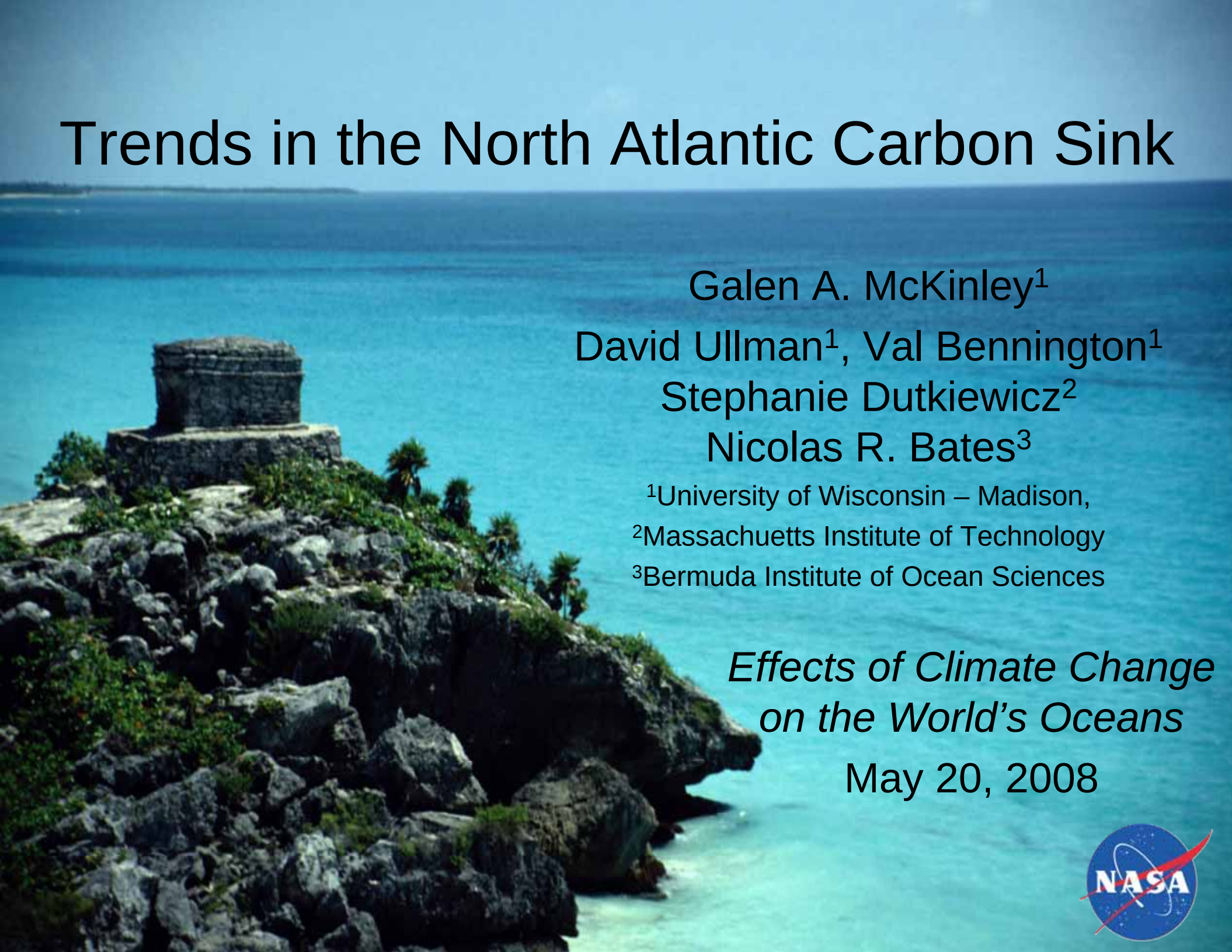
Trends in the North Atlantic Carbon Sink



Galen A. McKinley[1]

David Ullman[1], Val Bennington[1]

Stephanie Dutkiewicz[2]

Nicolas R. Bates[3]

[1]University of Wisconsin – Madison,

[2]Massachuetts Institute of Technology

[3]Bermuda Institute of Ocean Sciences

Effects of Climate Change on the World's Oceans

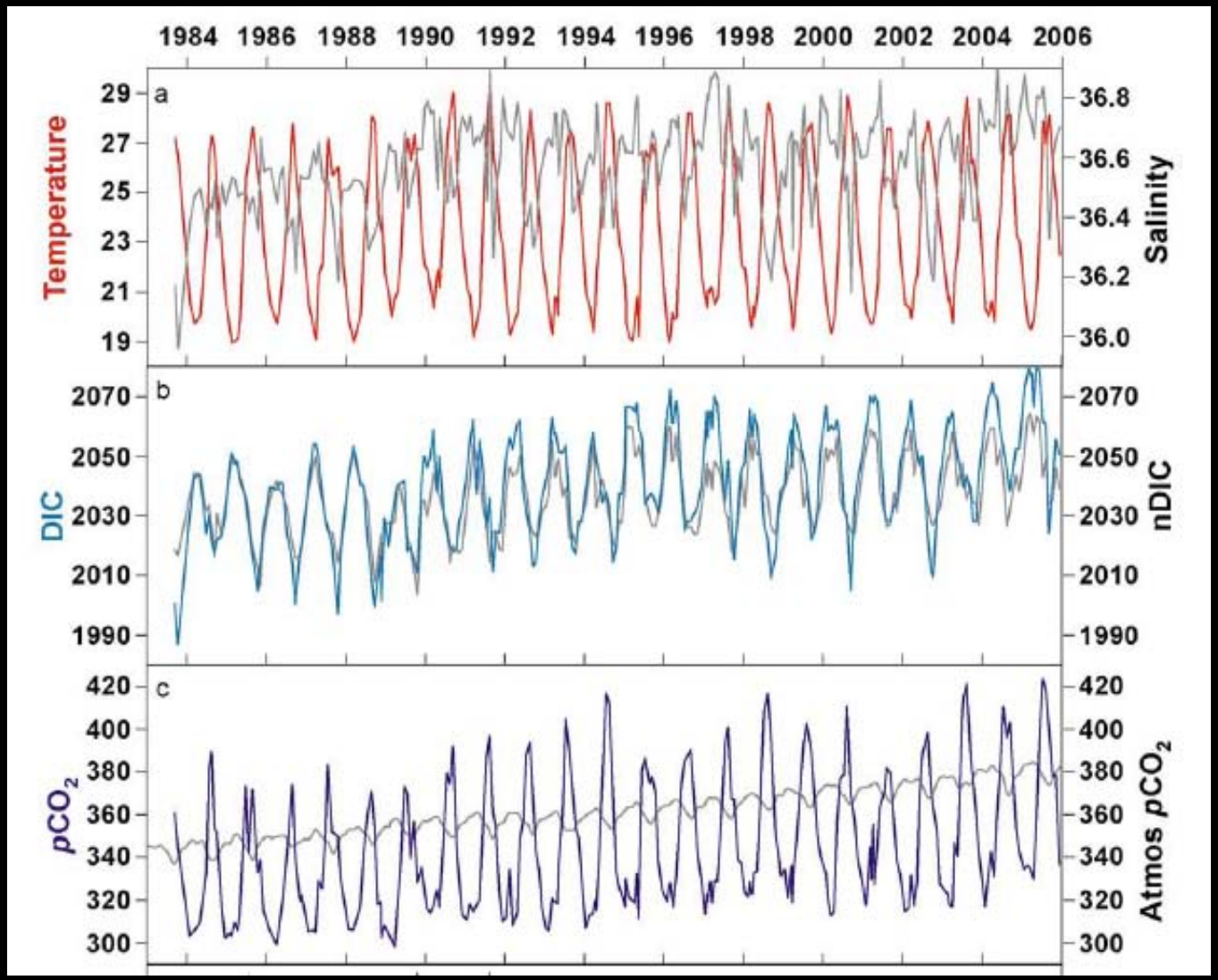
May 20, 2008

Overview

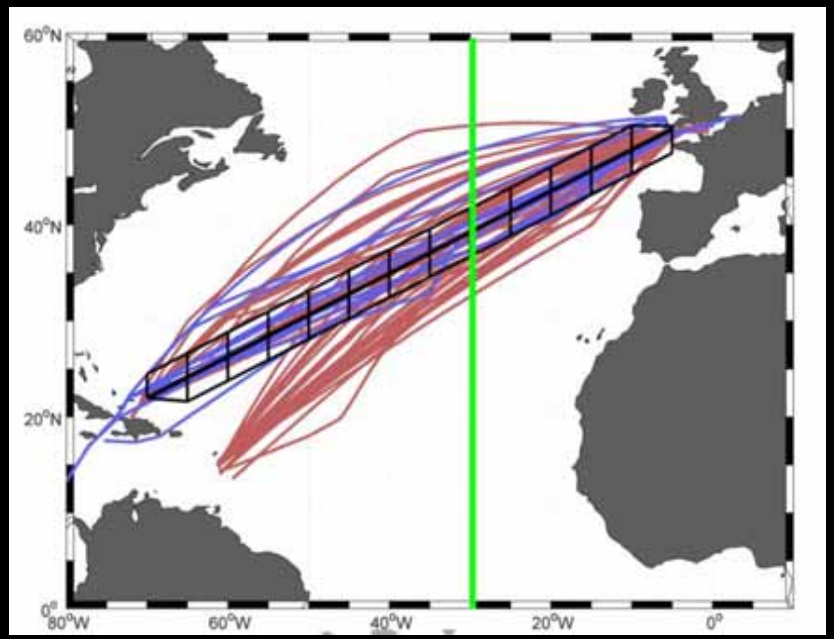
- N. Atlantic carbon cycle variability, data
- N. Atlantic regional model
- Basin-scale flux trend, 1992-2006
- Mechanisms driving flux change

