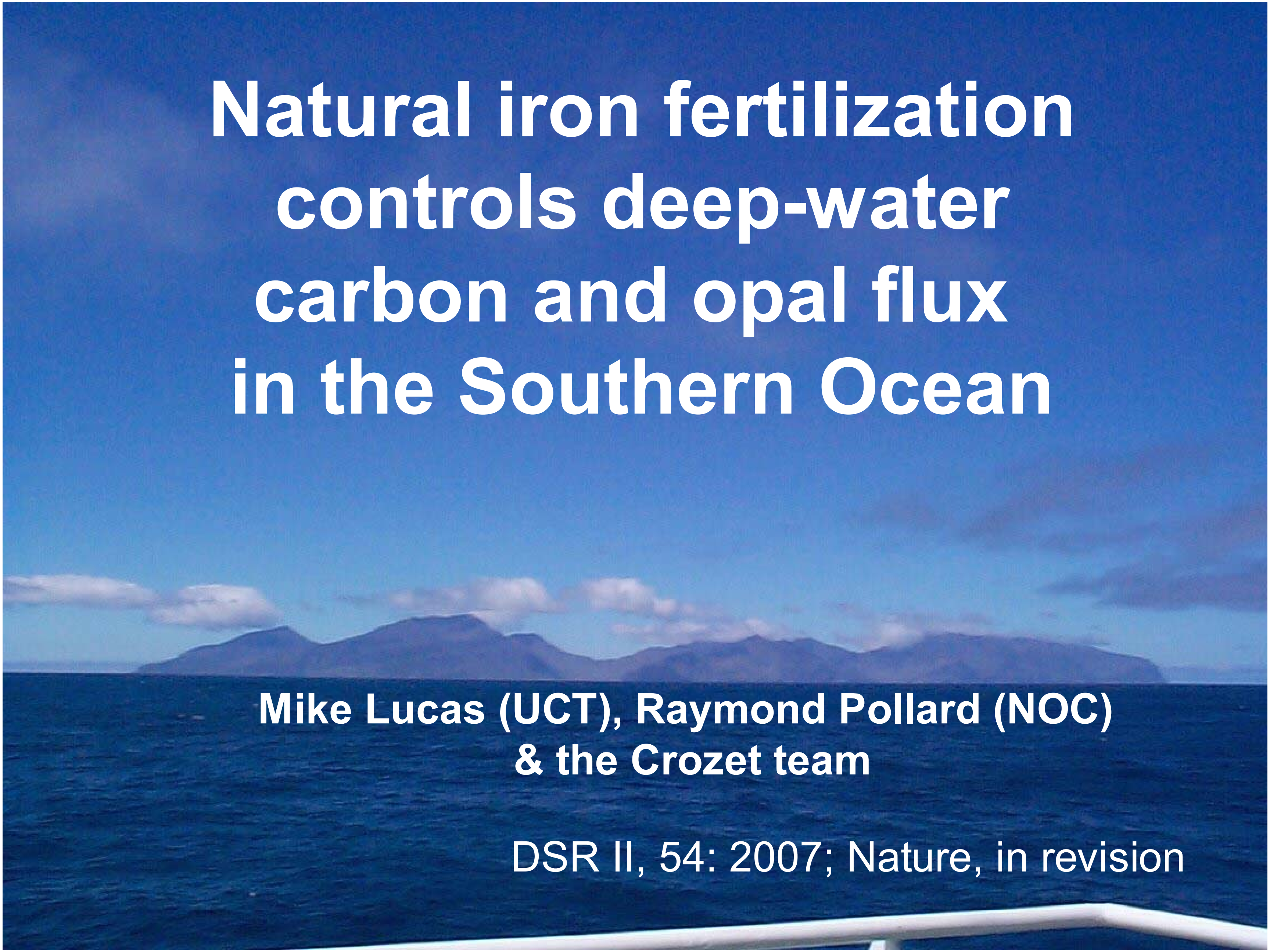
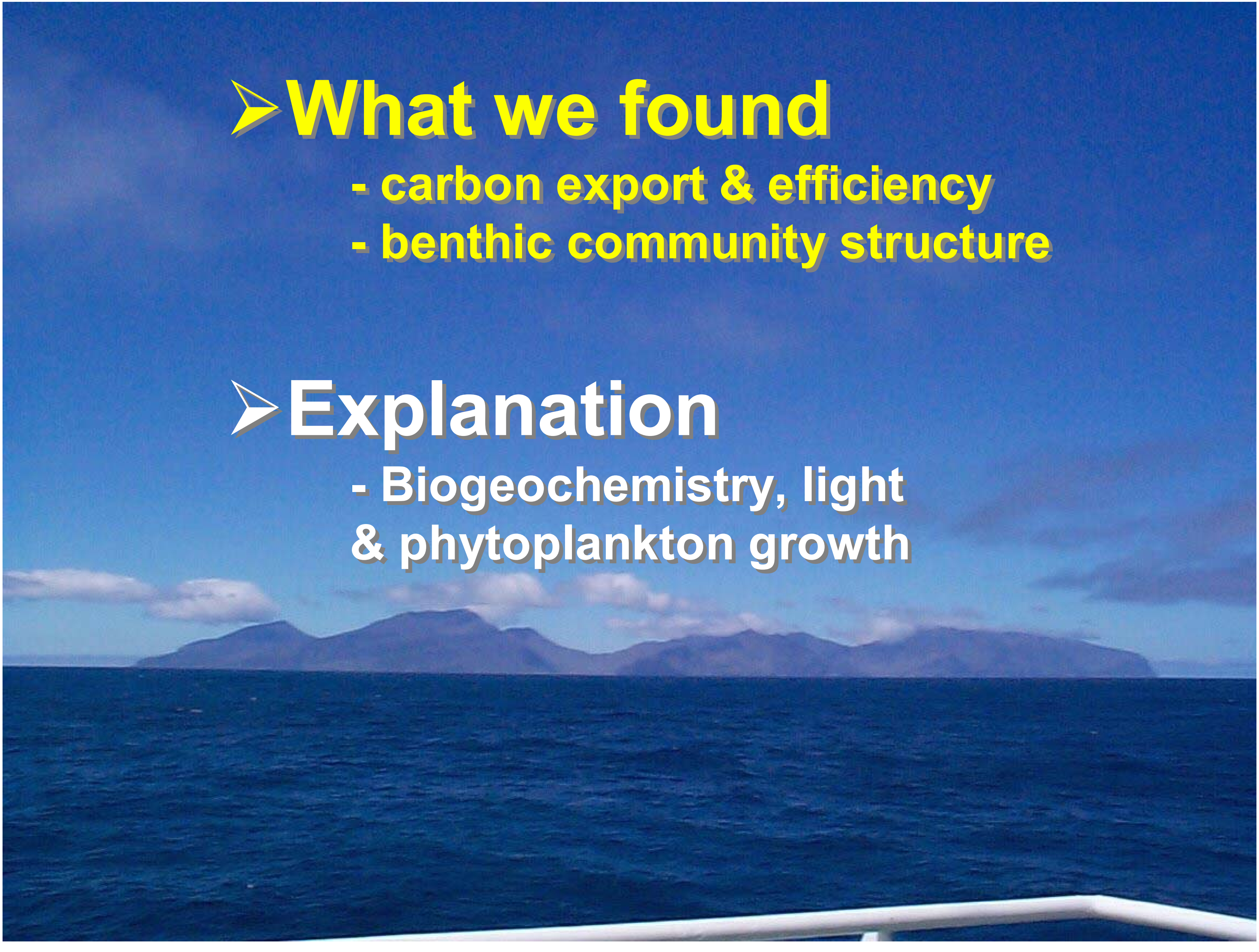
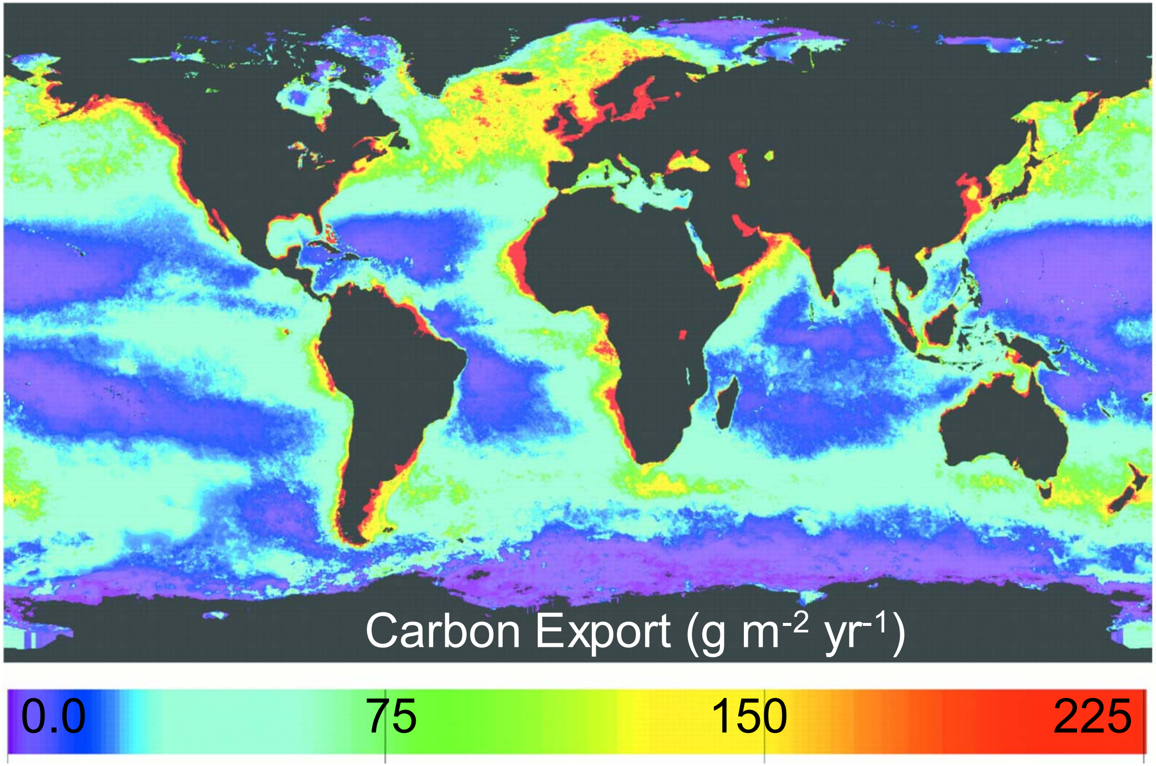


