Using Inverse Models to Estimate Biogeochemical Fluxes

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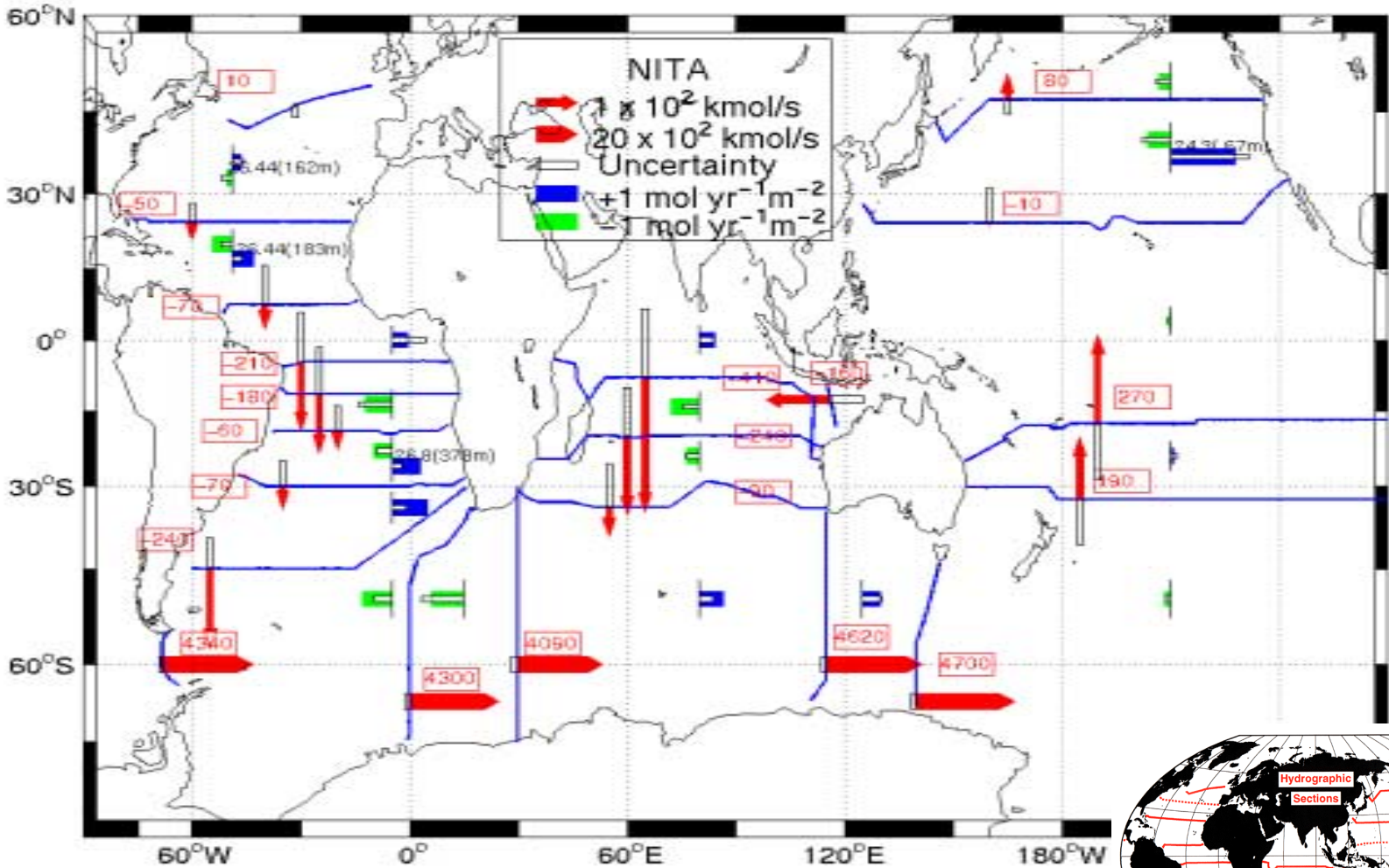
With input from:

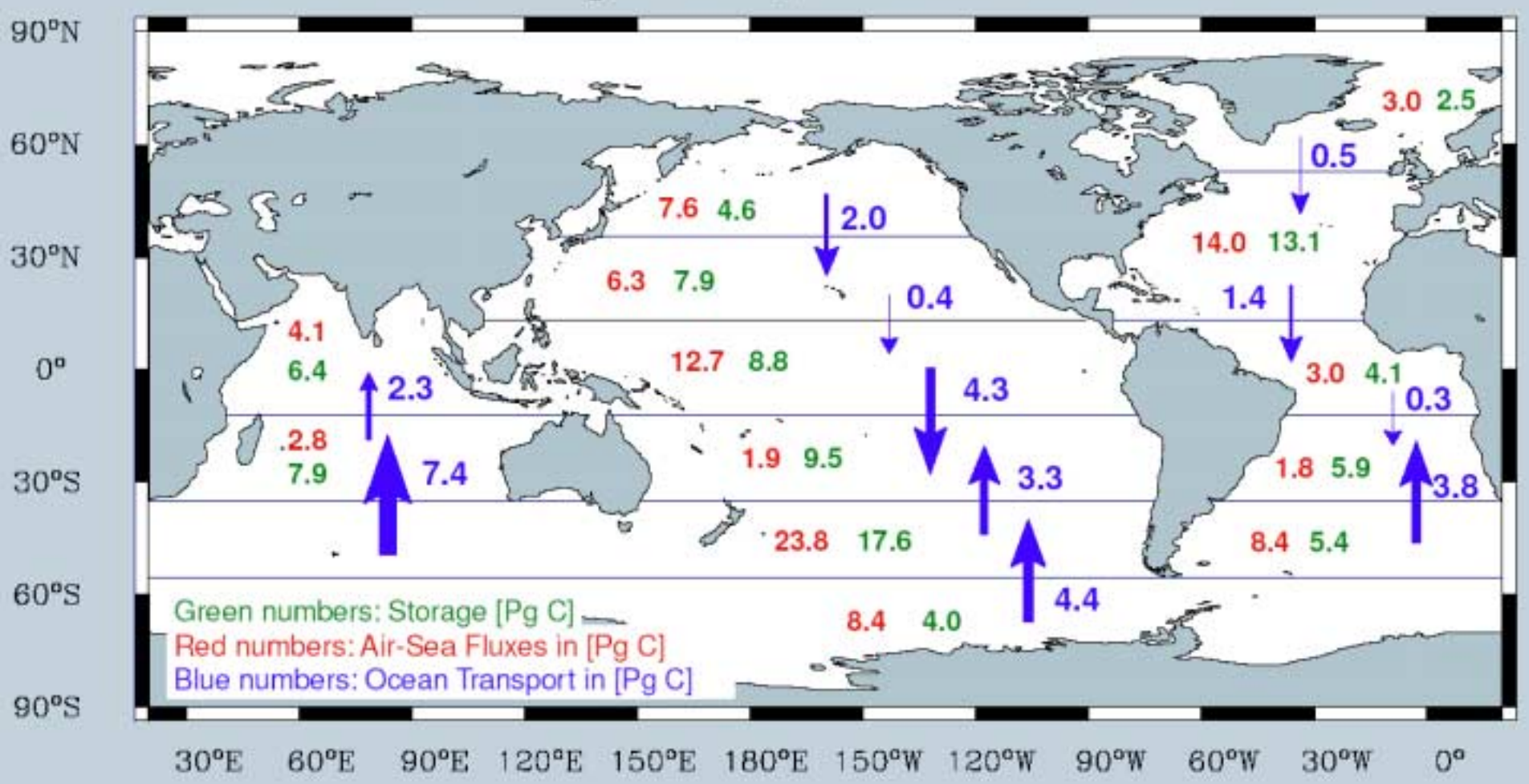
B. Anderson, M. Behrenfeld, J. Campbell, M.-E. Carr, A. Ganachaud, W. Geibert, N. Gruber, E. Tzipermann

Nitrate transports



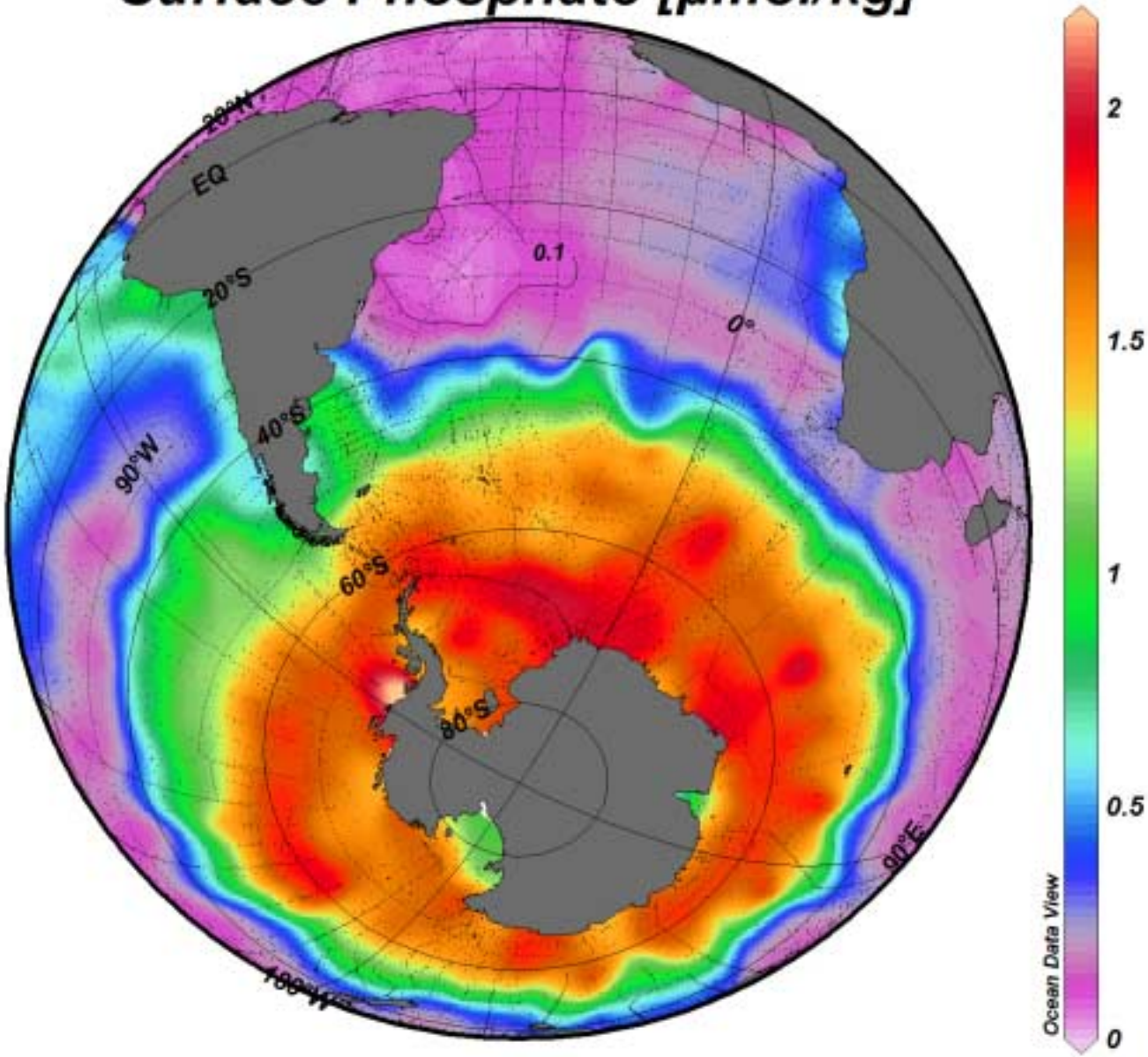
Ganachaud & Wunsch

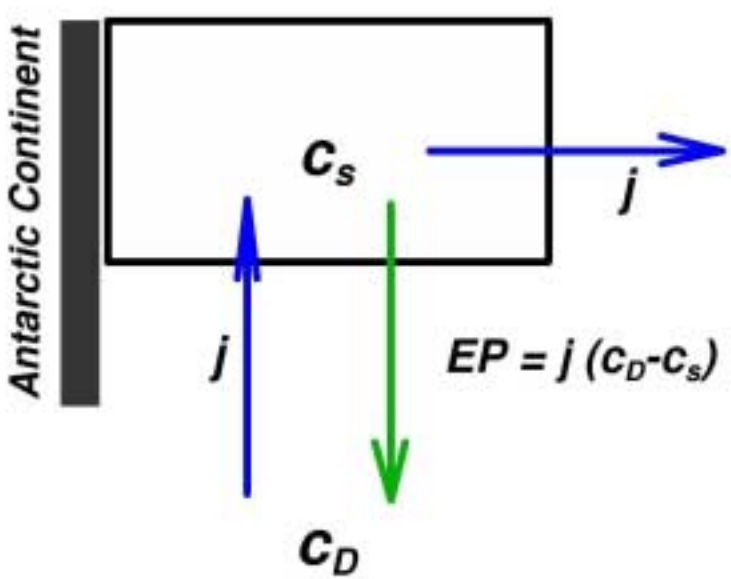
ANTHROPOGENIC CO_2 FLUXES, STORAGE AND TRANSPORT

