Roles of iron and light in limiting phytoplankton in island blooms and the wider Southern Ocean

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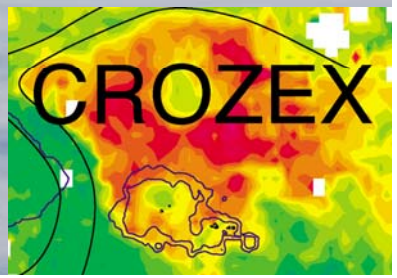
British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL



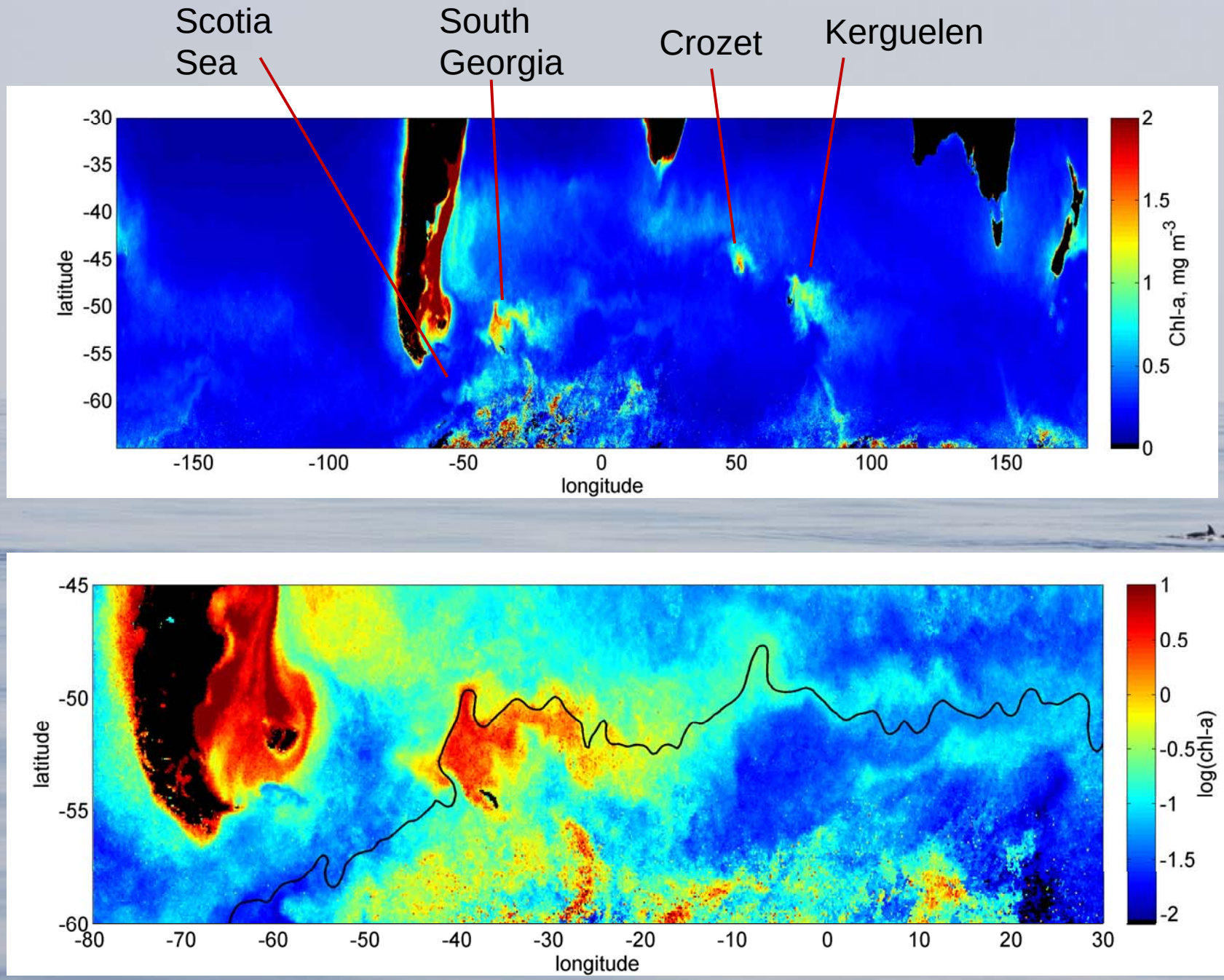
Iron and light (and grazing)

Scaling up from naturally iron fertilised blooms

What controls chlorophyll concentrations?

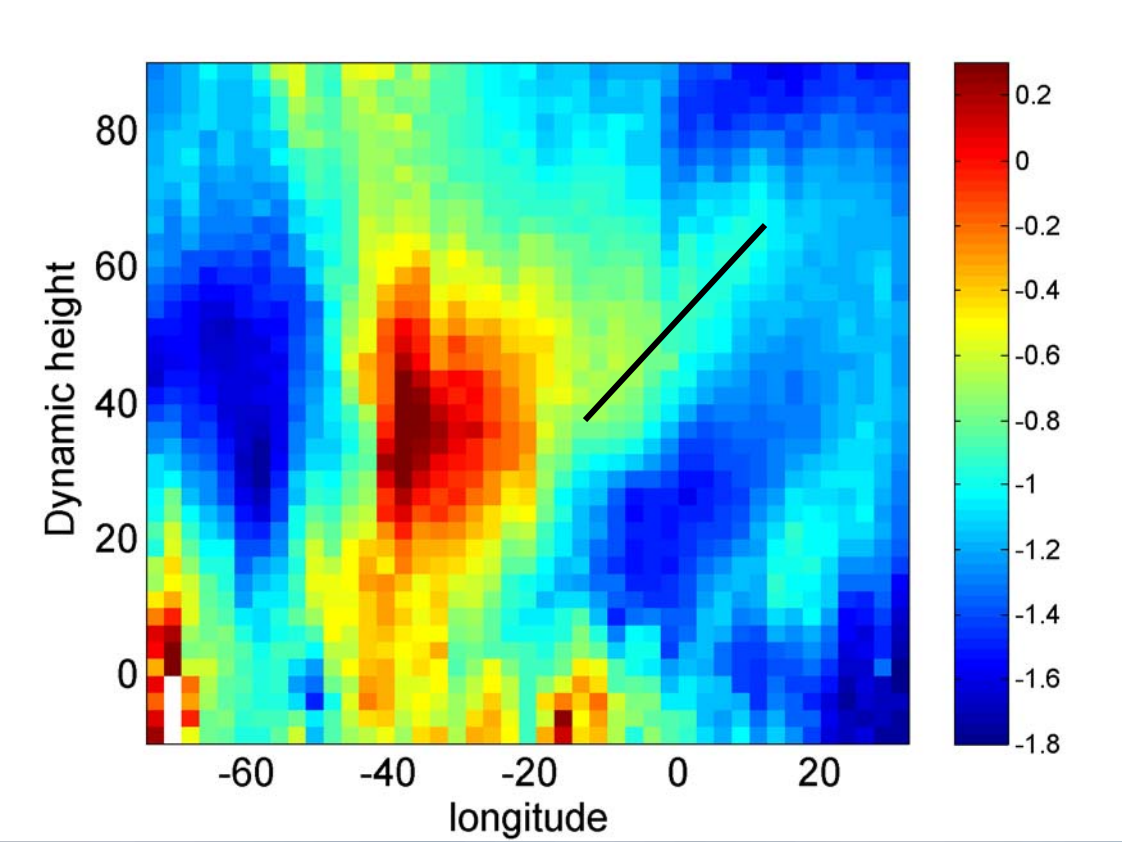
- Where?
- When?

