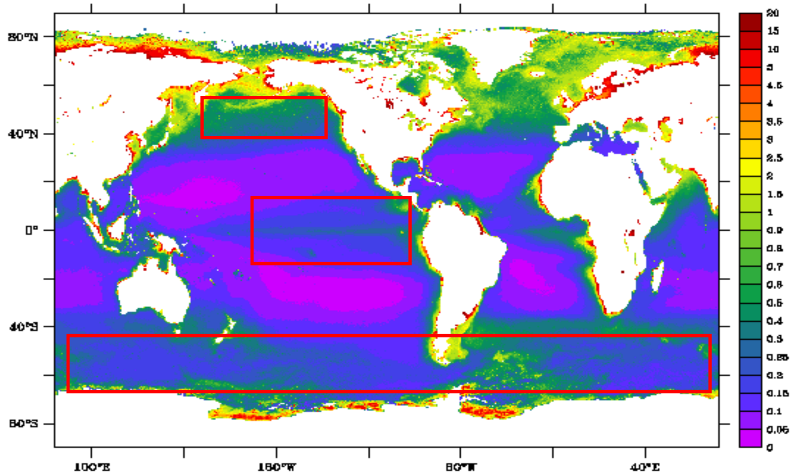
Assessing the efficiency of iron fertilization on atmospheric CO2 using an intermediate complexity ecosystem model of the global ocean

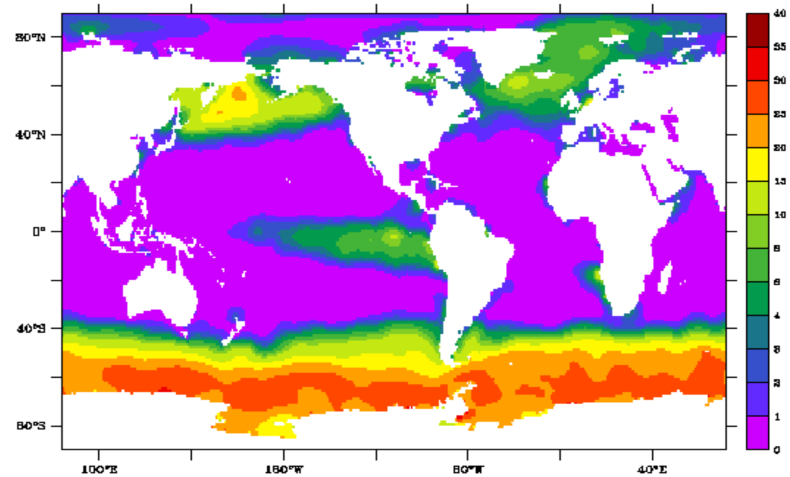
Olivier Aumont[1] and Laurent Bopp[2]

[1]IPSL / LODyC, Paris, France
[2]IPSL / LSCE, Gif s/ Yvette, France

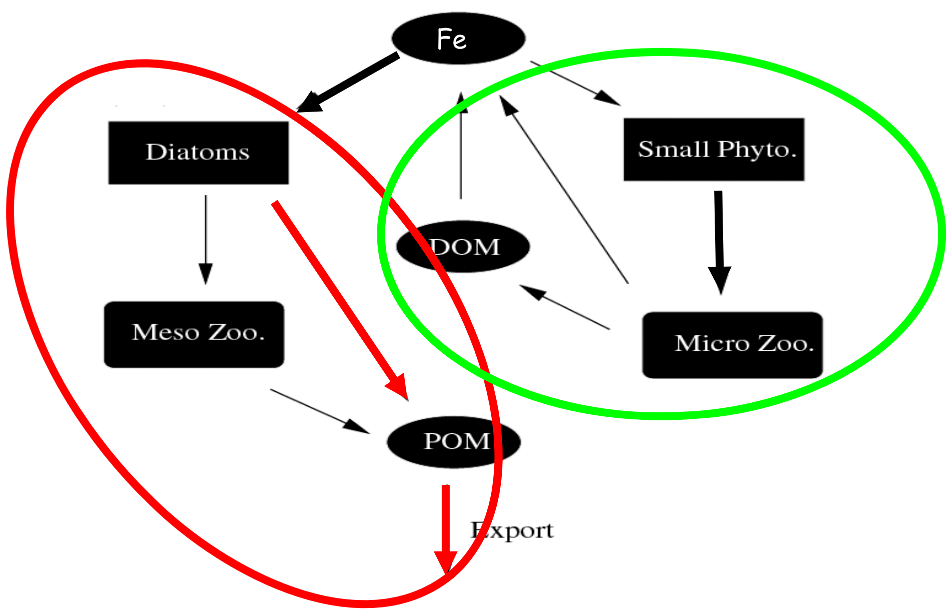
Laboratoire d'Océanographie Dynamique et de Climatologie
LODYC
IPSL
TUTELLES CNRS IRD ORSTOM

Introduction : The HNLC regions

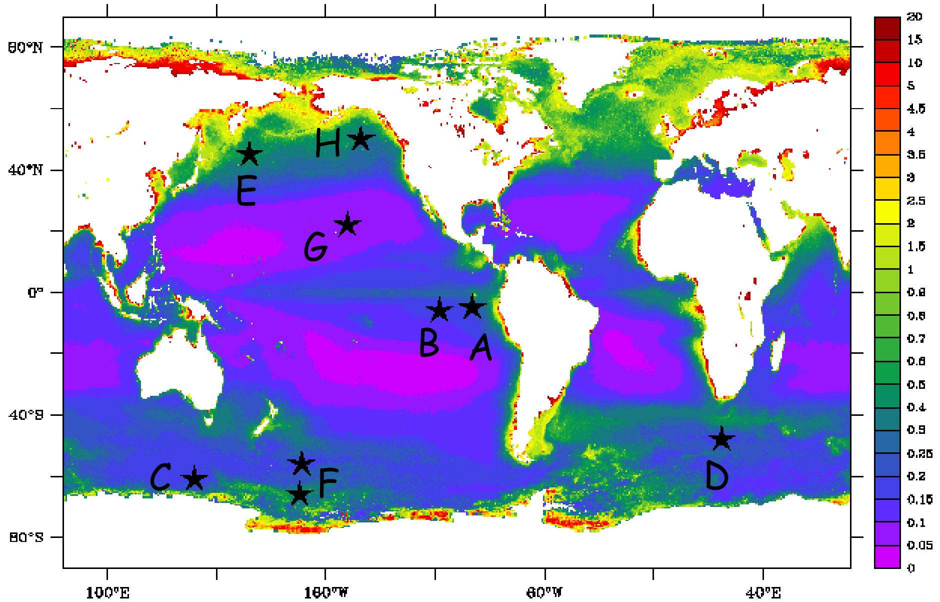




- The Iron hypothesis



The Iron fertilization experiments



A: IronexI

B: IronexII

C: SOIREE

D: EisenEx

E: SEEDS

F: SOFEX

G: Planktos

H: SERIES

▷ Main results

Chlorophyll	From a 3 to a 40-fold increase, generally as diatoms
pCO_2	A 30 to 90 µatm drawdown in surface pCO_2
Export Production	Contrasting results, generally an increase
DMS	An increase

Mitigation of atmospheric CO_2

Large scale iron fertilization

Iron fertilization can be used as a means of offsetting the anthropogenic carbone dioxide emission

(Martin et al., 1991)

Previous estimates (modeling studies)

Peng and Broecker, 1991 Joos et al., 1991	Box models	Southern Ocean	Preindustrial: -17 to -59 μatm Anthropogenic : -64 to -107 μatm
Sarmiento and Orr, 1991	OGCM Nutrient restoring	Global Ocean	Preindustrial: -3 to -72 μatm
Six and Maier-Reimer, 1993	OGCM HAMOCC	Southern Ocean	Preindustrial: -34 μatm Anthropogenic : -50 μatm
Archer et al., 2000	OGCM HAMOCC	Global Ocean	Preindustrial: -50 μatm
Ganadesikan et al., 2003	OGCM Nutrient restoring	Patchy, equatorial Pacific	Low efficiency, < 10% of increase in export production as atmospheric CO_2

Questions

Iron fertilization

Can the model simulate the main features of the iron fertilization experiments ?

What is the spatial and temporal variability of the response to fertilization ?

What is the long-term efficiency of the fertilization ?

