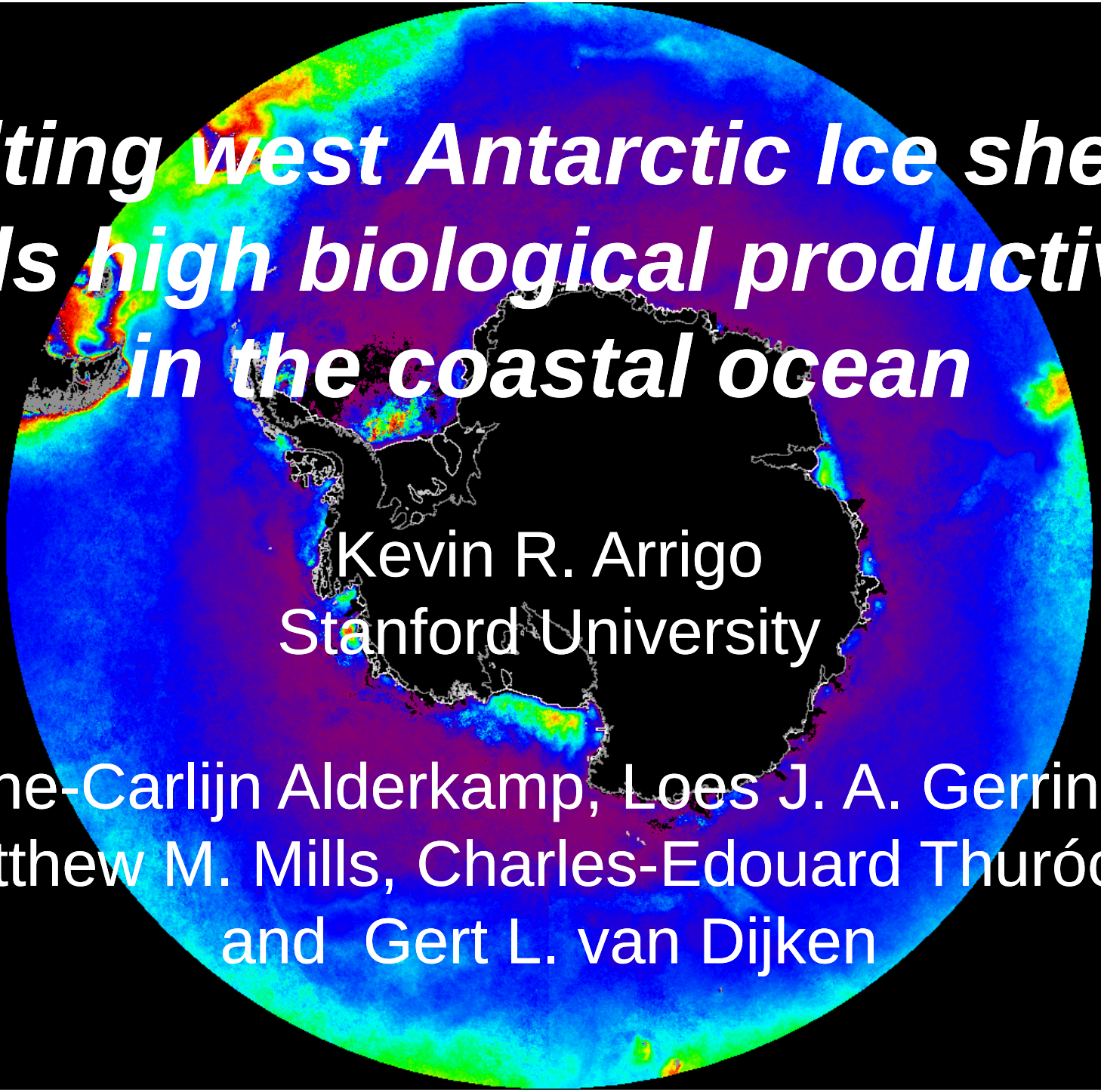
Melting west Antarctic Ice sheets fuels high biological productivity in the coastal ocean



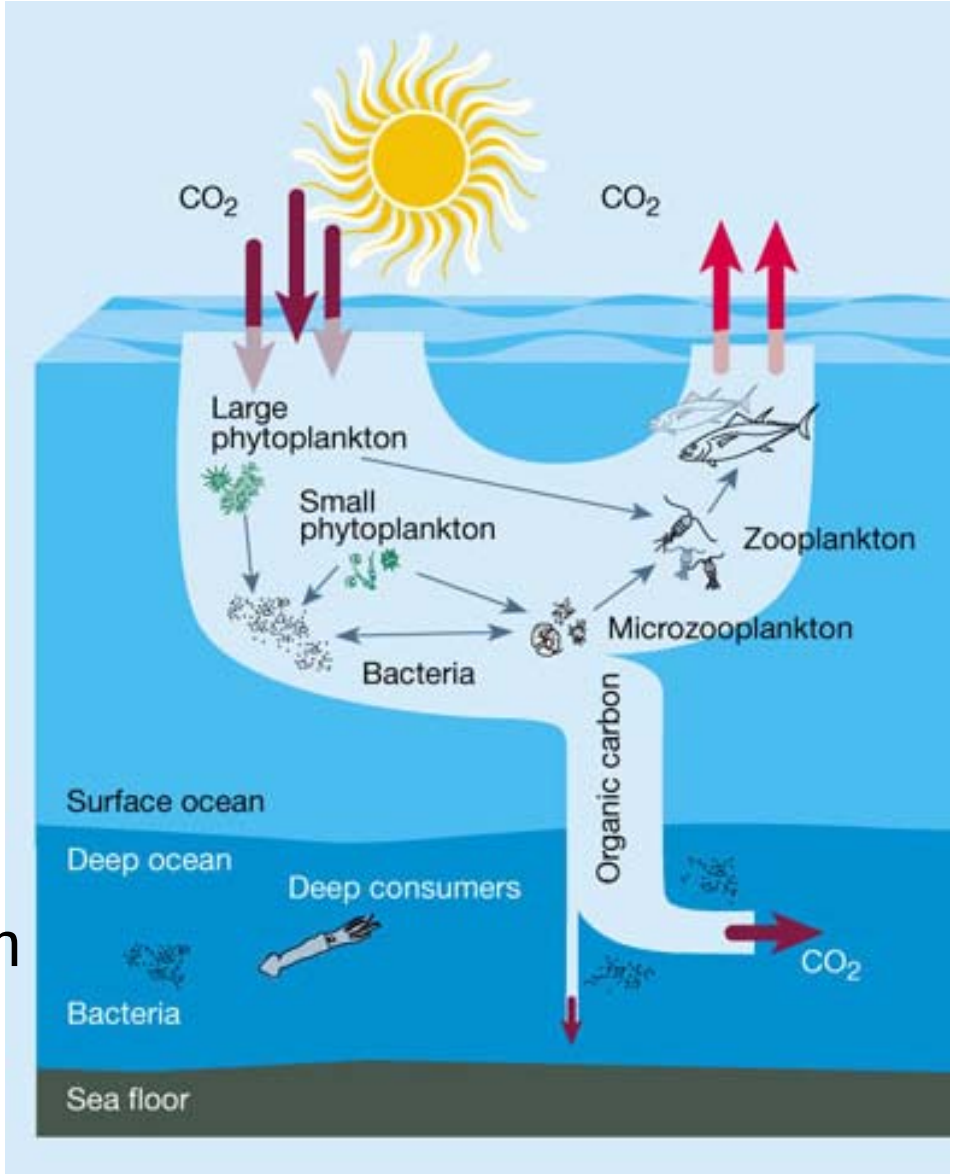
Kevin R. Arrigo
Stanford University

Anne-Carlijn Alderkamp, Loes J. A. Gerringa, Matthew M. Mills, Charles-Edouard Thuróczy, and Gert L. van Dijken

Some Background

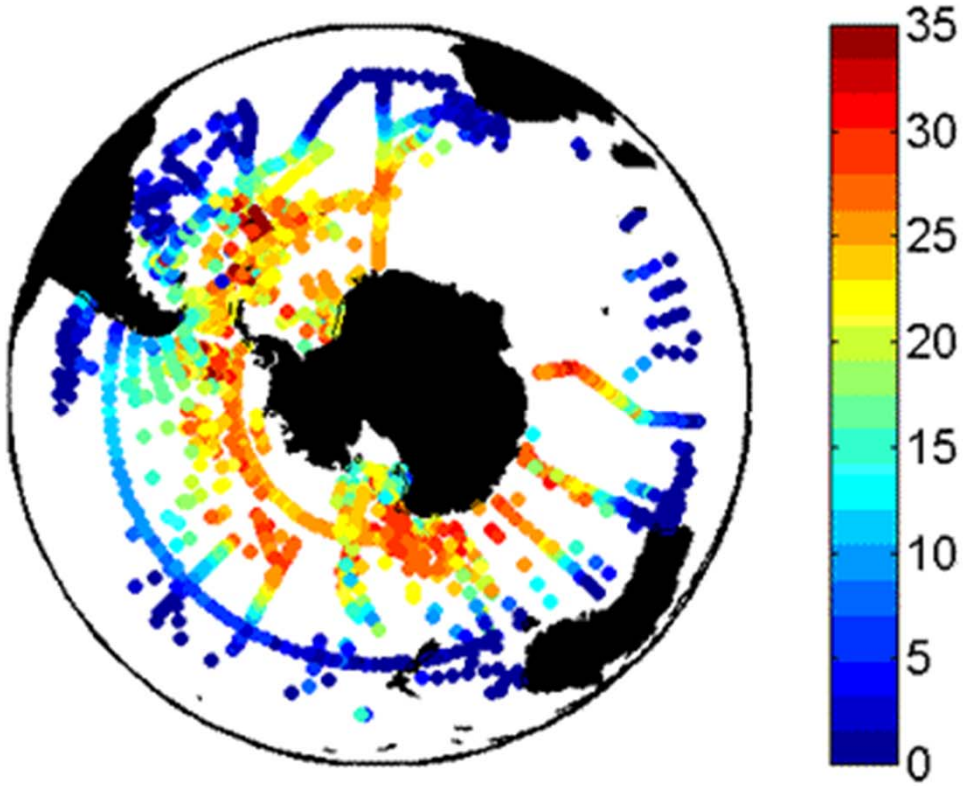
What is the biological pump?

