The Seasonal Dynamics of Iron Supply, Biological Consumption & Cycling in the Southern Ocean

Philip Boyd

Rationale

Iron plays a pivotal role in setting S. Ocean productivity and driving C and nutrient biogeochemistry

Iron datasets are sparse, and it is problematic to add iron sensors to gliders or bio-floats

Approaches & Collaborators

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, C06009, doi:10.1029/2011JC007726, 2012

Mapping phytoplankton iron utilization: Insights into Southern Ocean supply mechanisms

P. W. Boyd,[1,2] K. R. Arrigo,[3] R. Strzepek,[4] and G. L. van Dijken[3]

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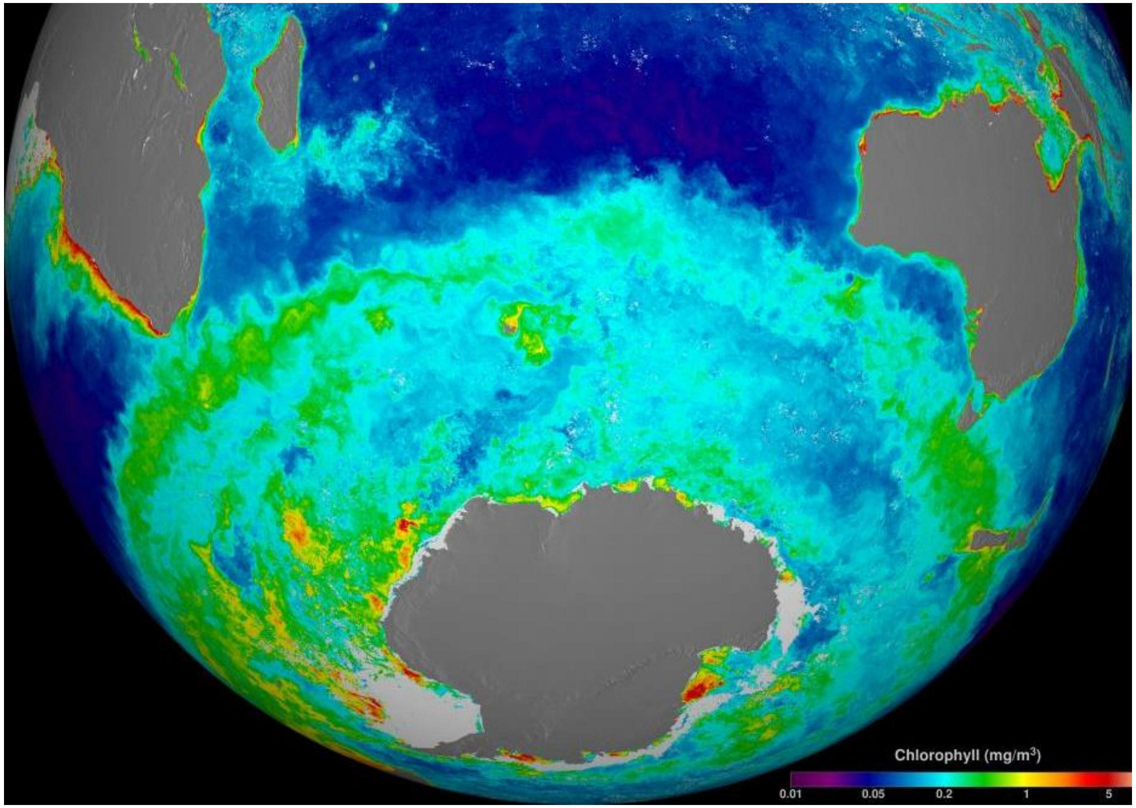
PUBLISHED ONLINE: XX MONTH XXXX | DOI: 10.1038/NGEO2101

Surface water iron supplies in the Southern Ocean sustained by deep winter mixing

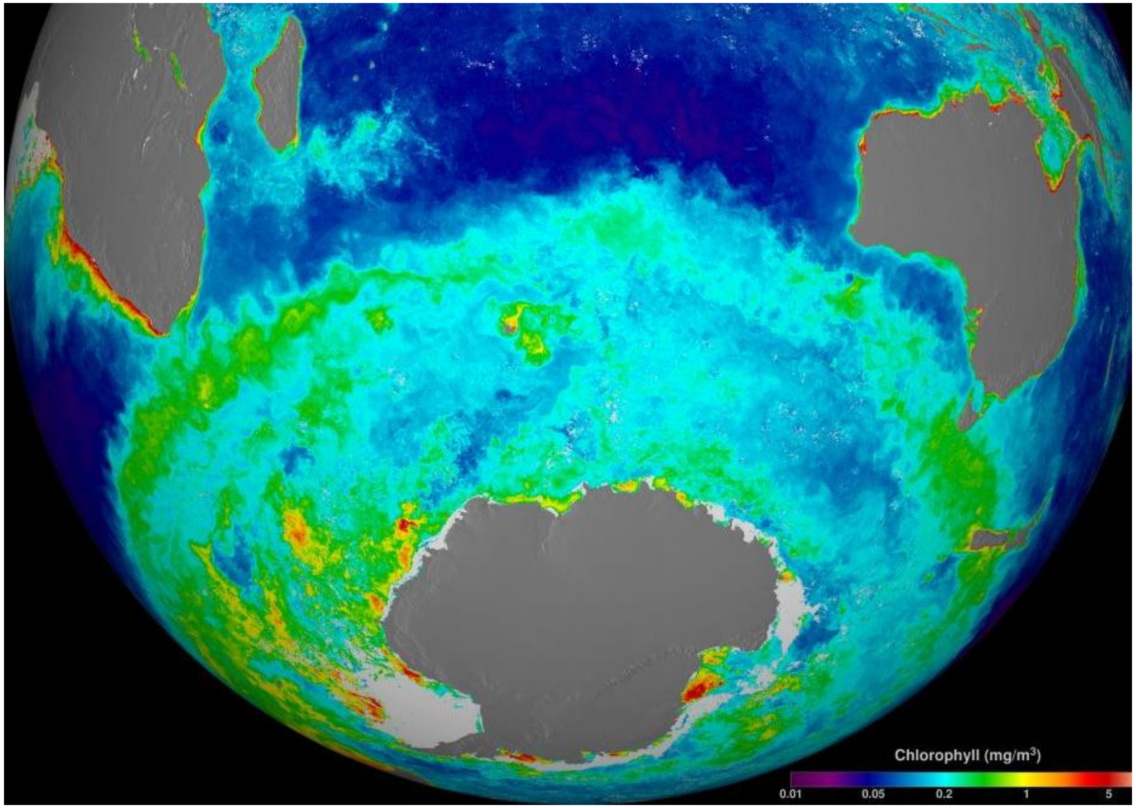
Alessandro Tagliabue[1,2*], Jean-Baptiste Sallée[3,4,5], Andrew R. Bowie[6], Marina Lévy[3,4], Sebastiaan Swart[2,7] and Philip W. Boyd[8,9]