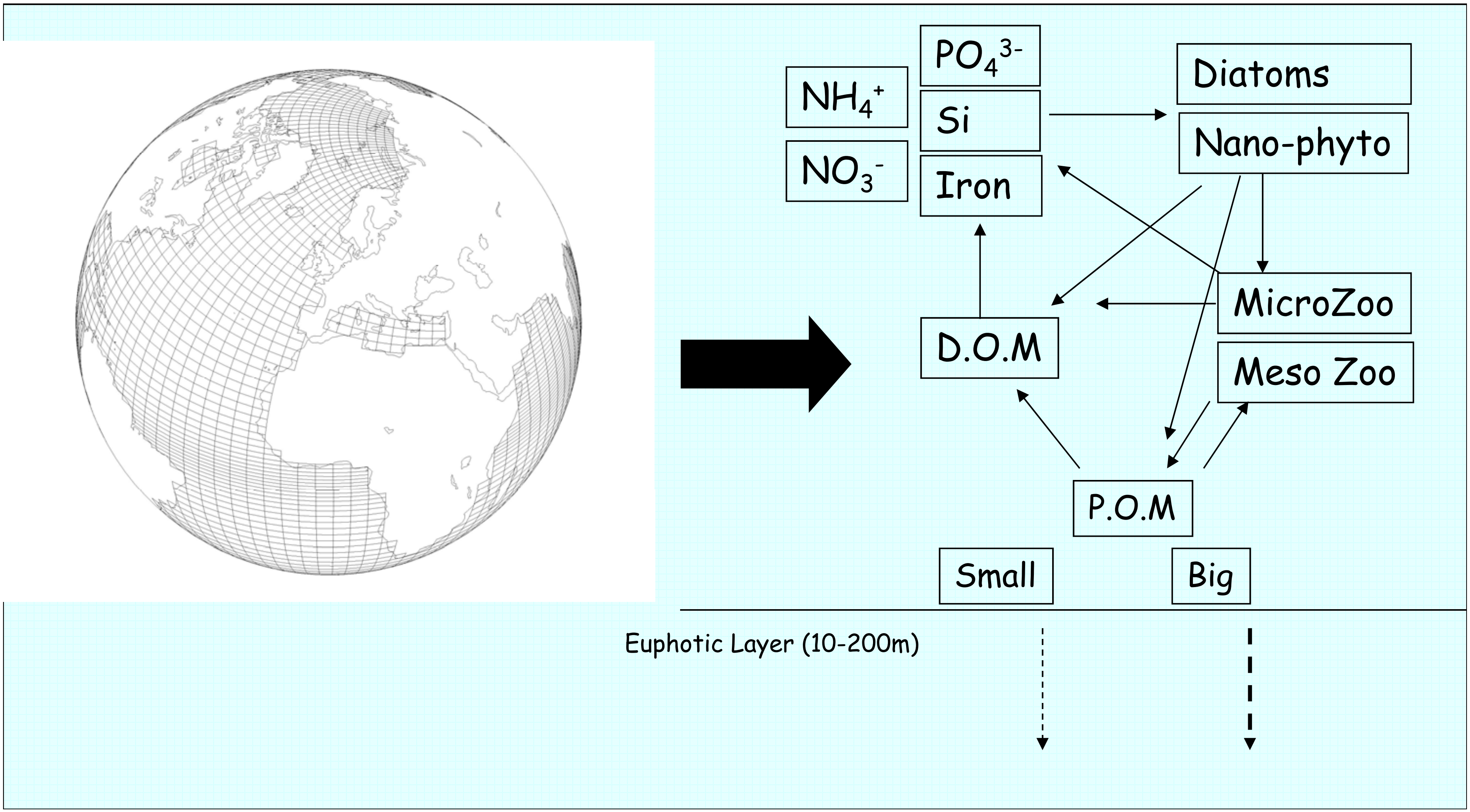
Outline

1. Model description
2. Patchy iron fertilization
3. long-term iron fertilization on the global scale

Tools : Models

OPA

PISCES

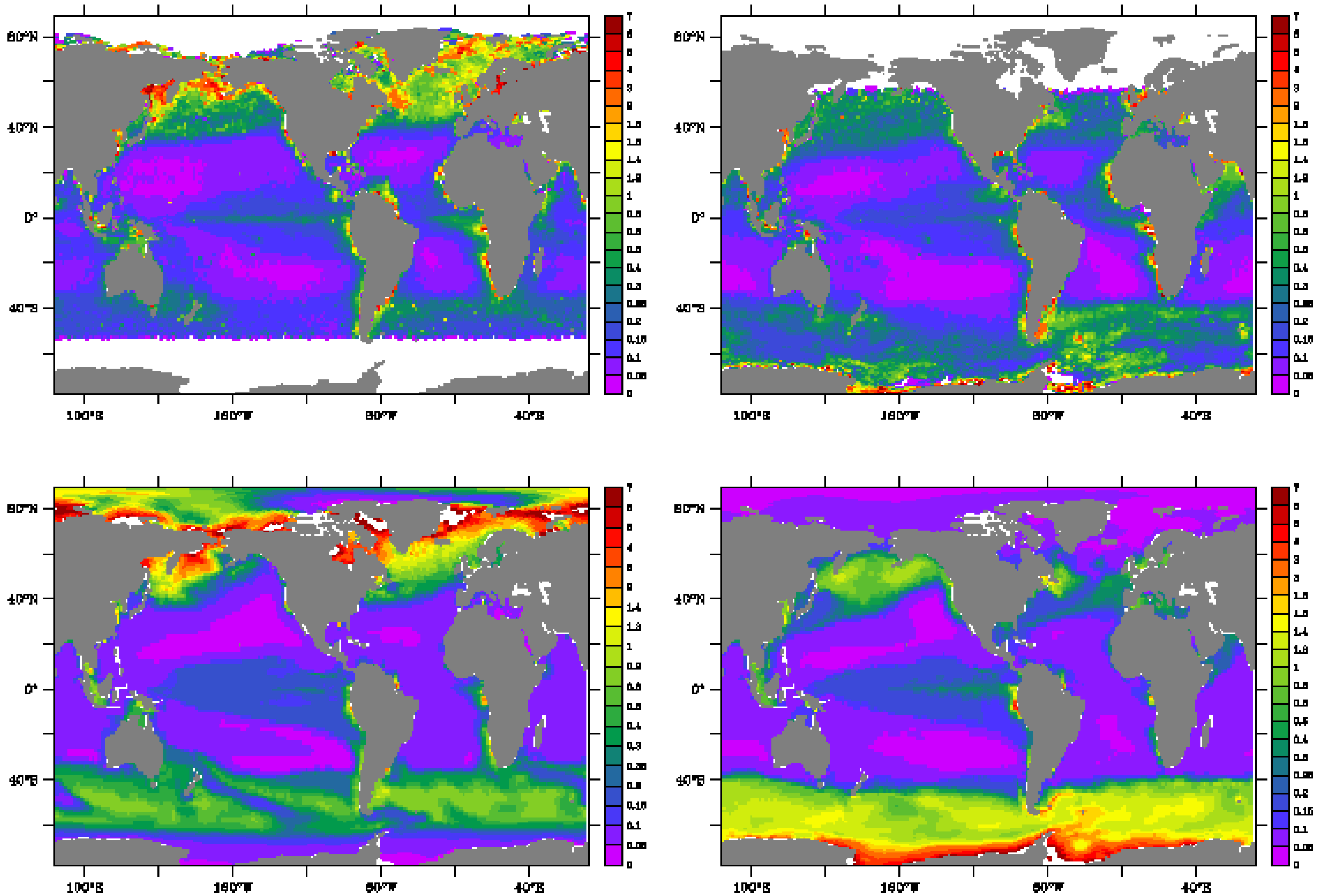


Chlorophyll surface concentrations

June | January

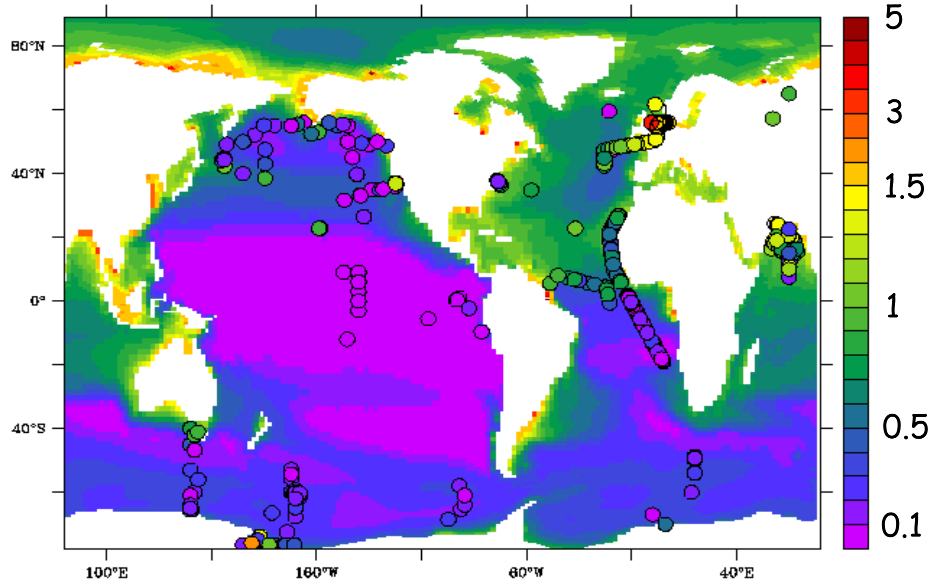
Seawifs (98-03)

