Uptake and Storage of CO_2 in Subtropical Mode Water (STMW) of the North Atlantic Ocean

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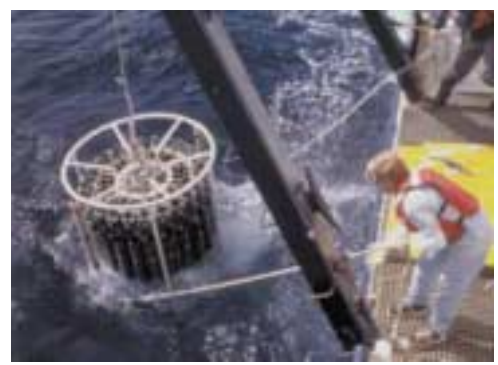
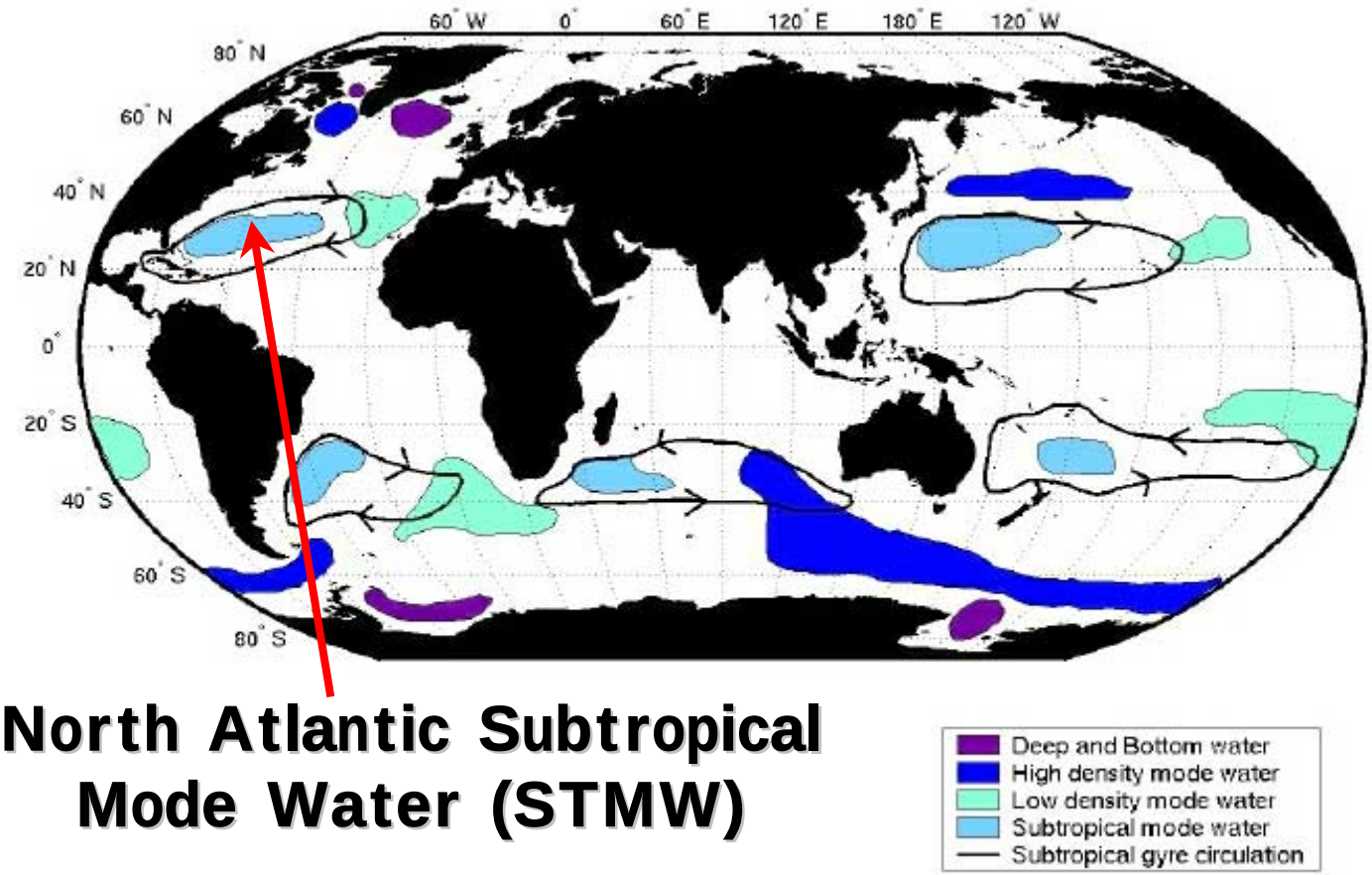


