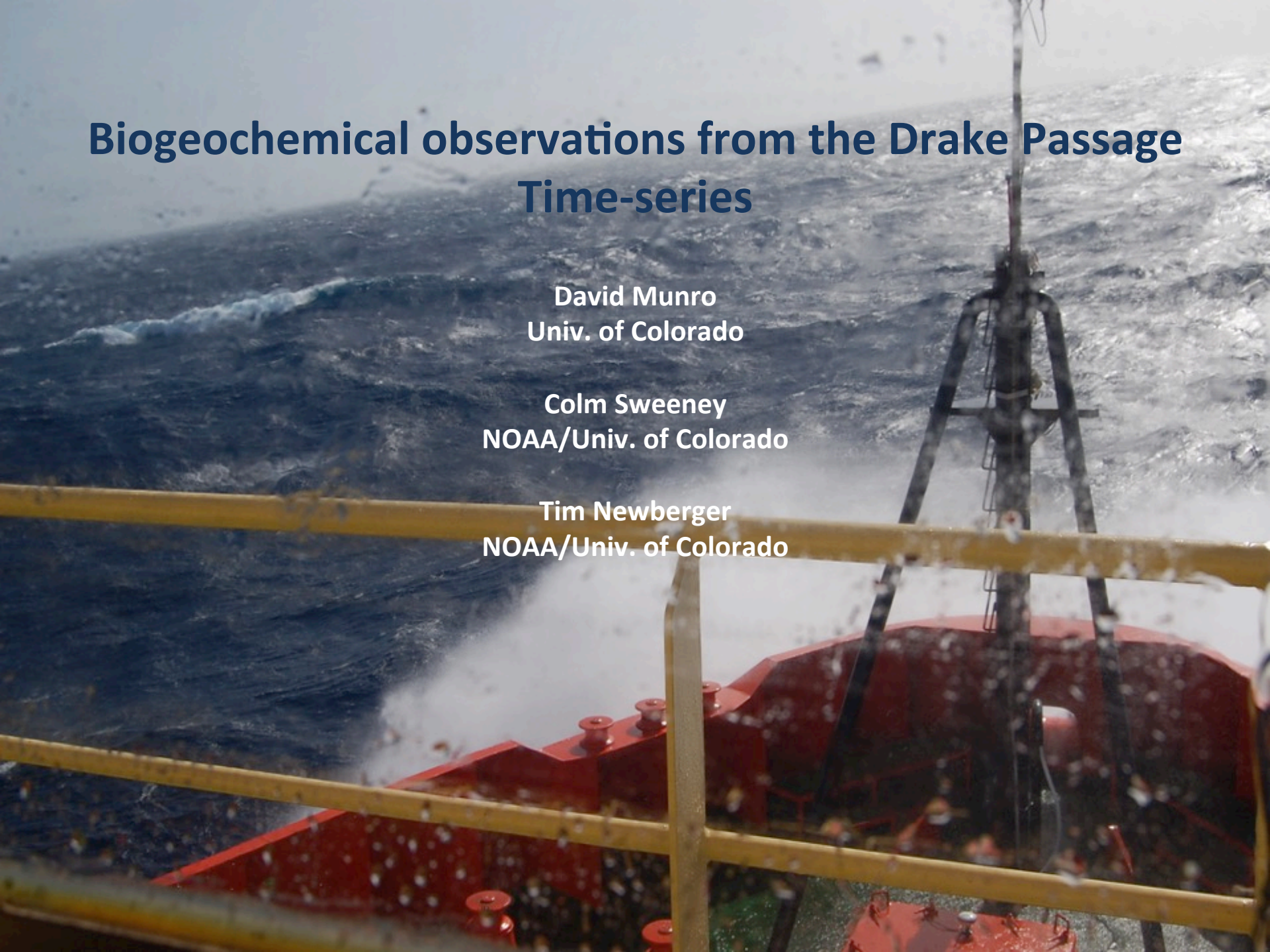


# Biogeochemical observations from the Drake Passage Time-series

David Munro  
Univ. of Colorado

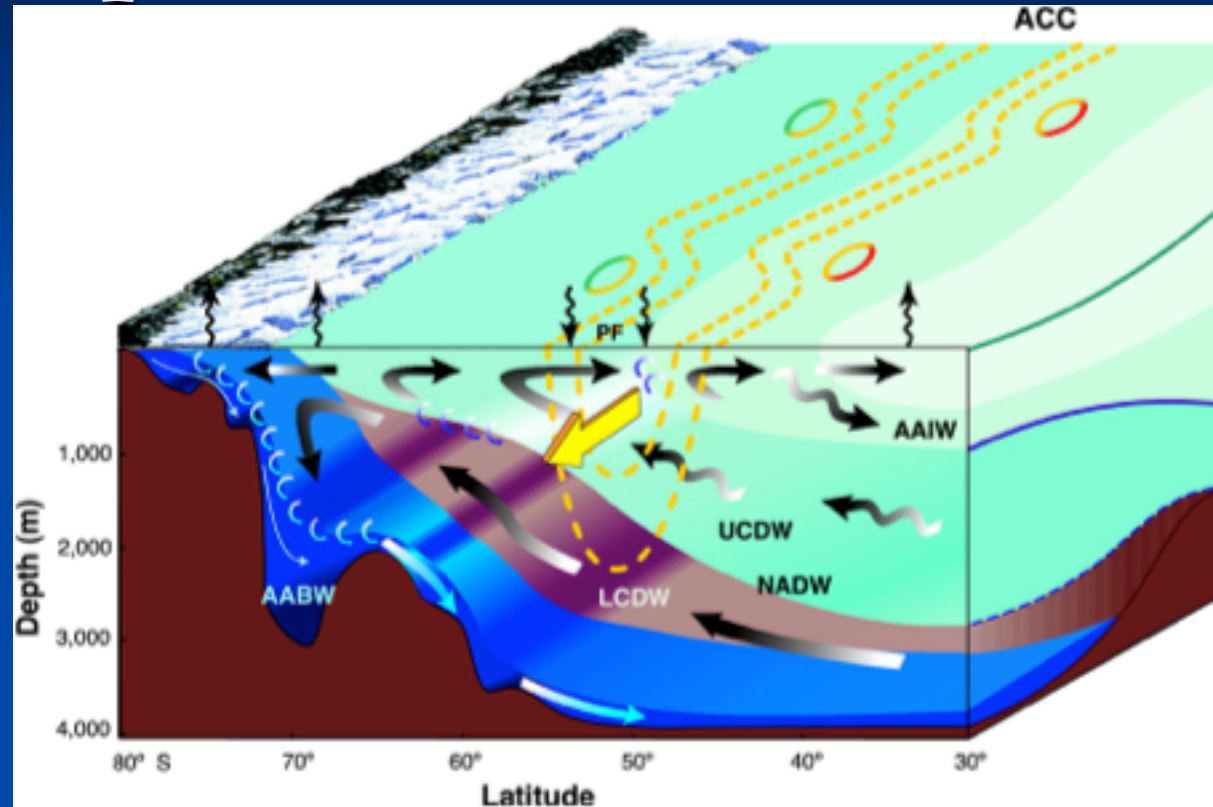
Colm Sweeney  
NOAA/Univ. of Colorado

Tim Newberger  
NOAA/Univ. of Colorado



# Southern Ocean has global importance

- 40% of anthropogenic CO<sub>2</sub> uptake to date (Khatiwala et al., 2009)
- SO Nutrients support ~75% of the global ocean biological production (Sarmiento et al., 2004)