- Phytoplankton live in surface
  - ocean
- Photosynthesis lowers CO_2 in
  - upper ocean
- Facilitates influx of
  - atmospheric CO_2
- New organic C sinks to bottom



Biological pump allows more CO_2 to enter the ocean from the atmosphere

Surface nitrate concentrations (μM)

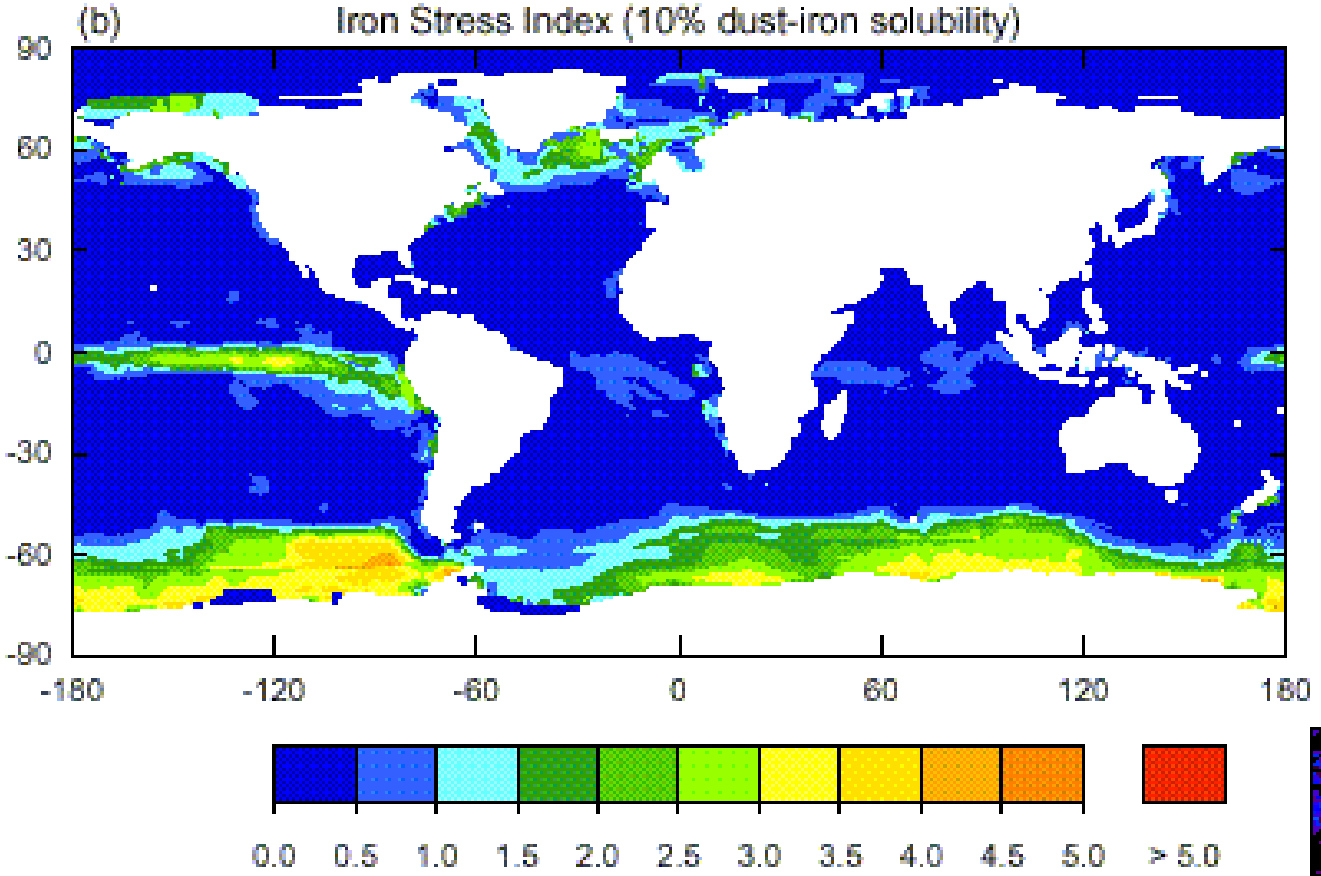


Southern Ocean has highest nitrate in the world's oceans

If all this nitrate were consumed by phytoplankton, CO_2 in the atmosphere would be dramatically reduced

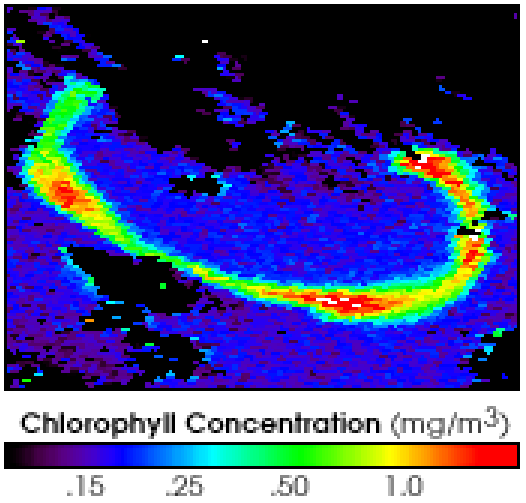
Why isn't more nitrate consumed today?

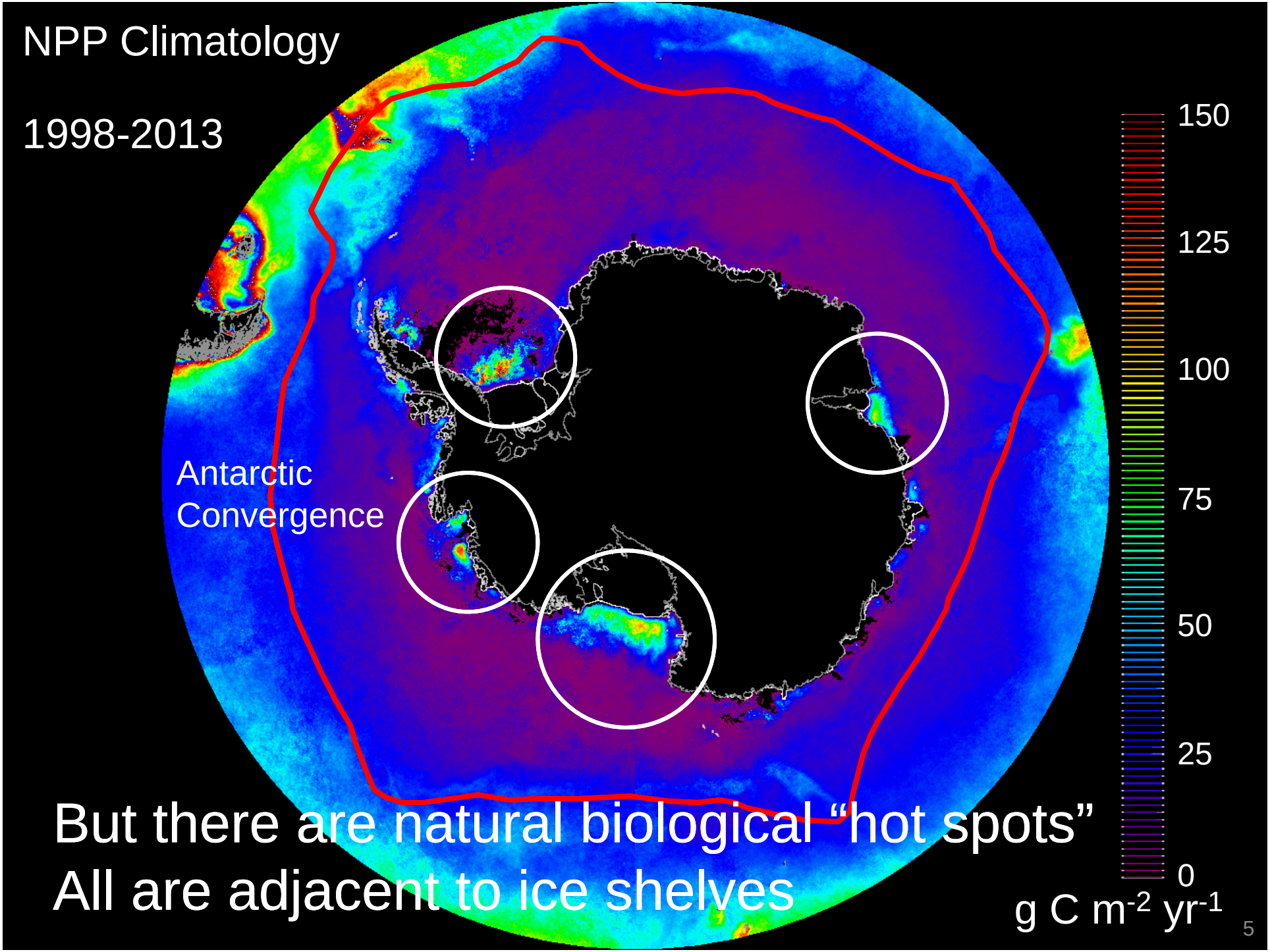
The Southern Ocean has too little iron

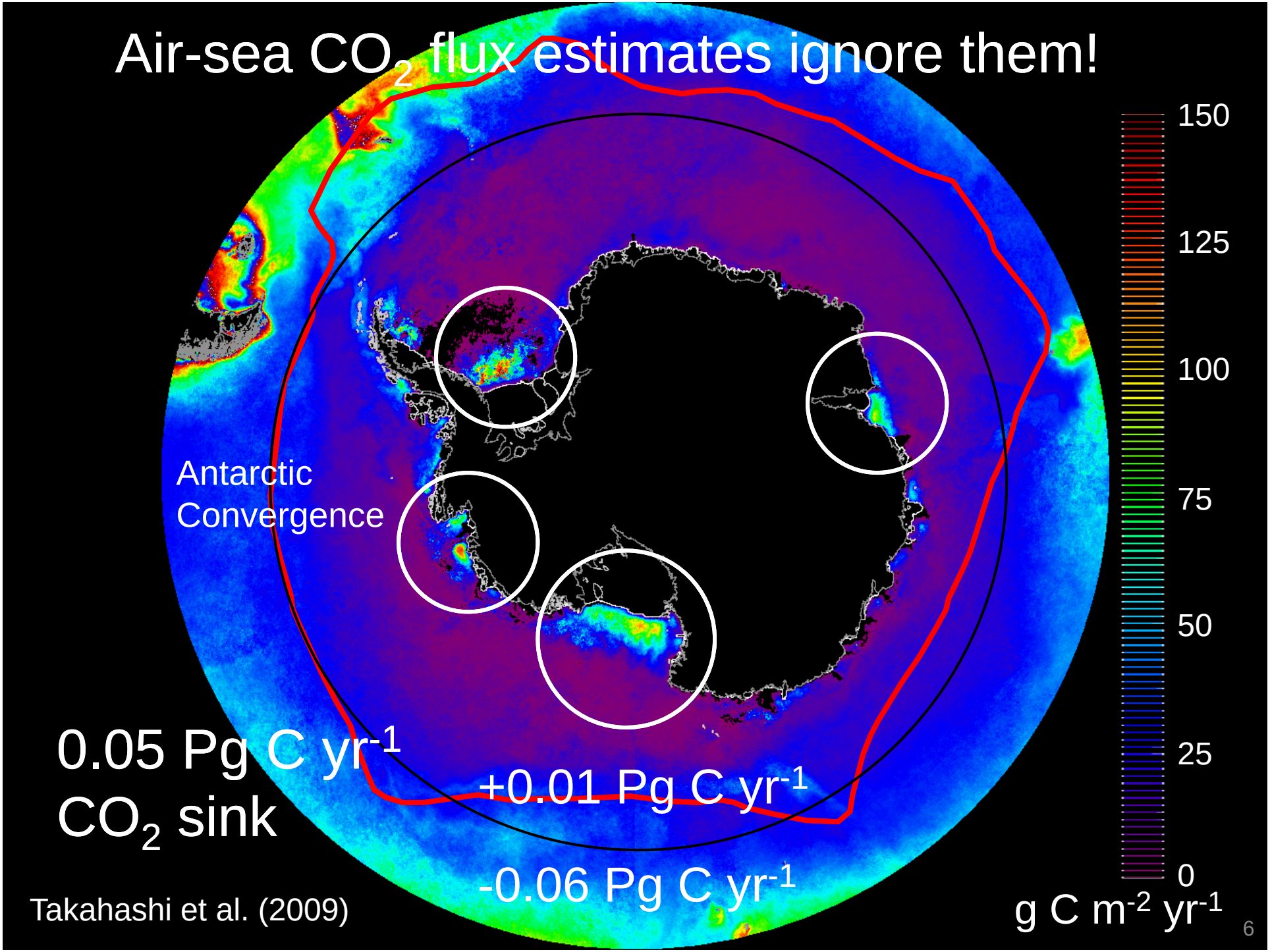


Southern Ocean is the largest of the 3 oceanic regions where iron limits phytoplankton growth

