

# A nitrogen isotope-assisted view of Southern Ocean nutrient cycling

Daniel Sigman

Dept. of Geosciences  
Princeton University

Peter DiFiore



Patrick Rafter



Sandi Smart



Sarah Fawcett



Dario Marconi



# Southern Ocean: leak in the biological pump

***low latitude***

***high latitude***

$\text{CO}_2$

low  
 $[\text{PO}_4^{3-}]$

$\text{CO}_2$

high  
 $[\text{PO}_4^{3-}]$

$\text{C}_{\text{org}}$   
rain

regenerated

preformed

$\text{PO}_4^{3-}$

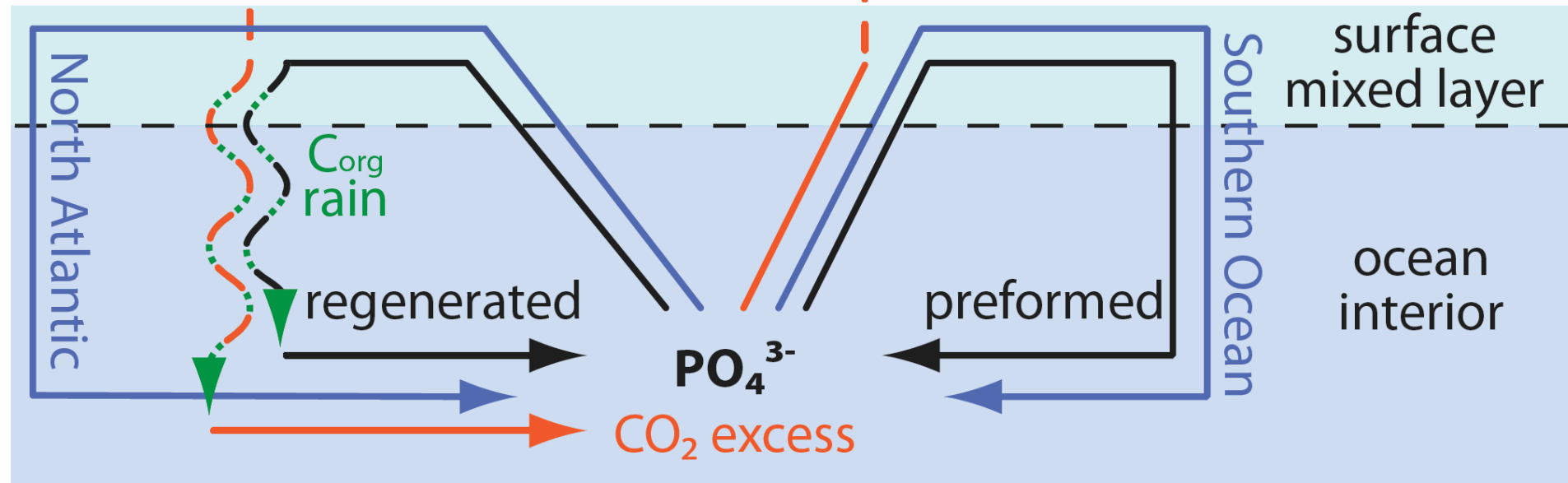
$\text{CO}_2$  excess

surface  