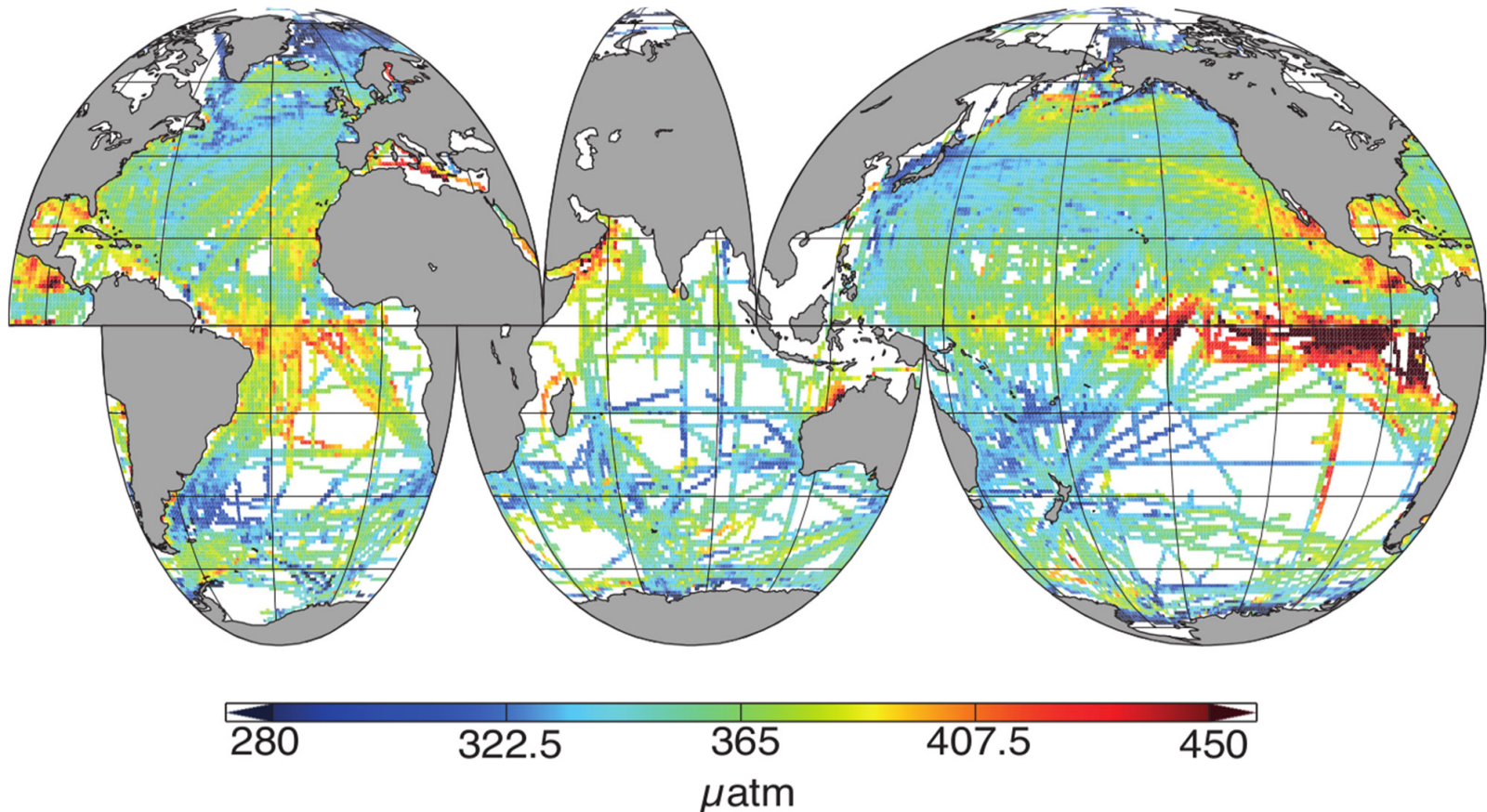




# Ocean pCO<sub>2</sub> measurements

## The SOCAT database

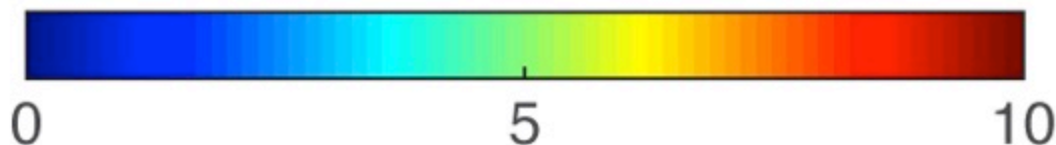
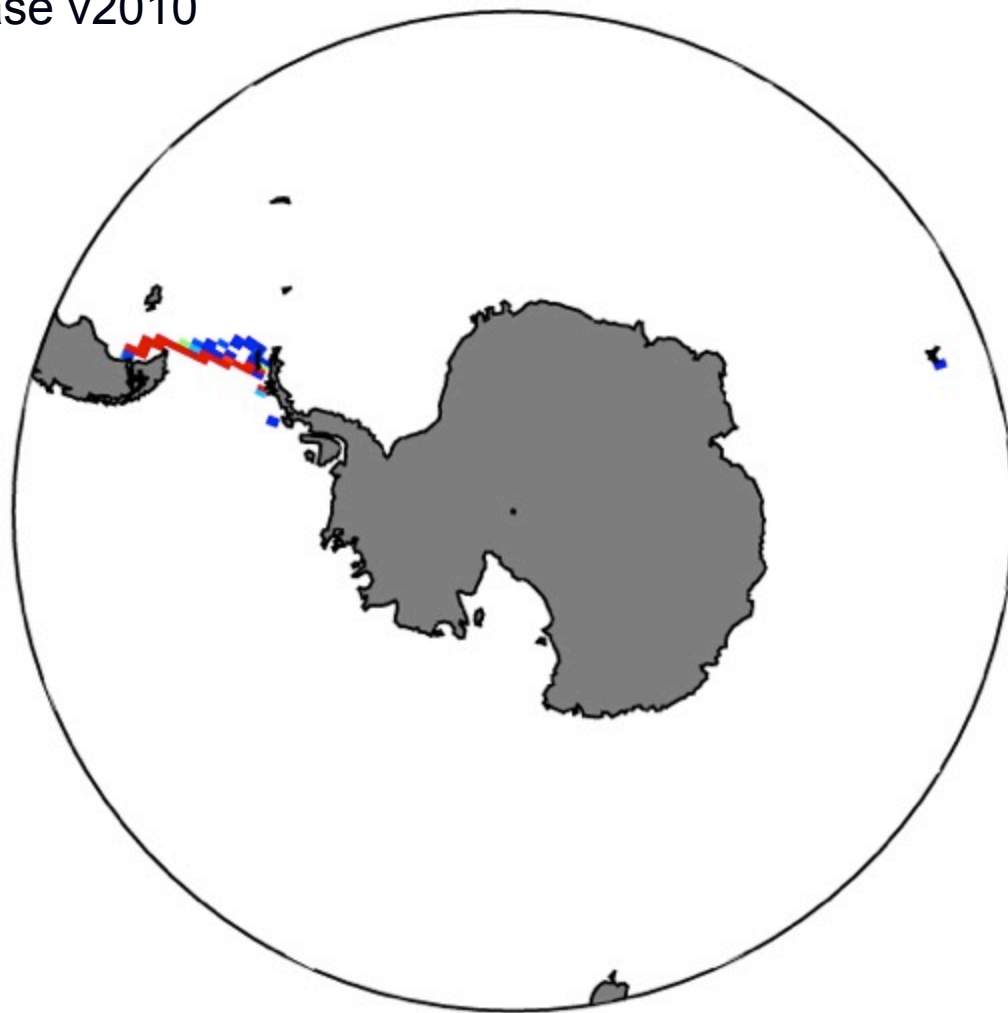
(1982-2014)



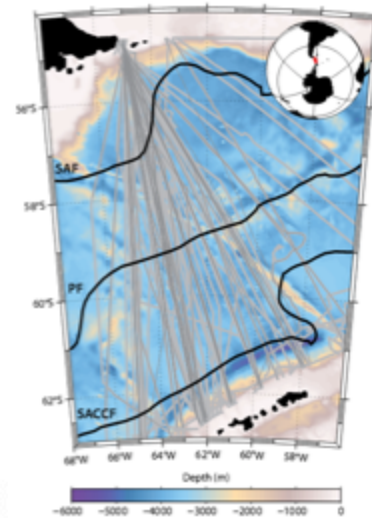
From LDEO database v2010

Temporal coverage of  $p\text{CO}_{2\text{surf}}$  data is sparse for the Southern Ocean – particularly for austral winter

Drake Passage has the best temporal resolution for  $p\text{CO}_{2\text{surf}}$  of any region in the Southern Ocean



Number of years with  $p\text{CO}_{2\text{surf}}$  data from at least six different months



Sprintall et al. (2012)





# Drake Passage Time-series

## Surface Ocean Measurements

### Underway

(~18-24 crossings yr<sup>-1</sup>)

ADCP (since 1996)

Atm and Oce CO<sub>2</sub> (since 2002)

Oce O<sub>2</sub> (since 2004)

### Discrete

(~6-8 crossings yr<sup>-1</sup>)

XBT/XCTD (since 1996)

TCO<sub>2</sub> (since 2002)

PO<sub>4</sub> (Since 2002)

NO<sub>3</sub> and SiO<sub>4</sub> (Since 2005)

<sup>13</sup>C of TCO<sub>2</sub> (since 2005)

<sup>14</sup>C of TCO<sub>2</sub> (2005 – 2010)