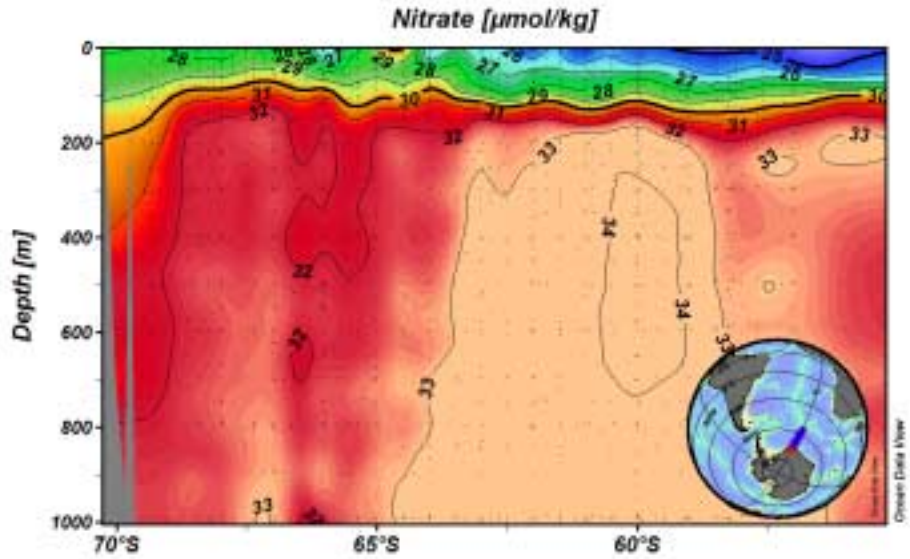


preliminary results: Gruber et al. [in prep.]

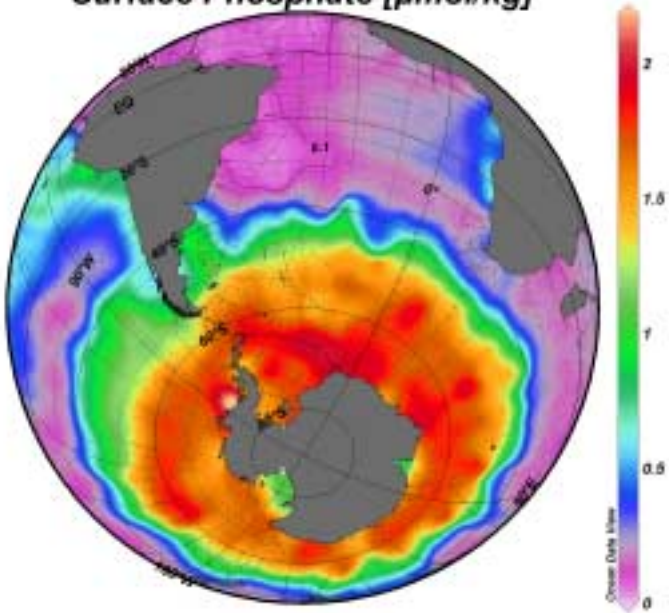
Surface Phosphate [µmol/kg]



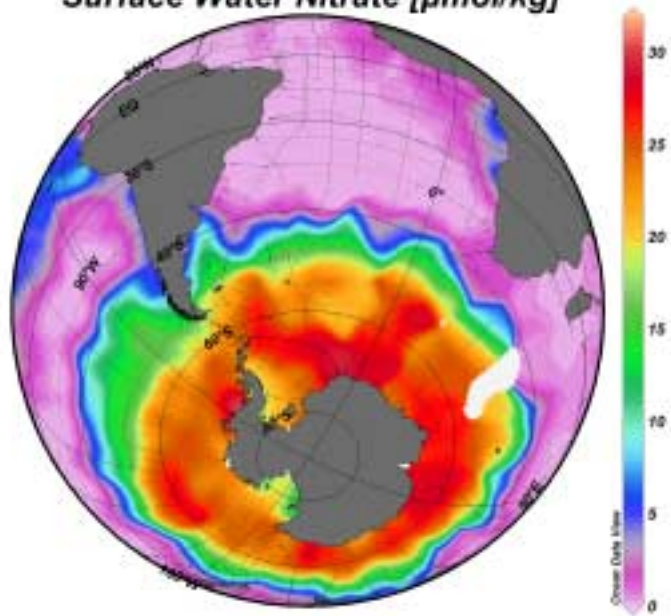

Antarctic Continent
c_s
j
j
$EP = j\,(c_D - c_s)$
c_D


Nitrate [µmol/kg]
Depth [m]
0
200
400
600
800
1000
70°S
65°S
60°S

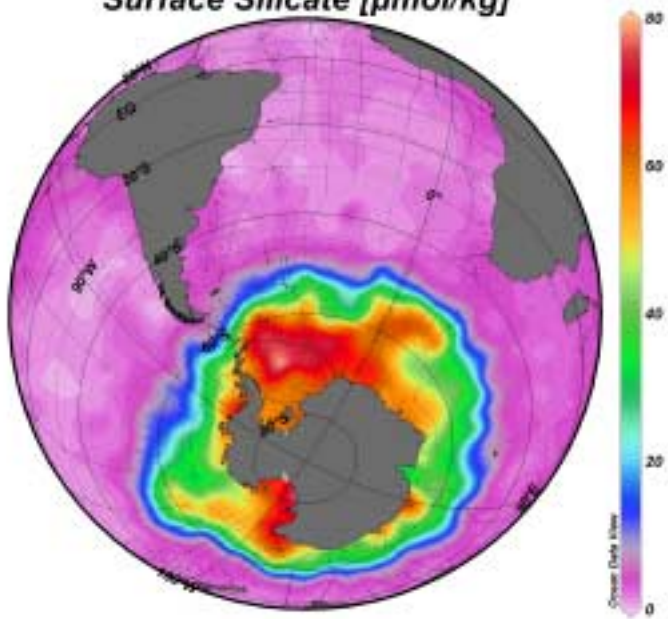
Surface Phosphate [µmol/kg]



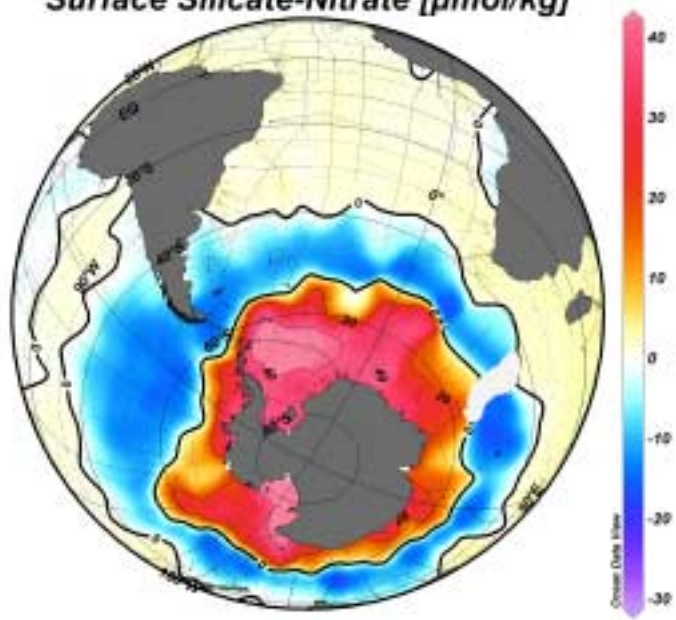
Surface Water Nitrate [µmol/kg]



Surface Silicate [µmol/kg]



Surface Silicate-Nitrate [µmol/kg]



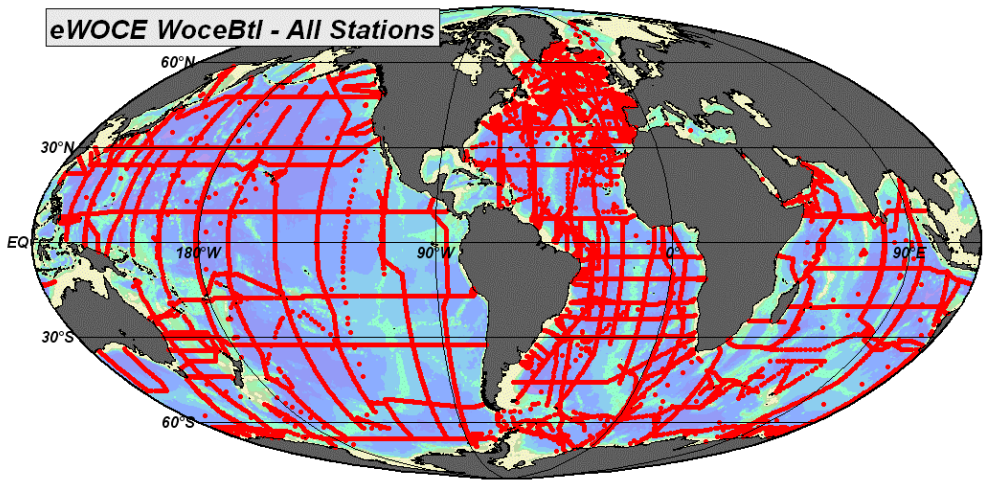
Objective:

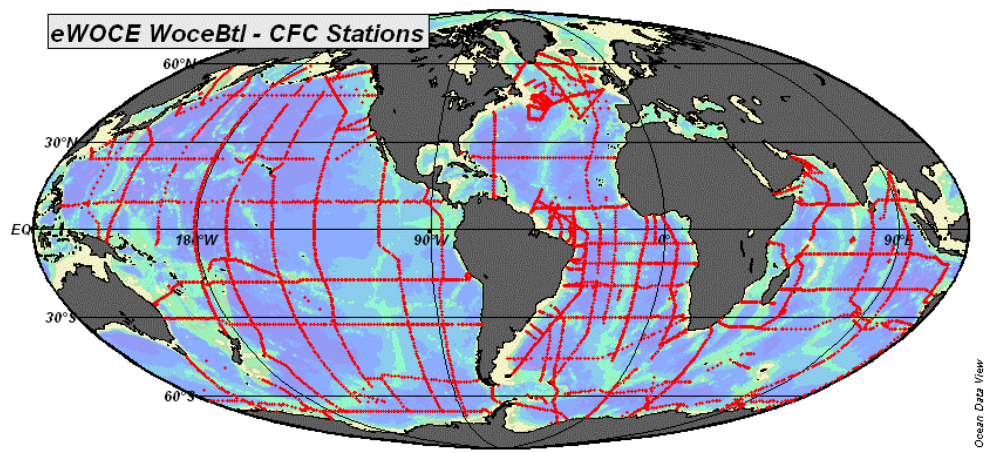
Use 3D global inverse model to determine ...