mixed layer

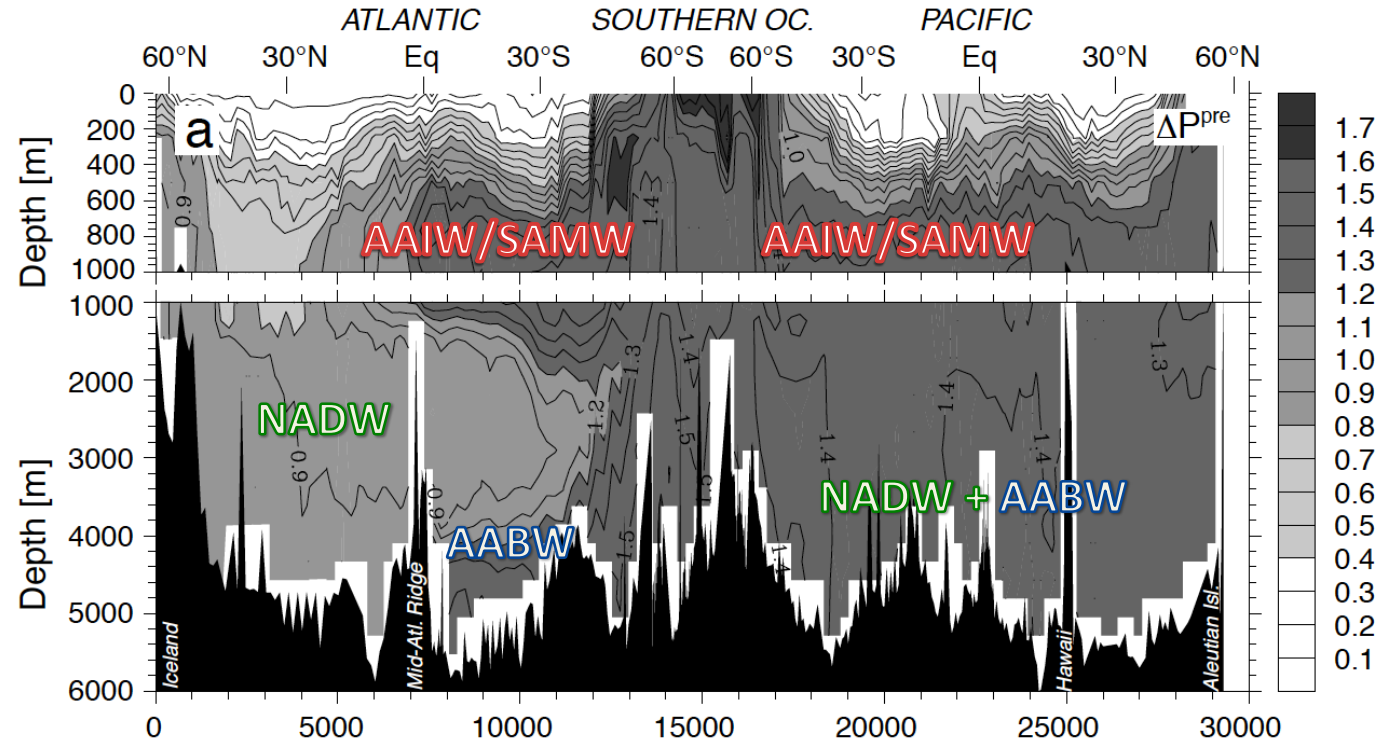
ocean  
interior

North Atlantic

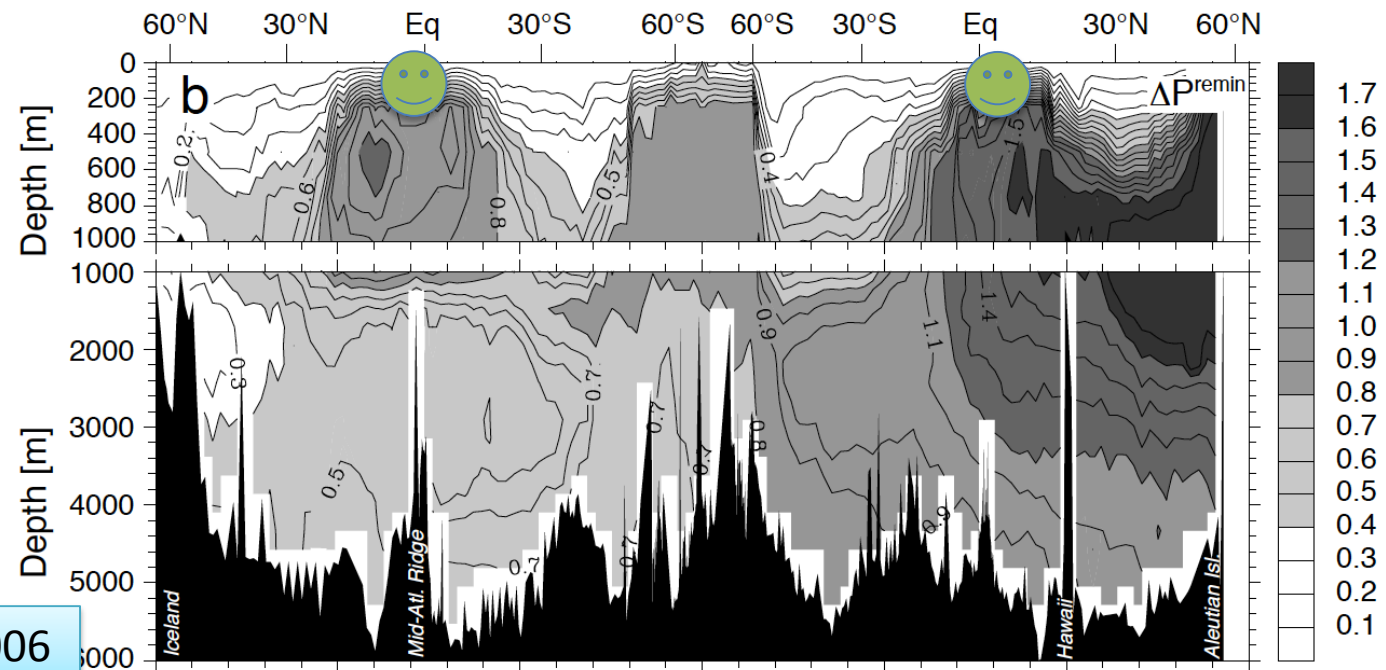
Southern Ocean



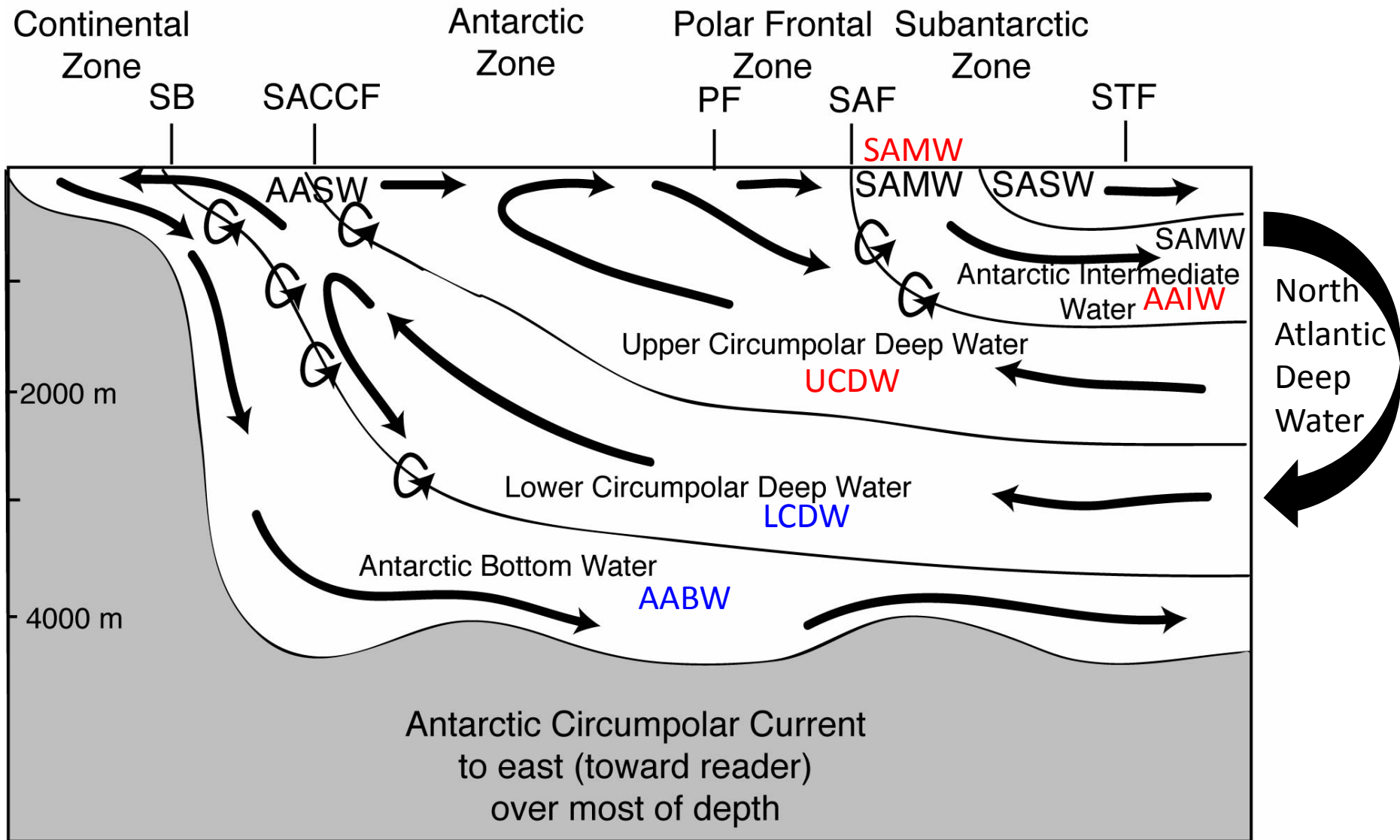
**Preformed  $[\text{PO}_4^{3-}]$**   
(carried in the water  
from the surface)