Temperature, DIC, pCO_2

1983-2005, merged Hydrostation S and BATS

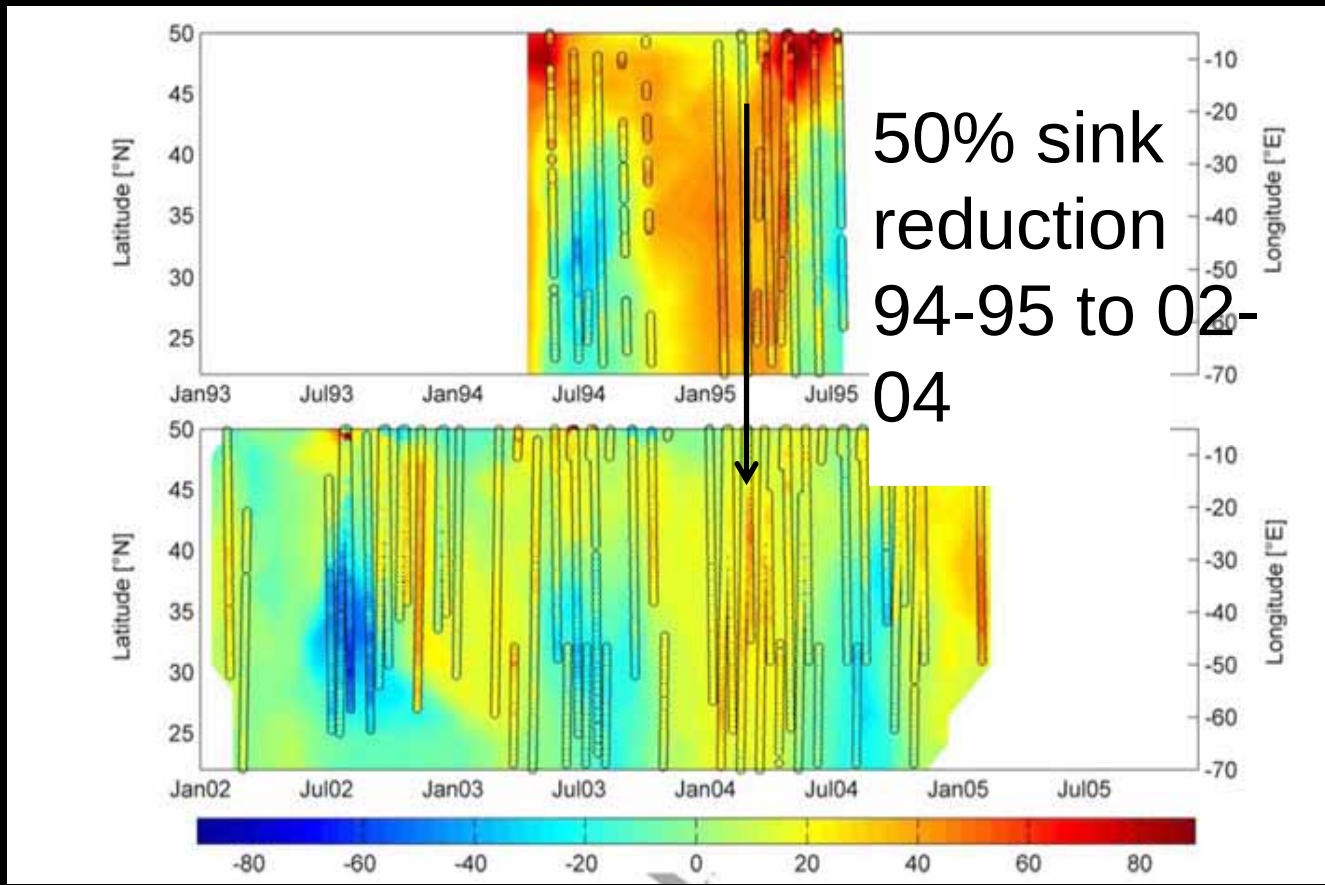


Bates, 2007



Understanding observed trends in ΔpCO_2

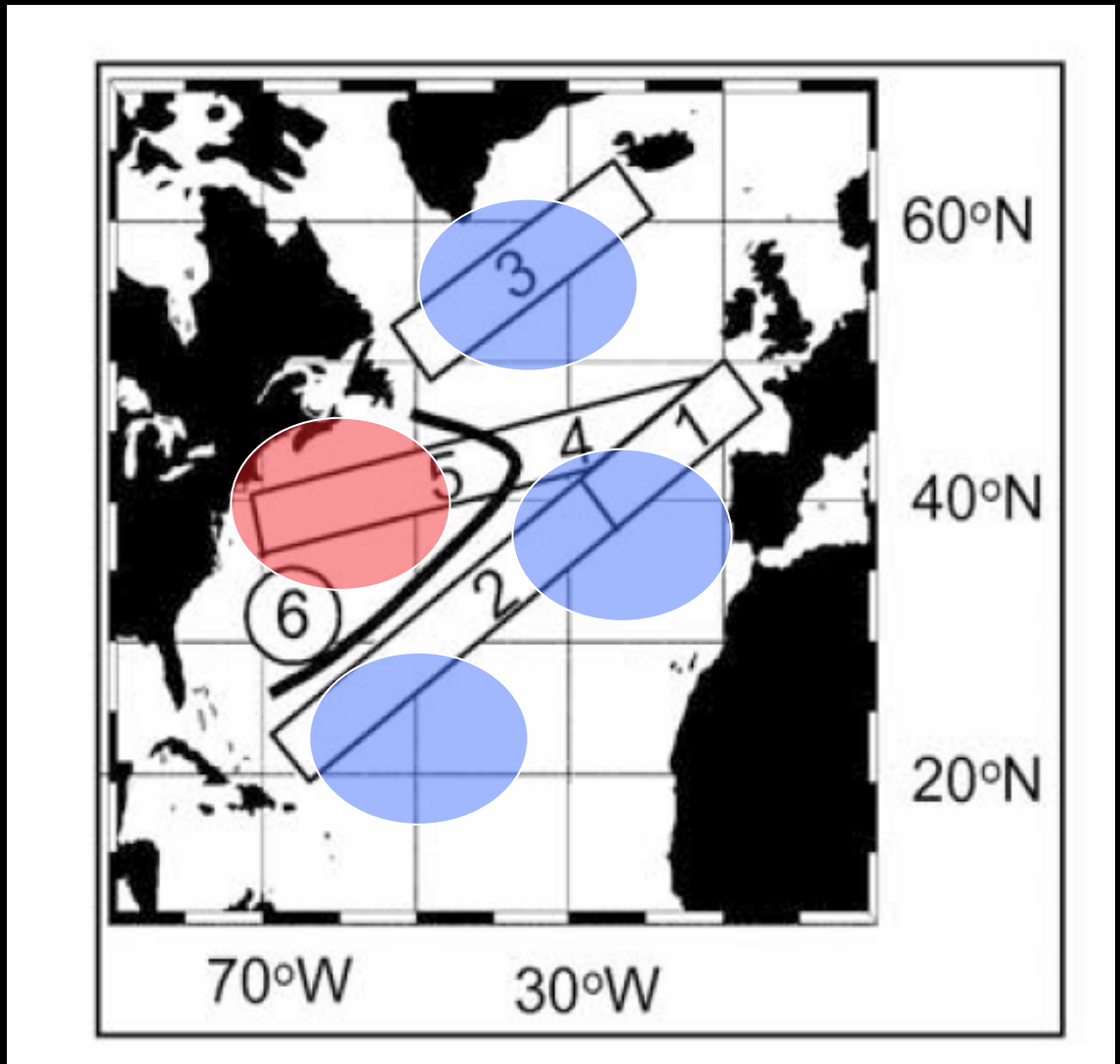
Schuster and Watson, 2007



50% sink reduction 94-95 to 02-04

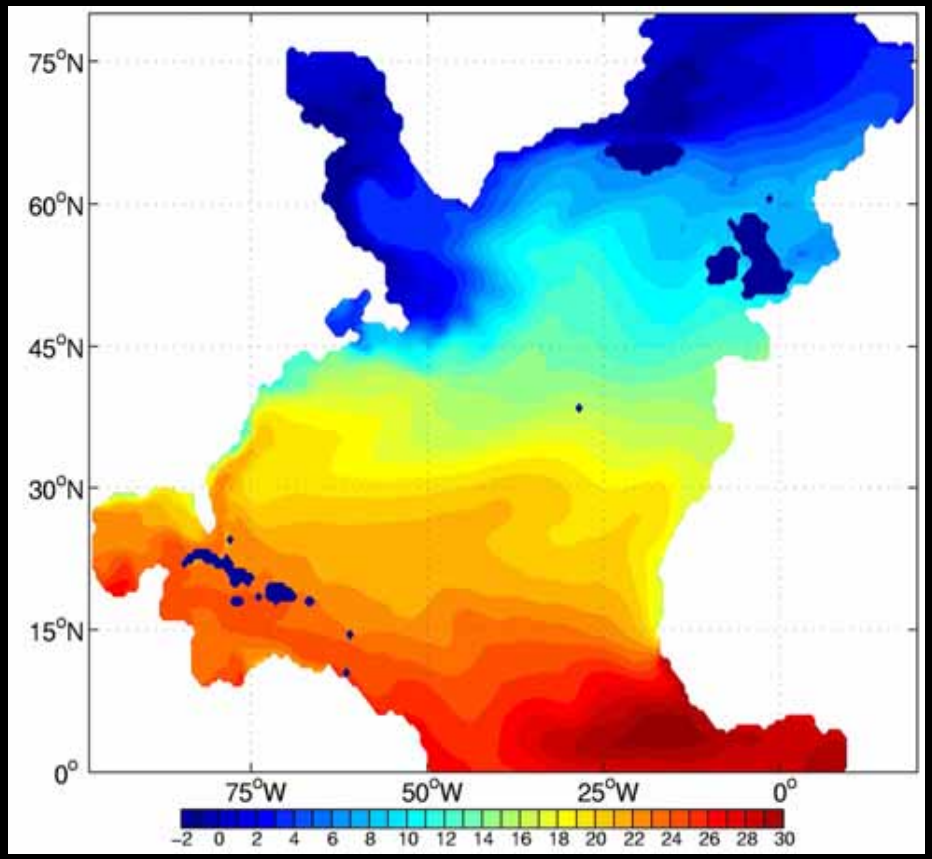
Summary for mid-1990's to early 2000's (Schuster and Watson, 2007)

- Regions 1-4 are declining in CO_2 uptake
- Region 5, 6 are neutral or increasing CO_2 flux