Phytoplankton stocks - a variegated Southern Ocean



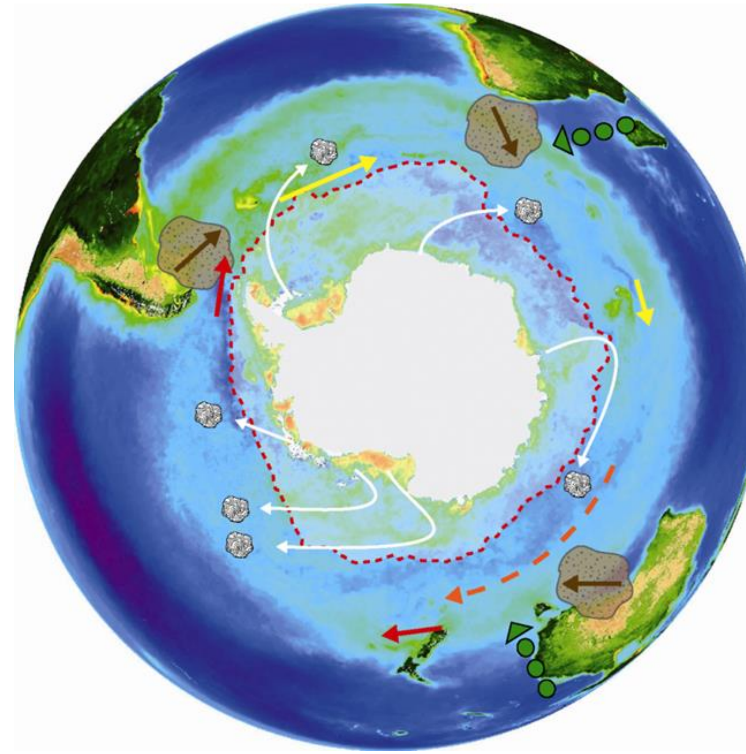
Courtesy NASA

Phytoplankton stocks - a variegated Southern Ocean



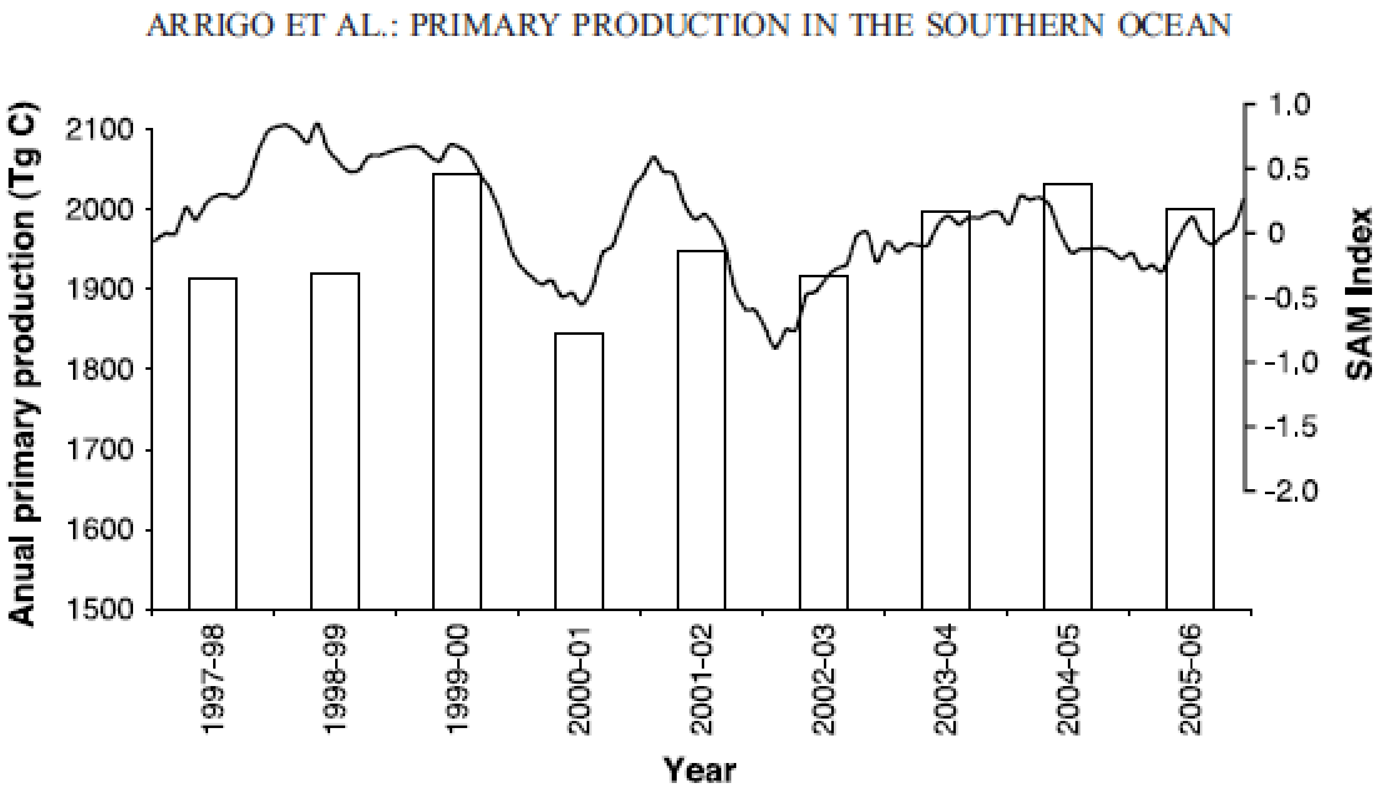
Courtesy NASA

Iron Supply Mechanisms



Boyd & Ellwood (2010)
Nature Geoscience

- Iron is the main driver of S. Ocean primary production
- It is supplied by multiple mechanisms (that likely vary interannually)
- Remotely-sensed primary production is largely invariant.



Arrigo et al. 2008. The above trend (+/-11%) has also been observed from 2006 to 2013 (K. Arrigo, pers. comm.)