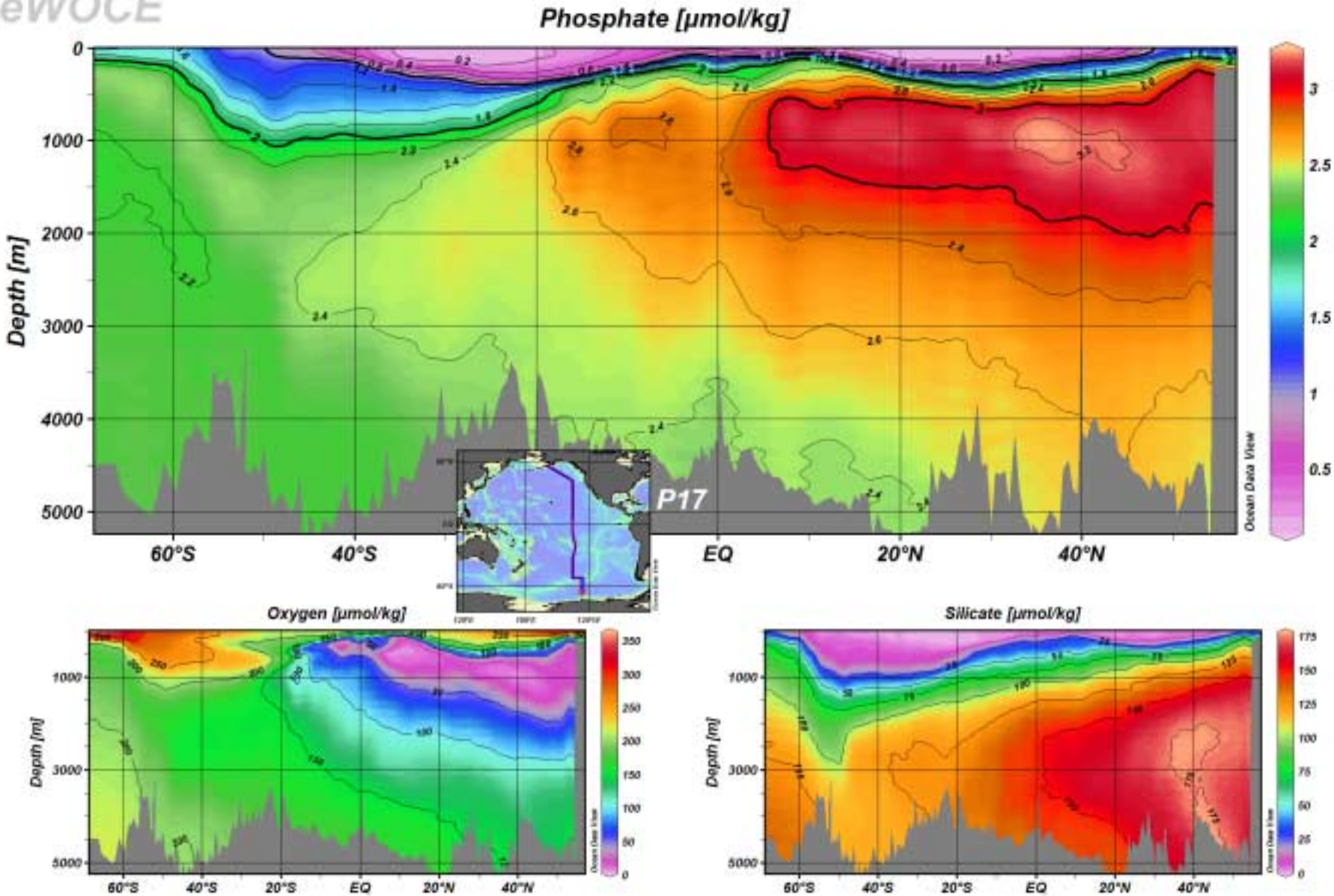
- **circulation**
- **POC & opal export fluxes**
- **remineralization parameters**

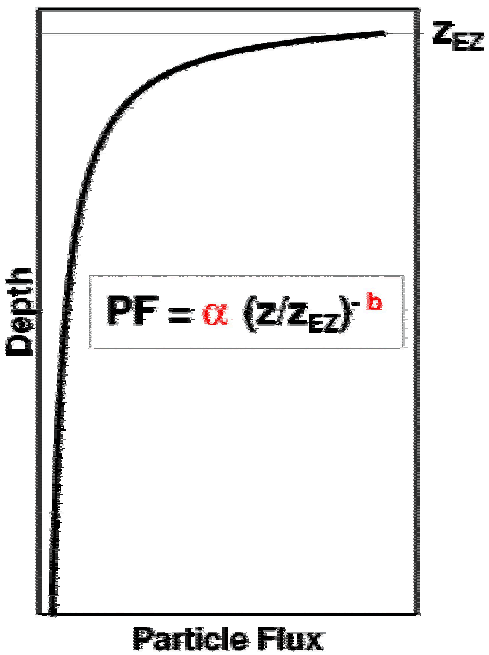
by fitting the model to global ocean, high-quality datasets of ...

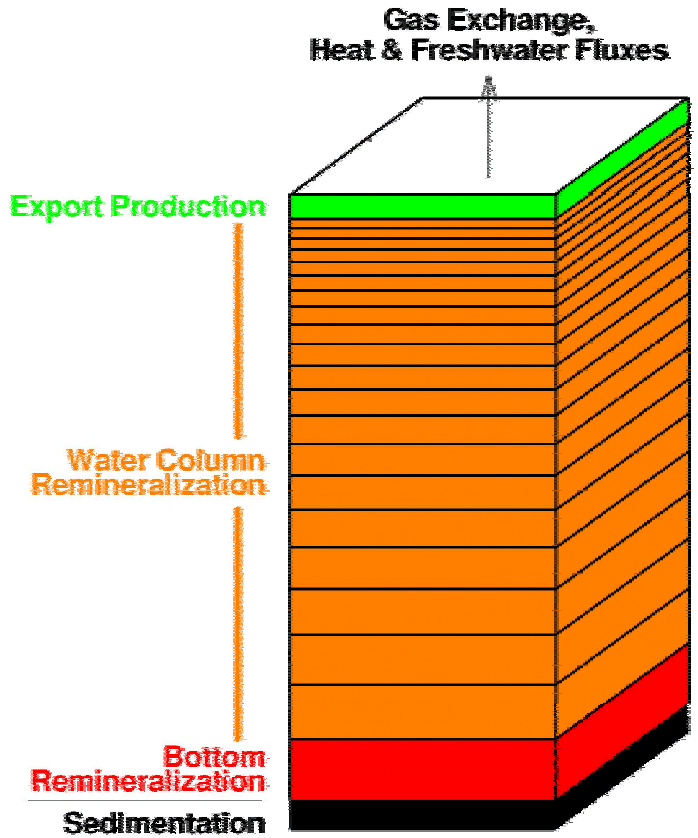
- **T, S**
- **oxygen, dissolved nutrients**
- **DIC, Alkalinity**
- **CFC, Radiocarbon**

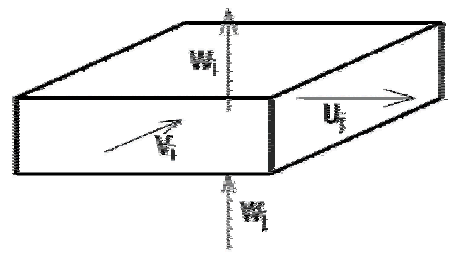





Phosphate [µmol/kg]
Depth [m]
0
1000
2000
3000
4000
5000
60°S
40°S
EQ
20°N
40°N
3
2.5
2
1.5
1
0.5
P17
Ocean Data View
Oxygen [µmol/kg]
Depth [m]
1000
3000
5000
60°S
40°S
20°S
EQ
20°N
40°N
350
300
250
200
150
100
50
0
Silicate [µmol/kg]
Depth [m]
1000
3000
5000
60°S
40°S
20°S
EQ
20°N
40°N
175
150
125
100
75
50
25
0

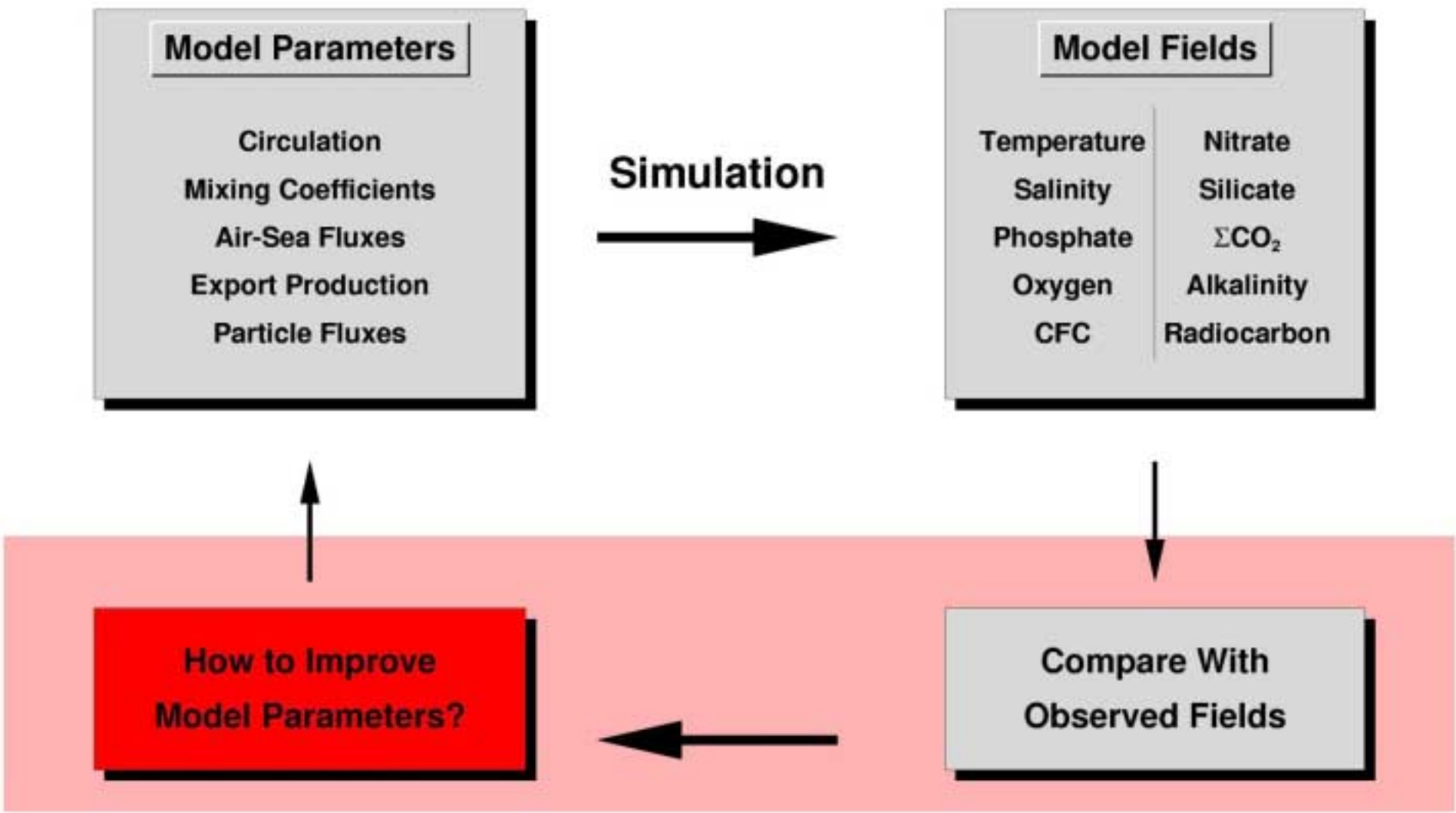






3-D Circulation

Inverse Approach – Sparse Data



How to Improve Model Parameters?