Comparison with in situ fertilisation experiments


Scotia Sea
South Georgia
Crozet
Kerguelen
latitude
longitude
Chl-a, mg m-3
log(chl-a)

Map chlorophyll in dynamic height/longitude space

Find trajectory of high chlorophyll

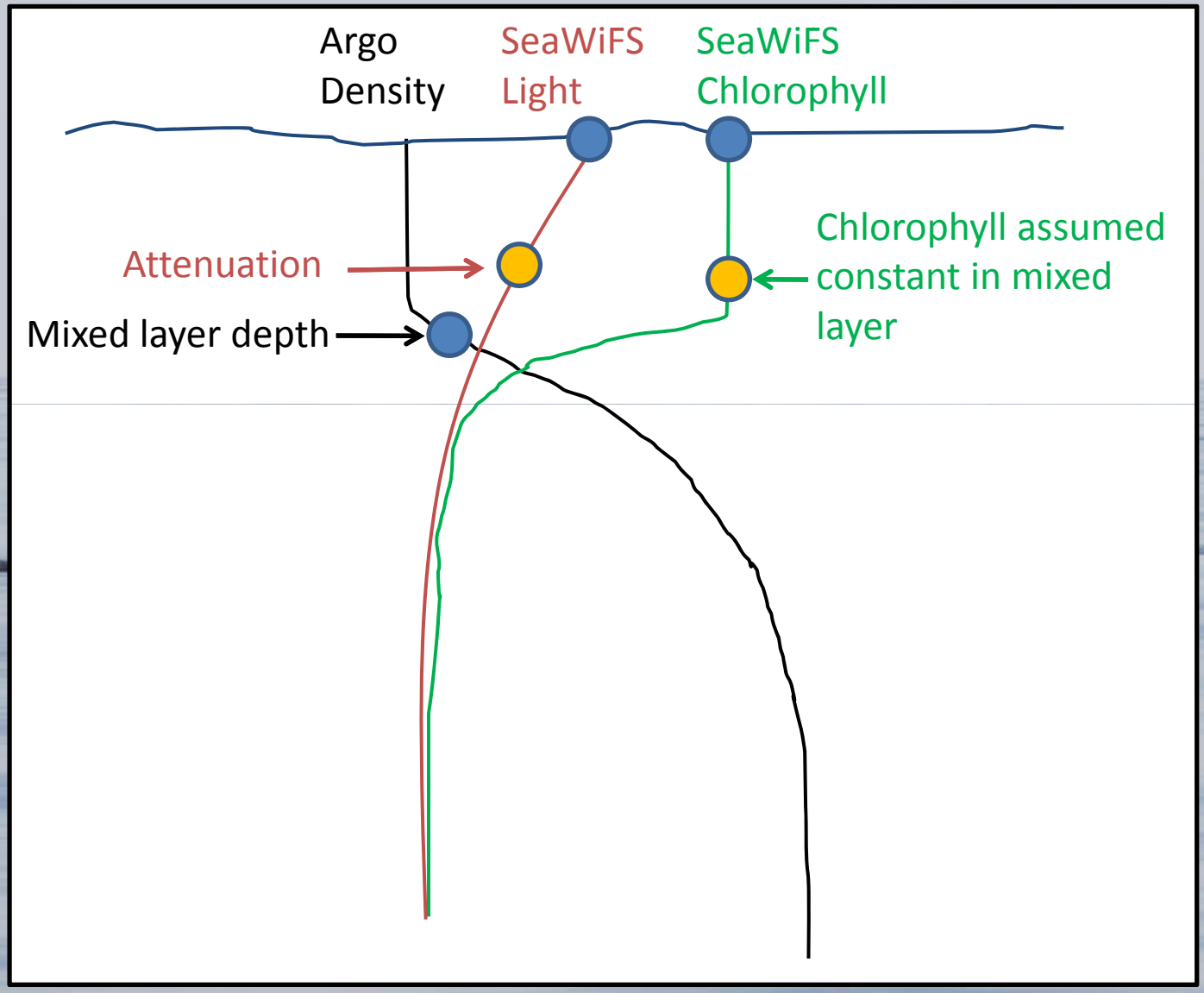


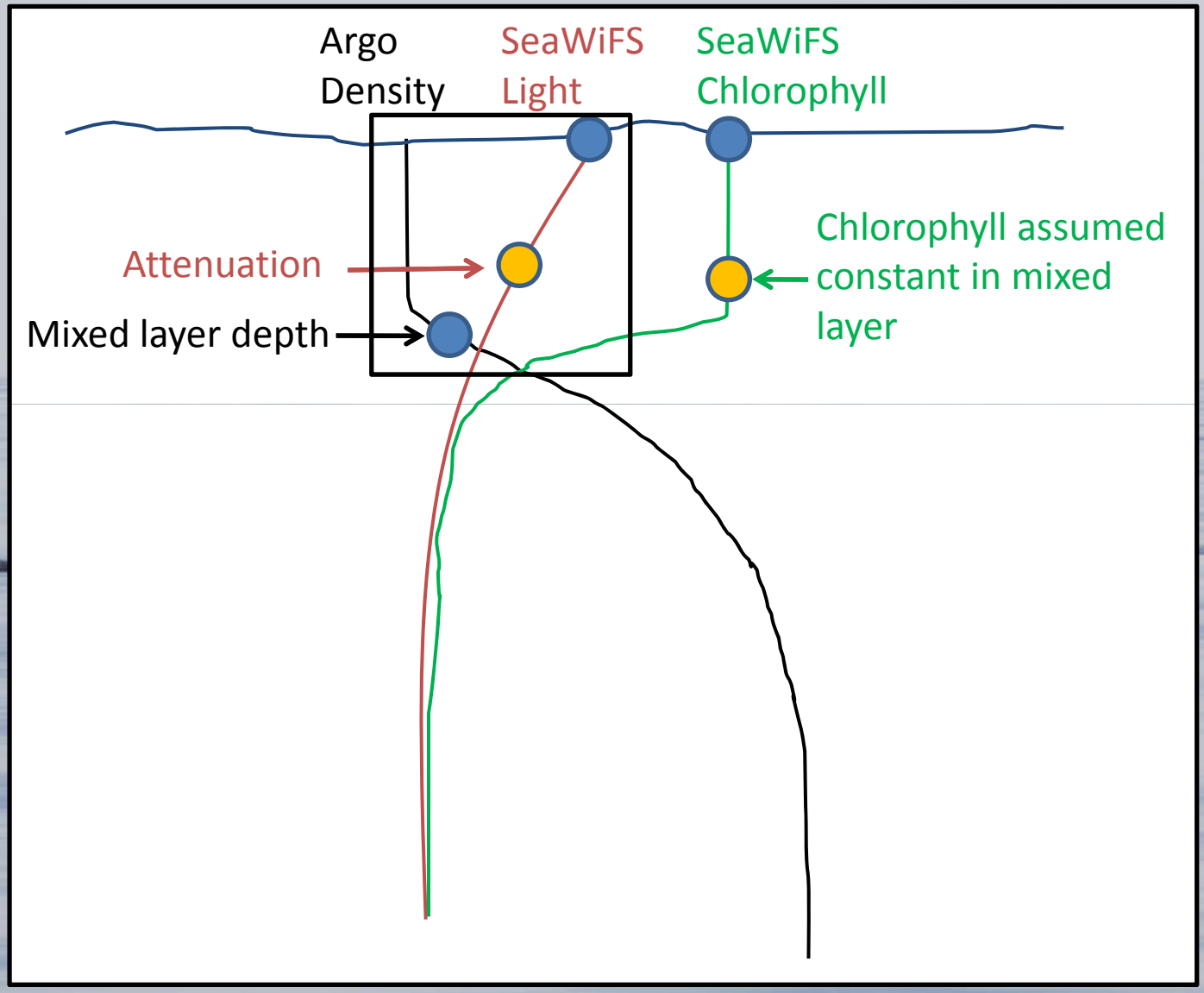
Gradient in dynamic height/longitude space

$$\frac{d\eta}{dx} = \frac{S_x}{\rho g d}$$

Possible to estimate from observations

Independent of latitudinal separation of dynamic height contours and *f*