Natural iron fertilization controls deep-water carbon and opal flux in the Southern Ocean

Mike Lucas (UCT), Raymond Pollard (NOC)
& the Crozet team

DSR II, 54: 2007; Nature, in revision


What we found
- carbon export & efficiency
- benthic community structure
Explanation
- Biogeochemistry, light
& phytoplankton growth

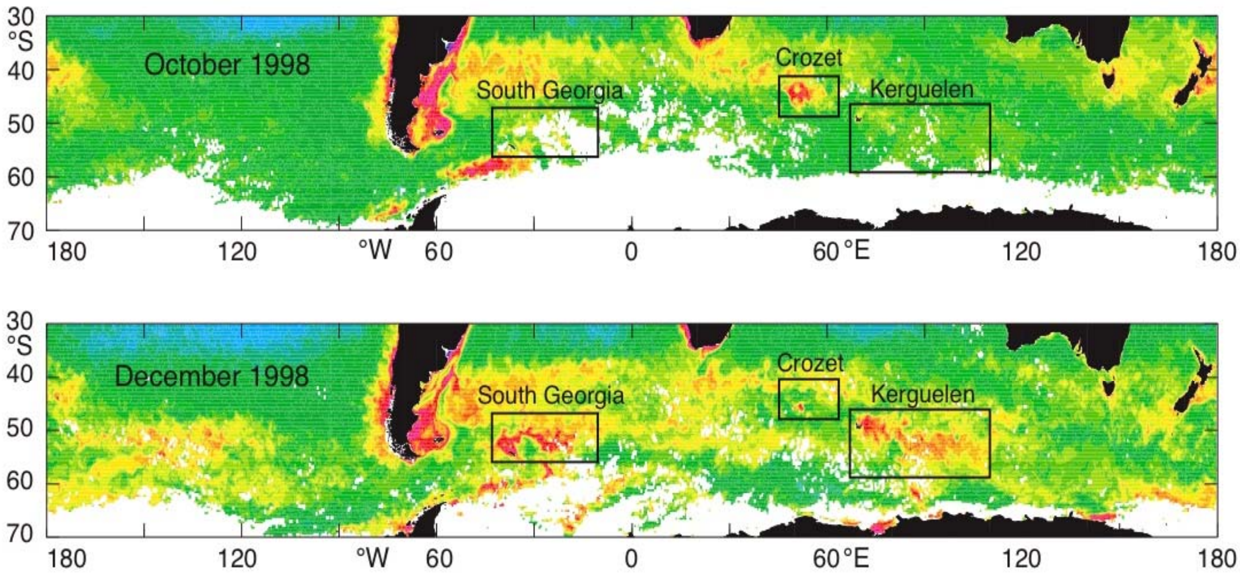


Low C. export in high nutrient Southern Ocean.

Due primarily to Fe limitation.

Would alleviation of Fe limitation enhance C. export?

Test this hypothesis from observations of blooms around sub-Antarctic Islands

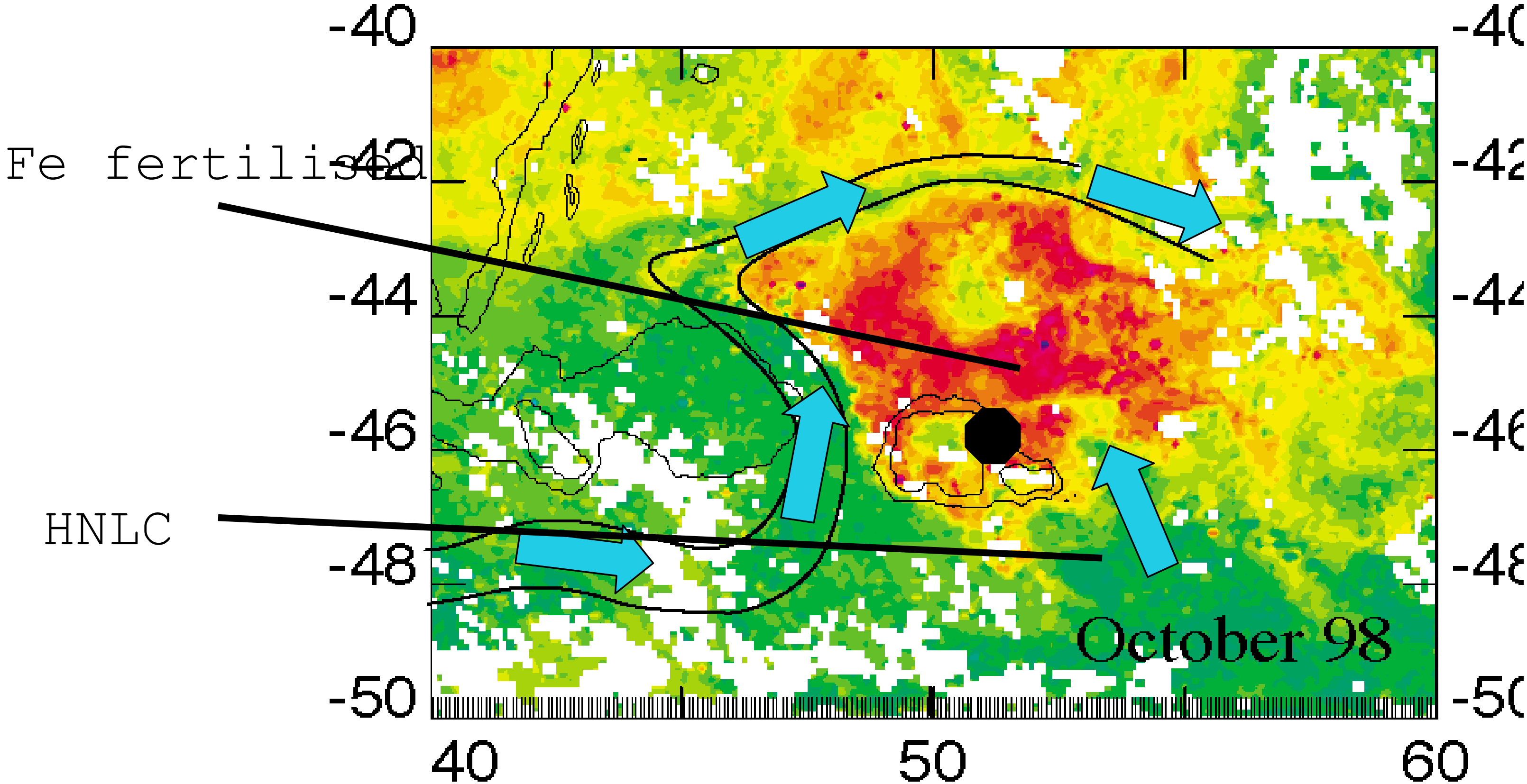


Pollard et al., DSR II, 54: 2007

Fig. 1

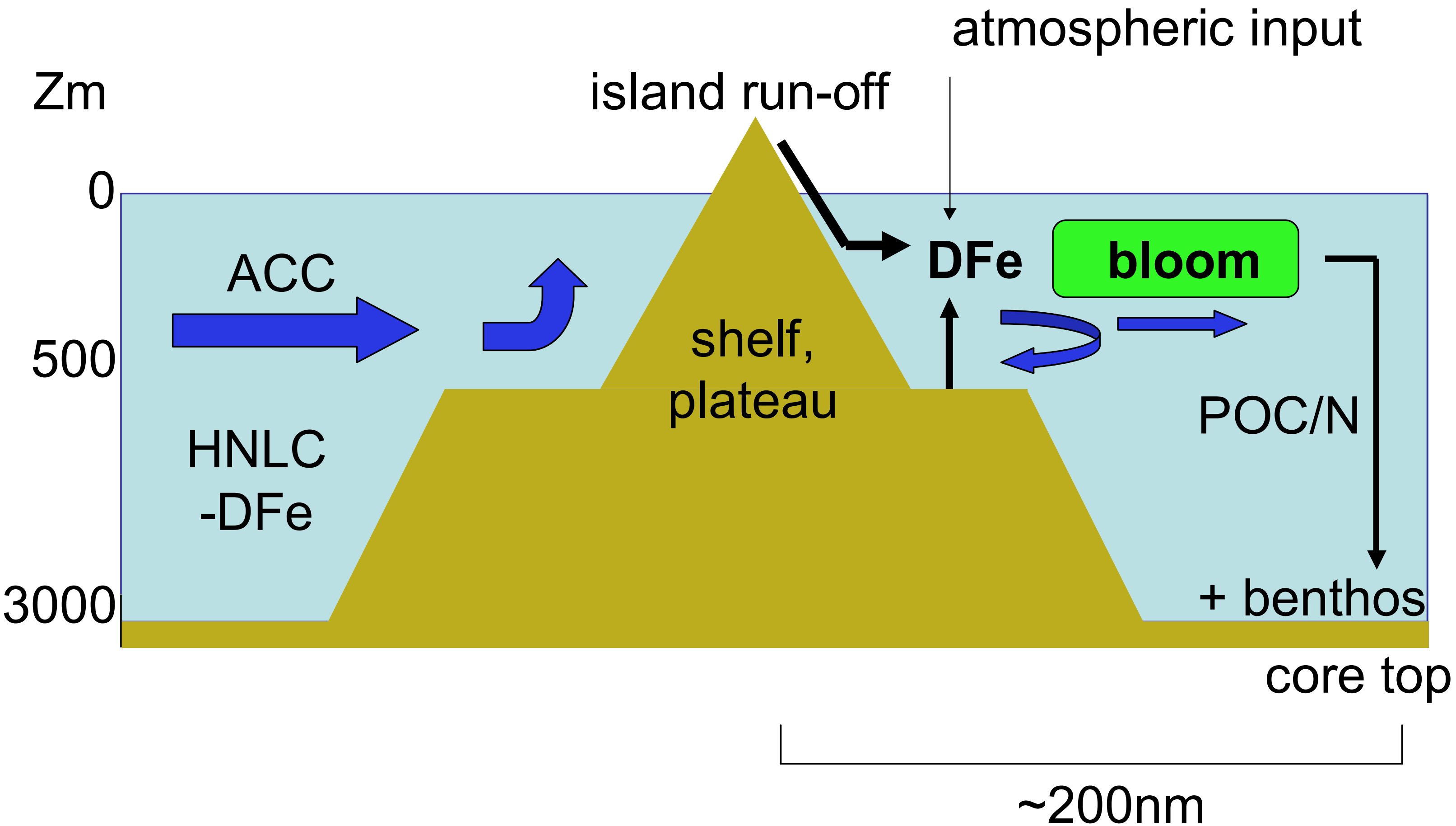
Test carbon export wrt Fe Fertilisation

(Pollard, Sanders, Lucas, Statham et al. 2007)