The head-against-the-wall approach:

Compare observations with simulations visually ⏵ analyze misfits ⏵ „figure out“ which parameters caused the misfits ⏵ modify parameter values ⏵ run new simulation.

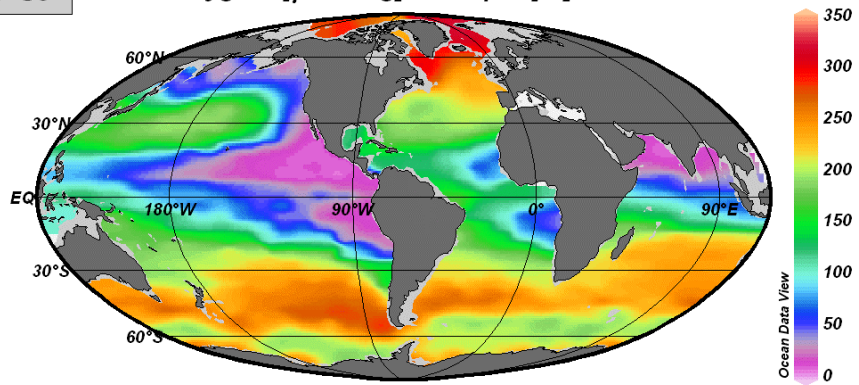
Is it more realistic?

A more efficient way: the ***Ajoint Method***

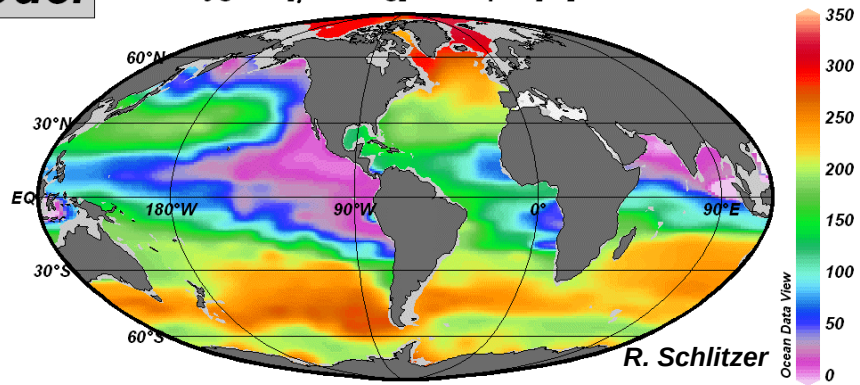
Construct the *Adjoint* for your forward model ⏵ let the *Adjoint* analyze model/data misfits and generate parameter corrections ⏵ run new simulation.

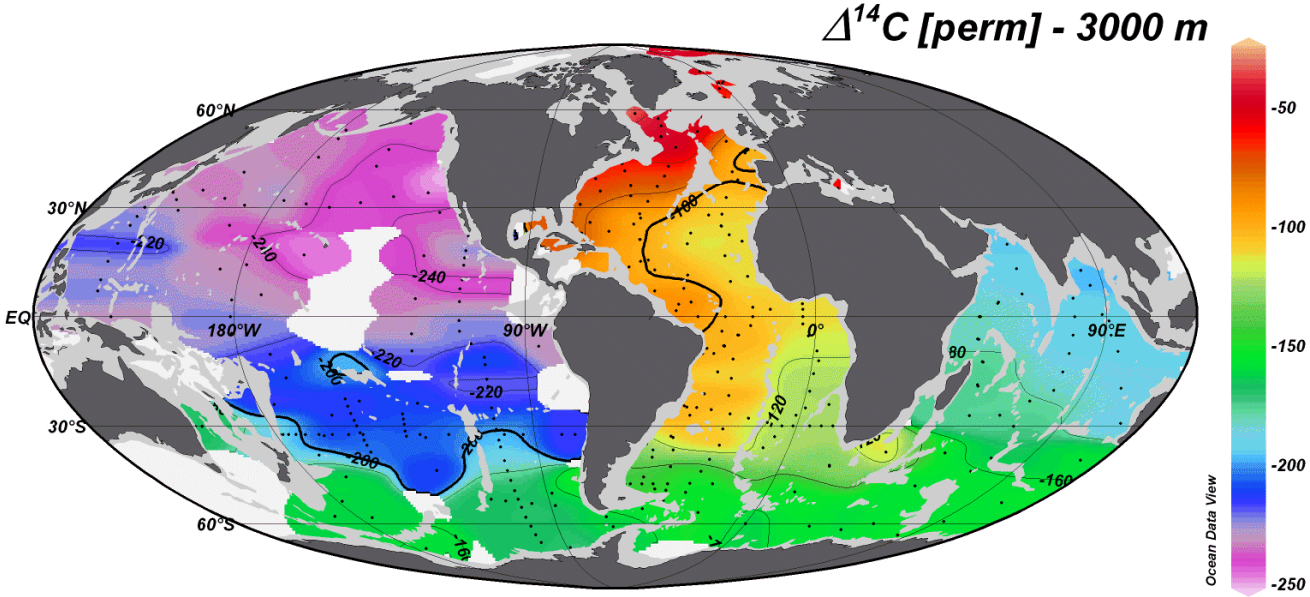
It is guaranteed to be more realistic!