Argo
Density
SeaWiFS
Light
SeaWiFS
Chlorophyll
Attenuation
Mixed layer depth
Chlorophyll assumed
constant in mixed
layer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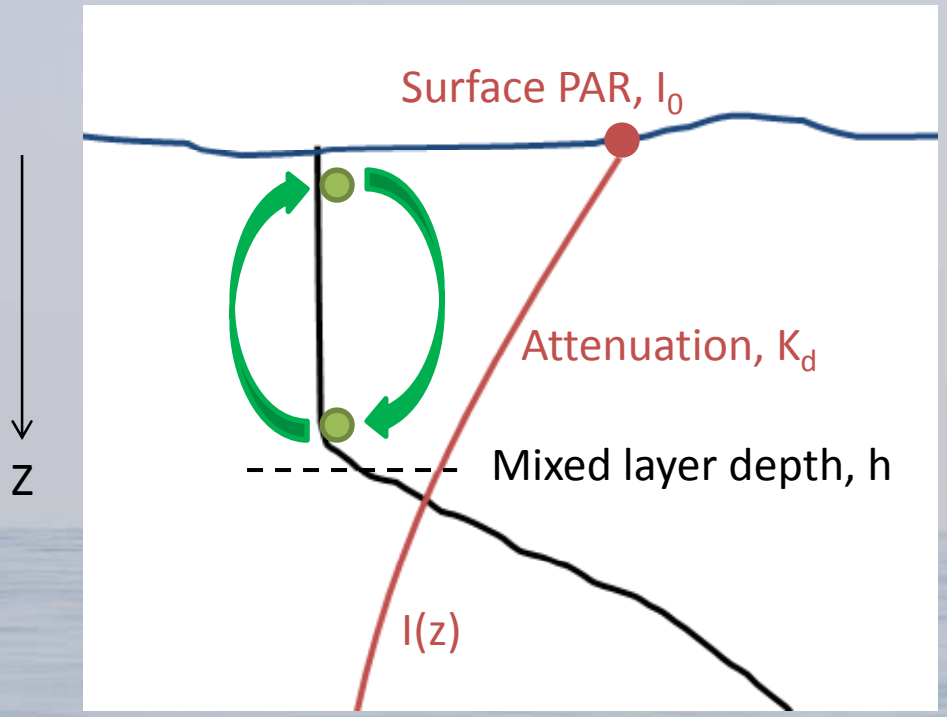


Exponential attenuation of light

$$I(z) = I_0 e^{-K_d z}$$

$$\bar{I}_{MLD} = \frac{1}{h}\int_0^h I_0 e^{-K_d z} dz$$

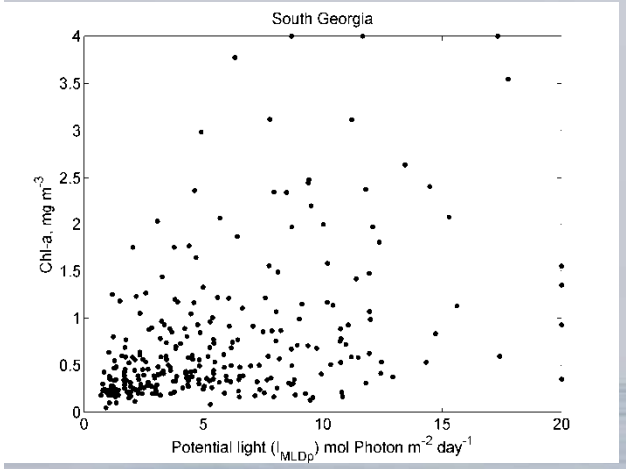
$$\bar{I}_{MLD} = \frac{I_0}{K_d h}\left(1 - e^{-K_d h}\right)$$

