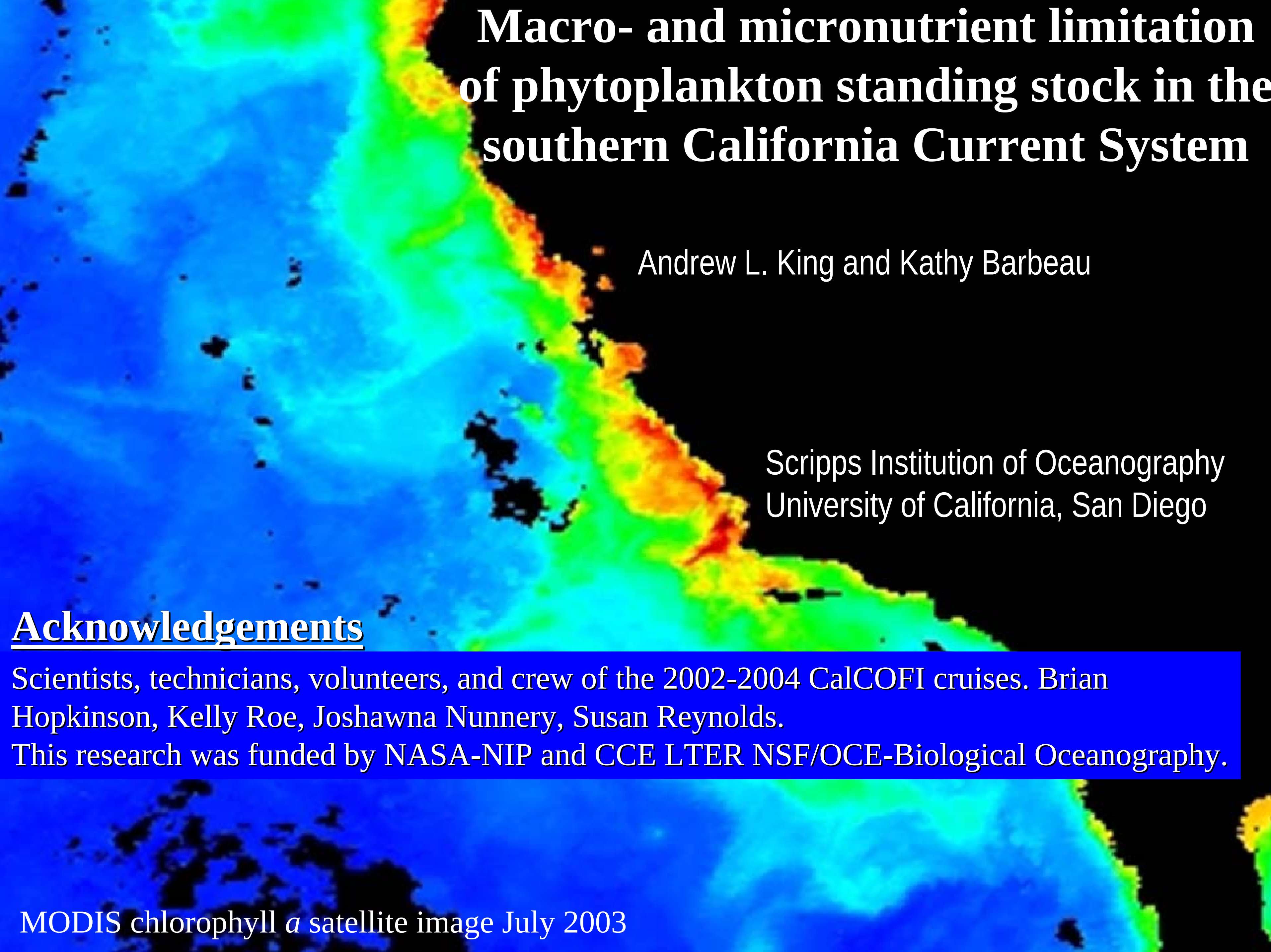
Macro- and micronutrient limitation of phytoplankton standing stock in the southern California Current System

Andrew L. King and Kathy Barbeau

Scripps Institution of Oceanography
University of California, San Diego

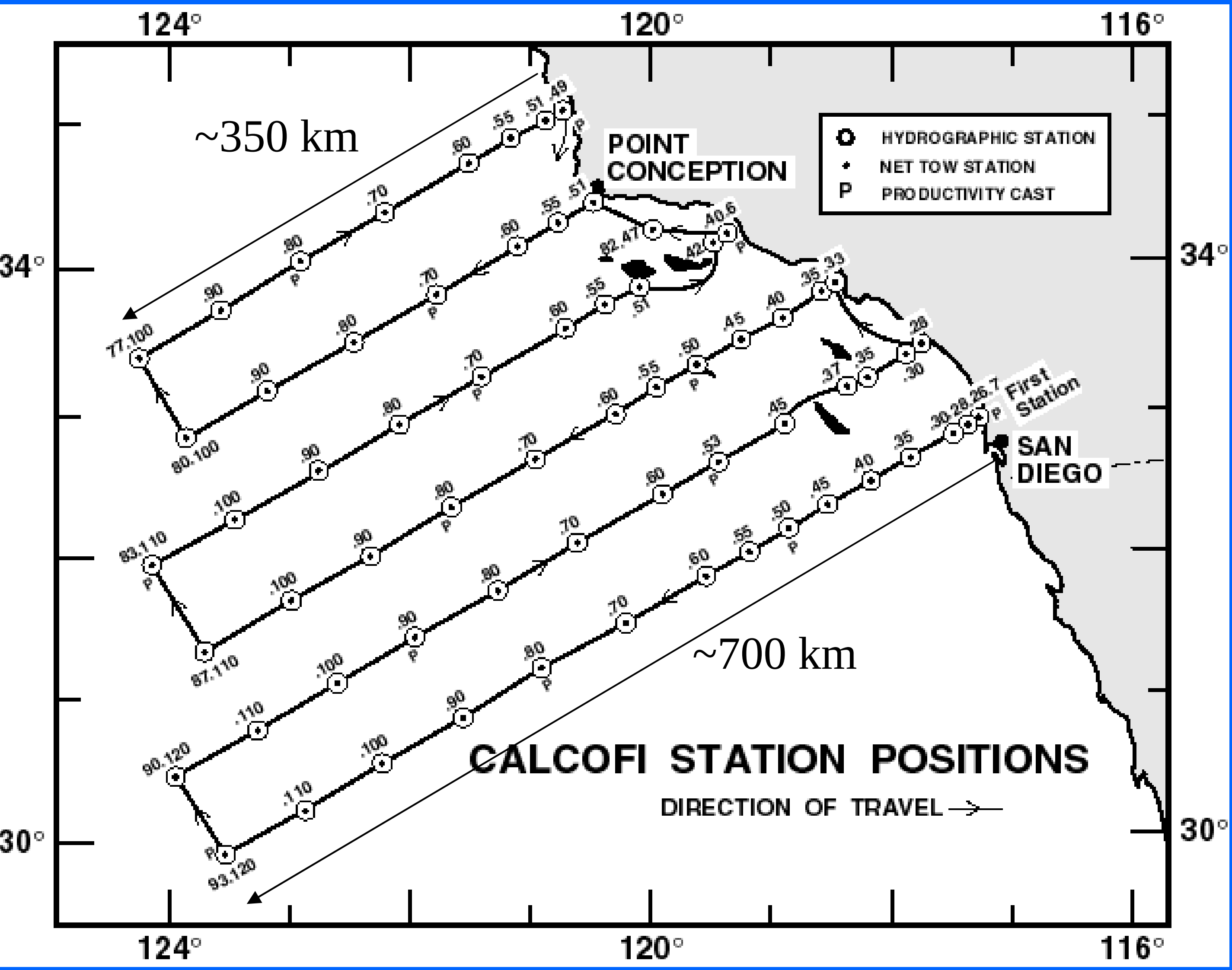
Acknowledgements

Scientists, technicians, volunteers, and crew of the 2002-2004 CalCOFI cruises. Brian Hopkinson, Kelly Roe, Joshawna Nunnery, Susan Reynolds.
This research was funded by NASA-NIP and CCE LTER NSF/OCE-Biological Oceanography.