Modeling the North Atlantic carbon cycle

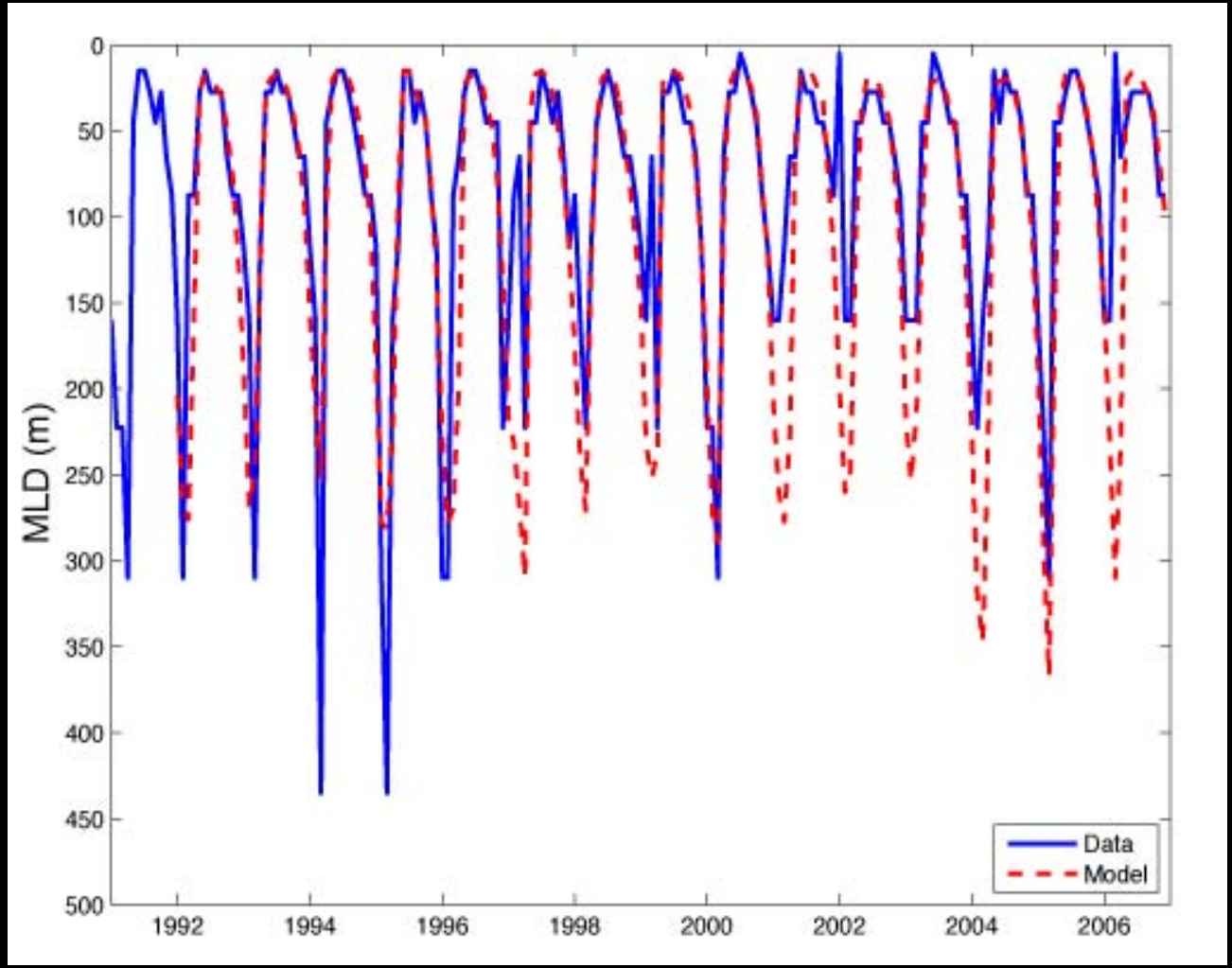
A North Atlantic regional model…



Sea Surface Temperature

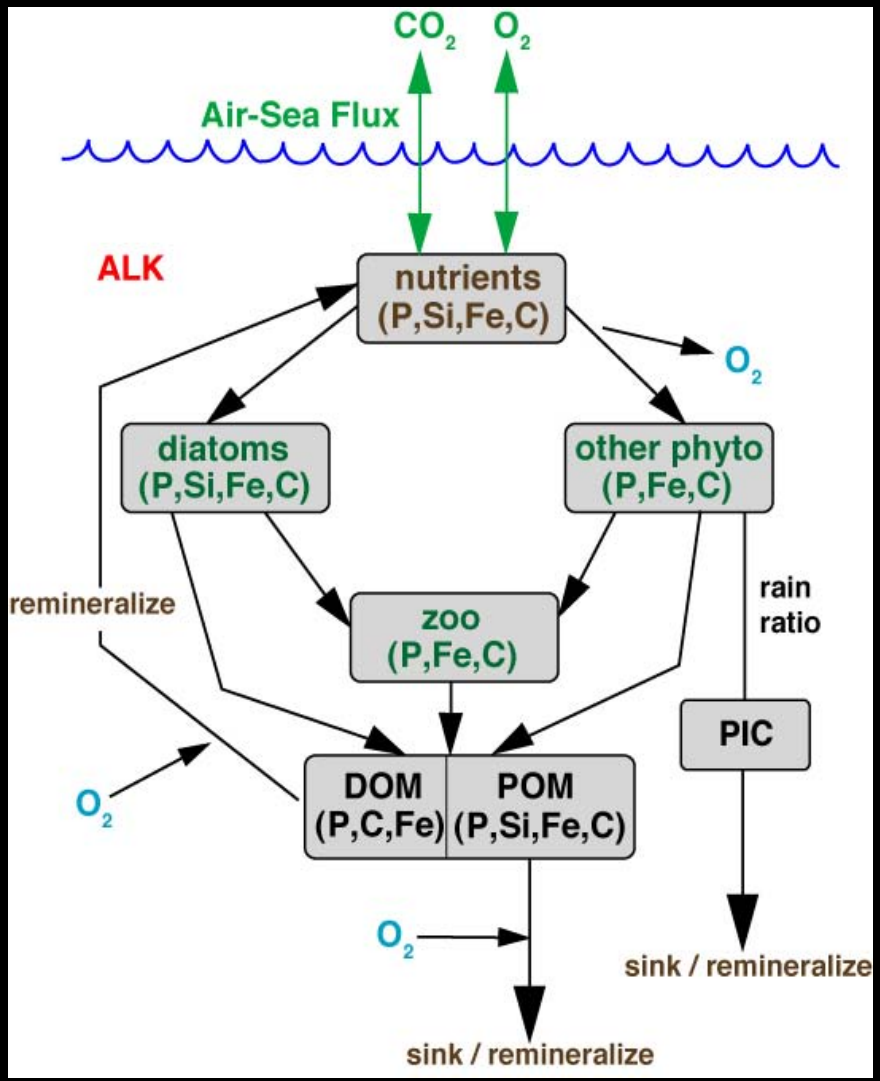
- MITgcm, 20S-80N
- 0.5 x 0.5 horizontal, 23 vertical
- Parameterizations
  - GM-Redi (isopycnal mixing)
  - KPP (mixed layer)
- Forcing:
  - daily NCEP
  - SST restored to Reynolds et al 2002
- 90 year physical spinup
- 10 year biogeochemical spinup
- 15 year (1992-2006) run

Mixed layer depth at Bermuda



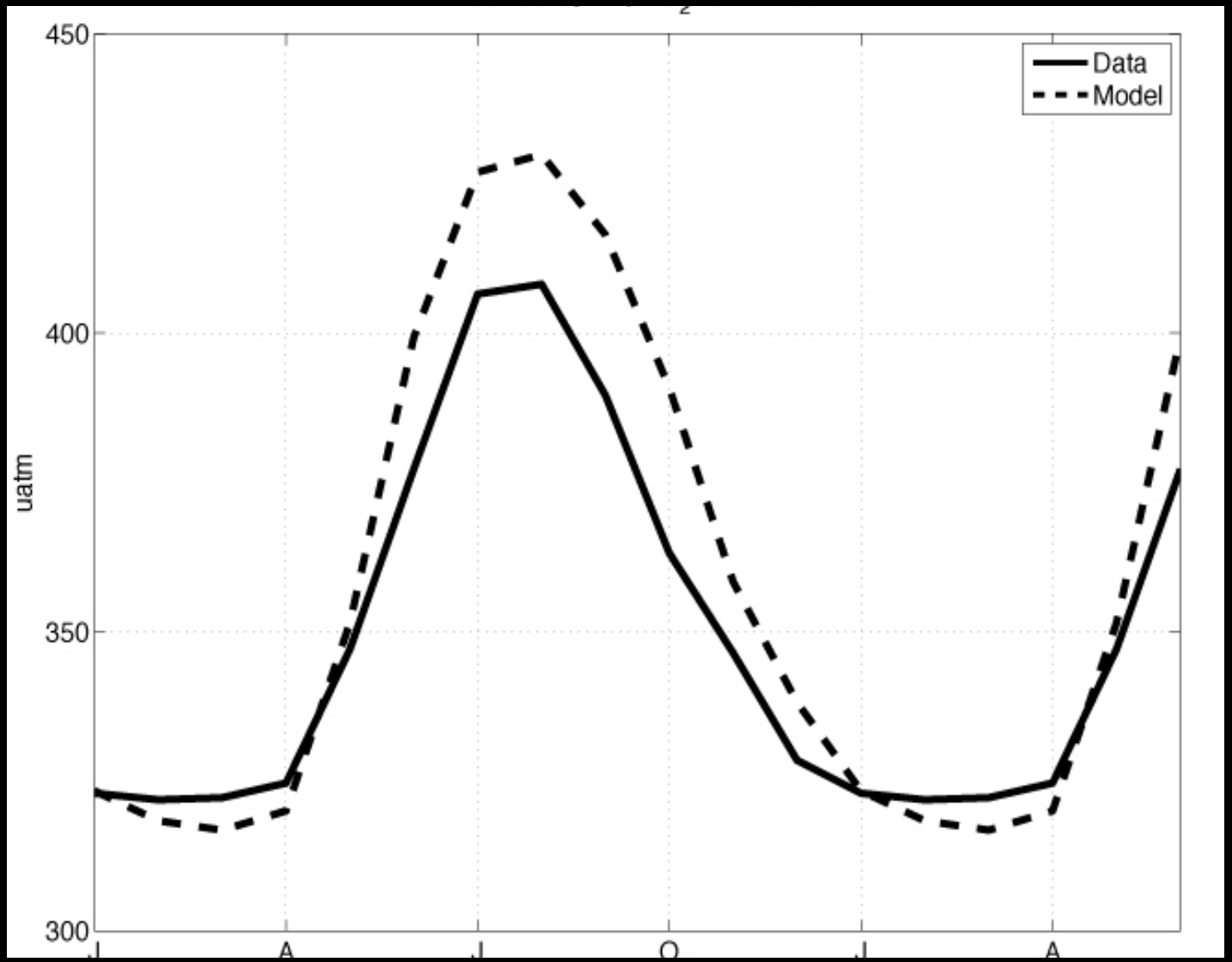
Model (red) captures mixing reasonably well

Ecosystem and carbon cycle



- Dutkiewicz et al. (2005) ecosystem
- 2 phytoplankton, 1 zooplankton class, dissolved and particulate detritus
- Explicit silica and iron
- Coupled carbon and oxygen cycles