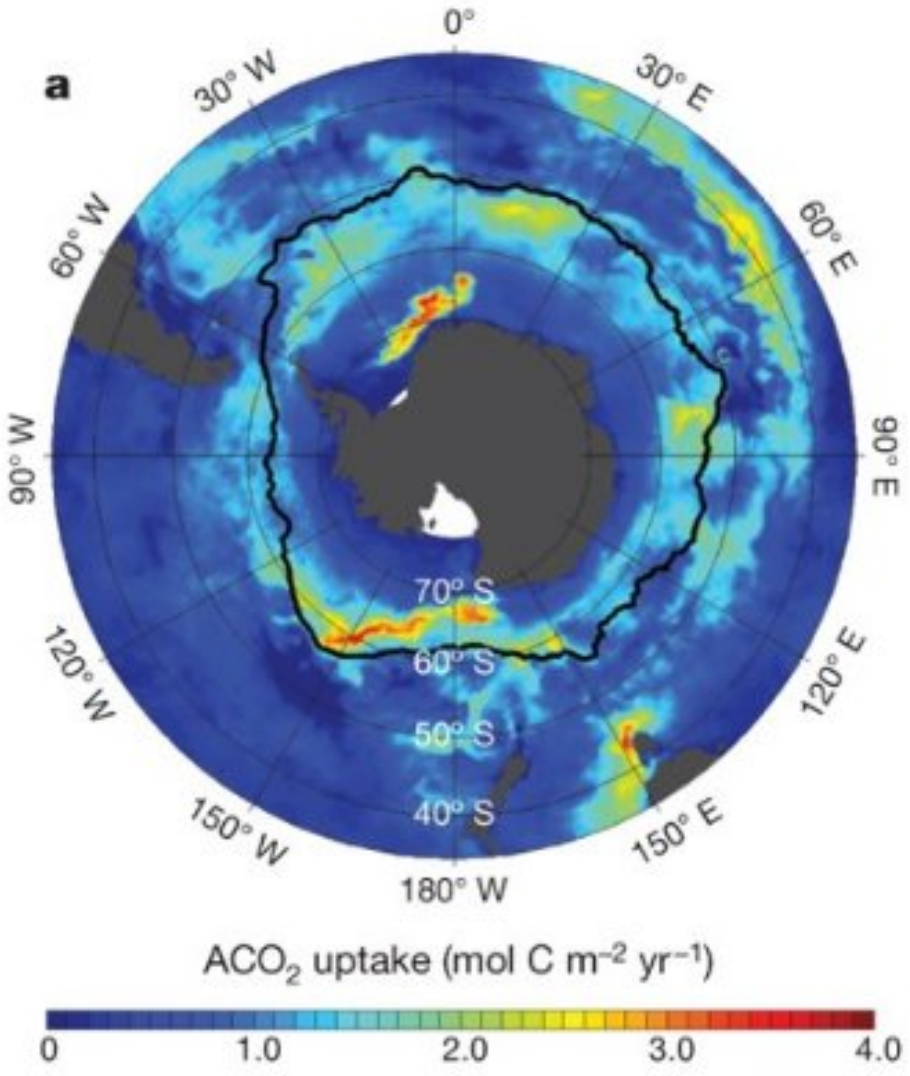
When iron is added to Southern Ocean waters, phytoplankton bloom

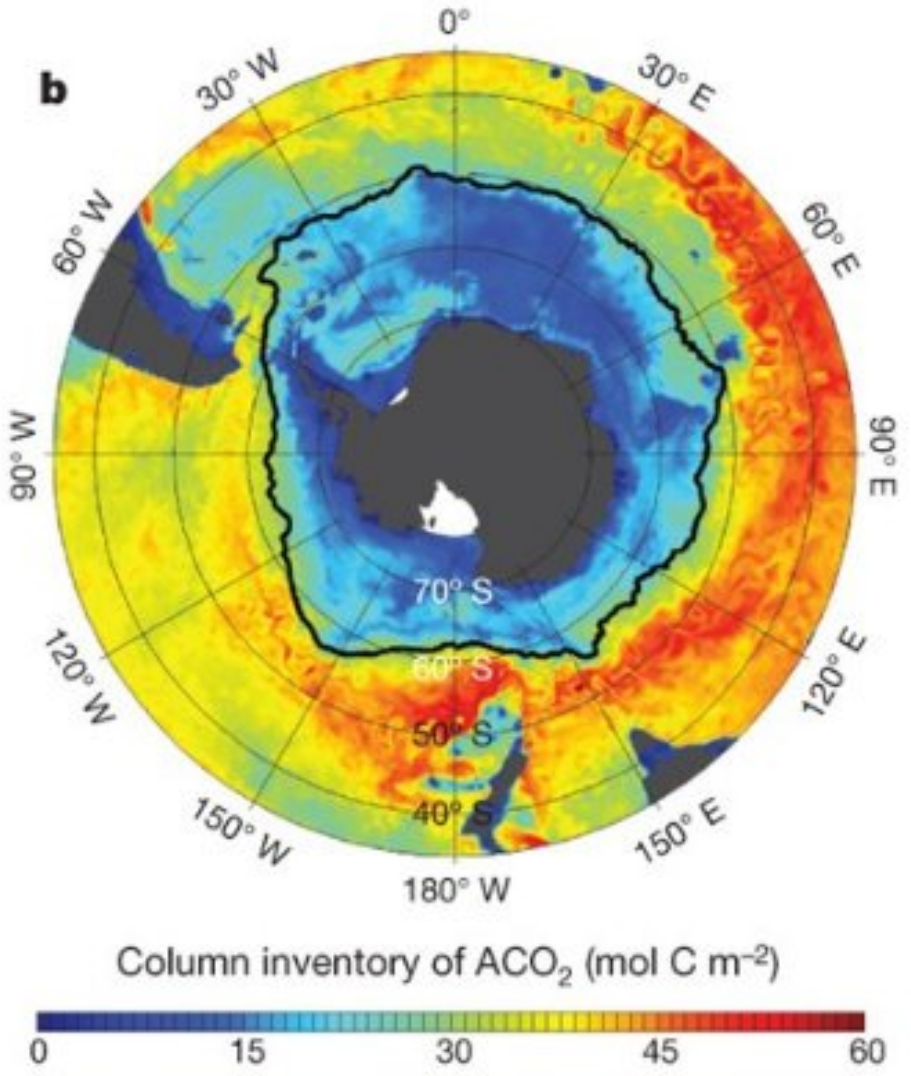



NPP Climatology
1998-2013
Antarctic
Convergence
150
125
100
75
50
25
0
g C m-2 yr-1
But there are natural biological “hot spots”
All are adjacent to ice shelves

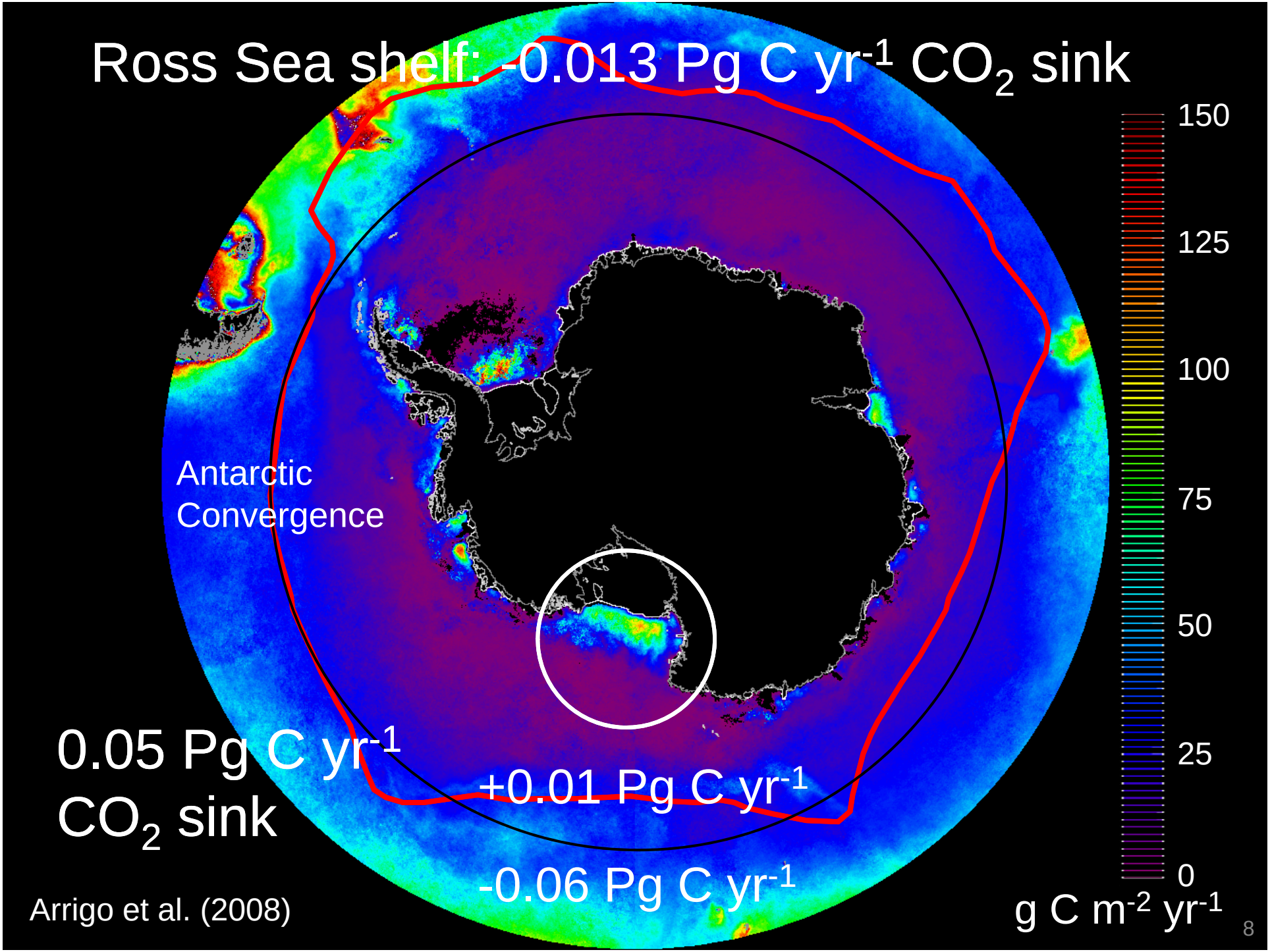

Air-sea CO_2 flux estimates ignore them!
Antarctic Convergence
0.05 Pg C yr^{-1} CO_2 sink
+0.01 Pg C yr^{-1}
-0.06 Pg C yr^{-1}
Takahashi et al. (2009)
150
125
100
75
50
25
0
g C m^{-2} yr^{-1}

So do most models of air-sea CO_2 exchange
(even high resolution ones)

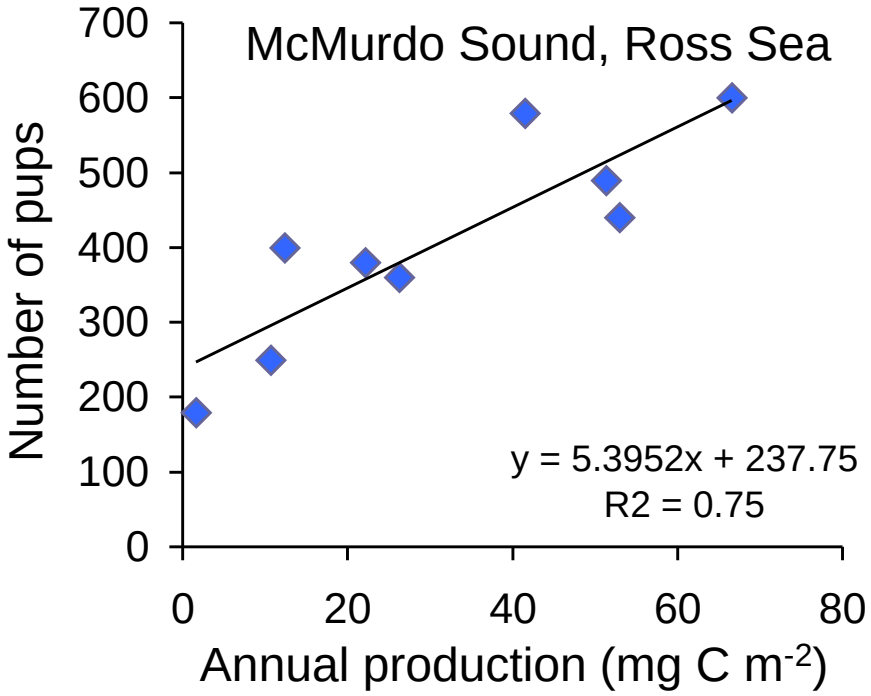


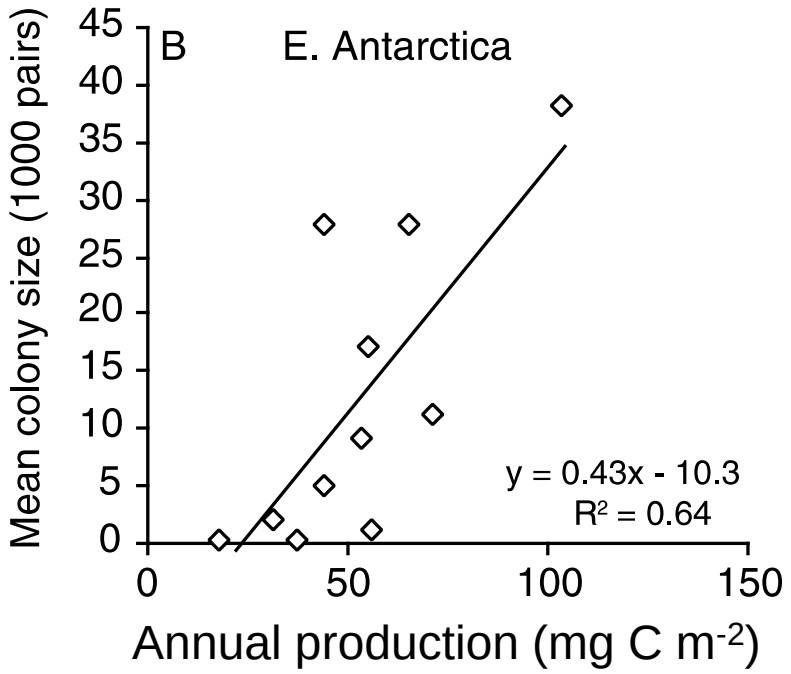


Ito et al. (2010)