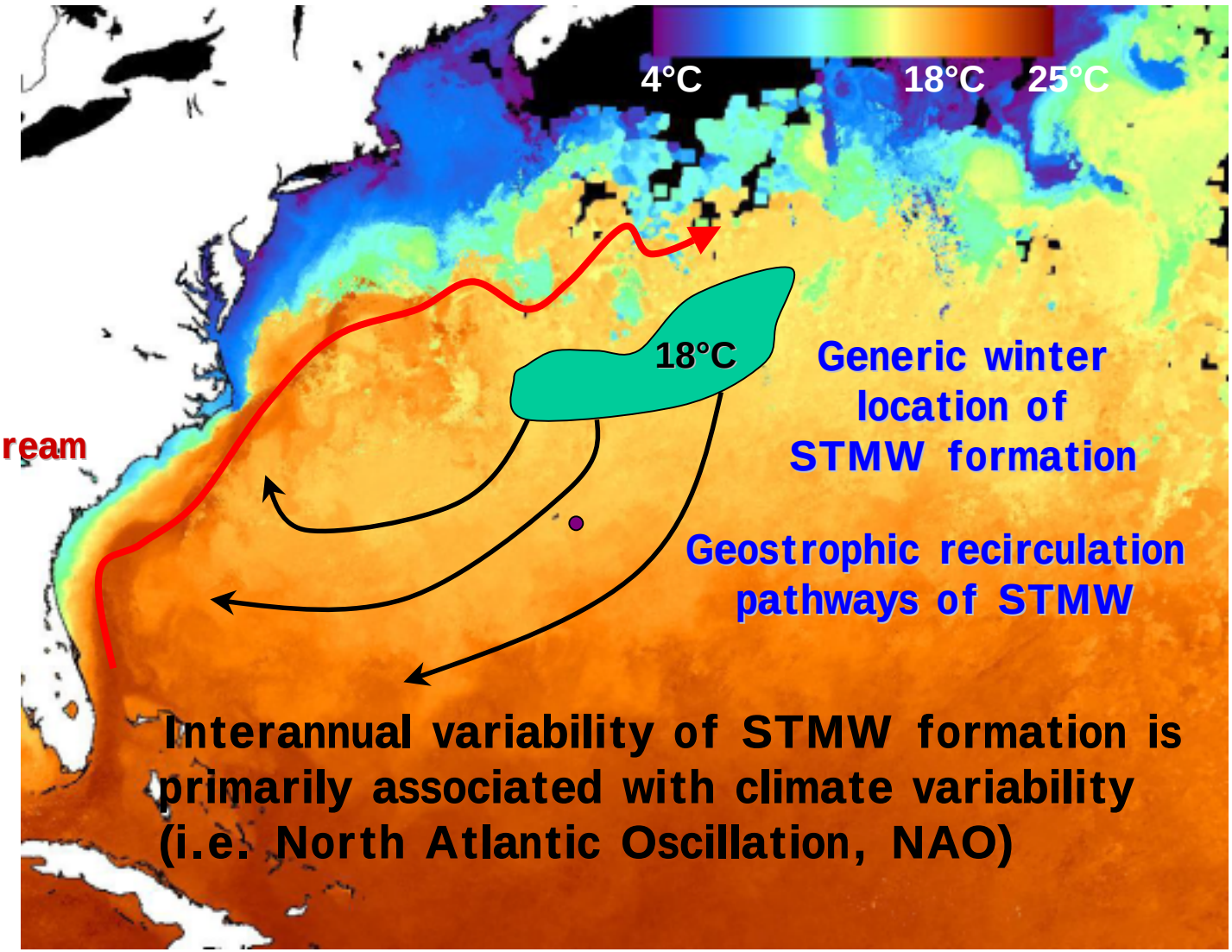
STMW Carbon Uptake and Storage

- **The magnitude and interannual variability of uptake and storage of carbon dioxide (CO_2) and storage into mode waters are poorly quantified.**