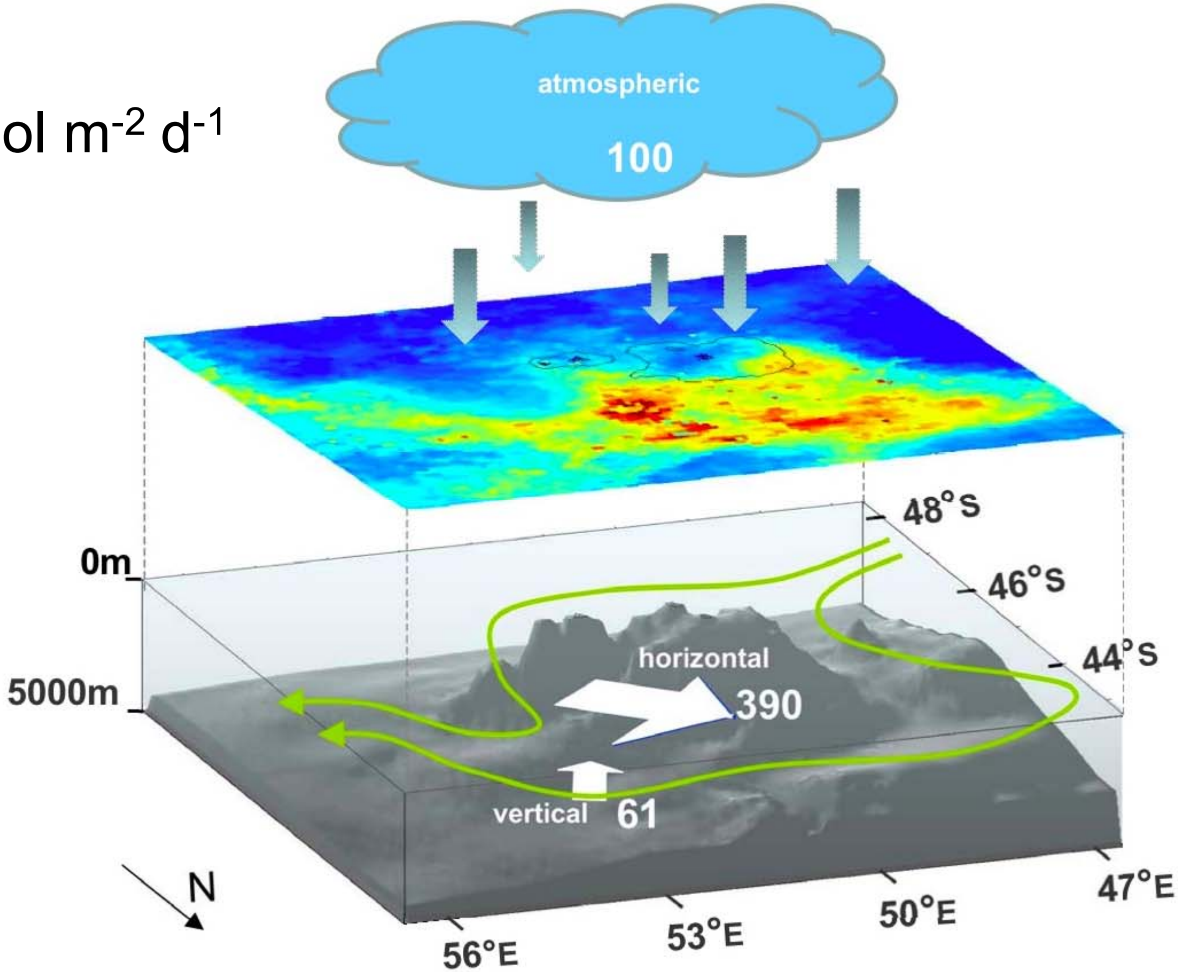
General Hypothesis: HNLC water sweeps north across the Crozet plateau and becomes *naturally* Fe fertilised from shallow (<1000m) sediments

Control of phytoplankton bloom and POC/N export around the Crozet Islands



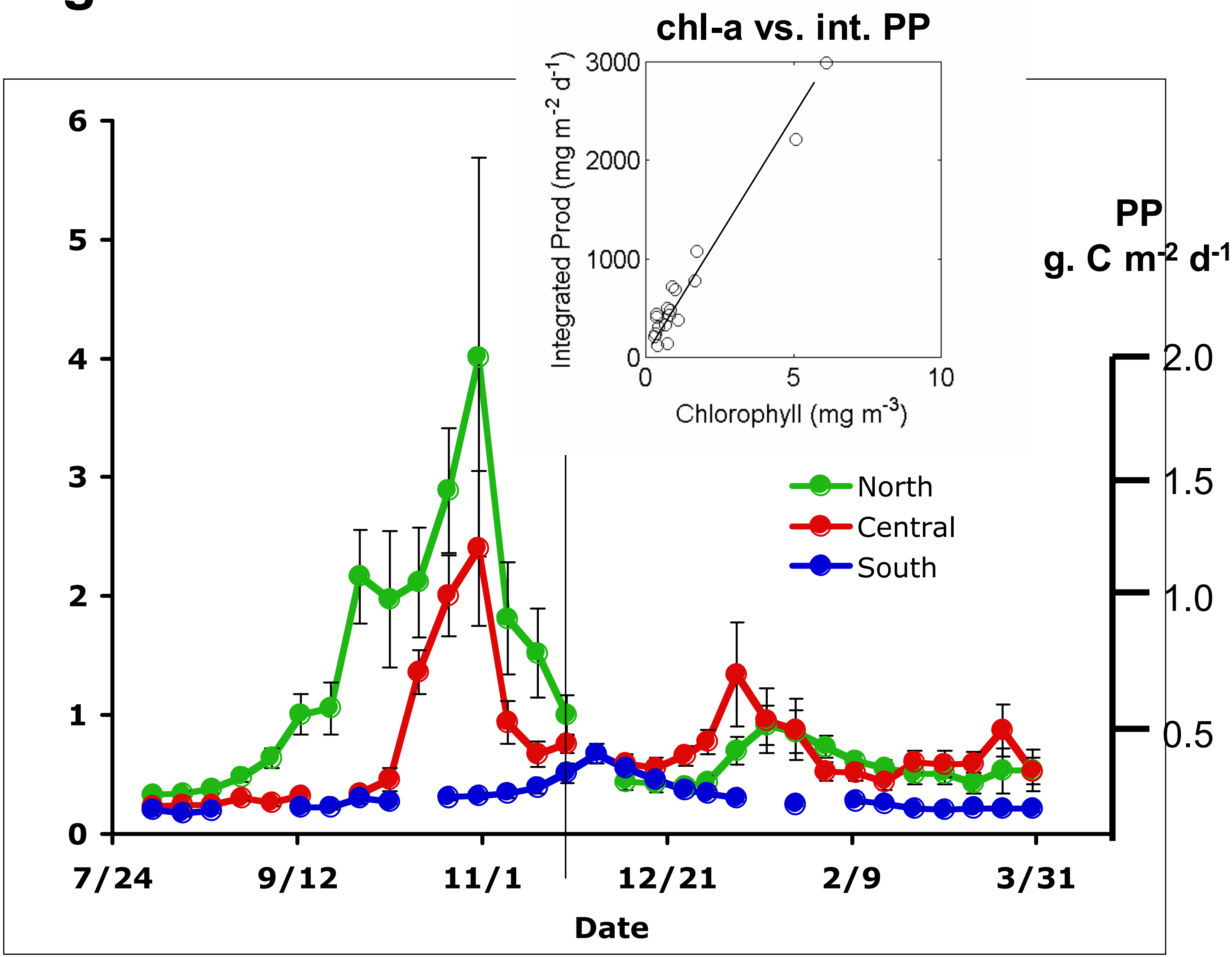
1) Iron inputs: DFe fluxes (nmol m^{-2} d^{-1})