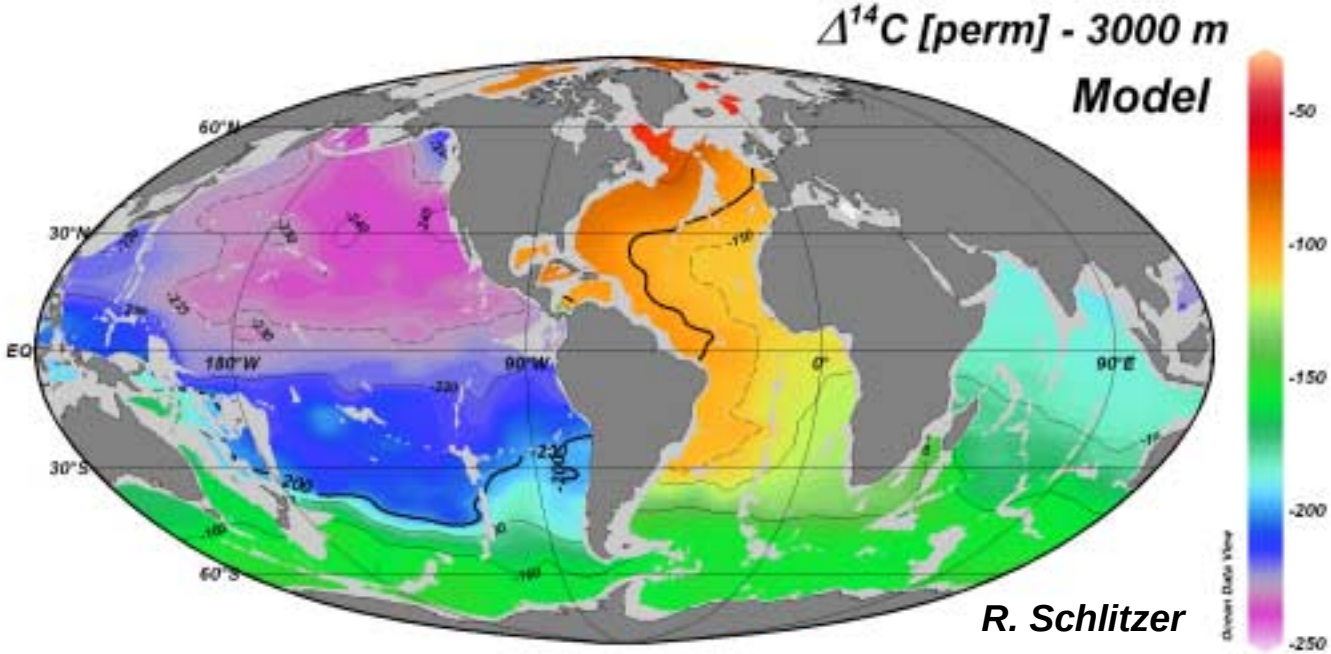
Data

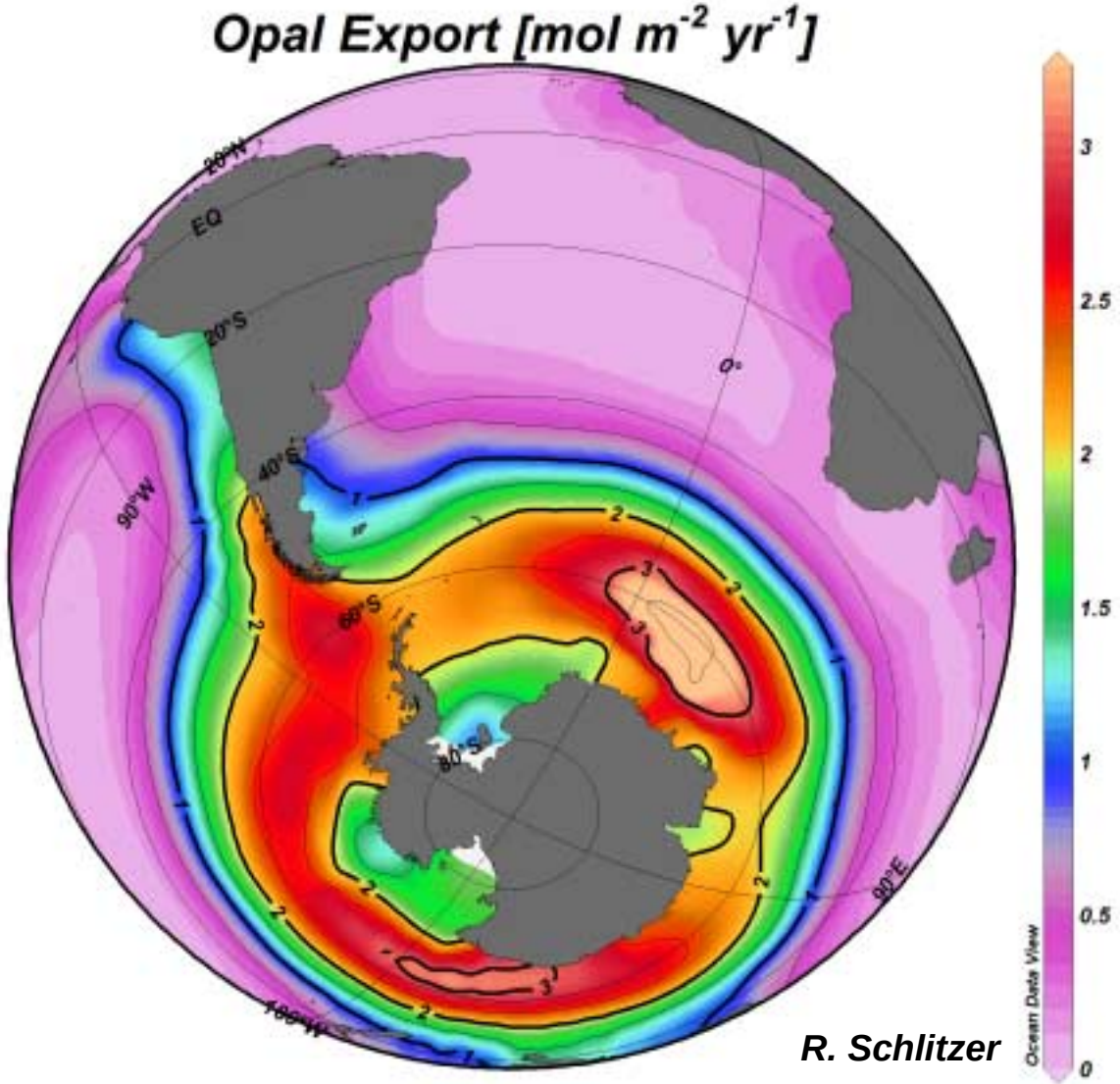

Oxygen$_d$ [µmol/kg] on Depth [m]=500
60°N
30°N
EQ
30°S
60°S
180°W
90°W
0°
90°E
350
300
250
200
150
100
50
0
Ocean Data View

Model

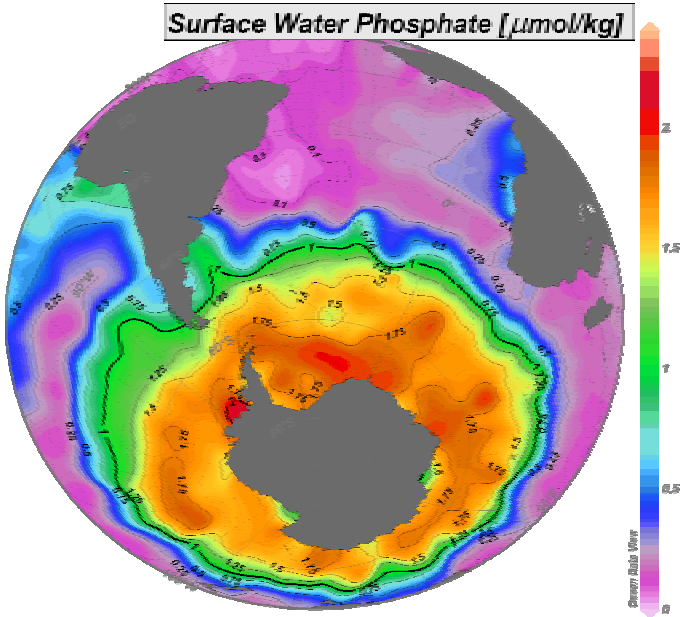

Oxygen$_m$ [µmol/kg] on Depth [m]=500
60°N
30°N
EQ
30°S
60°S
180°W
90°W
0°
90°E
350
300
250
200
150
100
50
0
Ocean Data View
R. Schlitzer

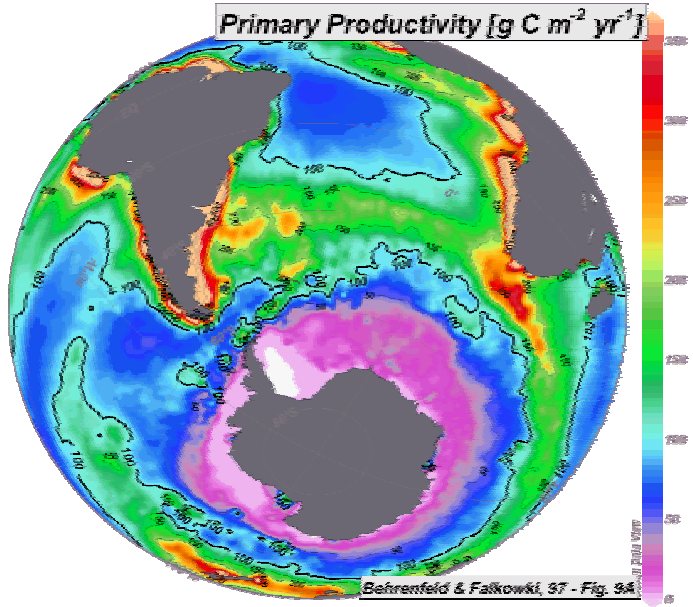

Δ14C [perm] - 3000 m
60°N
30°N
EQ
30°S
60°S
180°W
90°W
0°
90°E
-120
-210
-240
-180
-220
-200
-160
-50
-100
-150
-200
-250
Ocean Data View

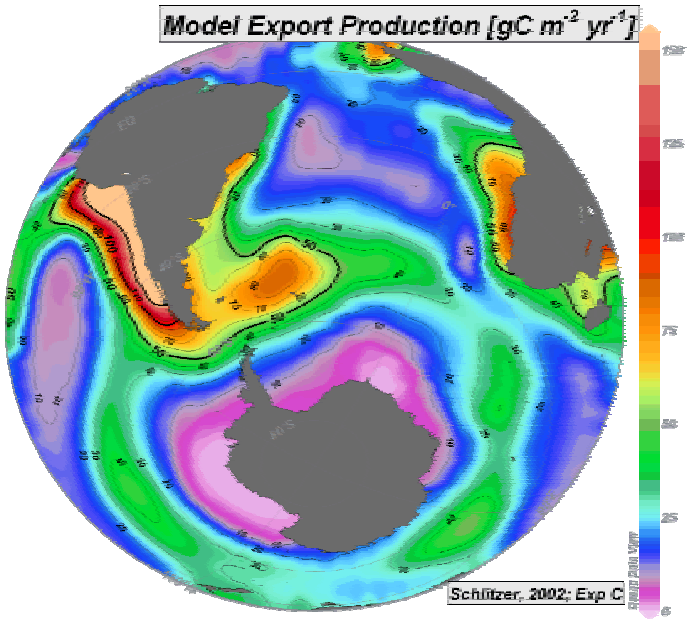

Δ14C [perm] - 3000 m
Model
60°N
30°N
EQ
30°S
60°S
180°W
90°W
0°
90°E
-50
-100
-150
-200
-250
R. Schlitzer

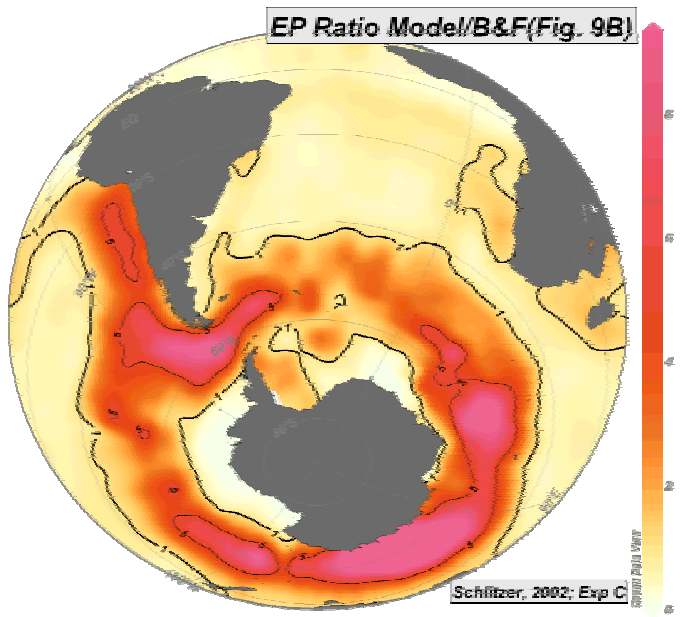


70 –100
Tmol Si yr^{-1}

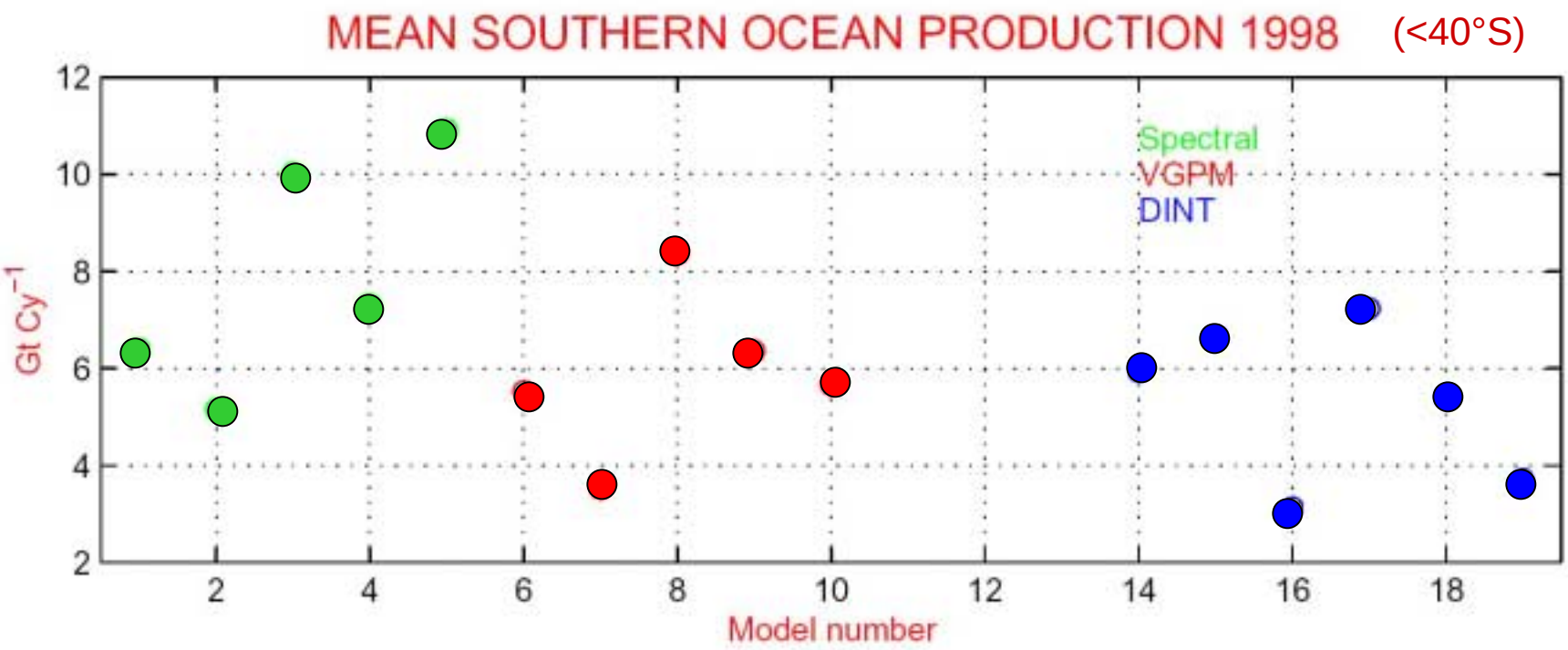

Surface Water Phosphate [µmol/kg]