PISCES

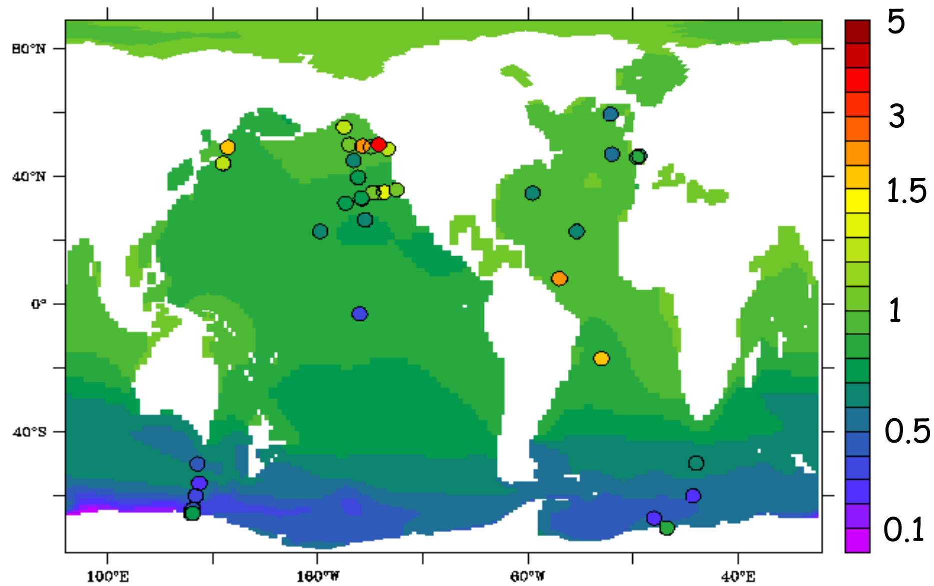


Iron distribution

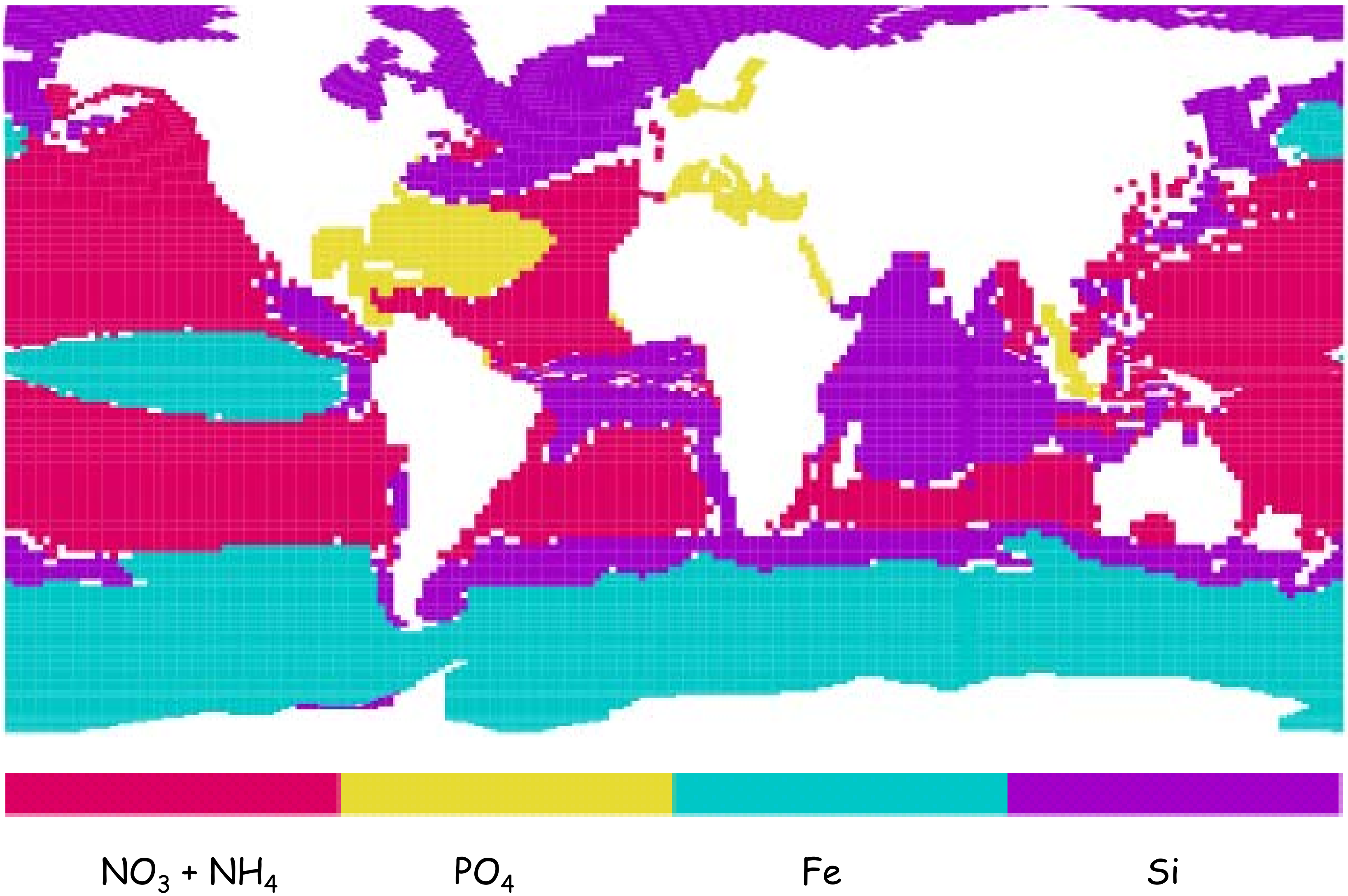
▷ Annual mean, surface



▷ Annual mean, 1000m

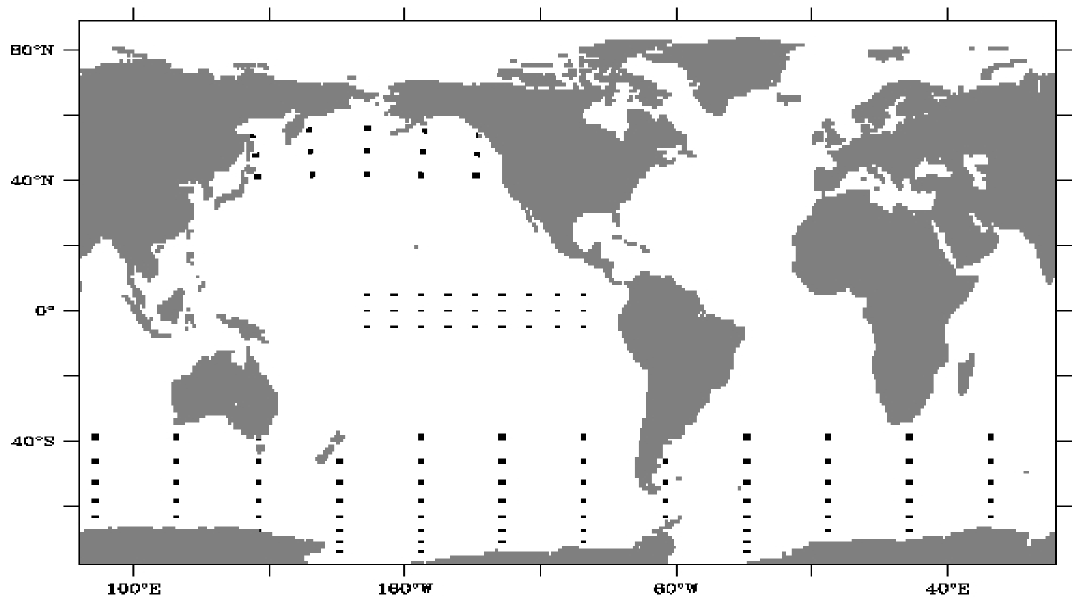


What limits diatoms growth ?



Iron Fertilization

- " Patchy " Iron Fertilization in the three main HNLC regions



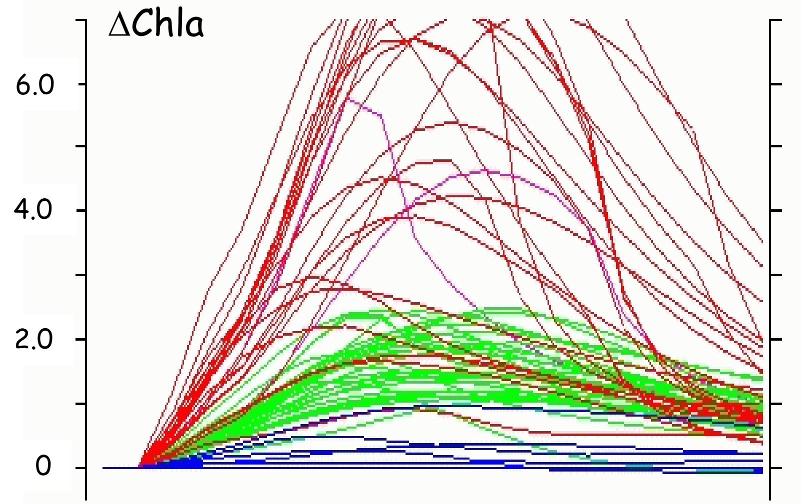
- Experimental design

  - Iron concentration set to 2 nM in the mixed layer at day 2 and 5

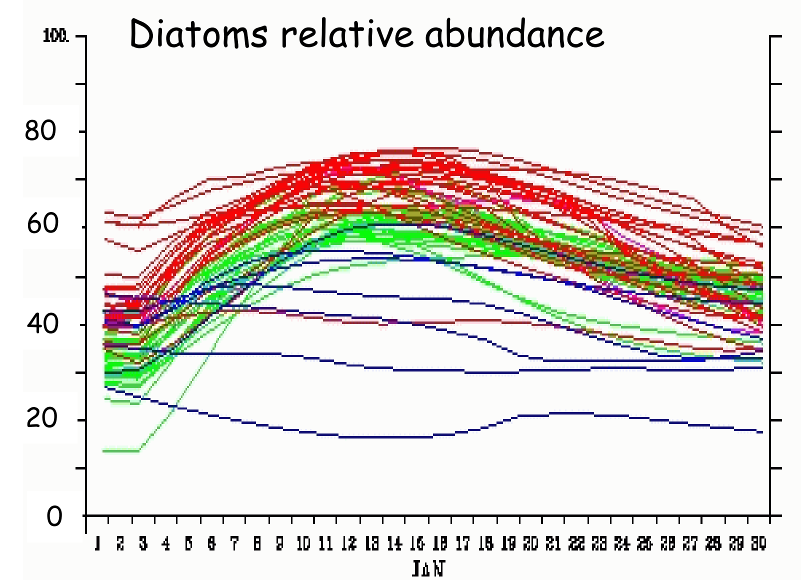
  - Fertilization applied over only one grid box

