National Oceanography Centre, Southampton

UNIVERSITY OF Southampton
School of Ocean and Earth Science

Workshop on
'Modelling and Synthesis of Southern Ocean Natural Iron Fertilization',
WHOI, June 2011

Natural Iron Fertilisation: Extrapolating the General from the Specific?

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NATURAL ENVIRONMENT RESEARCH COUNCIL

Overview of talk

How specific is each individual case of natural iron fertilisation? Are general responses discernable?

How does variability in biological response relate to:

Mode and magnitude of iron supply?

(in particular particle-biota interactions…)

Macronutrient supply?

The specific circumstances of proximity to shallow systems?

What do we mean by ‘natural fertilisation’?

Iron is a nutrient everywhere

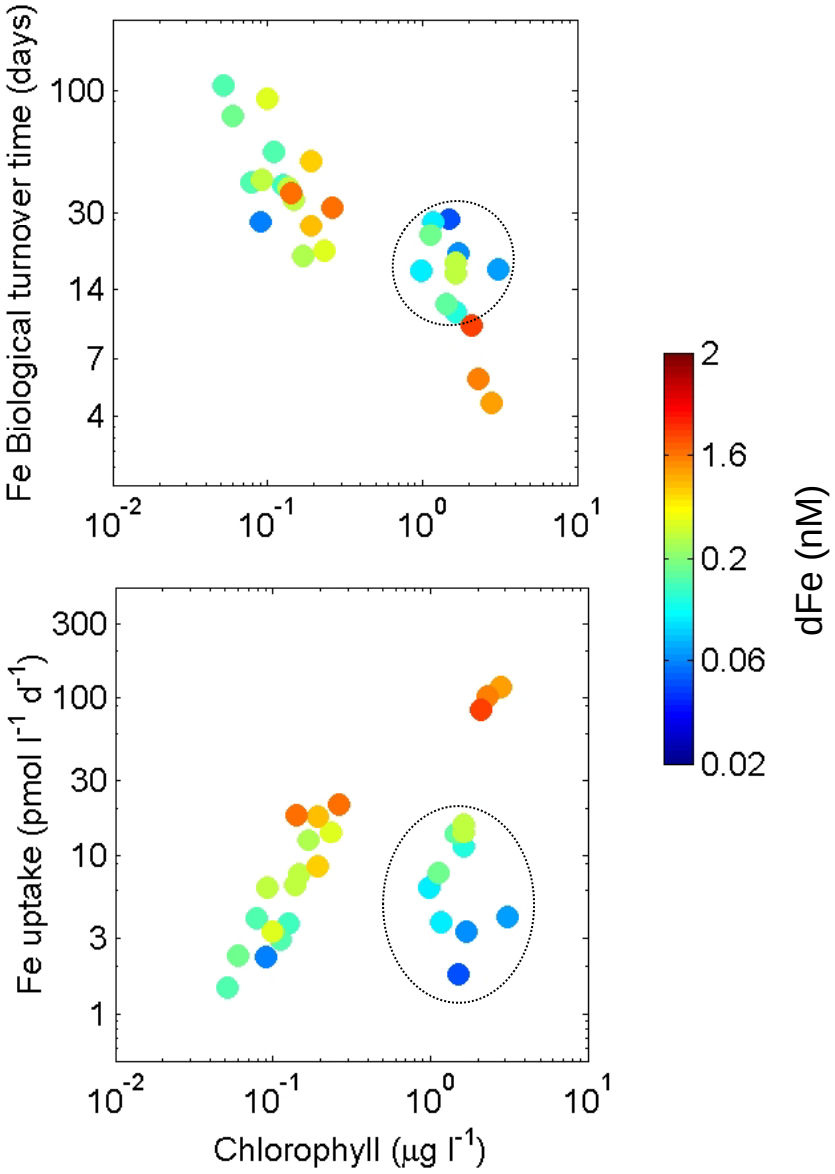
Much of the focus on Fe (and other micronutrients) has been within the 'HNitrateLC' regions.

But Fe (and Zn, Co, Cd, Mn etc.) are nutrients everywhere….

Uptake of ^{55}Fe across range of environments

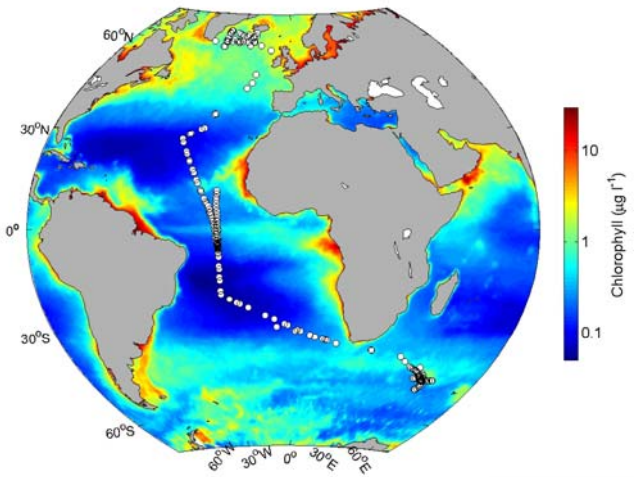
What do we mean by *'natural fertilisation'* ?

Any/all sources of Fe to the surface ocean? We don't really talk about 'natural N, P or Si fertilisation'?



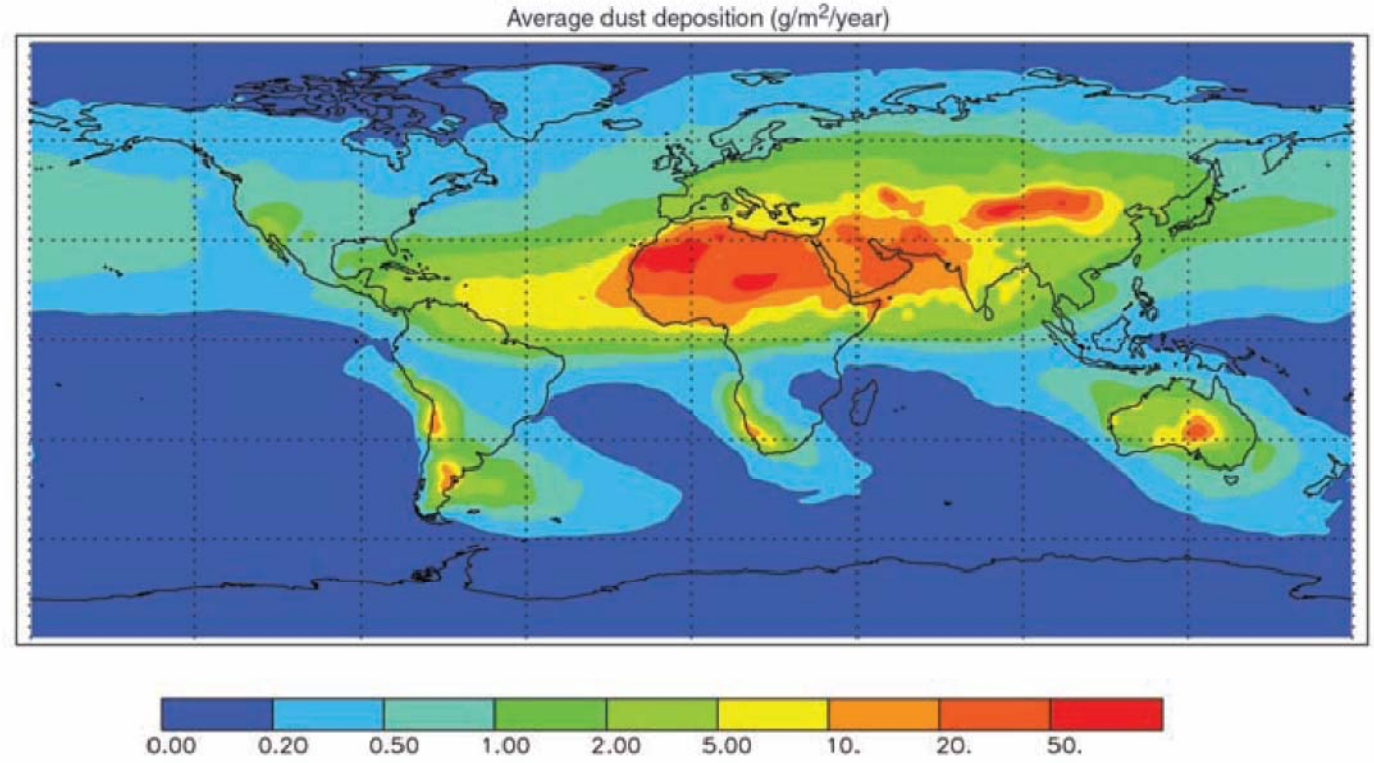
Data from Moore, Nielsdottir, Lucas and others unpublished.