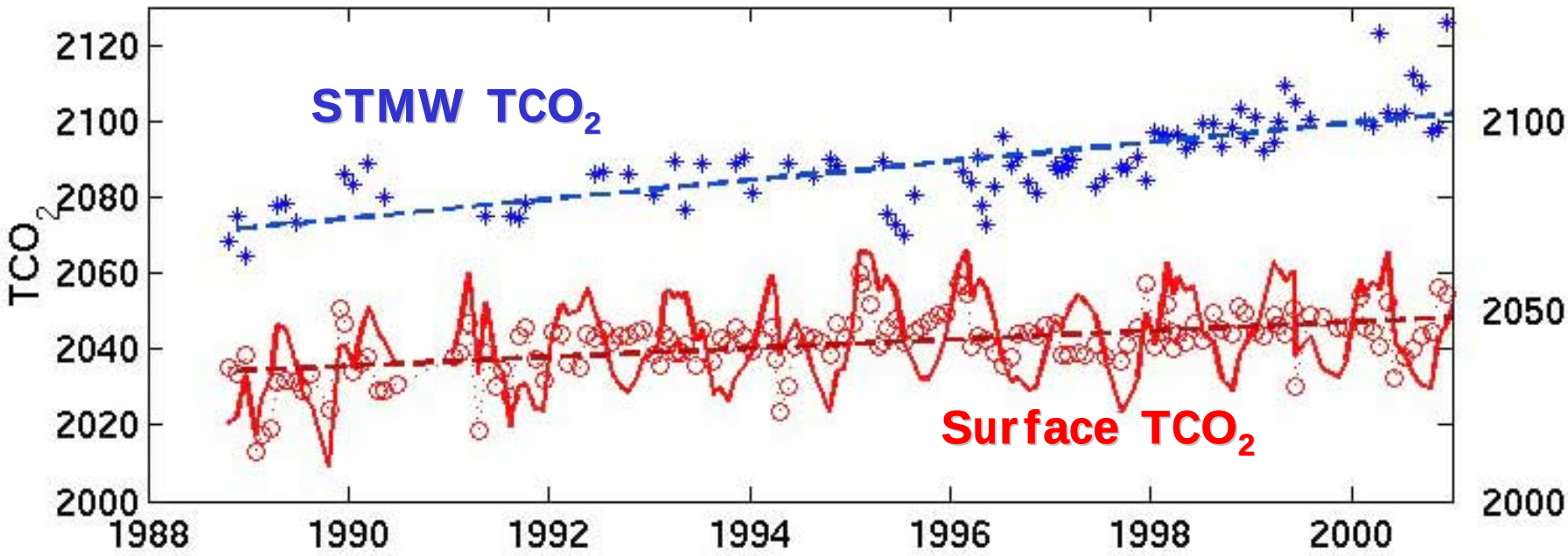
Source: Talley, 2000

STMW in the North Atlantic Ocean



February SST composite image source: Norm Nelson, UCSB

Interannual Variability of CO_2



- ***Mixed layer TCO_2*** **(µmoles kg^{-1} yr^{-1})**