Primary Productivity [g C m-2 yr-1]
Behrenfeld & Falkowski, 97 - Fig. 3A


Model Export Production [gC m-2 yr-1]
Schlitzer, 2002; Exp C


EP Ratio Model/B&F(Fig. 9B)
Schlitzer, 2002; Exp C

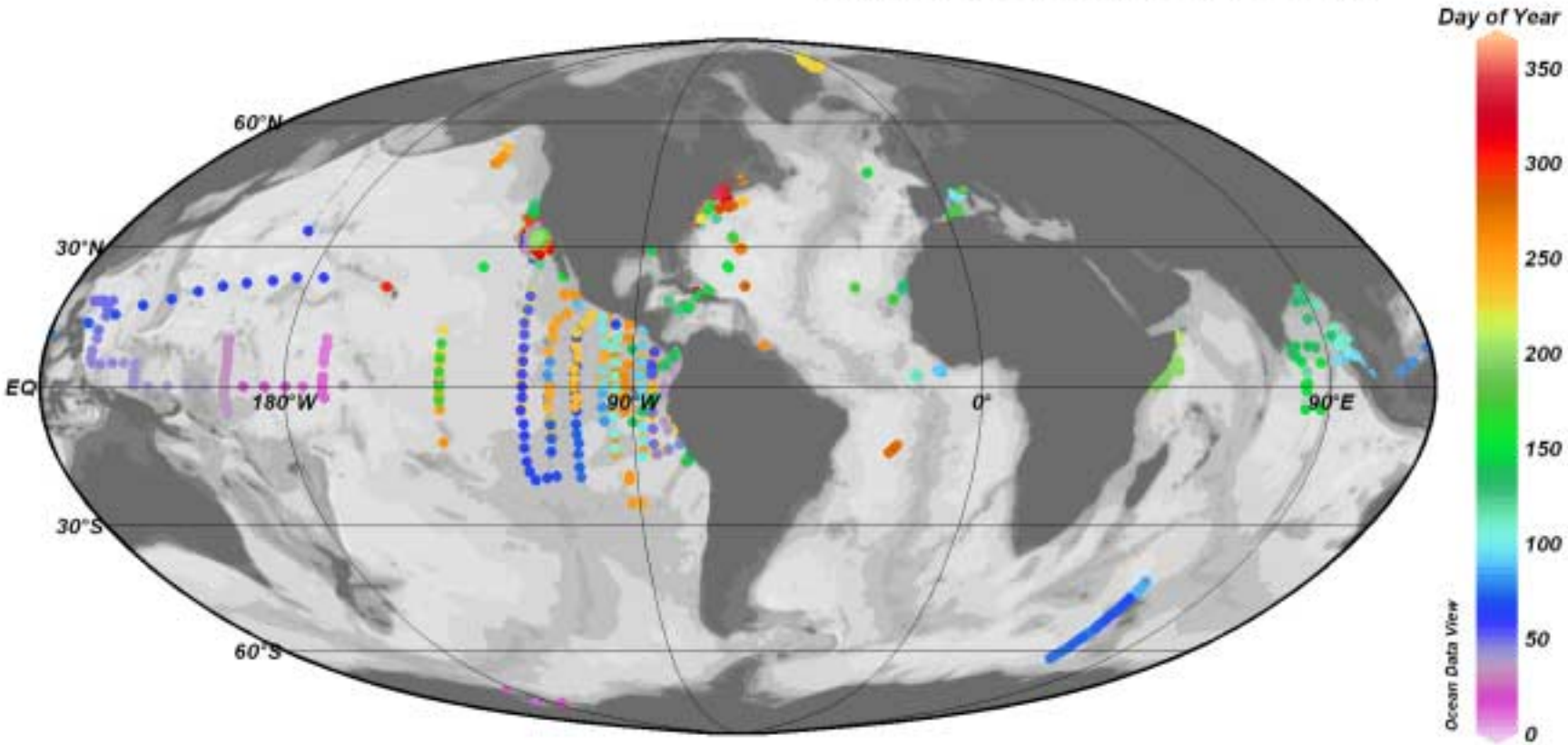
PRIMARY PRODUCTION ALGORITHM ROUND-ROBIN 3 (PPARR3)

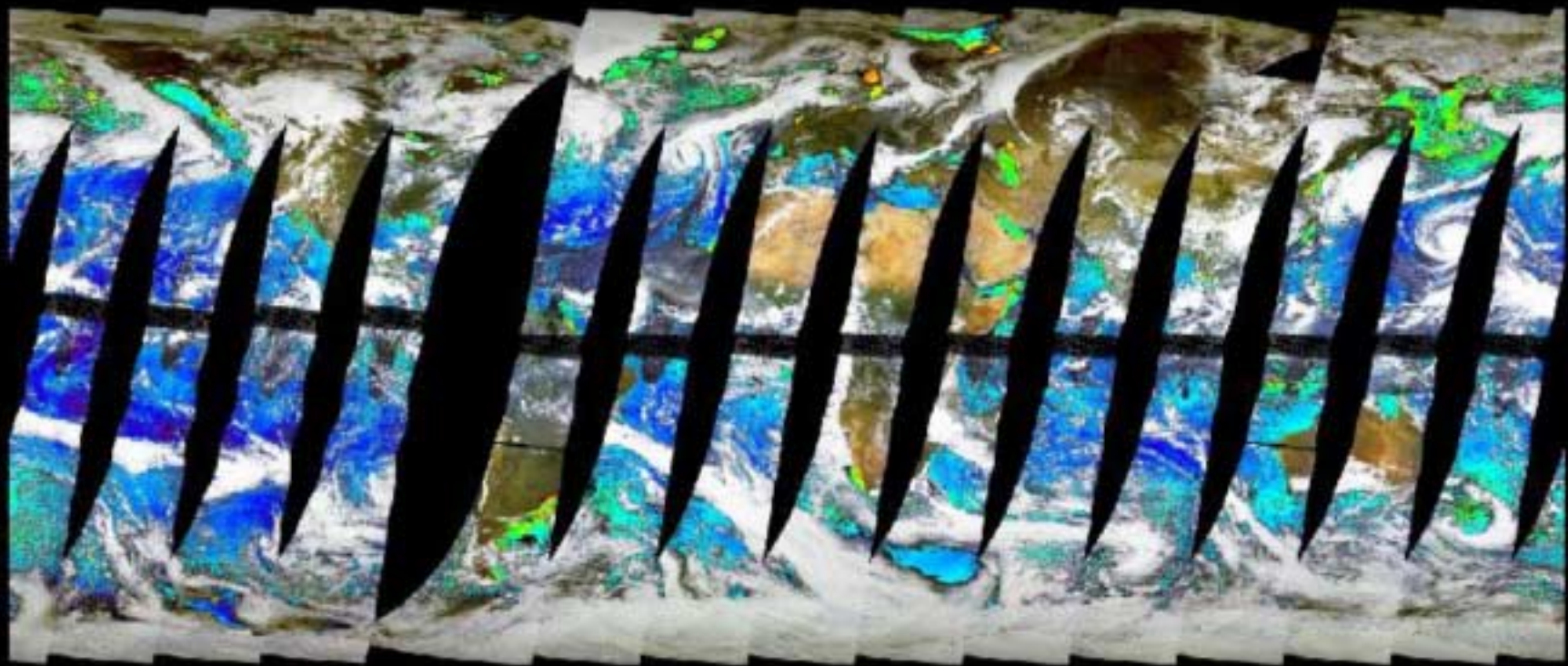


Carr et al.

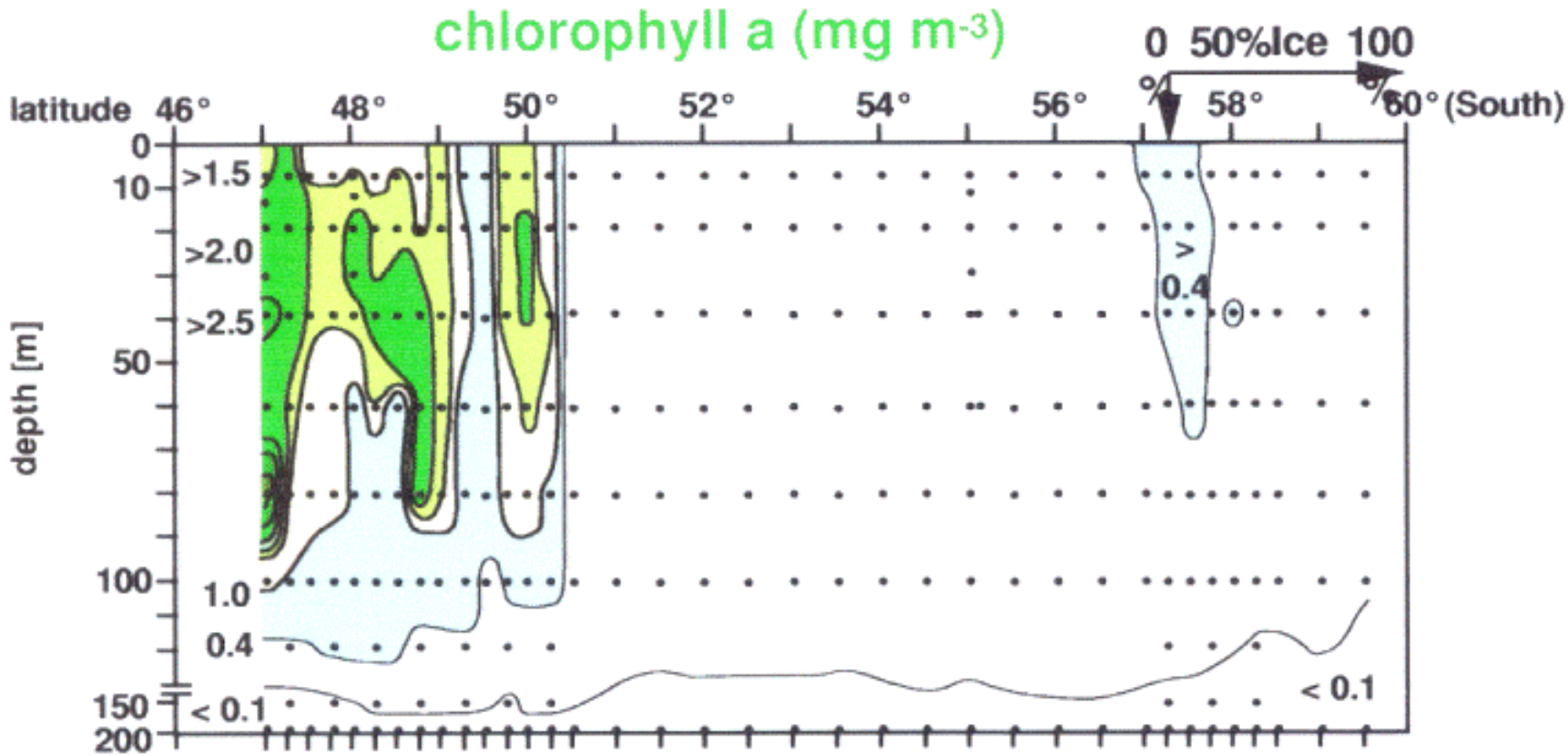
Map of in situ PP determinations used for B+F97 satellite callibration

(only 33 out of 3304 are from the Southern Ocean)