What controls where the HNLC condition develops?



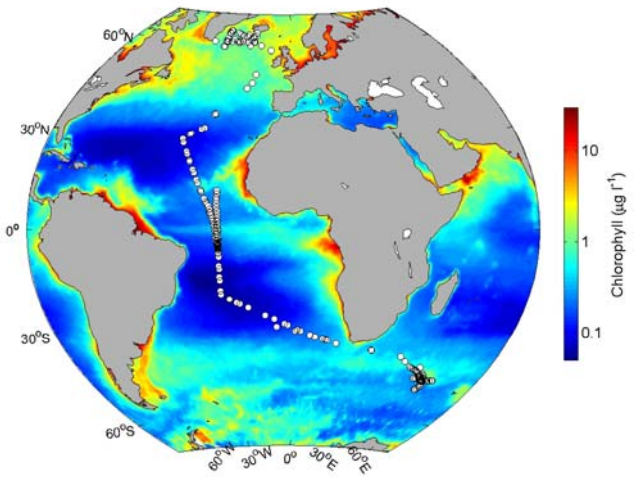
It's probably reasonably safe to assume that Fe inputs to the surface ocean (and the form they take) vary greatly.

But macronutrient supply to the surface ocean also varies hugely.

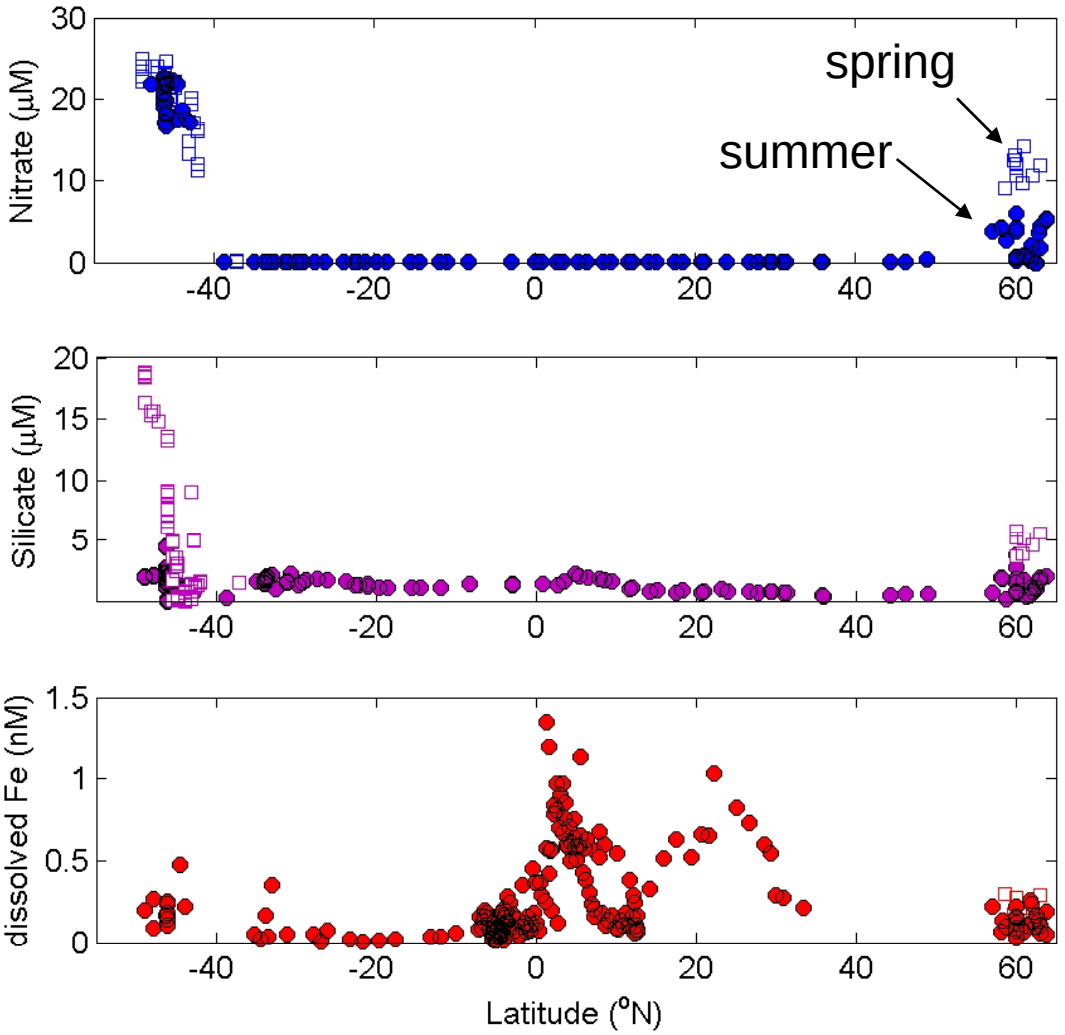


Jickells et al. 2005 Science

What controls where the HNLC condition develops?

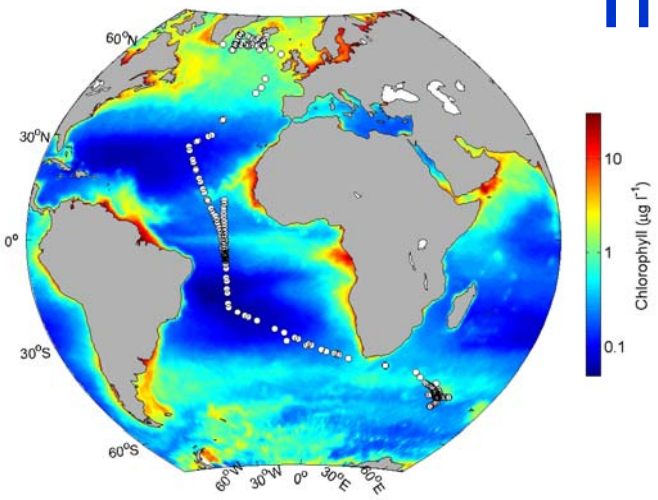


Acknowledging that standing stocks are poor proxies for supply, macronutrient concentrations are arguably much more variable than surface dFe concentrations.



Planquette et al. 2007 Deep sea res II; Moore et al. 2009 Nature Geoscience; Steigenberger et al. unpub.

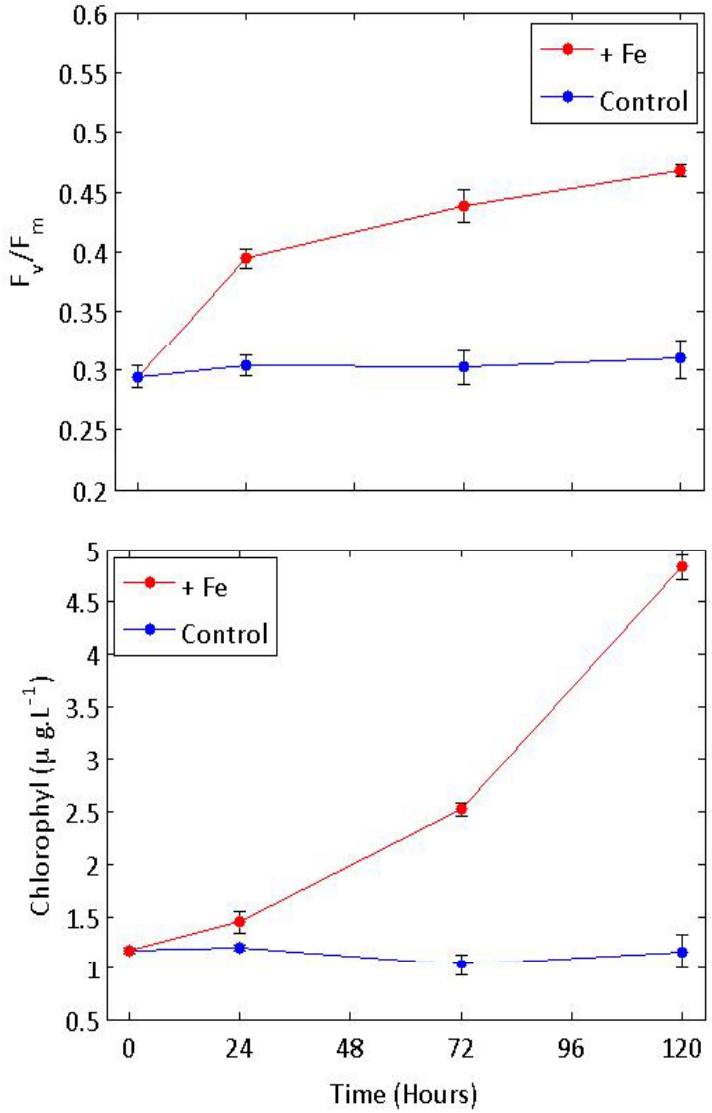
The high latitude N. Atlantic: nearly an HNLC?