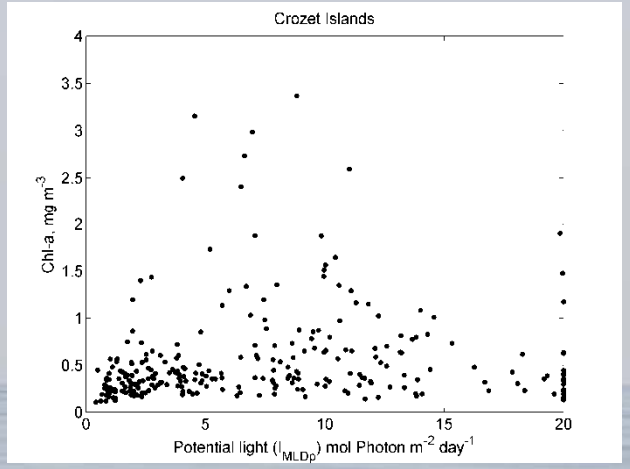
Attenuation increases as chlorophyll increases: $K_d = 0.05 + 0.057 Chl^{0.58}$

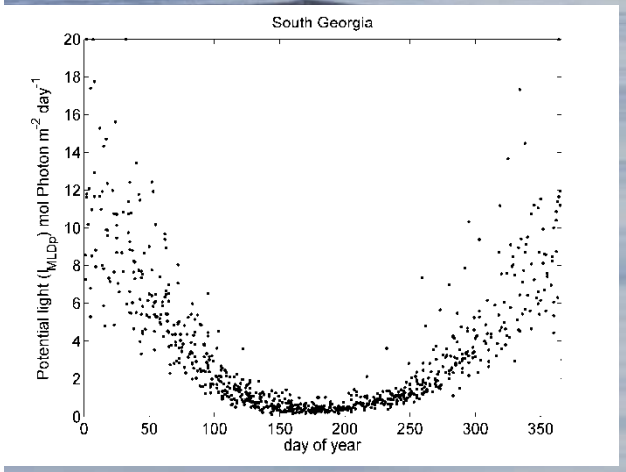
Chlorophyll values not always available – clouds, winter

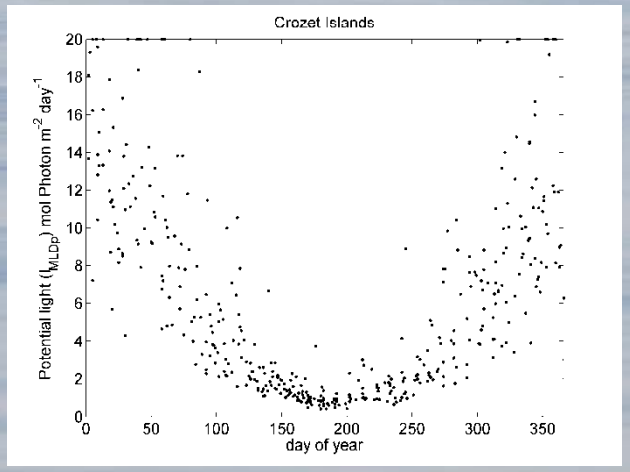
Want to control for effects of chlorophyll when comparing high and low chlorophyll areas - use fixed K_d and $\bar{I}_{MLDp}$ (can use all profiles)