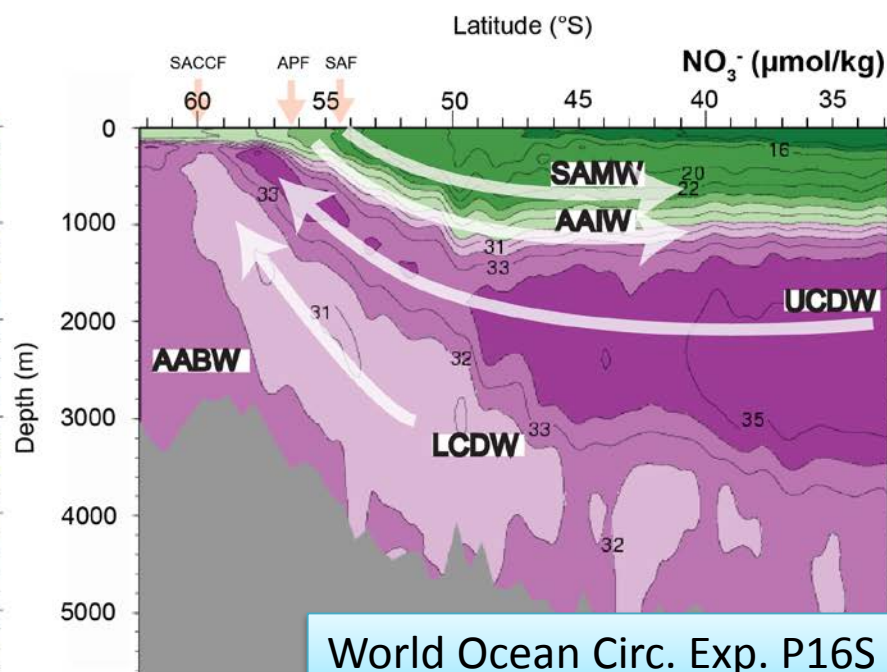
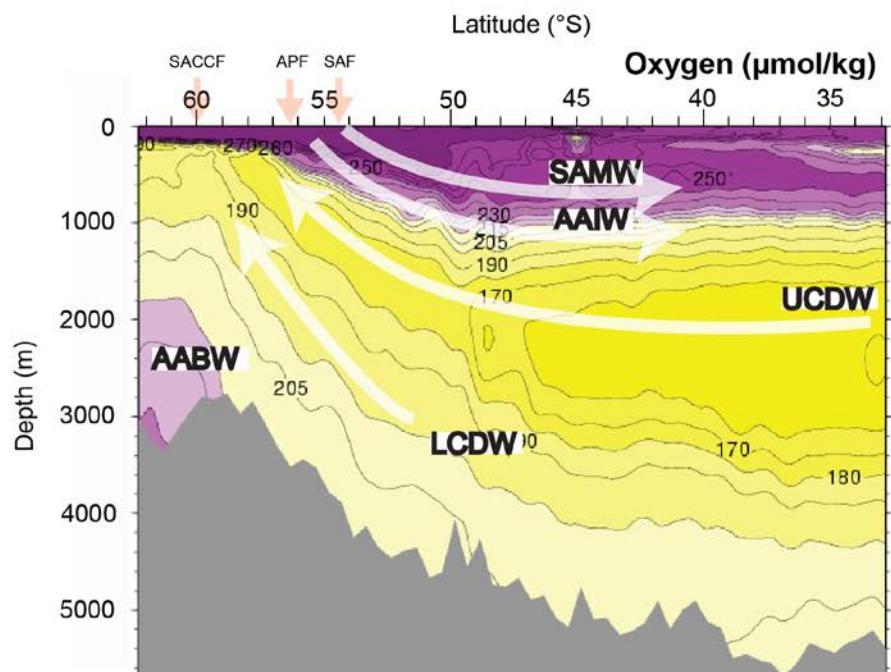
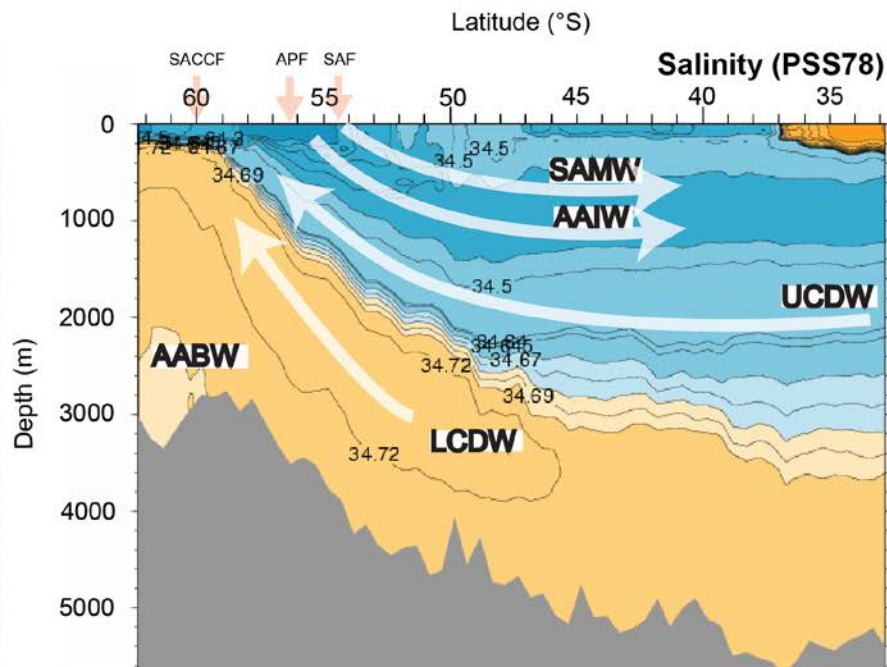
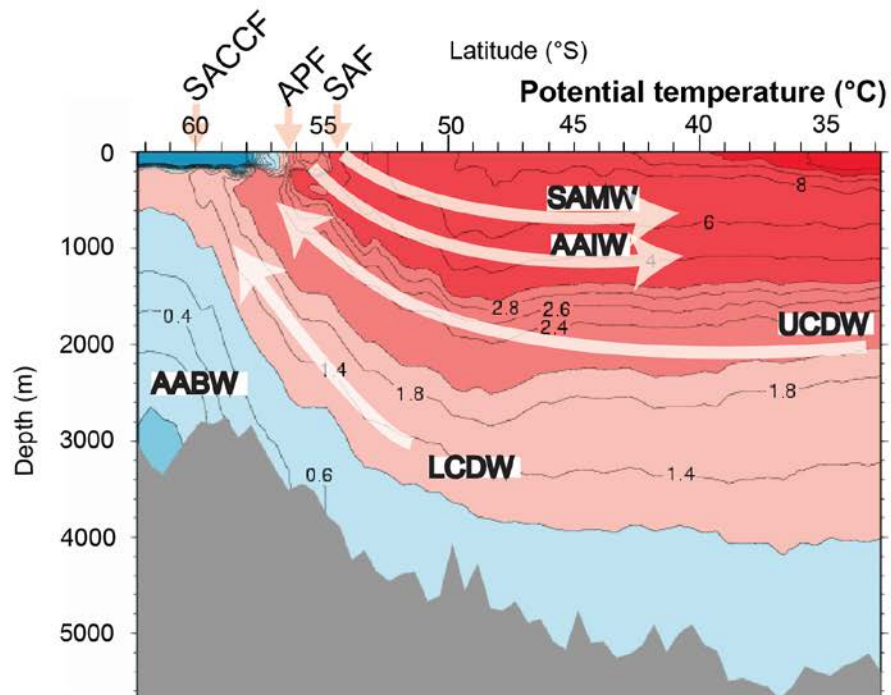
**Regenerated  $[\text{PO}_4^{3-}]$**   
(produced from  
degradation of  
sinking organic  
matter)