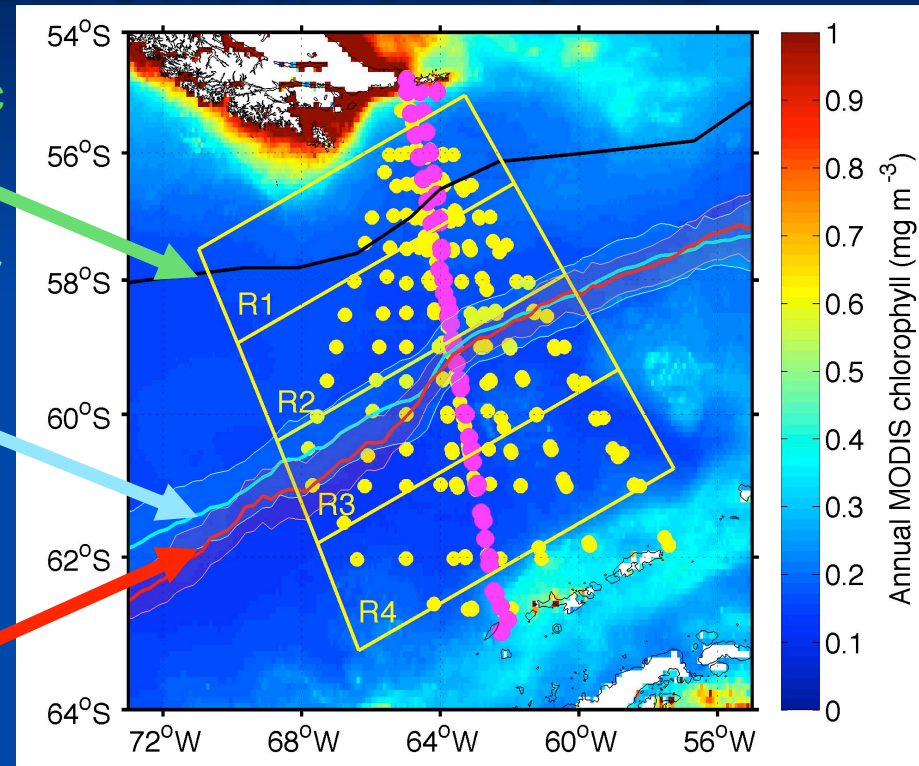
### Total water column

(Mar 2006 and Sep 2009)

Subantarctic  
Front

Winter Polar  
Front (JAS)

Summer  
Polar Front  
(JFM)

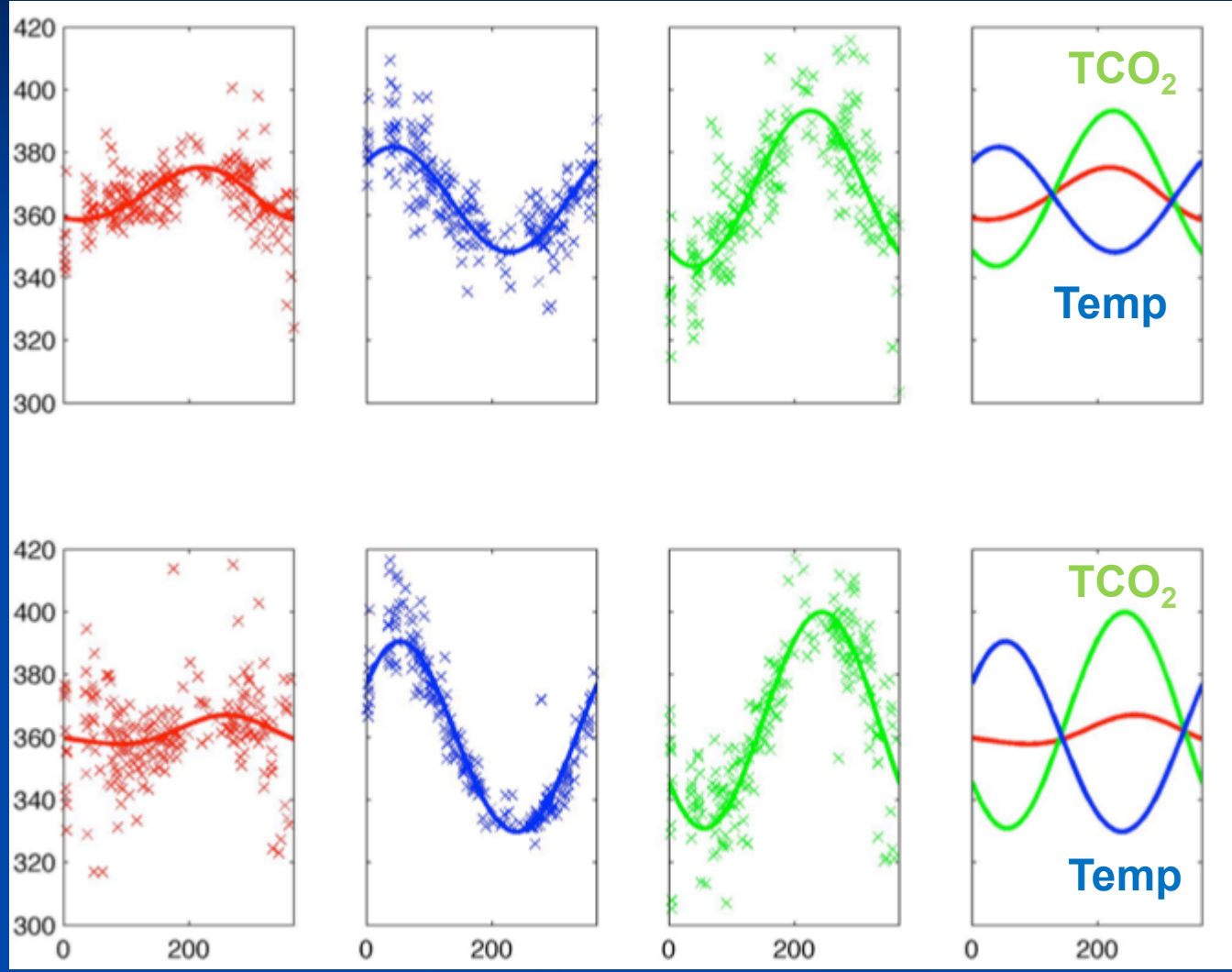


# Annual cycle of pCO<sub>2</sub> in Drake Passage

Observed pCO<sub>2</sub>      Temp-driven pCO<sub>2</sub>      TCO<sub>2</sub>-driven pCO<sub>2</sub>

Region 1  
(N of APF)

μatm



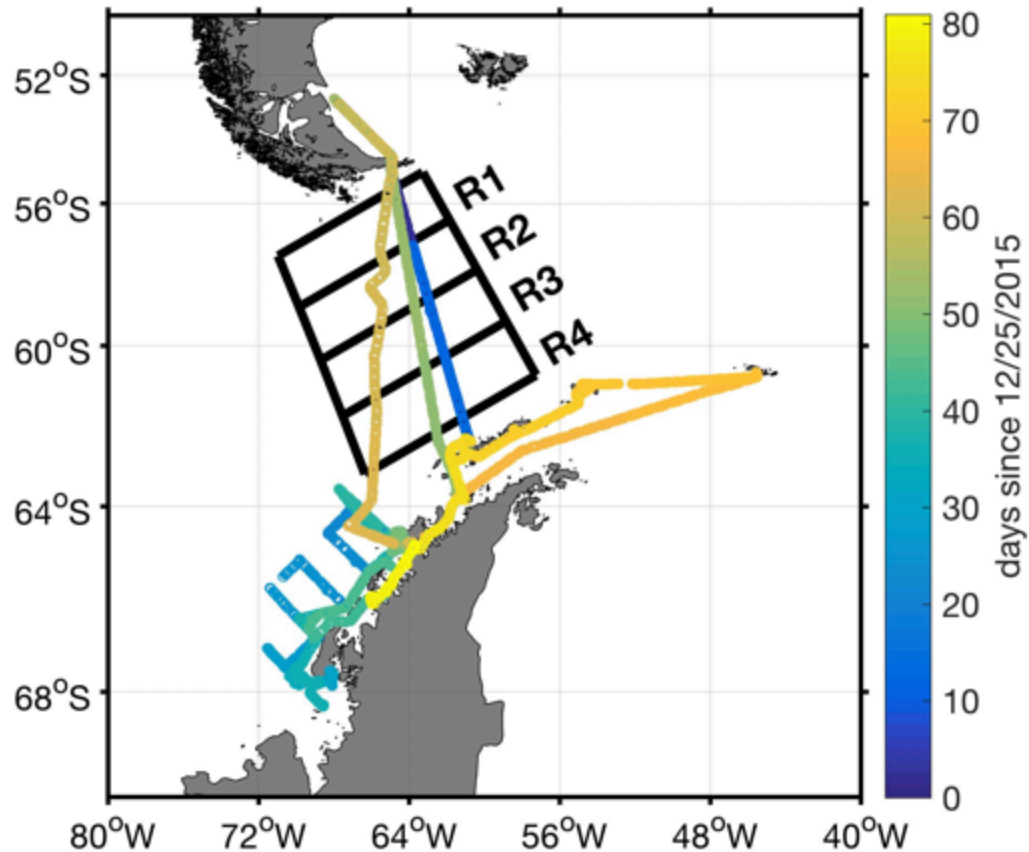
Region 4  
(S of APF)