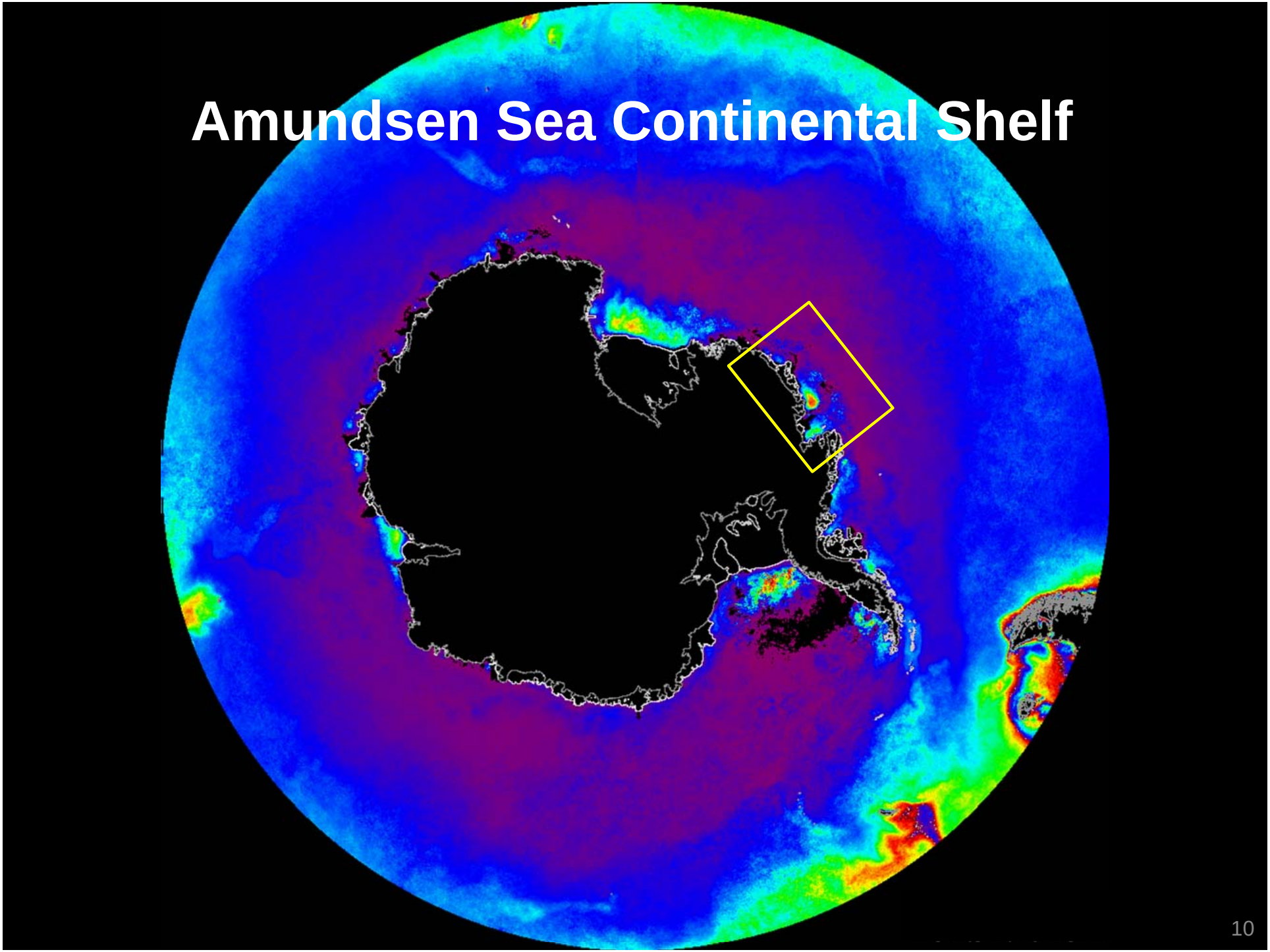

Ross Sea shelf: -0.013 Pg C yr-1 CO2 sink
Antarctic Convergence
0.05 Pg C yr-1 CO2 sink
+0.01 Pg C yr-1
-0.06 Pg C yr-1
Arrigo et al. (2008)
150
125
100
75
50
25
0
g C m-2 yr-1