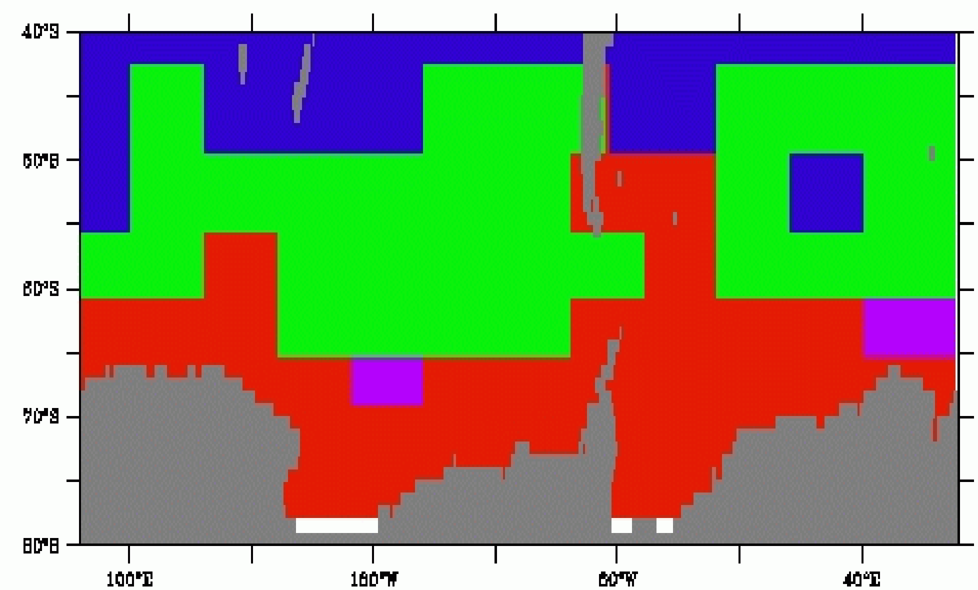
  - The model is integrated for 31 days

Iron Fertilization : The Southern Ocean (1)

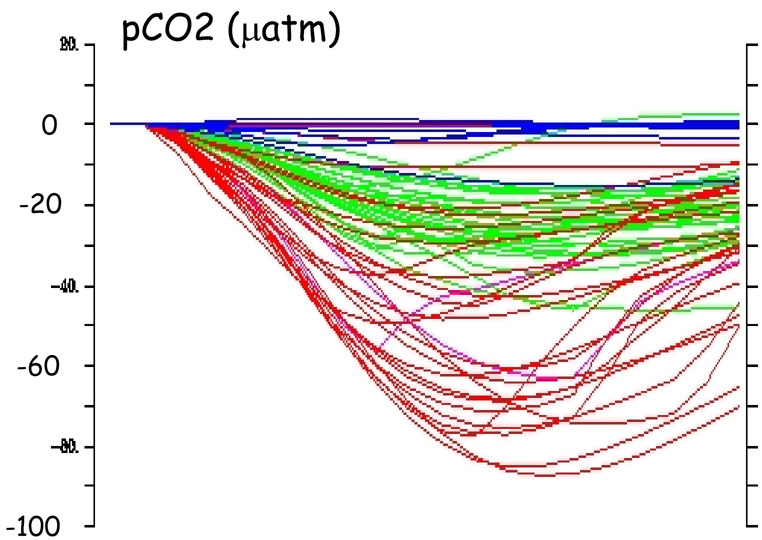


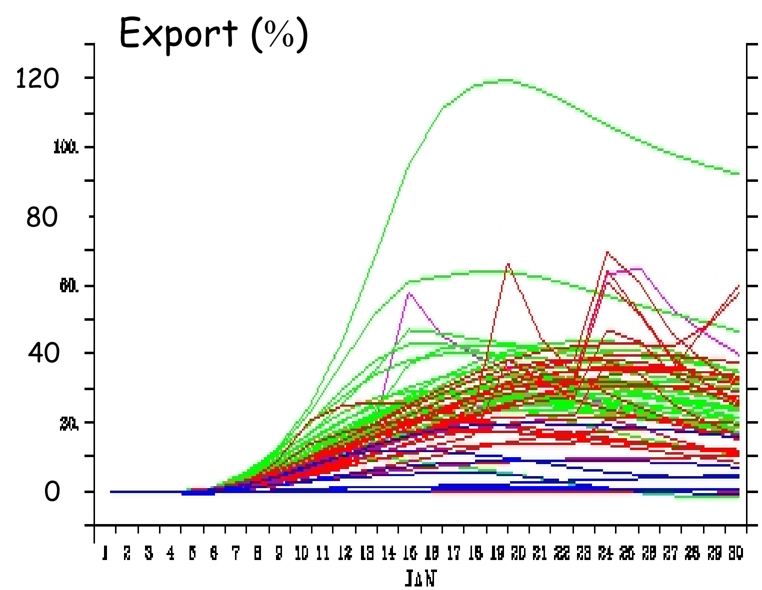
1. Blooming conditions (Chl > 1.5 mg Chl m^{-3})
2. Small response (ΔChl < 0.7 mg Chl m^{-3})
3. Moderate response (0.7 < ΔChl< 2.5 mg Chl m^{-3})
4. Strong response (2.5 mg Chl m^{-3} < ΔChl)





The Southern Ocean





Why such responses ?

