National Institute of Oceanography - CSIR, India
Alfred-Wegener Institute-Helmholtz Association, Germany
ANT XXV/3
POLARSTERN
Fe
CO_2
CO_2
CARBON

LOHAFEX

7 January - 17 March 2009

LOHA=iron (Hindi)

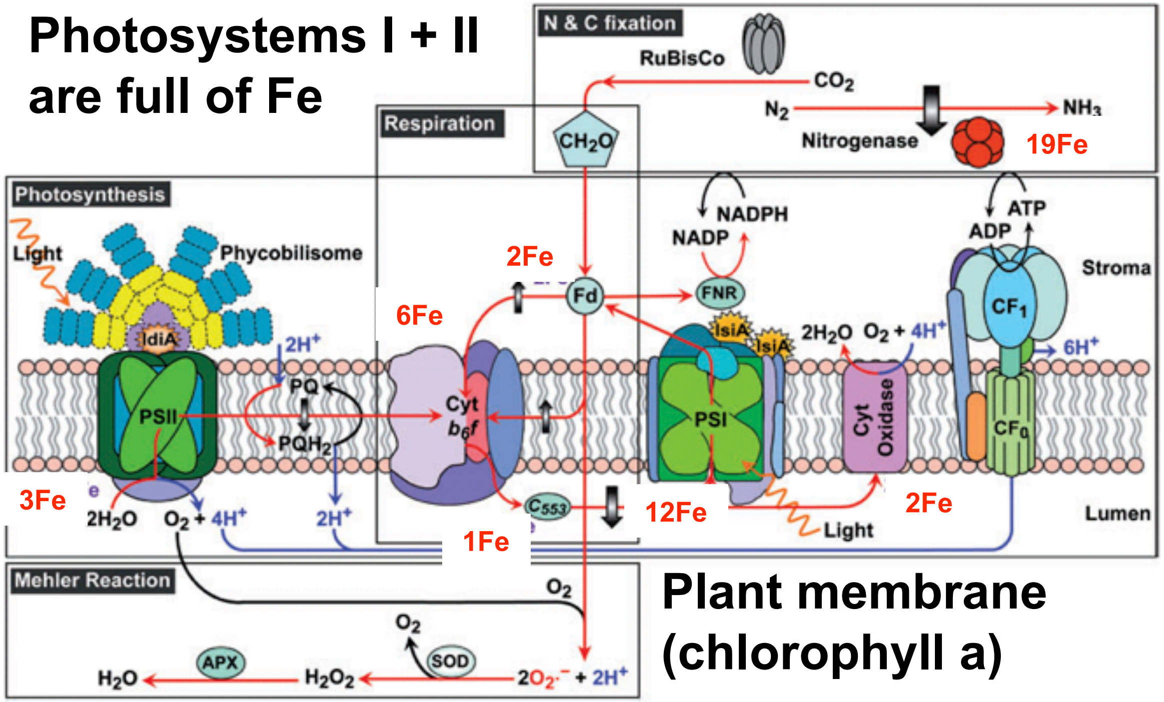
FEX = Fertilization EXperiment

Ulrich Bathmann
and the shipboard party (see last slide)

Motivation

A
R
C

Photosystems I + II are full of Fe



Shi et al. 2007

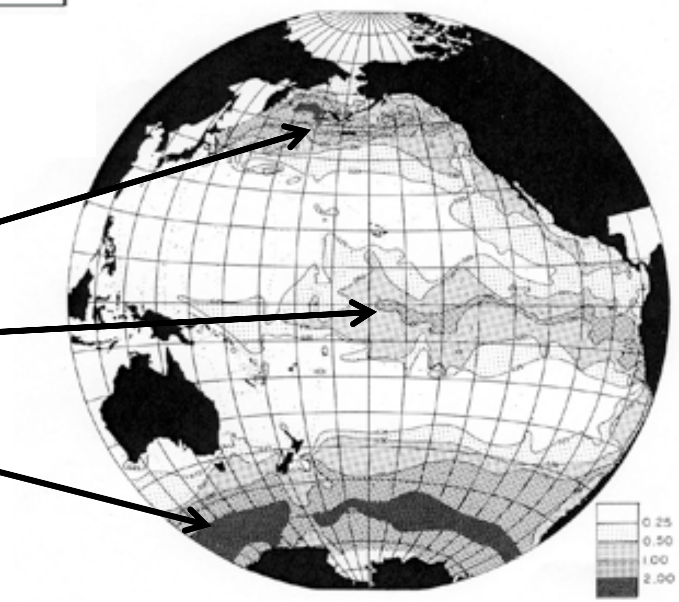
Plant membrane (chlorophyll a)

19 Fe
\+ 2 Fe
\+ 6 Fe
\+ 3 Fe
\+ 1 Fe
+12 Fe
\+ 2 Fe

= 51 Fe

High Nutrient (NO_3, PO_4) Low Chlorophyll (HNLC) regions

Iron defizit



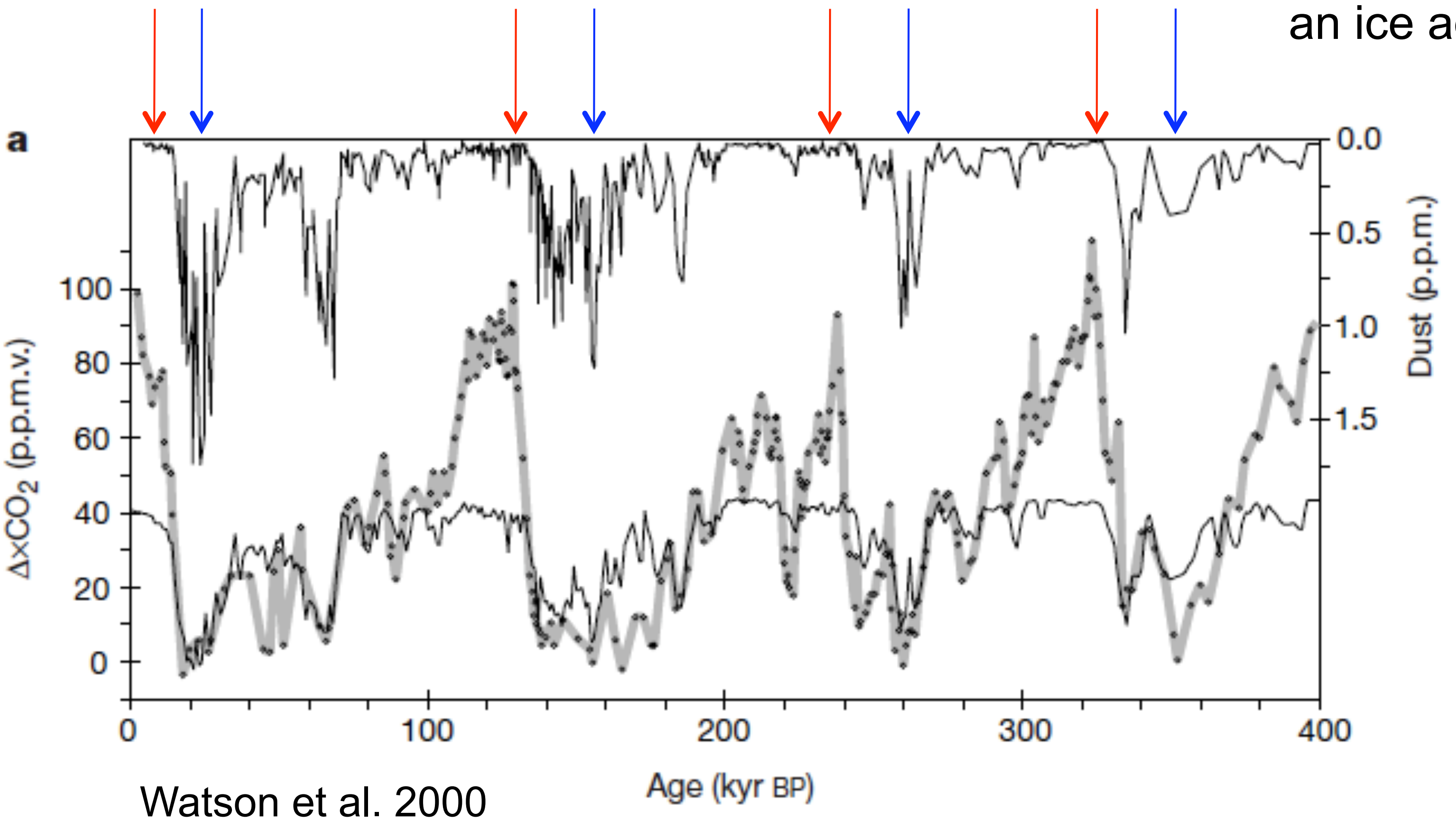
$[PO_4]$ in upper 50 m layer
Reid, Limnol. Oceanogr., 1962