Total:
551nmol m^{-2} d^{-1}

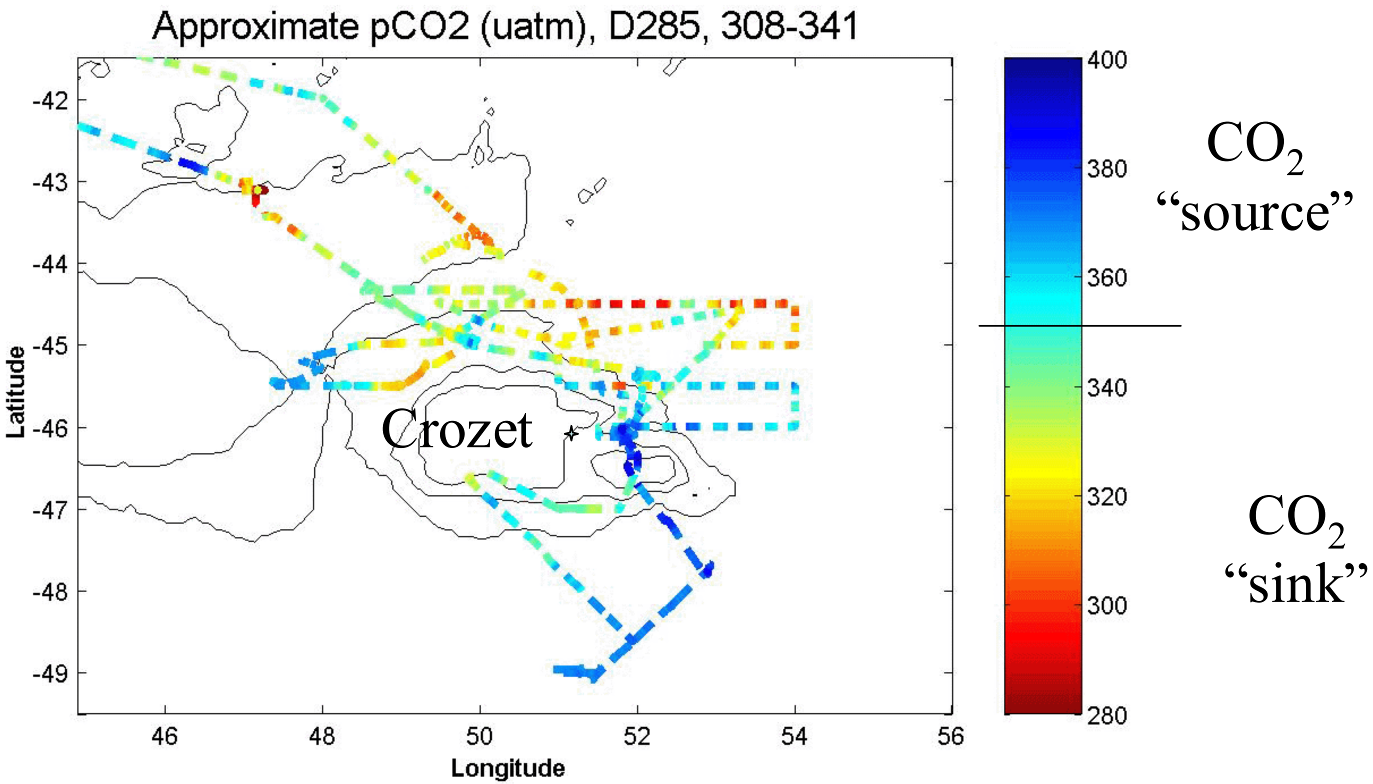


Planquette et al., DSR II, 54: 2007

2.) Magnitude of bloom

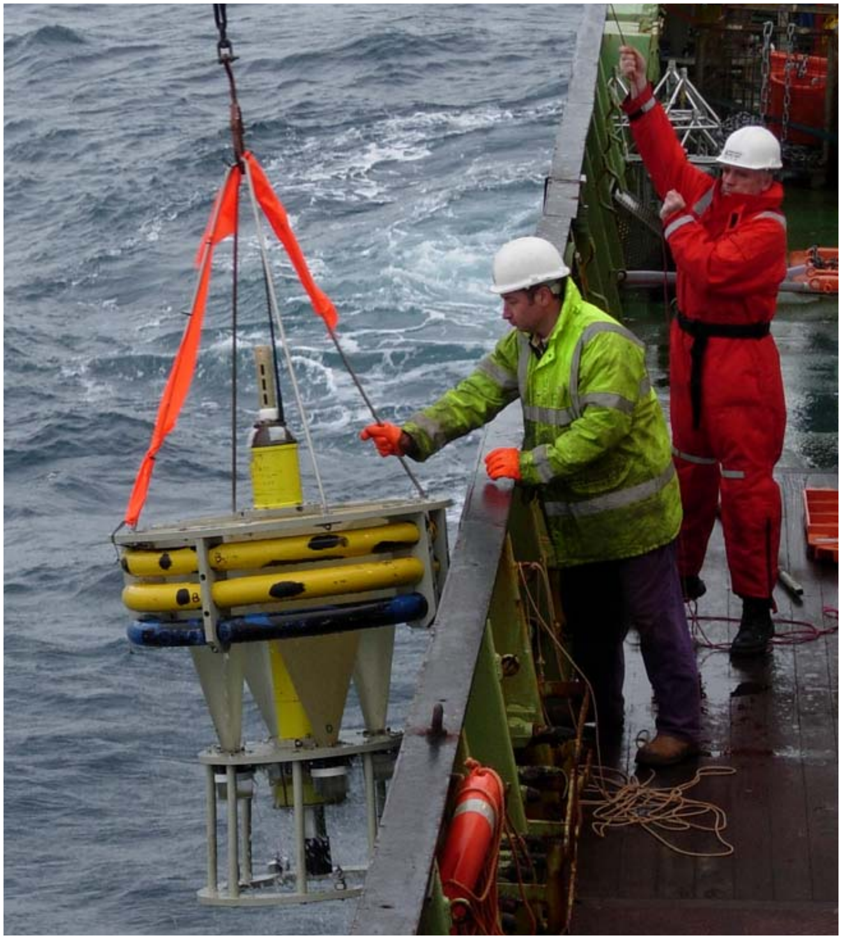


Under-saturation of surface pCO_2 in regions of high production



D. Bakker et al, DSR, *in press*

Carbon Export Measurements



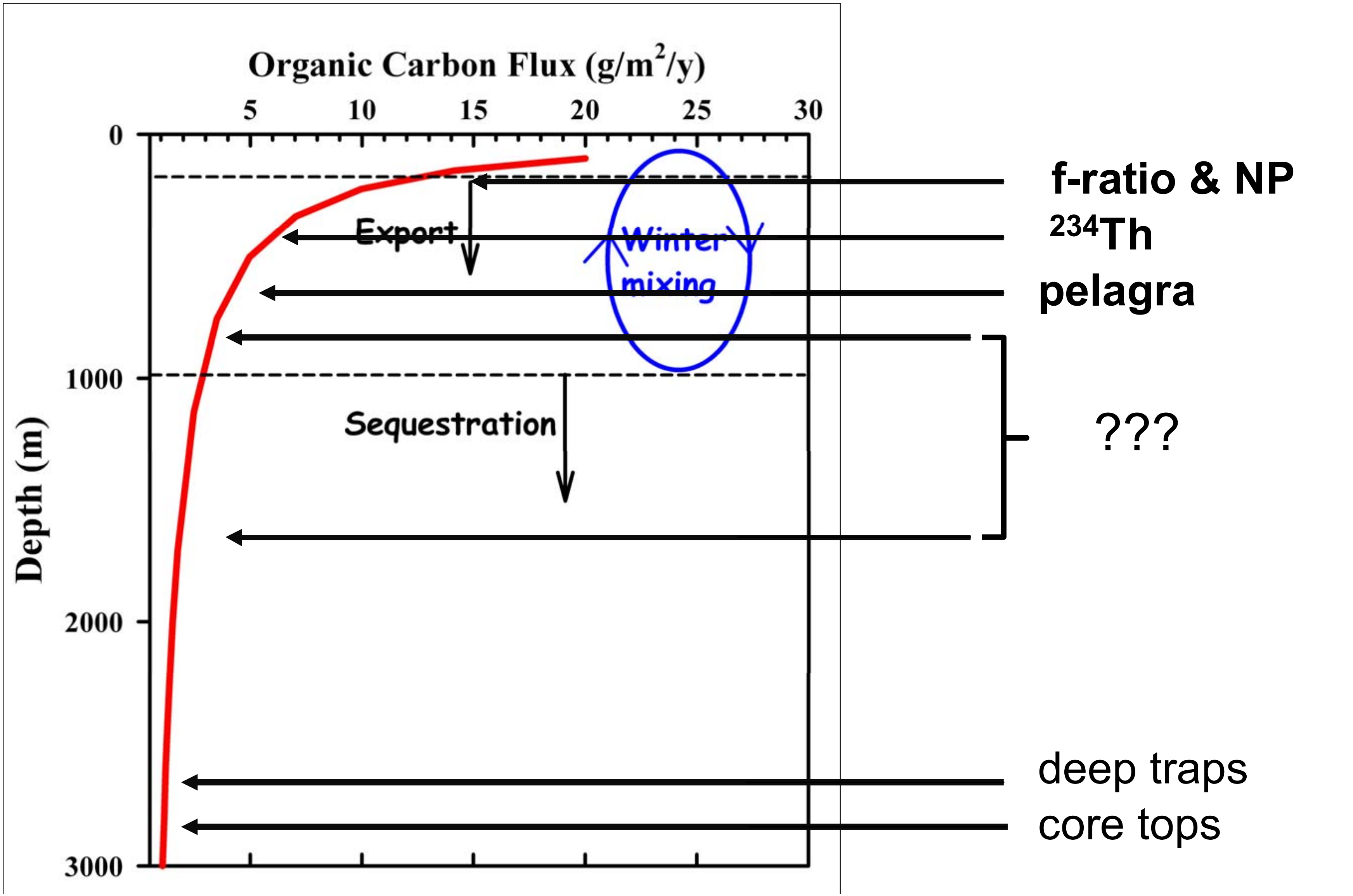
1) ^{15}N stable isotopes & f-ratio. (~55m) (Lucas)

2) "Pelagra"; Pelagic lagrangian sediment trap @ ~250m. (Sanders)

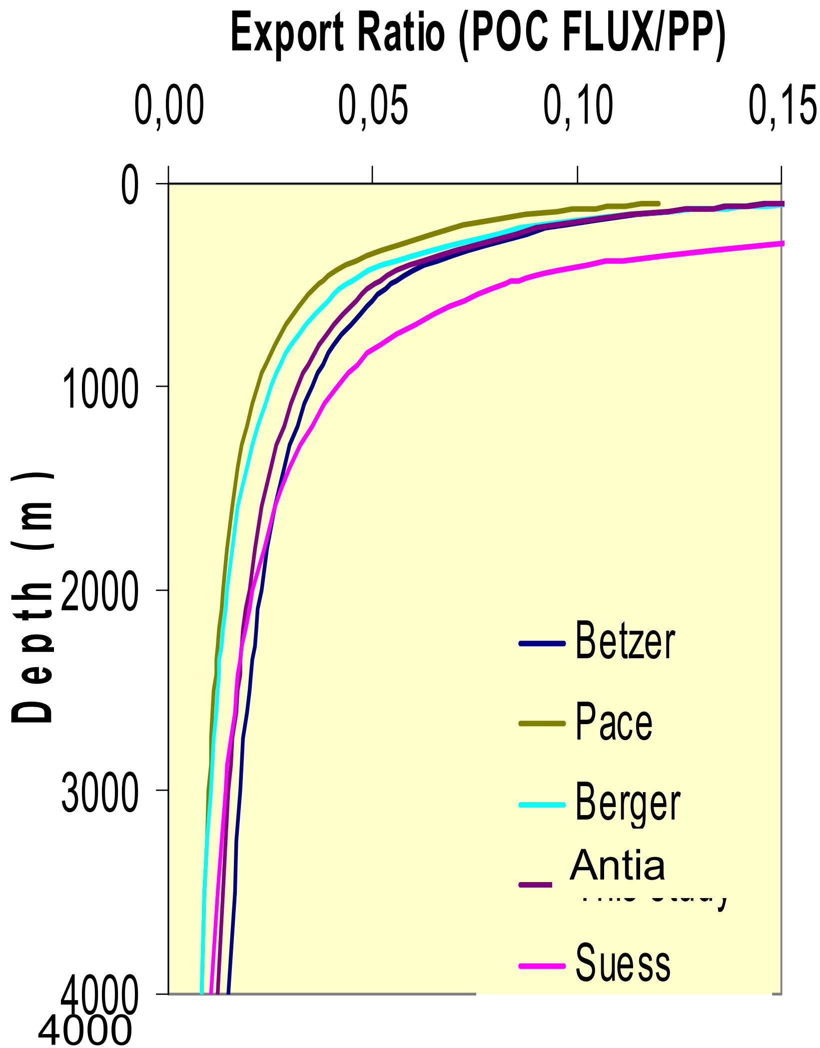
3) ^{234}Th / ^{238}U (~150m) (Morris & Thomalla)

4) long-term (~1yr) deep moorings (~3000m)

Does + Fe result in C sequestration?