MODIS chlorophyll *a* satellite image July 2003

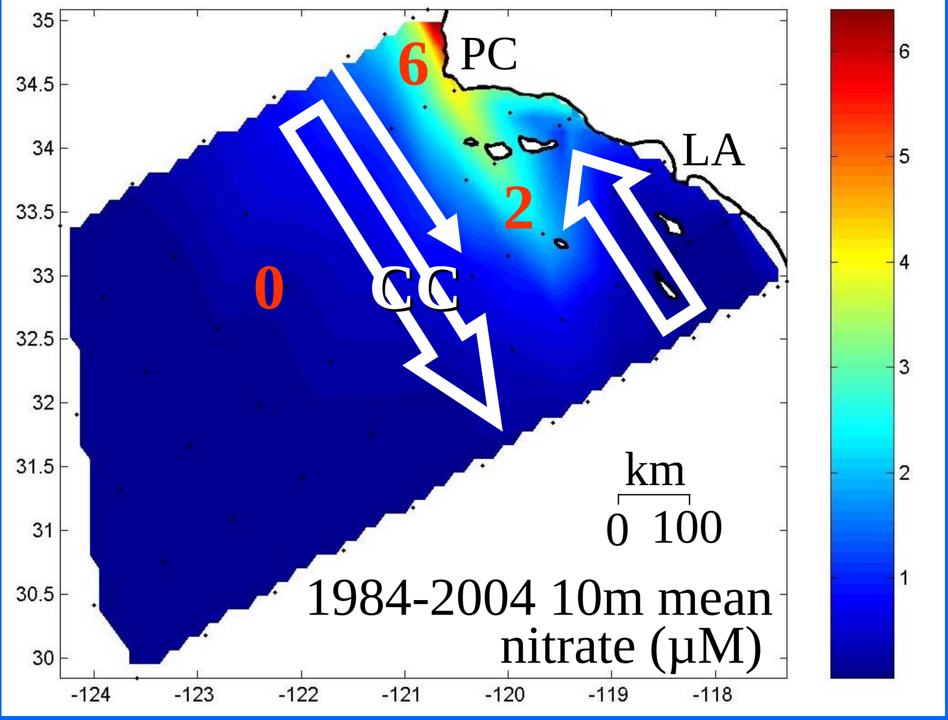
California Cooperative Oceanic Fisheries Investigations station plan since 1984, California Current Ecosystem LTER since 2005

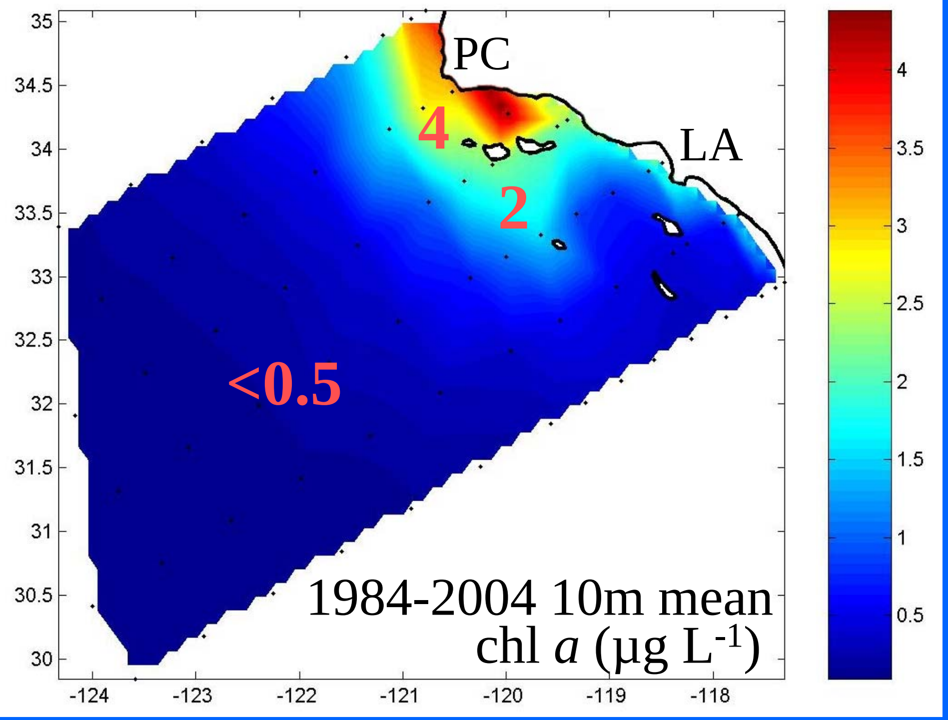


- ~191,000 km^2
- 66 stations
- 4 cruises/yr
- 500m CTD casts
- Chlorophyll *a*
- Macronutrients
- Salinity
- Temperature
- Oxygen
- Plankton nets
- 1° production

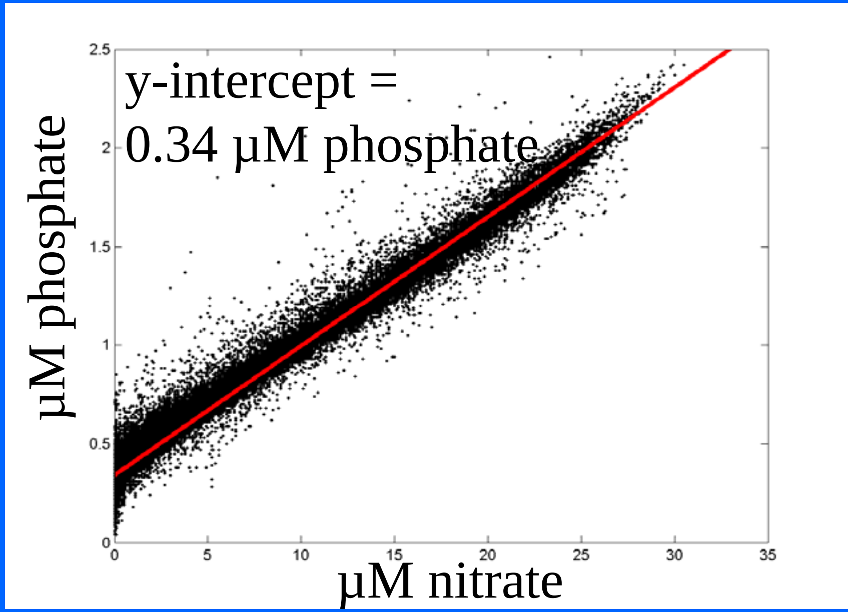
- *NEW* 1 “process cruise” every 2 years