Year day

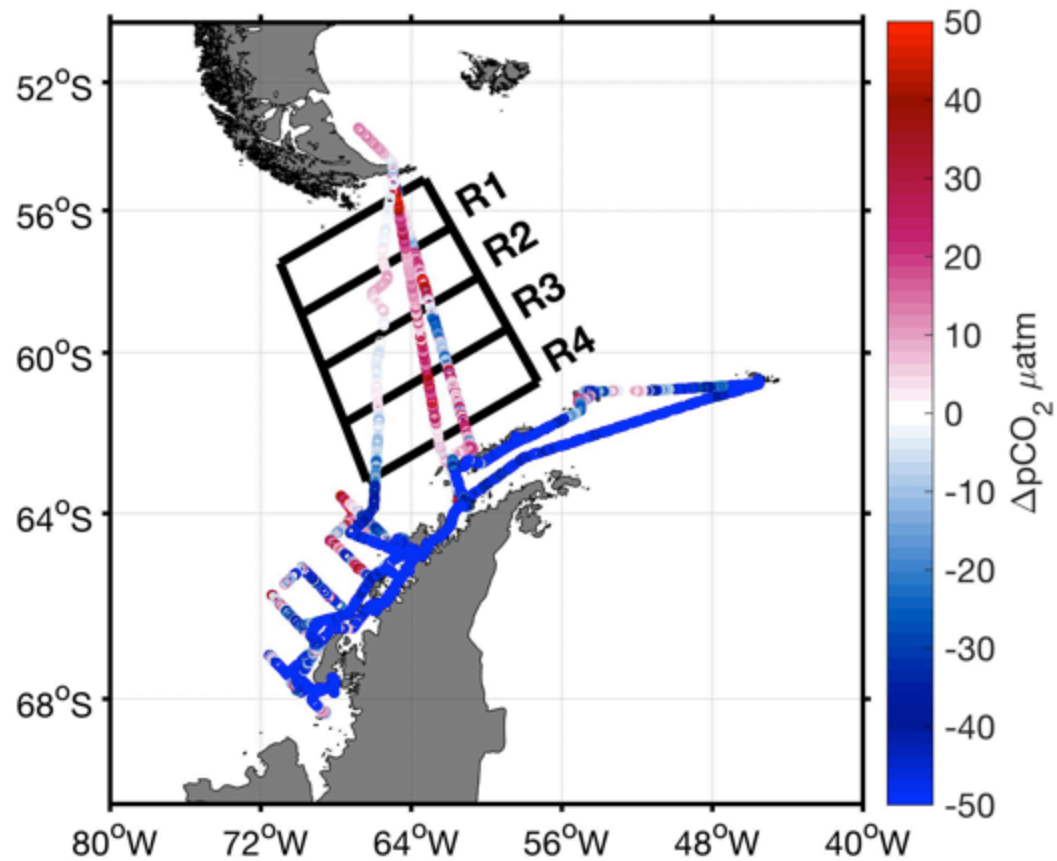
Munro et al. (2015)