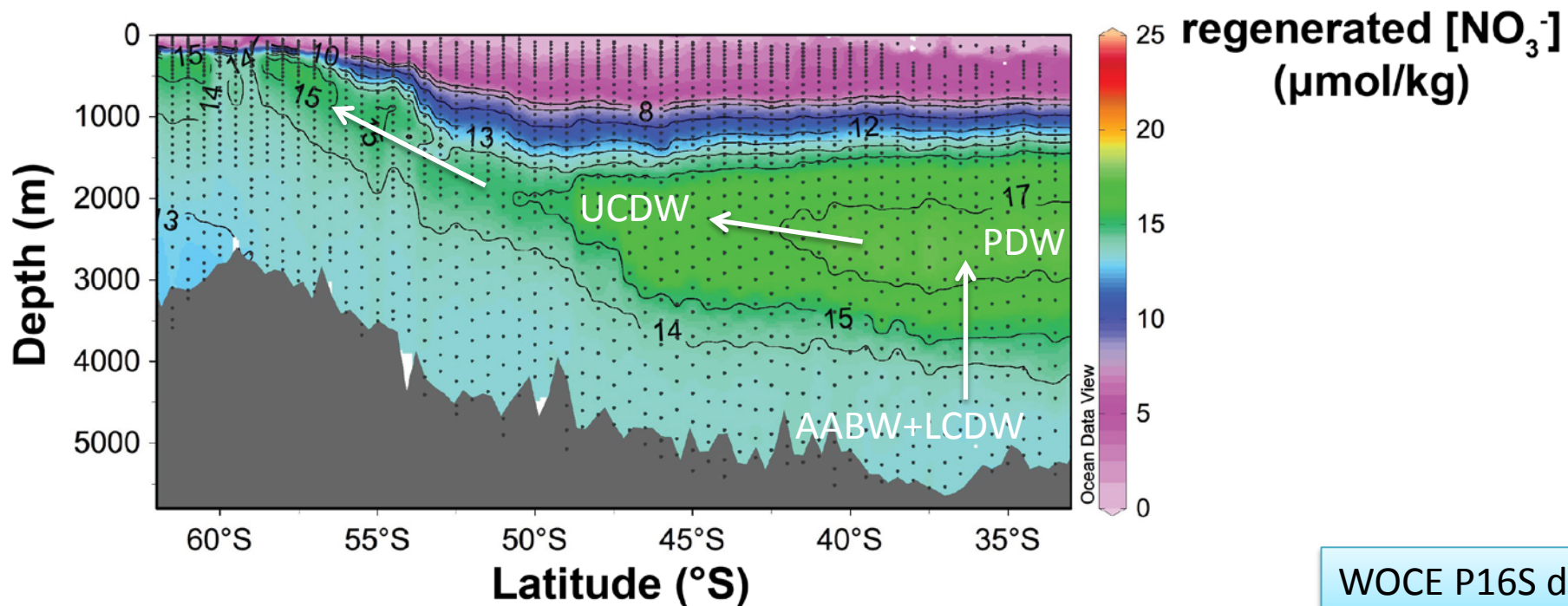
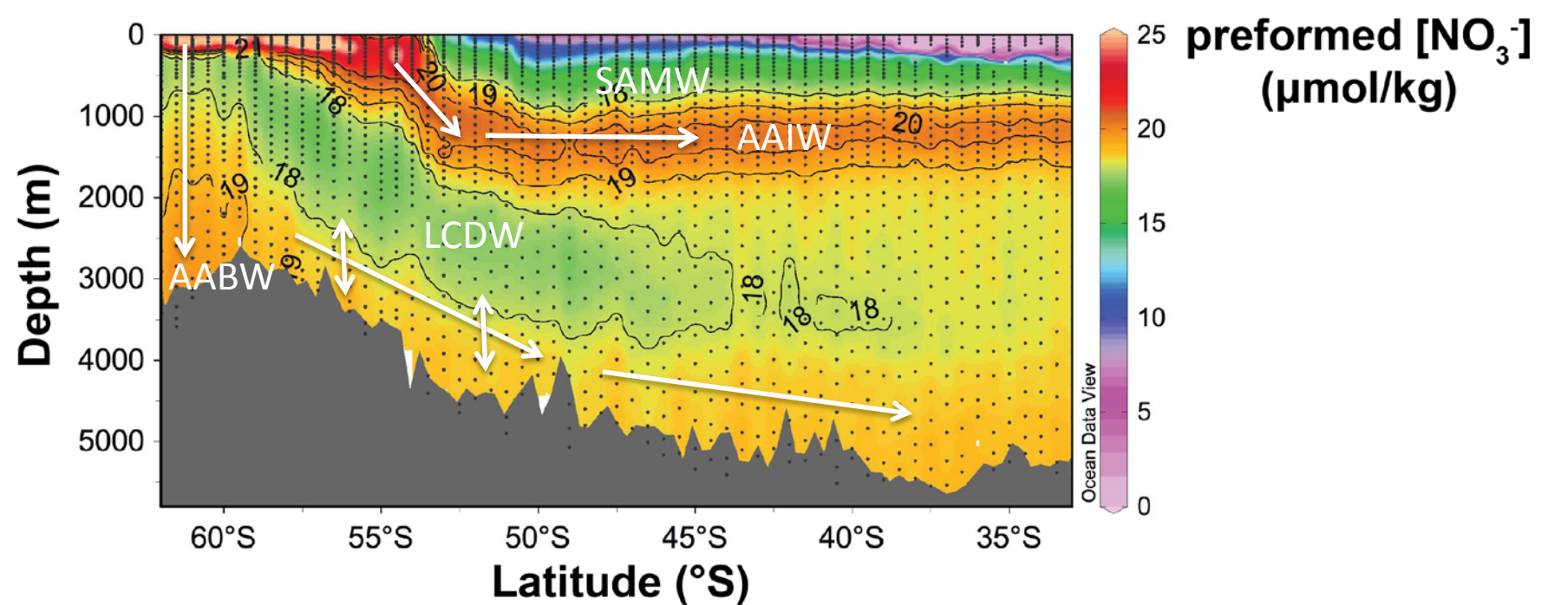
# Southern Ocean meridional circulation







