Net and gross production in the Southern Ocean mixed layer

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Many shipboard scientists collecting samples

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Determining net community production in the mixed layer

Photosynthesis

$CO_2 + H_2O \text{ --> } CH_2O + O_2$

Respiration

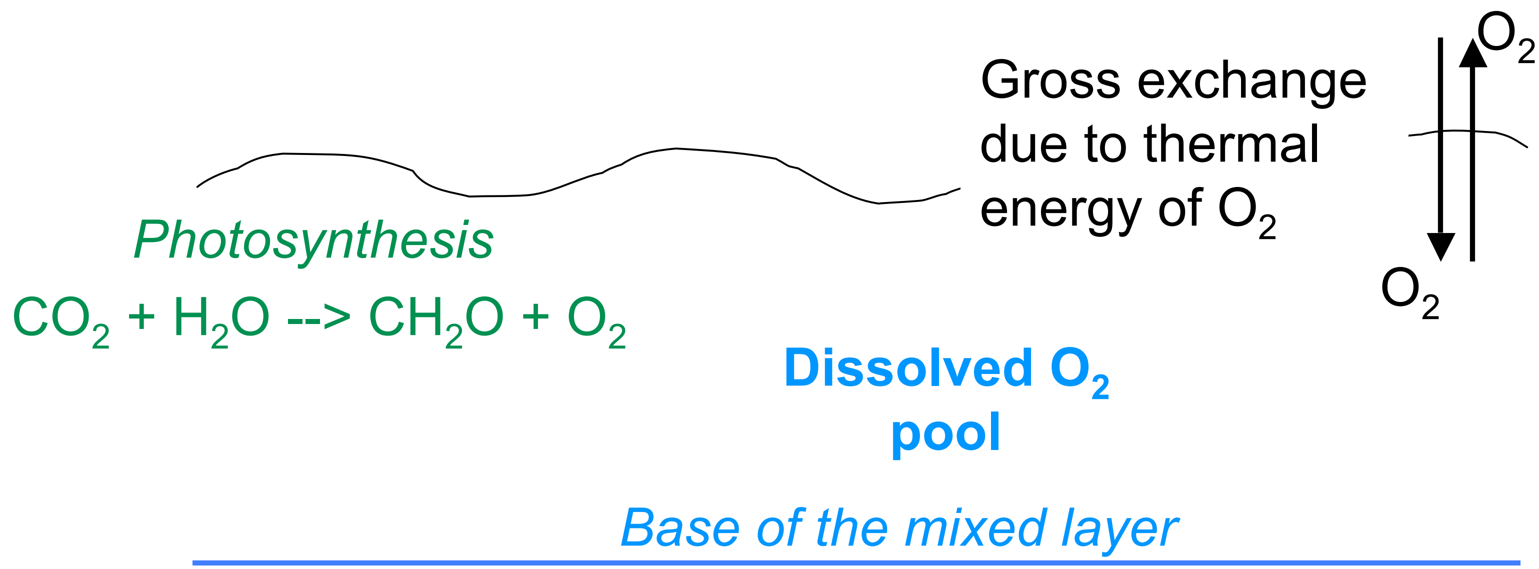
$CH_2O + O_2 \text{ --> } CO_2 + H_2O$

P - R = O_2 NCP = O_2 efflux to atmosphere = ($[O_2] - [O_2]_{sat}$) * gas exch. coeff.

Base of the mixed layer

- $[O_2] > [O_2]_{sat}$, lost to atmosphere
  - O_2 efflux = ($[O_2] - [O_2]_{sat}$) * gas exchange coefficient
- Net community O_2 production = flux to atmosphere
- Complication: $[O_2] > [O_2]_{sat}$ because of warming and bubble entrainment
- Measure Ar as inert analog to O_2 to correct for physical supersaturation (Jenkins, Quay, Emerson, Luz…)

Determining gross photosynthesis in the mixed layer



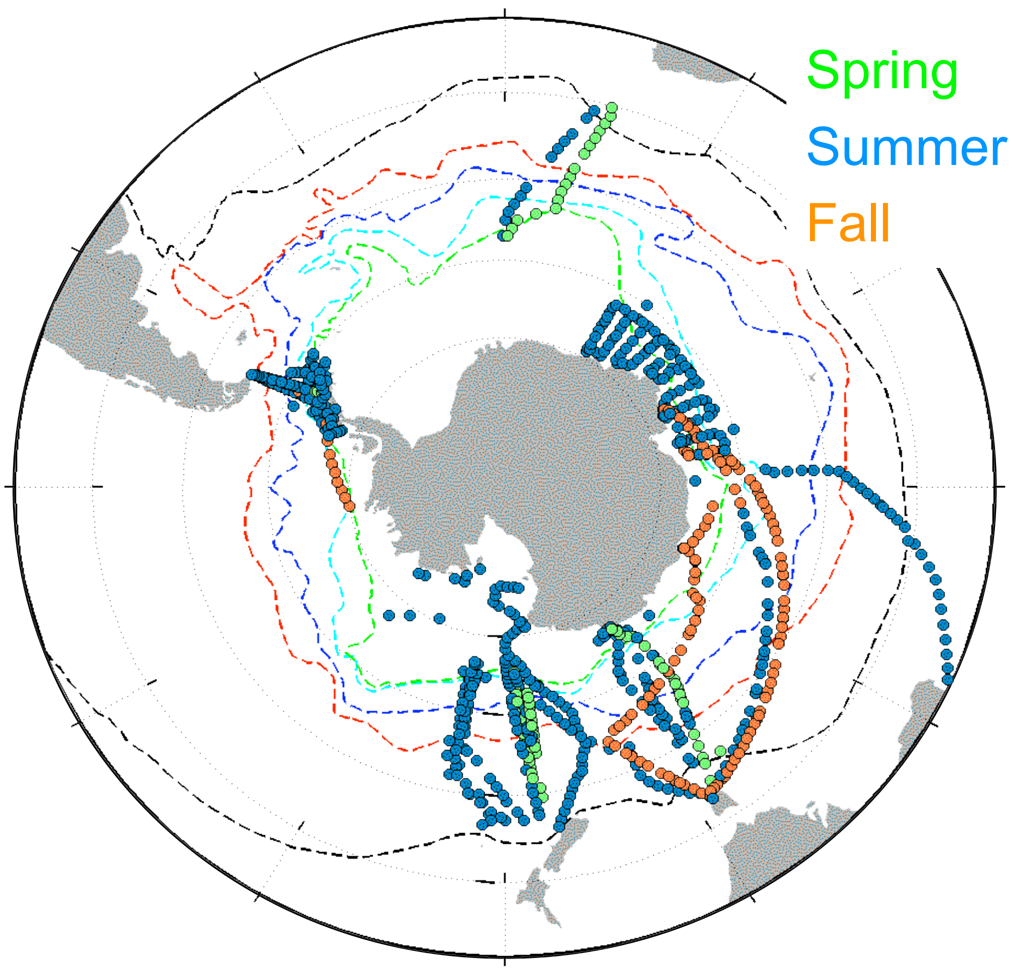
Determining the fraction of photosynthetic O_2 from $^{17}\Delta$ (Luz and Barkan)

- 2 sources of O_2 to surface water:
  - Gross photosynthesis and gas exchange
- Determine fraction of photosynthetic O_2 from $^{17}\Delta$ *of dissolved* O_2
  - $^{17}\Delta$ *of dissolved* O_2 *from air = 0*
  - $^{17}\Delta$ *of dissolved* O_2 *from photosynthesis = + 0.25 ‰*
- Measure $^{17}\Delta$ of dissolved O_2; calculate fraction and conc. from photosyn.
- Apply gas exchange coefficient to calculate GPP