Want to look at self-shading effects - use $K_d = f(chl)$


South Georgia
Chl-a, mg m-3
Potential light (IMLDp) mol Photon m-2 day-1


Crozet Islands
Chl-a, mg m-3
Potential light (IMLDp) mol Photon m-2 day-1


South Georgia
Potential light (IMLDp) mol Photon m-2 day-1
day of year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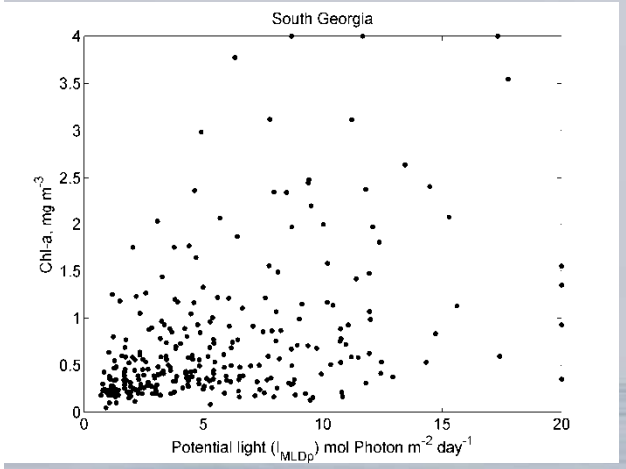
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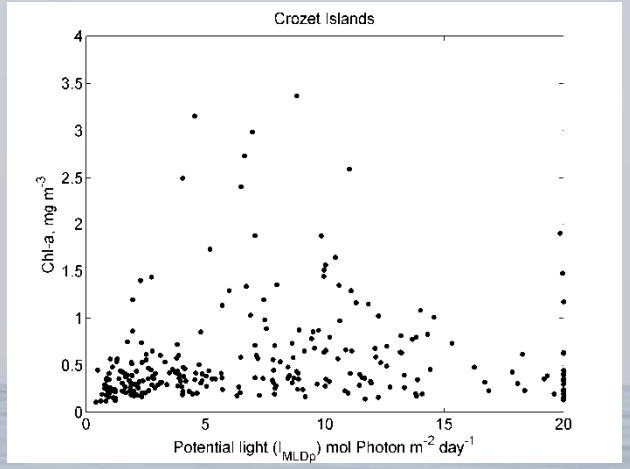
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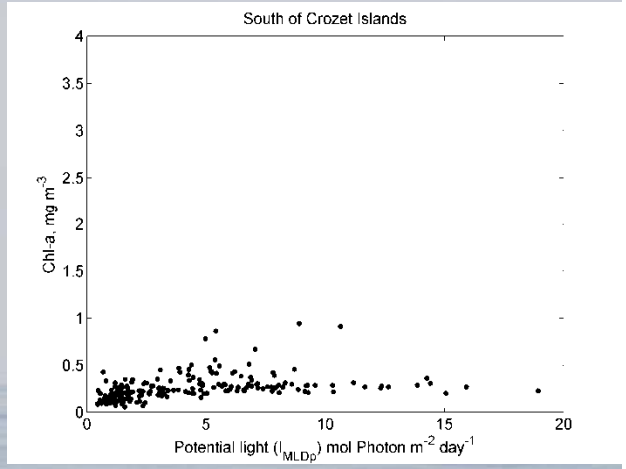
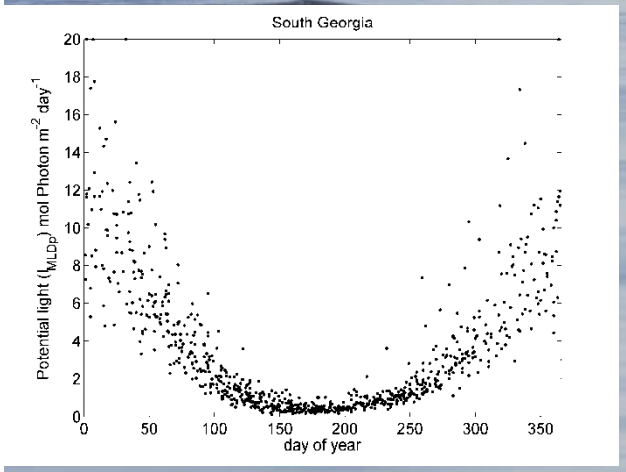
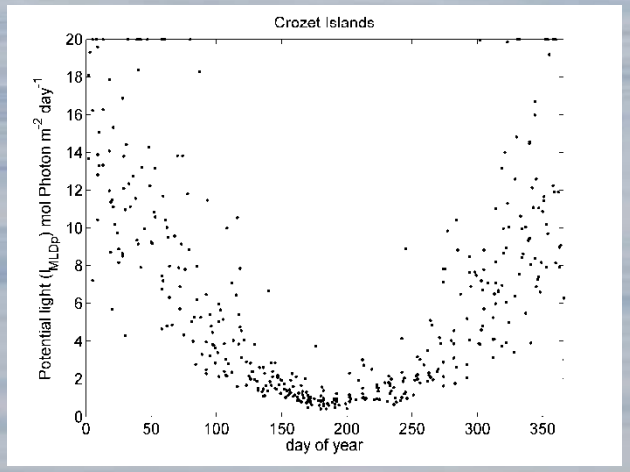
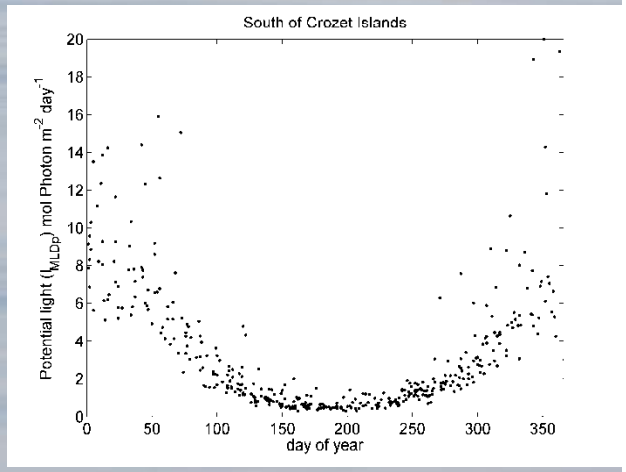
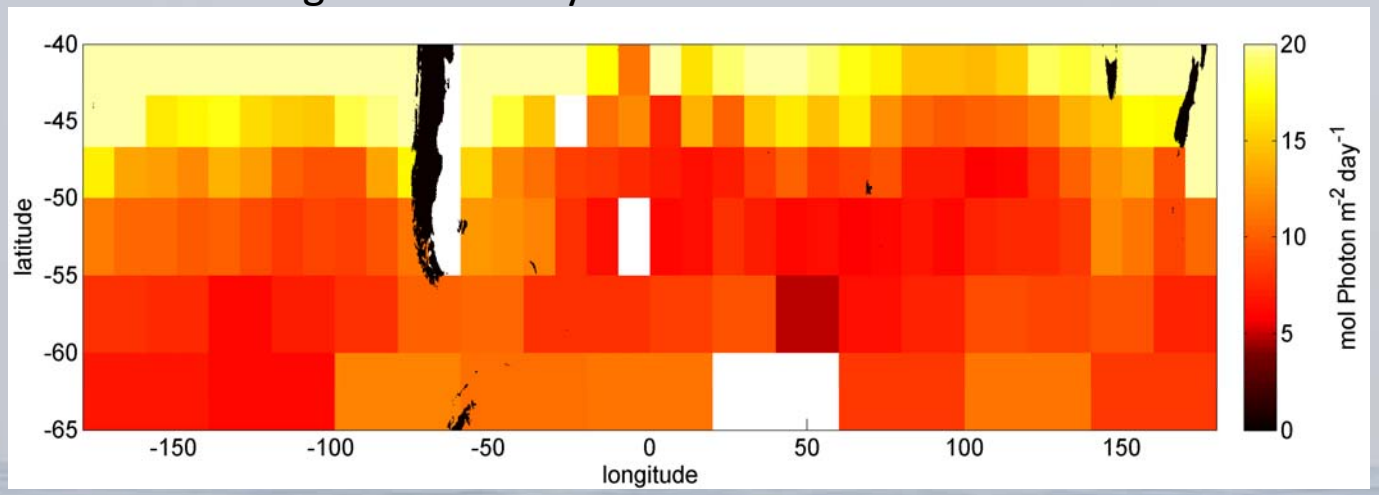

South of Crozet Islands
Chl-a, mg m-3
Potential light (IMLDp) mol Photon m-2 day-1