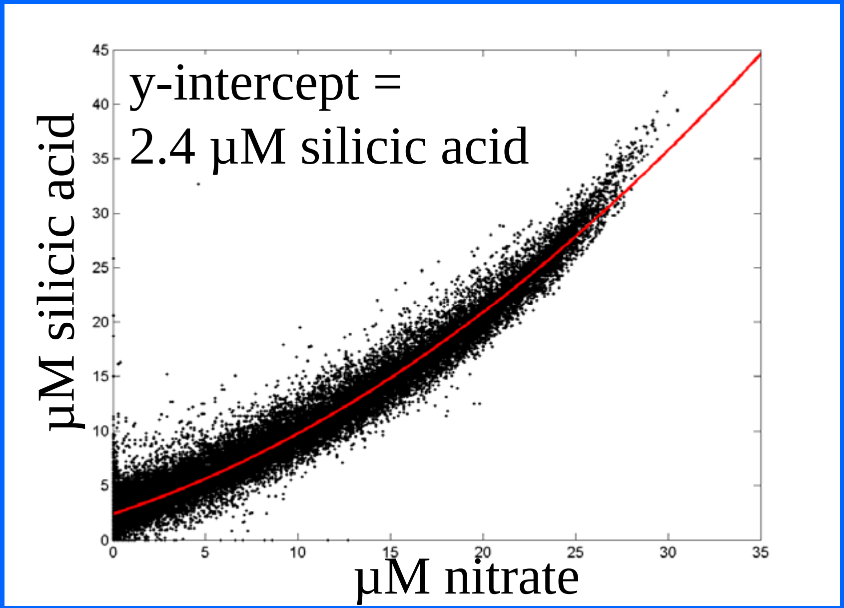
and much more…



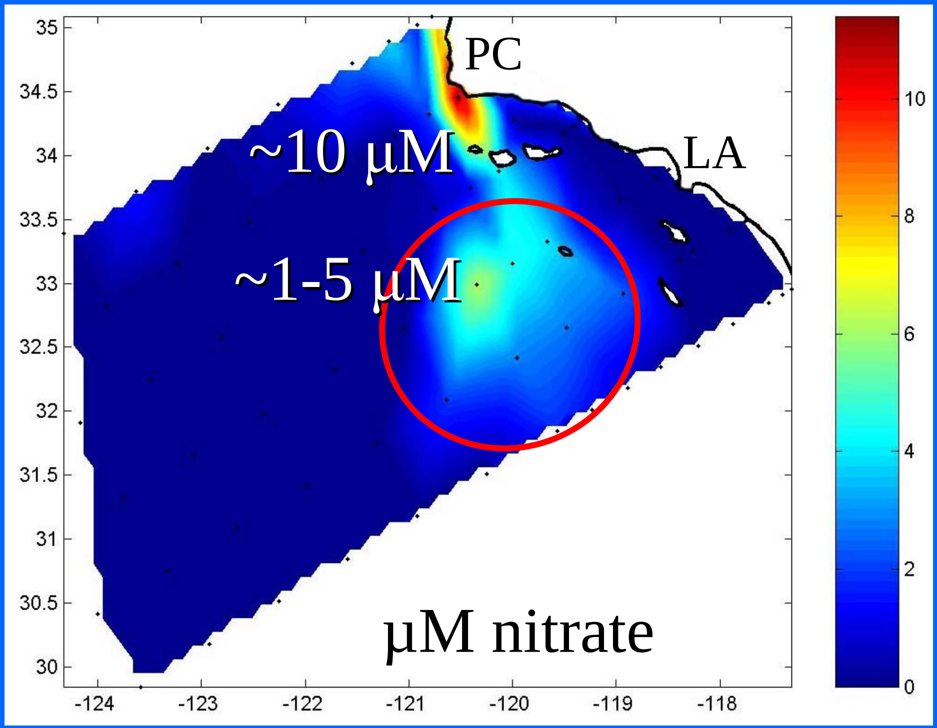


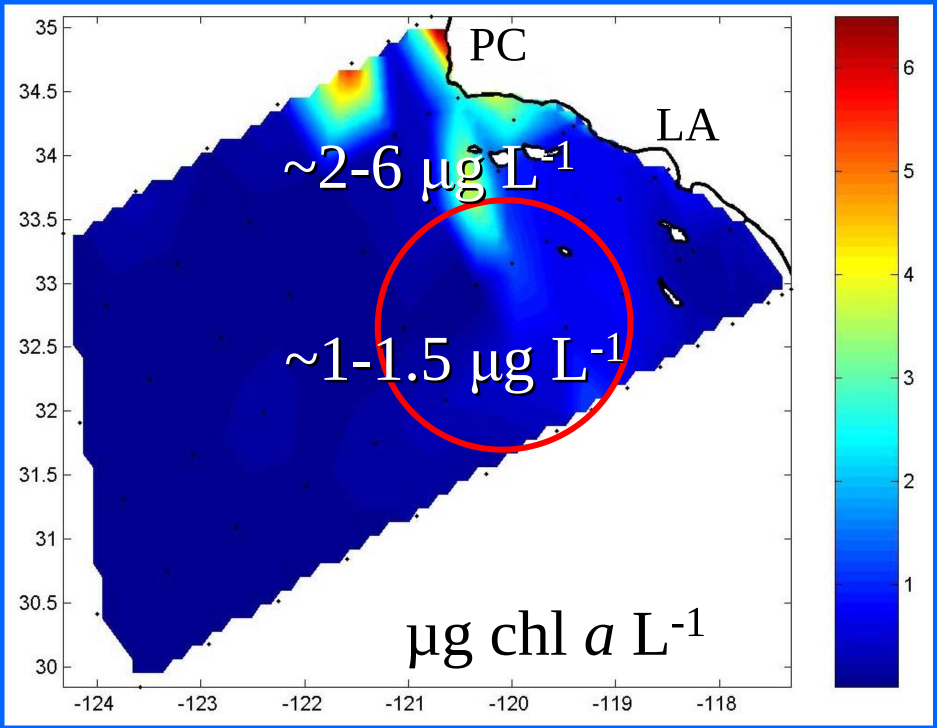
Phytoplankton standing stock is generally limited by nitrate





CalCOFI June 2000 cruise - 10 m



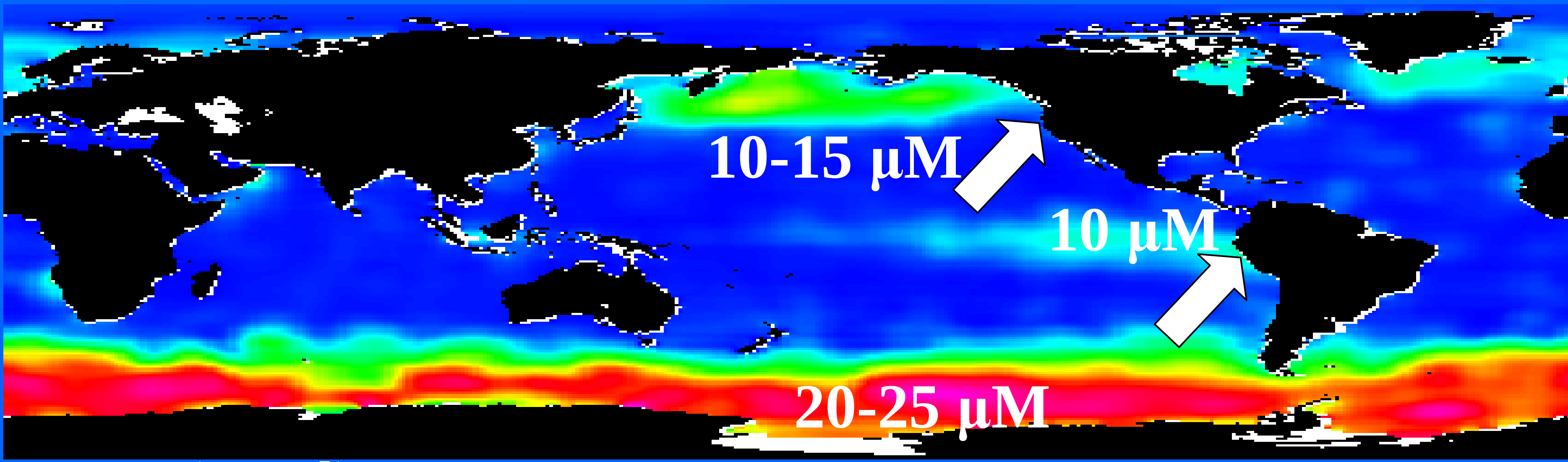


> Temporal lag in phytoplankton growth with respect to nitrate supply (e.g. MacIsaac et al., 1985)

> Proximate grazing control, reducing nitrate utilization (e.g. Miller et al., 1991)