Despite potentially higher Fe inputs and (crucially?) lower overwinter macronutrient concentrations, there is evidence for Fe stress (limitation) in both the Iceland and Irminger Basins of the high latitude N. Atlantic

Nielsdottir et al. 2009 Global Biogeochemical Cycles.

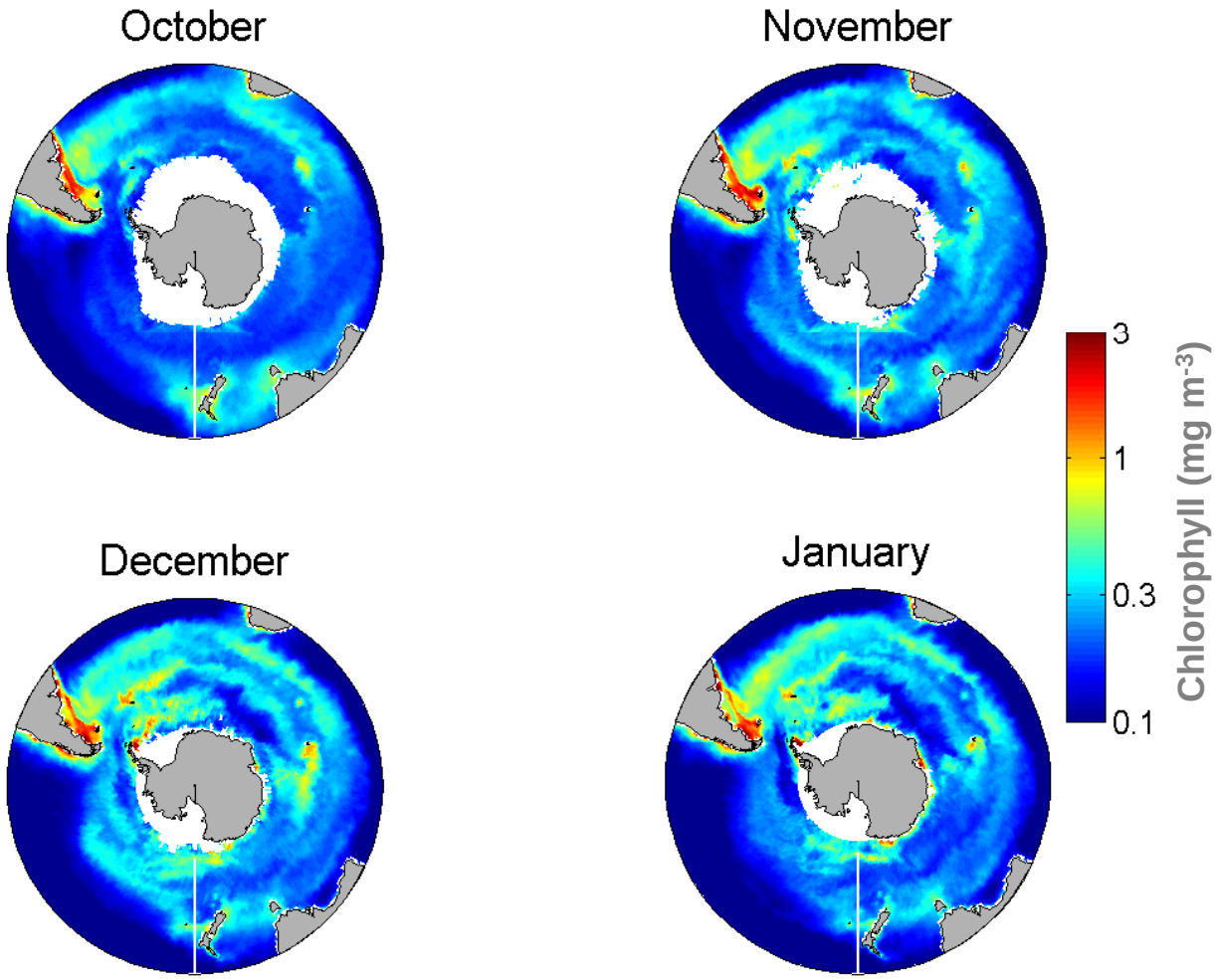
Ryan-Keogh et al. In prep.



The Southern Ocean

‘It cannot be too strongly emphasised that in all probability phytoplankton production is always governed by a complex of inter-dependent factors, rather than by one or two which are clearly definable’