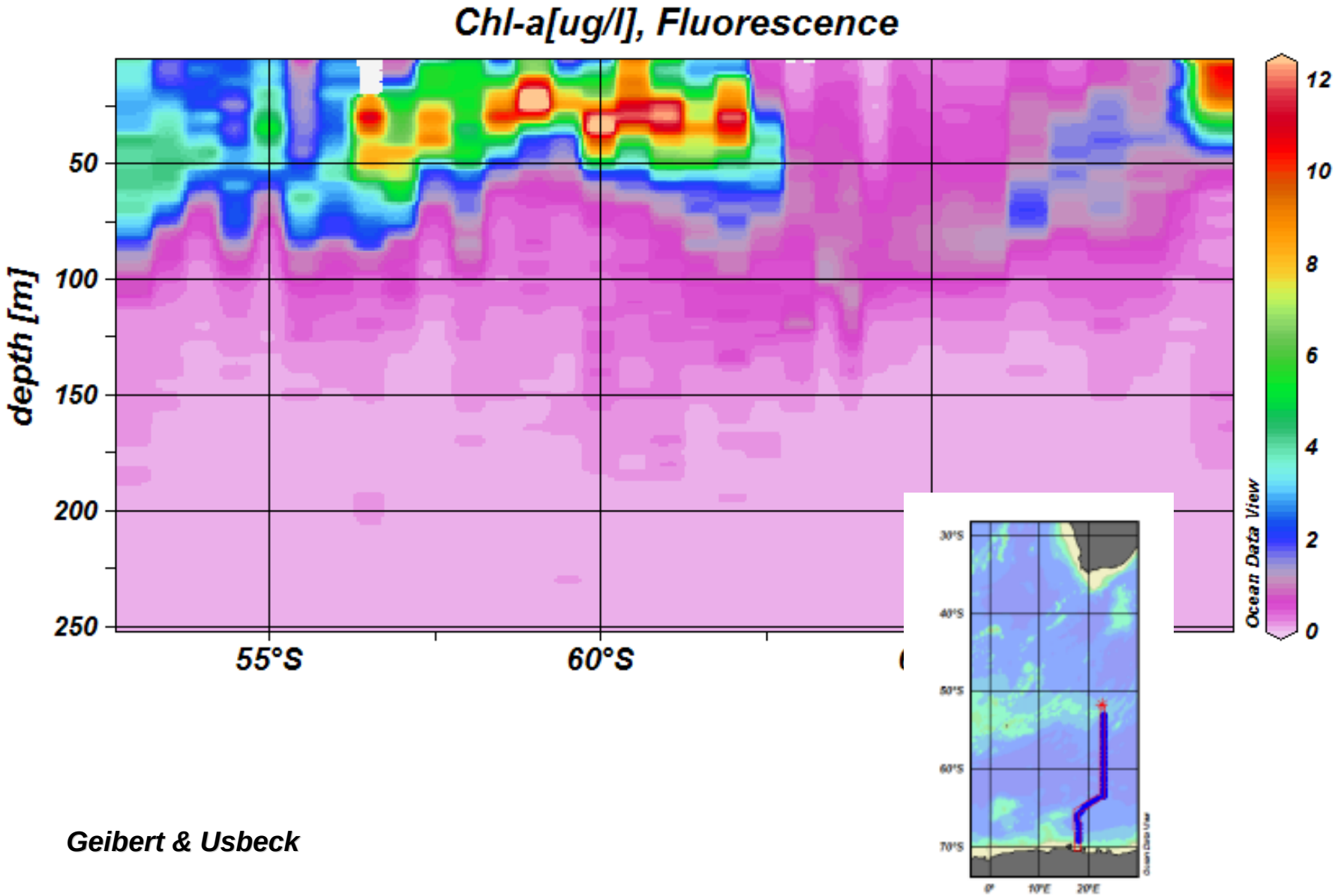




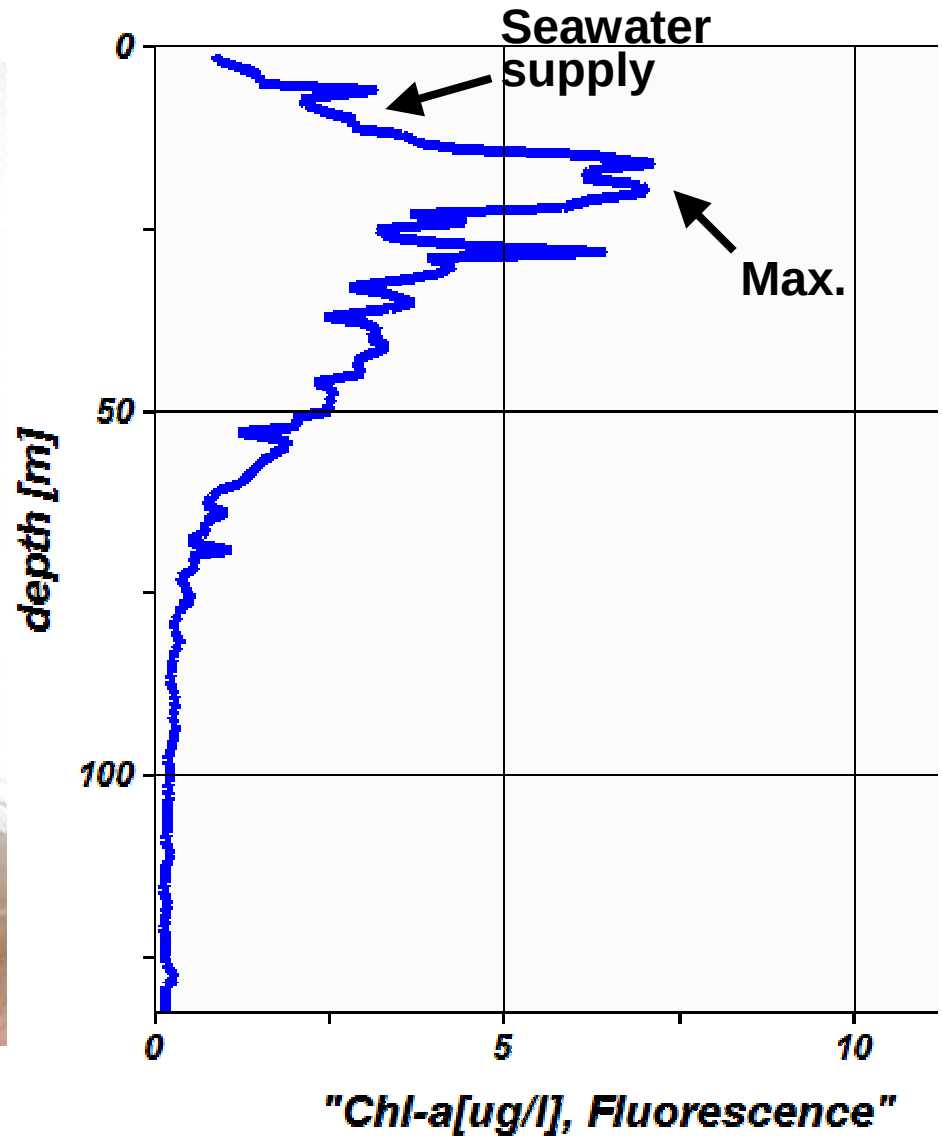
SeaWiFS and MODIS acquire complete global coverage within two days … but cloudiness limits the view.



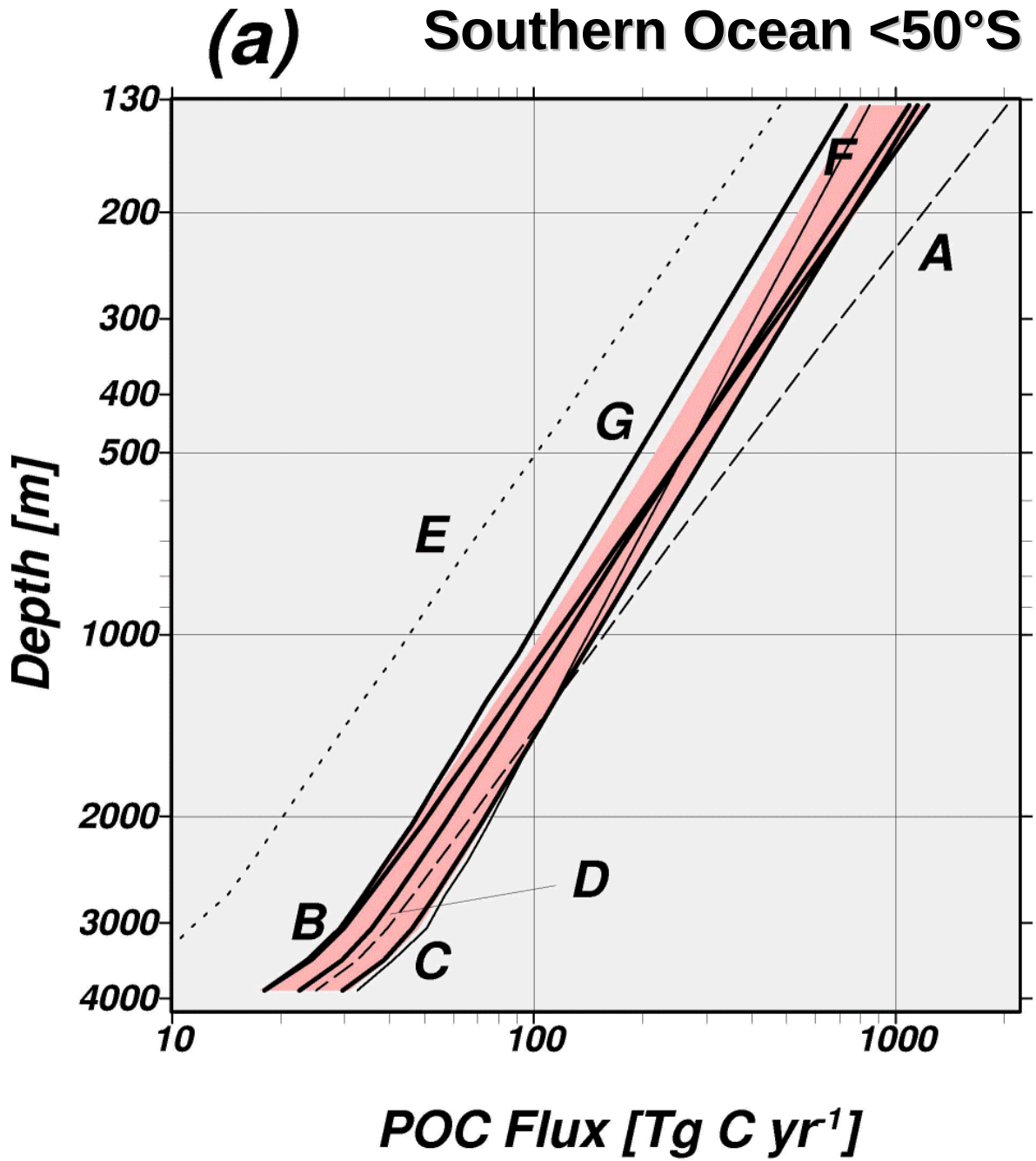
Polarstern ANT X/6 (Oct-Dec 92); Bathmann&Veth, unpublished