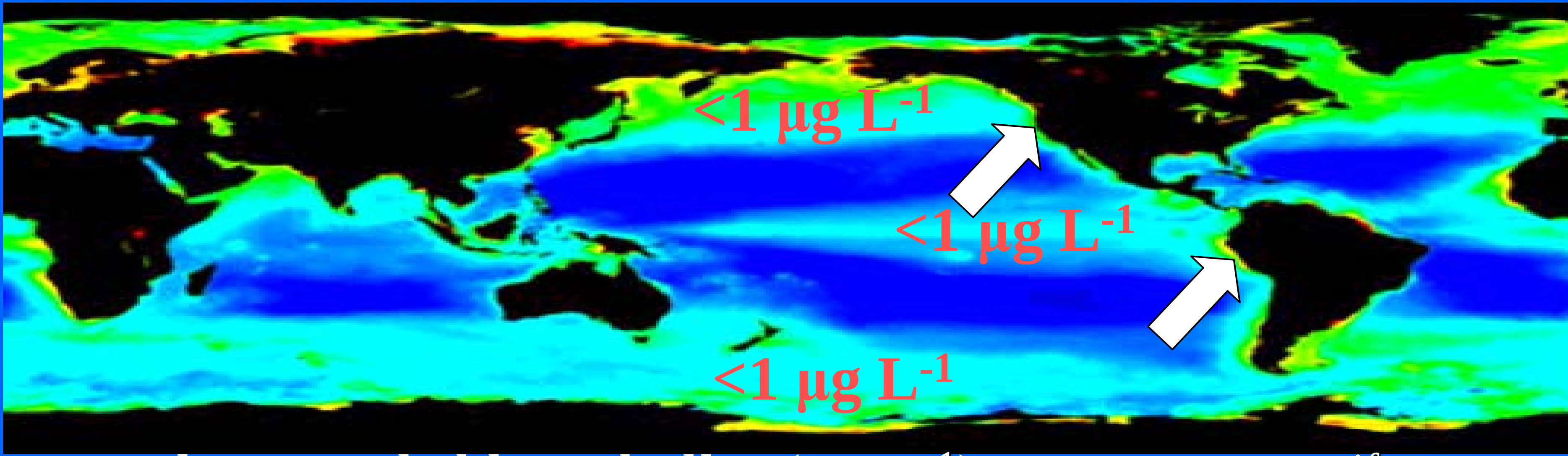
> Limitation by a physical process or nutrient other than nitrate; iron? (e.g. Martin and Fitzwater, 1988)

High nutrient (>10 μM nitrate), low chlorophyll (<1 μg chl a L^{-1})



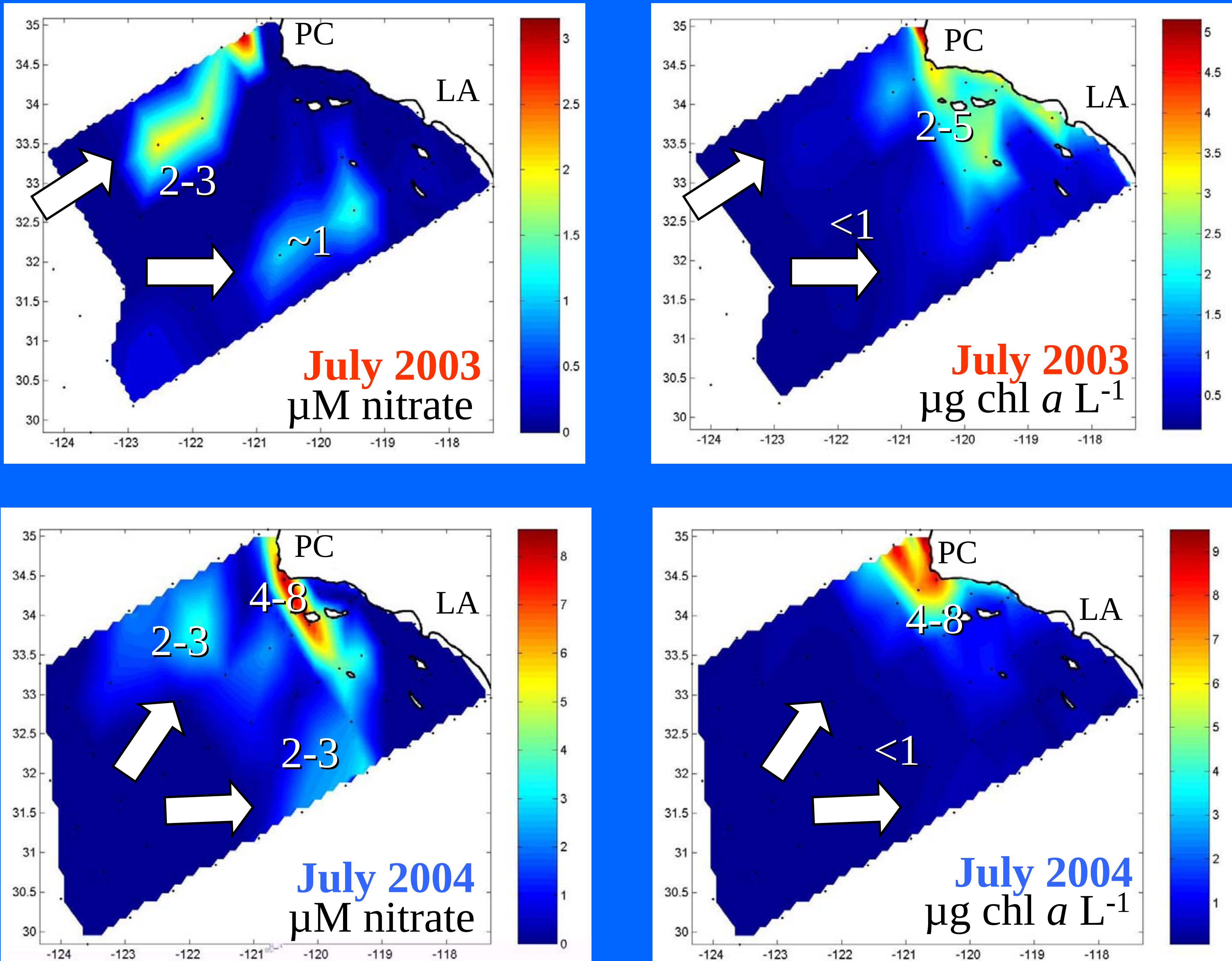
nitrate (μmol)

Levitus (1994)



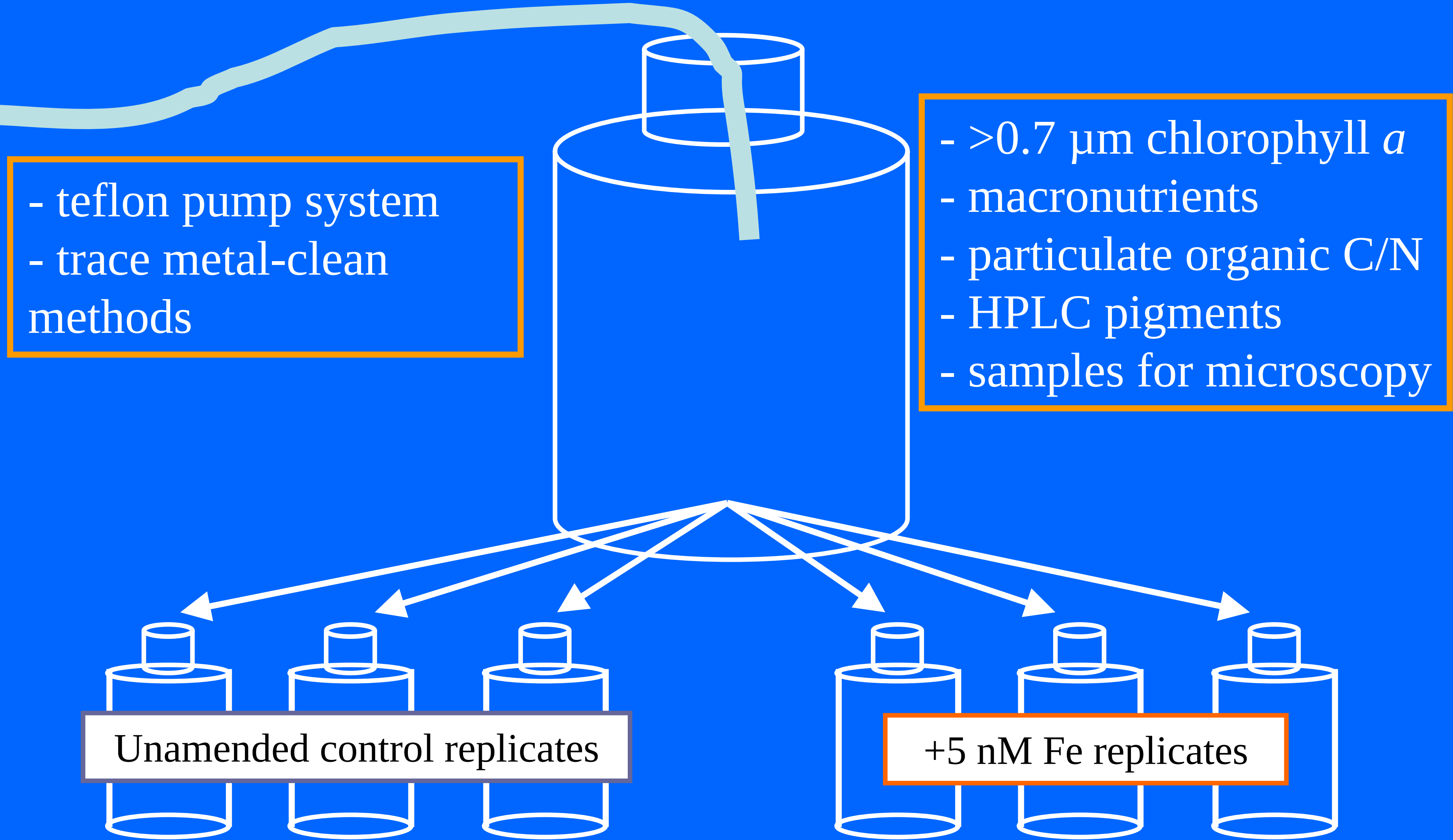
remotely-sensed chlorophyll *a* (μg L^{-1})