# pCO<sub>2</sub><sub>oce</sub> obs during ORCAS

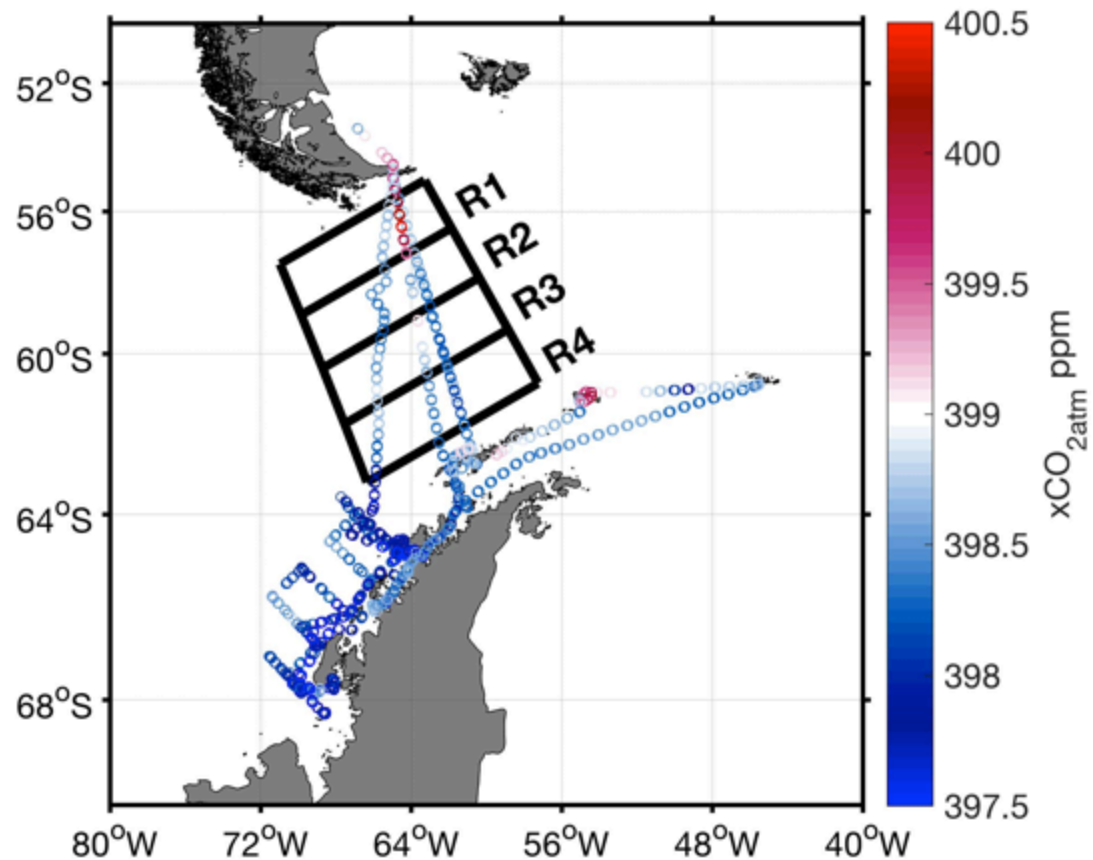


# $\Delta p\text{CO}_2$ obs during ORCAS

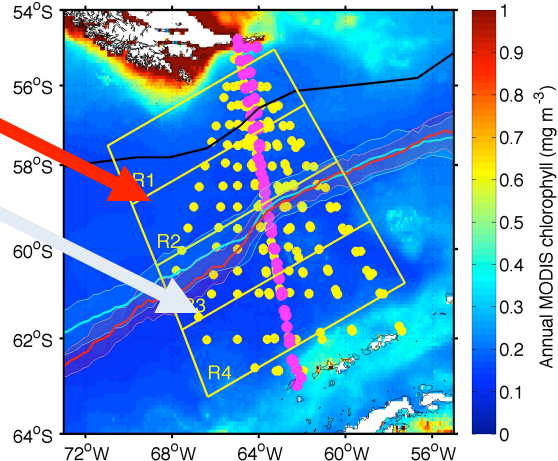




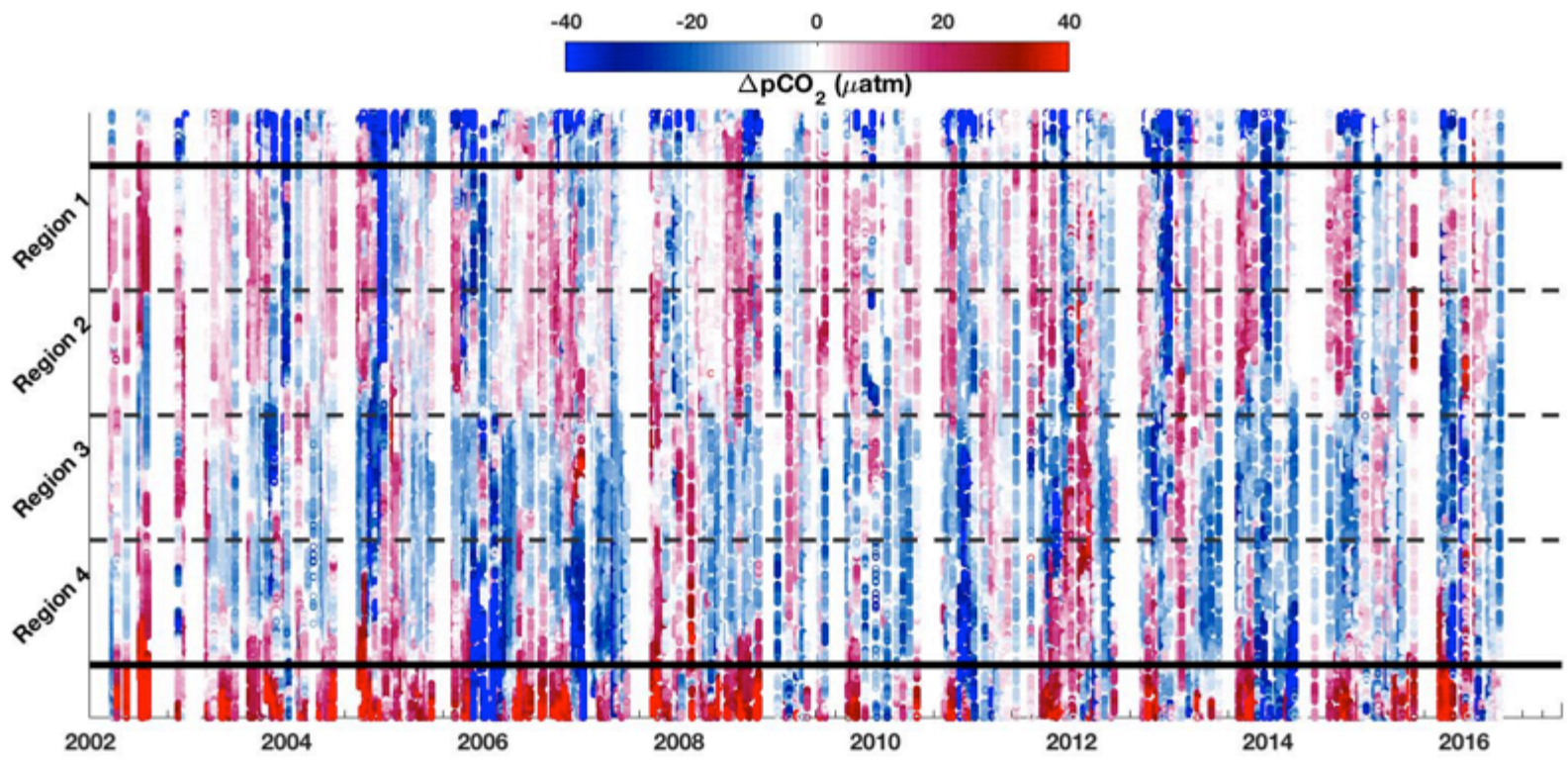
# $x\text{CO}_{2\text{atm}}$ obs during ORCAS



- N of Polar Front ( $\Delta p\text{CO}_2 +$ ) source (R1 and R2)
- S of Polar Front ( $\Delta p\text{CO}_2 -$ ) sink (R3 and R4)
- $\Delta p\text{CO}_2$  more negative ( $\uparrow$  ocean uptake) south of the Polar Front over the time series

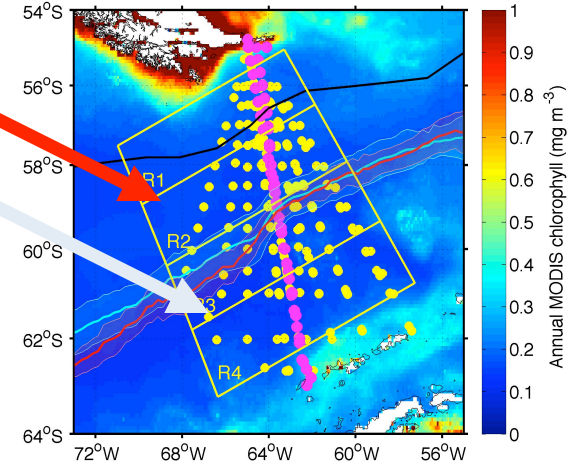


$$\Delta p\text{CO}_2 = p\text{CO}_{2\text{oce}} - p\text{CO}_{2\text{atm}}$$

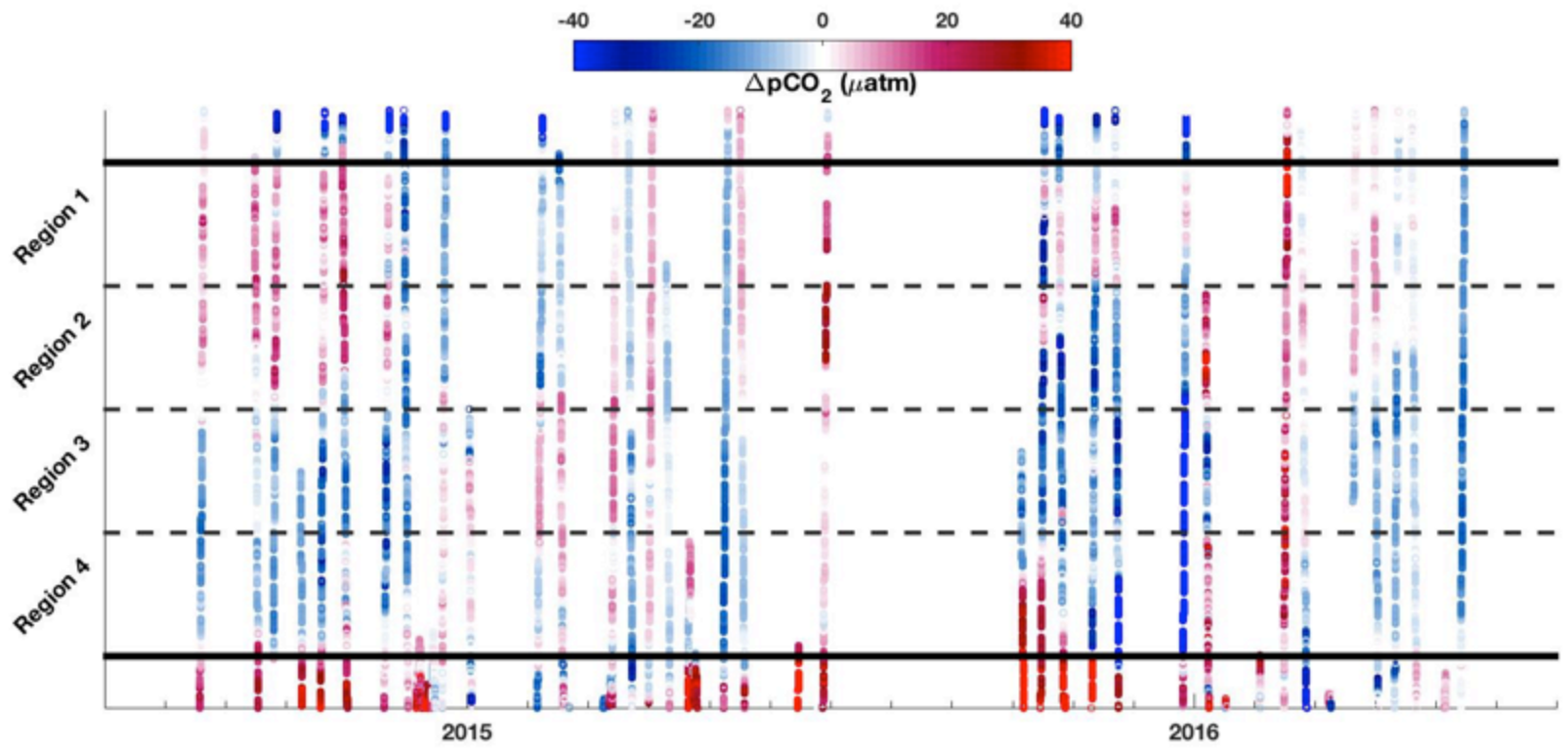




- N of Polar Front ( $\Delta p\text{CO}_2 +$ ) source (R1 and R2)
- S of Polar Front ( $\Delta p\text{CO}_2 -$ ) sink (R3 and R4)
- $\Delta p\text{CO}_2$  more negative ( $\uparrow$  ocean uptake) south of the Polar Front over the time series