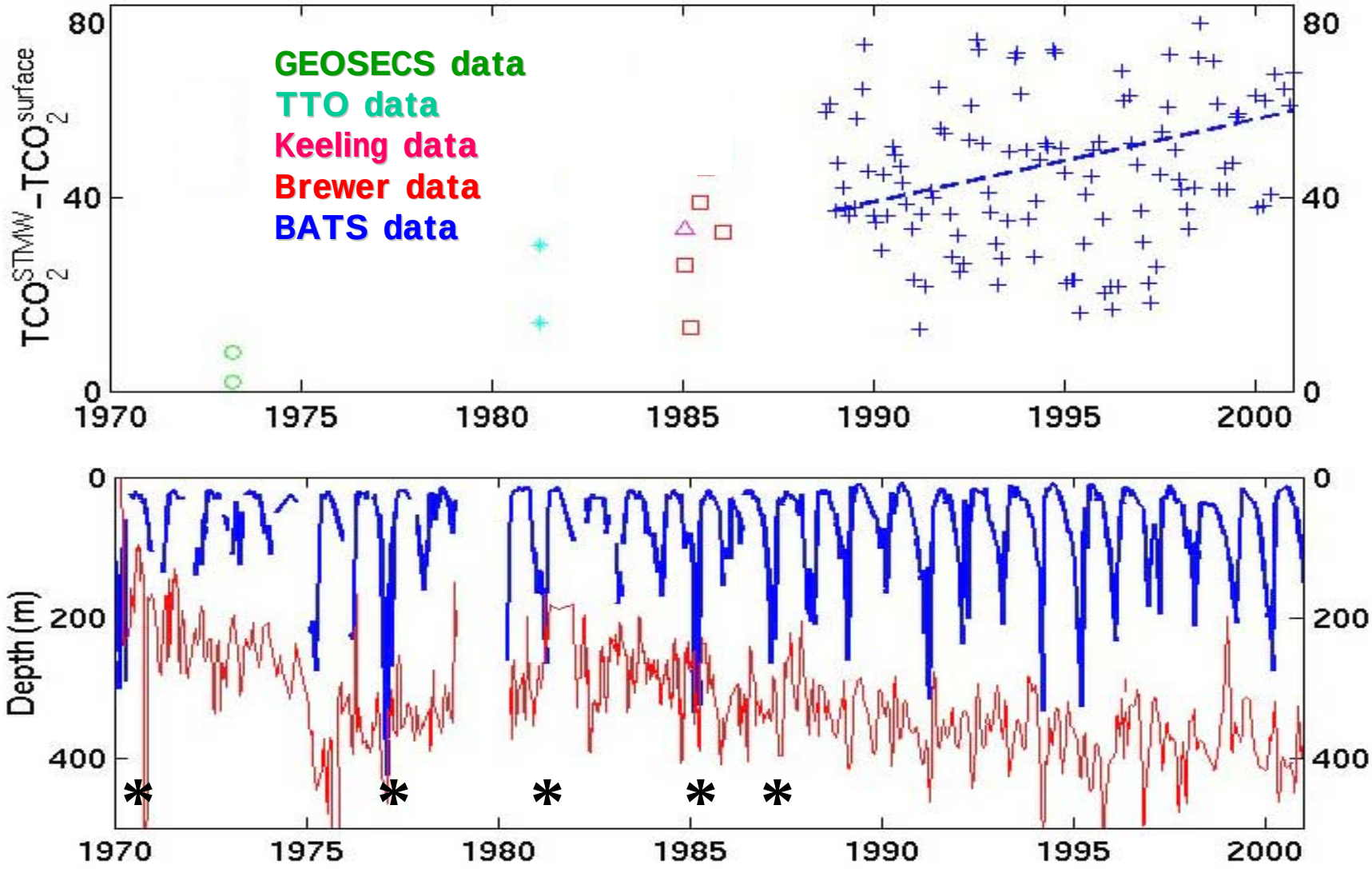
TCO_2	+1.20 ± 0.35 (r^2= 0.36*)
$nTCO_2$	**+1.19** ± 0.25 (r^2= 0.37*)
DO	-0.10 ± 0.24 (r^2= 0.00)

- ***STMW TCO_2*** **(µmoles kg^{-1} yr^{-1})**

TCO_2/$nTCO_2$	**+2.22** ± 0.27 (r^2= 0.65)
DO	-0.58 ± 0.22 (r^2= 0.27)