Iron input varies ...

Ocean Iron Fertilization (OIF)

`Give me half a tanker of iron and I will give you an ice age´, John Martin 1989

... on glacial-interglacial time scales

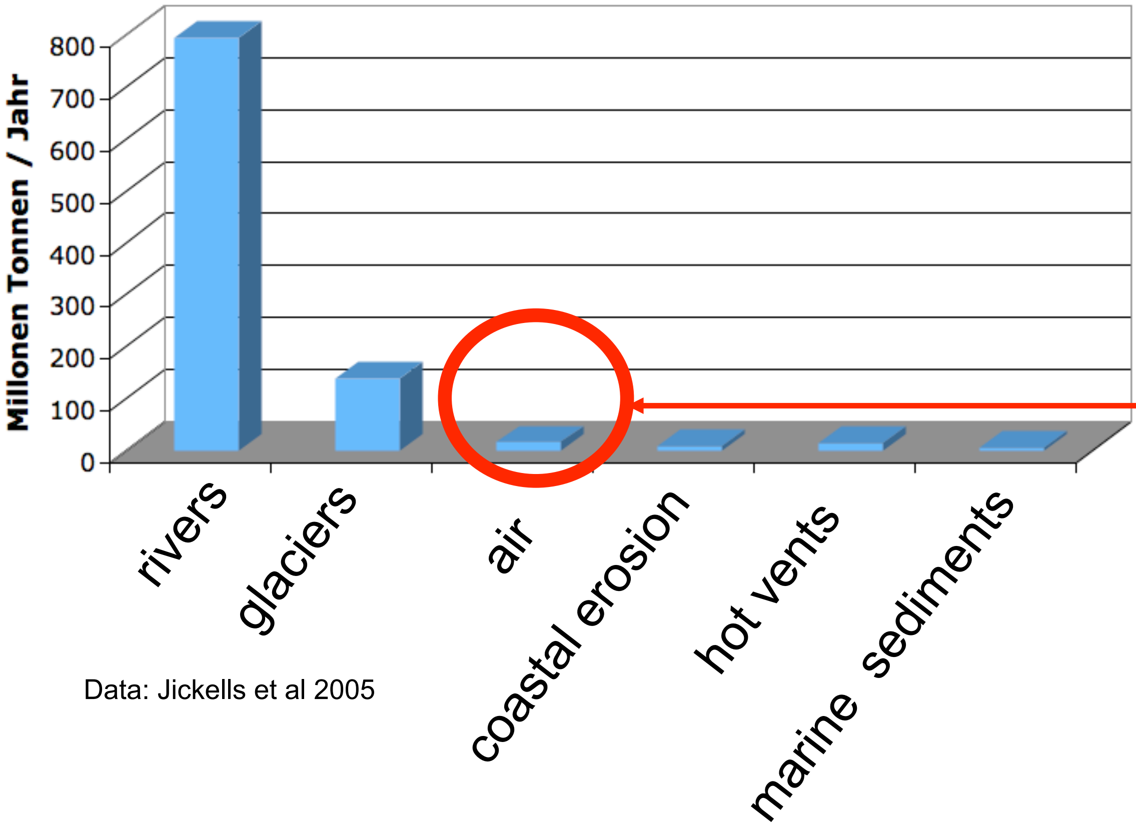


Watson et al. 2000
Petit et al. 1999

Iron input varies ...

... on glacial-interglacial time scales

... on subseasonal time scales
(large storms provide dust from the continents)



Data: Jickells et al 2005

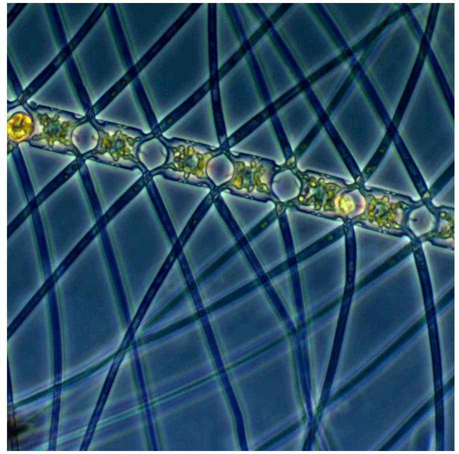
most important iron source in the open ocean:
16 million tons / year with dessert dust,
ca. 1 million ton -> to the Southern Ocean

Motivation

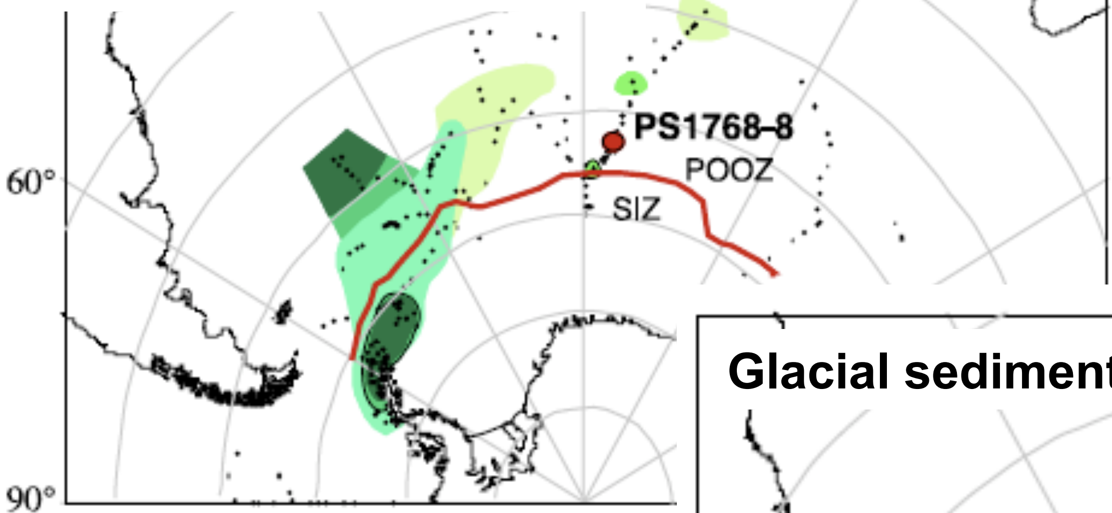
A
R
C

Extensive phytoplankton blooms in the Atlantic Sector of the glacial Southern Ocean