Iron sources - Approaches

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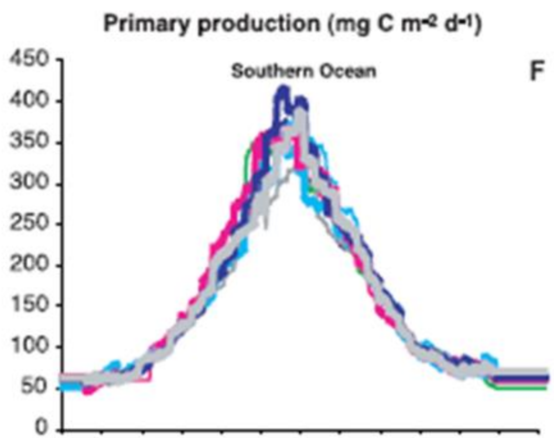
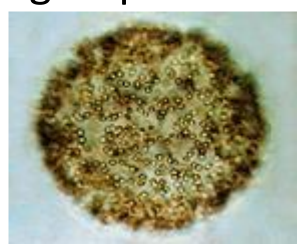
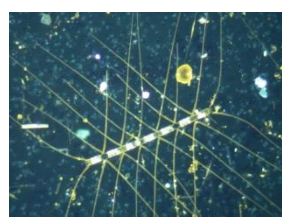
Satellite estimates
Of primary production



Fe:C ratios
of phytoplankton
groups



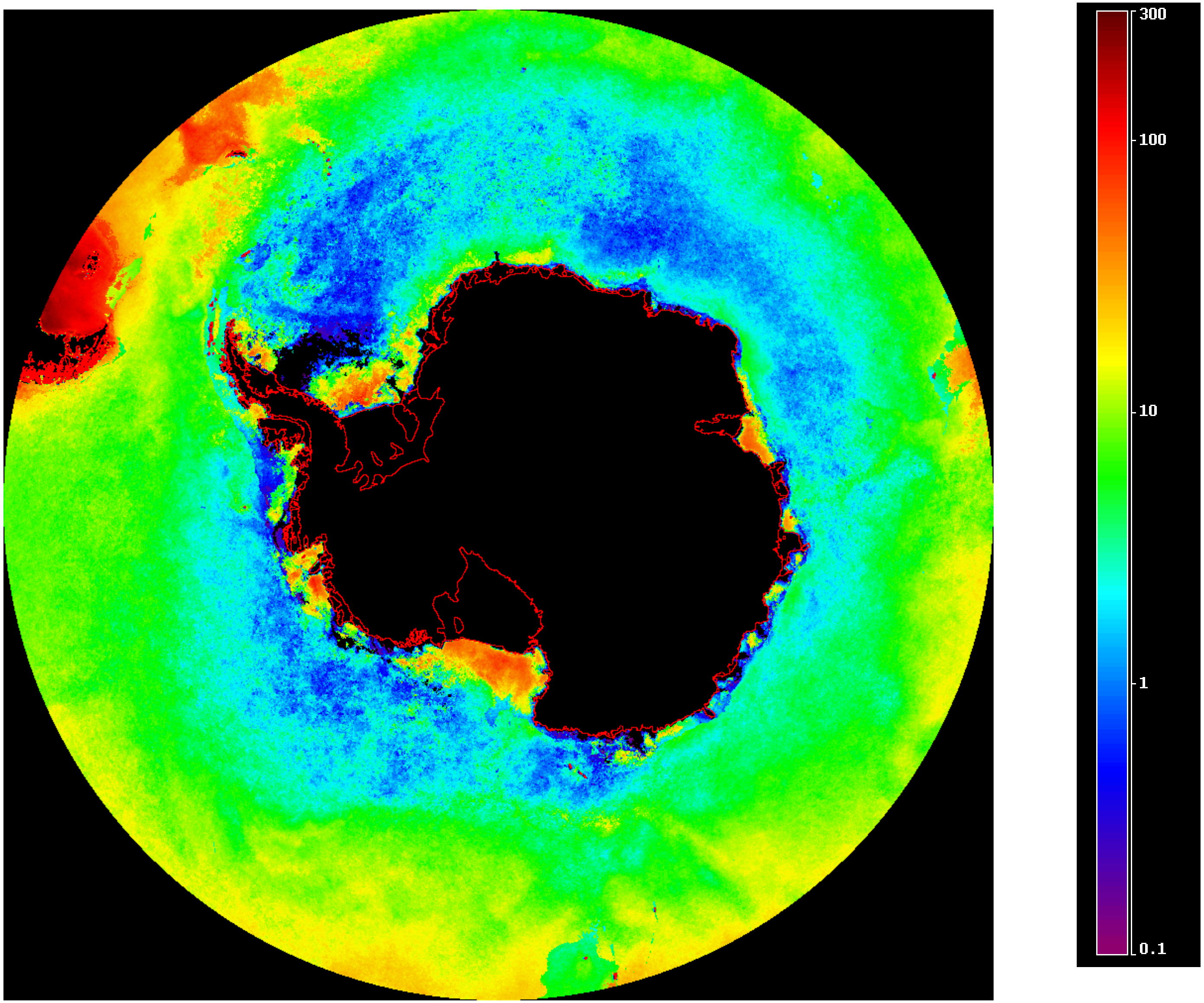


Iron
Utilization
Rate
(new &
Regen)