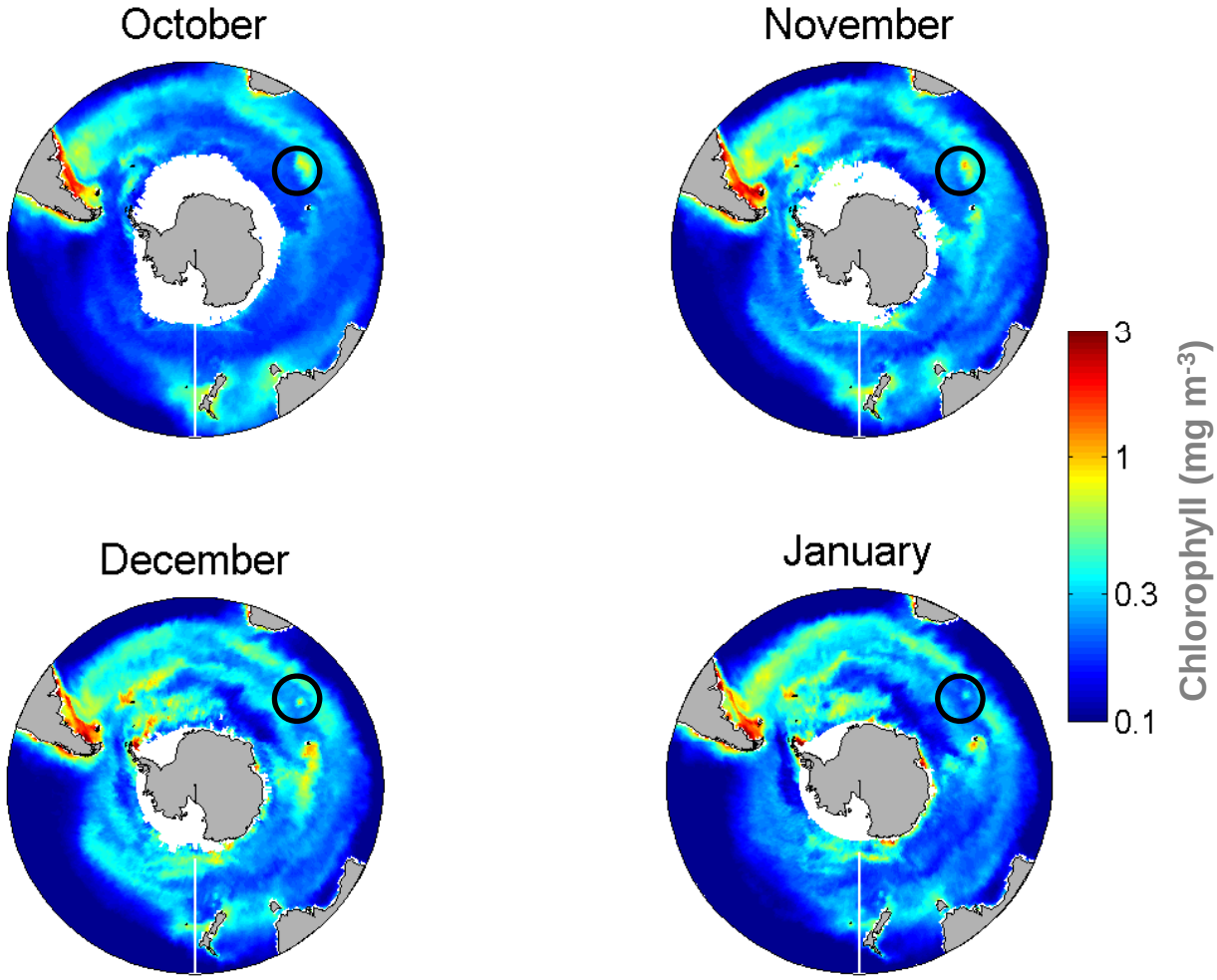
Hart, 1934



CROZEX

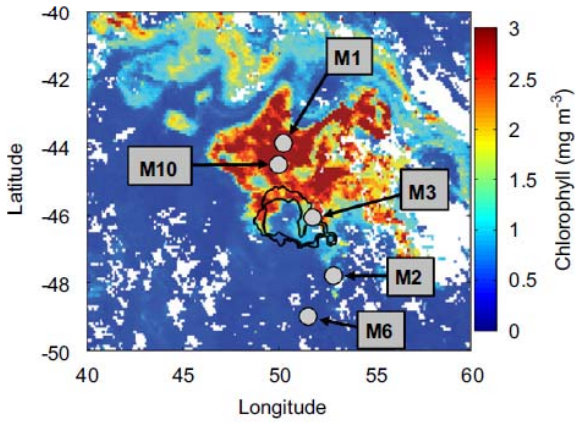
CROZet natural Fe bloom and EXport experiment. Nov 2004 - Jan 2005

Sampling in a region of the Southern Ocean where chlorophyll levels are natural enhanced.

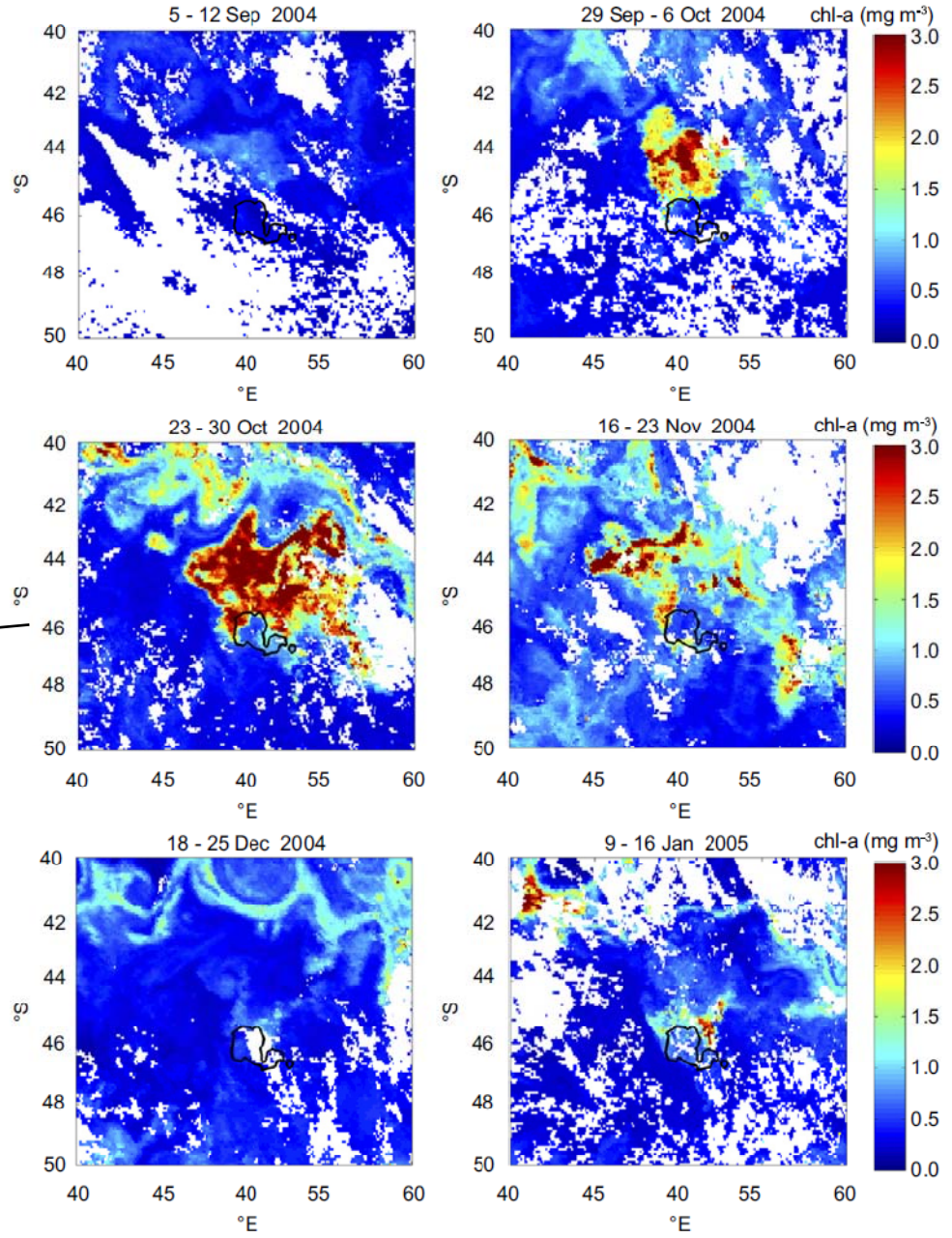


CROZEX

Bloom to the north of the plateau was already in decline at the time of initial sampling in November 2004

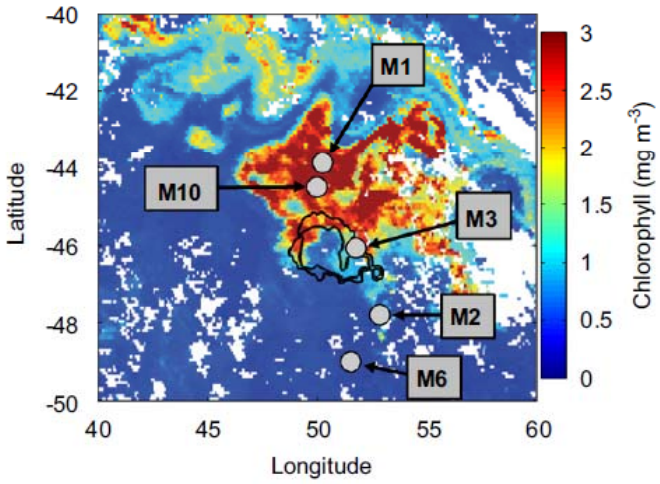


Small secondary bloom originated near islands in January.