World Ocean Circ. Exp. P16S data



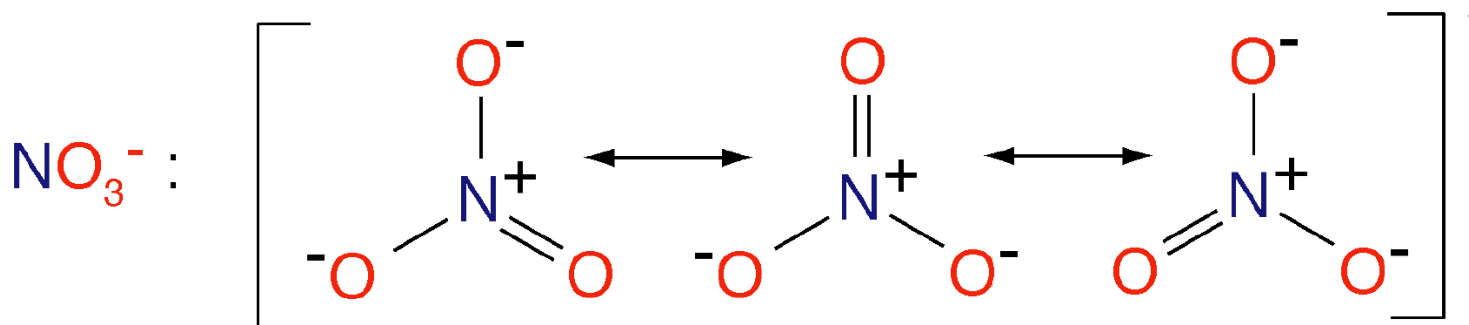
# N and O isotopes

N :  $^{14}\text{N}$  99.6337%     $^{15}\text{N}$  0.3663%

O :  $^{16}\text{O}$  99.7630%     $^{17}\text{O}$  0.0375%     $^{18}\text{O}$  0.1995%

$$\delta^{15}\text{N} \text{ (vs. atm. N}_2\text{)} = \left( \left( (^{15}\text{N}/^{14}\text{N}) / (^{15}\text{N}/^{14}\text{N})_{\text{air}} \right) - 1 \right) * 1000\text{‰}$$

$$\delta^{18}\text{O} \text{ (vs. VSMOW)} = \left( \left( (^{18}\text{O}/^{16}\text{O}) / (^{18}\text{O}/^{16}\text{O})_{\text{VSMOW}} \right) - 1 \right) * 1000\text{‰}$$

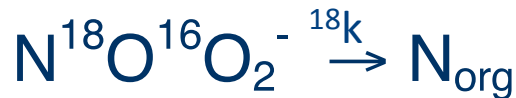
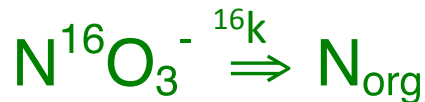