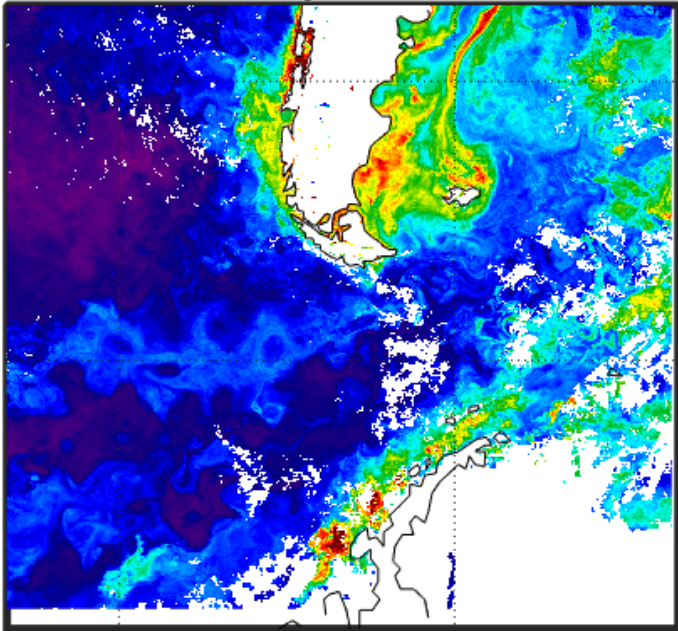


- $\Delta p\text{CO}_2 = p\text{CO}_{2\text{oce}} - p\text{CO}_{2\text{atm}}$



# CaCO<sub>3</sub> production in DPT: Geochemical evidence for the “Great Calcite Belt”

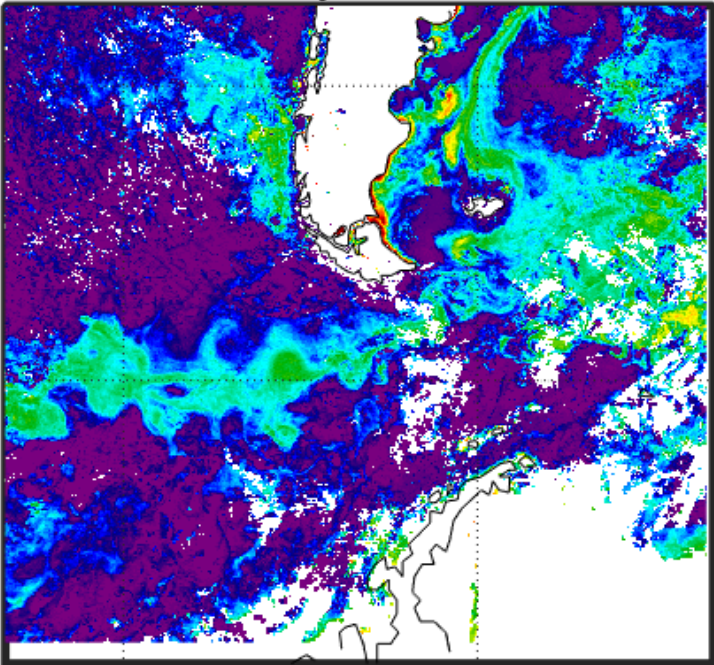
Yearday:009-040 V



0.1 1 10

Log(chl) micrograms/L

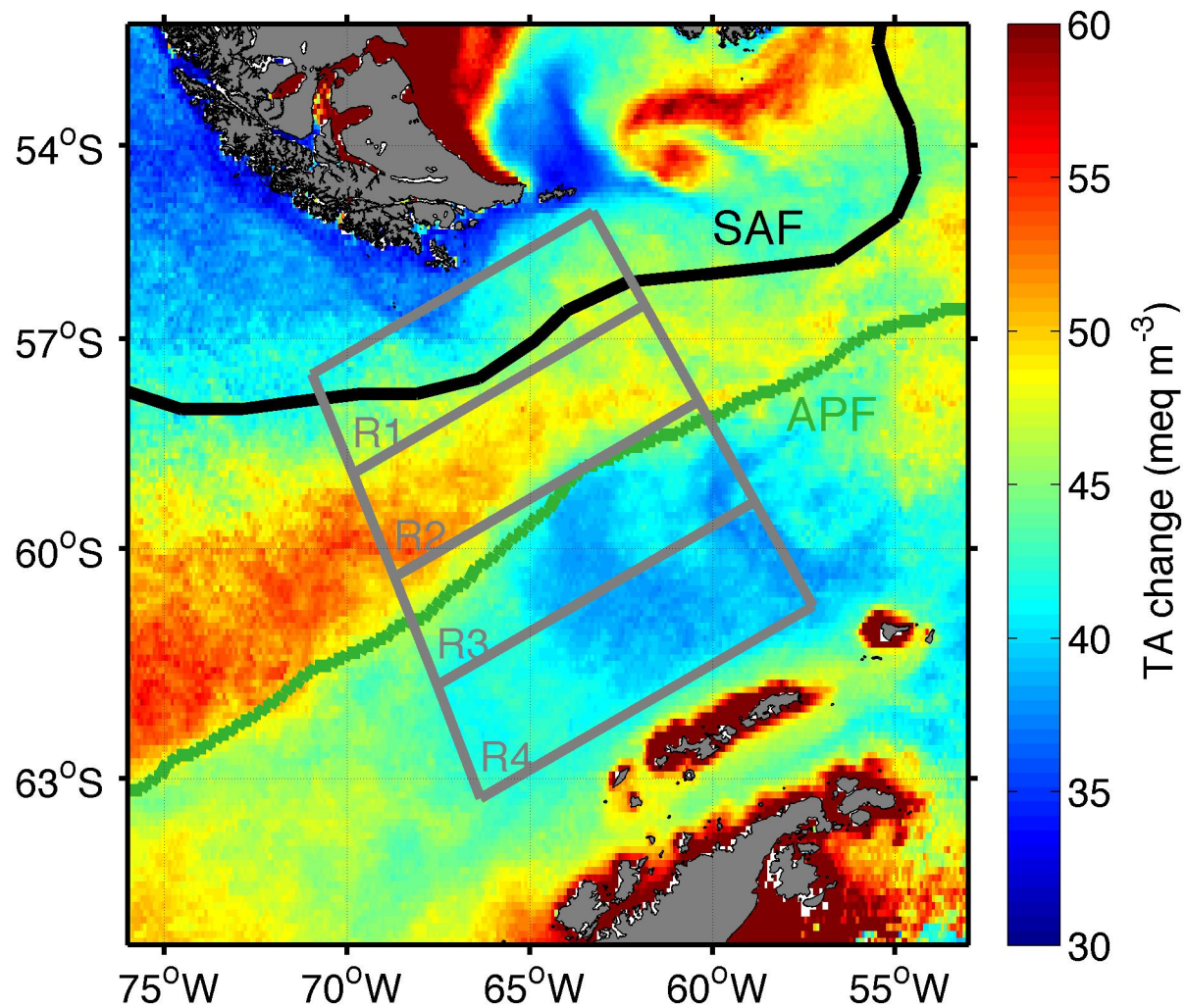
Yearday:009-040 V



-5 -4 -3 -2

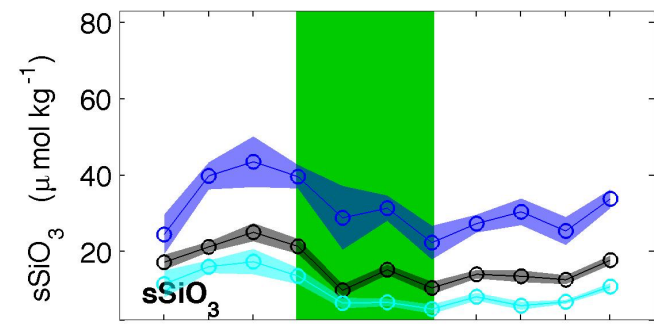
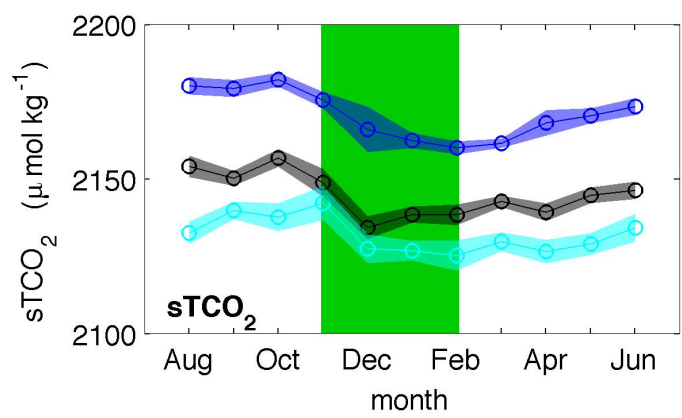
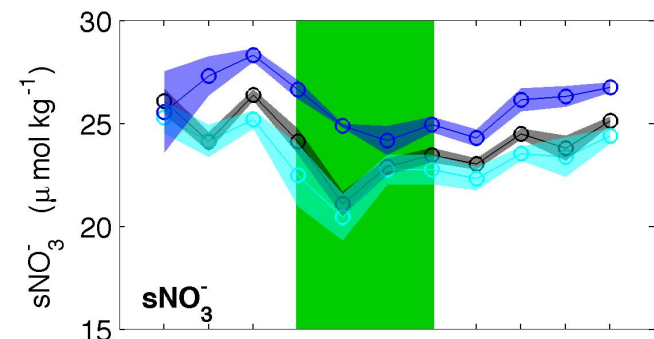
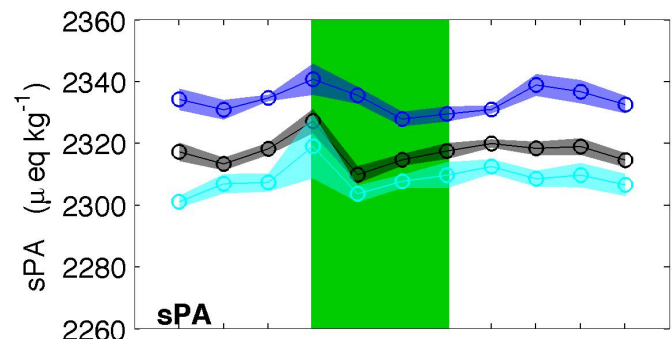
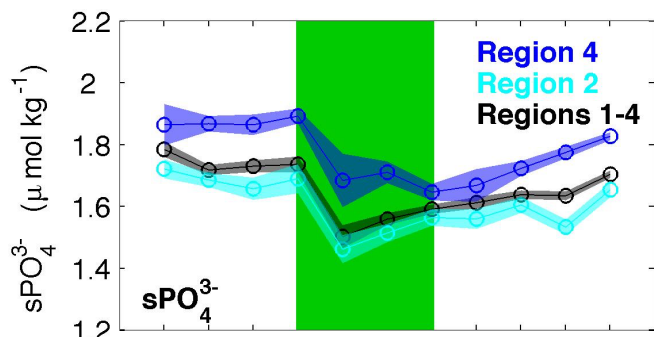
Log(PIC) micrograms/L