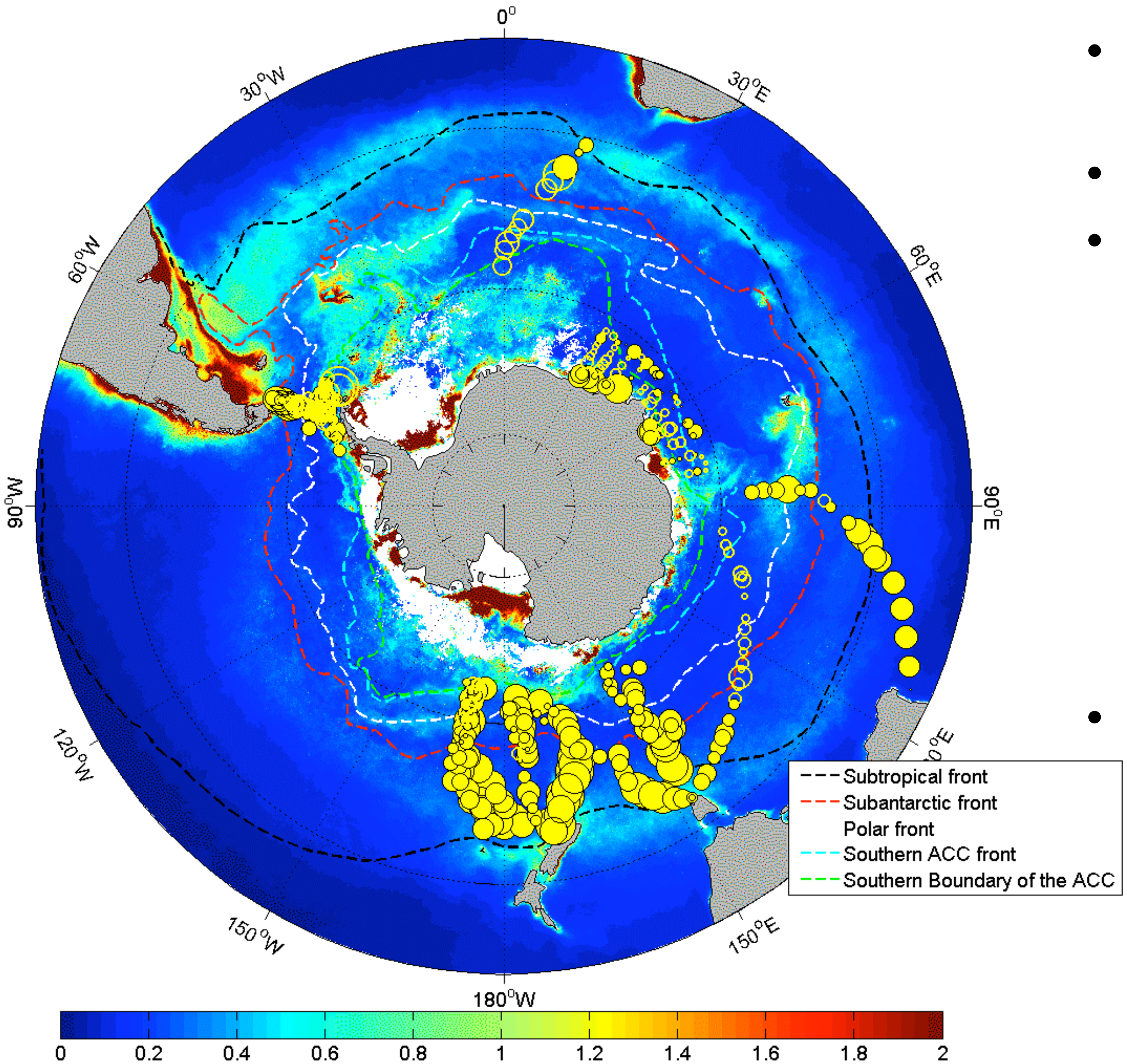
What is $^{17}\Delta$ of O_2?

- $^{17}\Delta$ of $O_2 \approx \delta^{17}O - 0.5\ \delta^{18}O$
- Normally ^{17}O is fractionated 0.5 x ^{18}O and $^{17}\Delta$ is the same for "everything"
- O_2 is an exception (work of Thiemens, Boering, Luz and Barkan)
  - Isotope exchange reaction between O_2 and CO_2 in stratosphere
  - ^{17}O is fractionated 1.7 x ^{18}O
- Consequence:
  - $^{17}\Delta$ of O_2 is different from $^{17}\Delta$ of H_2O (and photosynthetic O_2)

Southern Ocean studies of net and gross production: sampling sites as of fall, 2006 (25 crossings)

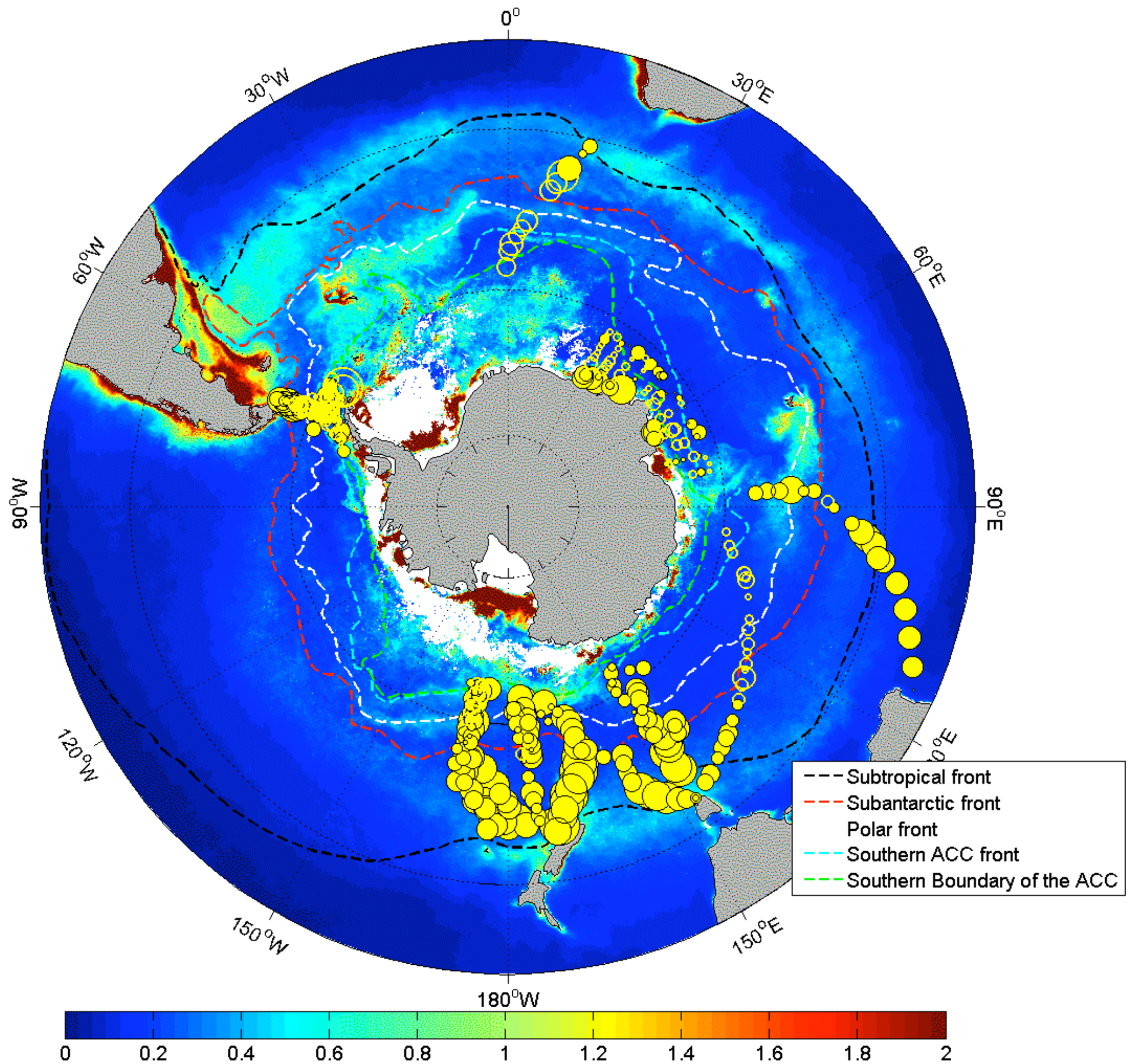


Distribution of summertime net community production



- Colors: Southern Ocean summertime chl
- Lines: frontal positions
- Filled circles: O_2 flux to atmosphere
  - NCP>0
  - Calculate magnitude assuming steady state NCP, observed winds, constant MLD, no mixing from below
- Open circles: O_2 flux into oceans
  - Ventilation or net heterotrophy?