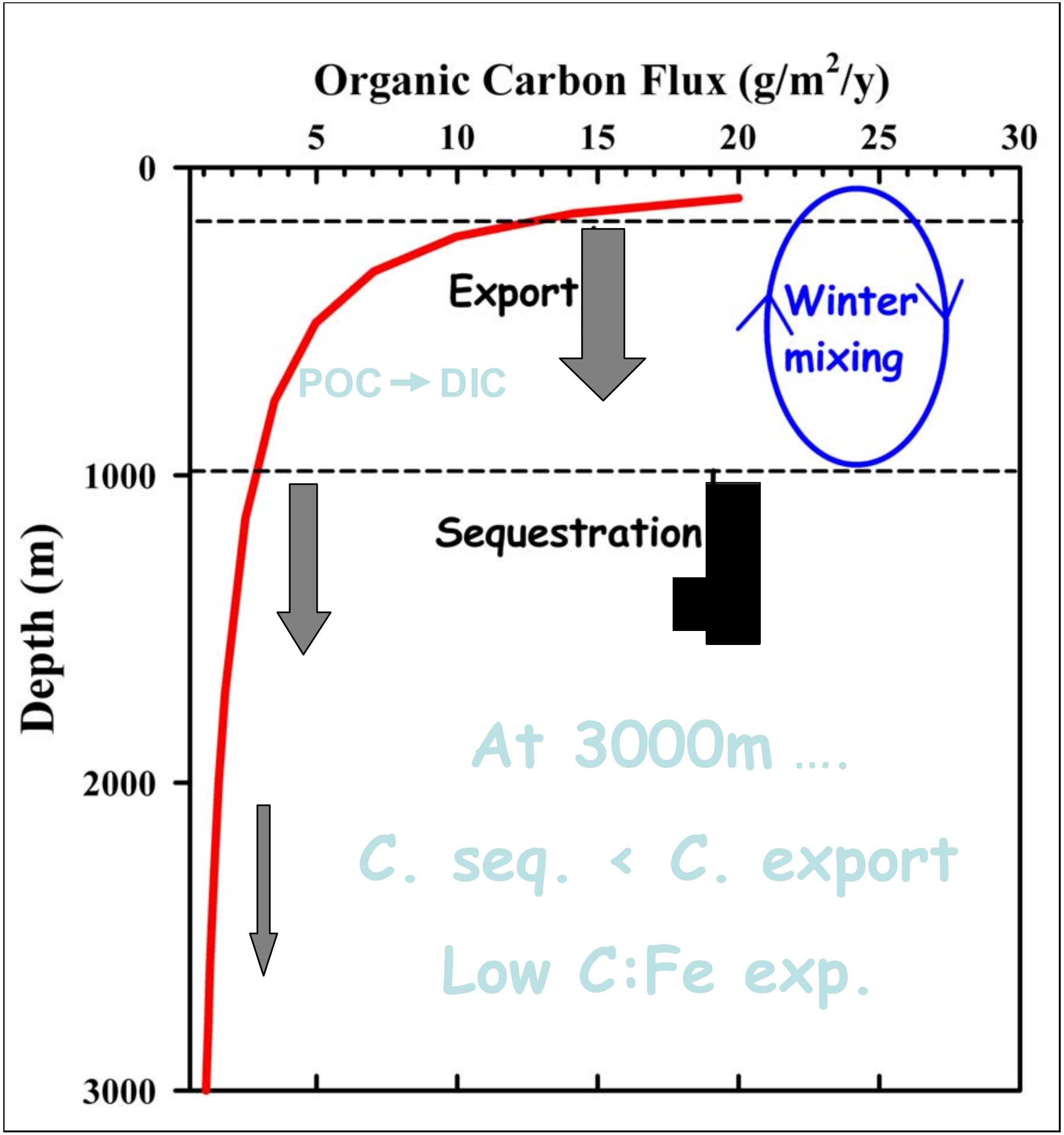
Carbon export results consistent with Martin curve



Limited C sequestered

Deep Traps

3000 m



Reality of C. removed by Fe.

Interglacial to Glacial ~60 billion tonnes

Early 1990's climate models based on lab exps:-
Fe-fertilisation of entire S.O. removes 1-2 billion tonnes C / yr
(~10-25% of current CO_2 emissions)

Natural Fe fertilisation (Blain et al., '07, Pollard et al., '07:-
1 tonne Fe exports just ~1000 tonnes carbon to 3000m
(Scaled to entire S.O. is << 1% of current CO_2 emissions)

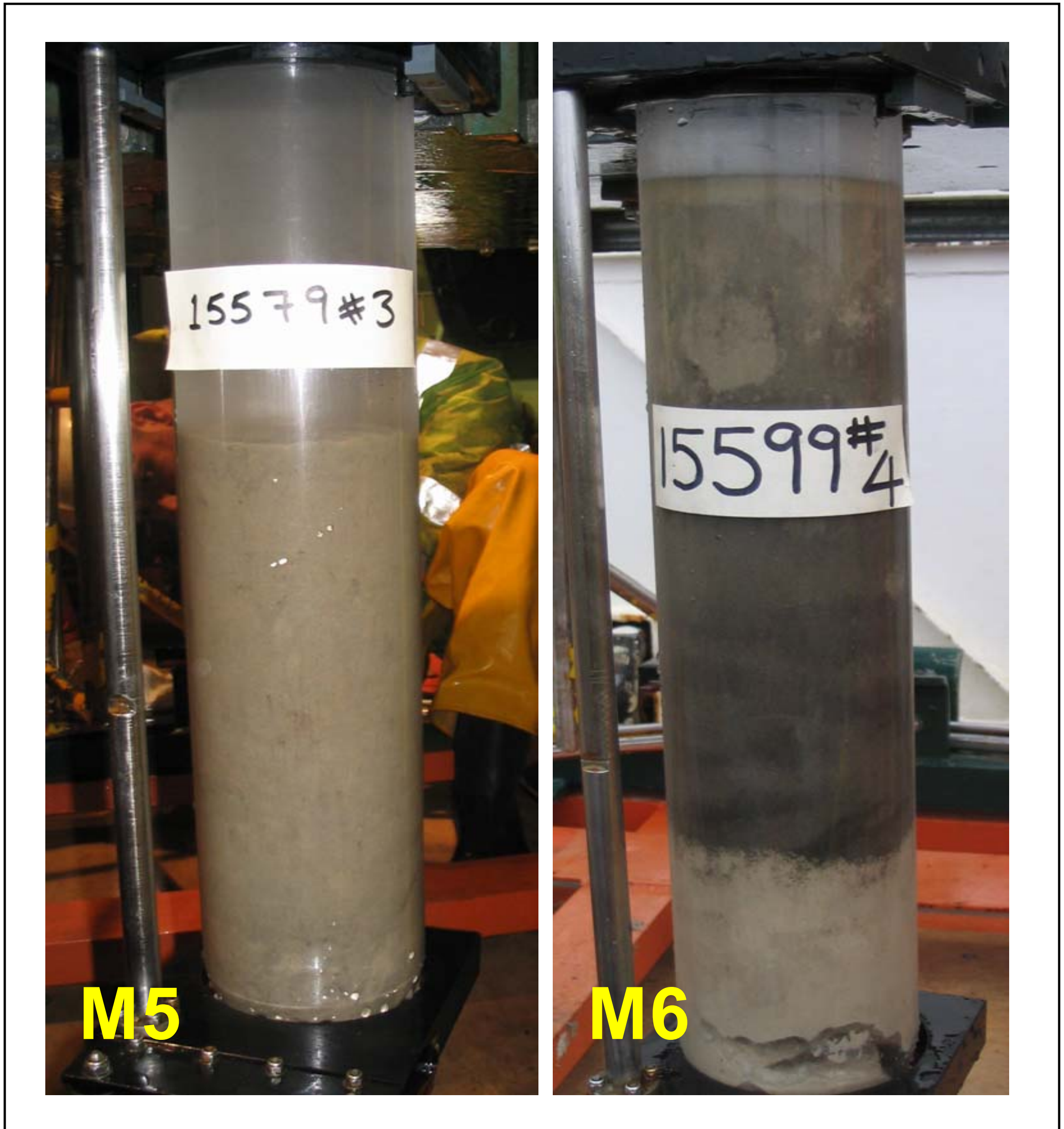
Benthic Communities?