Production important for ecosystems

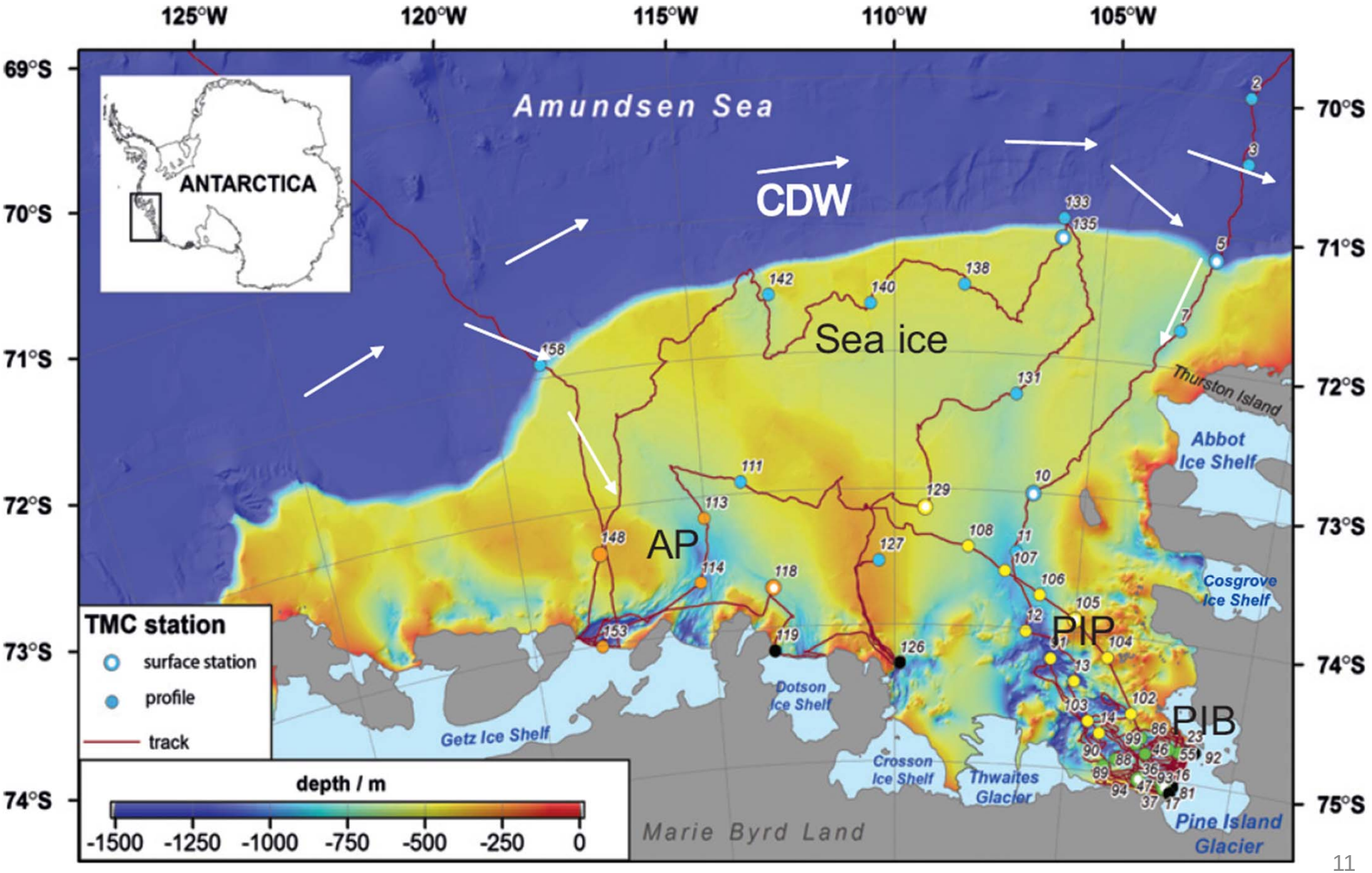




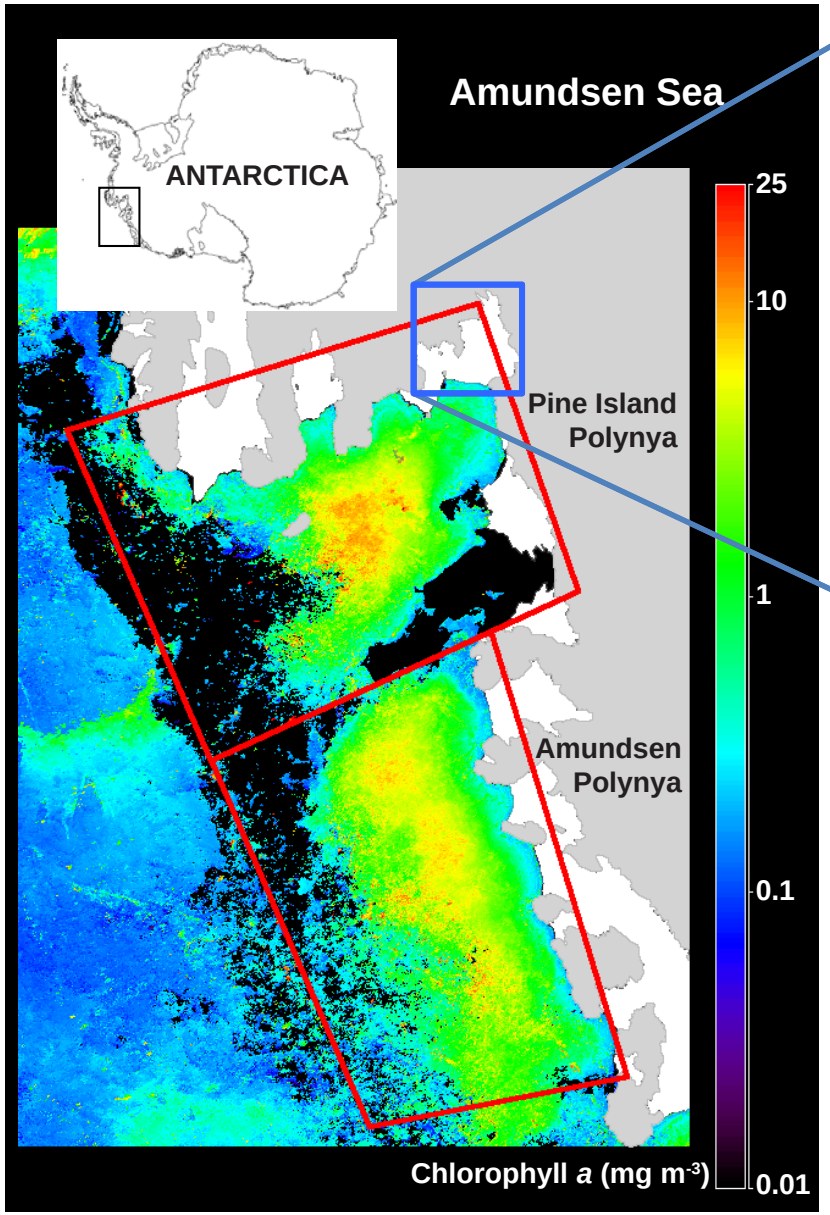
Amundsen Sea Continental Shelf

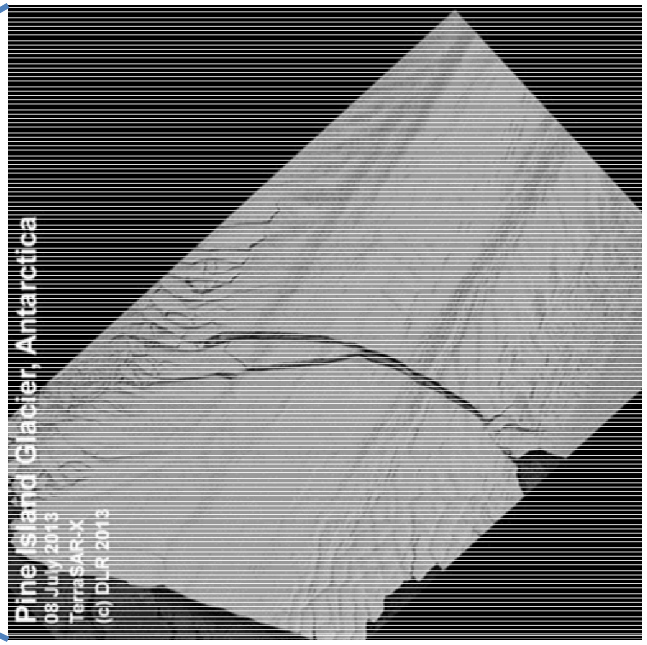


Amundsen Sea



Amundsen and Pine Island polynyas





Pine Island Glacier calved July, 2013
720 km^2

Amundsen Sea

Near ice edge

Amundsen Polynya

Photo: Dave Munroe

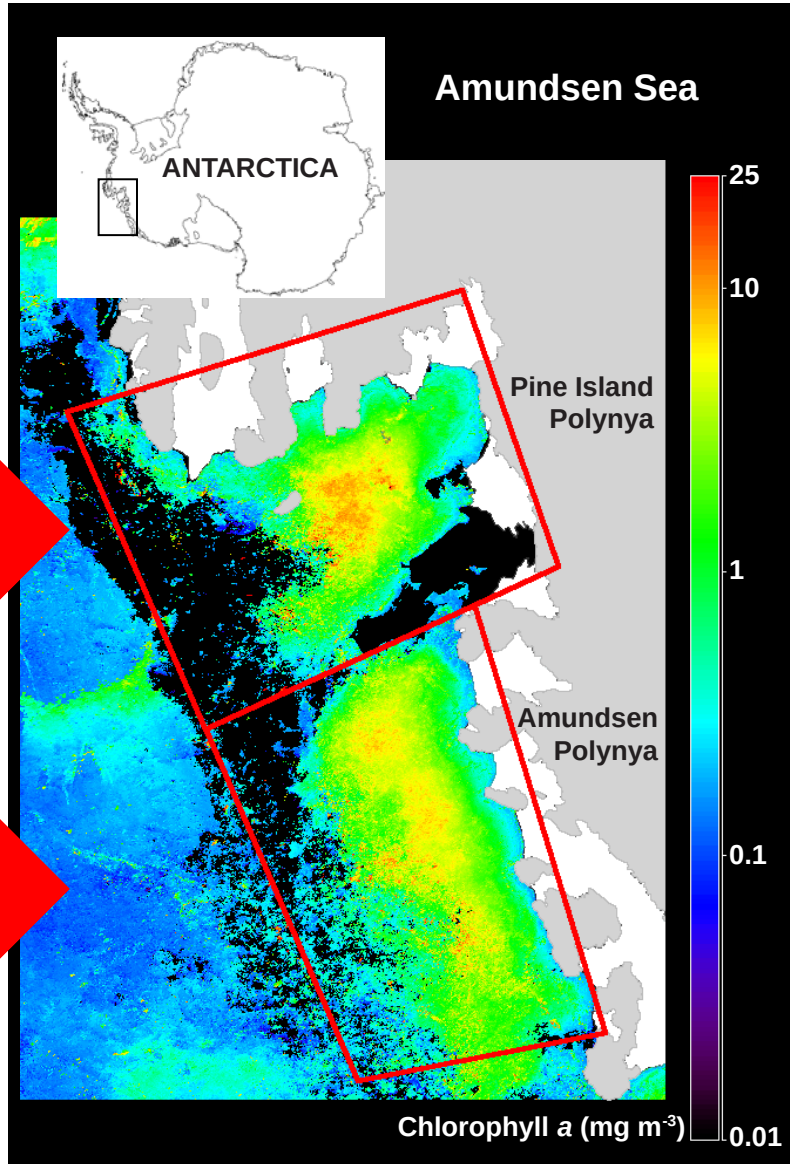
Intense blooms in polynyas near melting glaciers

Amundsen Sea

Response to Fe?