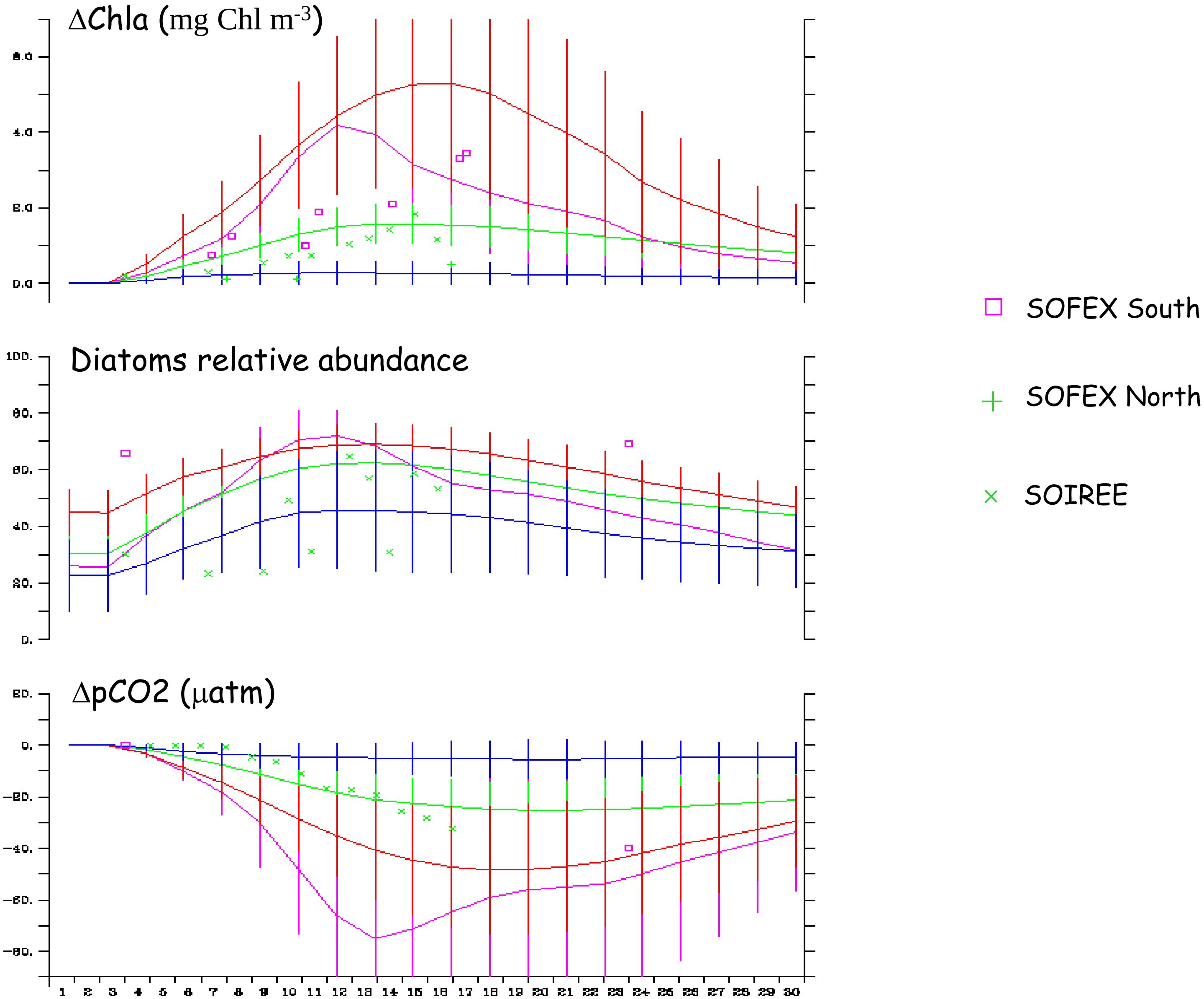
1. Stratification, ice retreat

2. Si limitation, Si initial < 6 umol L

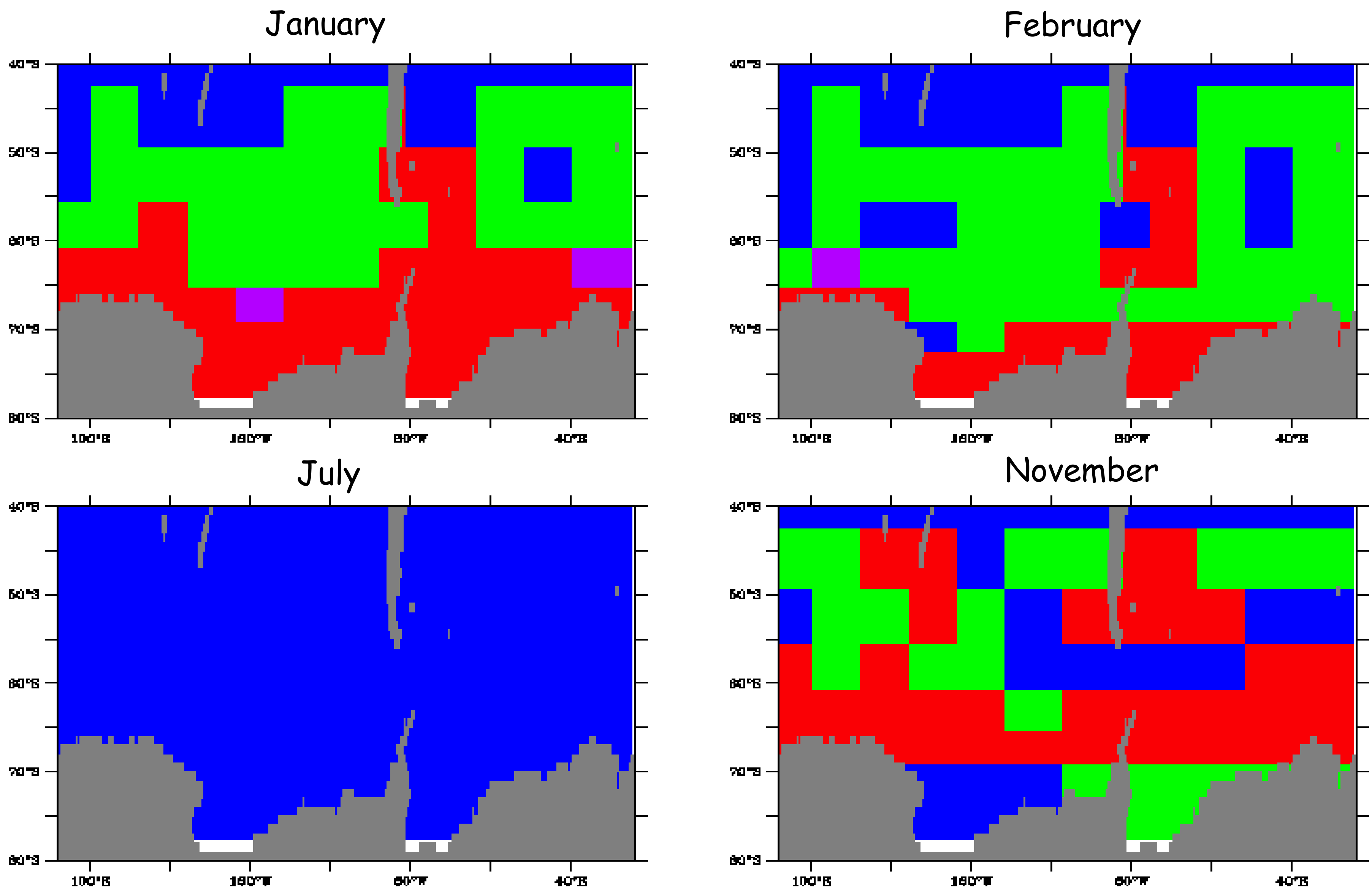
3. Mixed layer depth > 30 m, macronutrient replete

4. Favorable conditions, strongly iron limited

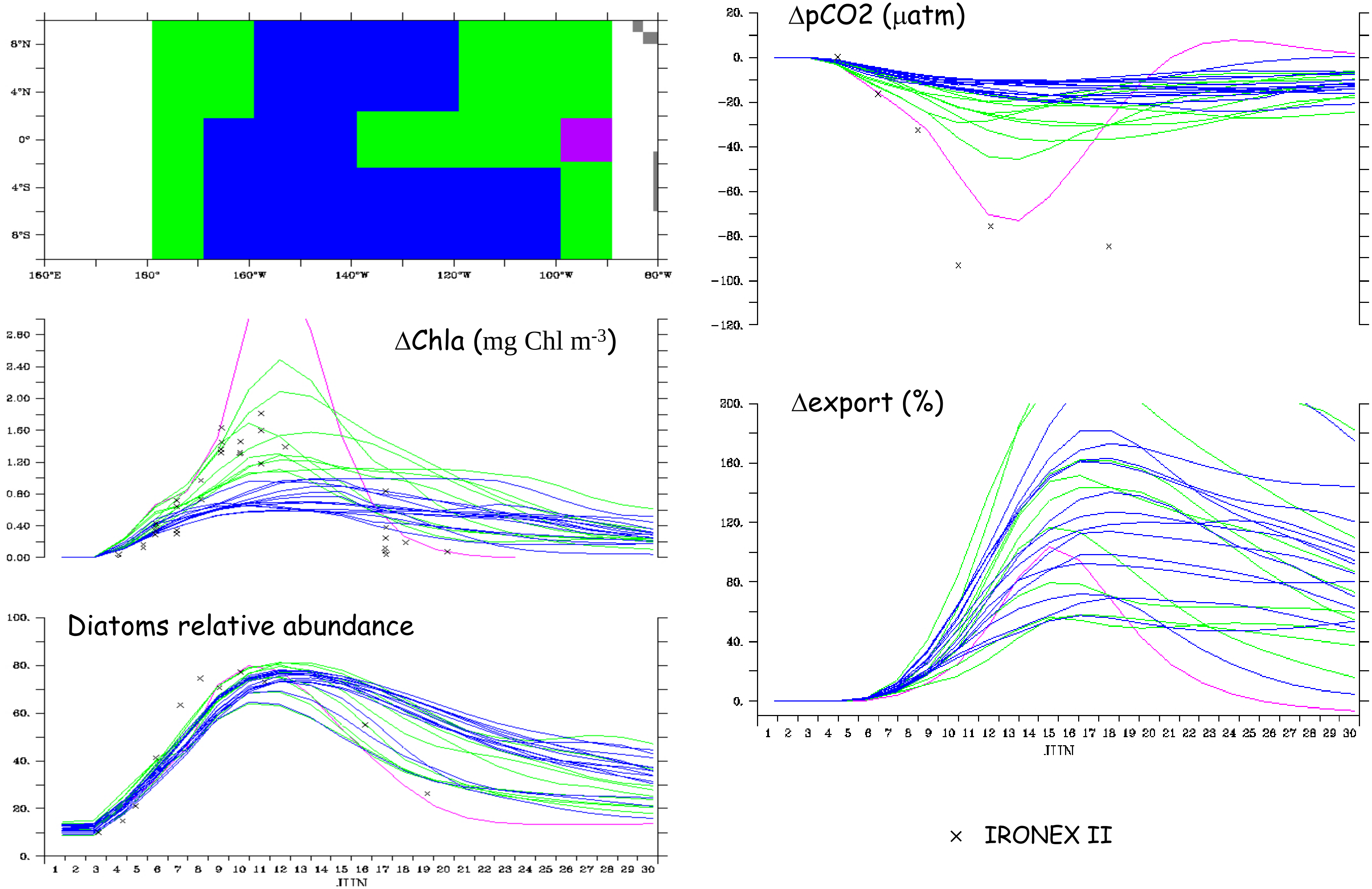
The Southern Ocean : Comparison with data