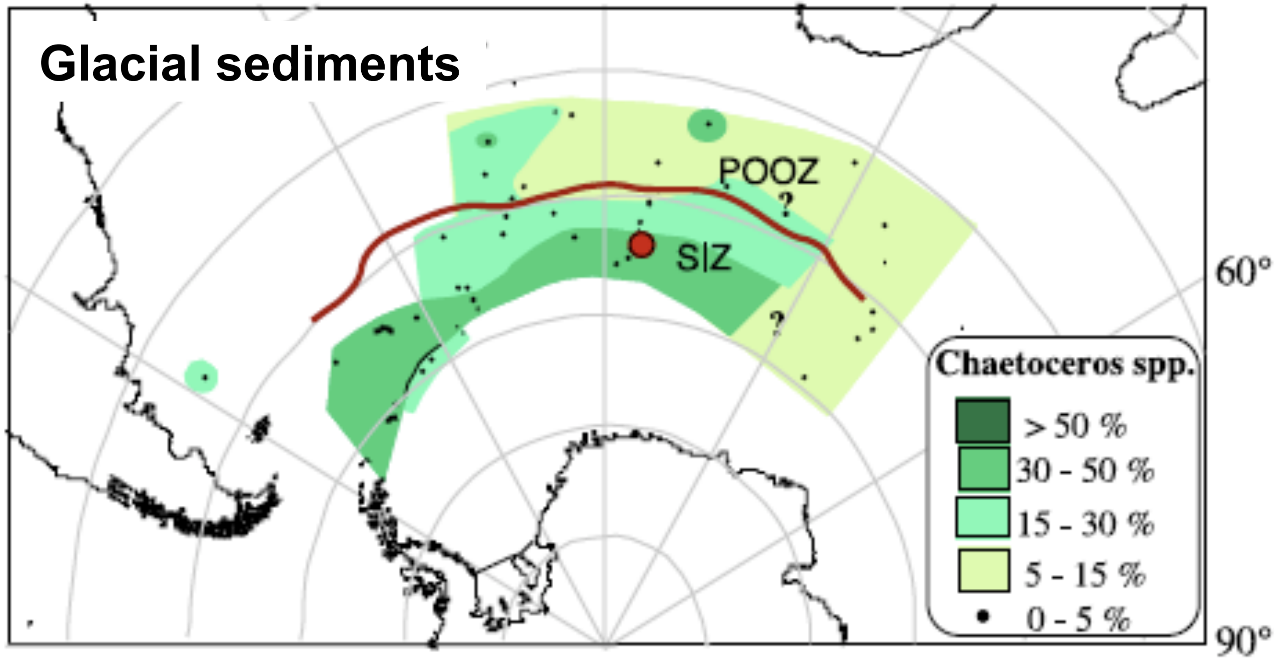
Abelmann, Gersonde, Cortese, Kuhn, Smetacek (2006)



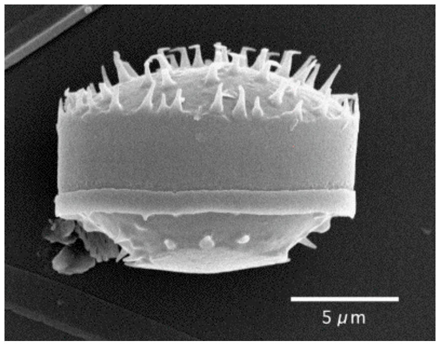
Recent surface sediments



Glacial sediments



Chaetoceros spores



Perturbation experiment

... to investigate the structure and functioning of pelagic ecosystems.

- How will the ecosystem react?
- What are the concequences to the carbonate system (CO_2)?
- What will the export production be?

Pertubation:
Add 20 t of iron sulfate over an area of 300 km^2
≈ 6 t of iron ≈ 0.01 g Fe m^{-2}
(4000 m water column contains about ten times more Fe)

Goal: concentration in mixed layer: 2 nmol L^{-1}
(tap or mineral waters show 100 times higher concentrations)

Avoid too much spreading of patch
by fertilizing the centre of a mesoscale eddy.

A good eddy should ...

... be **stable** for at least 2 months.

... contain **high nutrient concentrations** in surface layer.

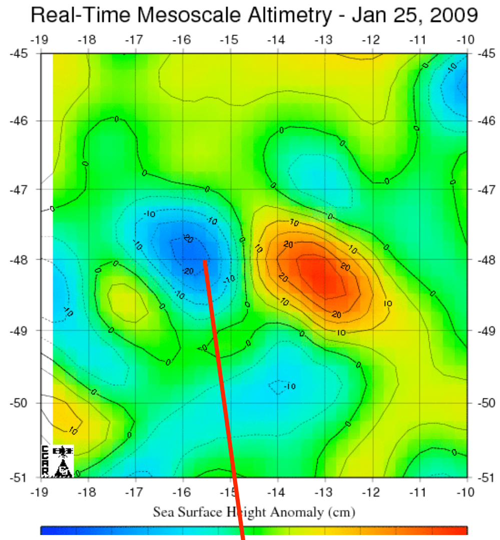
... contain a **seed population of phytoplankton** (0.5 mg chlorophyll m^{-3} is lower limit).

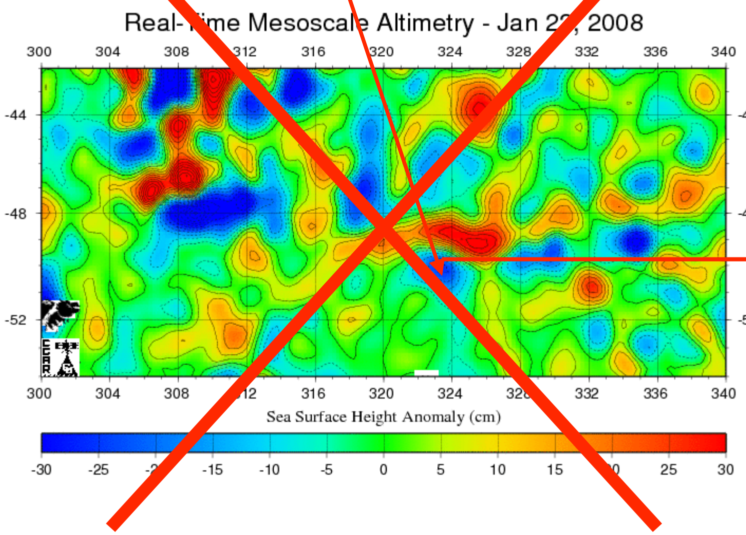
M
Approach
R
C

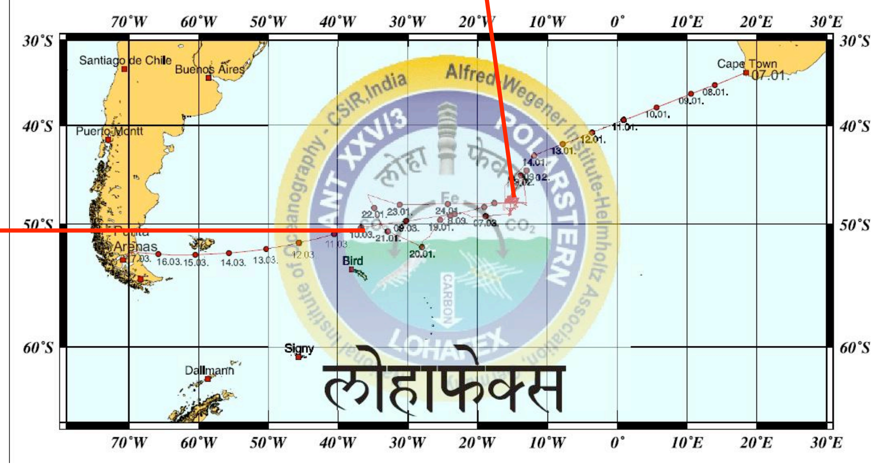
Experimental site

Original target: A cyclonic eddy at ~50ºS, 35ºW that existed during the austral summers of 2007 and 2008 - was absent in 2009. Other eddies investigated in this region did not look promising.