pCO_2 seasonal cycle at Bermuda, Data and model

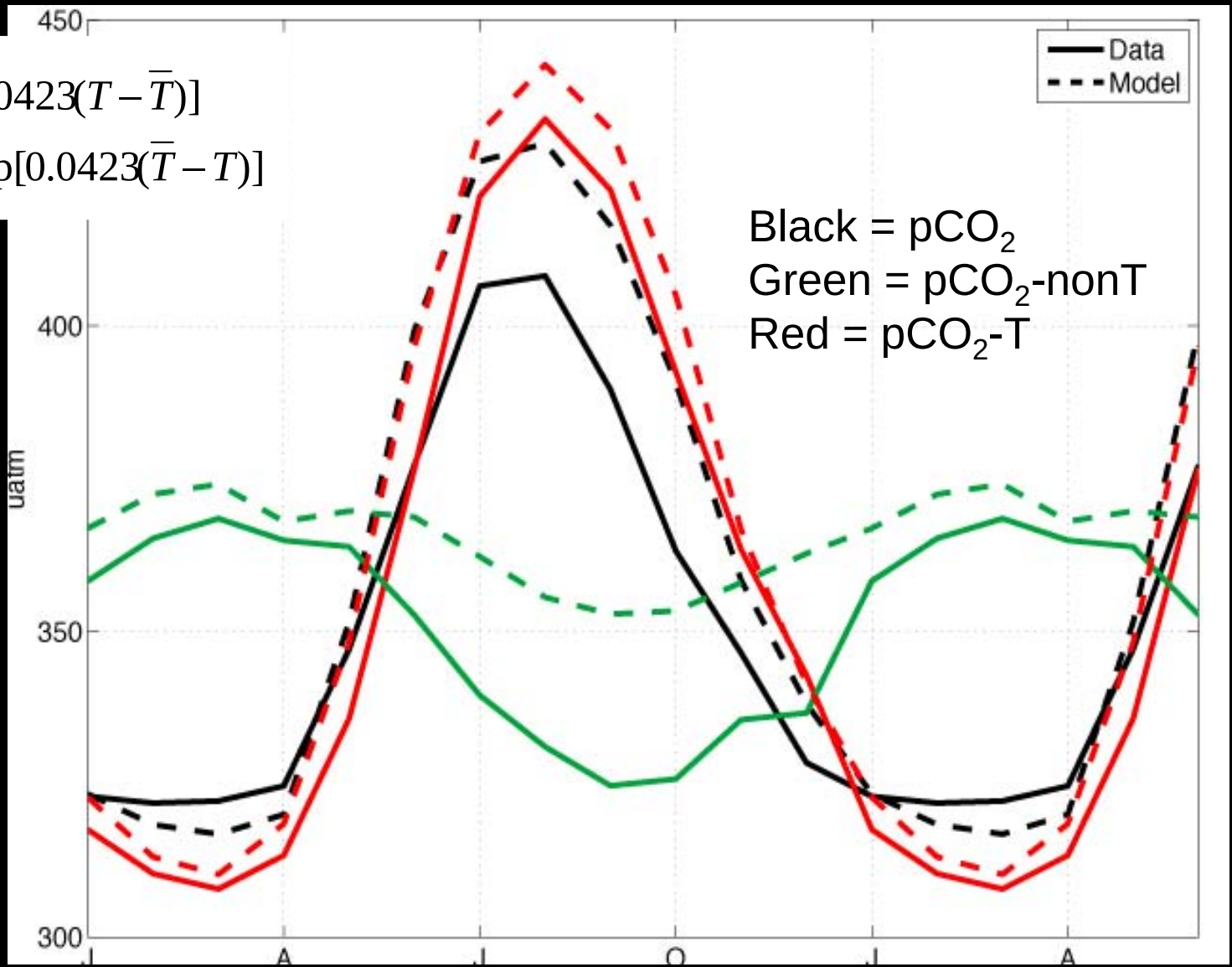


pCO_2 seasonal cycle at Bermuda, Data and model

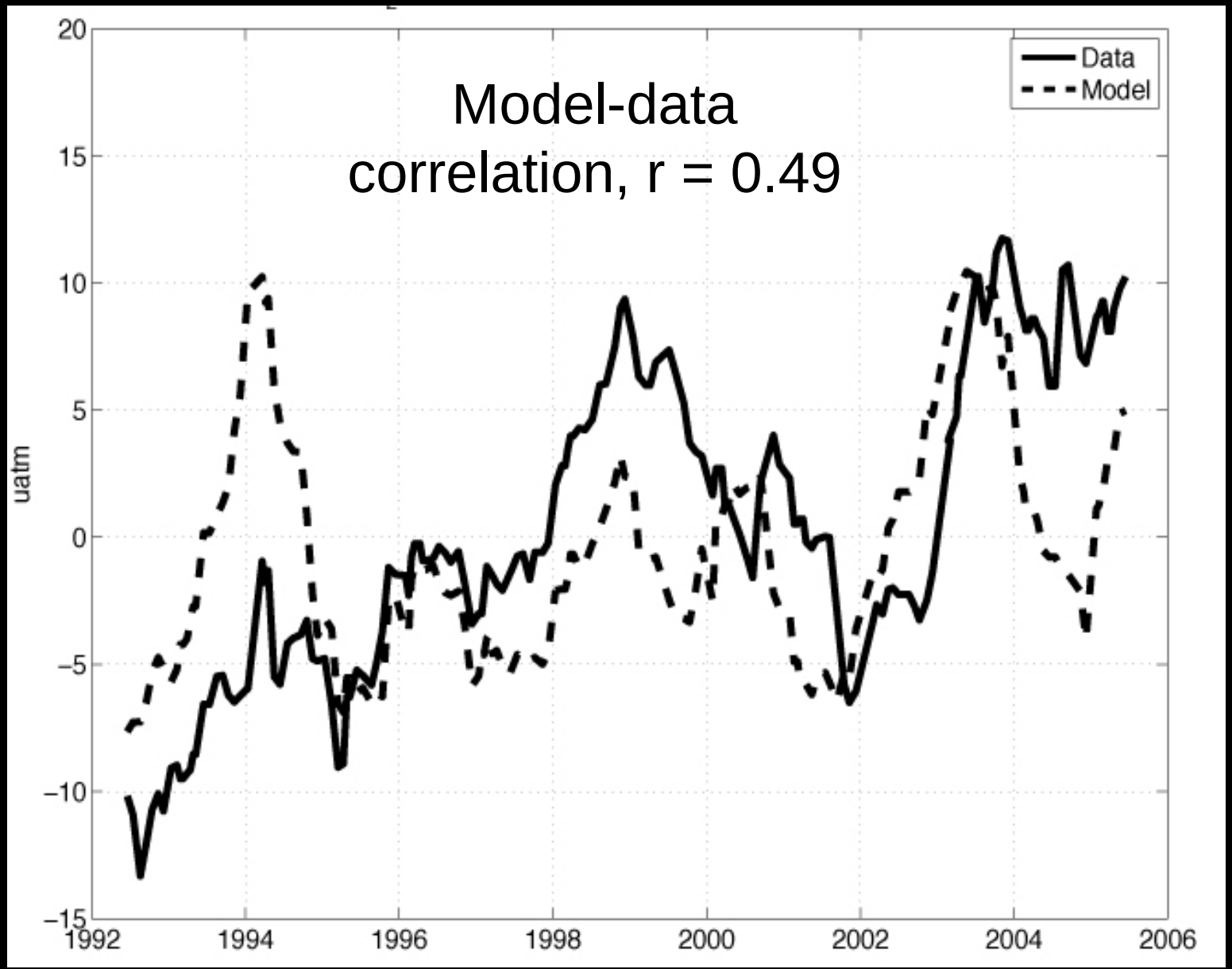
$$pCO_2 - T = \overline{pCO_2} \cdot \exp[0.0423(T - \bar{T})]$$