# CaCO<sub>3</sub> production in DPT: Estimated change in TA from satellite PIC production

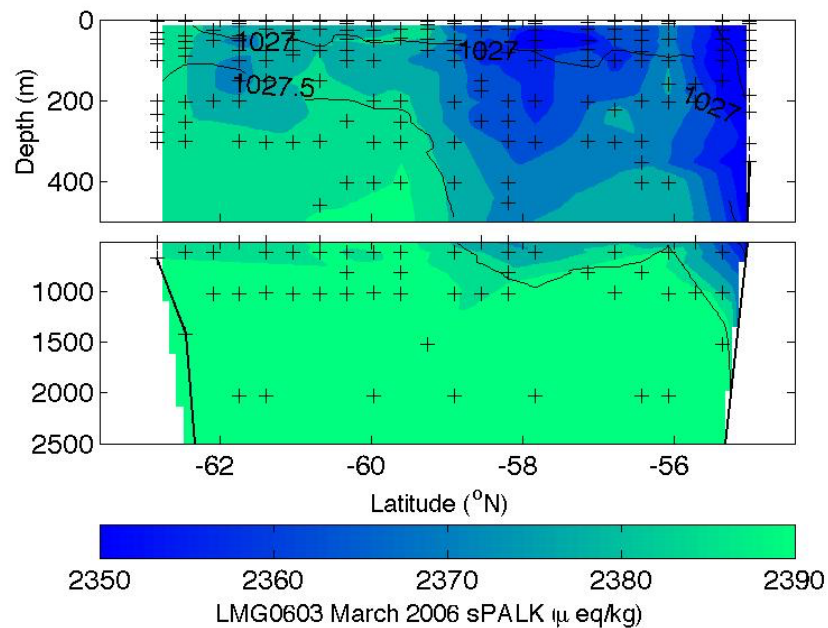
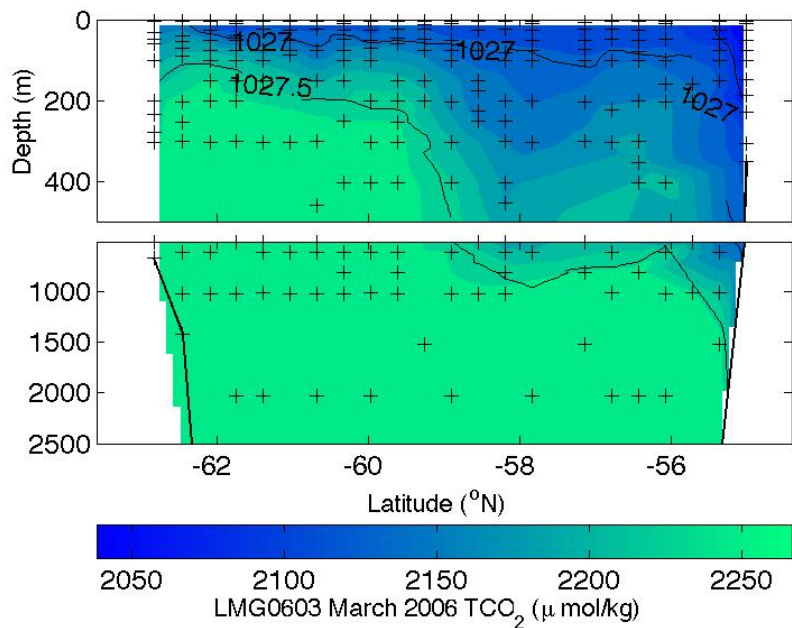
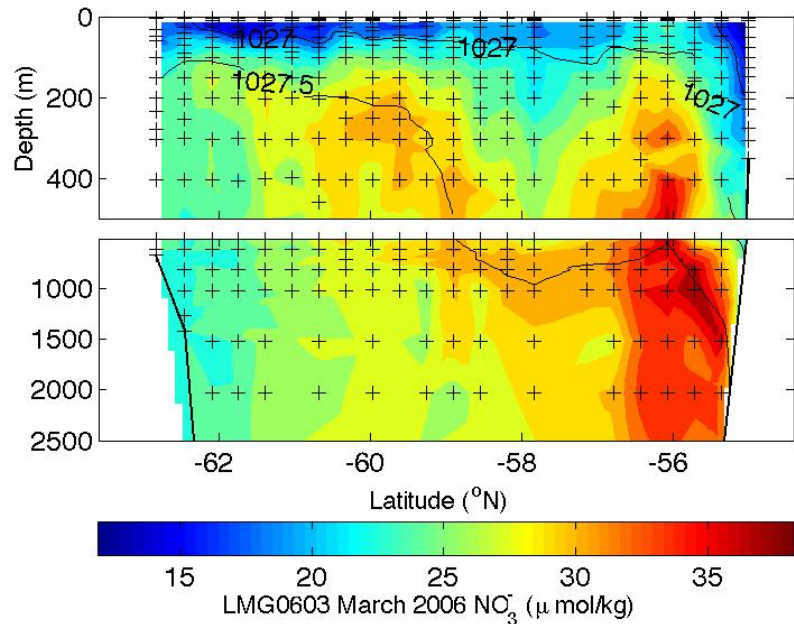
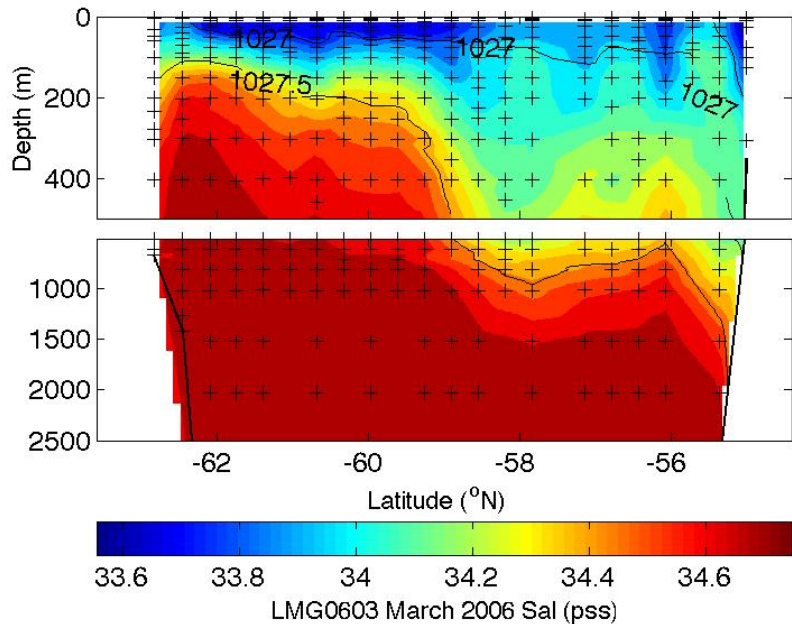




# CaCO<sub>3</sub> production in DPT: Seasonal change in sPA from DPT (2002-2016)



# CaCO<sub>3</sub> production in DPT: Depth profiles from March 2006



# CaCO<sub>3</sub> production in DPT: Depth profiles from March 2006

## Drake Passage March 2006 cruise

Region	Number of Stations	PIC:OC Export Ratio
1	3	0.074
2	4	0.075
3	6	0.015
4	6	0.001
Regions 1-4	19	0.029