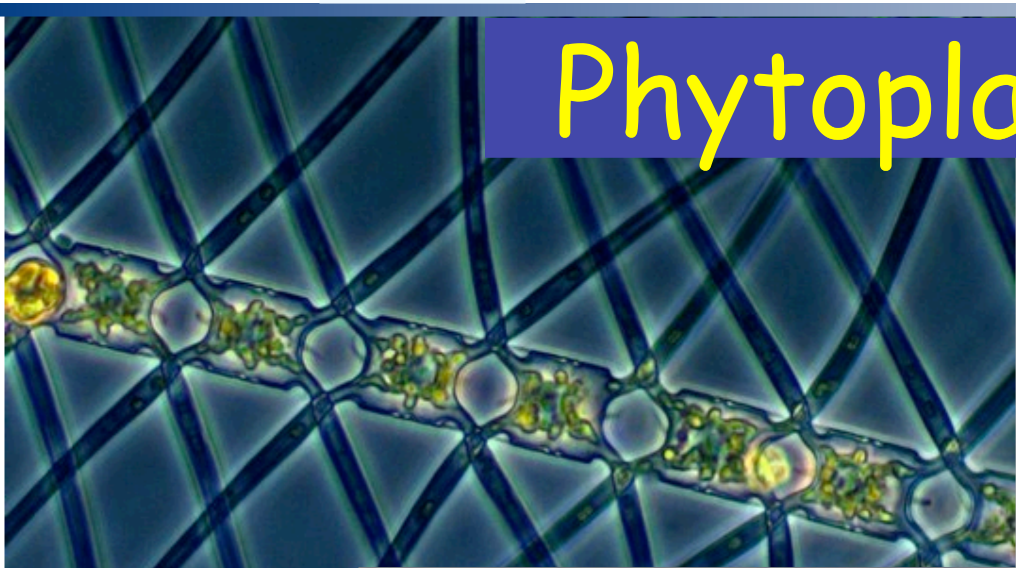
The LOHAFEX eddy around 48ºS, 16ºW was suitable.