$$pCO_2 - nonT = pCO_2 \cdot \exp[0.0423(\bar{T} - T)]$$

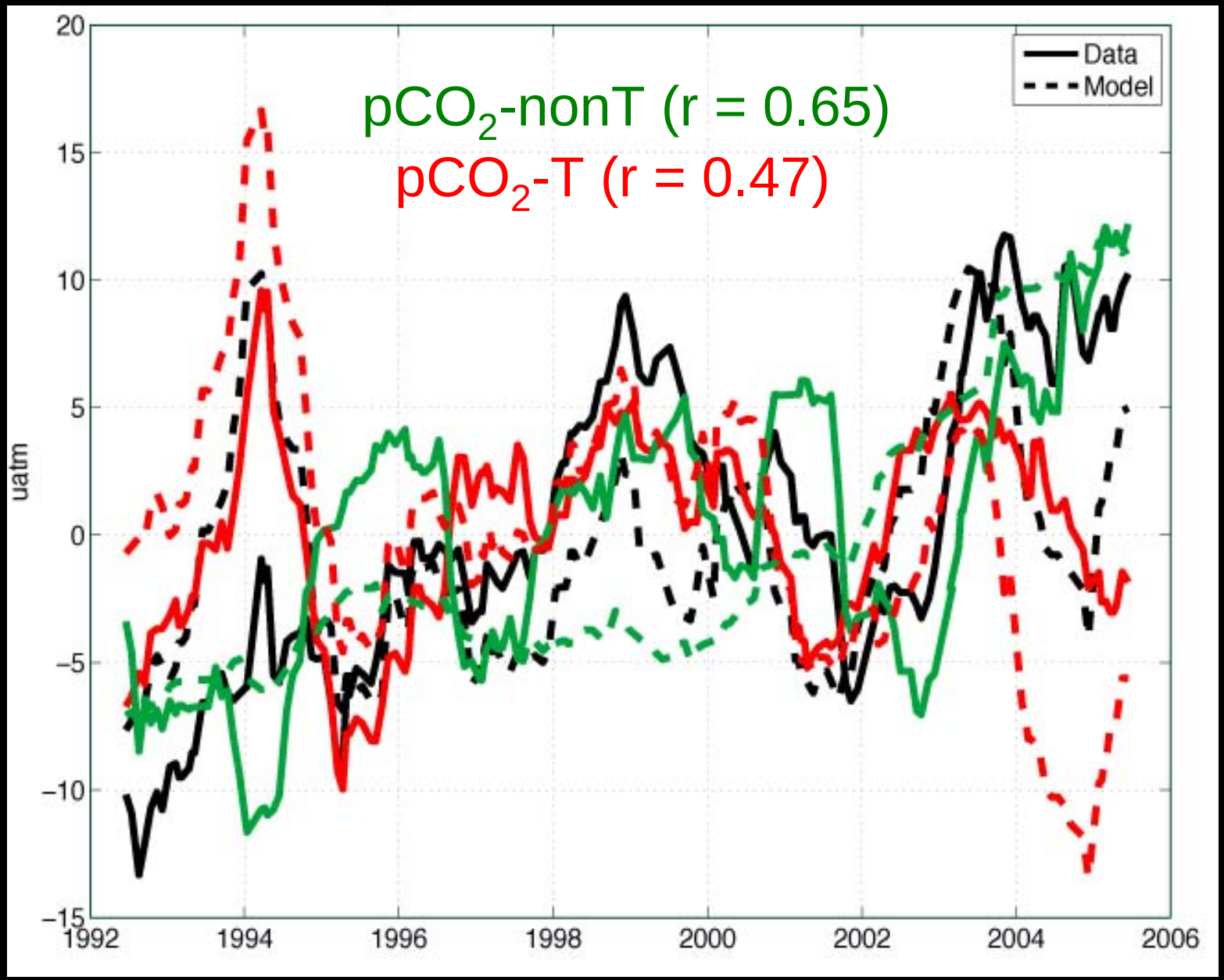
Takahashi et al, 2002



Low frequency (>1 year) pCO_2 variability at Bermuda



Low frequency (>1 year) pCO_2 variability at Bermuda

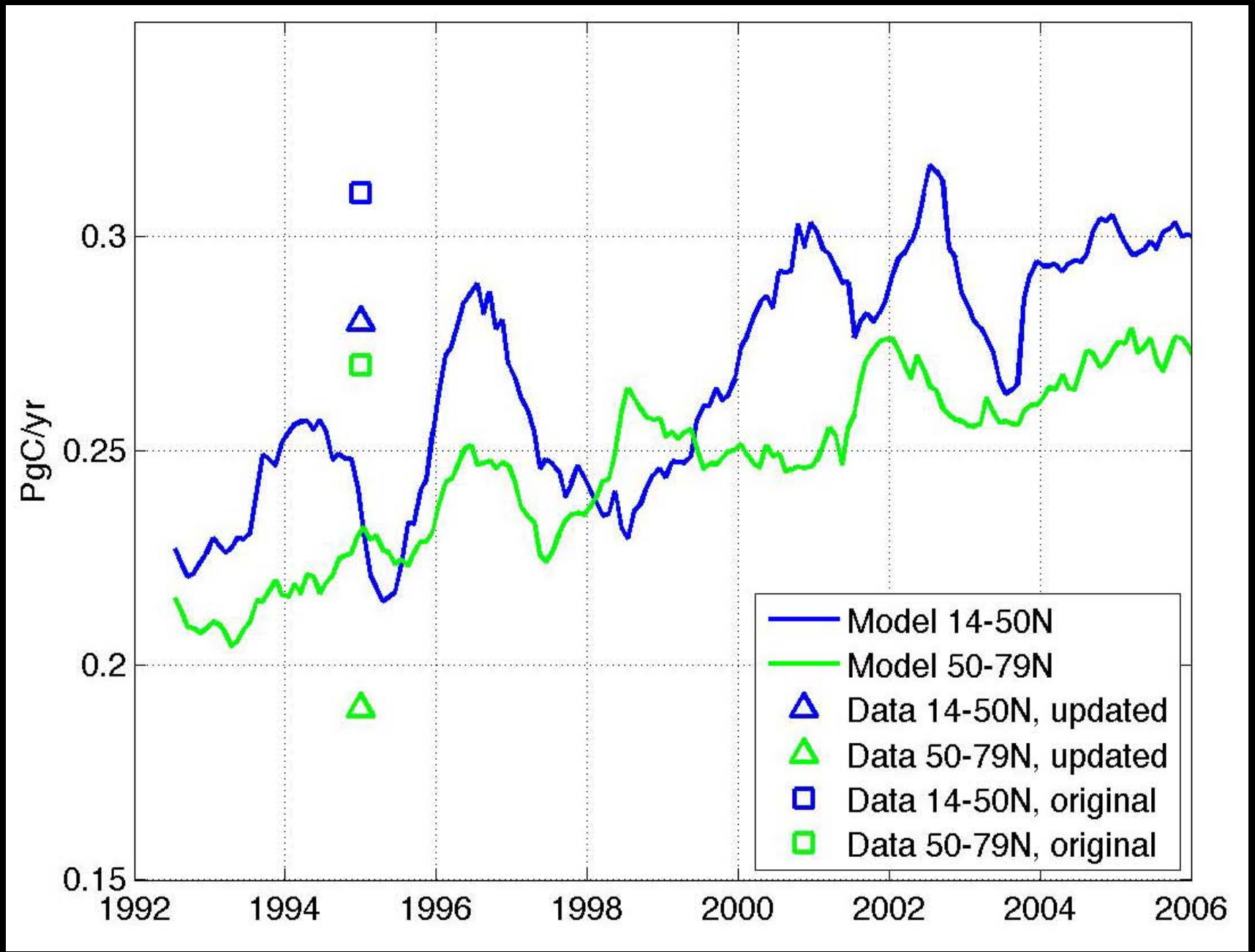


Variability and trends across the North Atlantic

1992-2006

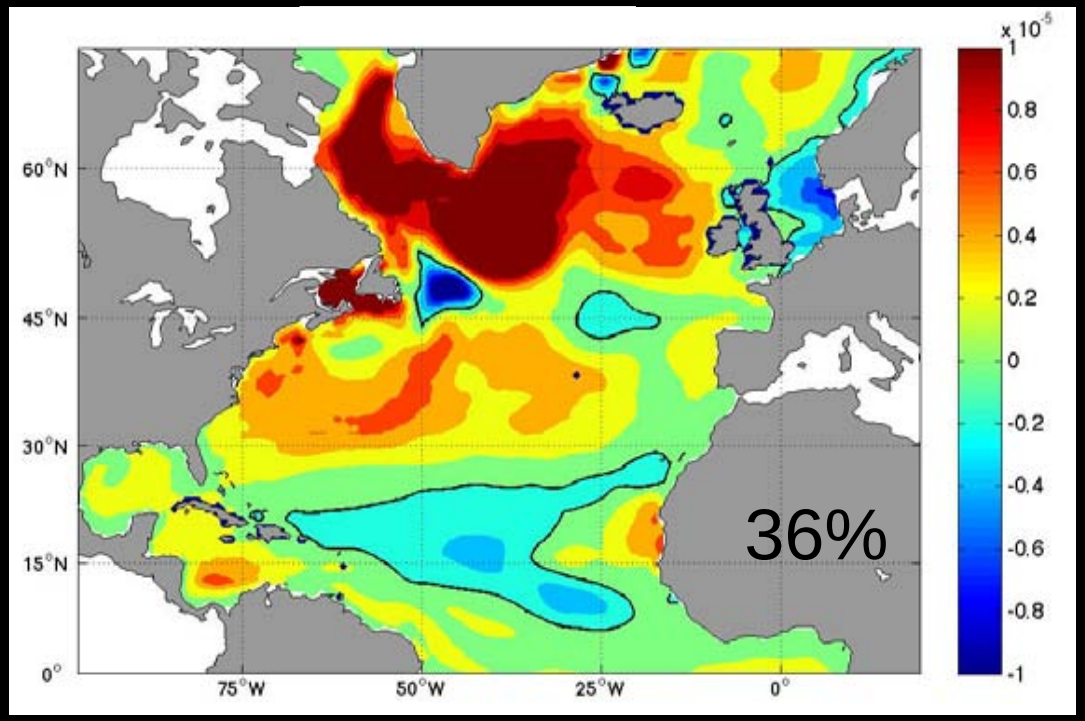
Basin-scale CO_2 flux variability

compared to Takahashi et al. 2002 in 1995

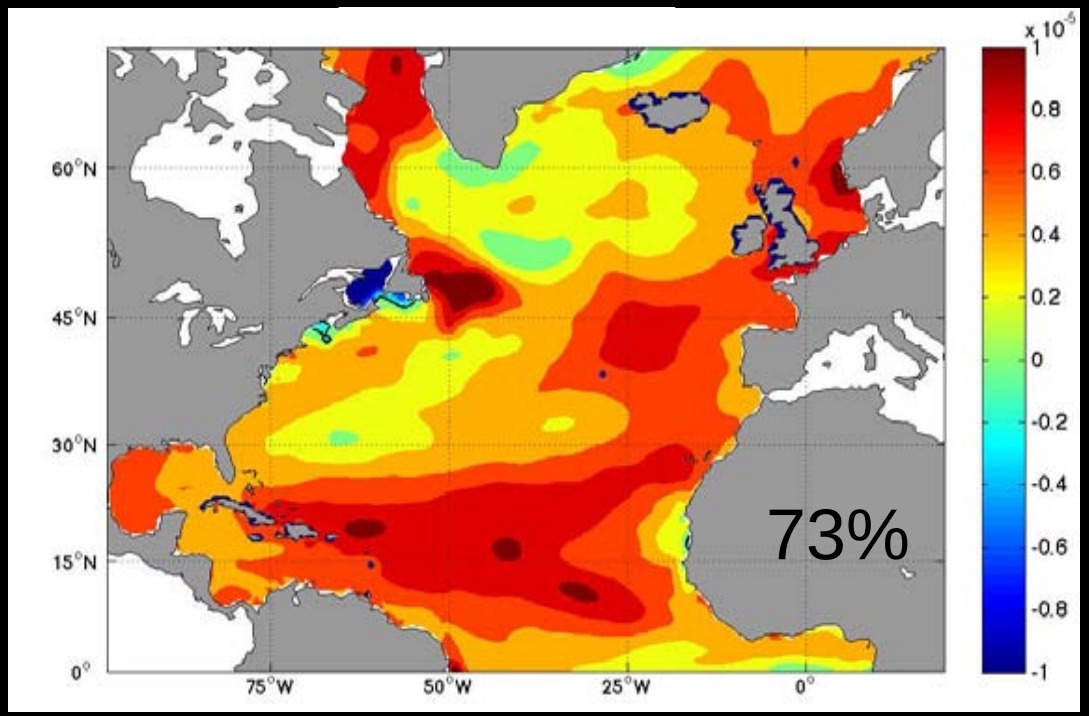


EOF1 pCO_2 and CO_2 flux

CO_2 FLUX



pCO_2

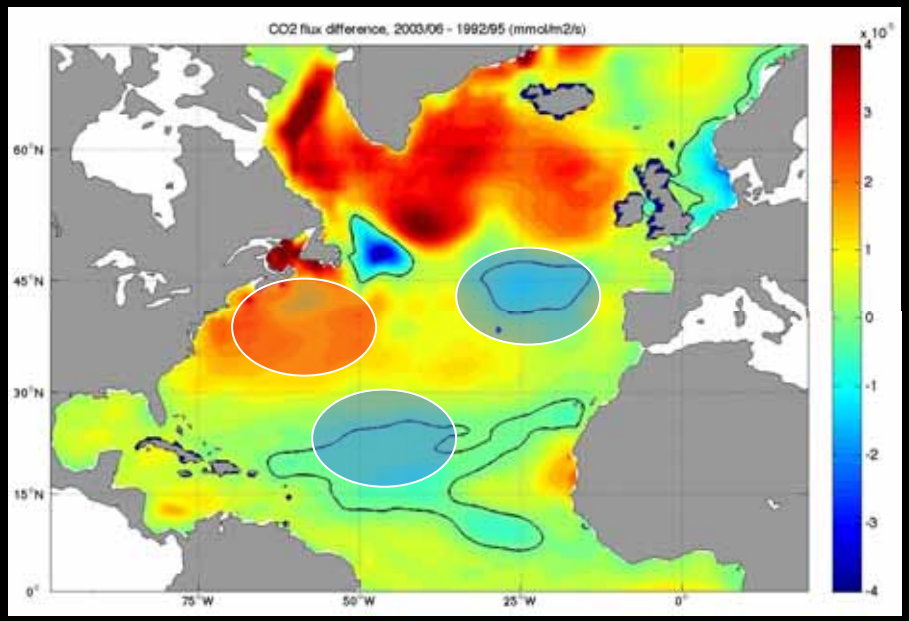


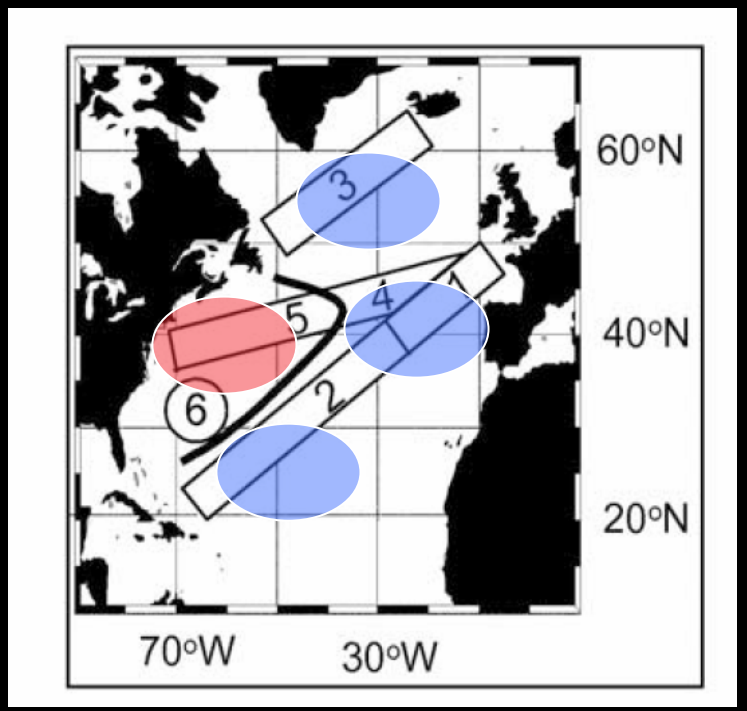
PC1 of pCO_2 (blue) and flux (red) r = 0.87

What drives the modeled trend?