Comparisons:

M5 - downstream +Fe region

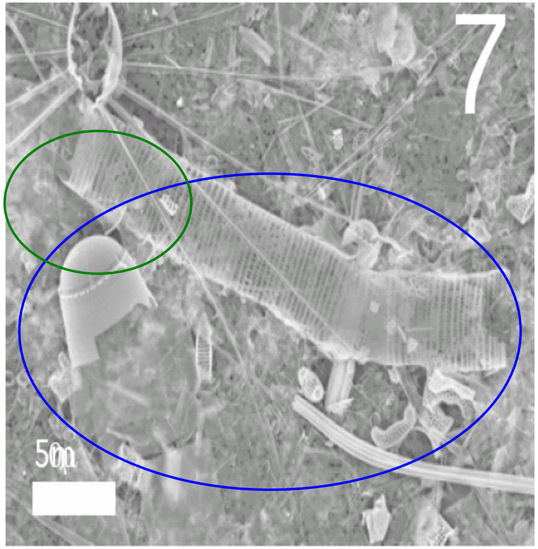
M6 - HNLC -Fe region

+ Fe



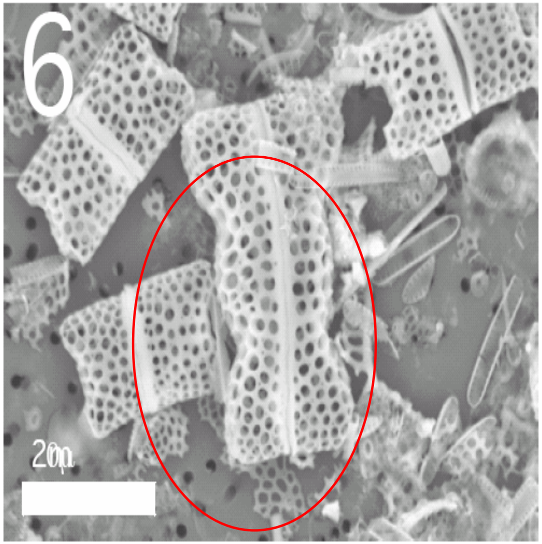
- Fe

Particulate material rich in diatom frustules



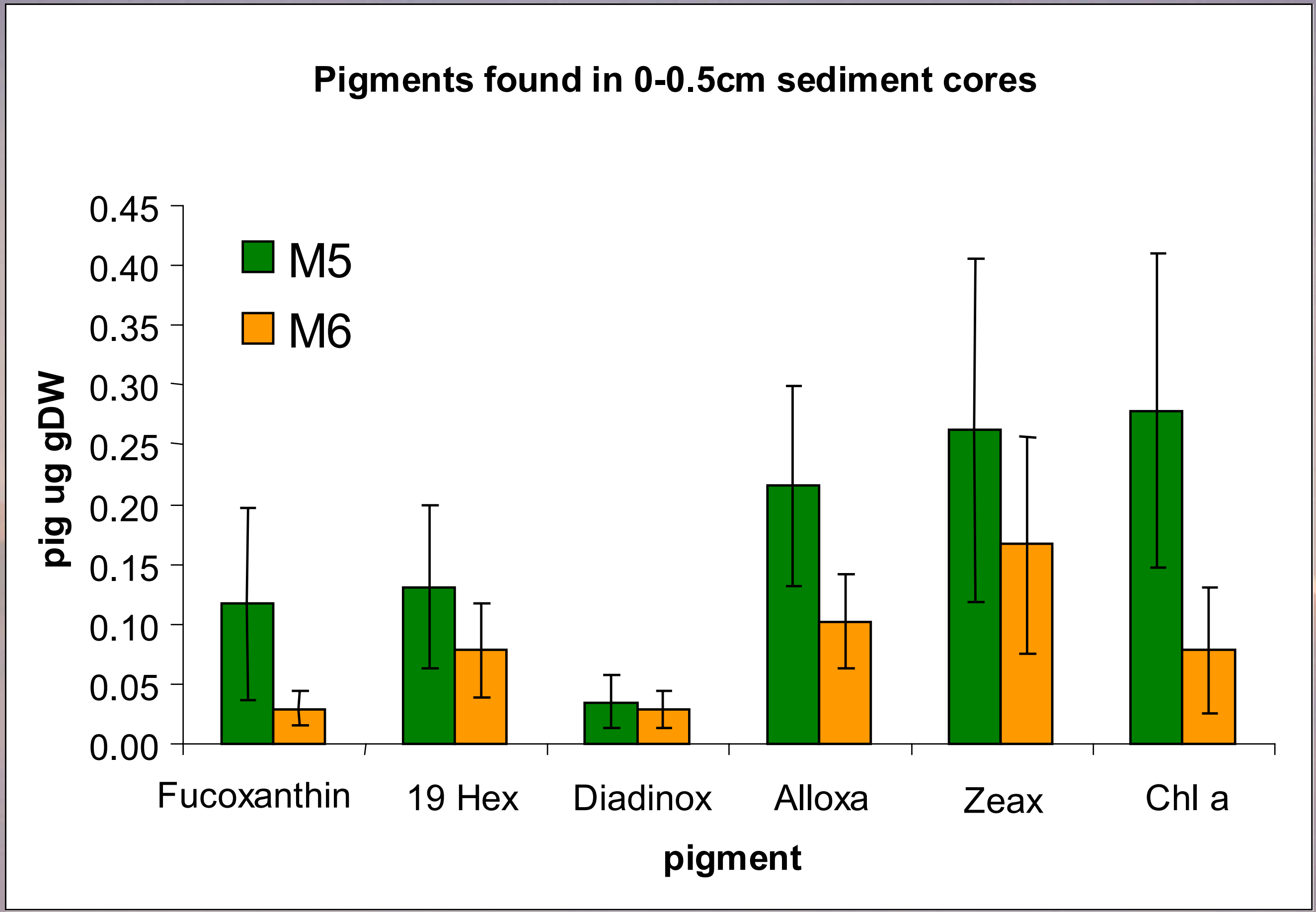
D. antarcticus

C. criophilium



E. antarctica

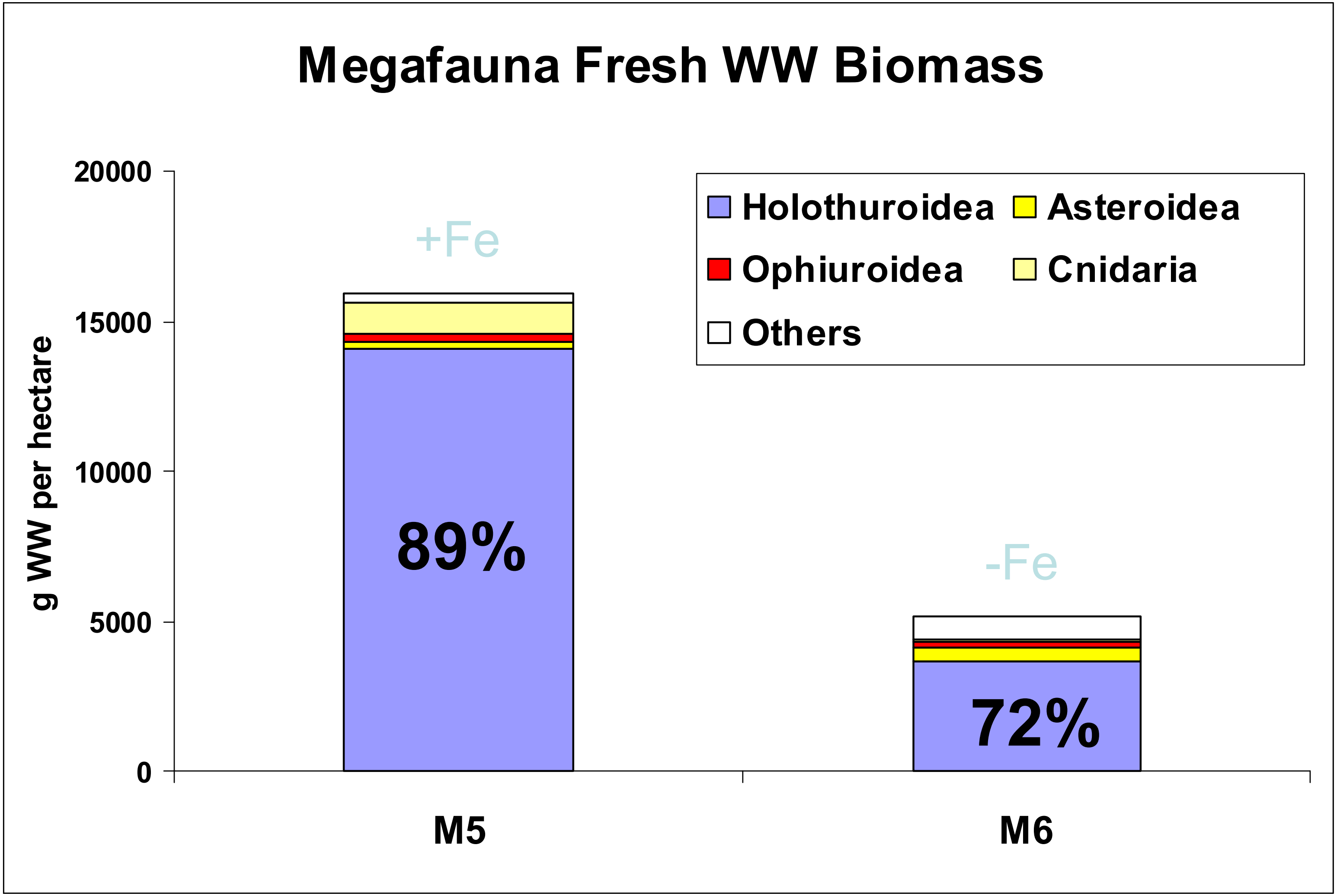
HPLC Pigment analyses

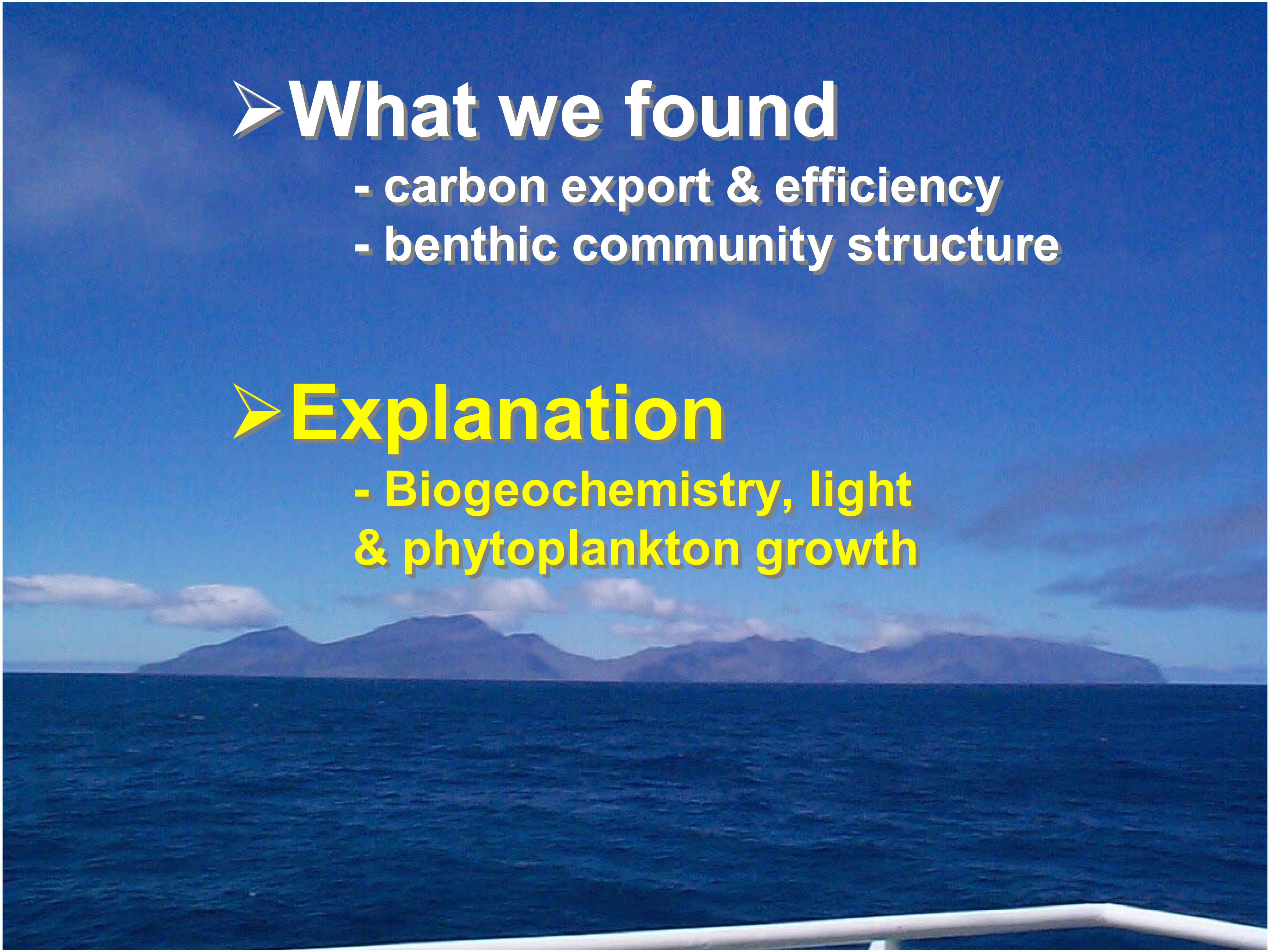


Stations significantly different ($P < 0.02$)

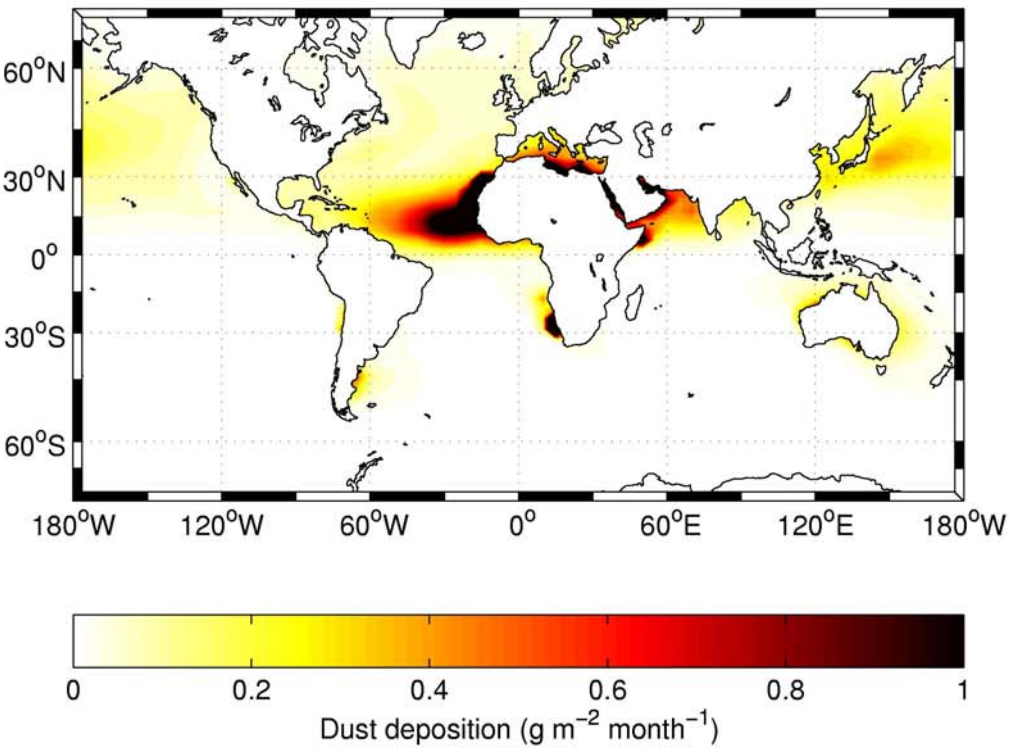
Tania Smith