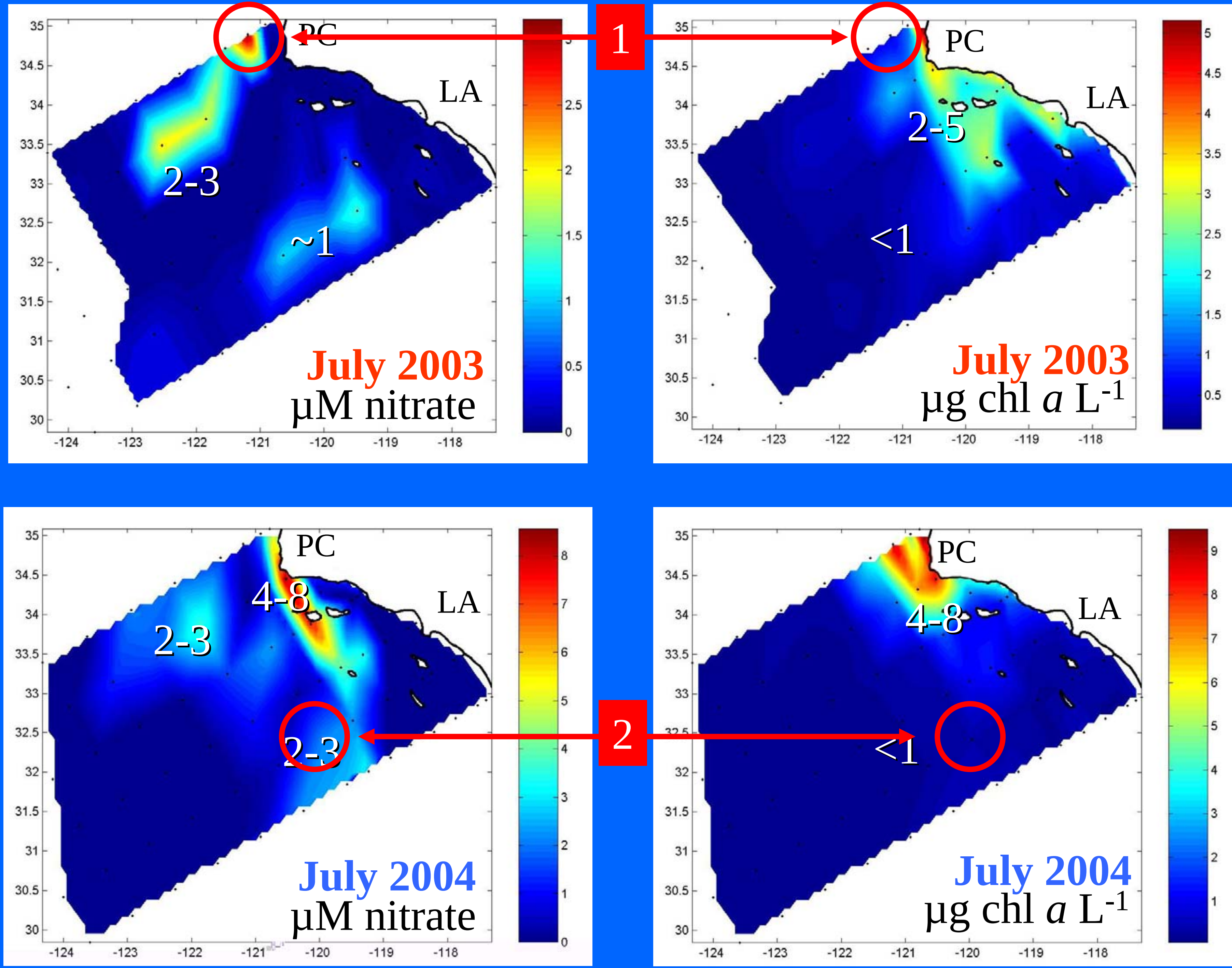
seawifs.nasa.gov



PC
LA
2-3
~1
July 2003
µM nitrate
PC
LA
2-5
<1
July 2003
µg chl a L-1
PC
4-8
LA
2-3
2-3
July 2004
µM nitrate
PC
LA
4-8
<1
July 2004
µg chl a L-1

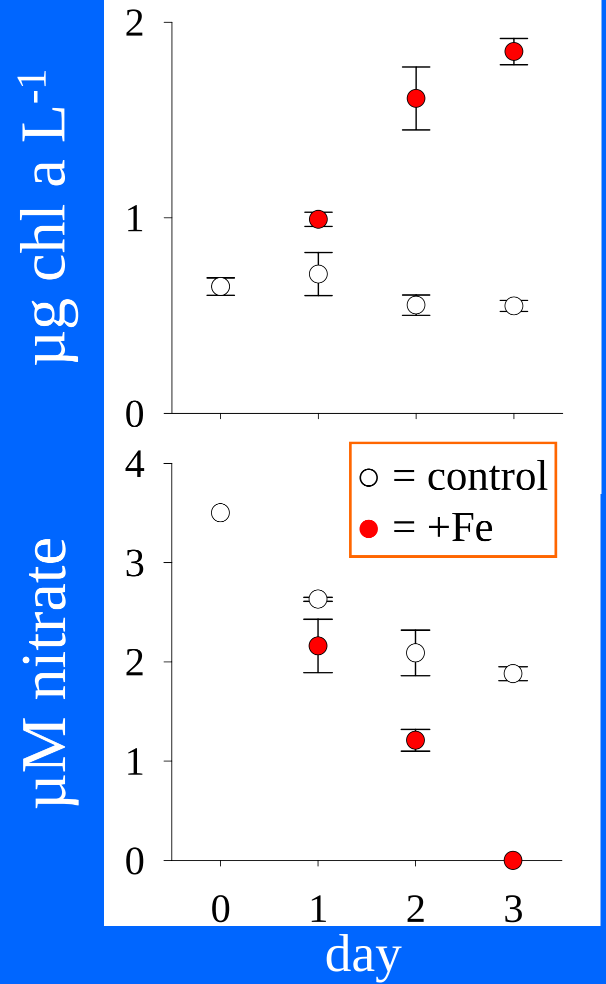
Fe addition grow-out experimental protocol