Multiply
by *fe* ratio
to estimate
new iron
utilisation
rate

Back out iron supply rates for specific mechanisms – such as dust

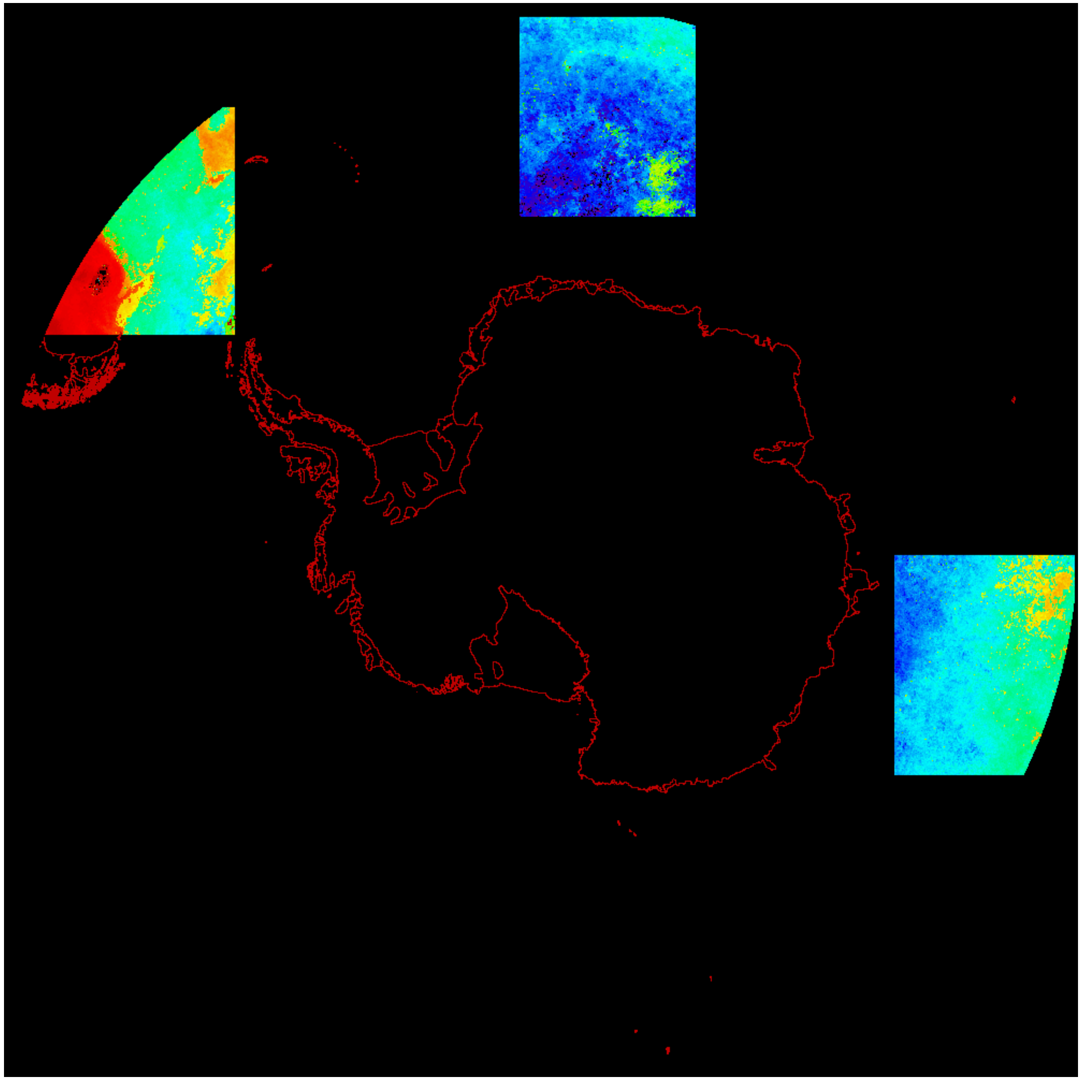
Phytoplankton iron utilisation map (µmol Fe m^{-2} a^{-1})



Boyd et al. (2012)

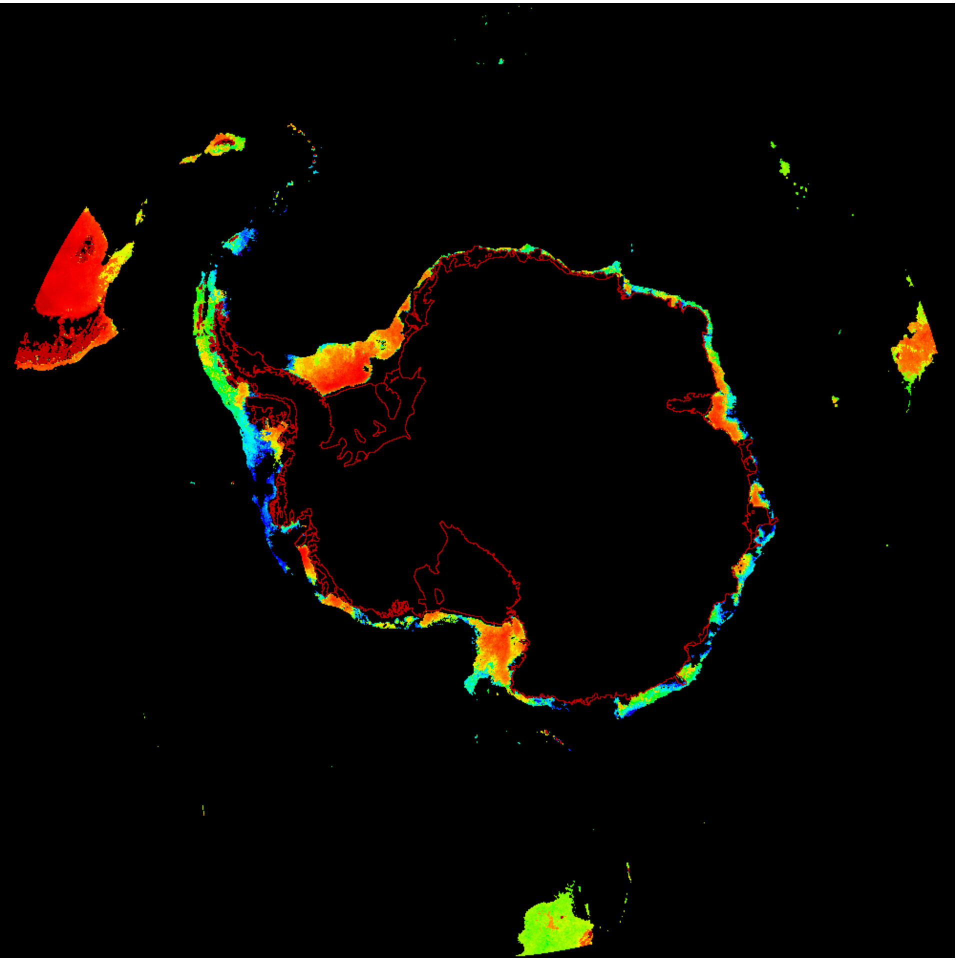
The circumpolar iron utilisation map is ‘subsampled’ based on knowledge of the geographical bounds on iron source mechanisms