Seasonal evolution

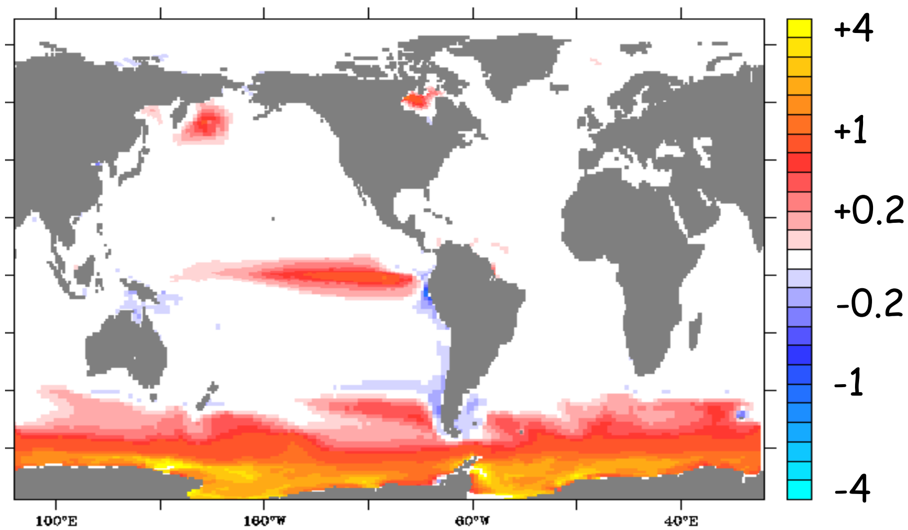


Iron Fertilization : The equatorial Pacific

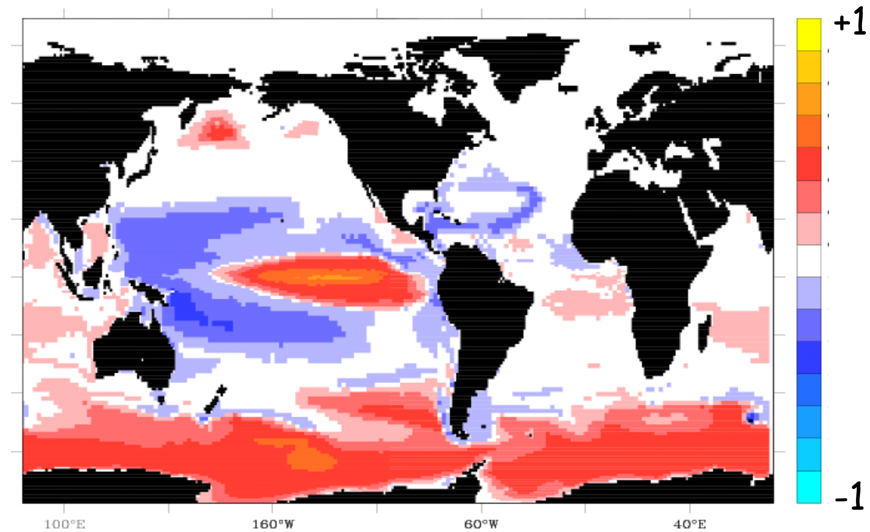


Iron Fertilization : everywhere & 50 yr long

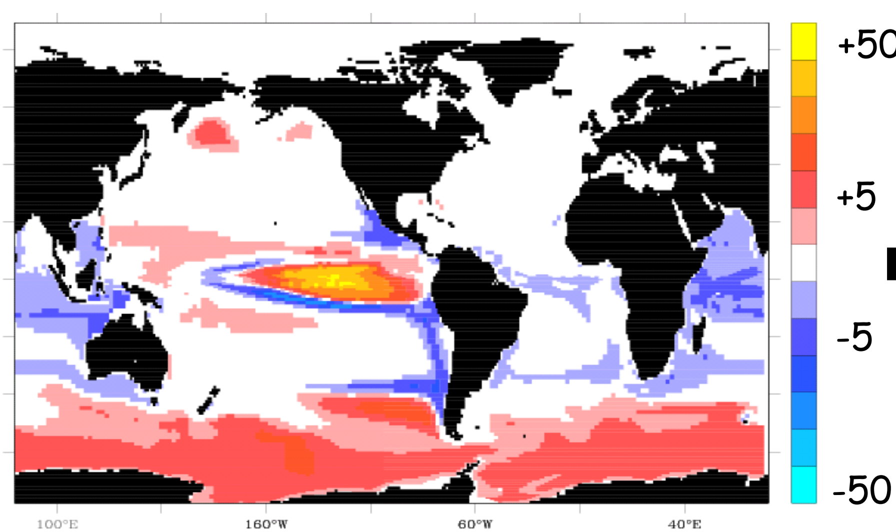
Changes in Chla (mg Chl m^{-3})

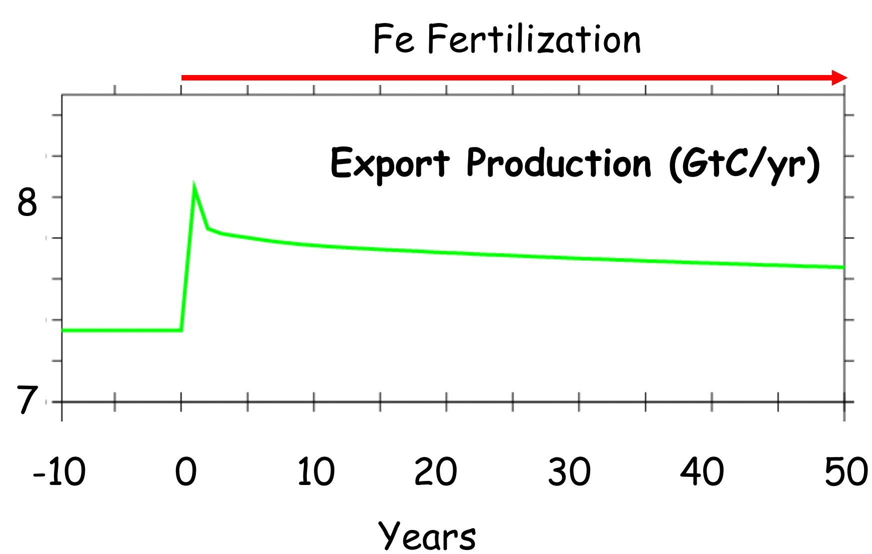


Changes in Diatoms Relative Abundance



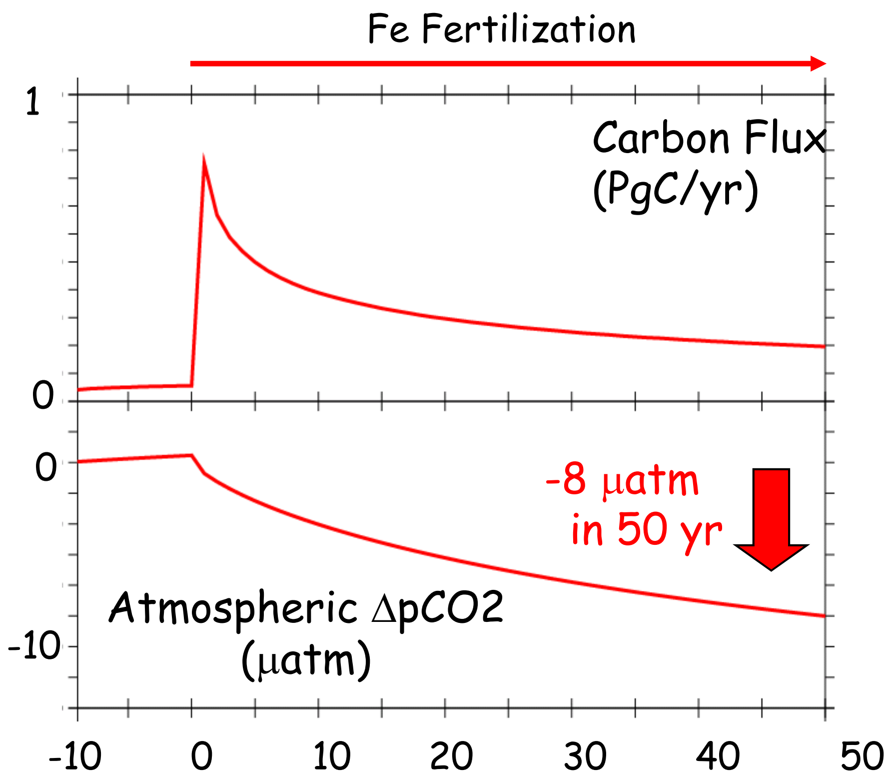
Increase of Export Production (gC/m2/yr)