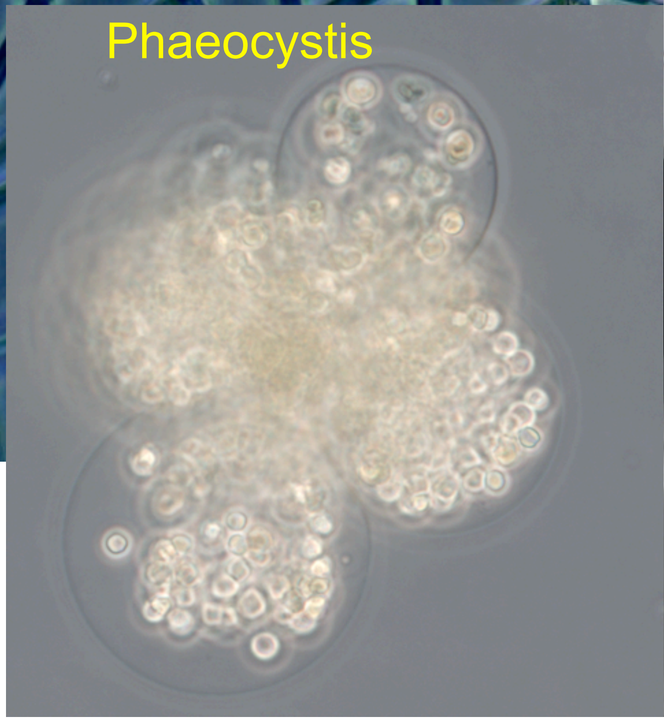


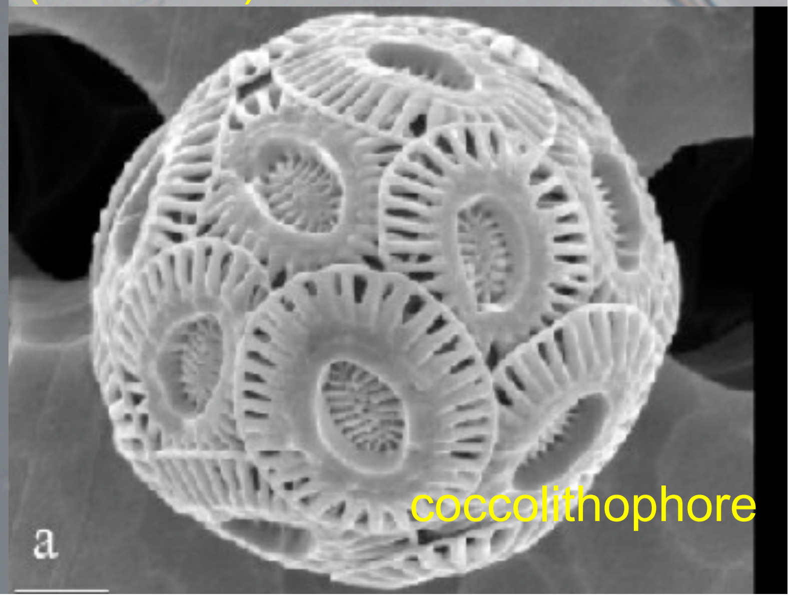




Phytoplankton

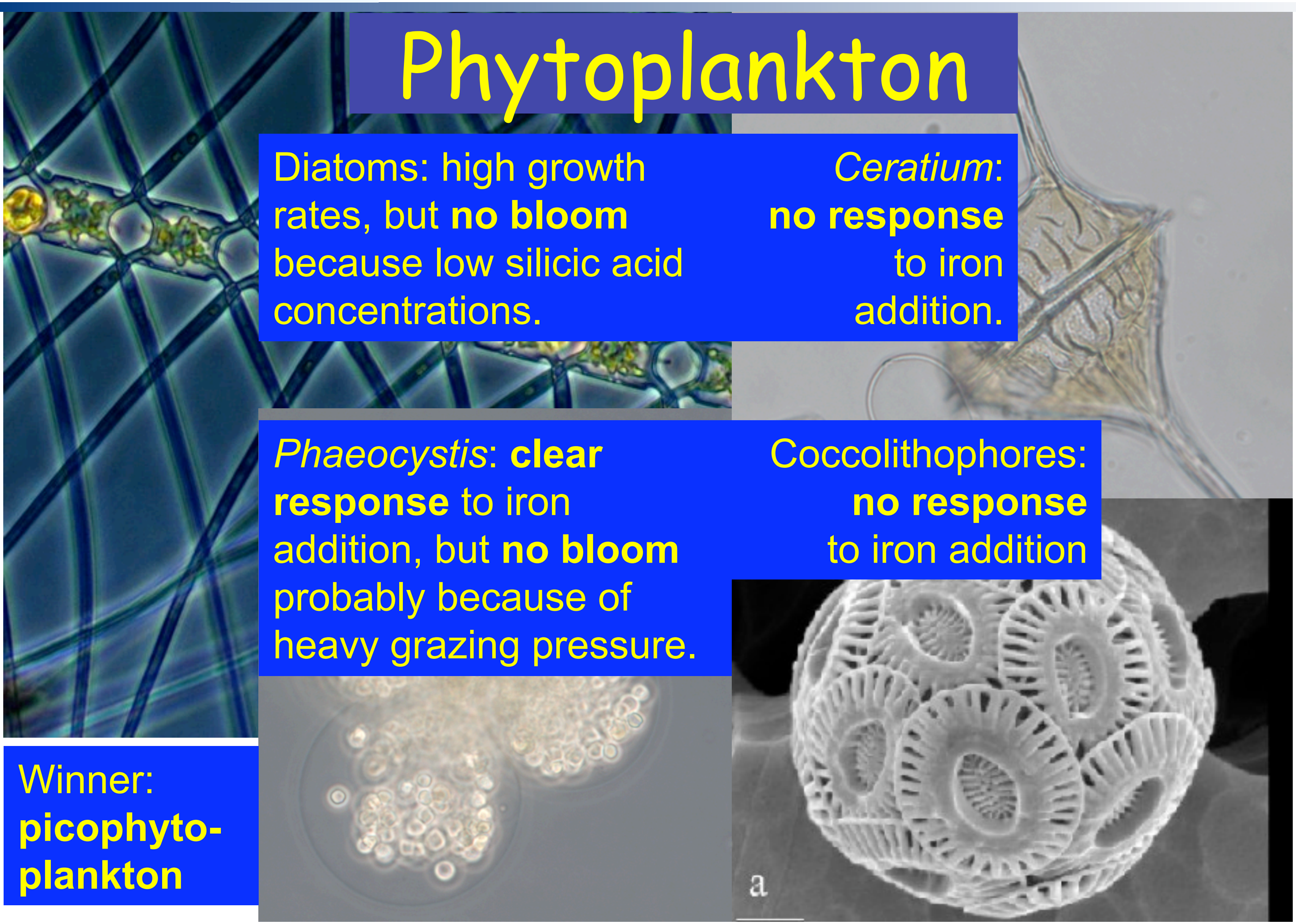




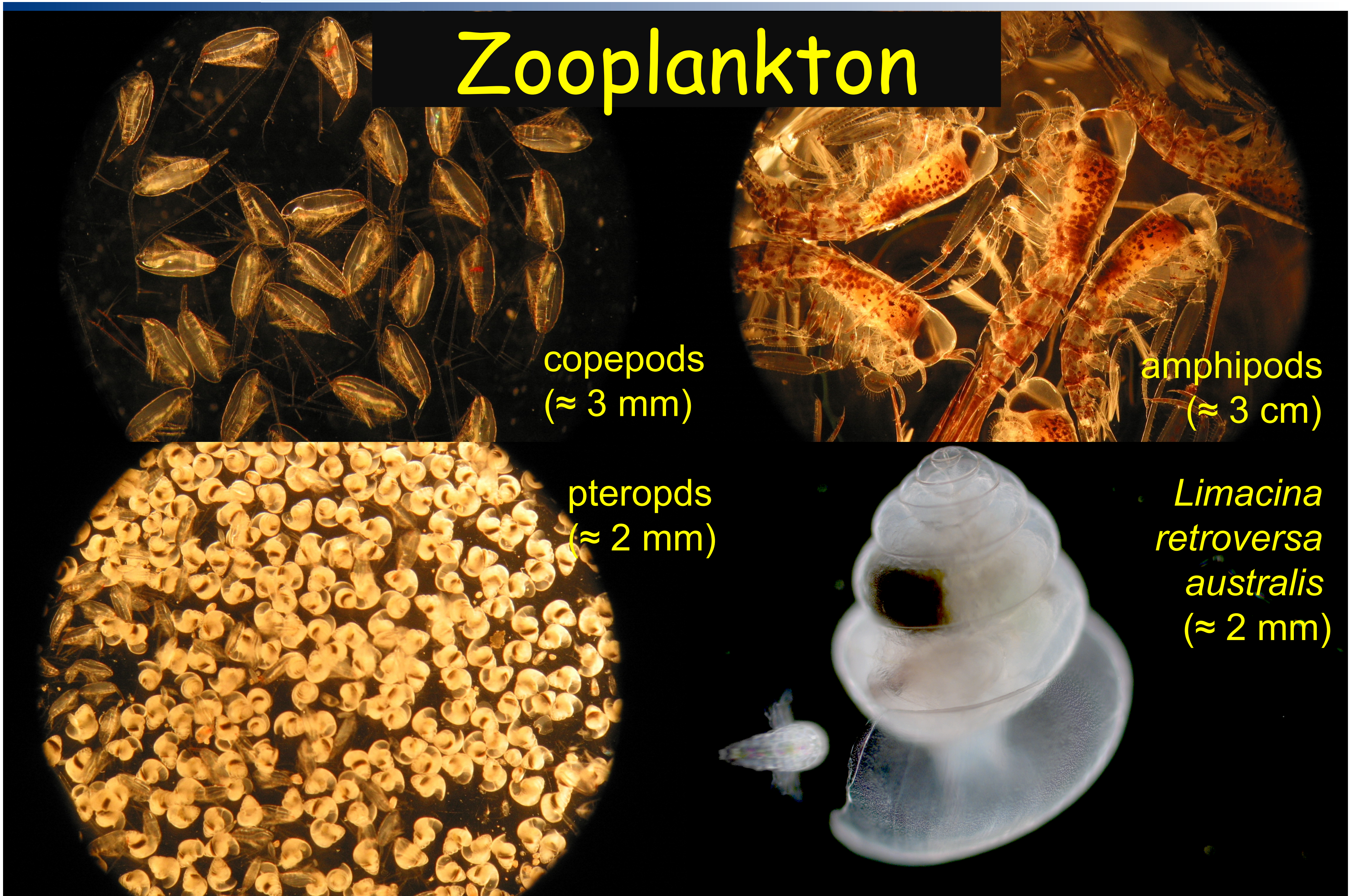


Who will win?