Distribution of net community production in summer

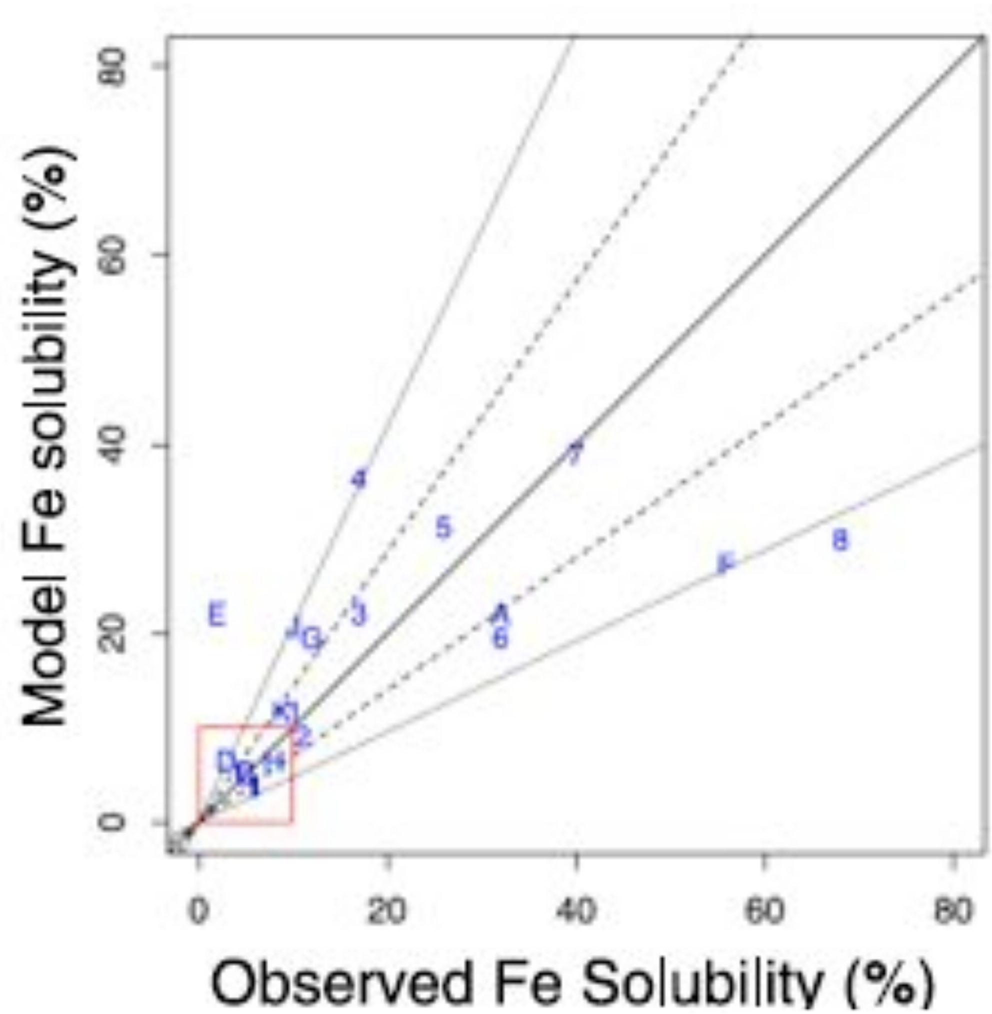


- General pattern of NCP decreasing to the south, then rising again near the coast
- High NCP coincides with high chl around STF and close to Antarctic coast
- Origin of southward decrease in open ocean:
  - Not SiO_2
  - Not ss PAR or MLD
  - Grazing?
  - Not upwelling iron
- Possibly aerosol iron input

Fan et al. (2006) model for input of soluble iron by aerosols

- Dust entrained in dry continental areas
- Fe progressively solubilized as dust is attacked by H_2SO_4 and HNO_3^-
- Dust settles out by gravity
- Soluble Fe ranges from about 5-35 % of total
- Soluble Fe distribution delivery is very different from constant solubility model
  - Less delivery near sources
  - More delivery in farfield
- Surely uncertainties are large