Venables et al. 2007 Deep Sea Research II

CROZEX



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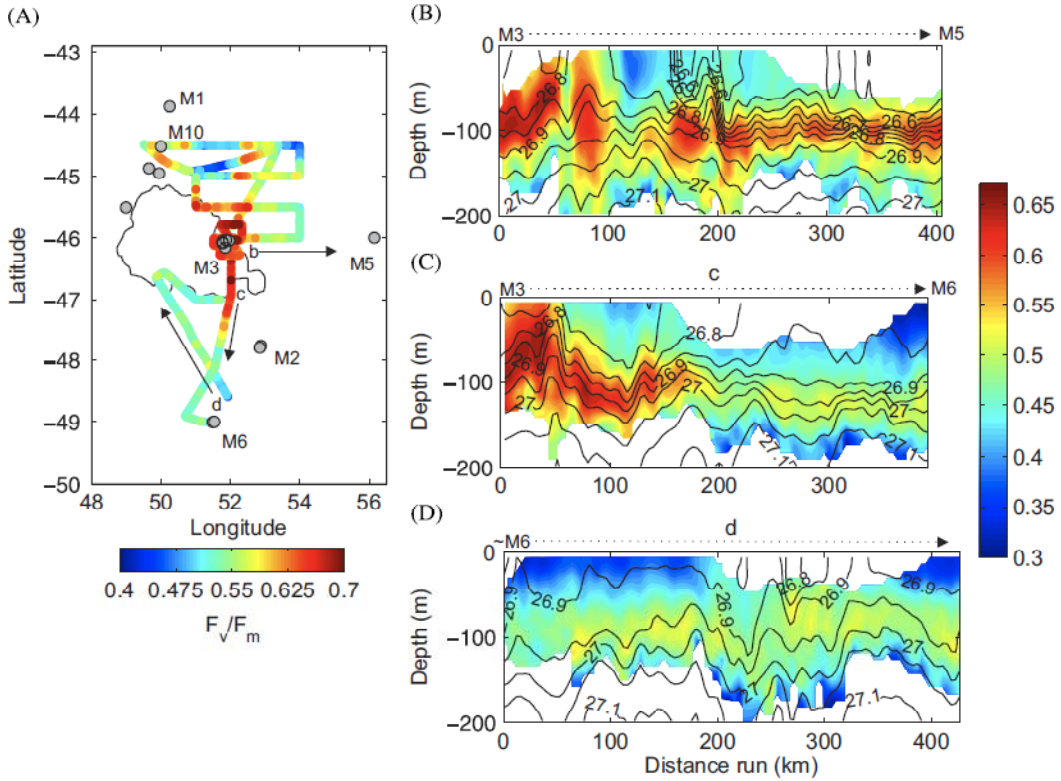
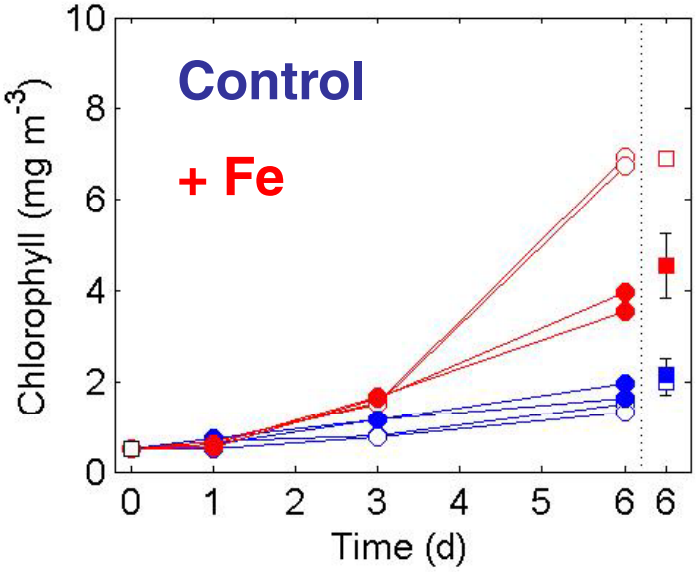
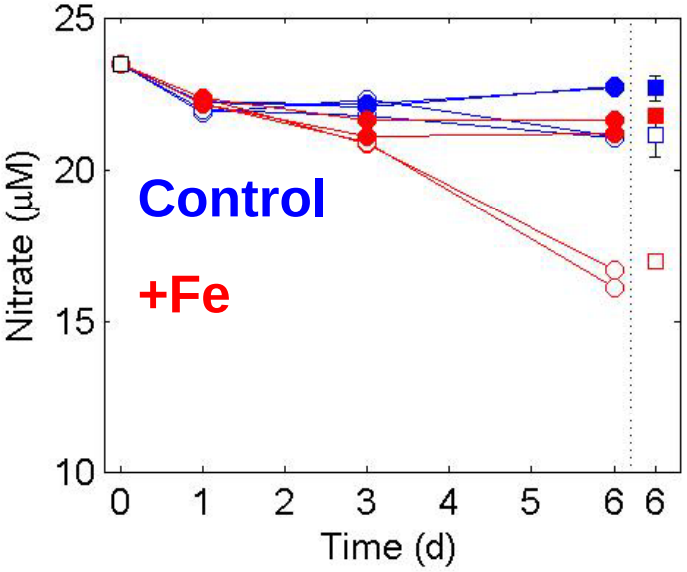


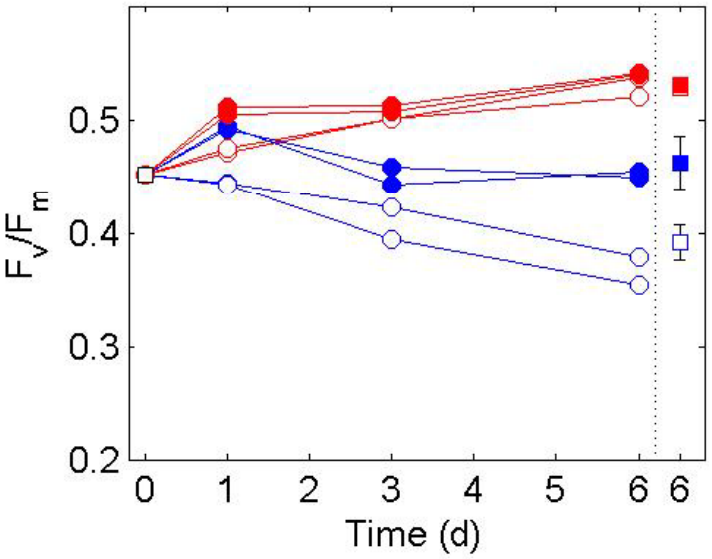
Evidence for Fe stress within in situ community except from in close proximity to plateau