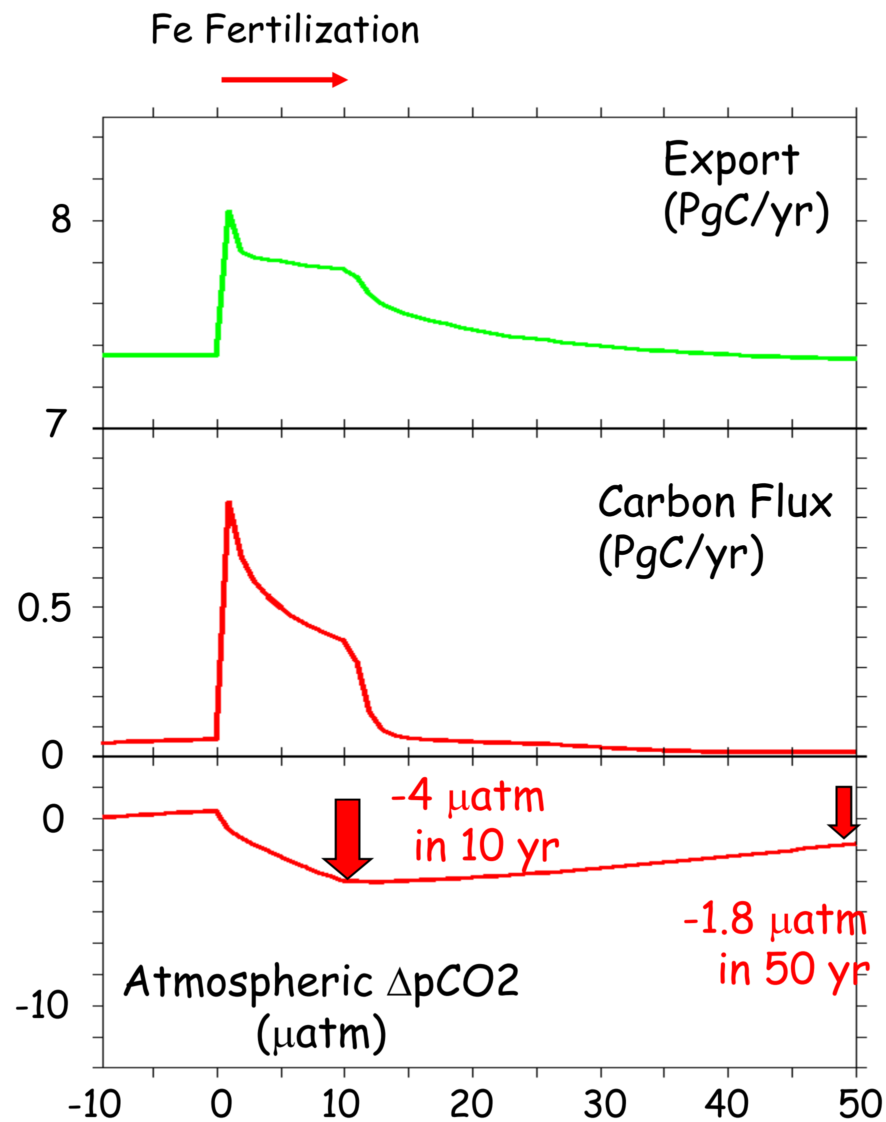




Impact on atmospheric pCO2

- Preindustrial conditions

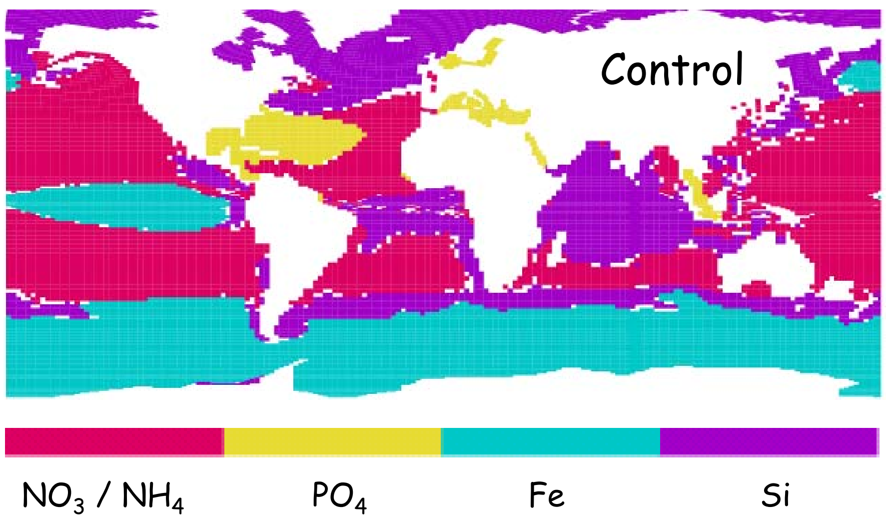


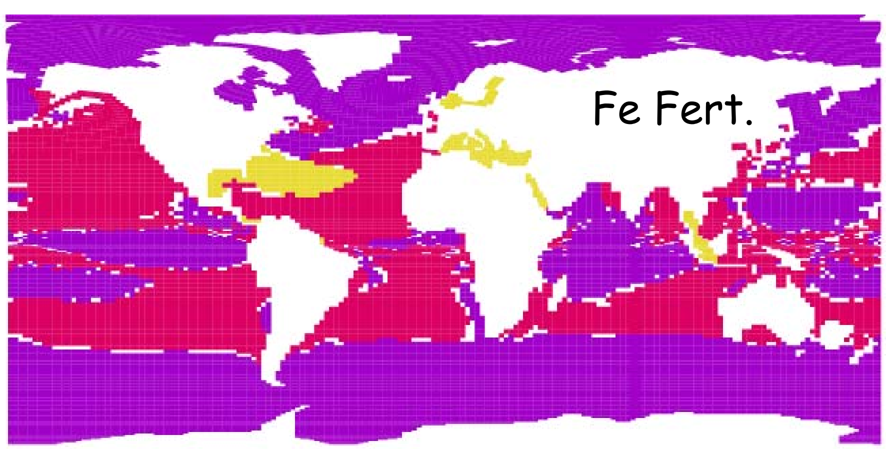


- **>80% due to Southern Ocean**

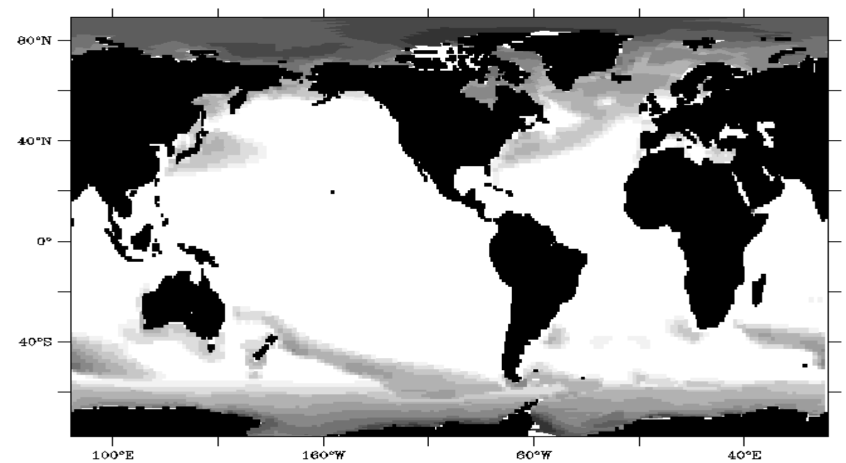
Why such a small efficiency ?

Nutrient Limitation of Diatoms Growth

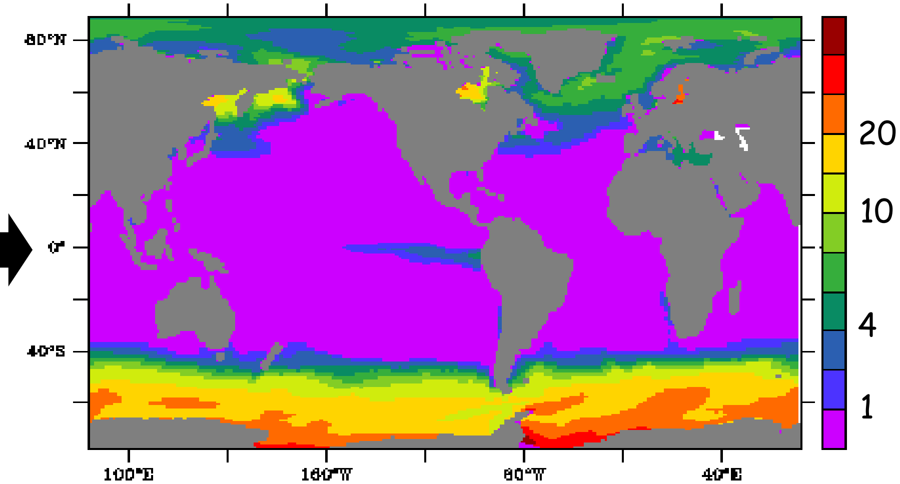




Light limitation



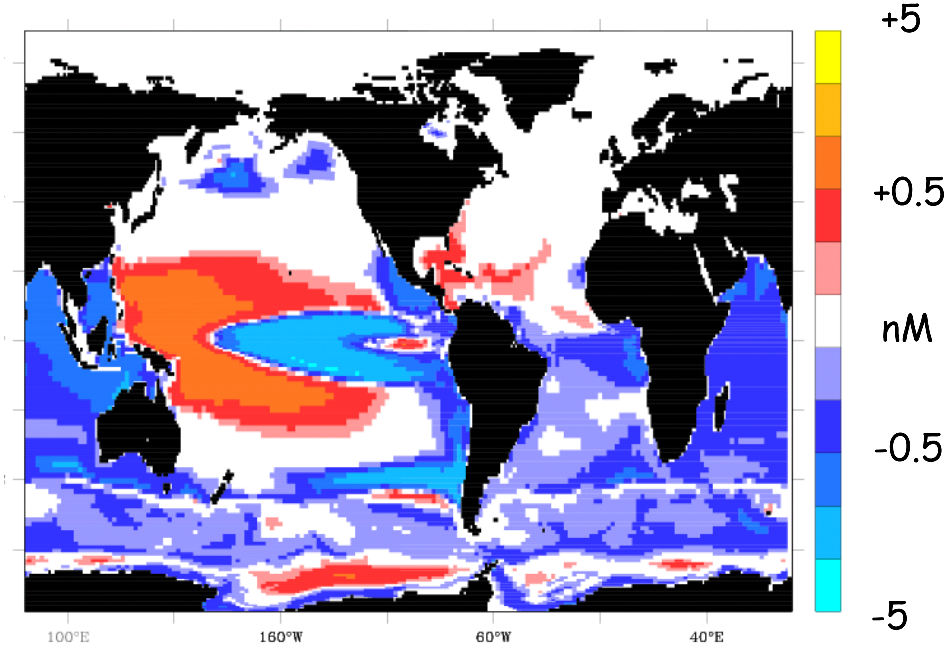
NO3 (µmol/L)