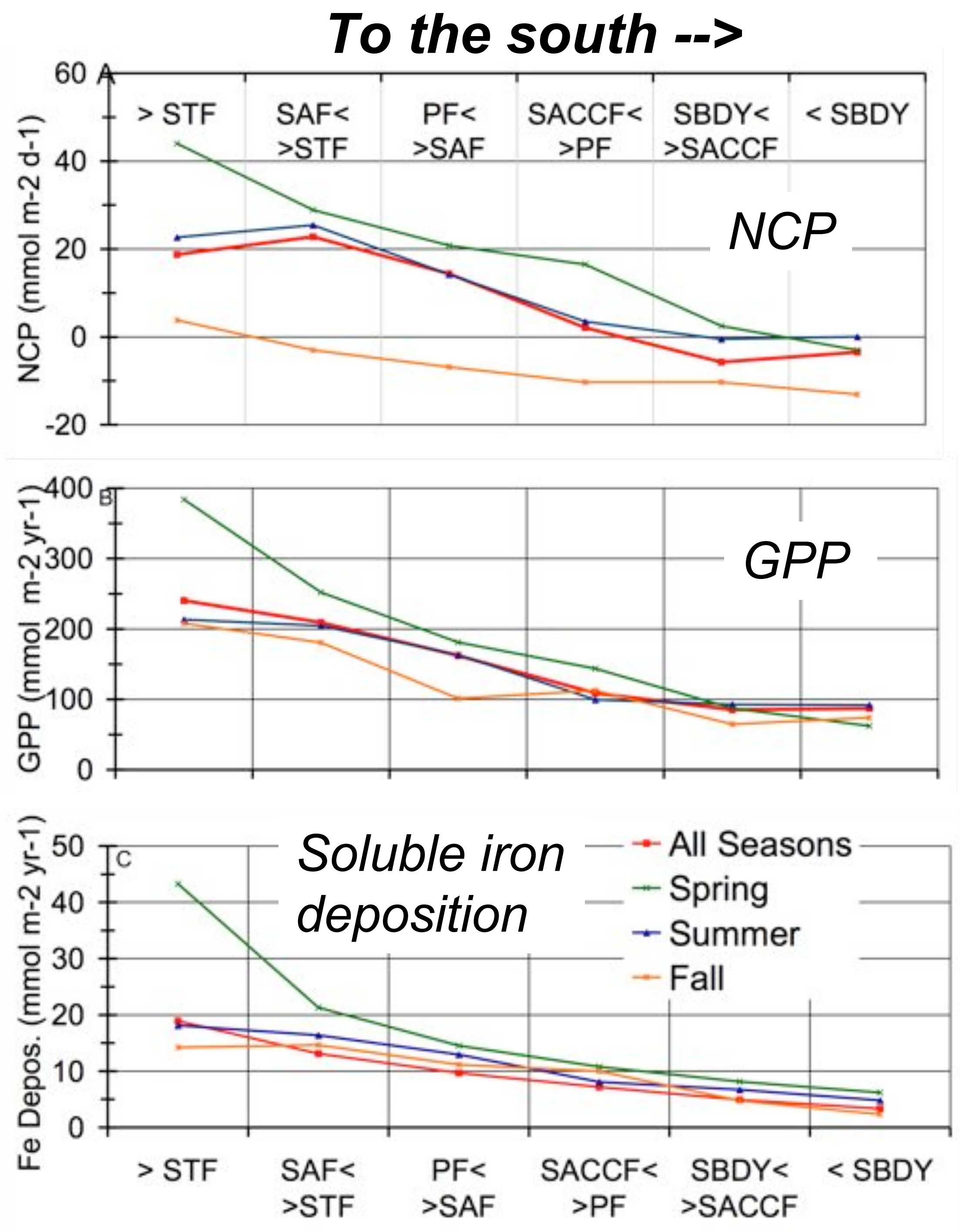
Model-data comparison



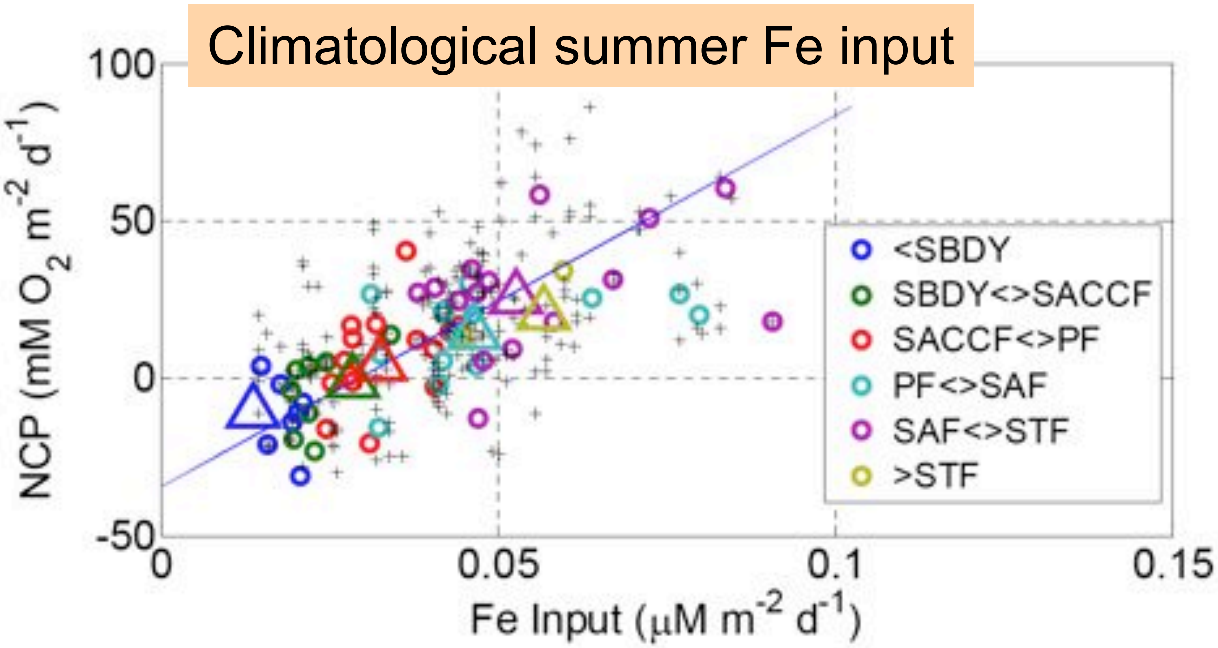
NCP and GPP vs. latitude and season

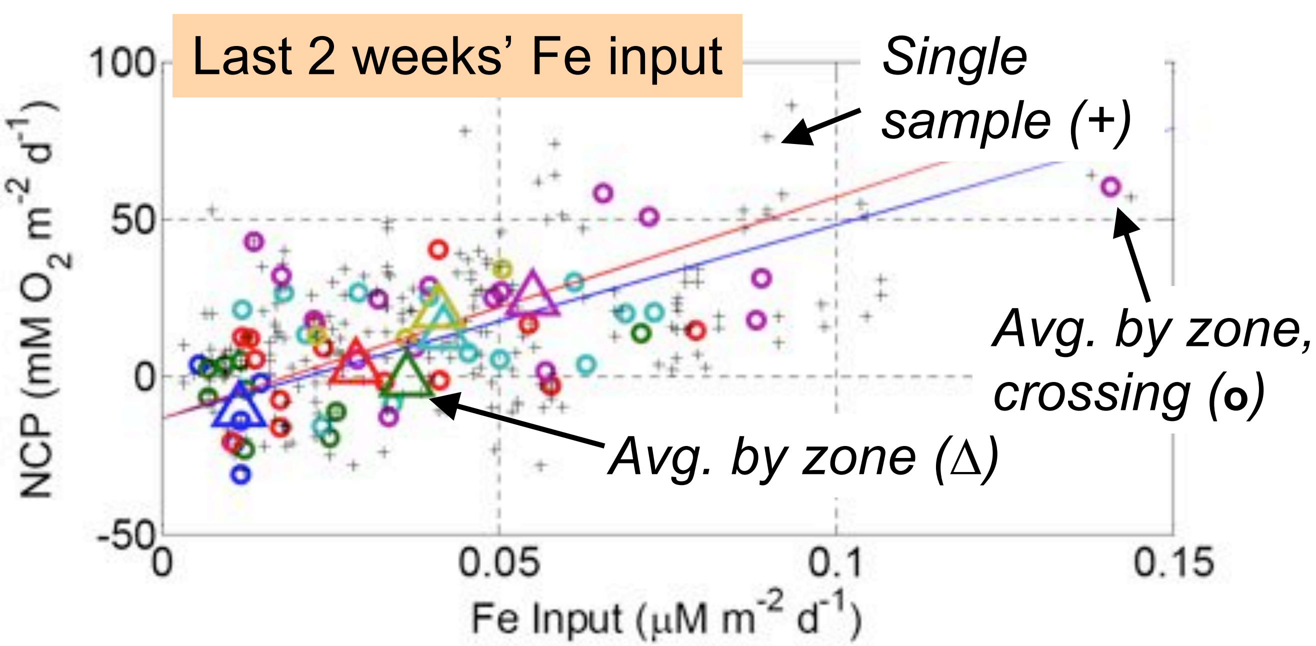
NCP, GPP and iron deposition all are highest in the north, decrease to the south

NCP, GPP, and iron deposition all are highest in spring, lower in summer, lowest in fall