Source: Bates *et al.*, 2002

Non-steady state changes in CO_2

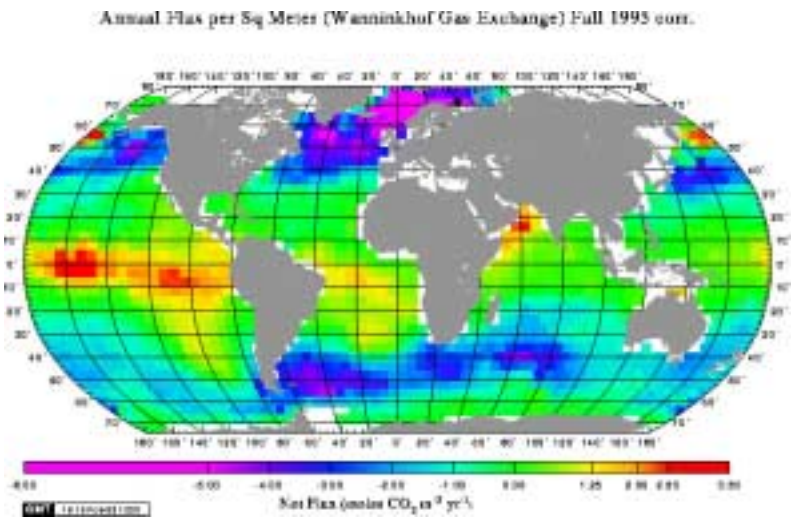


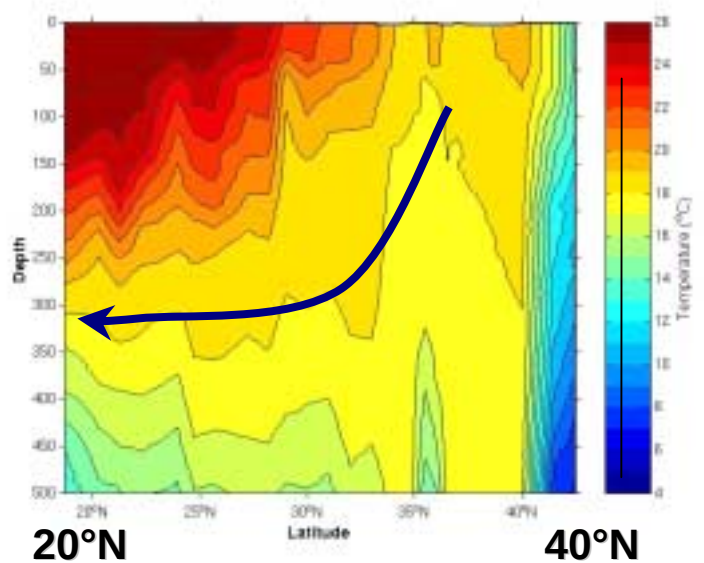
* Extensive ST MW

Increased Oceanic CO_2 Sink in 1990's

- Annual global ocean uptake of CO_2 is about 2 Pg C yr^{-1}.
- Over the last 12 years, the extra uptake of CO_2 into STMW (~ 0.6 to 2.8 Pg C) has the same range as the global annual uptake of CO_2.
- Since 1988, STMW has taken up (~ 0.05 to 0.23 Pg C yr^{-1}). This is ~3 to 11% of the best estimate of annual uptake of CO_2 into the global ocean.