3 major dust supply regions

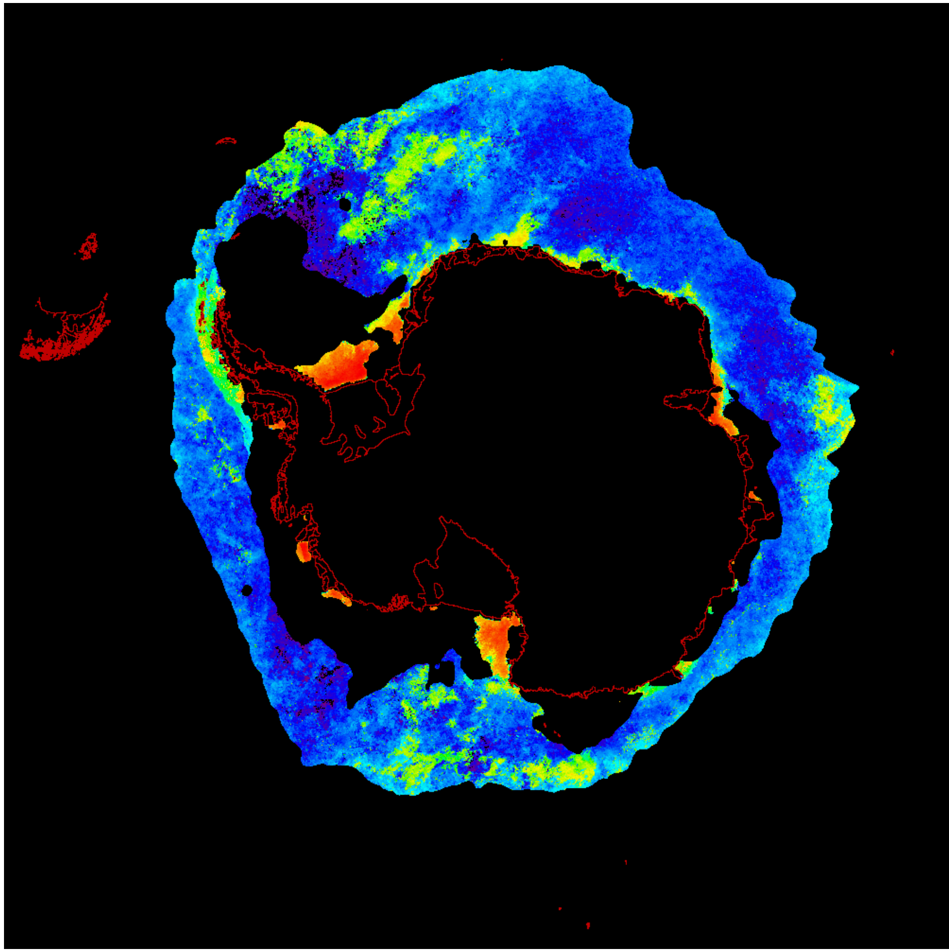


Boyd et al. (2012)

Iron utilisation maps for regions where iron is supplied from re-suspended sediments or sea-ice retreat



< 1000 m depth mask

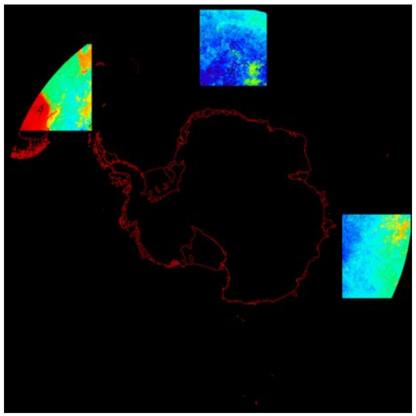


Seasonal sea-ice retreat

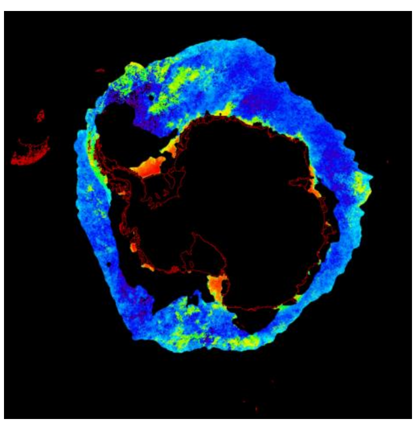
Boyd et al. (2012)

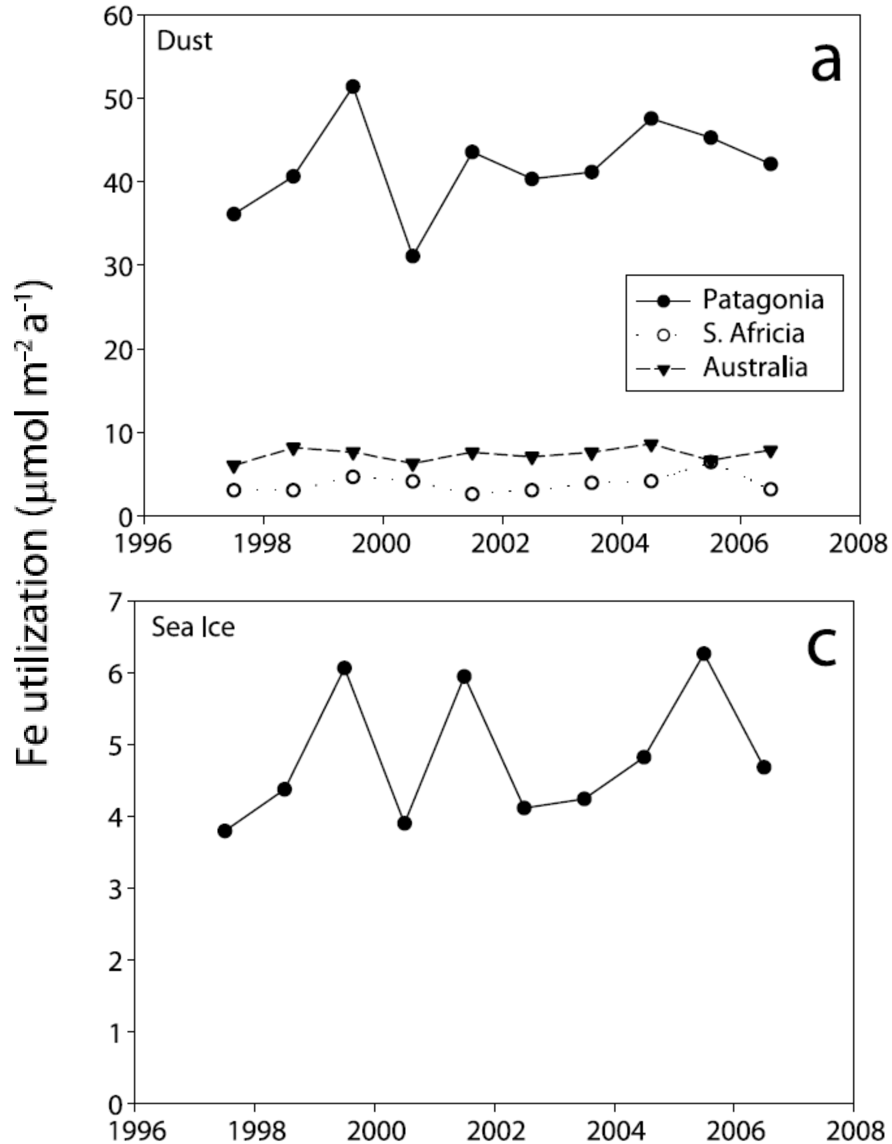
Converting maps to iron utilisation rates

Aerosol iron



Sea-ice melt Fe ‘satellite templates’