Consider difference of 4yr means
(2003-2006) – (1992-1995)

Flux trend vs. Observations

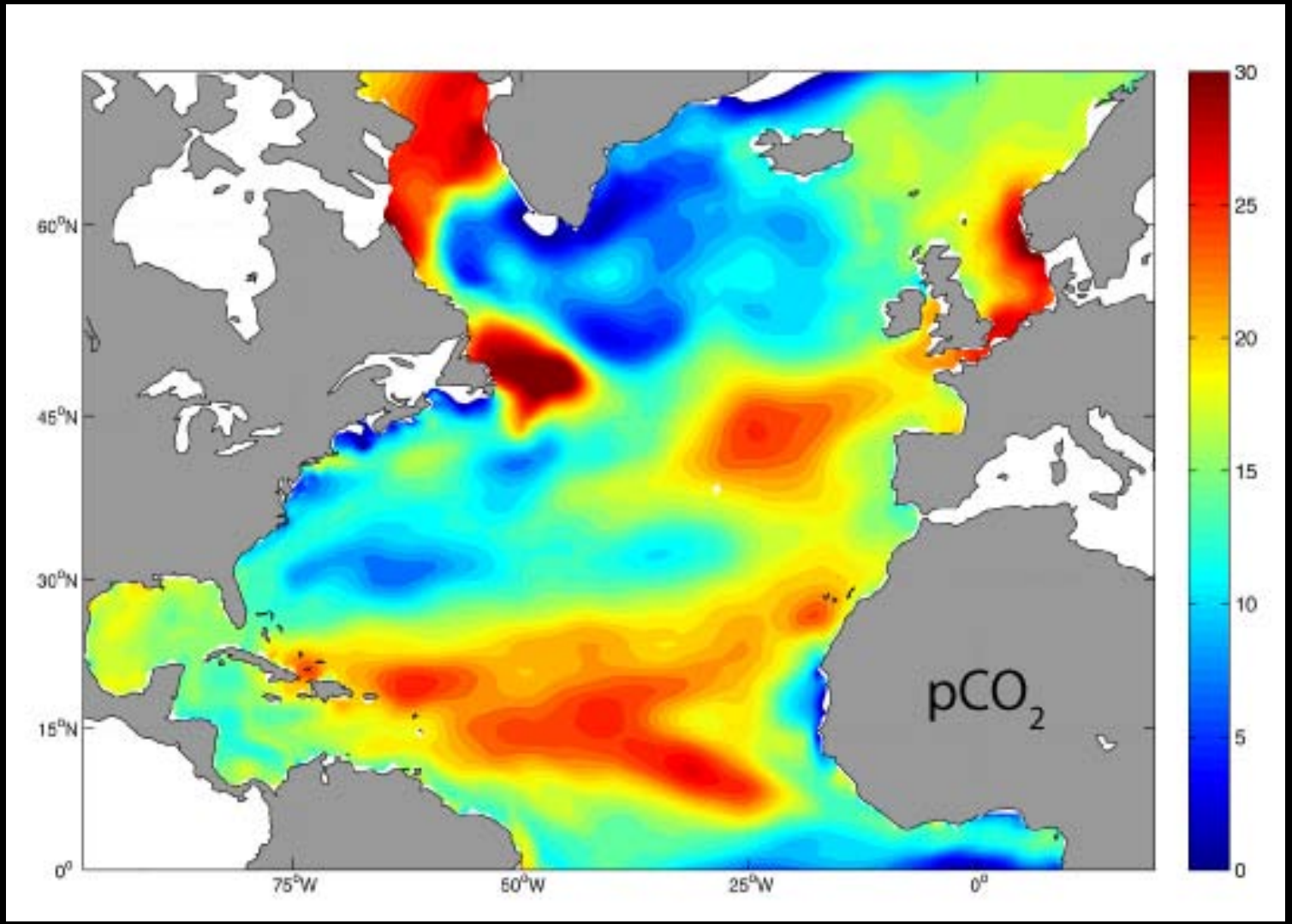




- Consistent with available data in West, East, South
- Not consistent in North

Ocean pCO_2 trend

(2003-2006) – (1992-1995)

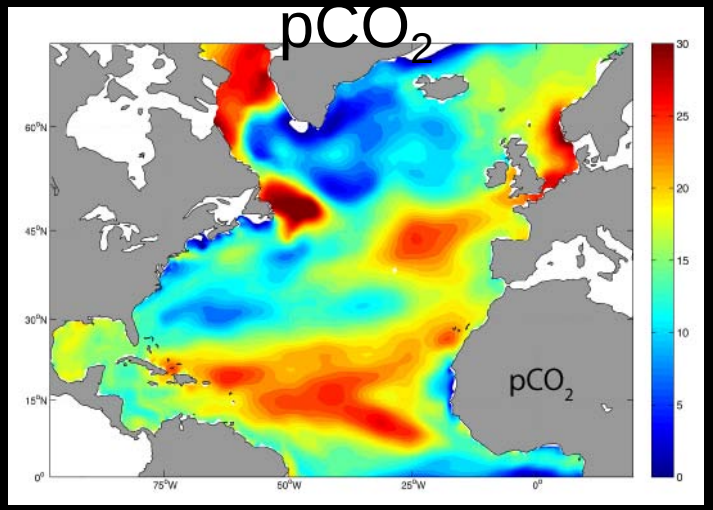


30 uatm

0 uatm

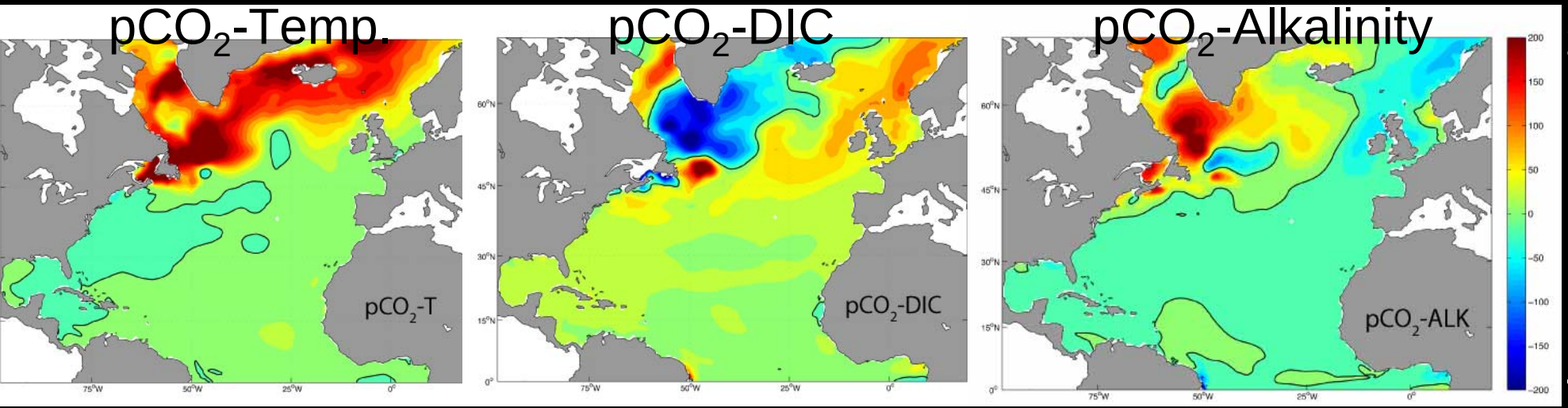
pCO_2 and component trends

(2003-2006) – (1992-1995)



30 uatm

0 uatm

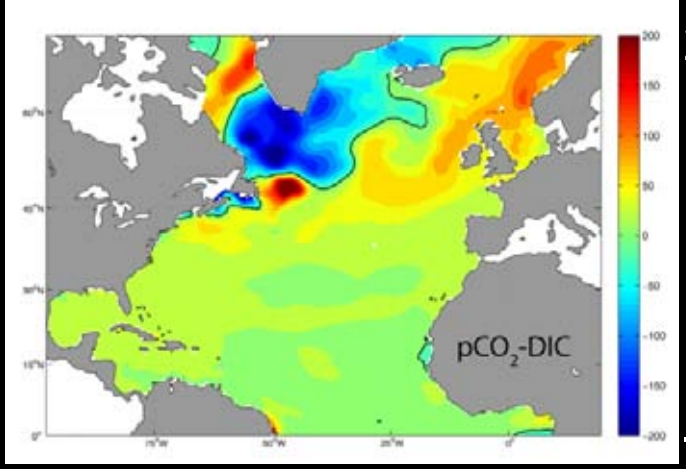


200 uatm

-200 uatm

Summary: pCO_2 Trends

- Model illustrates Northwest/Southeast asymmetry in flux trend
  - In West, East & South: consistent with data
- Due to combined effect of SST, DIC and ALK on ocean pCO_2
  - SST change consistent with data, including intensification in Northwest (ICES, 2006)
  - What drives DIC change?