# Kinetic isotope fractionation

Nitrate assimilation:



$$^{15}\epsilon = ((^{14}\text{k}/^{15}\text{k}) - 1) * 1000\text{‰}$$



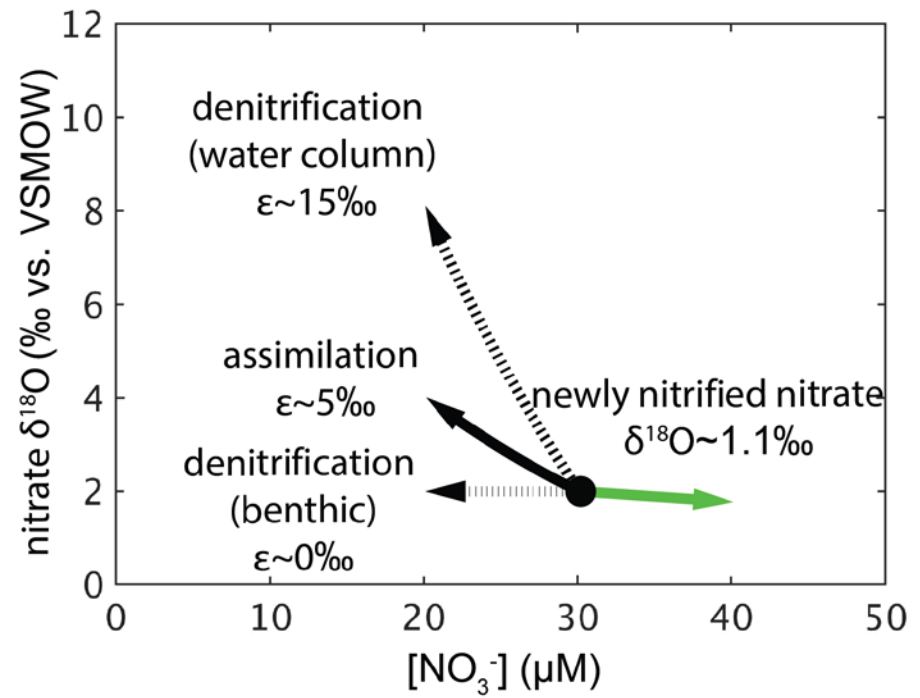
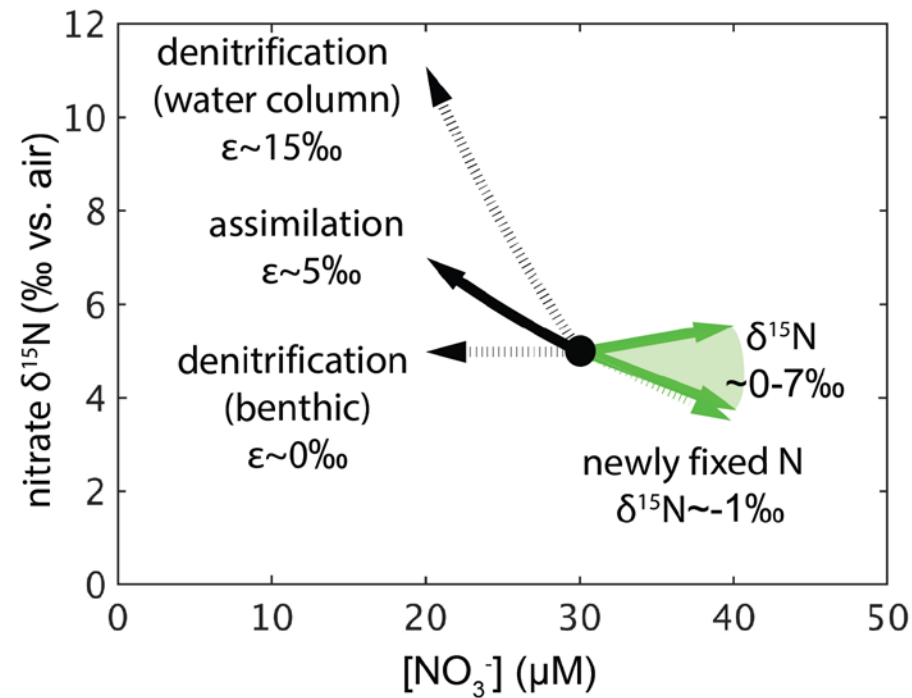
$$^{18}\epsilon = ((^{16}\text{k}/^{18}\text{k}) - 1) * 1000\text{‰}$$

$$^{15}\epsilon \sim \delta^{15}\text{N}_{\text{NO}_3^-} - \delta^{15}\text{N}_{\text{NO}_3^- \text{ consumed (inst.)}}$$