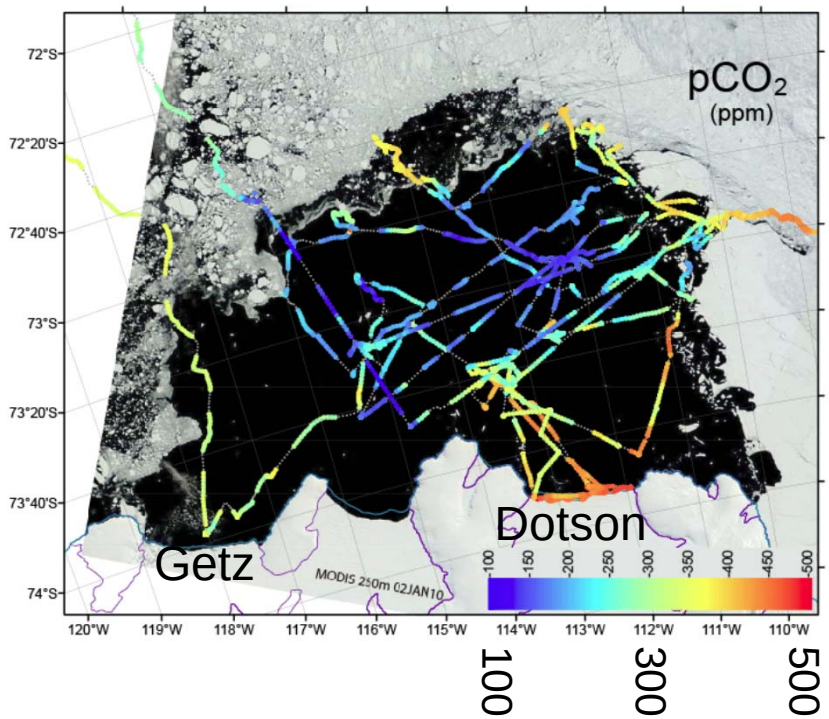
DynaLiFe
13 Jan – 18 Feb 2009

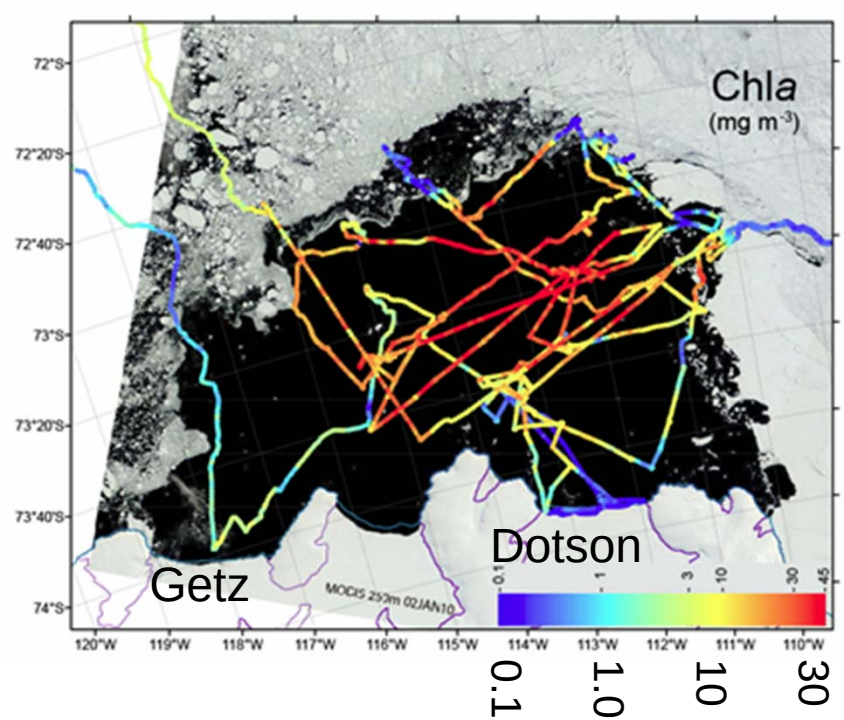
ASPIRE
14 Dec 2010 – 5 Jan 2011



Amundsen Sea – Amundsen Polynya

ASPIRE

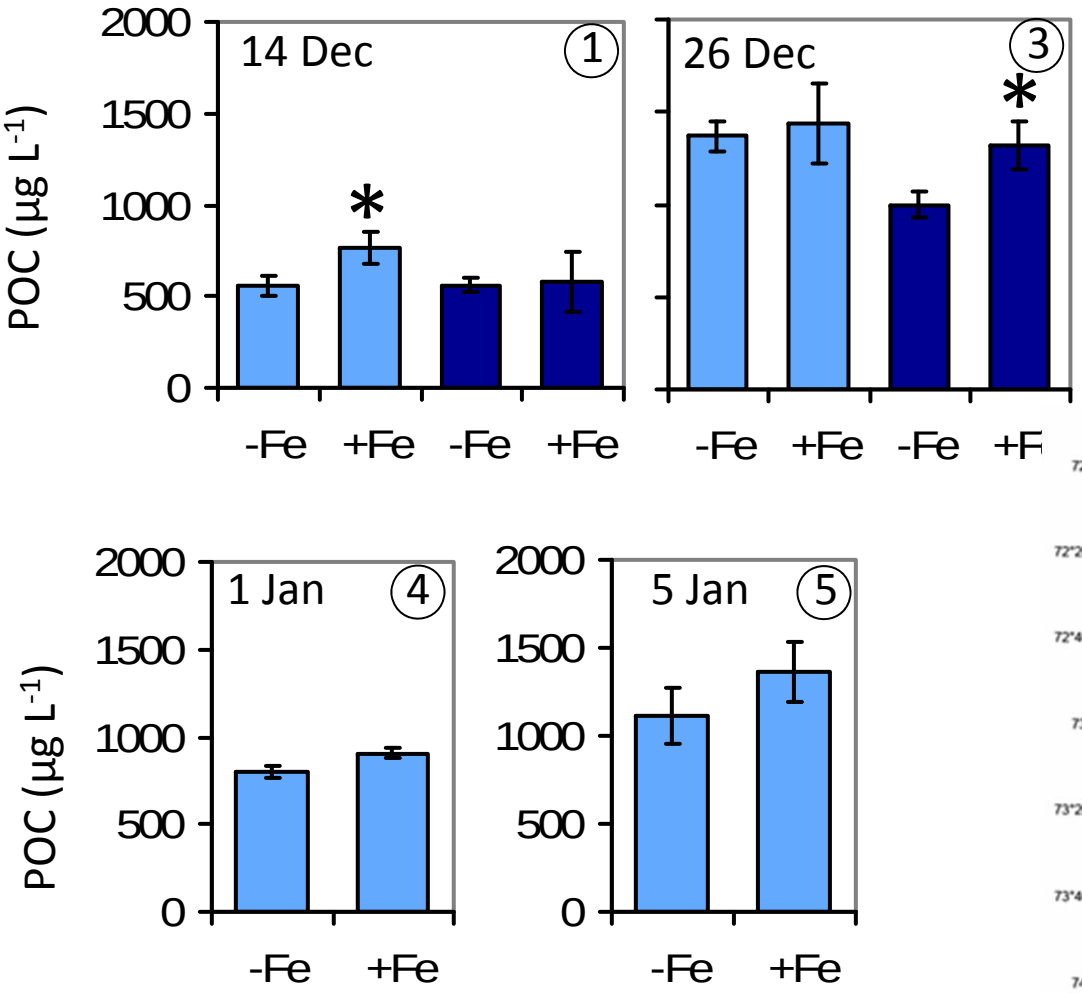


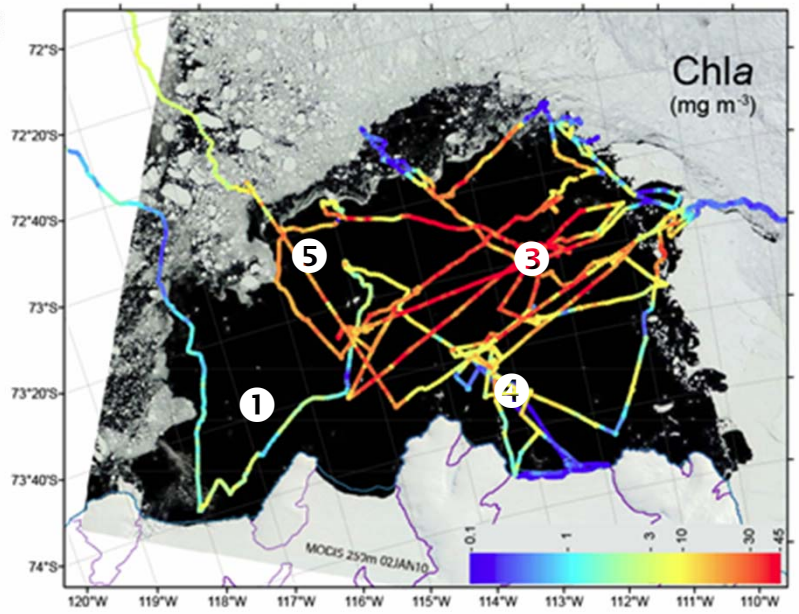


- Upwelled MCDW outflow in front of Dotson Ice Shelf
  Low phytoplankton biomass
- High biomass in central polynya (>20 µg Chl *a* L^{-1})

Amundsen Sea – Amundsen Polynya

Fe addition bioassay experiments

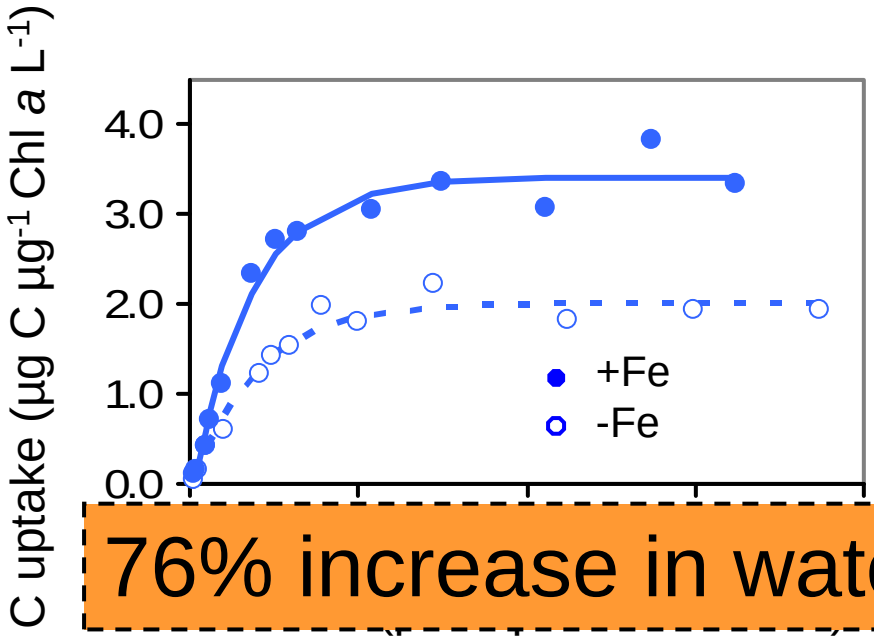


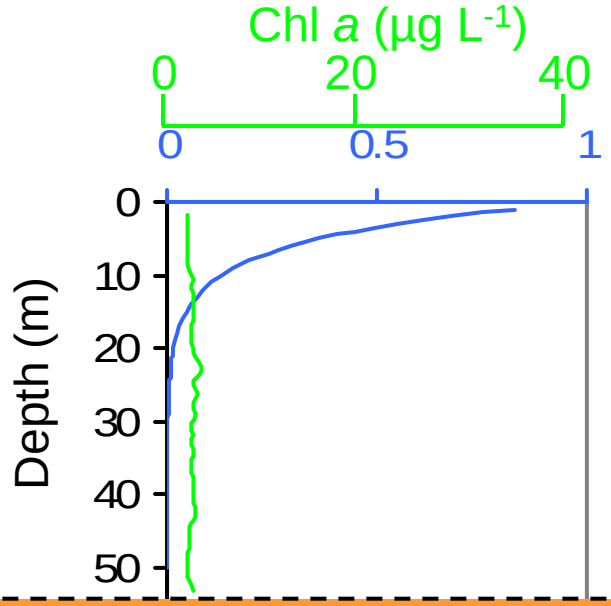


Amundsen Polynya is Fe-limited in some locations

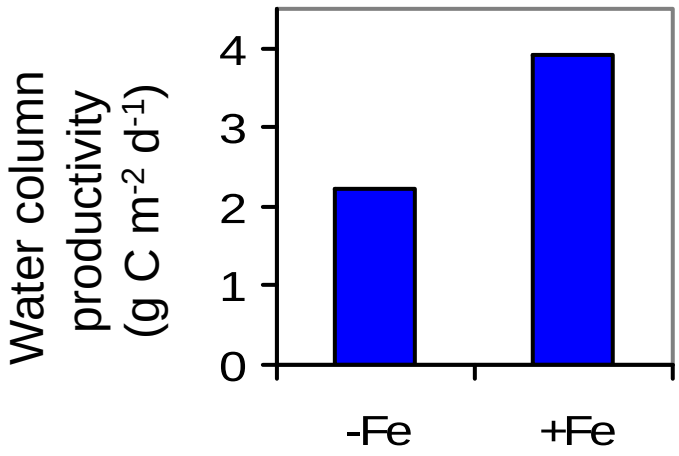
Amundsen Sea – Amundsen Polynya

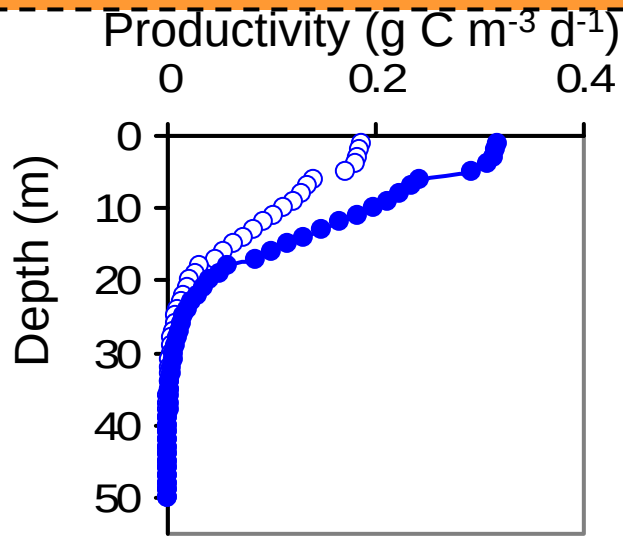
Fe effects on NPP – Sta 5



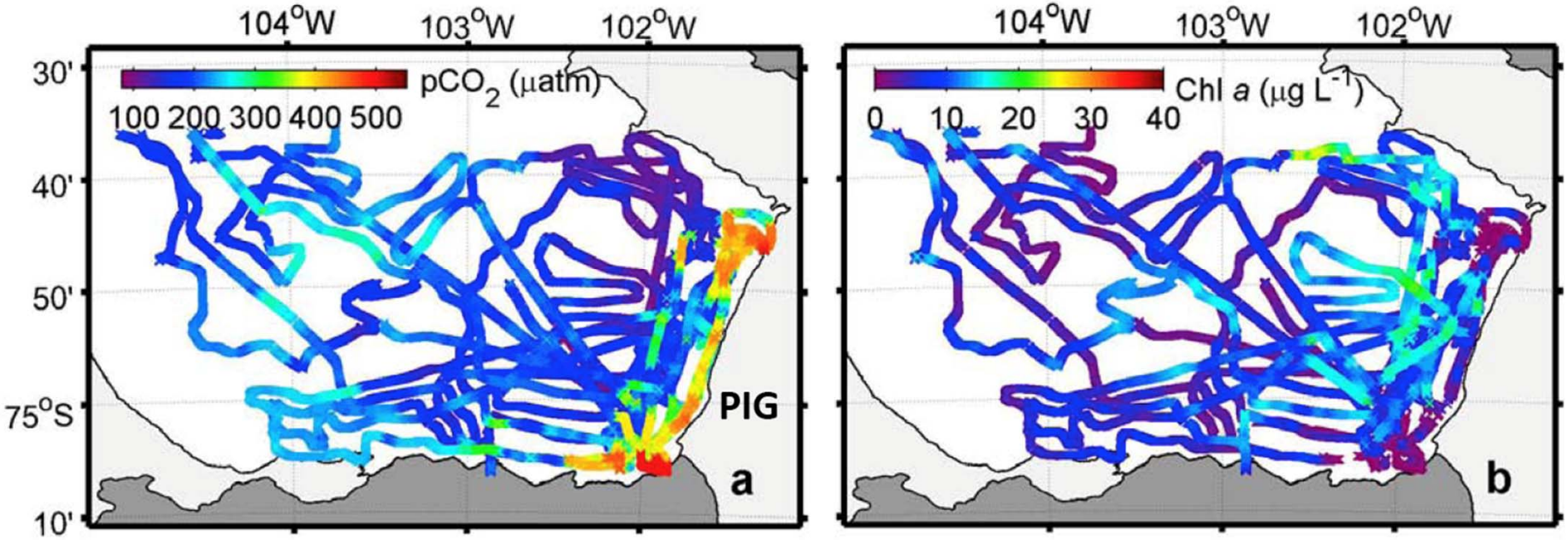


76% increase in water column productivity



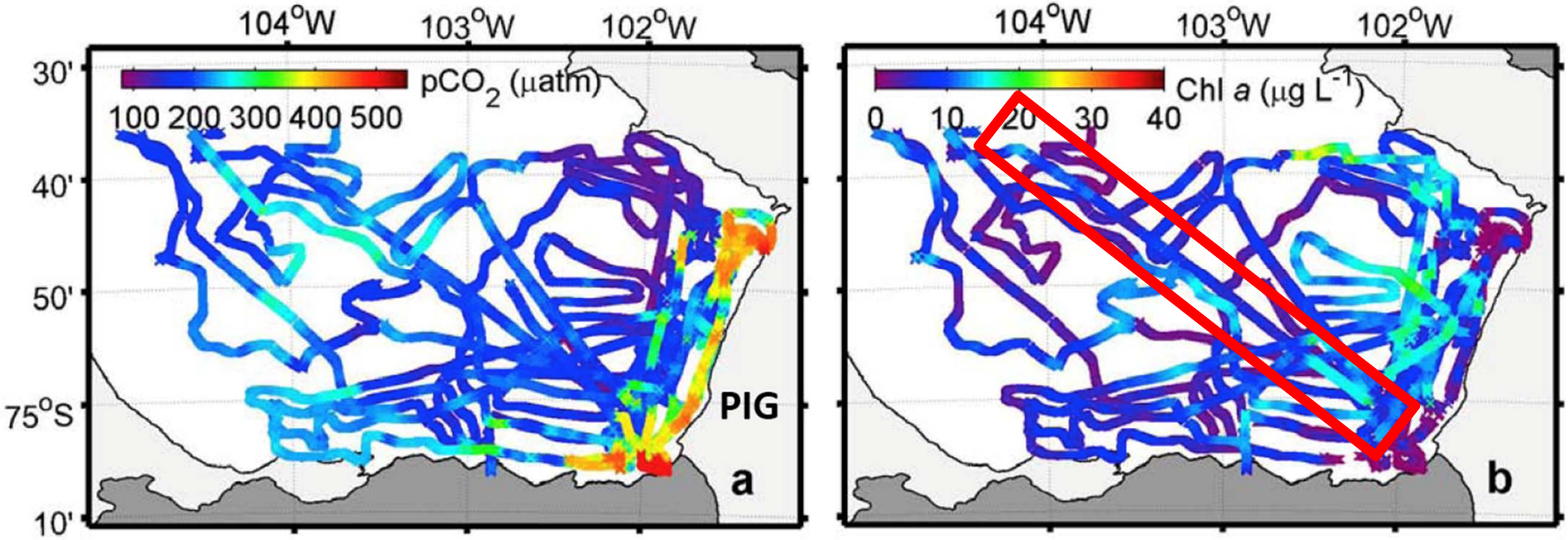


Amundsen Sea – Pine Island Polynya



Tortell et al. (2012)