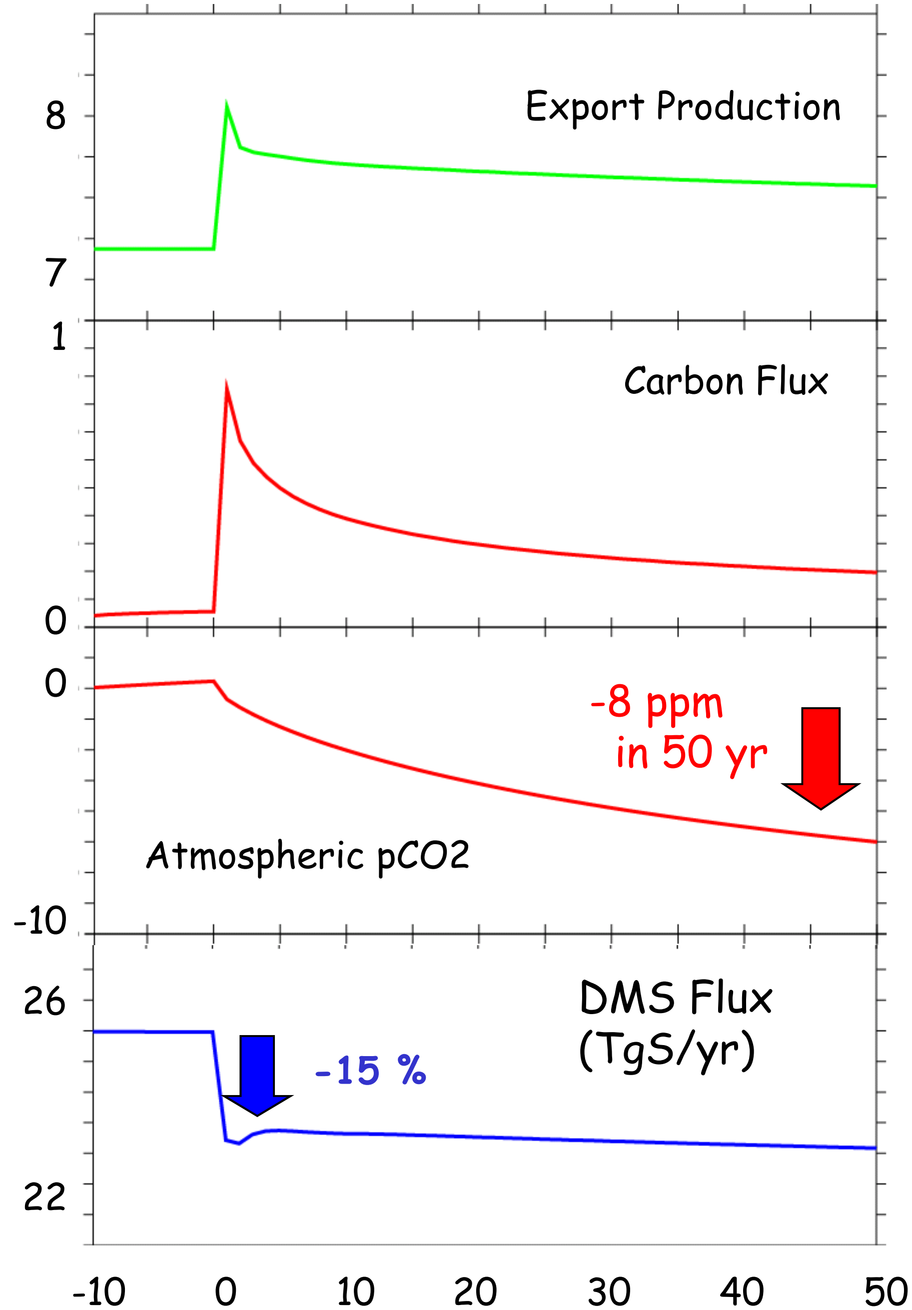


Iron Fertilization :

Implications for the Sulfur Cycle

- Changes in Surface DMS Concentrations





Conclusions

- **Patchy Iron fertilization :**

The model roughly captures the main features of in situ iron fertilization experiments, except in the North Pacific.

In the Southern Ocean, the response depends highly on the location and the time period of the iron release. Main controlling factors are Si concentrations, the mixed layer depth, and the status of the ecosystem.

The favorable season extends from November to March.

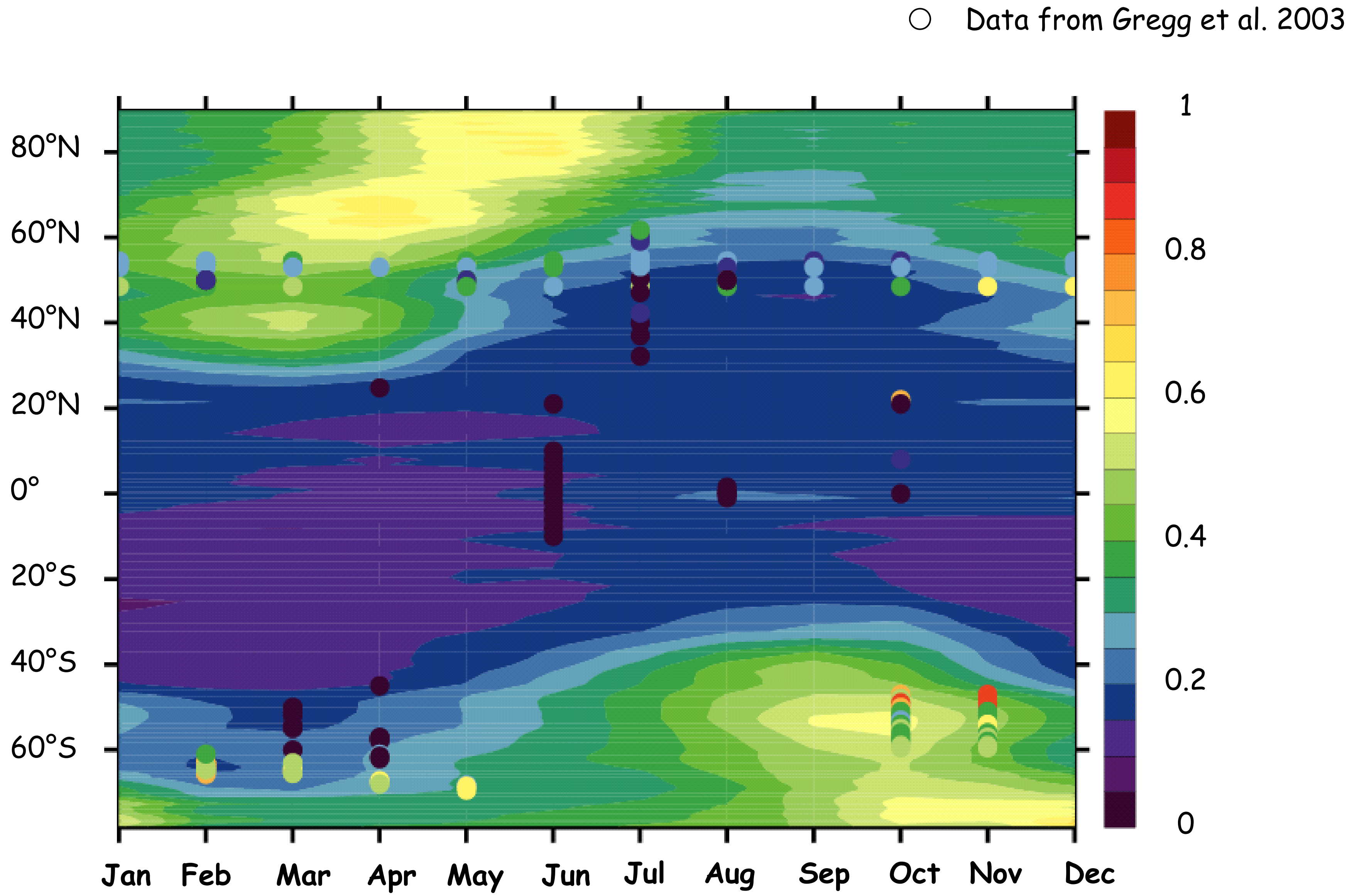
- **Large-scale Iron fertilization :**

Very low efficiency : only 8 ppmv drawdown in atmospheric pCO_2 after 50 years.

Iron fertilization should be done continuously to keep the additionally stored CO_2 within the ocean.

Possible drawbacks : N_2O production, extension of the anoxic regions, changes in the fisheries, possible decrease in DMS production, …

Diatoms relative abundance : vs Data



Iron Fertilization : The North Pacific