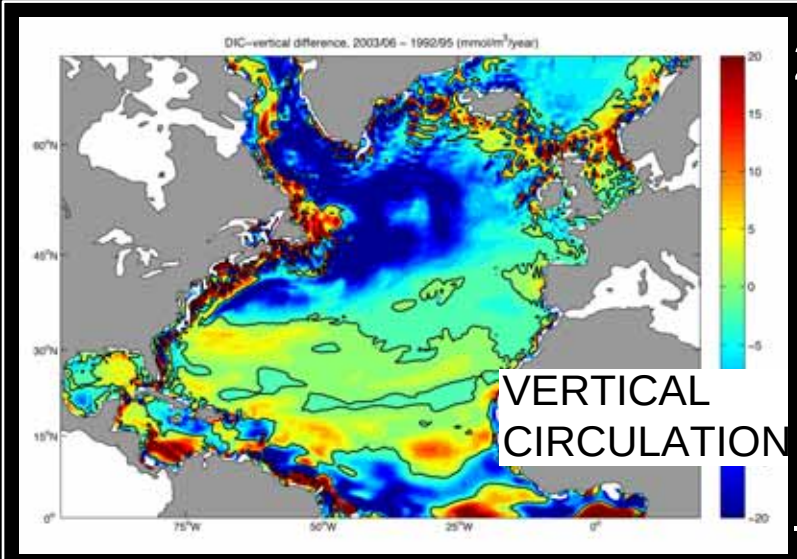


200 uatm

-200 uatm

DIC change

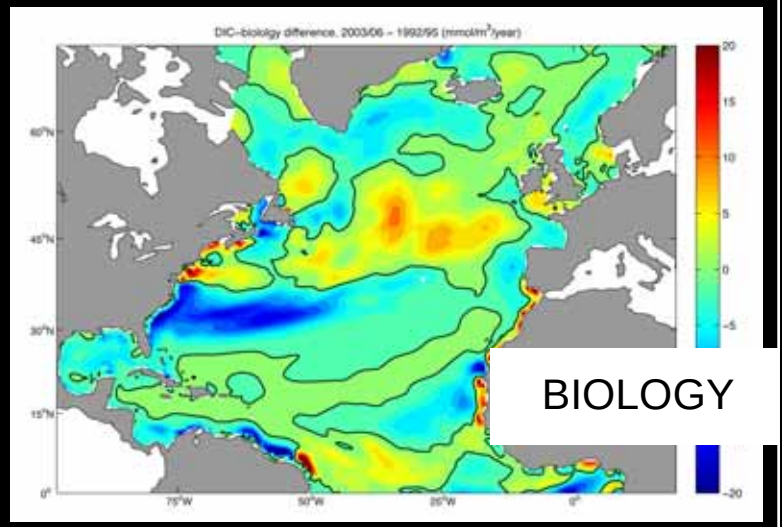
(2003-2006) – (1992-1995)



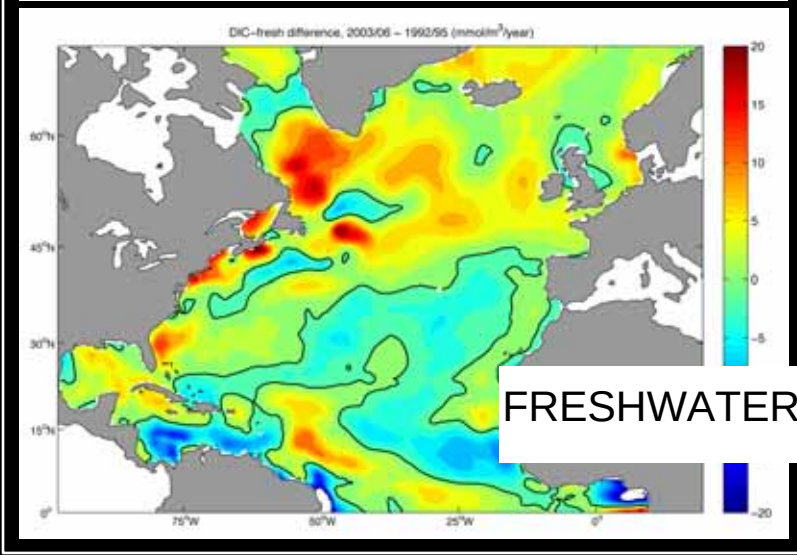
VERTICAL CIRCULATION

20 mmol/m^3/yr

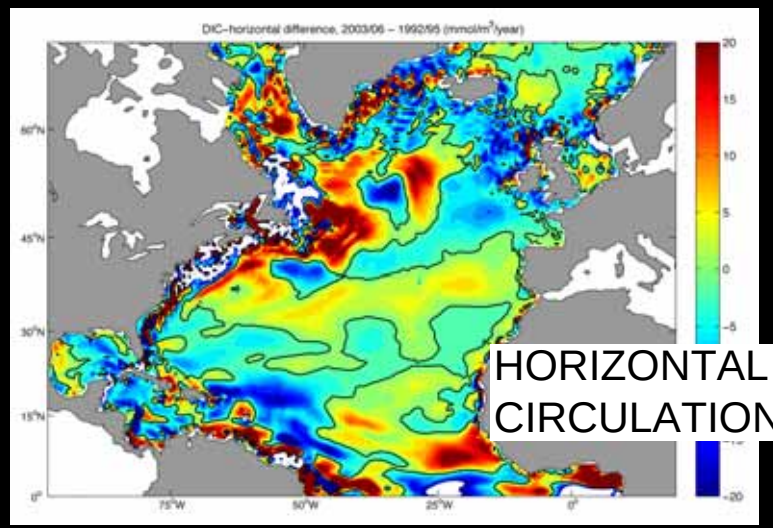
-20 mmol/m^3/yr



BIOLOGY



FRESHWATER

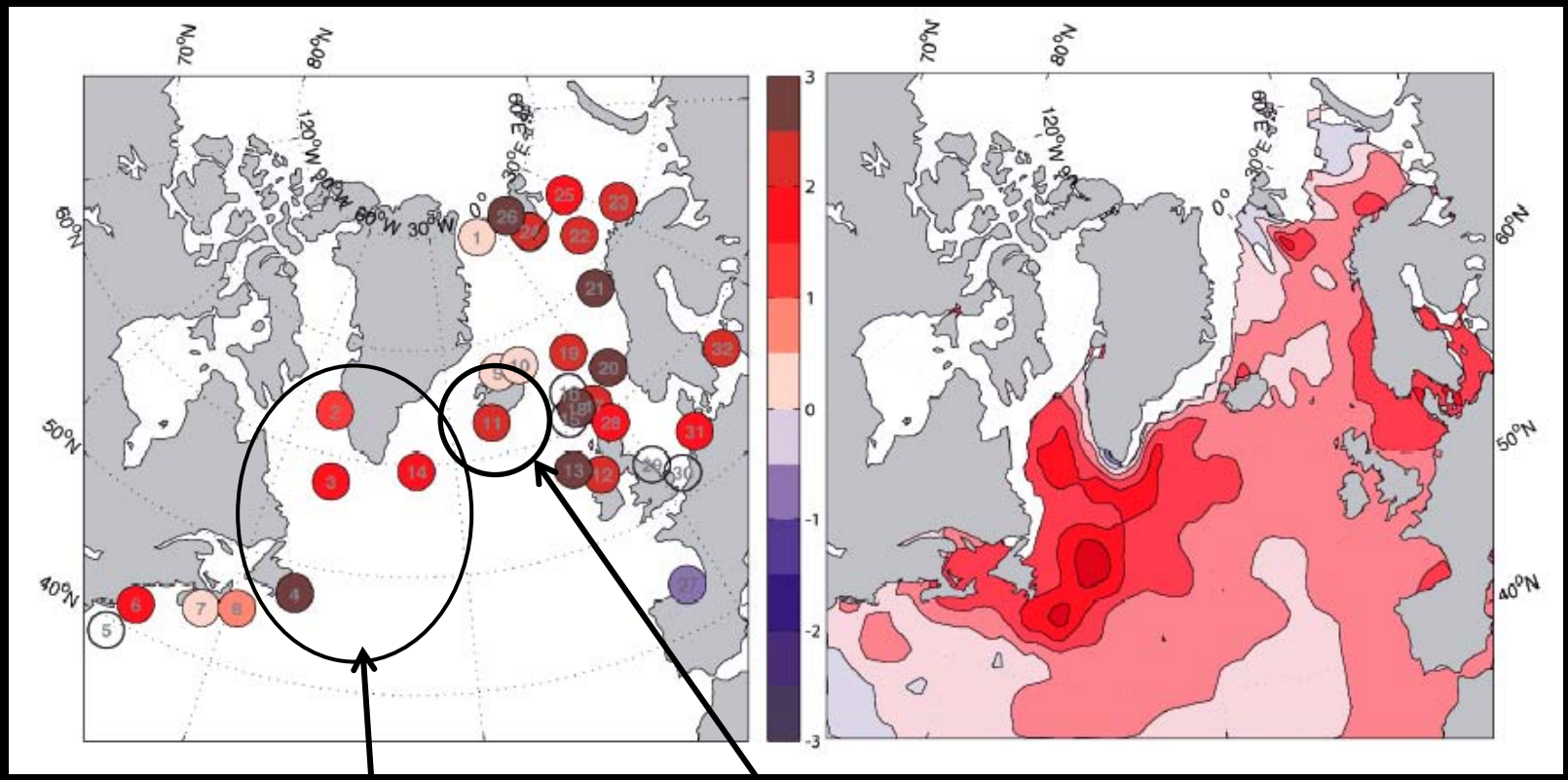


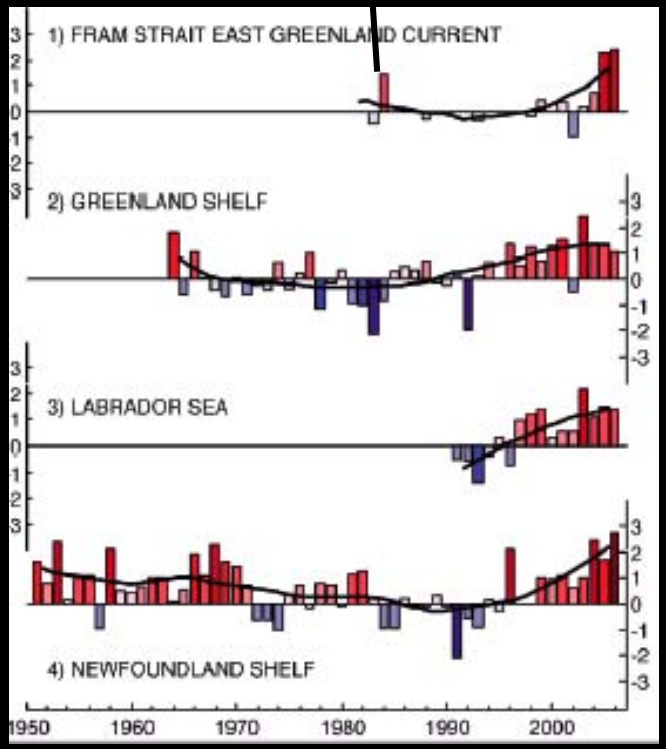
HORIZONTAL CIRCULATION

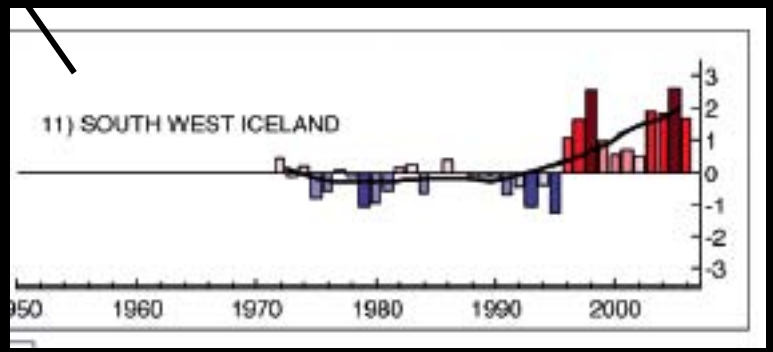
Conclusions

Surface ocean carbon cycle trends, North Atlantic, 1992-2006

- Model captures pCO_2 trend, mechanisms at BATS
- pCO_2 increase spatially variable, max 30 μatm
  - pCO_2-SST, pCO_2-ALK, pCO_2-DIC trend ±200 μatm, but largely counteract each other
  - Vertical mixing, biology, freshwater and horizontal transport all contribute to pCO_2-DIC trend
    - Vertical, biology, freshwater changes consistent with data
- Observed ΔpCO_2 trends can be partially explained while the basin-wide sink increases