Mega-benthos Biomass




What we found
- carbon export & efficiency
- benthic community structure
Explanation
- Biogeochemistry, light
& phytoplankton growth

Atmospheric Dust Deposition ($g\ m^{-2}\ month^{-1}$)

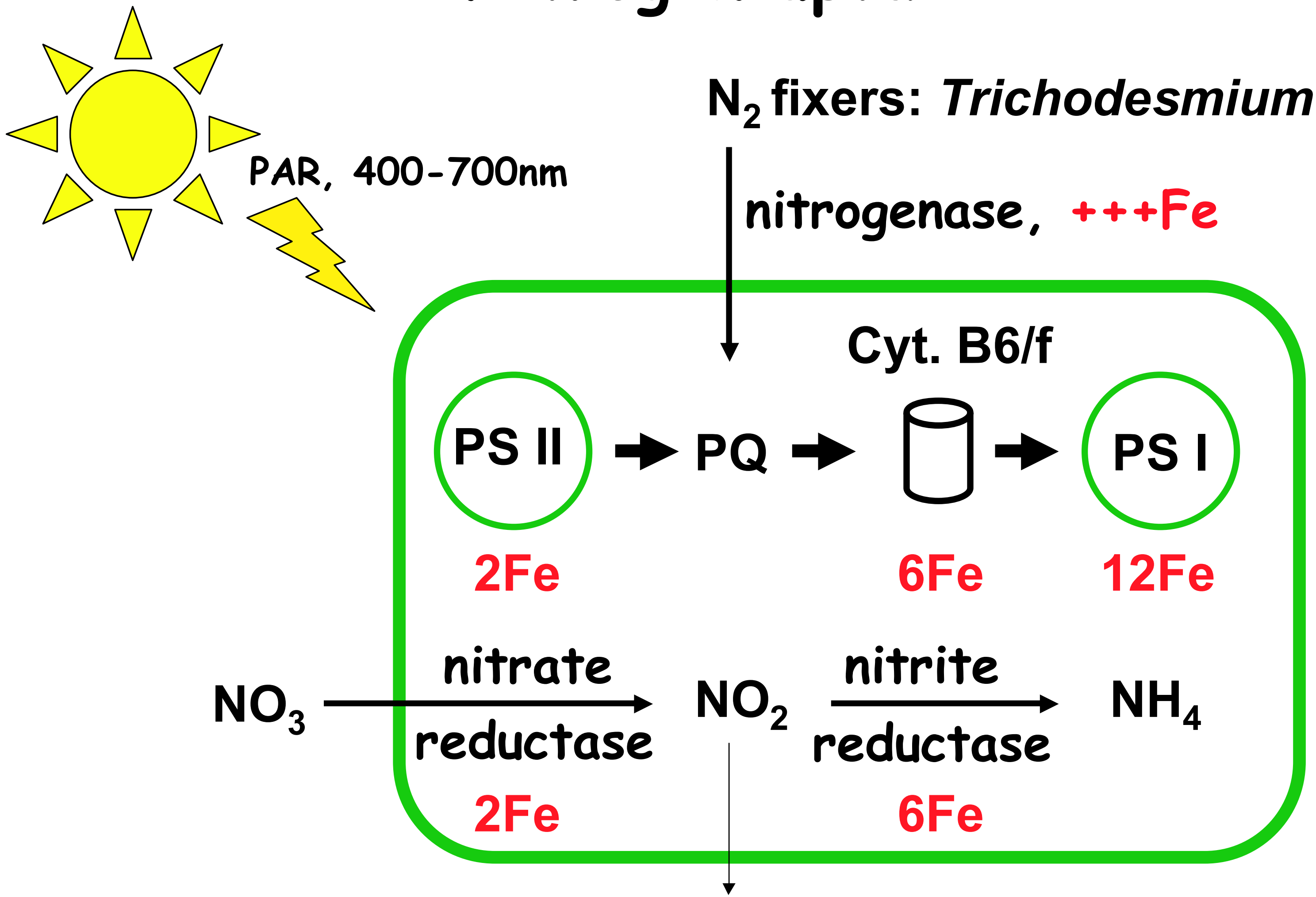


Little / no Fe input into S.O. or Equ. Sth. Pacific / Atl.

Results in low biomass & PP dominated by non-diatoms & small cells

Iron limitation has now been unequivocally established, Martin et al. 1994; Coale et al. 1996, 2004; Boyd et al. 2000, Tsuda et al. 2003.