South Georgia
Potential light (IMLDp) mol Photon m-2 day-1
day of year


Crozet Islands
Potential light (IMLDp) mol Photon m-2 day-1
day of year


South of Crozet Islands
Potential light (IMLDp) mol Photon m-2 day-1
day of year

Summer light availability

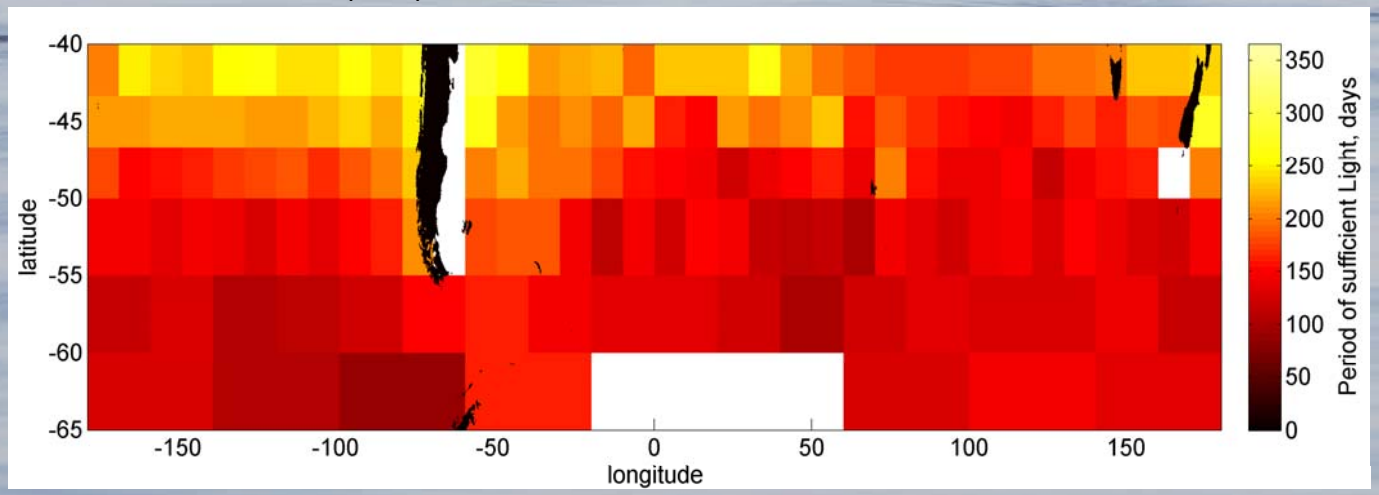


Light exceeds I_{cp} everywhere during January

Mean (days)

Period of $\overline{I_{MLDp}} > I_{cp}$

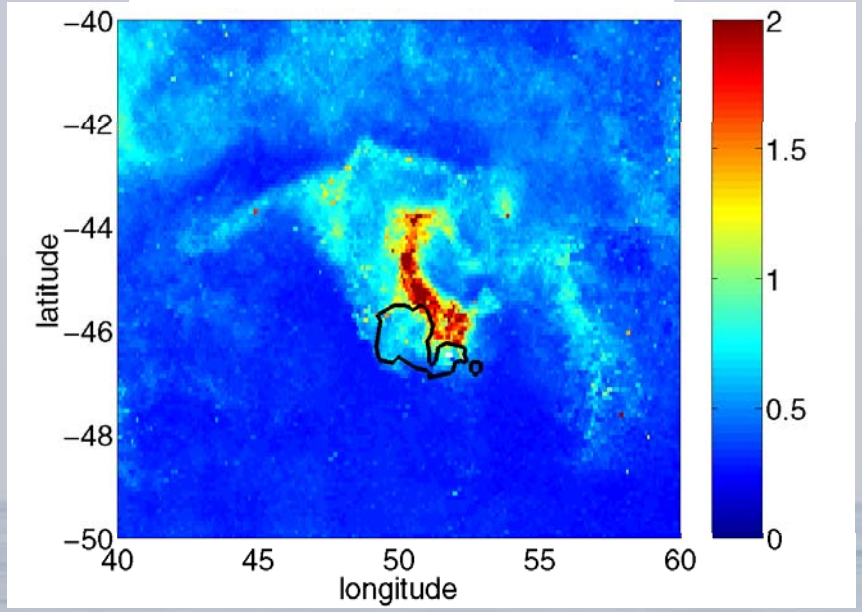
240
211
179
148
137
135



Southern Ocean is not light limited in the summer

(Venables and Moore 2010, JGR)

Annual average



Crozet bloom

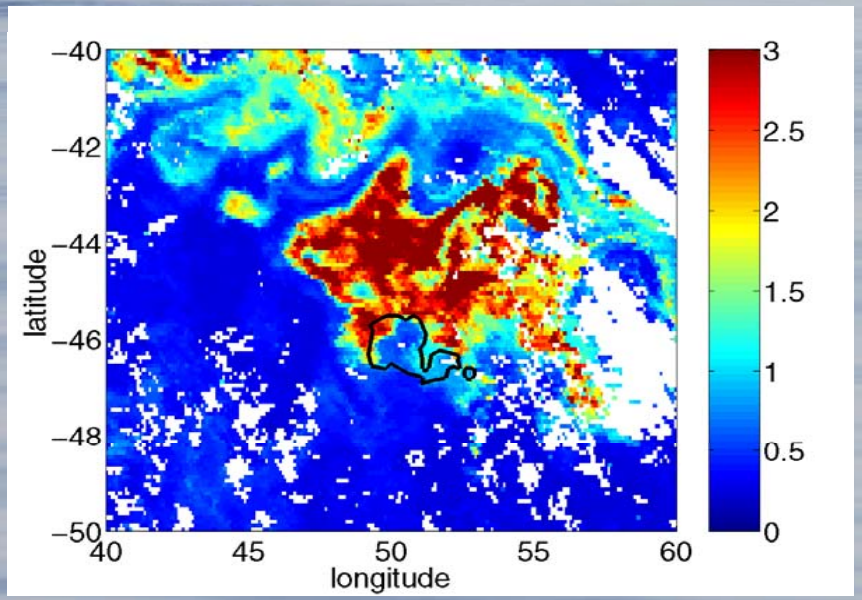
Iron input from south

Light greatest to north

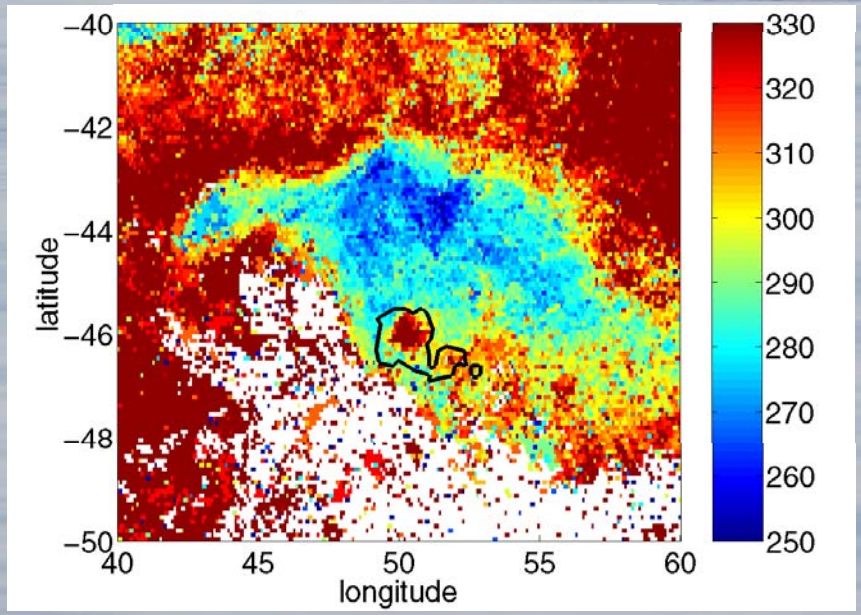
Different response during different bloom stages