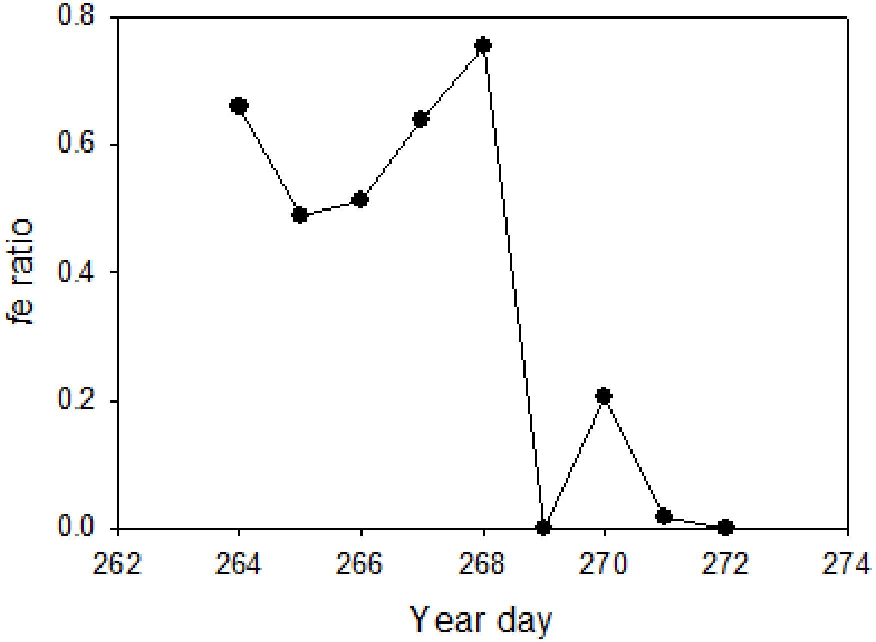


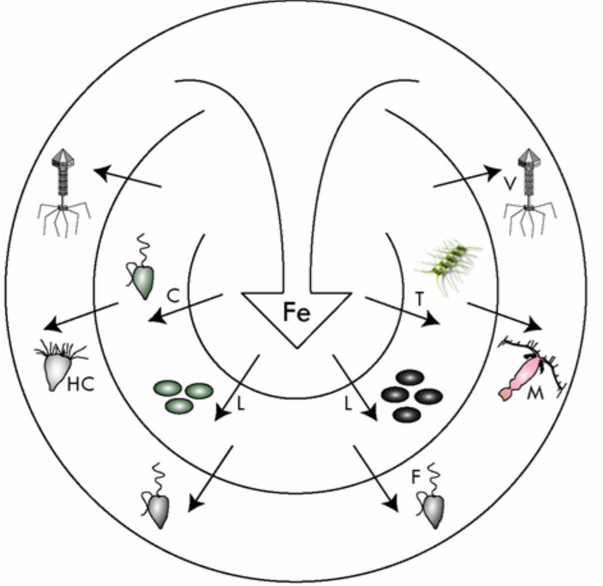


Boyd et al. (2012)

Teasing apart new from regenerated iron using the *fe* ratio

Time-series of the *fe* ratio in a Quasi-lagrangian GEOTRACES process study





Boyd et al. (in review) GBC

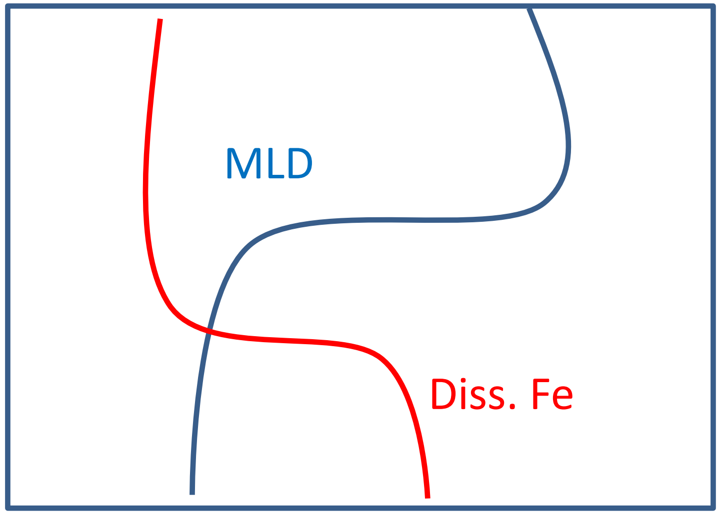
fe ratios reported in other studies

Boyd et al. (2003) HNLC subantarctic 0.1-0.15

Sarthou et al. (2008) High Fe S. Ocean ~0.5

Iron sources - Approaches

Depth



From Boyd & Ellwood (2010)

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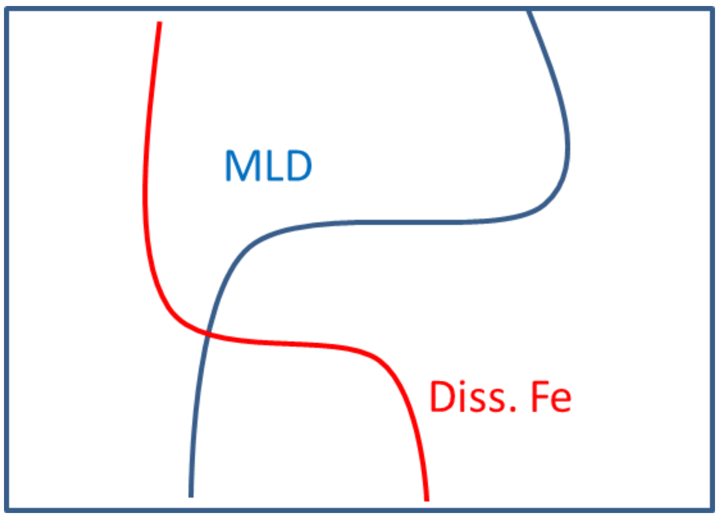
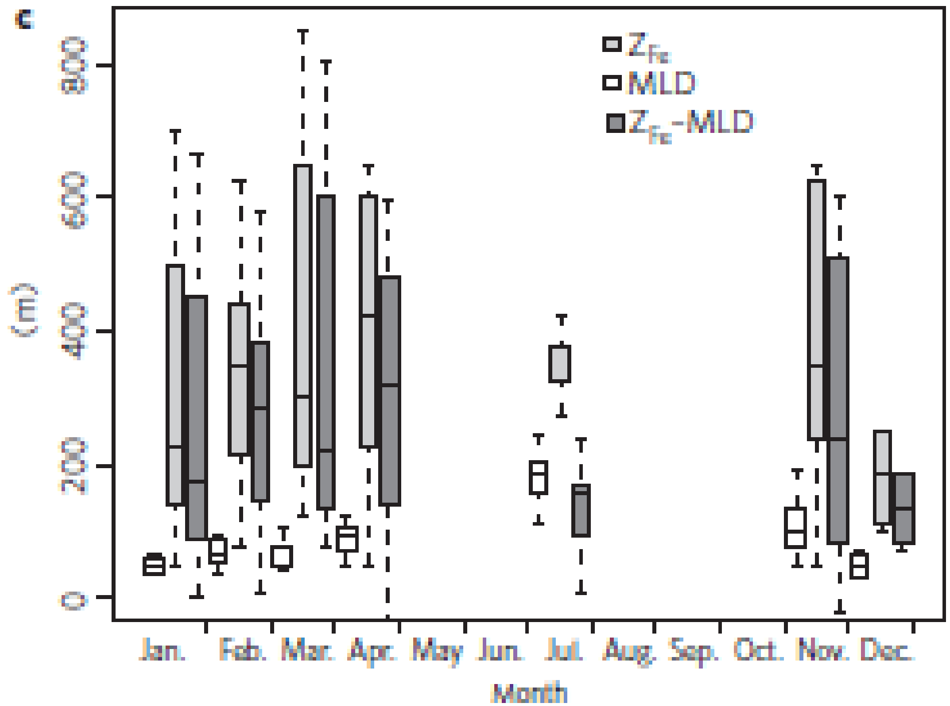
Combines a decade of ARGO float data (mixed layer depth), IPY-GEOTRACES profiles of dissolved iron (ferricline) and GEOTRACES process studies (iron recycling) to assess basin scale iron supply – upwelling, entrainment, diffusion