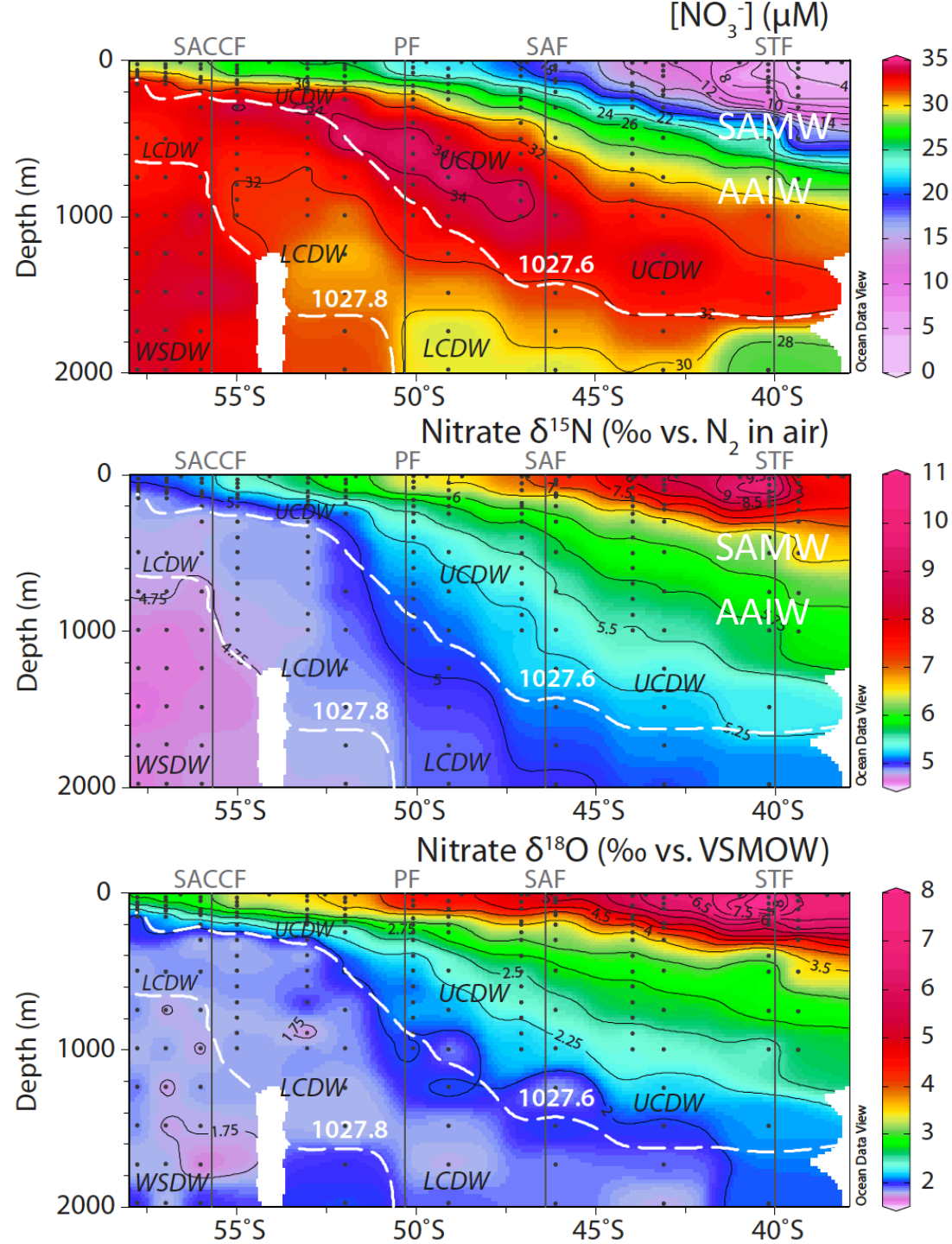
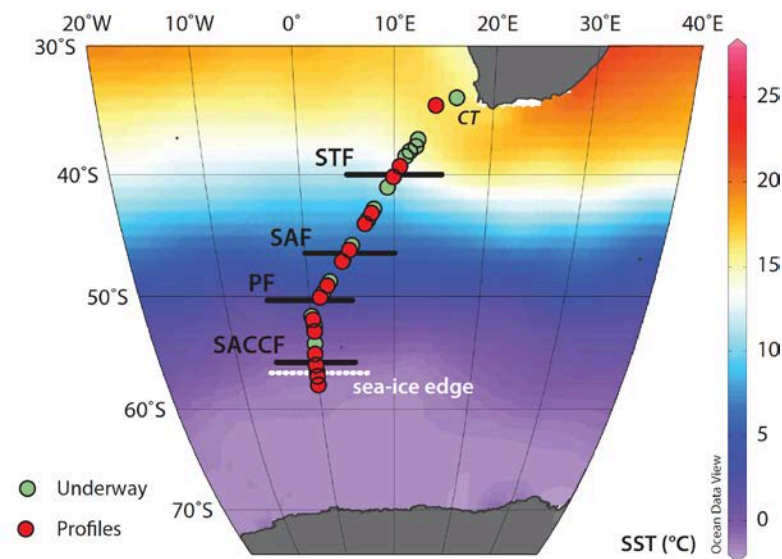
$$^{18}\epsilon \sim \delta^{18}\text{O}_{\text{NO}_3^-} - \delta^{18}\text{O}_{\text{NO}_3^- \text{ consumed (inst.)}}$$



# Nitrate N and O isotopic effects of N cycle processes



# Southern Ocean nitrate isotopes – Atlantic sector, winter



# South Pacific nitrate N and O isotopes

CLIVAR P16S, 151°W, January-February 2005