Phytoplankton



Zooplankton

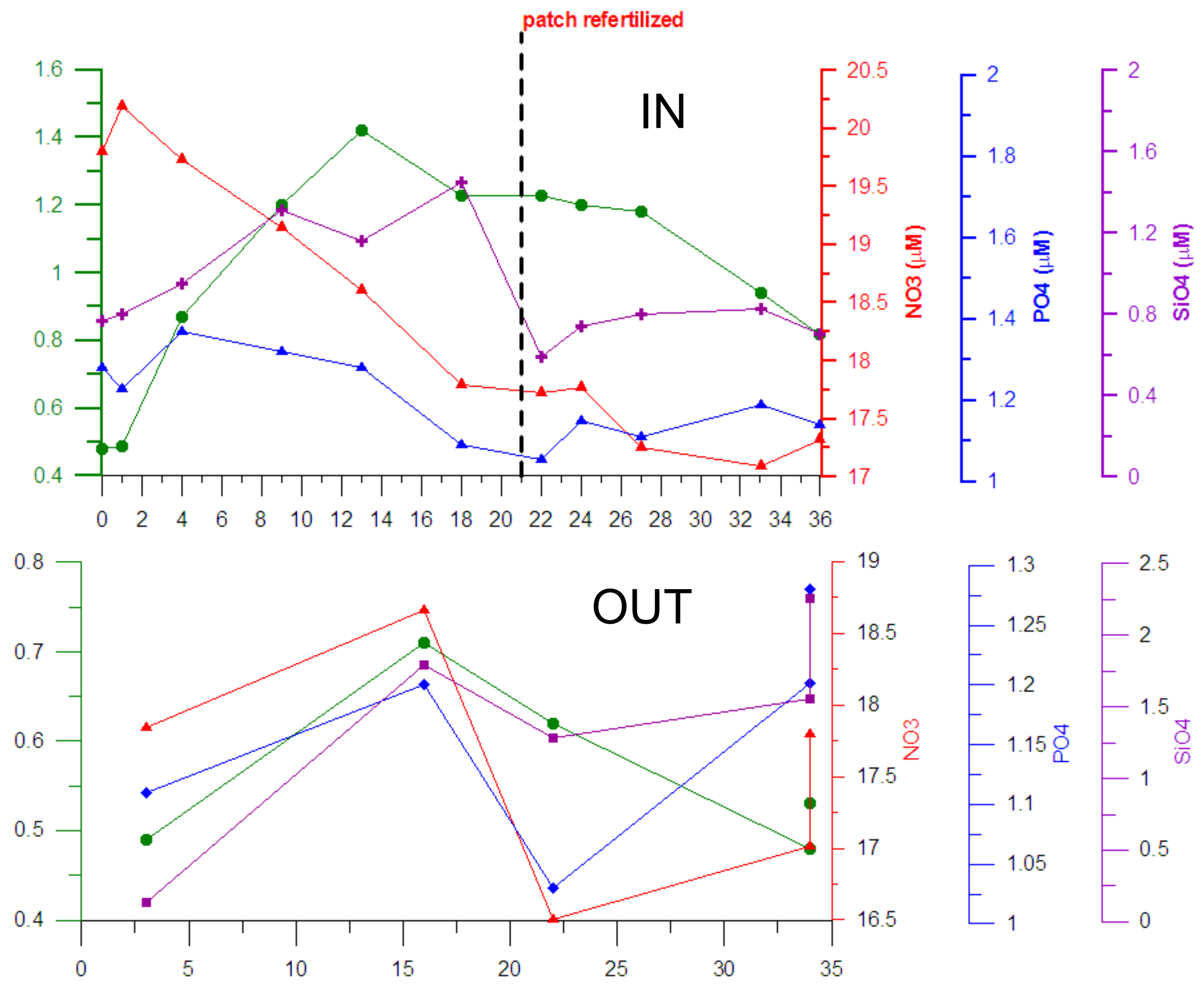


Nutrients

Mixed-layer nitrate and phosphate concentrations decreased with time (e.g. > 2.5 µmol L^{-1} for nitrate) inside the patch.

Outside, the variations were irregular.

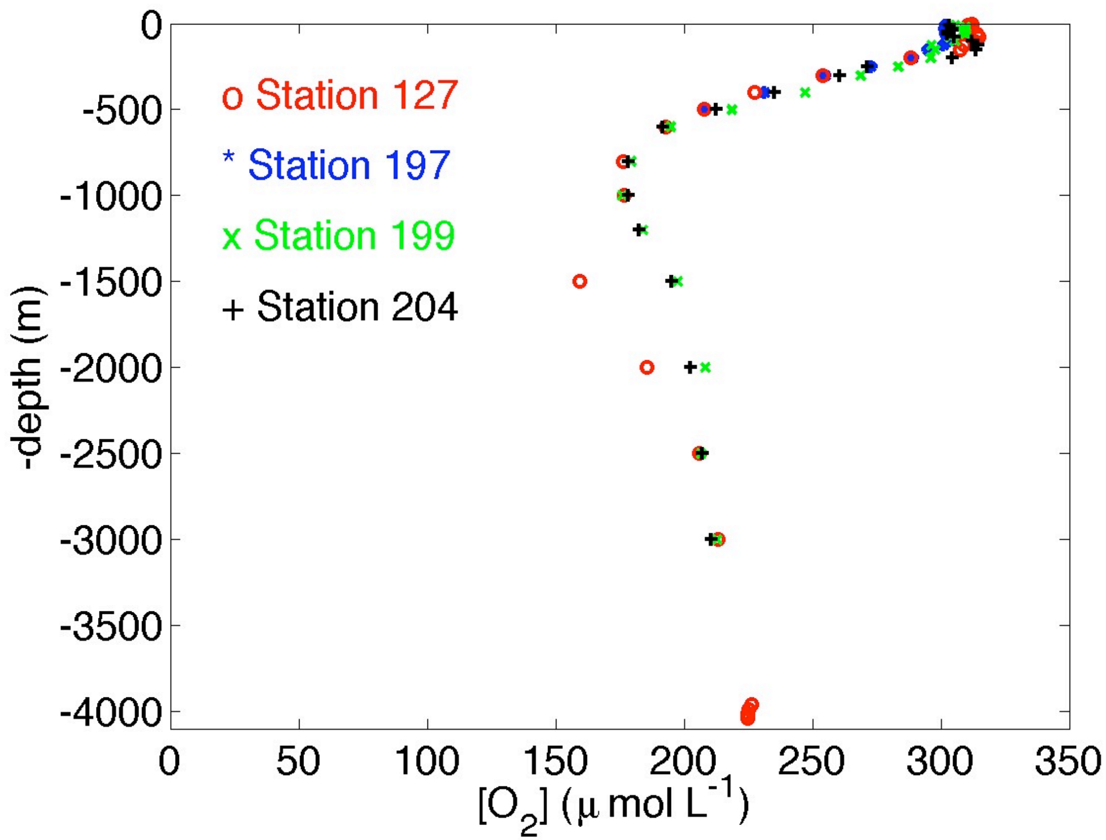
Silicate remained low throughout the experiment.



Gases: Oxygen

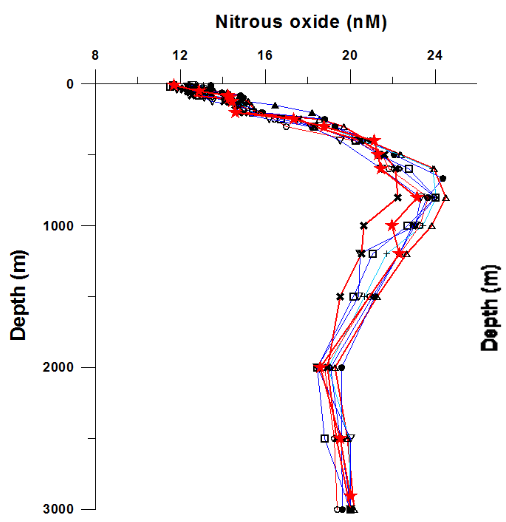
Little station-to- station variability in deep waters.

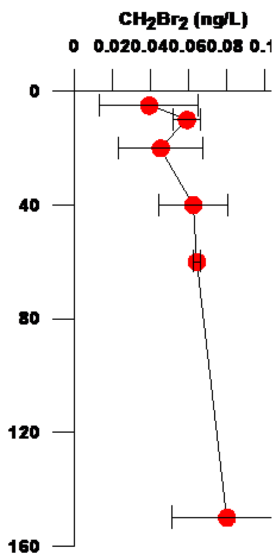
But high variability in the surface layer due to biological activity.