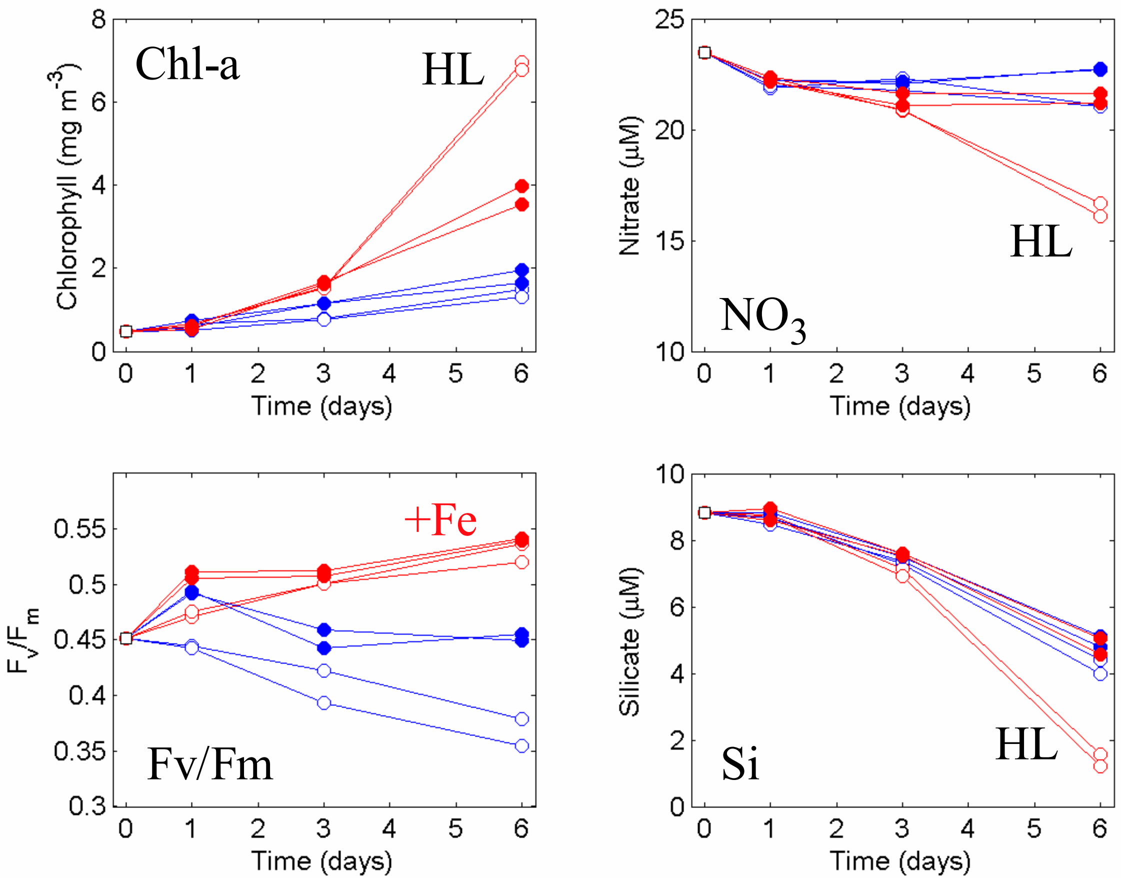
Light & Fe dependency of Photosynthesis & Nitrogen uptake



Bottle incubations: M3 Diatom Dominated

Red: +2nM Fe, Blue: controls

Low light **High light**



Light + Fe control NO_3 uptake.

Si uptake is relatively insensitive to both Fe and light.

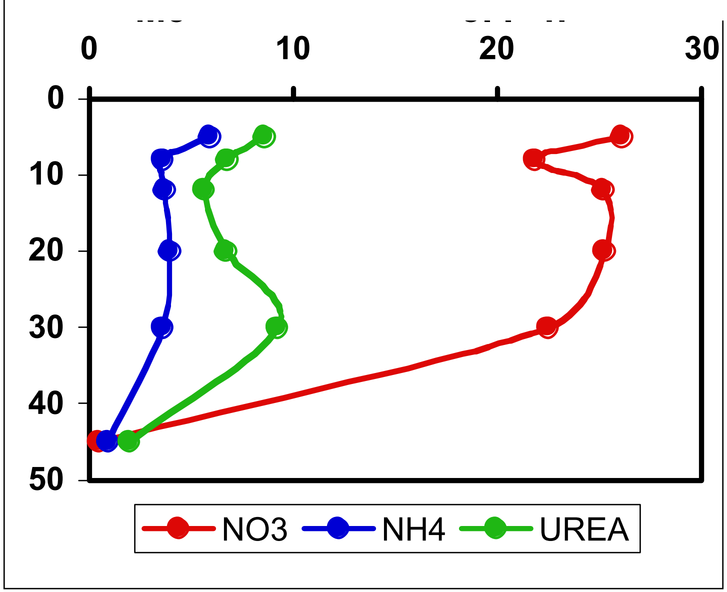
Physiological "health" (Fv/Fm) improves

Moore et al., DSR II, 54: 2007

Fe impacts Nitrogen uptake rates

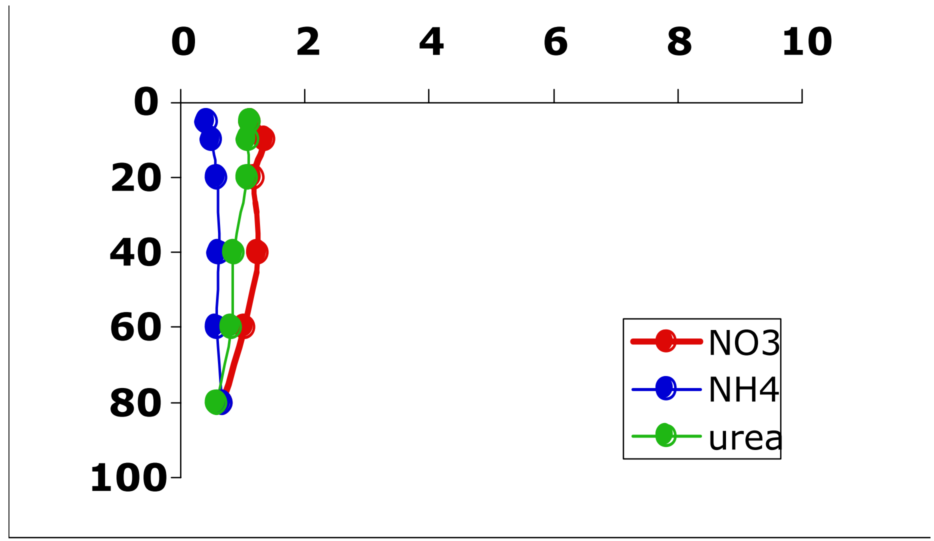
Lucas et al., DSR, 54: 2007

M3 ρN (nmol l^{-1} h^{-1})



North: Bloom (+Fe)

M6 ρN (nmol l^{-1} h^{-1})



South: HNLC Control (-Fe)

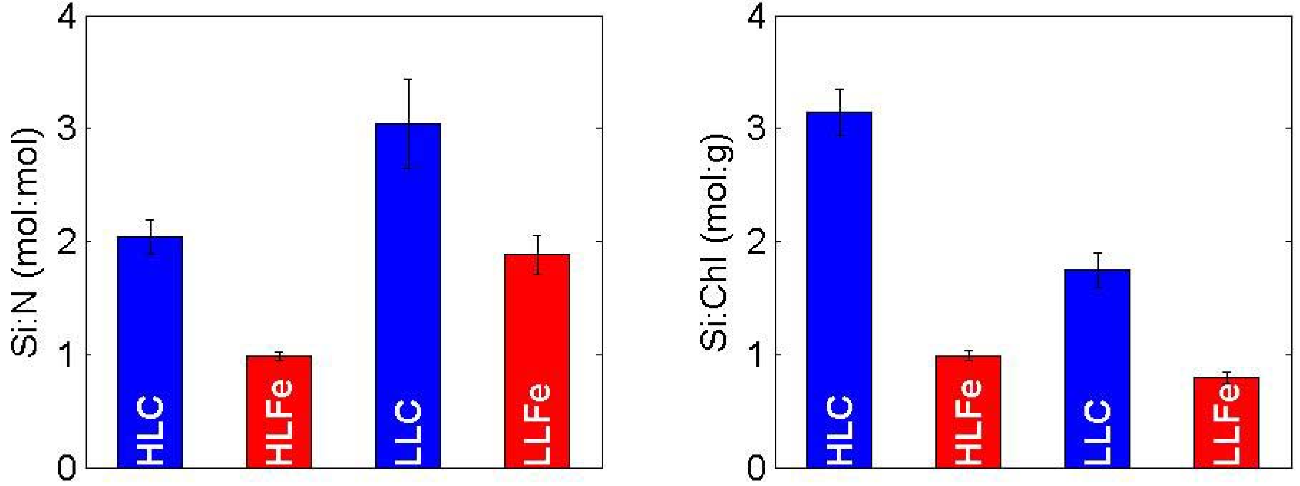
Low Fe impacts on ρNO_3 and chl-a synthesis

	PON/chl-a (µmol:µg)	**ρNO_3/PON** (VNO_3 d^{-1})
North (Post-bloom)	2.3±0.3	0.05±0.02
M3 Bloom (+Fe)	0.98±0.5	0.10±0.03
South (HNLC)	3.23±0.8	0.02±0.01

Lucas et al., DSR II, 54: 2007

Fe & the Global Si Cycle

Iron and light drive variability in Si:N draw-down

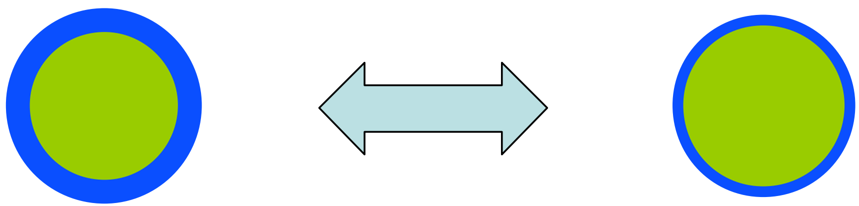


Moore et al., DSR II, 54: 2007

Un-couples Si:N Redfield Ratio (~1:0.9) and changes Si:N draw-down ratio

HNLC | **HNLC + light + Fe**

Slow growth | Fast growth



Si:N 3:1 | Si:N 1:1

<u>Implications for</u>-

- Glacial "Si leakage" hypothesis
- "Rain-rate"of biogenic silica
- Ballasting / sinking rate of diatoms
- Resistance to herbivory by zooplankton

Key Conclusions (1)

Annual integrated POC flux is 5 x higher in +Fe region
Sequestr. efficiency (POC flux : Fe added) is 700 mol:mol (3000m)

Artificial Fe addition exp., efficiency is ~7000 mol:mol (100-200m)

POC flux is depth & Fe sensitive

Benthic community responds to Fe mediated bloom & C. export

Key Conclusions (2)

+ Fe allows nitrate to be used since PSII, PSI & nitrate reductase are Fe dependent

LGM $pC0_2$ decrease was ~80-100 ppm
Fe fertilisation to SO contributes just 30-50 ppm
But "Si leakage" to lower latitudes could account for balance.

But - our evidence suggests NO silicate leakage.

Other mechanisms to account for pCO_2 decrease in LGM?

Thank you!