NCP vs. aerosol deposition of soluble iron

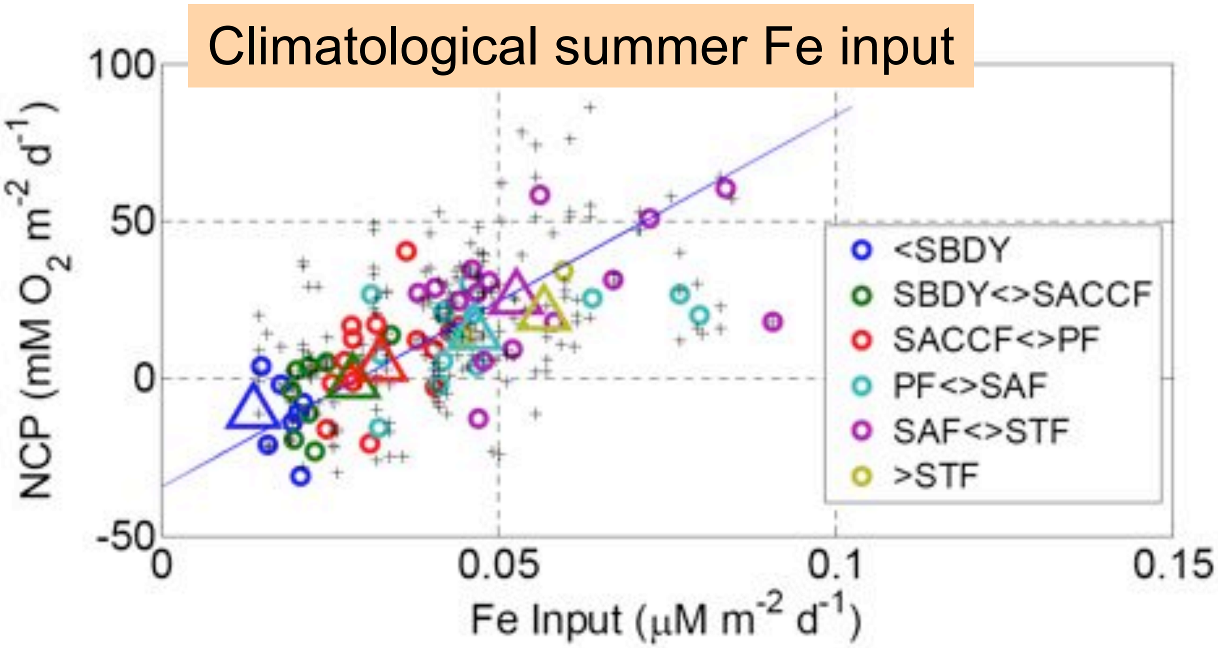


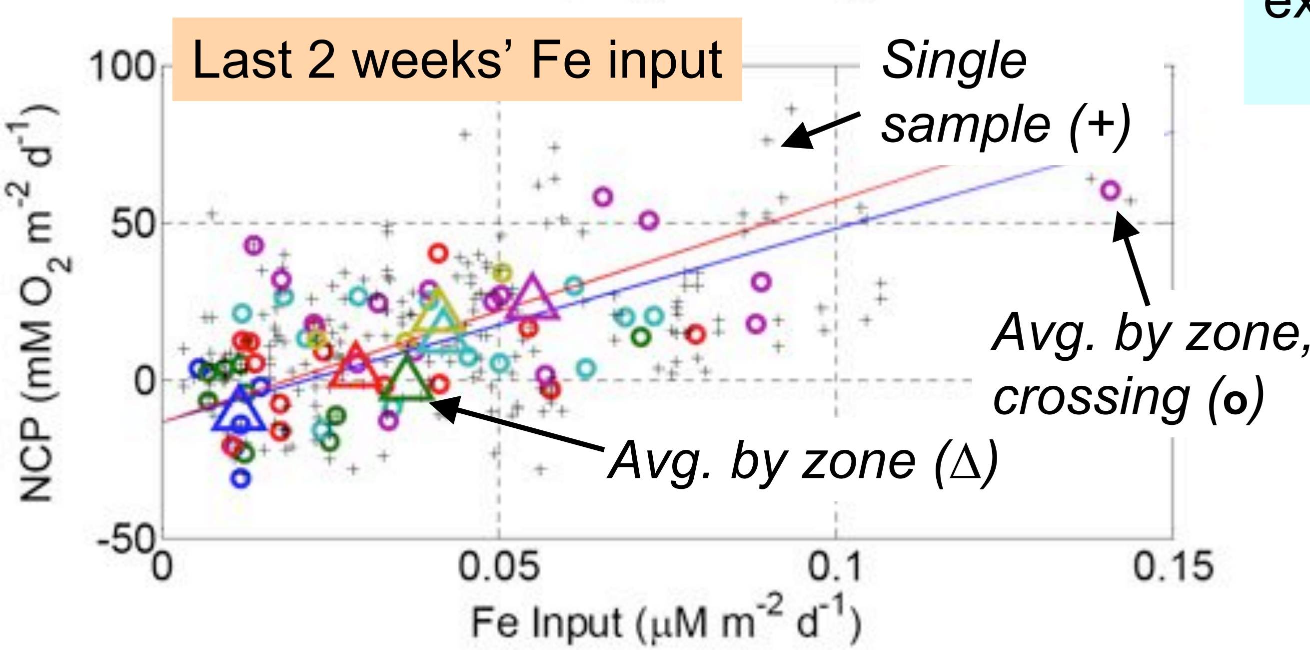


NCP increases with soluble iron deposition

Scatter decreases with averaging

NCP vs. aerosol deposition of soluble iron





NCP increases with soluble iron deposition

Why so much scatter?

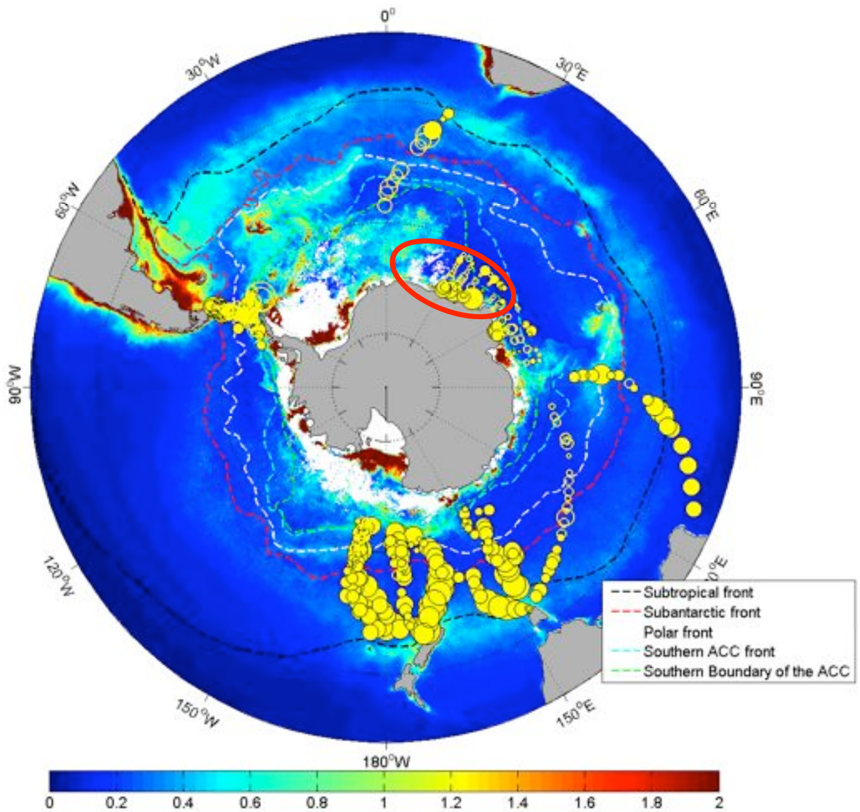
Variations in light, SiO_2, grazing, other influences

Analytical errors and uncertainty in gas exch. coeff.

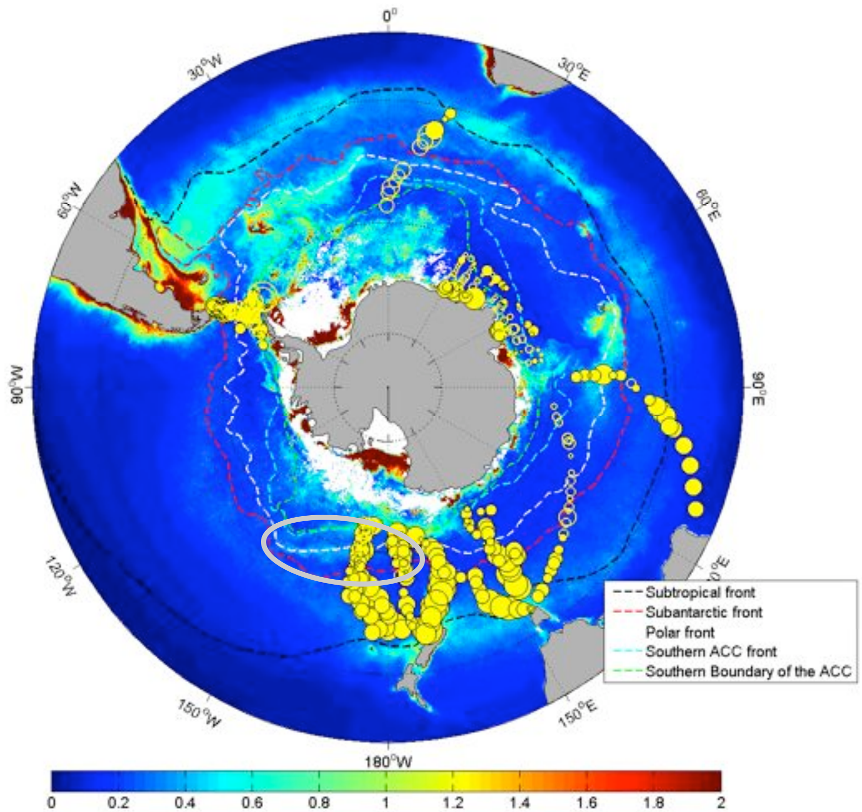
Other sources of iron

Links between chlorophyll, productivity, and enhanced iron sources in the Southern Ocean: *Contributions of many authors*