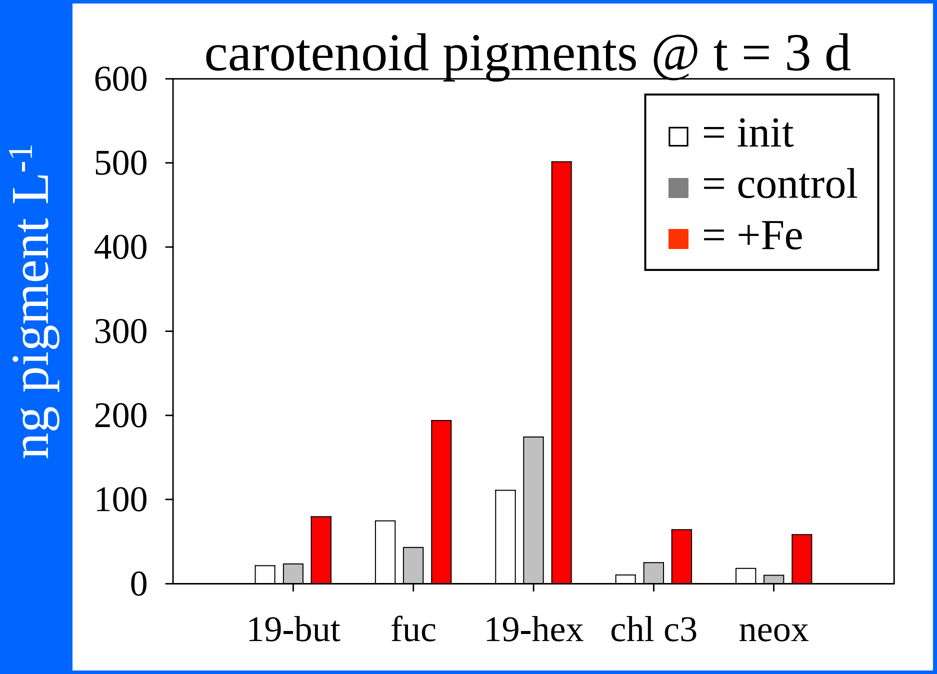



PC
LA
2-3
~1
July 2003
µM nitrate
1
PC
LA
2-5
<1
July 2003
µg chl a L-1
PC
LA
4-8
2-3
2-3
July 2004
µM nitrate
2
PC
LA
4-8
<1
July 2004
µg chl a L-1

Expt 1 - July 2003
~50 km offshore

	t = 0	t = 3 d control	t = 3 d +Fe
µg chl a	0.65	0.55	1.85
µM nitrate	3.5	1.9	0.0
µM phosphate	0.5	0.5	0.4
µM silicic acid	1.5	0.5	0.4
nM Fe	0.2	-	-

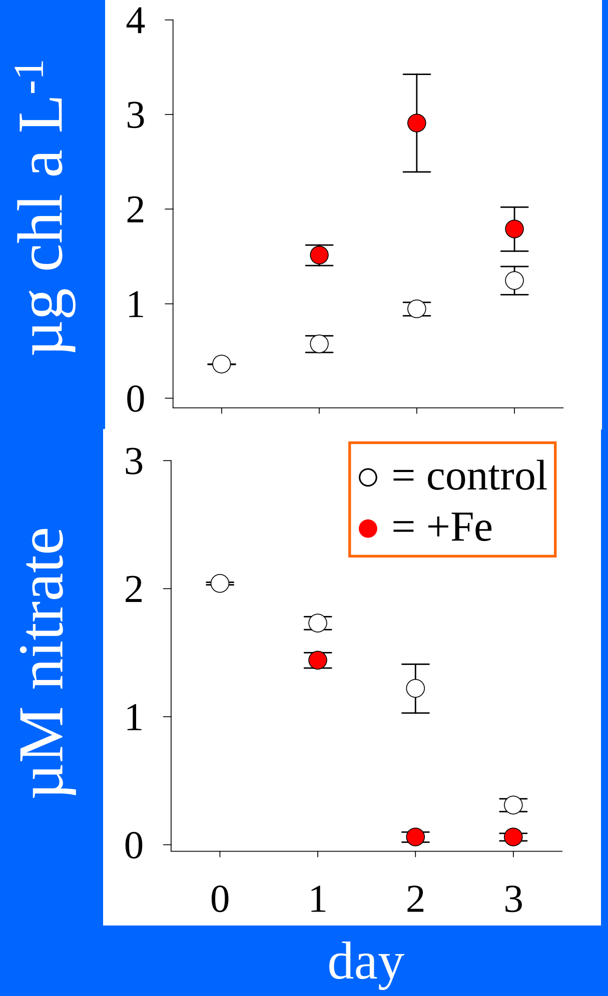


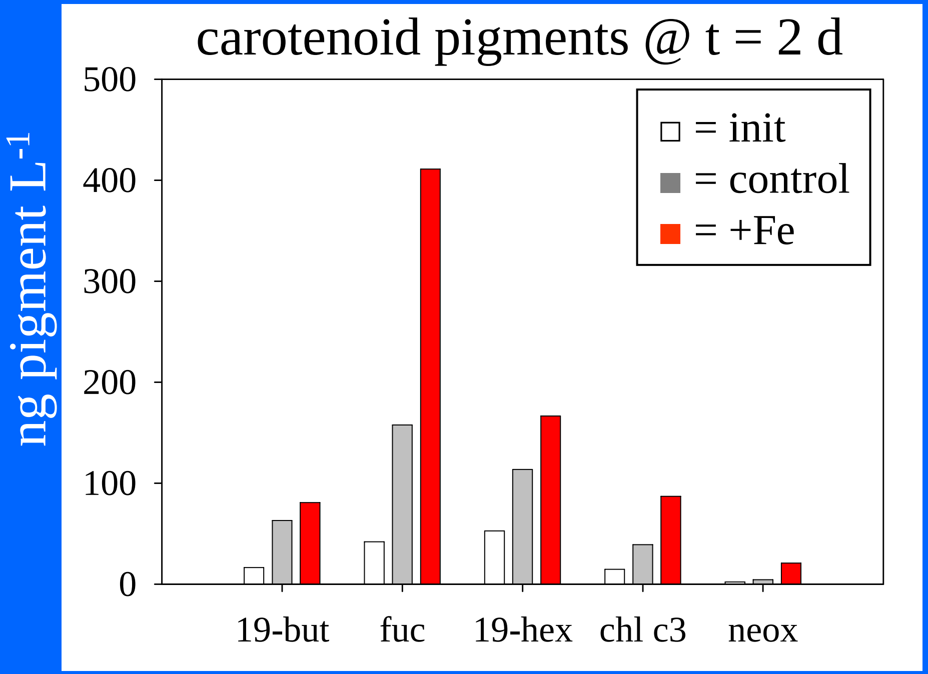


19-but = pelagophytes, chrysophytes
fuc = diatoms
19-hex = prymnesiophytes, diatoms
chl c3 = prymnesiophytes, diatoms
neox = chlorophytes

