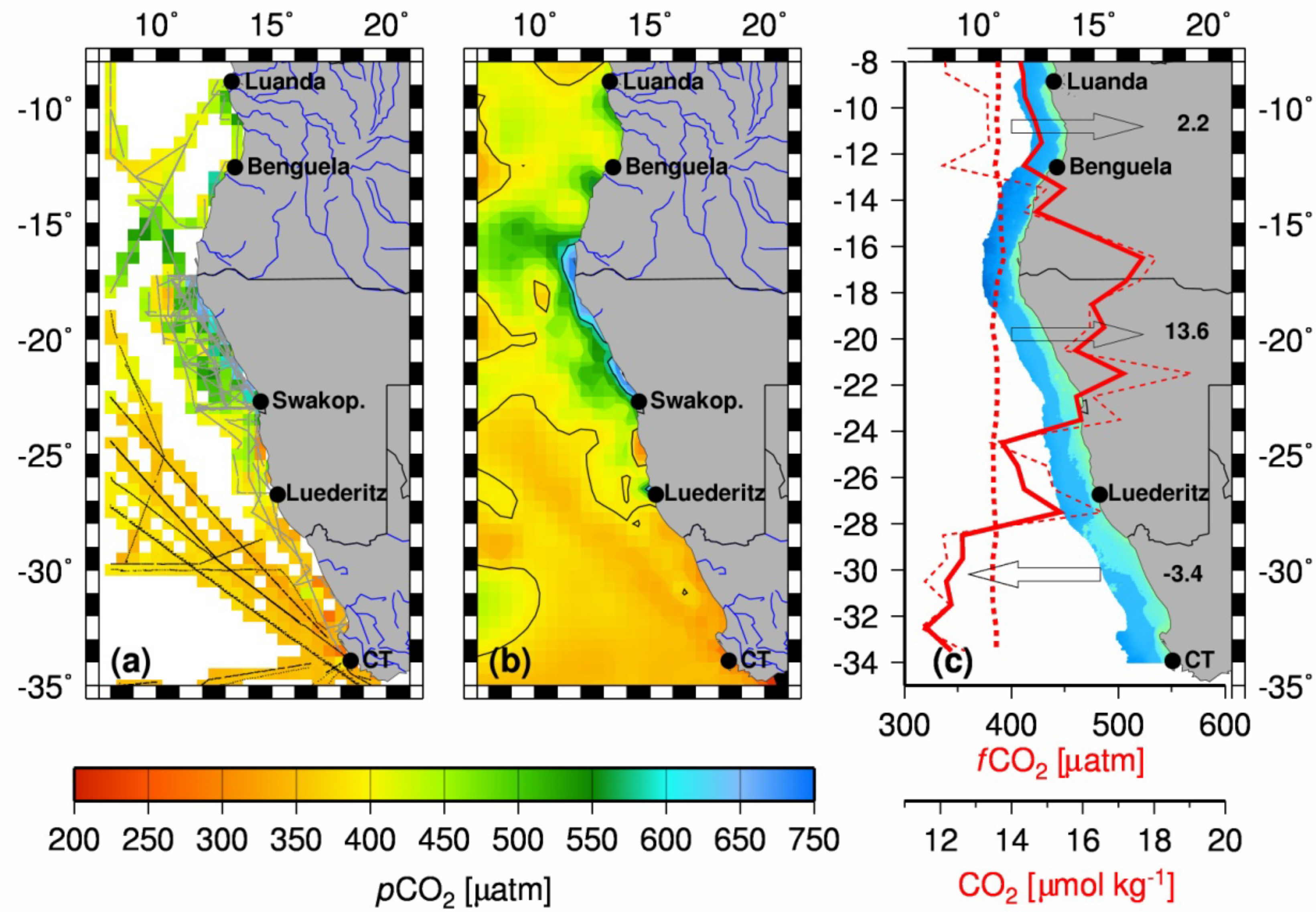


AF-258 Dec
2009



atmosphere

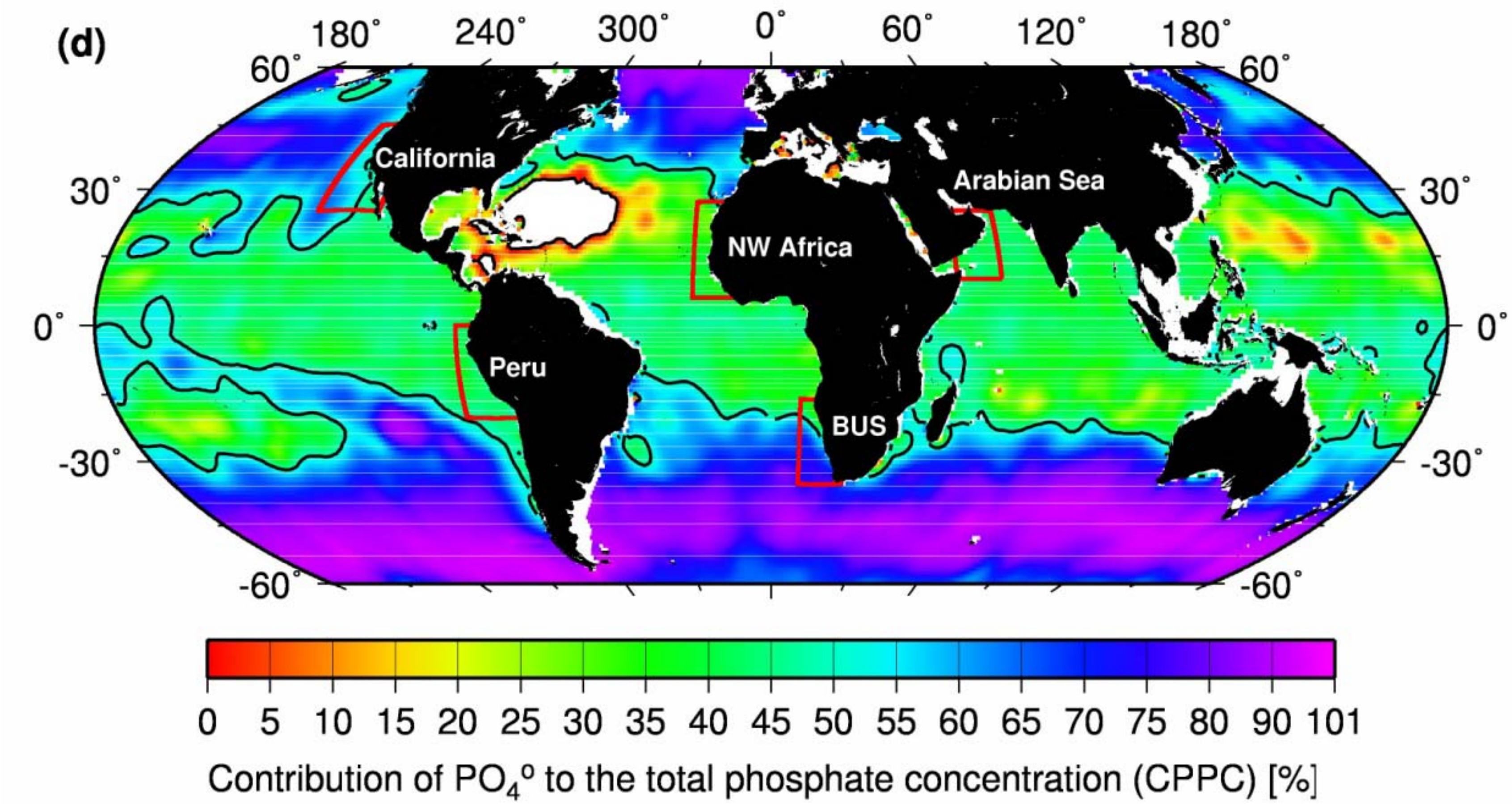
CO_2-balance of the Benguela upwelling system



moderate CO_2 uptake in S-BUS
strong CO_2 release in N-BUS

Rixen et al., in prep.

Why this variability?



Southern sector: Significant assimilation of pre-formed phosphate that is not associated with CO_2 → CO_2 is taken up from the atmosphere

Northern sector: Upwelling of phosphate mainly from organic matter recycling → outgassing of CO_2 liberated from organic matter during recycling

Conclusions? Research needs!

a) Clarify the trend of oxygenation in the BUS by observation and modeling, geological archives, search for/recognise remote forcing

b) Expand the view beyond the immediate BUS and look for changes in the adjacent hemipelagic ocean to test if upwelling fertilisation occurs; further clarify the role of material exchange at the sediment-water interface; quantify N_2 fixation (why is it not ubiquitous?)

c) Investigate the short-term and small-scale dynamics in the coupled CO_2, N, P, Si and O_2 system of matter fluxes, explore the links to biological productivity and foodwebs patterns (current r/v *Meteor* expedition 100)