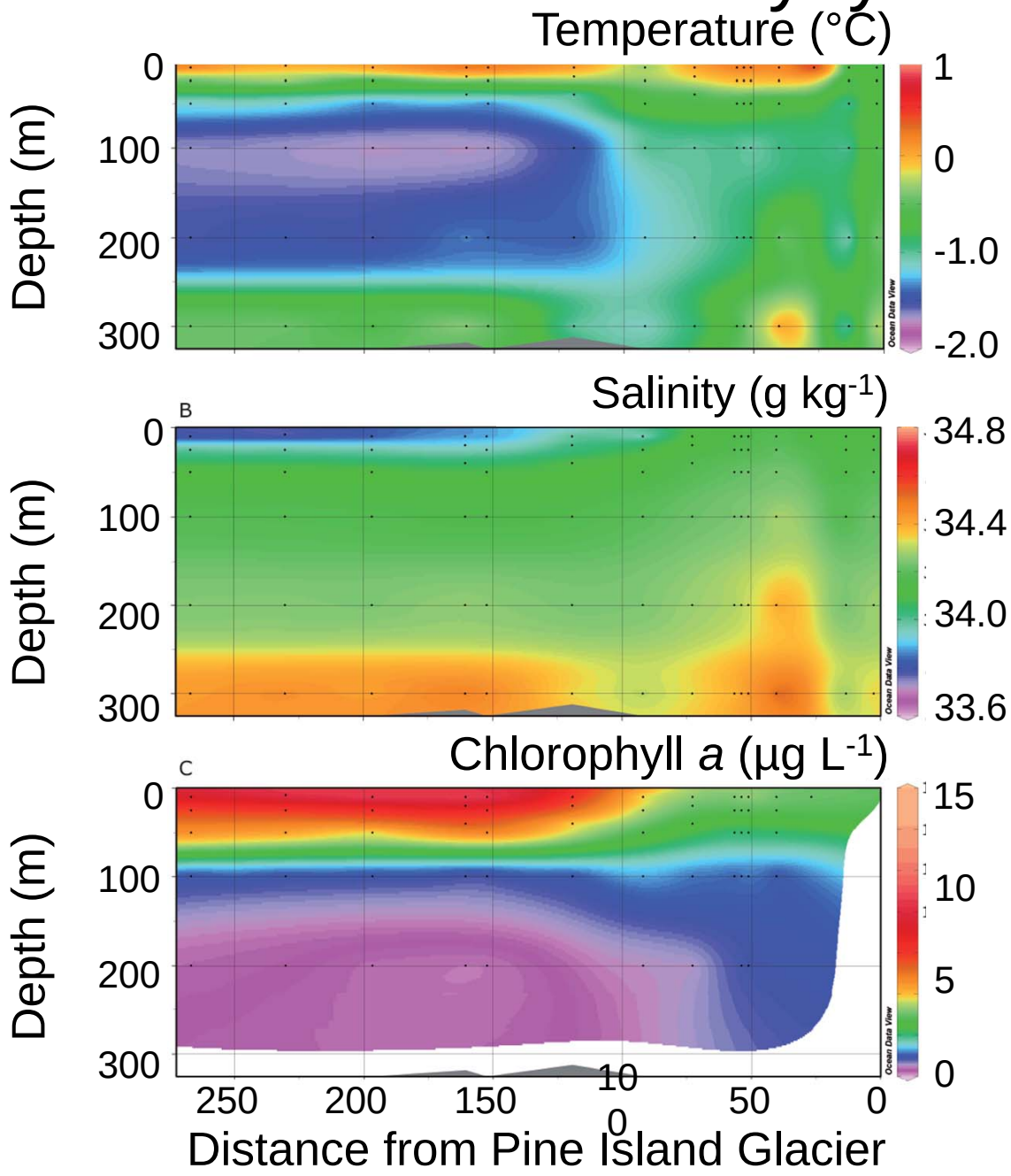
Amundsen Sea – Pine Island Polynya



Tortell et al. (2012)

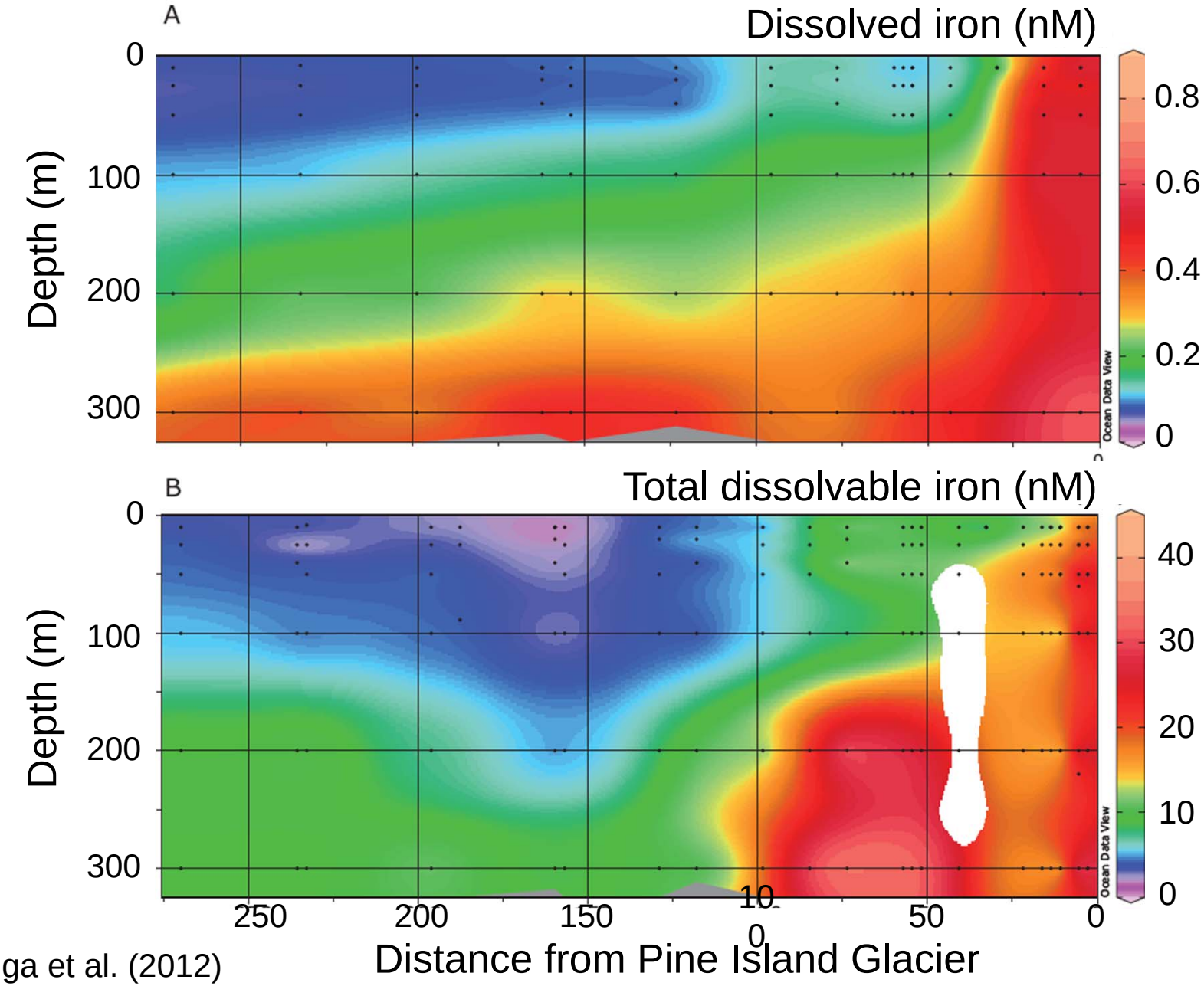
Amundsen Sea – Pine Island Polynya

Water upwells at front of polynya



Gerringa et al. (2012)

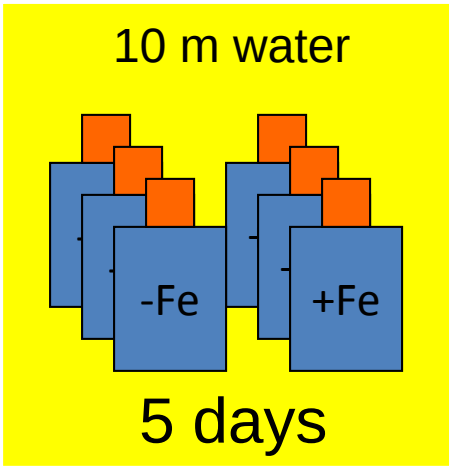
Amundsen Sea – Pine Island Polynya

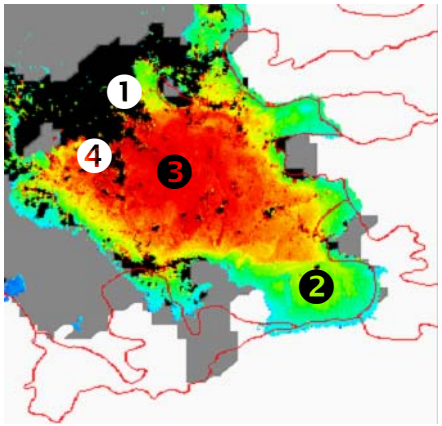


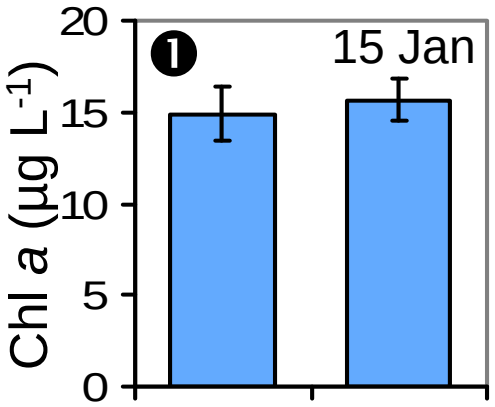
Gerringa et al. (2012)