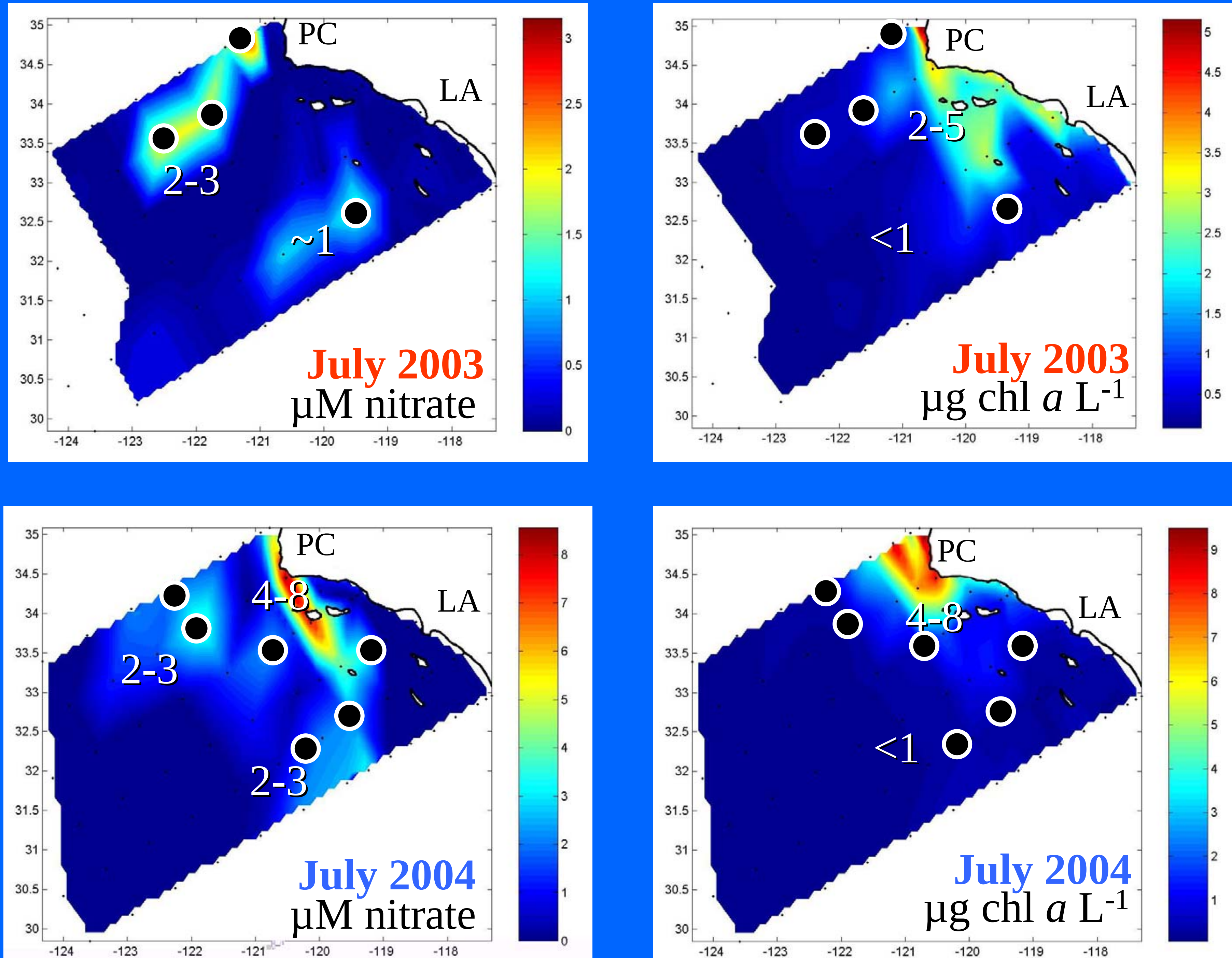
Expt 2 - July 2004
~200 km offshore

	t = 0	t = 2 d control	t = 2 d +Fe
µg chl a	0.36	0.94	2.91
µM nitrate	2.0	1.2	0.1
µM phosphate	0.3	0.2	0.2
µM silicic acid	0.5	0.3	0.1
nM Fe	0.2	-	-

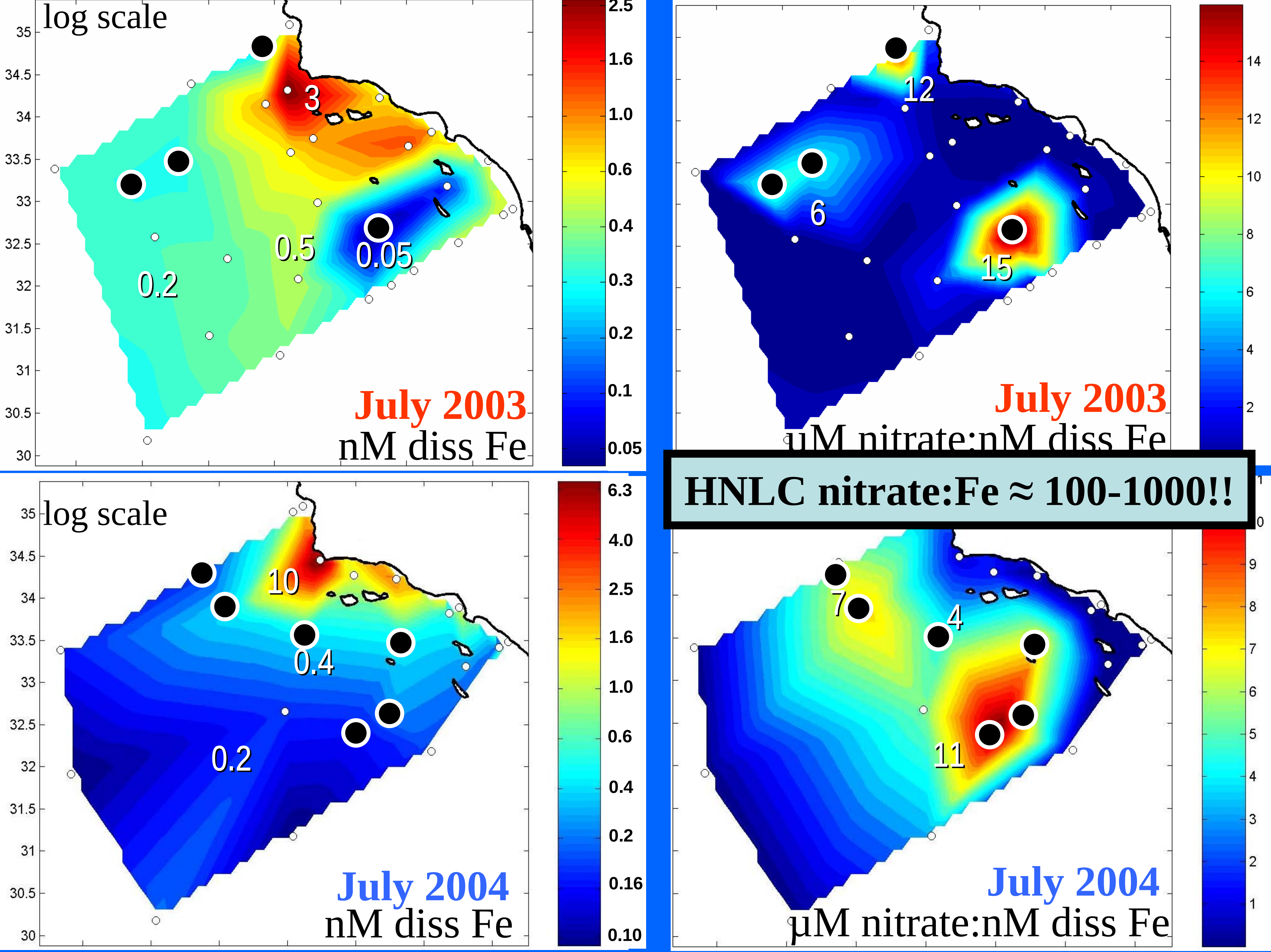




19-but = pelagophytes, chrysophytes
fuc = diatoms
19-hex = prymnesiophytes, diatoms
chl c3 = prymnesiophytes, diatoms
neox = chlorophytes