Iron sources - Approaches

Tagliabue et al. (2014) found that the ferricline was consistently deeper than the seasonal mixed layer depth – implications for vertical iron supply

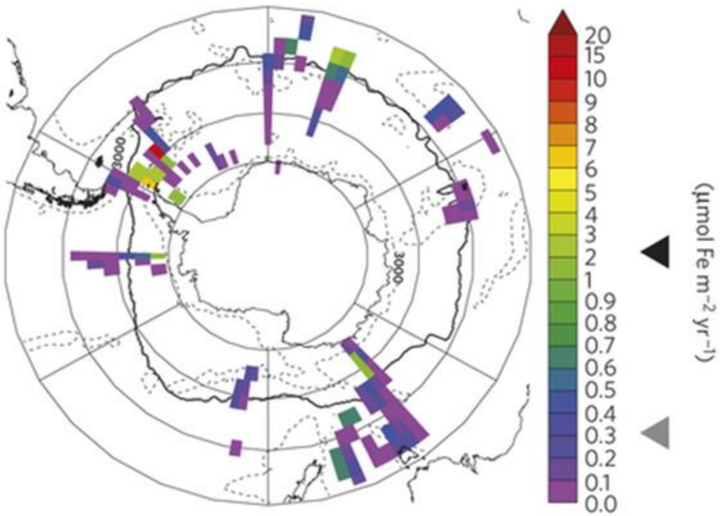




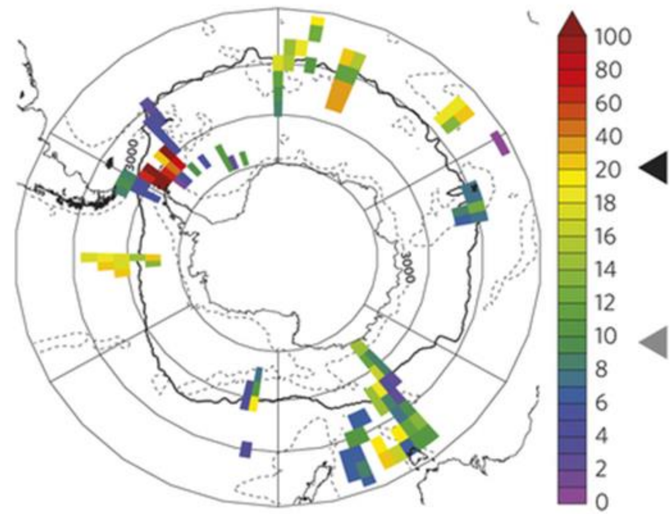
"That Z_{Fe} is almost always much deeper than the concomitant MLD indicates limited input of DFe from diapycnal diffusion due to weak $\delta Fe/\delta z_{MLD}$"

(surface-density difference criterion of 0.03kg m^{-3})

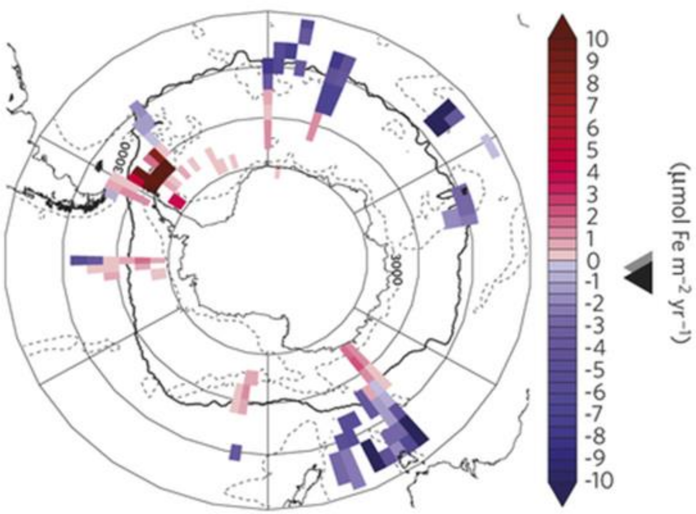
Circumpolar maps of iron supply from GEOTRACES IPY sections



Diapycnal diffusion Fe flux across the mixed layer



Entrainment flux of Fe



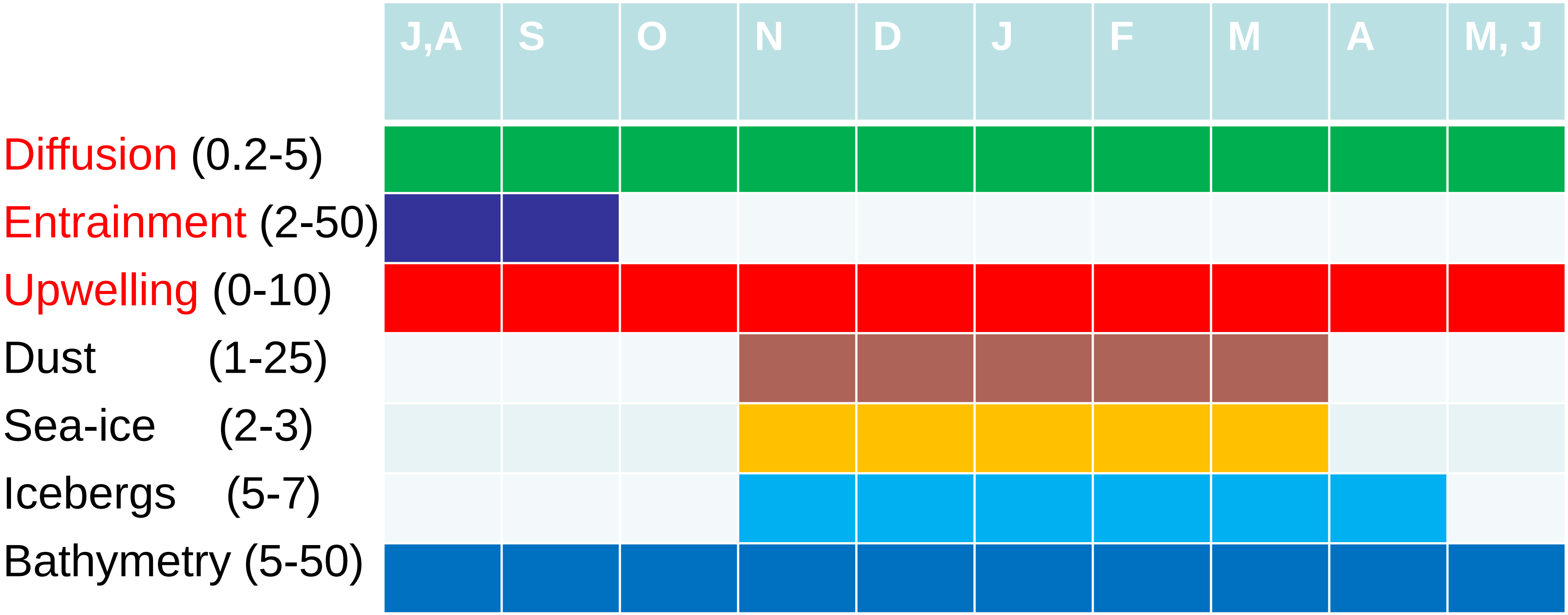
Ekman Fe term (+ upwelling/ - downwelling)