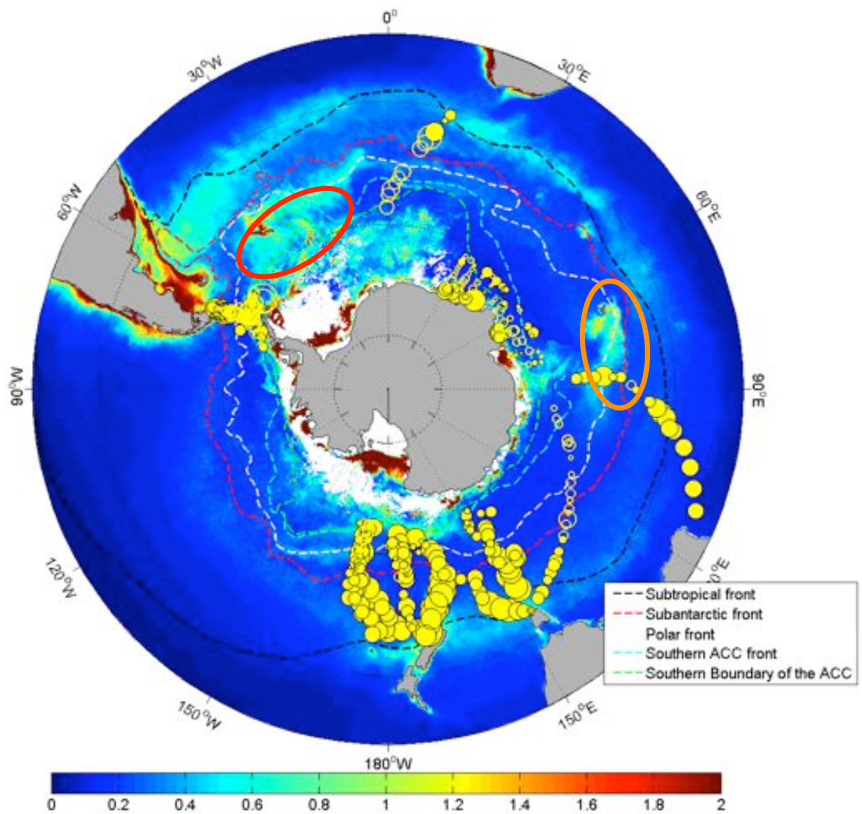
Chlorophyll, productivity, and iron sources: shallow sediments (coastal areas around Antarctica)

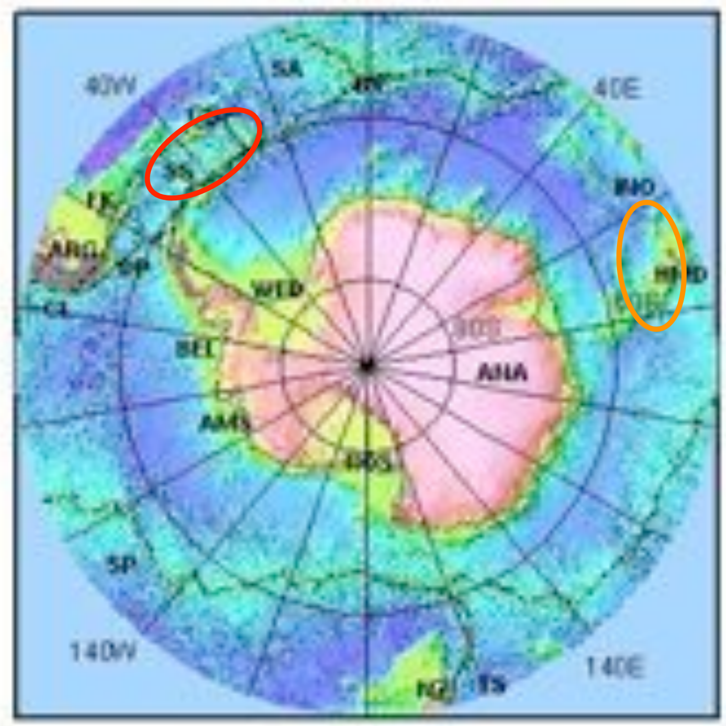


Chlorophyll, productivity, and iron sources: deep water upwelling (Polar Front)

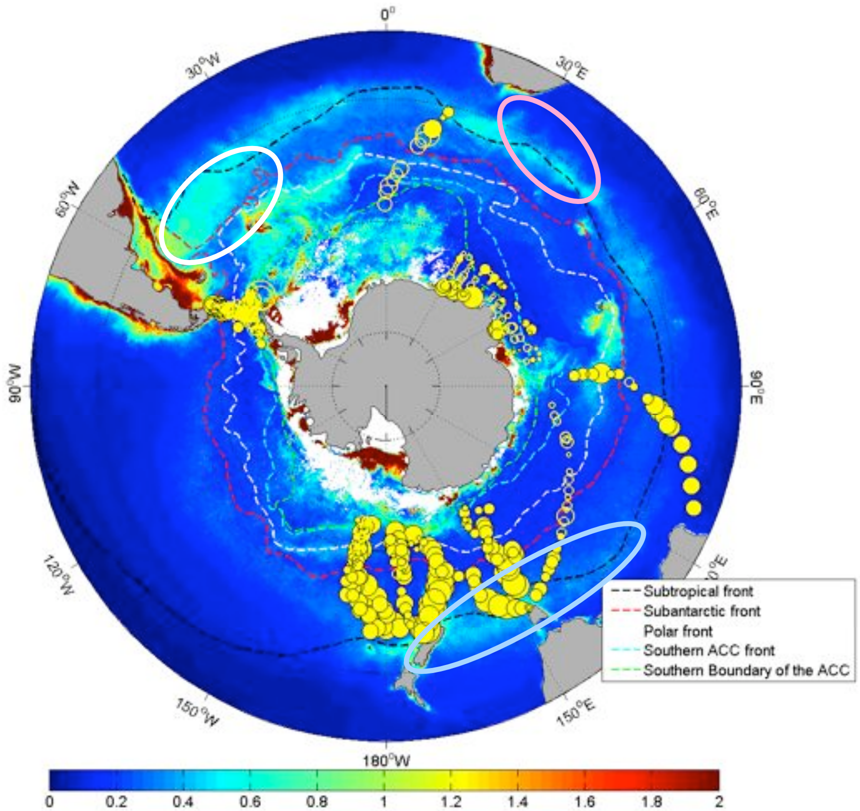


Chlorophyll, productivity, and iron sources: deep mixing induced by topography (Scotia Sea, Kerguelen Plateau)