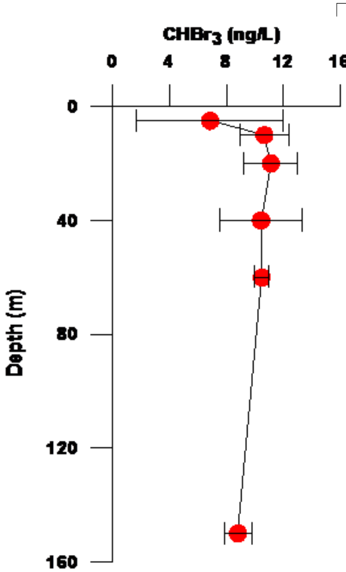


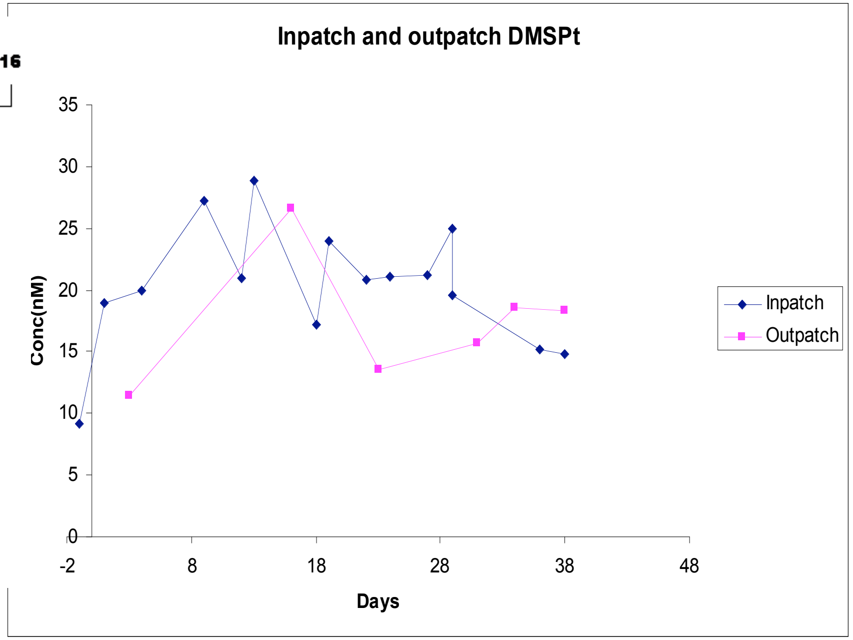
Gases: N_2O - Halocarbons- DMS

Concentrations of all other gases measured were within the normal ranges for the open ocean. Data available at:
www.awi.de/en/news/selected_news/2009/lohafex/





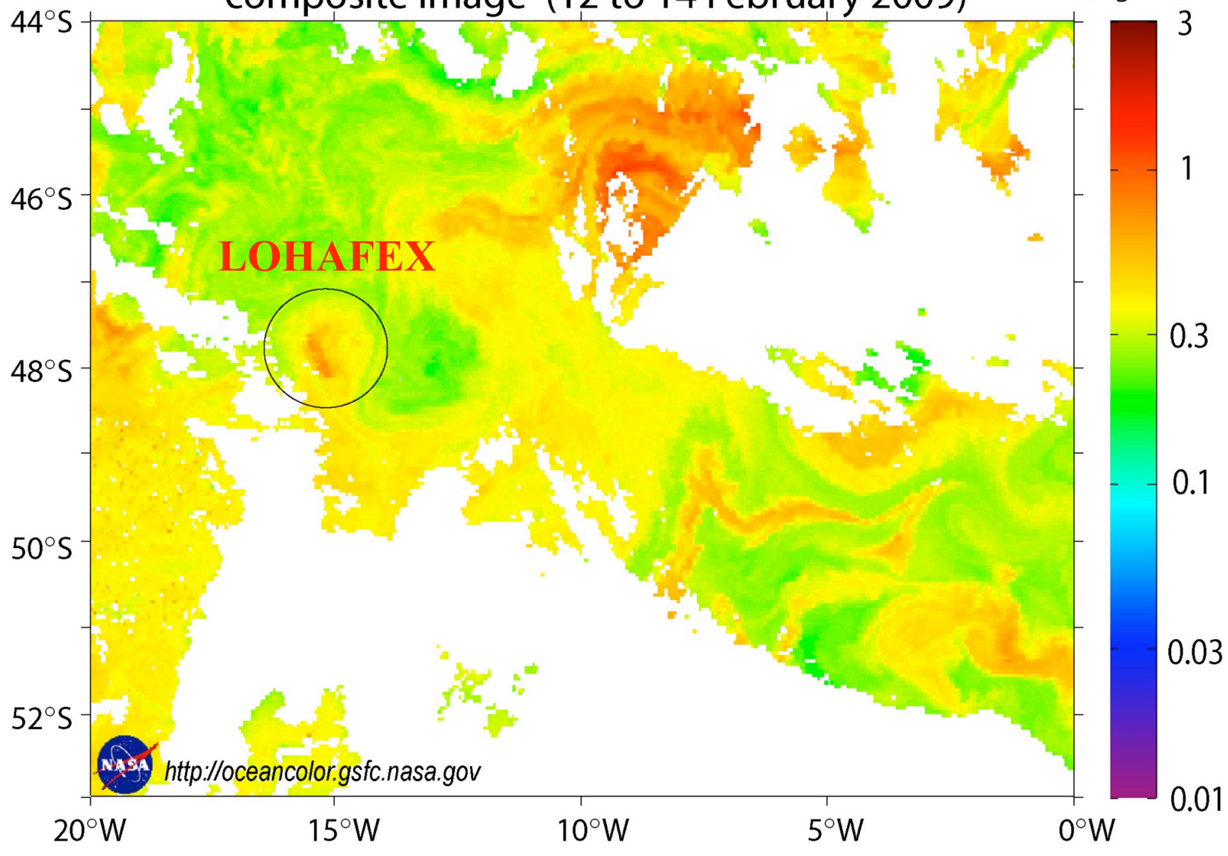




LOHAFEX bloom: visible from space

Initial conditions different from most previous Southern Ocean OIFs (e.g. low silicate in surface waters)

MODIS chlorophyll *a* composite image (12 to 14 February 2009)



Phytoplankton responded instantaneously to Fe enrichment (high Fv/Fm)

Modest chlorophyll increase (maximum ~1.7 mg m^{-3})

PP increased by factor 2

small changes in bacterial biomass and production.

CO_2 uptake? Carbon export?

Chlorophyll increased by factor 2-3 (5 during EIFEX), mainly due to pico-phytoplankton.

Recycling system with considerable turnover.

-> Expectation: low carbon export.

Confirmed by sediment traps, particle recorder, ...

CO_2 uptake from atmosphere was low.

Conclusions

Iron addition stimulated production. Accumulation rates of phytoplankton increased for a very short time only (if at all) because of heavy grazing pressure by zooplankton. **Picophytoplankton and zooplankton profited most**. Positive effects are expected for higher trophic levels.

LOHAFEX showed that iron fertilization of nutrient-rich (NO_3,PO_4) waters does not necessarily lead to algal blooms, carbon export and thus CO_2 uptake (it‘s not just chemistry: NO_3 + PO_4 + Fe -> ...)

The state and functioning of the whole ecosystem plays an essential role; in particular: the plankton assemblage (initial conditions) and the amount of silicic acid.

Major conclusion

Potential of OIF as a means of CO_2 sequestration is substantially smaller than believed so far.

The Times — Counter-acting arguments

Rogue ship sails into storm over experiment

Bobby Jordan **Published:Jan 11, 2009**

Critics say dumping fertiliser into ocean to 'fix' climate change is fraught with risk

International Emissions Trading Association (IETA)

I do not support the view that this experiment suggests that OIF in the rest of the Southern Ocean is unlikely to make a contribution to climate mitigation.