Moore et al. 2007a Deep Sea Research II

CROZEX bioassays





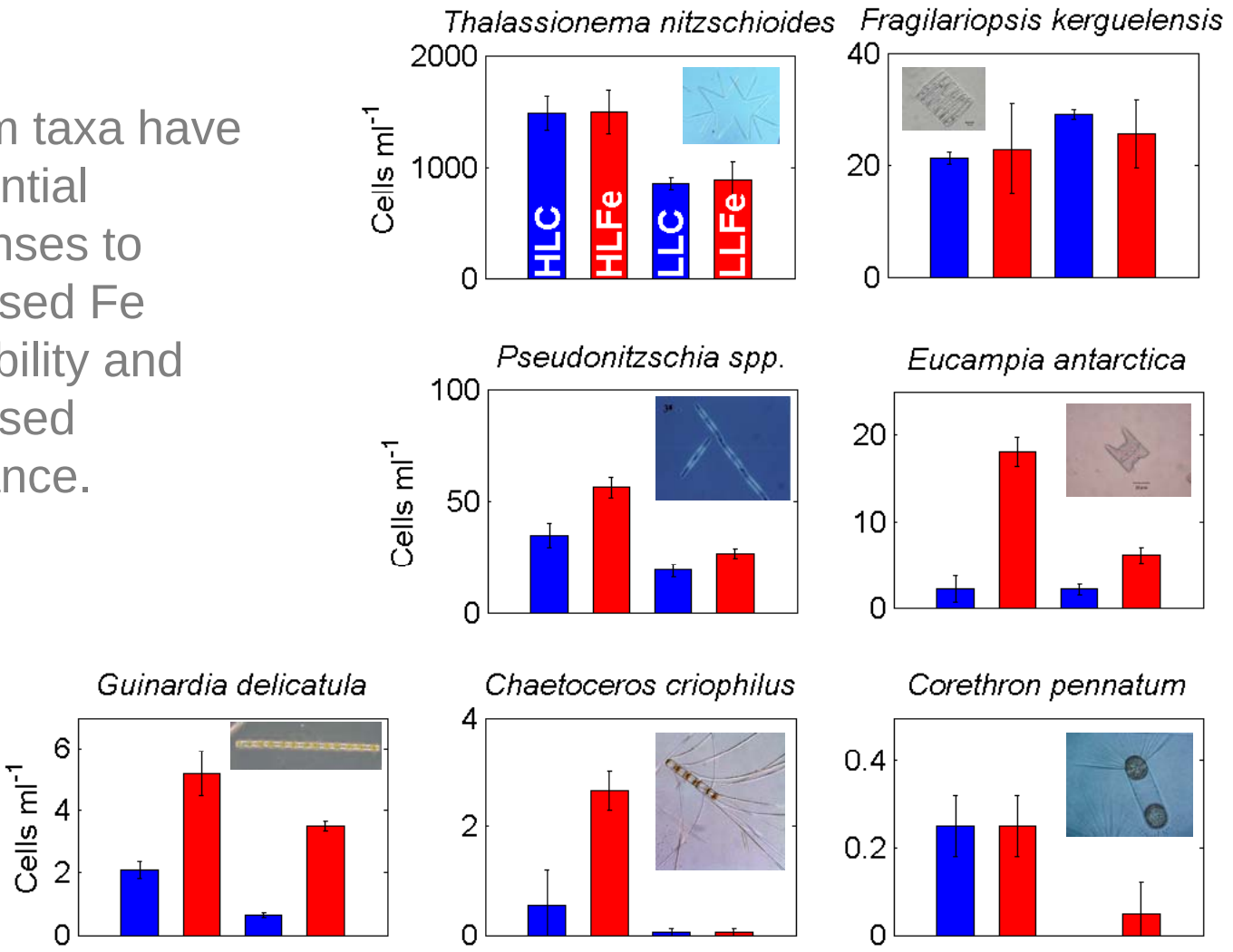


Rapid changes in photophysiology, increased chlorophyll and nutrient drawdown result from Fe addition.

Moore et al. 2007a Deep Sea Research II

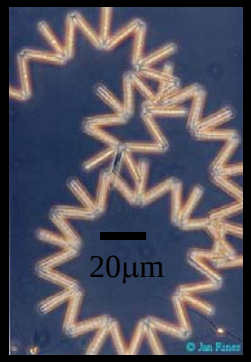
Fe and grazing: ecological implications

Diatom taxa have differential responses to increased Fe availability and increased irradiance.



Moore et al. 2007b Deep Sea Research II

Fe and grazing: ecological implications

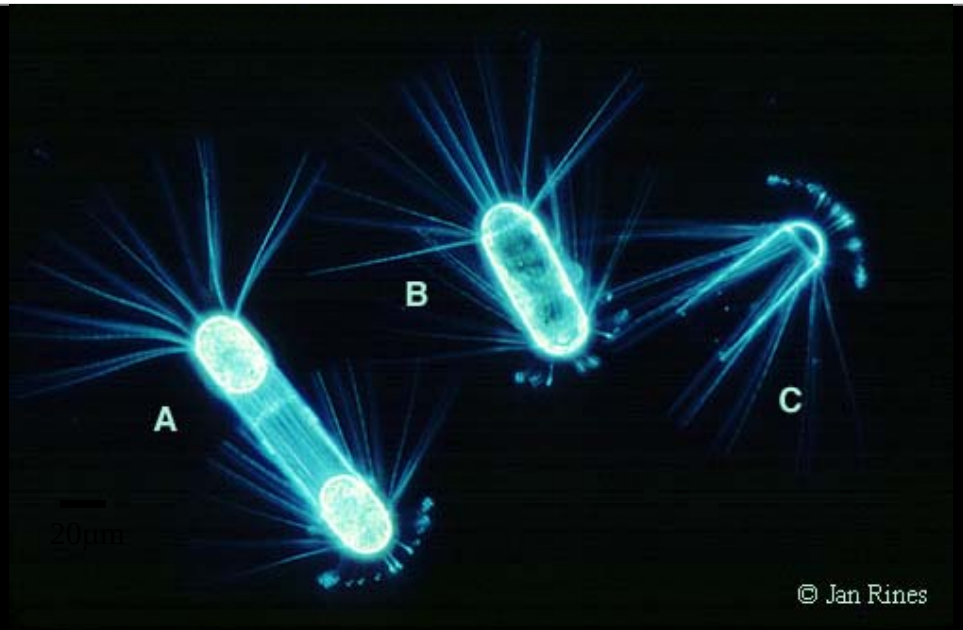


T. nitzschioides

>1000 fold increase in Vol.

>100 fold increase in SA

>10 fold decrease in A/V



C. pennatum

Increasing cell size (and presumably chain formation, spines and heavy silicification) are likely adaptations to heavy grazing pressure.

Increased cell size decreases A/V, reducing nutrient uptake efficiency.

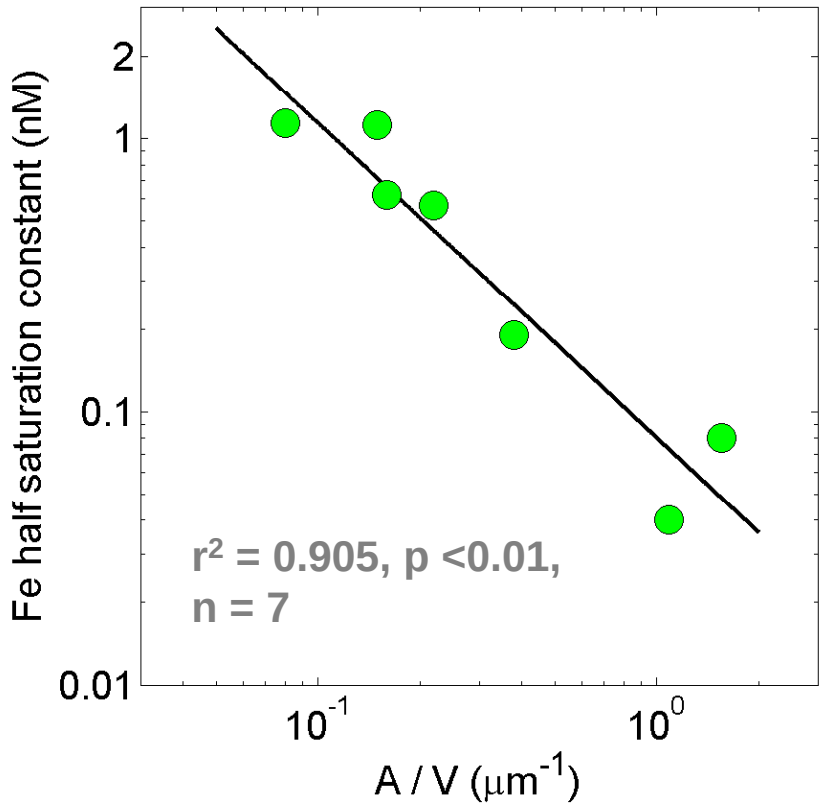
e.g. Smetacek et al. 2004 Antarctic Science

Fe and grazing: ecological implications

'Iron limitation is diffusion limitation of large diatoms'

de Baar (this morning)

Allows construction of empirical models to predict relative response of different cell sizes to increased Fe availability.