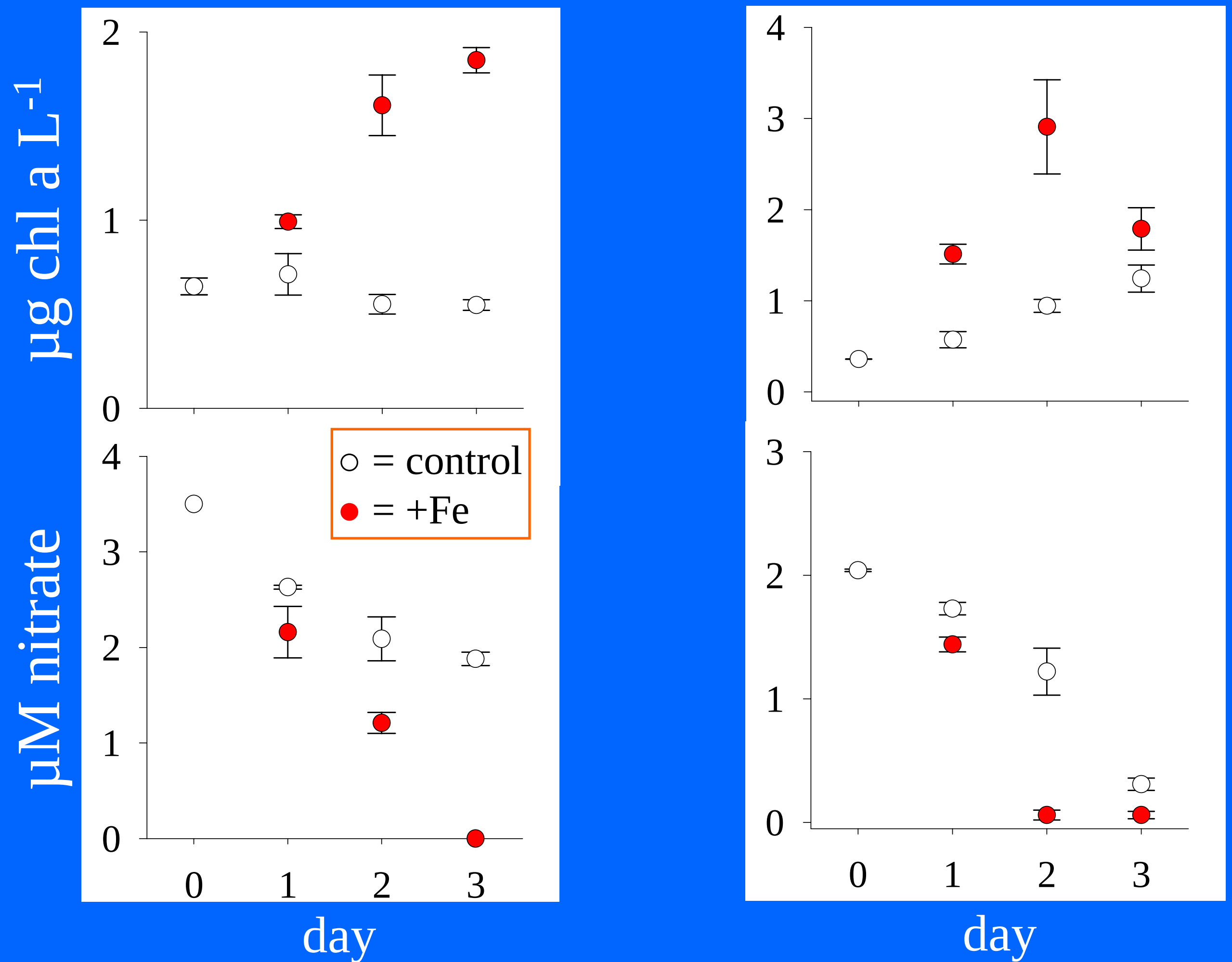
PC
LA
2-3
~1
July 2003
µM nitrate
PC
LA
2-5
<1
July 2003
µg chl a L-1
PC
LA
4-8
2-3
2-3
July 2004
µM nitrate
PC
LA
4-8
<1
July 2004
µg chl a L-1



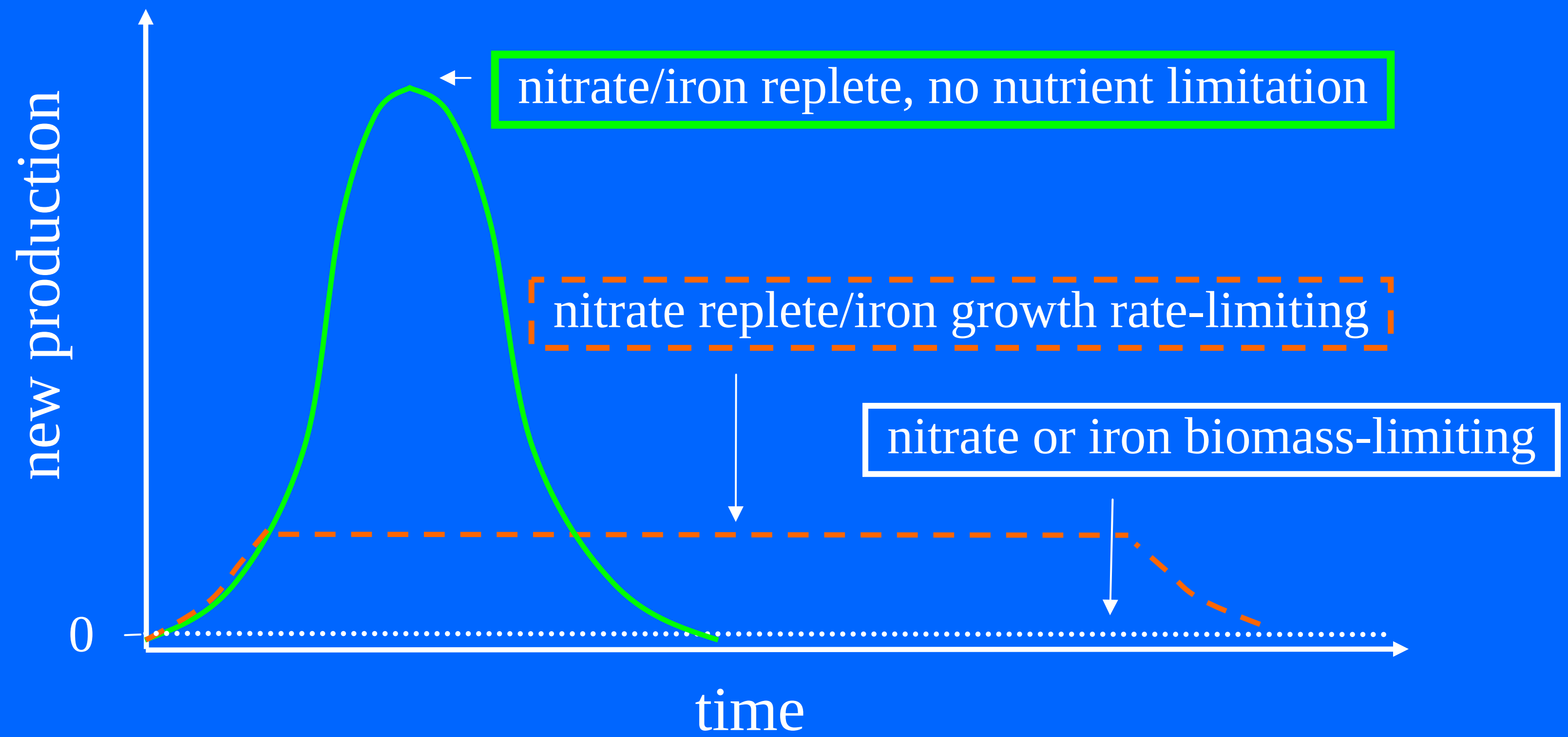
log scale
3
0.5
0.2
0.05
July 2003
nM diss Fe
12
6
15
July 2003
µM nitrate:nM diss Fe
HNLC nitrate:Fe ≈ 100-1000!!
log scale
10
0.4
0.2
July 2004
nM diss Fe
7
4
11
July 2004
µM nitrate:nM diss Fe

***Biomass-limited* by nitrate, *growth rate-limited* by Fe,**

Expt 1 - July 2003 / Expt 2 - July 2004



Significance of growth rate-limitation by iron



In both "nitrate/iron replete" and "nitrate replete/iron growth rate-limiting", new production should be comparable

BUT, this could result in variability (both spatial and temporal) in macronutrient biogeochemistry and phytoplankton community structure and distribution

> We observed iron limitation in a non-HNLC regime, in relatively close proximity to the continent.

> In general, the high nitrate, high iron nearshore is *biomass-limited* by **<u>nitrate</u>**. The medium nitrate, low iron transition zone is *biomass-limited* by **<u>nitrate</u>** and *growth rate-limited* by **<u>iron</u>**. There is some evidence to support Fe-limitation during spring-time as well.

> Assessing nitrate and iron limitation adds to the understanding of phytoplankton distribution and nutrient biogeochemistry in the southern California Current System (not to discount other limiting or controlling processes).

> The alteration to the supply of micronutrients such as iron could have potentially important effects on phytoplankton and nutrient biogeochemistry.