Mean
median

Tagliabue et al. (2014)

Iron supply $\mu mol\ m^{-2}\ a^{-1}$

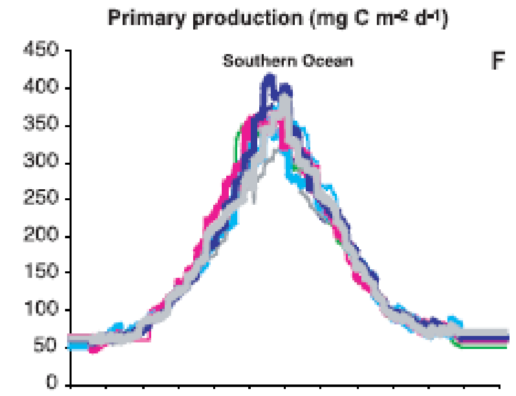
Month



Boyd (unpublished)

Not included, eddy transport, hydrothermal vents, bottom pressure torque, island wake

S. Ocean interannual variability– such as SAM – will likely influence the magnitude of each of these iron supply mechanisms, but productivity is invariant

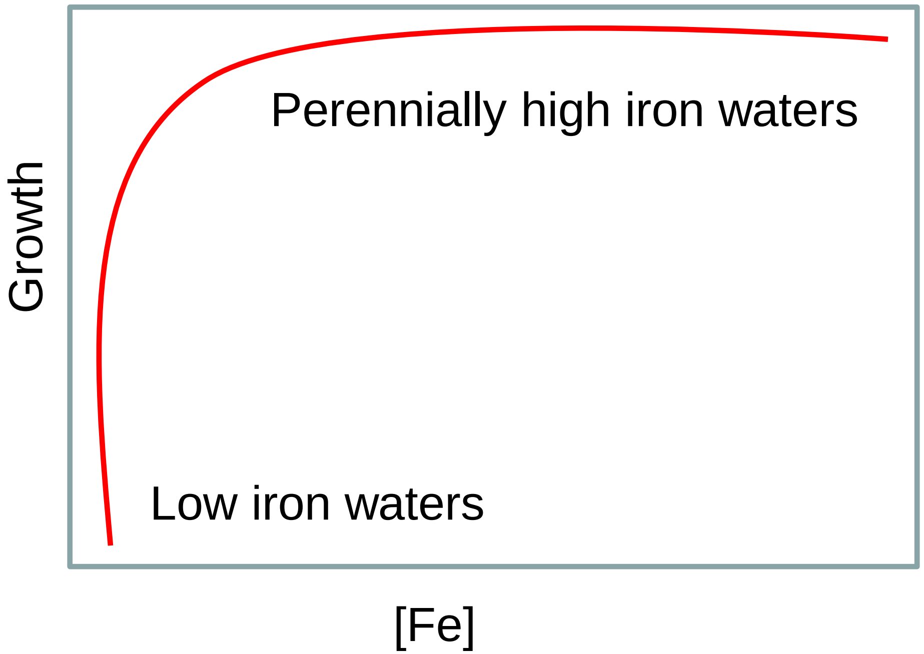


Does the spatial and temporal overlap of different Fe supply mechanisms act as a buffer for productivity?

Region	Bathymetry & dust maps (km^2)	
	< 1000 m depth	> 1000 m depth
Patagonia	360183	1271606
S. Africa	2543	2224634
Australia	285	2256366

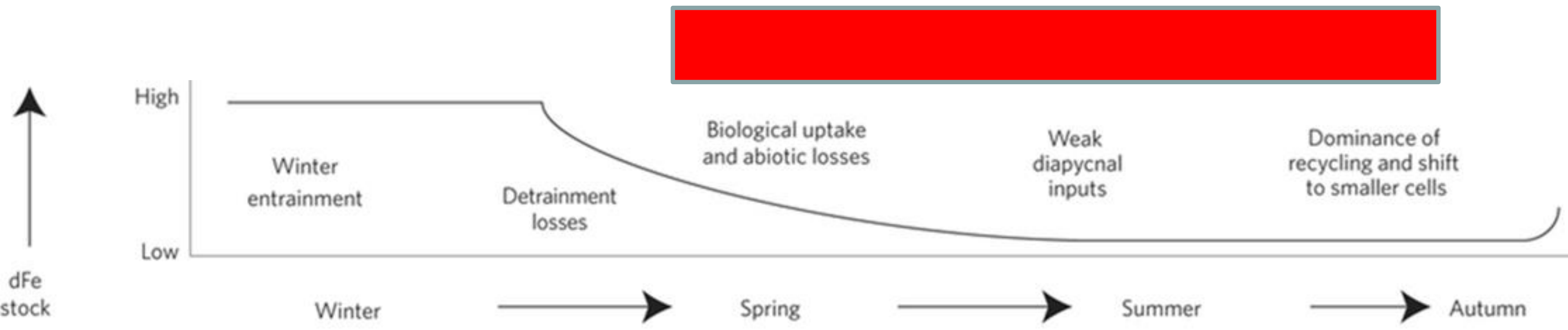
Boyd et al. (2012)

Is there a divide between low & high iron waters that variability cannot influence?



Summary

Regional Fe inputs from other mechanisms



A changing climate will alter some iron supply mechanisms – dust versus Hydrothermal vents – more than others.

Will it significantly alter the variegated chlorophyll patterns in the S. Ocean?