Offers chance to deconvolve effects

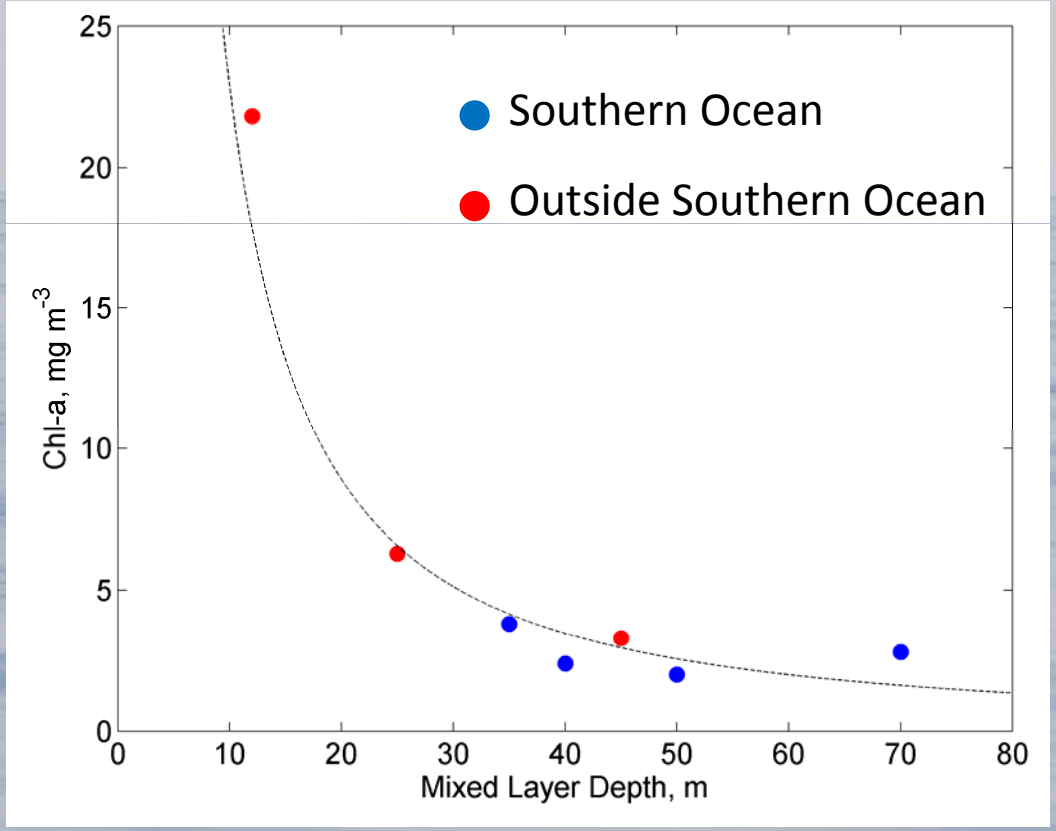
Peak Chlorophyll



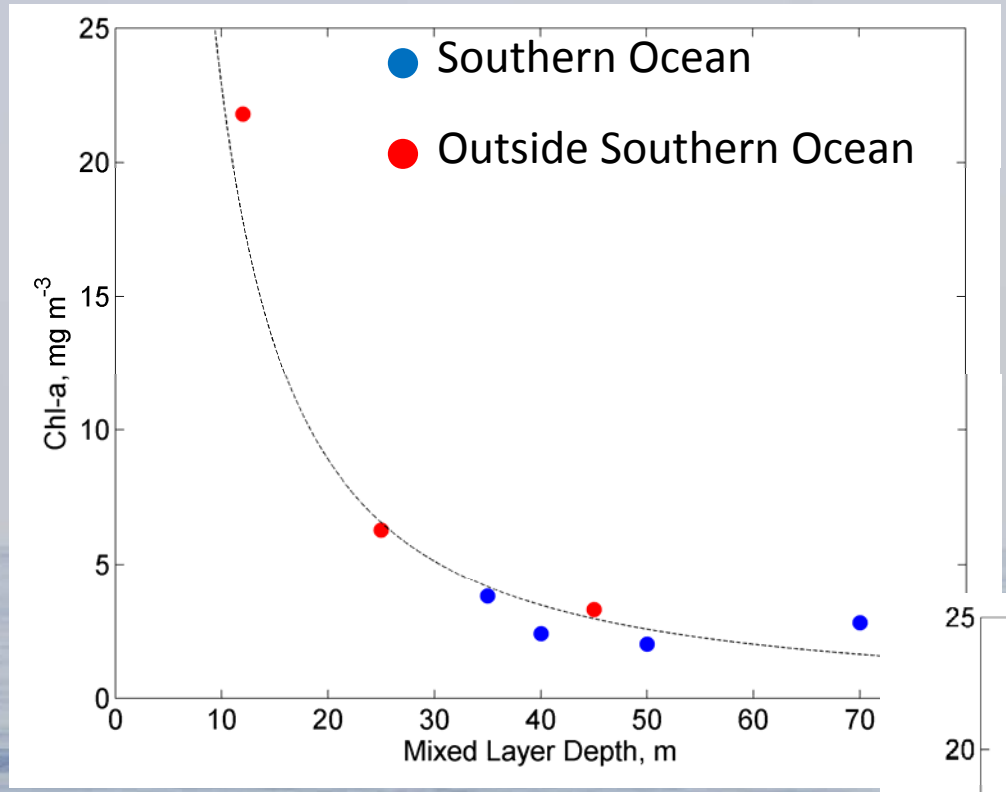
Bloom timing

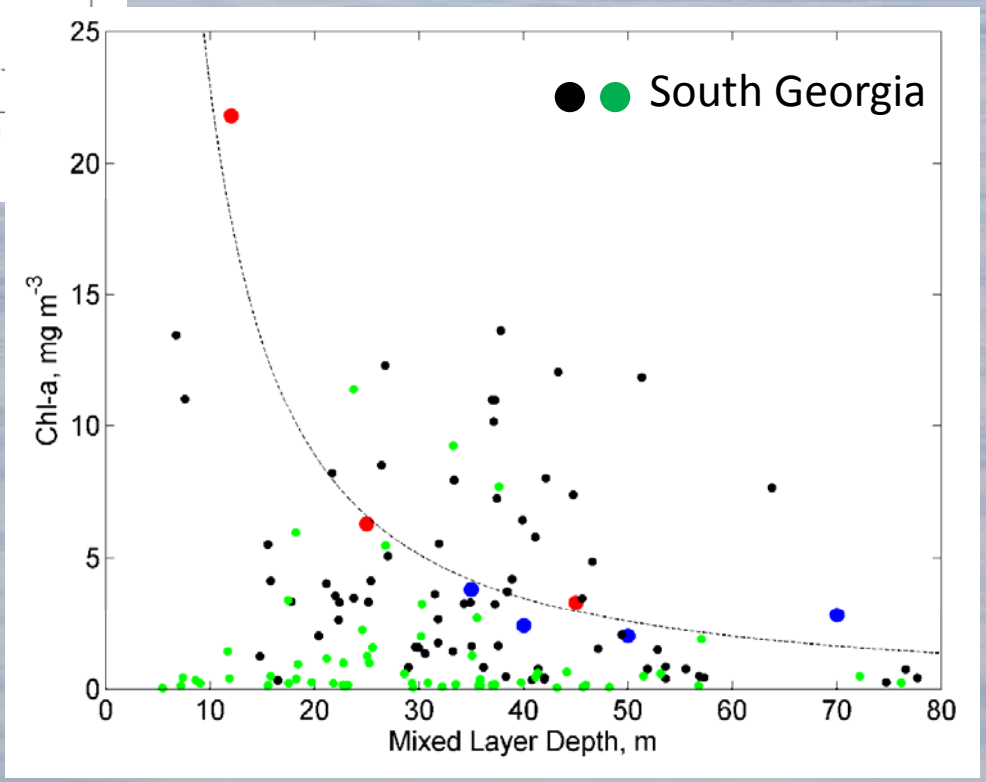


Comparing natural and in situ enrichment experiments



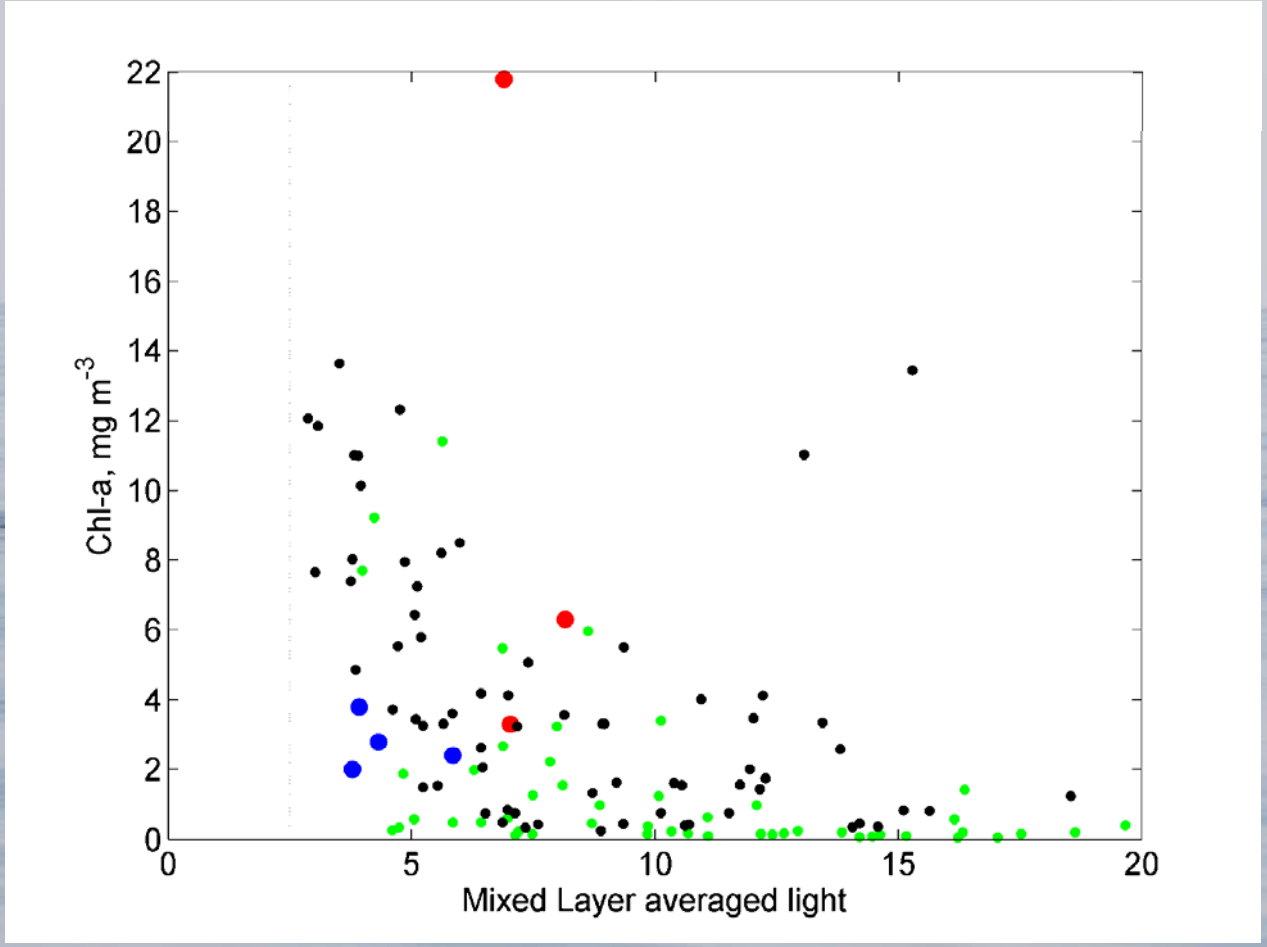
From de Baar *et al.* 2005





South Georgia Data does not sit underneath curve

Consider mixed layer averaged light



Summary

Argo and ocean colour satellites allow an assessment of South Ocean wide light availability

Everywhere has more light than in naturally fertilised blooms for at least 3 months

Areas without high chlorophyll (including near other islands) limited by factor other than light

Close look at the structures within the blooms can be useful

High chlorophyll in Atlantic sector of Polar Front is due to advection from South Georgia

Longer timescale of natural iron fertilisation gives different results to artificial enrichment experiments