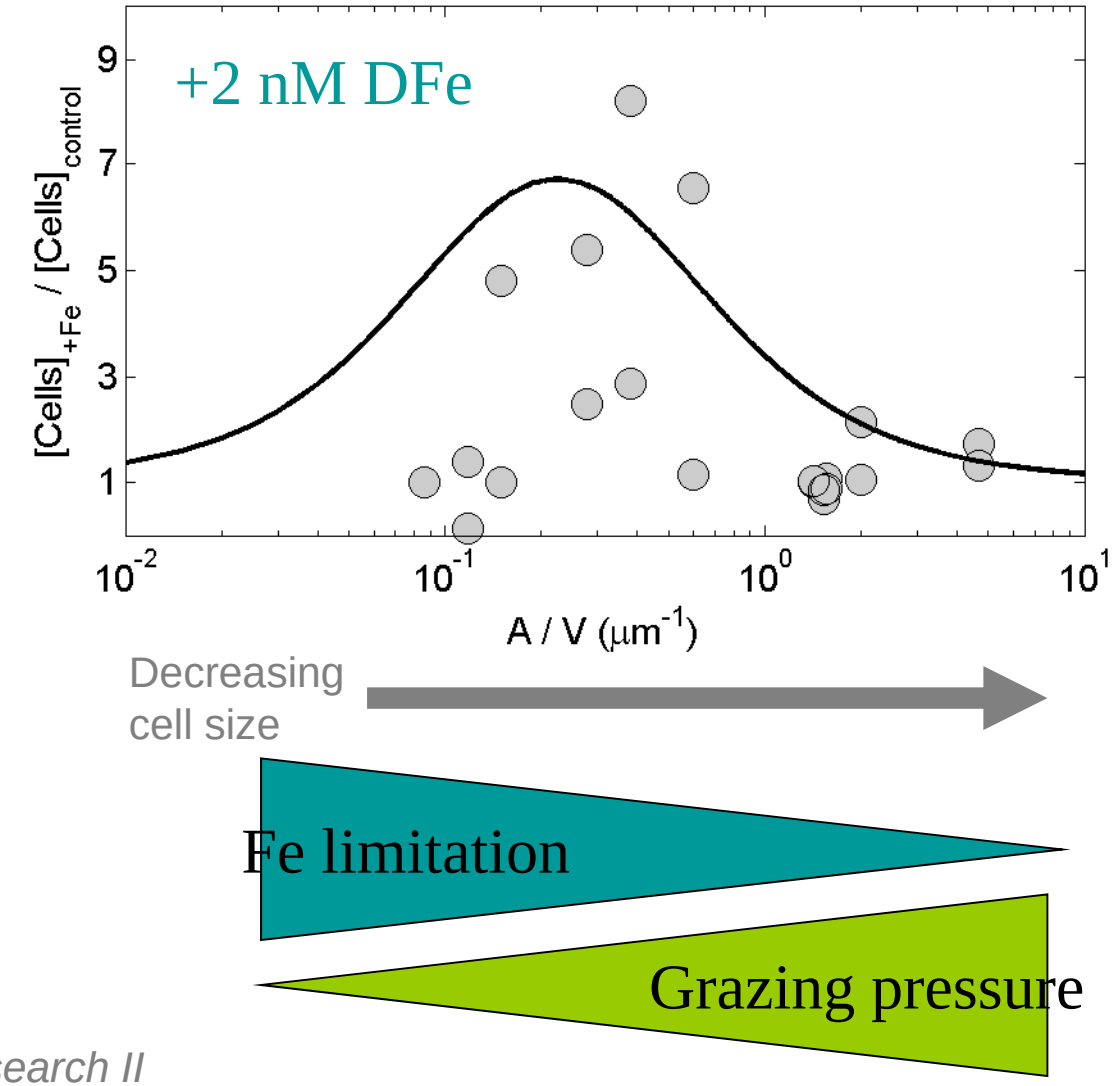


Data from: Sunda and Huntsmann, 1995, Timmermans et al. 2001, 2004 as collated by Timmermans et al. 2004, de Baar et al. 2005.

Fe and grazing: ecological implications

Comparison of differential taxonomic responses within bioassay experiment with prediction.

Medium-large diatoms respond the most strongly, consistent with prediction.



Moore et al. 2007b Deep Sea Research II

Fe and grazing: ecological implications

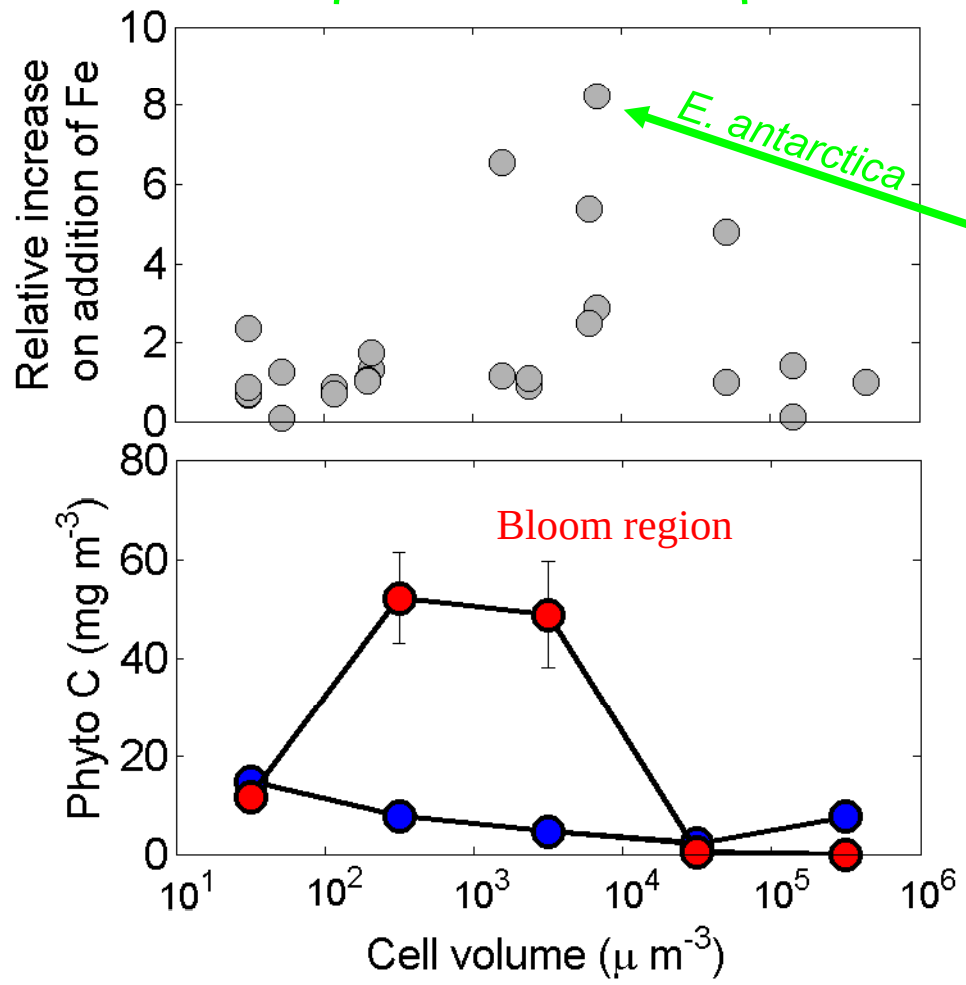
Fast growing opportunists

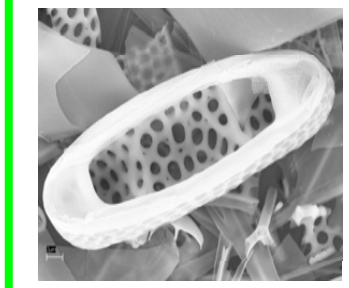
Resource acquisition specialists

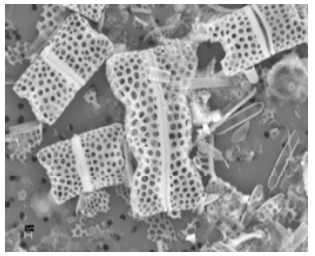
Slow growing defence specialists

Expt.

In situ





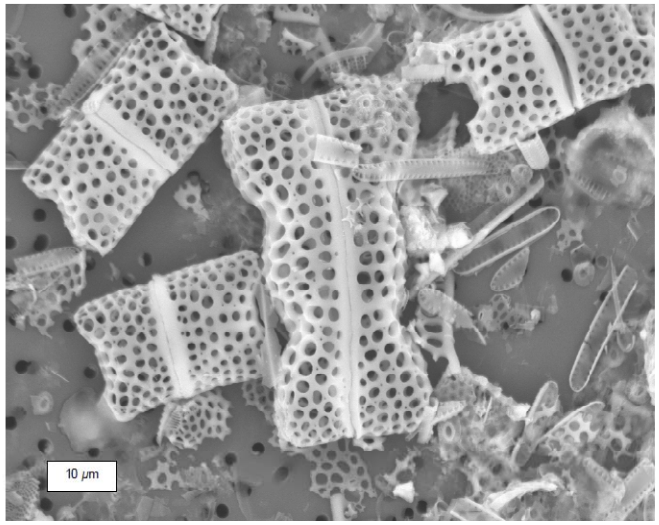


SEMs Courtesy I. Salter

Moore et al. 2007b Deep Sea Research II

Diatom ecology: biogeochemical implications?