...and...

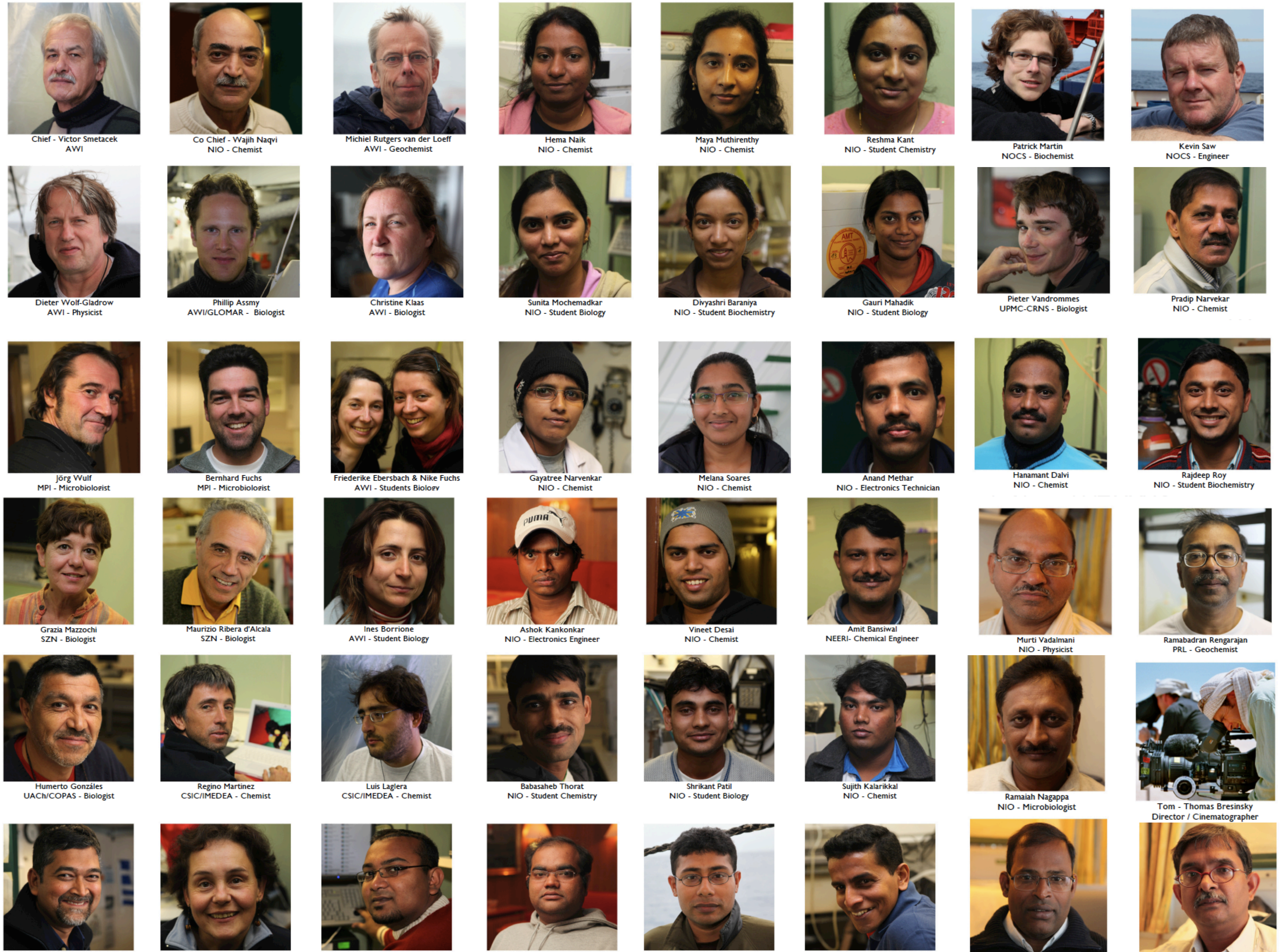
"I would be reluctant to extrapolate from any one experiment anything having to do with the efficacy of iron fertilization as a carbon-sequestration strategy," says Coale." [Science, ScienceInsider, March 31, "Debate: Do Gobbled Algae Mean Carbon Fix Sunk?"

Geoengineering or Basic Research?

Geoengineering is purposeful action intended to manipulate the environment on a very large - especially global - scale. Geoengineering is, presumably, undertaken to reverse or reduce impacts of human actions.´´(R.A. Frosch, Physics Today 3/2009)

Geoengineering: develop, optimize, and apply methods for the reduction of atmospheric greenhouse gases or reduction of incoming solar radiation in order to mitigate climate change. Observation of low C export is a major problem.

Basic research: Investigate the structure and functioning of ecosystems under various conditions. Observation of low C export is a major result and a big step foreward to understand and model the system.



Chief - Victor Smetacek
AWI

Co Chief - Wajih Naqvi
NIO - Chemist

Michiel Rutgers van der Loeff
AWI - Geochemist

Hema Naik
NIO - Chemist

Maya Muthirenthy
NIO - Chemist

Reshma Kant
NIO - Student Chemistry

Patrick Martin
NOCS - Biochemist

Kevin Saw
NOCS - Engineer

Dieter Wolf-Gladrow
AWI - Physicist

Phillip Assmy
AWI/GLOMAR - Biologist

Christine Klaas
AWI - Biologist

Sunita Mochemadkar
NIO - Student Biology

Divyashri Baraniya
NIO - Student Biochemistry

Gauri Mahadik
NIO - Student Biology

Pieter Vandrommes
UPMC-CRNS - Biologist

Pradip Narvekar
NIO - Chemist

Jörg Wulf
MPI - Microbiologist

Bernhard Fuchs
MPI - Microbiologist

Friederike Ebersbach & Nike Fuchs
AWI - Students Biology

Gayatree Narvenkar
NIO - Chemist

Melana Soares
NIO - Chemist

Anand Methar
NIO - Electronics Technician

Hanamant Dalvi
NIO - Chemist

Rajdeep Roy
NIO - Student Biochemistry

Grazia Mazzochi
SZN - Biologist

Maurizio Ribera d'Alcala
SZN - Biologist

Ines Borrione
AWI - Student Biology

Ashok Kankonkar
NIO - Electronics Engineer

Vineet Desai
NIO - Chemist

Amit Bansiwal
NEERI- Chemical Engineer

Murti Vadalmani
NIO - Physicist

Ramabadran Rengarajan
PRL - Geochemist

Humerto Gonzáles
UACh/COPAS - Biologist

Regino Martinez
CSIC/IMEDEA - Chemist

Luis Laglera
CSIC/IMEDEA - Chemist

Babasaheb Thorat
NIO - Student Chemistry

Shrikant Patil
NIO - Student Biology

Sujith Kalarikkal
NIO - Chemist

Ramaiah Nagappa
NIO - Microbiologist

Tom - Thomas Bresinsky
Director / Cinematographer

Anselmo Almeida
NIO - Physics technician

Marina Montresor
SZN - Biologist

Amit Sarkar
NIO - Student Chemist

Sanjay Singh
NIO - Student Microbiology

Anil Pratihary
NIO - Chemist

Mangesh Gauns
NIO - Biologist

Sathya Gundlapally Reddy
CCMB - Microbiologist

Sundar Vetaikorumagan

Wissenschaftler ANT-XXV-3

German-Indian project