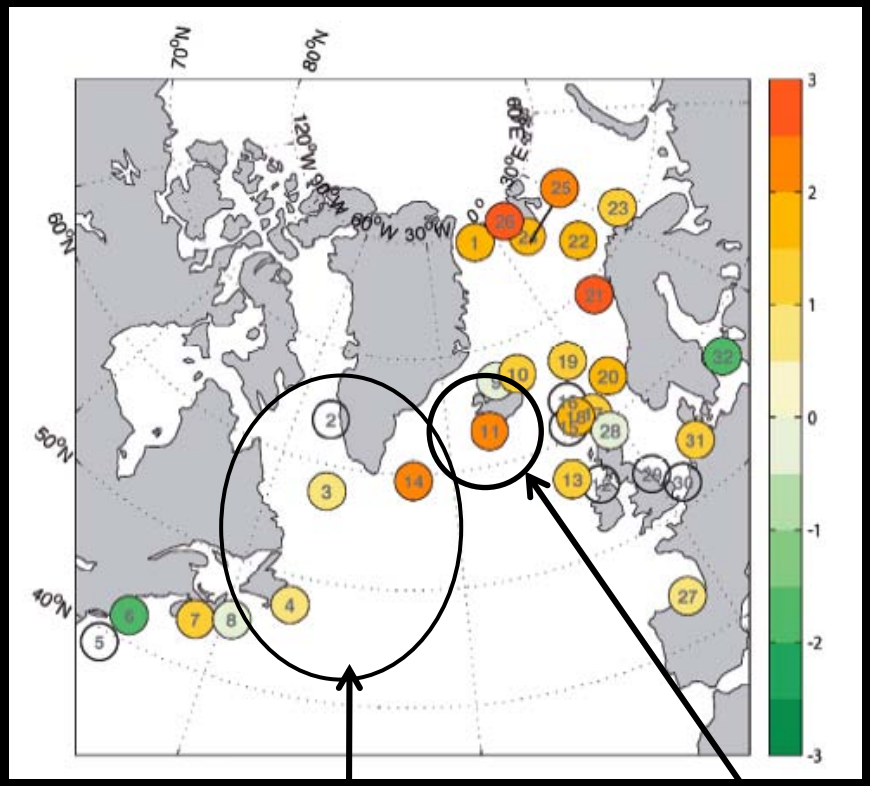


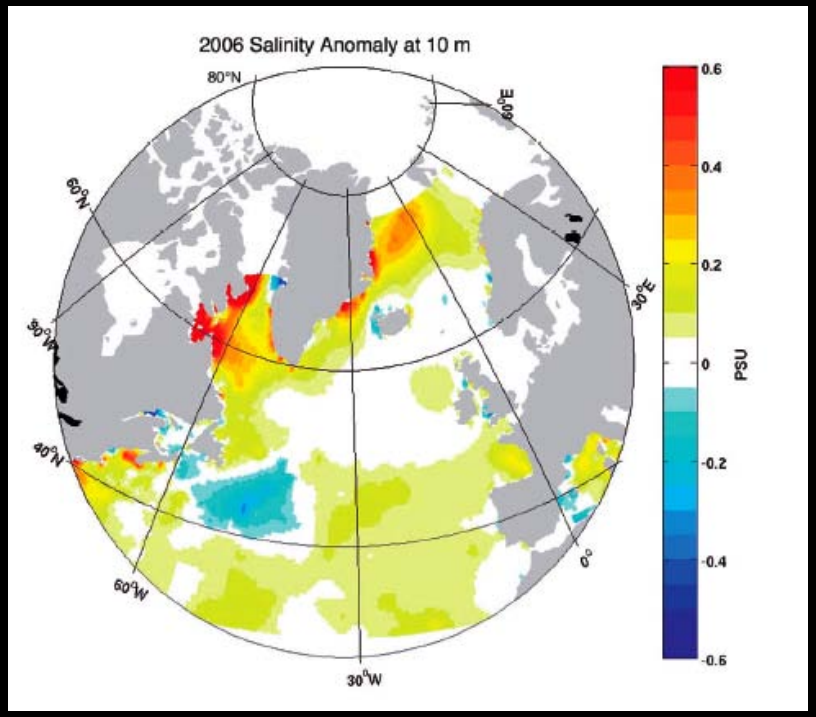


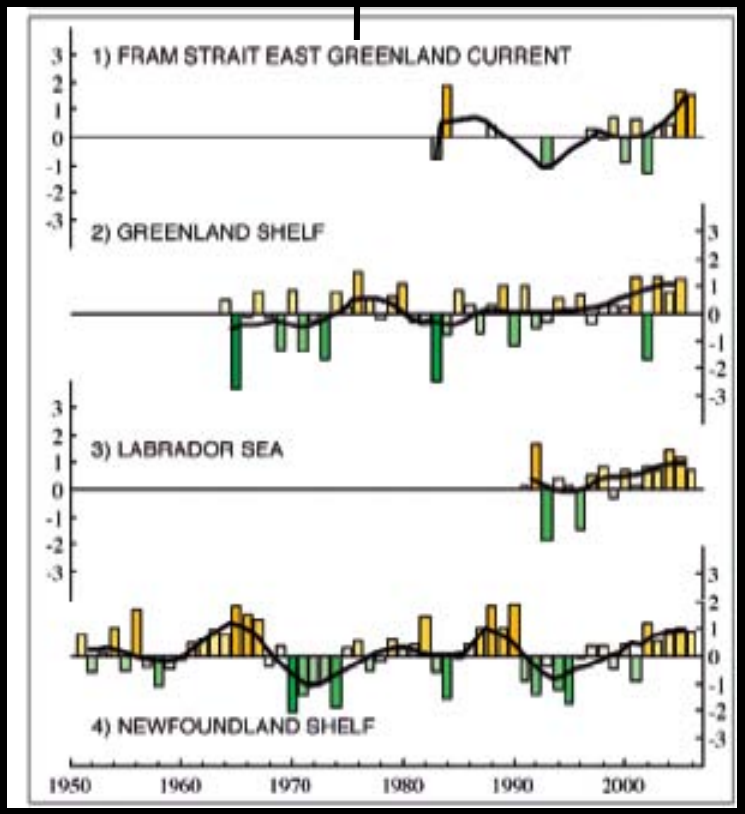


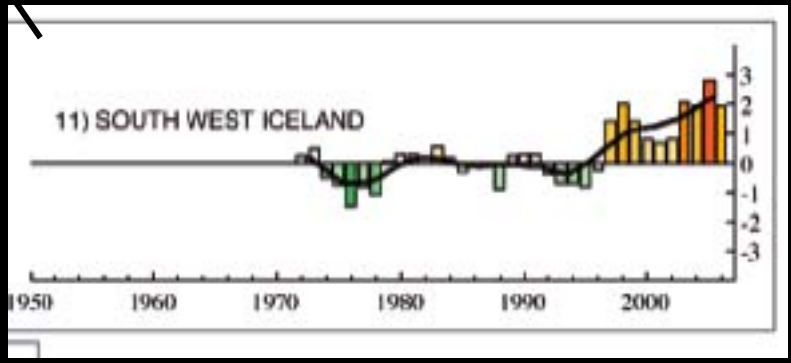
Observed Temperature Trend

ICES, 2006





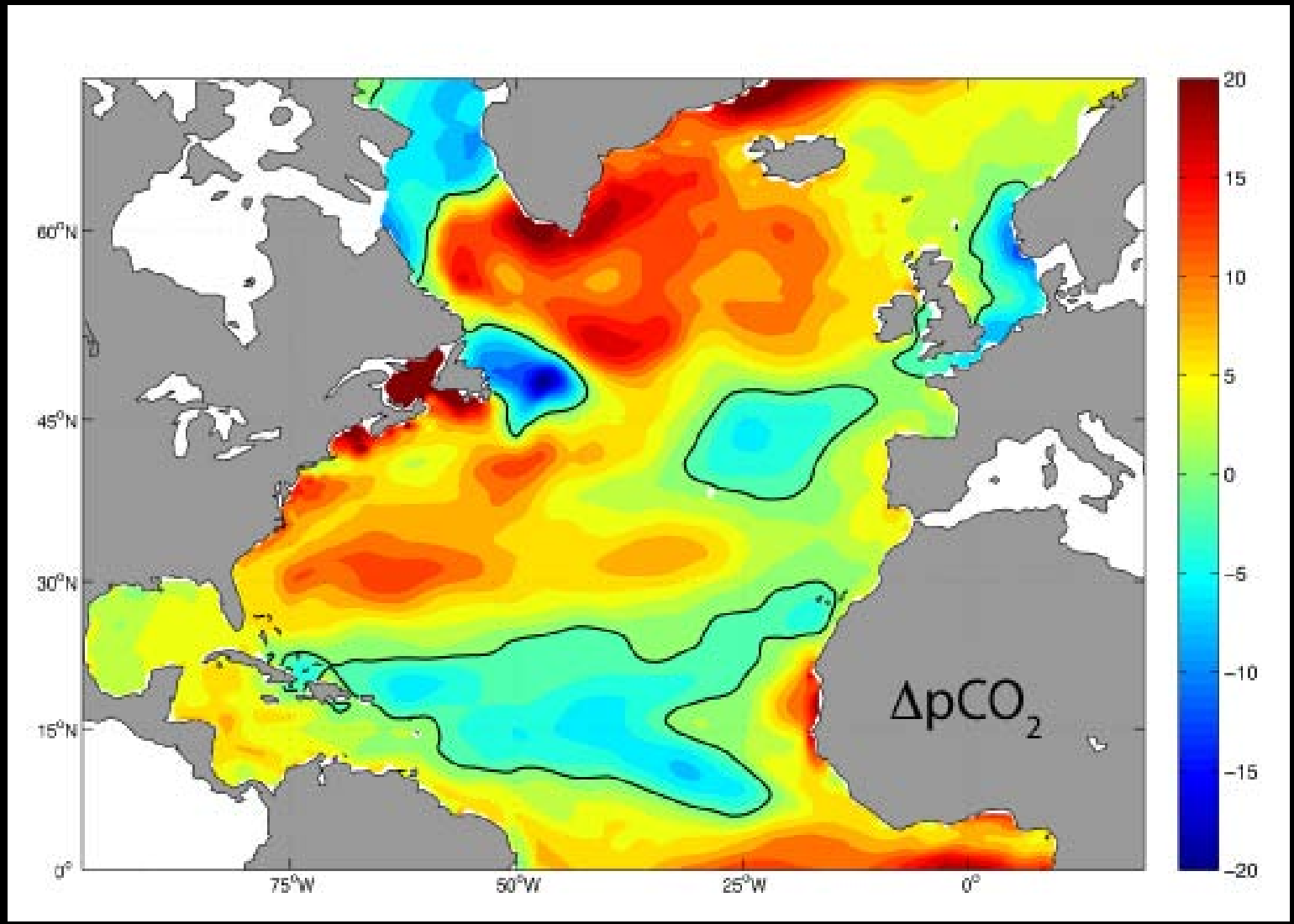




Observed Salinity Trend

ICES, 2006

ΔpCO_2 trend
(2003-2006) – (1992-1995)



20 uatm

-20 uatm

June chlorophyll, STD 98-05

log10(mg Chl/m^3)