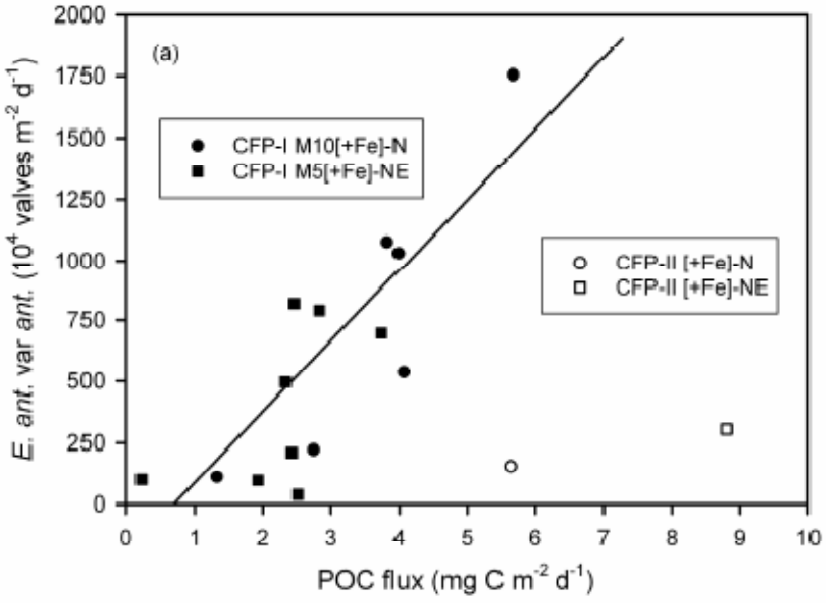
Deep water flux of unusually fresh POC was associated with spores of *E. antarctica* var. *antarctica*



Wolff et al. 2011 PLoS One

Salter et al. Global Biogeochemical Cycles in review

In keeping with other systems this suggests the intriguing possibility that the spore forming ecology of such diatoms may be a significant factor dictating export efficiency.



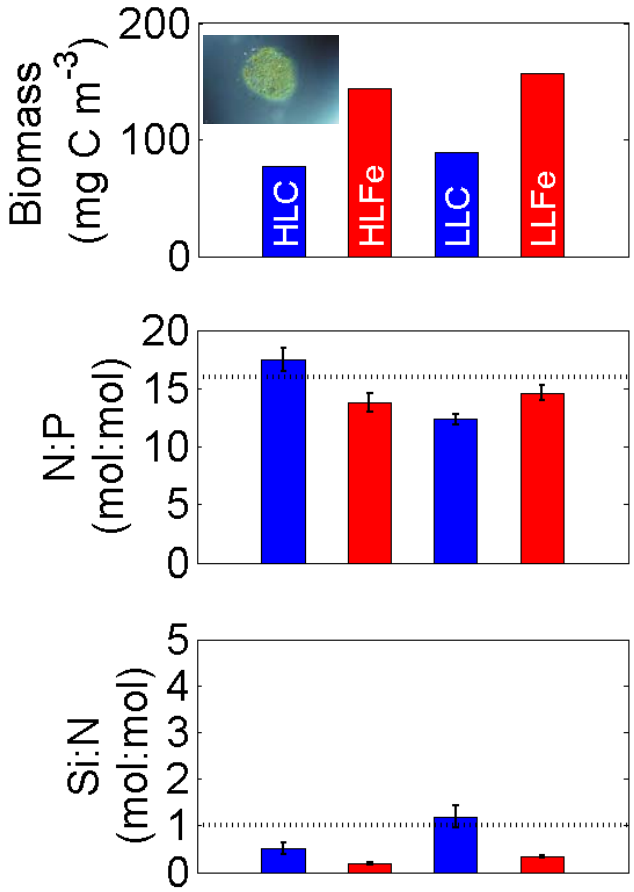
e.g. Armand et al. 2008a,b Deep Sea Research II

Biogeochemical implications

Community structure depends on availability of Fe, Si, light and influence of grazers.

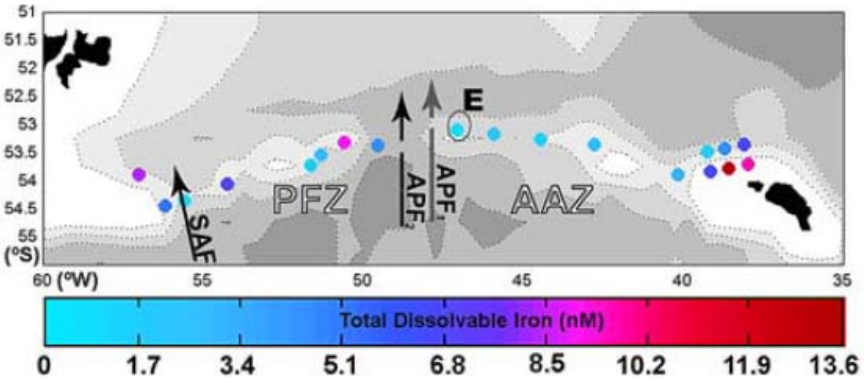
Stoichiometry of nutrient uptake is influenced by community structure and growth environment.

Low [Si], *Phaeocystis*



Poulton et al. 2007; Moore et al. 2007b Deep Sea Research II

South Georgia



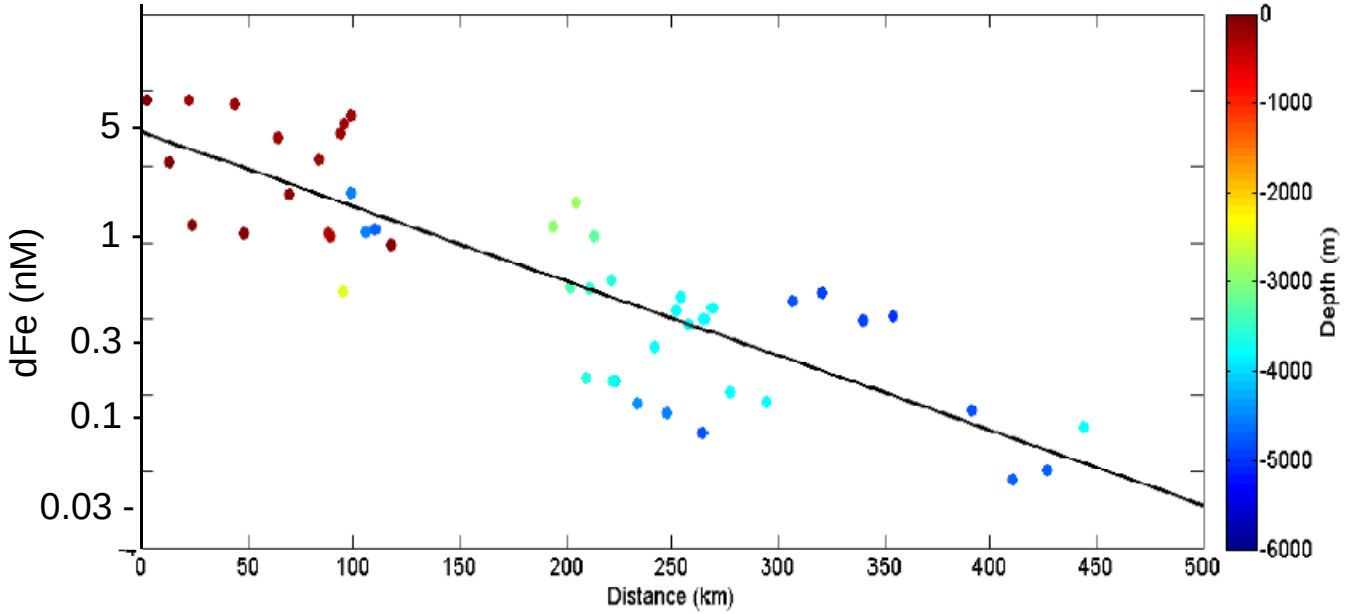
Holeton et al. 2005 Polar Biology

V. large diatoms (e.g. *Corethron* spp.) have been observed over South Georgia shelf.

Korb et al. 2008 Mar Ecol Prog Ser

Potentially related to very high observed Fe concentrations?

(TFe, Holeton et al., dFe Nielsdottir et al.)



Nielsdottir et al. Marine Chemistry In review

Implications for synthesis

All natural situations will likely be special cases:

Biological response depends on setting, including:

Macronutrient availability,

Proximity to shallow bathymetry,

Local circulation patterns etc. etc.

Totality of Fe inputs/bioavailability