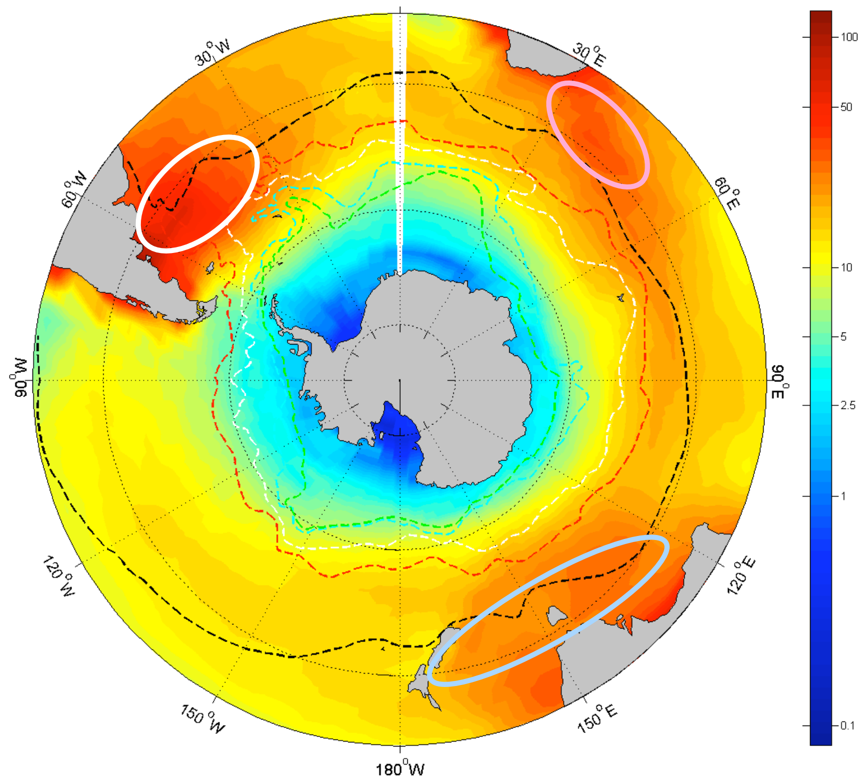




Chlorophyll, productivity, and iron sources: aerosols

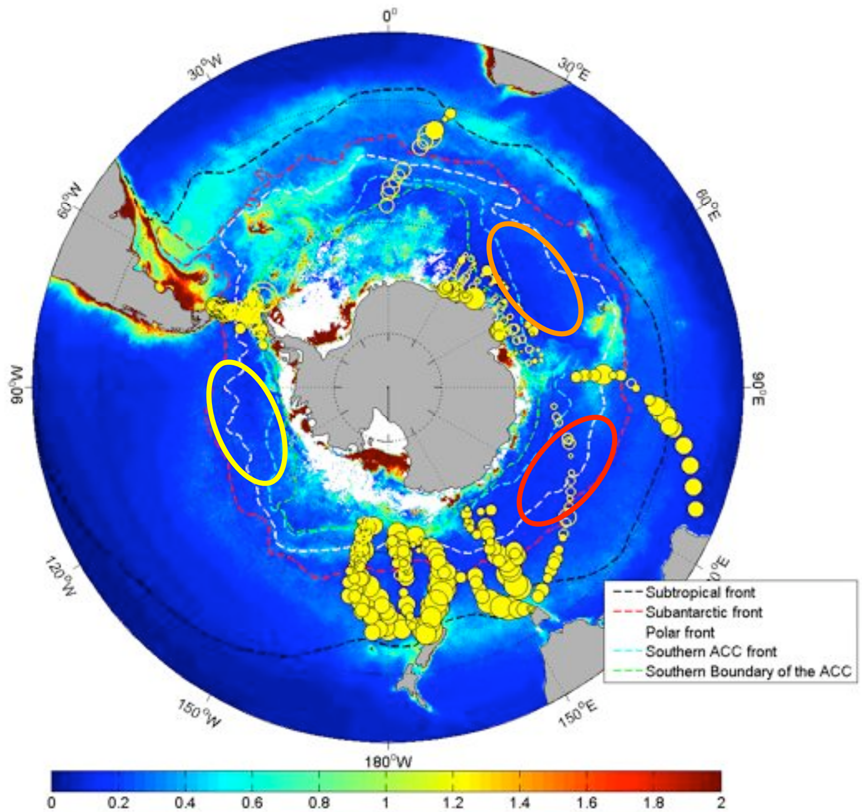


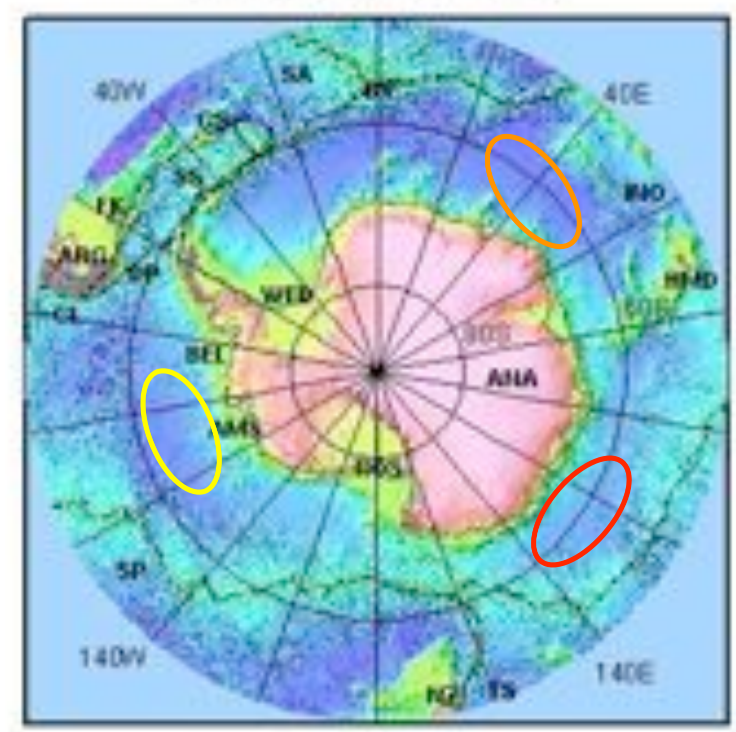
Summer climatology of
dissolved iron supply



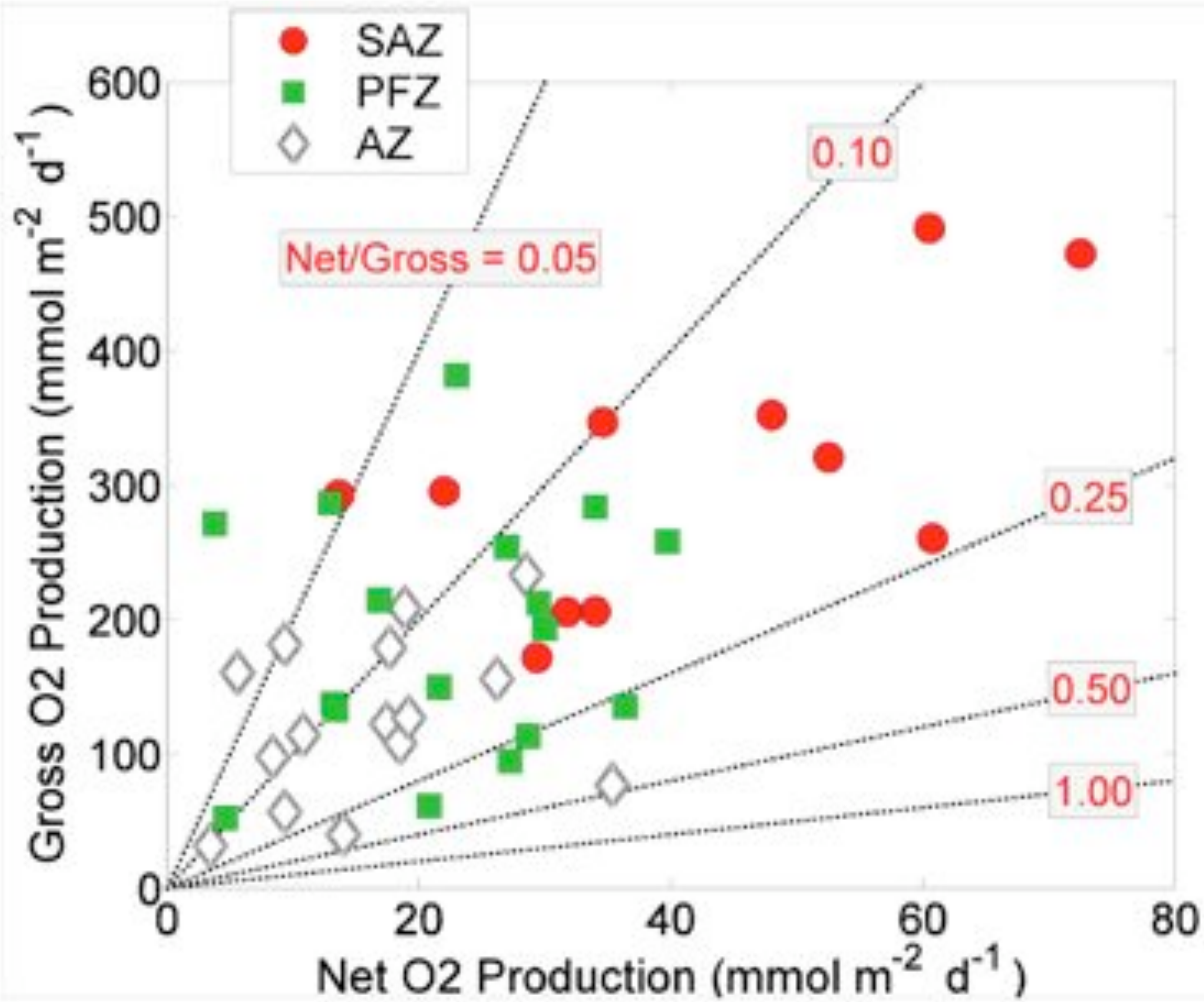
Modeled Iron Deposition
(modified from Fan et al. 2006)

Low chlorophyll, productivity, and iron sources: southern deep waters overlying abyssal plains





Can we scale NCP in the Southern Ocean?