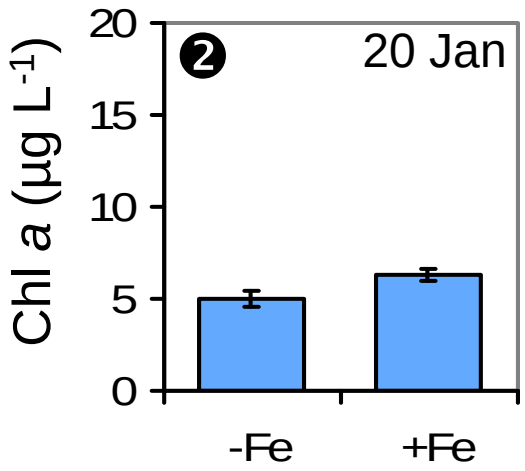
Amundsen Sea – Pine Island Polynya

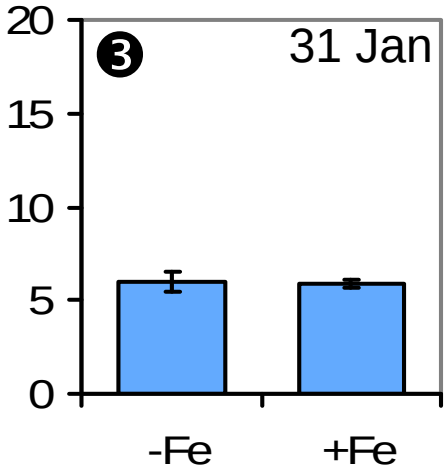
Fe addition bioassay experiments

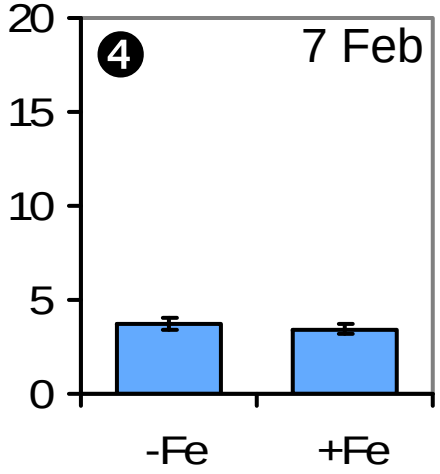








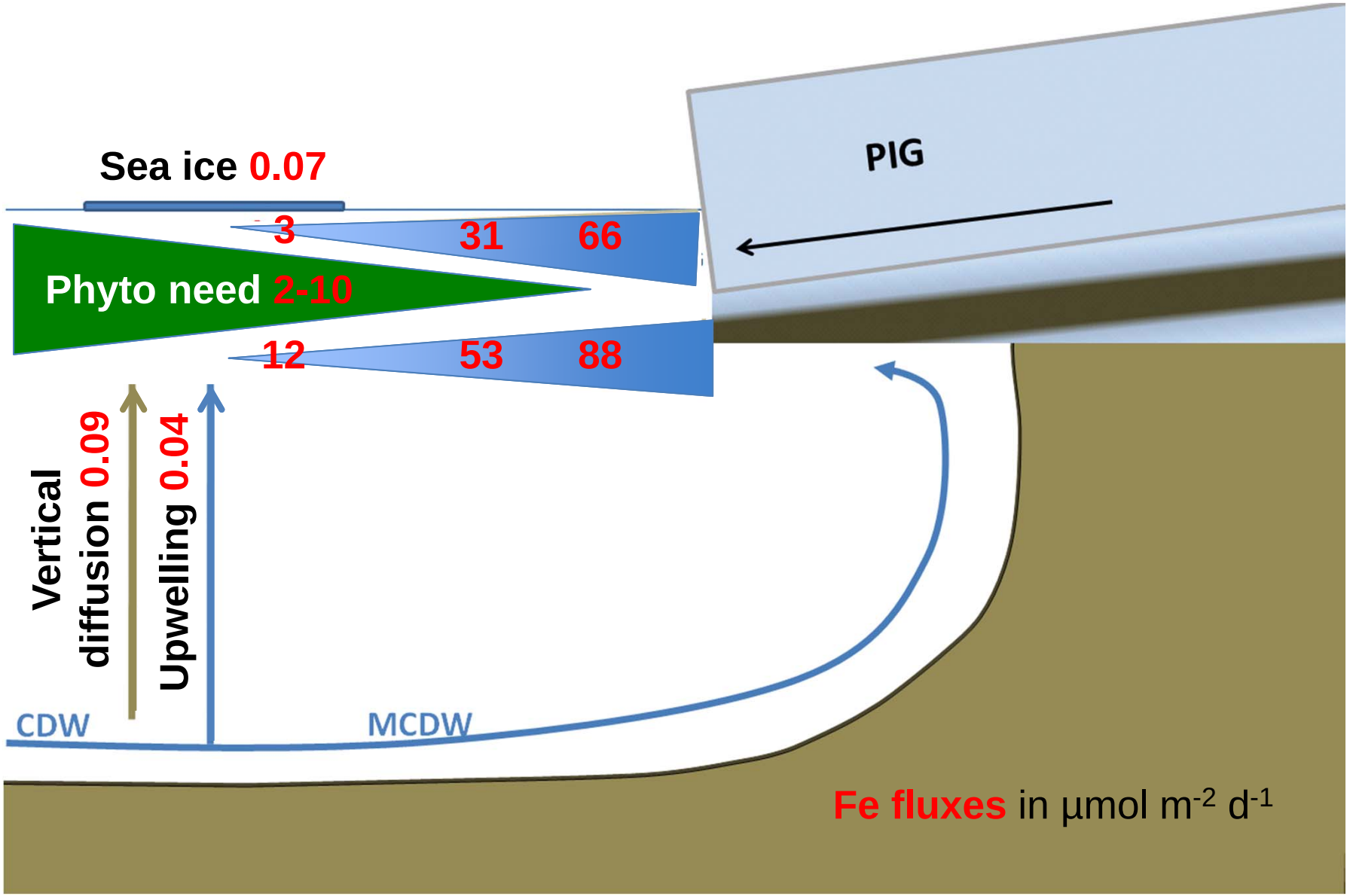




Mills et al. (2012)

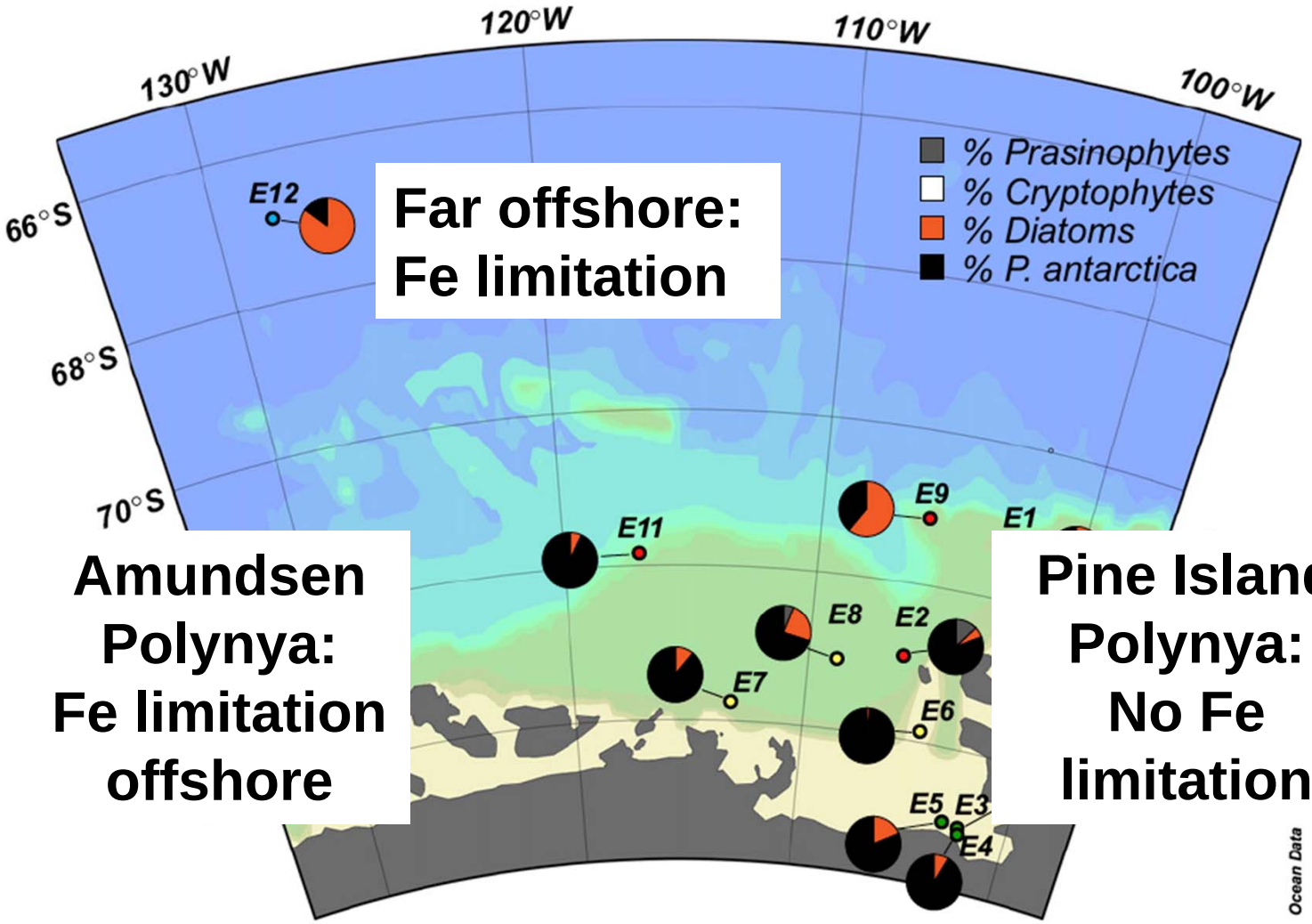
Phytoplankton in Pine Island Polynya are never Fe limited

Amundsen Sea – Pine Island Polynya



Gerringa et al. (2012)

Amundsen Sea



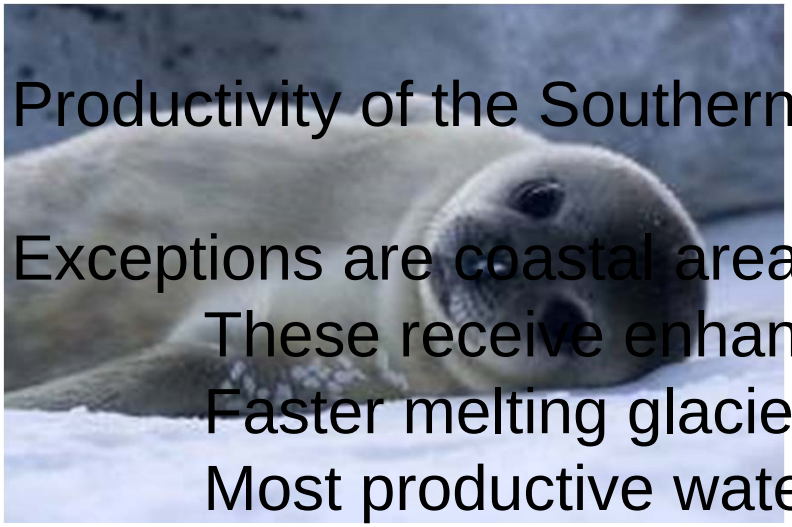
Far offshore: Fe limitation

Amundsen Polynya: Fe limitation offshore

Pine Island Polynya: No Fe limitation

Ross Sea shelf: Fe limitation

Conclusions



Productivity of the Southern Ocean is limited by Fe availability

Exceptions are coastal areas, especially near melting glaciers
- These receive enhanced Fe fluxes
- Faster melting glaciers = more Fe released into water
- Most productive waters in Southern Ocean

Increasing glacial melt should:
- Enhance Fe input into Antarctic shelf waters
- Increase primary production in Fe-limited shelf regions
  - (e.g., part of Amundsen Sea, all of Ross Sea)
- Increase biological pump
- Provide more food for marine ecosystems

THANK YOU

Gert van Dijken
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Casey Smith
Anne-Carlijn Alderkamp
Matt Mills
Tish Yager (ASPIRE)
Hein de Baar
Loes Gerringa
Philippe Tortell

Ocean Biology and Biogeochemistry

Cryosphere Science Program