Geibert & Usbeck



Geibert & Usbeck

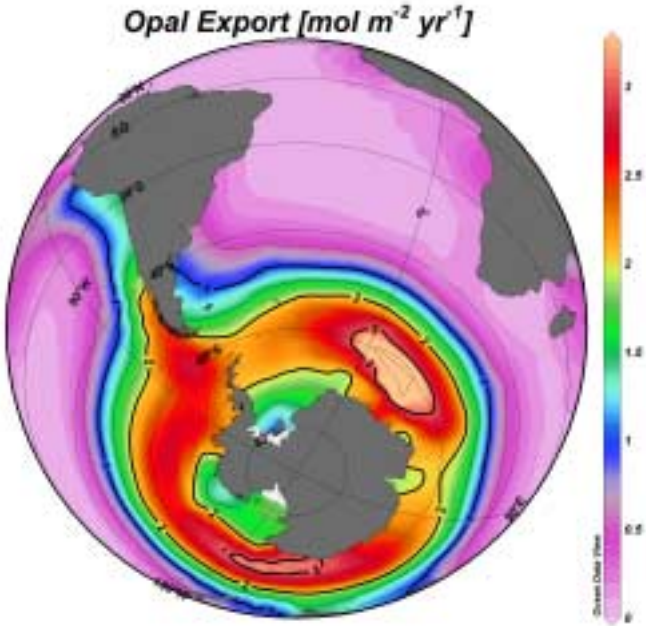


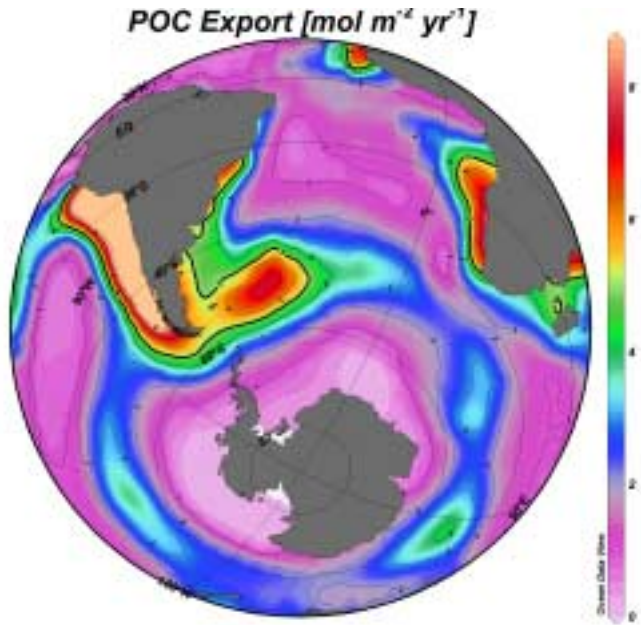
$\bar{b}$=1.04

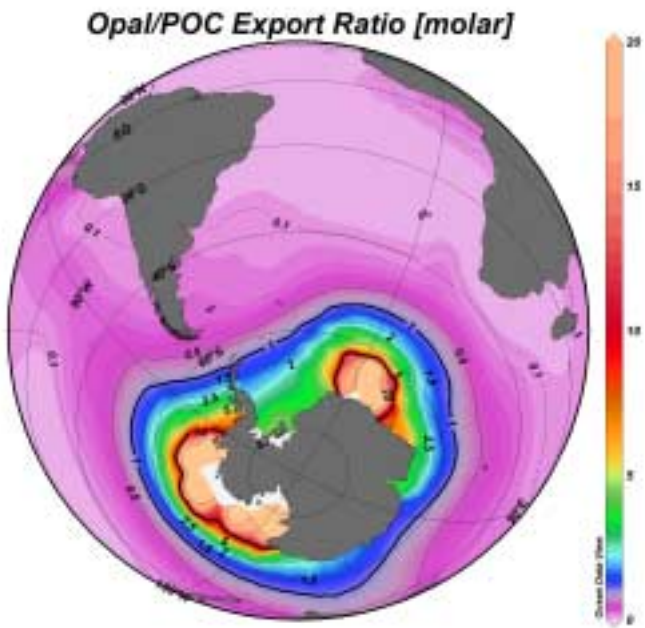
Flux in 1000 m 35% smaller as compared to *b*=0.856 case.

Schlitzer, 2002

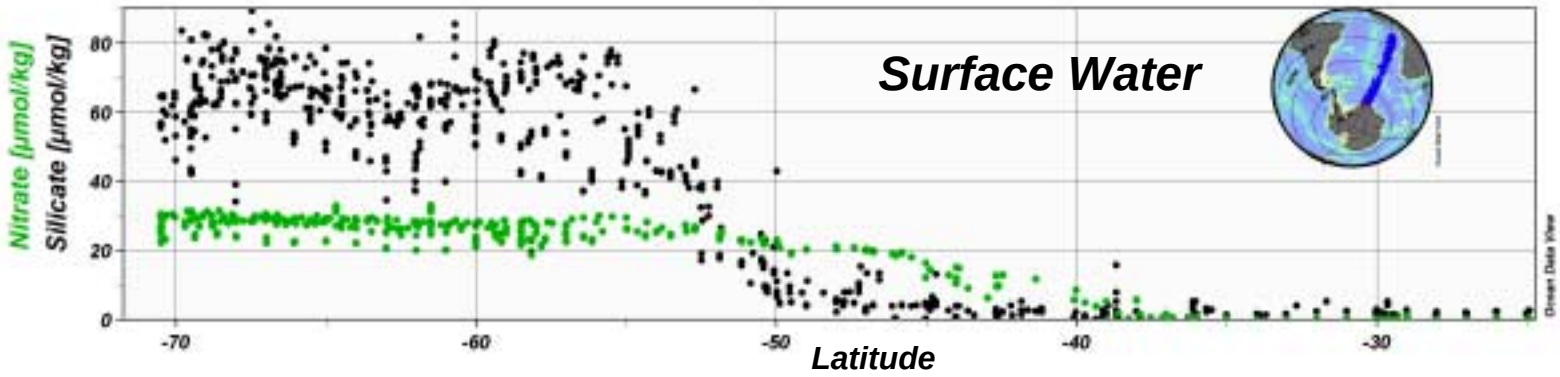
Export Comparison

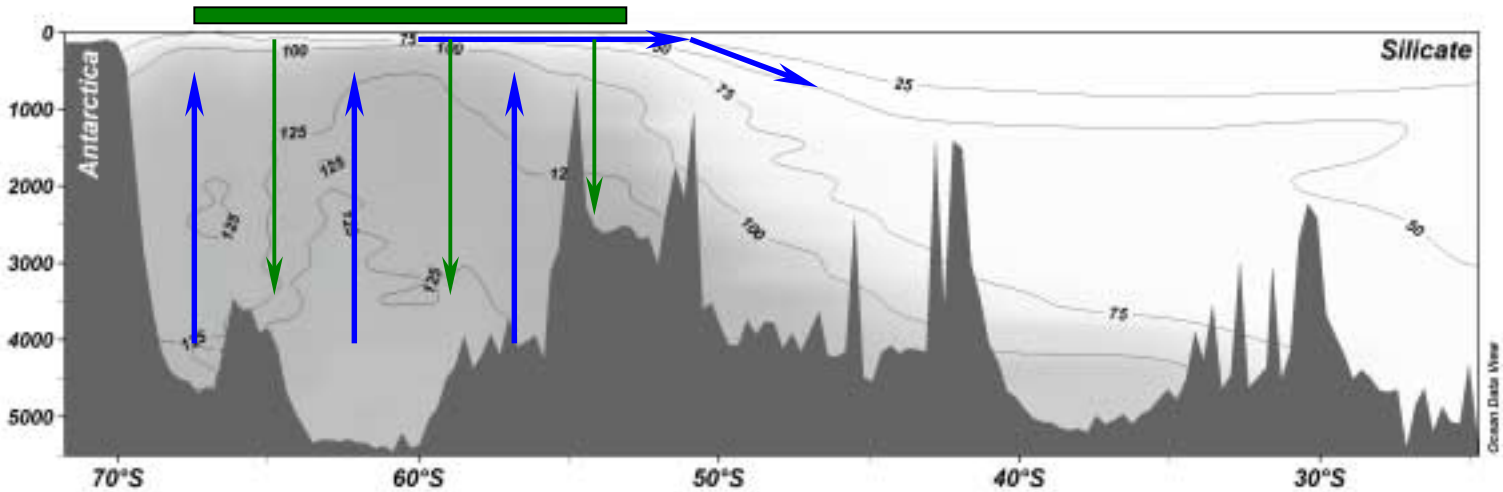


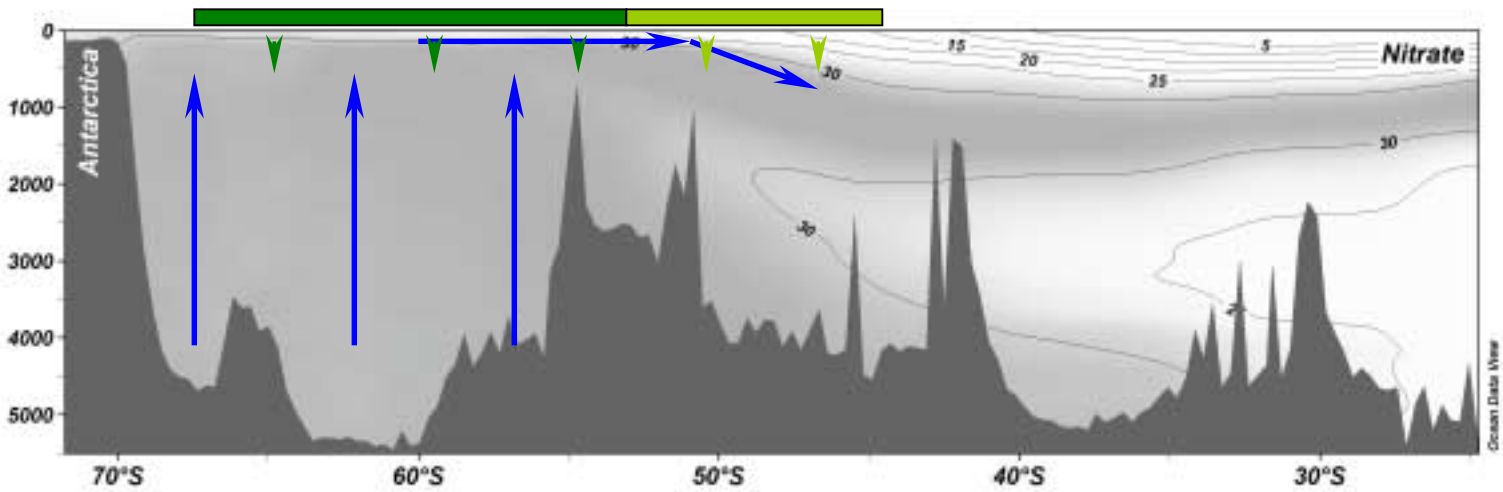




R. Schlitzer


Surface Water
Nitrate [µmol/kg]
Silicate [µmol/kg]
Latitude
Ocean Data View


Silicate
Antarctica
70°S
60°S
50°S
40°S
30°S
Ocean Data View


Nitrate
Antarctica
70°S
60°S
50°S
40°S
30°S
Ocean Data View

Conclusions

- *Significant POC Export in the Southern Ocean*
  (ca 1 Gt C/yr south of 50°S out of ca. 9 Gt C/yr globally)

- *Previously Underestimated by Satellite PP Algorithms*
  (callibration issue; sub-surface chlorophyll)

- *Zonal Succsession of Opal and Carbon Flux Maxima*
  (explained as delicate balance between upward physical transport and downward flux by particles; differences in remineralization matter)

- *C-sequestration due to Iron Fertilization in Upwelling Regimes likely to be inefficient*
  (exported POC is remineralized shallow and quickly returned to surface layer)

Acknowledgements

Thanks to JGOFS & WOCE PIs for producing high quality, global datasets of biogeochemical variables and circulation tracers !!!