- O_2 GPP / O_2 NCP ~ 0.15 in the AZ, PFZ, and SAZ
- ==> f ratio of about 0.3
  - New/ total N uptake
  - 6.6 New N/^{14}C
- If net/gross ~ constant, we can scale local results with ^{14}C production from ocean color

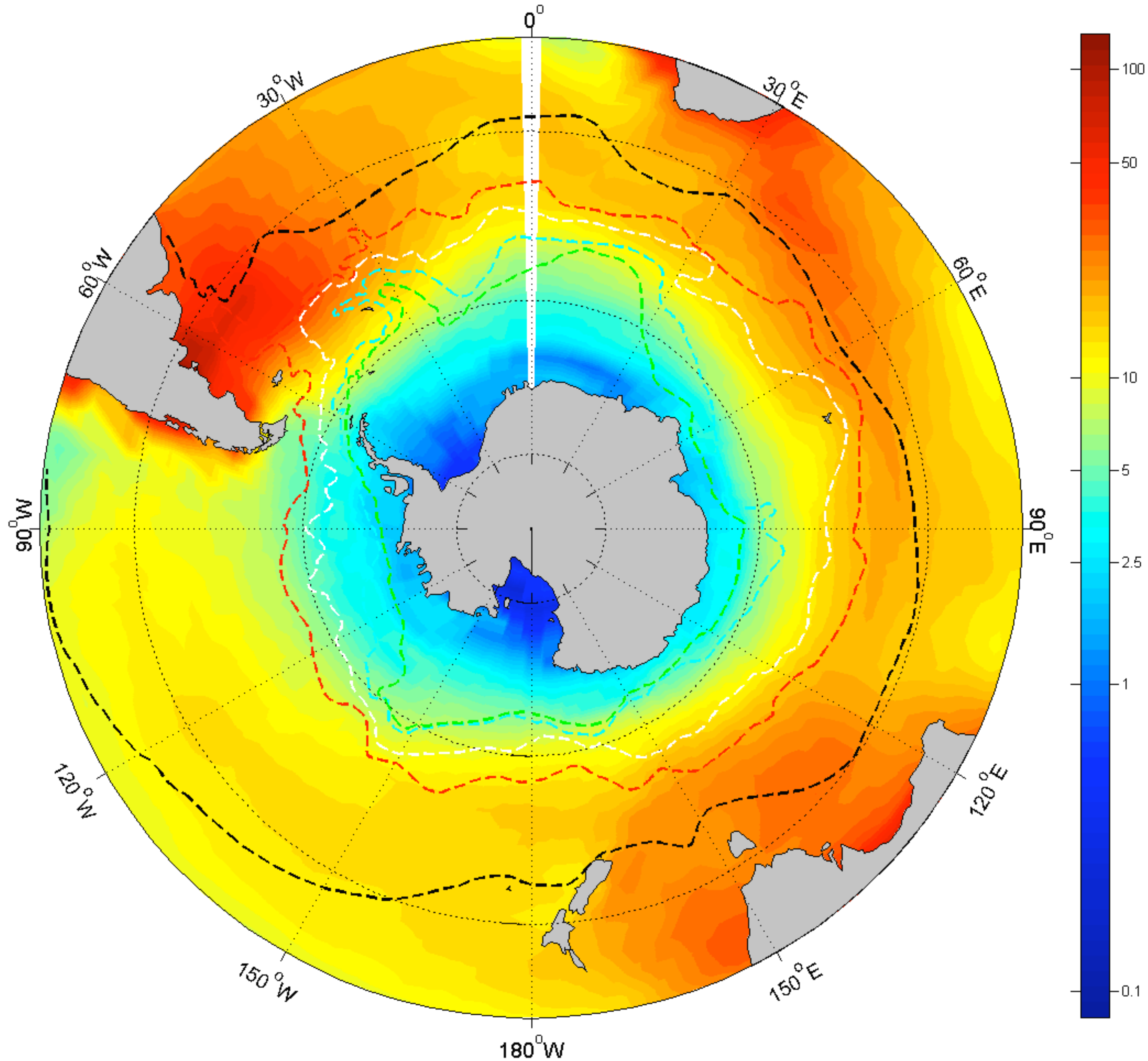
Conclusions

- NCP (and GPP) characterized over a wide reach of the Southern Ocean
- We hope that these data will be used for validating models

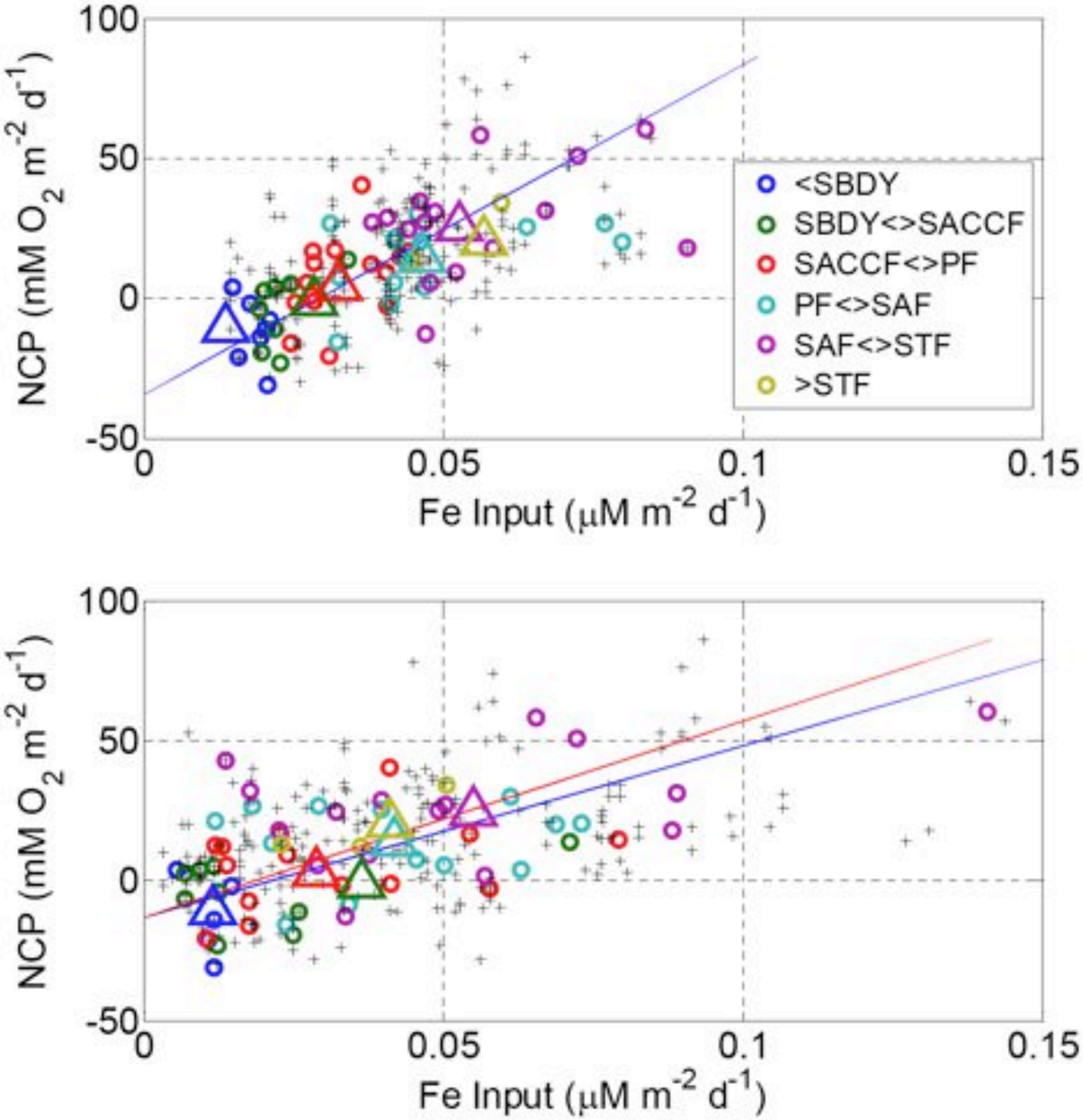
- Productivity is highest in the northern reaches
- NCP increases with recent or climatological Fe input
- Various sources of Fe input can explain variations in Southern Ocean chlorophyll and productivity
- Scaling NCP values assuming constant NCP/productivity may be possible

Conclusions

- NCP (and GPP) characterized over a wide reach of the Southern Ocean
- These data can be used to test and validate algorithms and models
- Higher values linked to chl and ^{14}C productivity (VGPM)
- NCP increases with recent or climatological Fe input
- Various sources of Fe input can explain variations in Southern Ocean chlorophyll and productivity
- Scaling NCP values assuming constant NCP/productivity may be possible



Modeled Iron Deposition (modified from Fan et al. 2006)



100
50
0
-50
NCP (mM O2 m-2 d-1)
0
0.05
0.1
0.15
Fe Input (μM m-2 d-1)
<SBDY
SBDY<>SACCF
SACCF<>PF
PF<>SAF
SAF<>STF
>STF