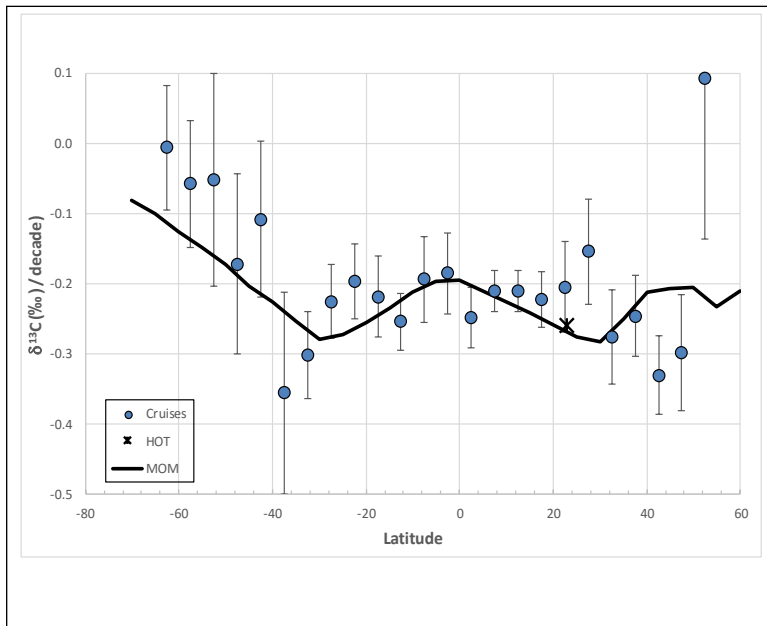
## GLODAP version 2

Region	Number of Stations	PIC:OC Export Ratio
Atlantic Ocean		
30 to 45°S	205	0.066
45 to 60°S	192	0.022
60 to 75°S	194	0.028
45 to 75°S	386	0.025
Indian Ocean		
30 to 45°S	434	0.089
45 to 60°S	185	0.003
60 to 75°S	126	0.023
45 to 75°S	311	0.011
Pacific Ocean		
30 to 45°S	461	0.081
45 to 60°S	365	0.008
60 to 75°S	224	0.034
45 to 75°S	589	0.021

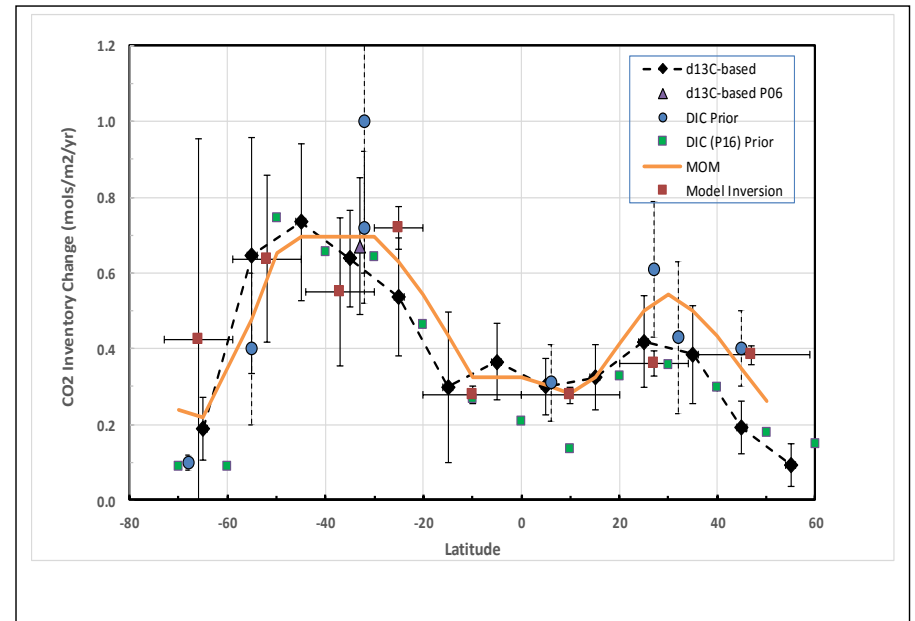


# Anthropogenic C uptake from DPT

$$\delta^{13}\text{C}_{\text{TCO}_2}$$



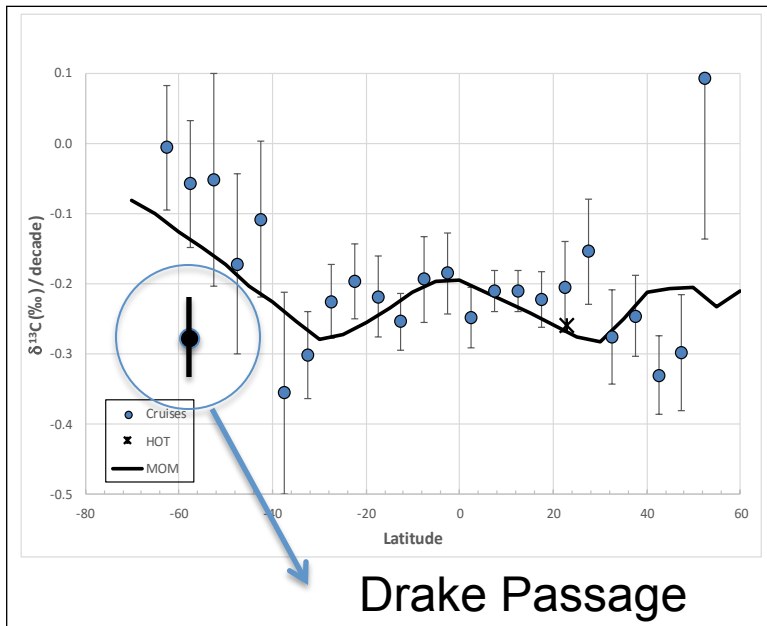
Surface  $\delta^{13}\text{C}_{\text{TCO}_2}$  change from the 1990s to the 2000s



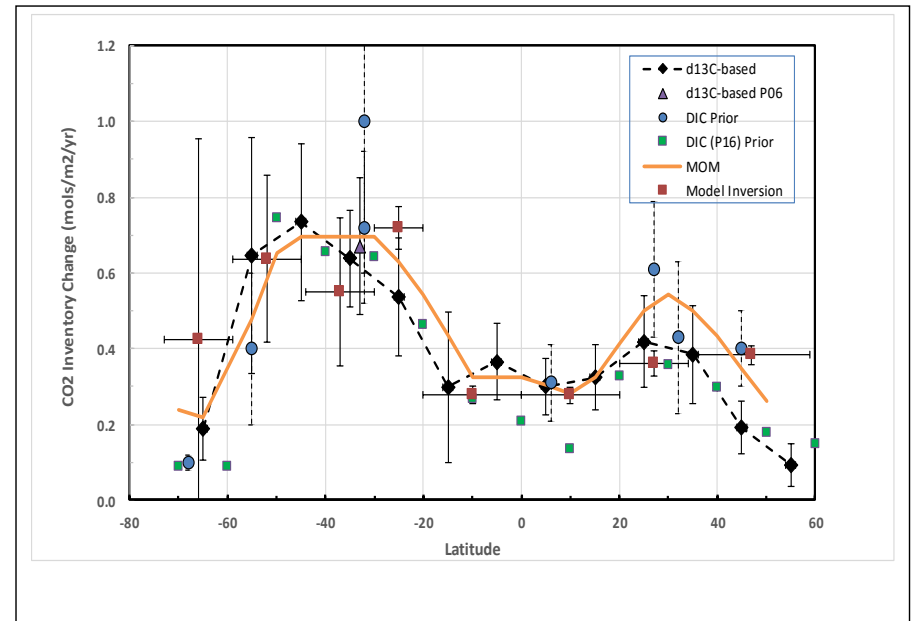
Interior C inventory change from the 1990s to the 2000s based on  $\delta^{13}\text{C}_{\text{TCO}_2}$  depth profiles

# Anthropogenic C uptake from DPT

$$\delta^{13}\text{C}_{\text{TCO}_2}$$



Surface  $\delta^{13}\text{C}_{\text{TCO}_2}$  change from the 1990s to the 2000s



Interior C inventory change from the 1990s to the 2000s based on  $\delta^{13}\text{C}_{\text{TCO}_2}$  depth profiles

# Conclusions

- Drake Passage Time-series provides the densest dataset of ocean  $p\text{CO}_2$  in the Southern Ocean
- DPT observations help constrain:
  - 1) Biological production in the ocean
  - 2) Ocean uptake of  $\text{CO}_2$
  - 3)  $\text{CaCO}_3$  production in the surface ocean



# Questions