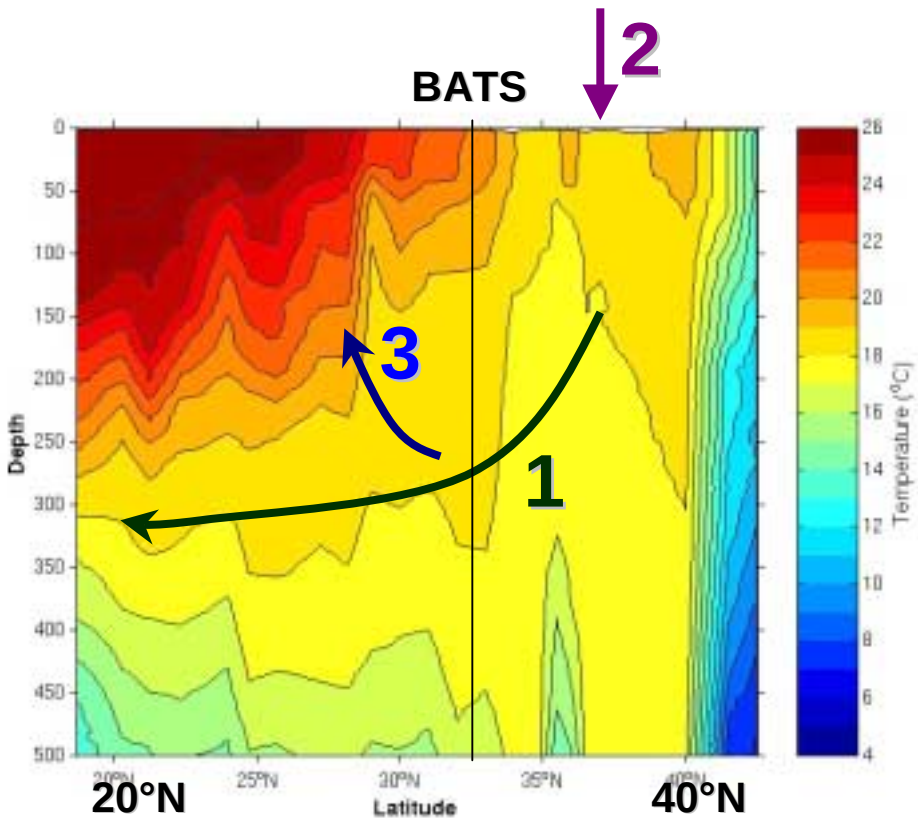
3-11% of global CO_2 uptake

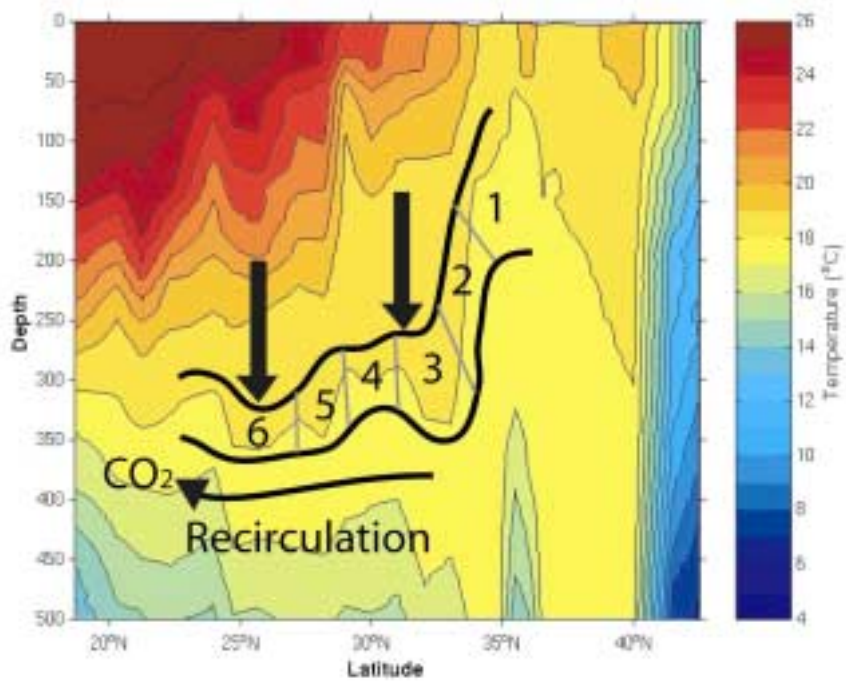




Causes for changes in CO_2

- 1. **Remineralization of OM** (sampling older water over time)
- 2. Changing **flux** of CO_2 through gas exchange
- 3. Retention of CO_2 or **loss** from STMW (by mixing)



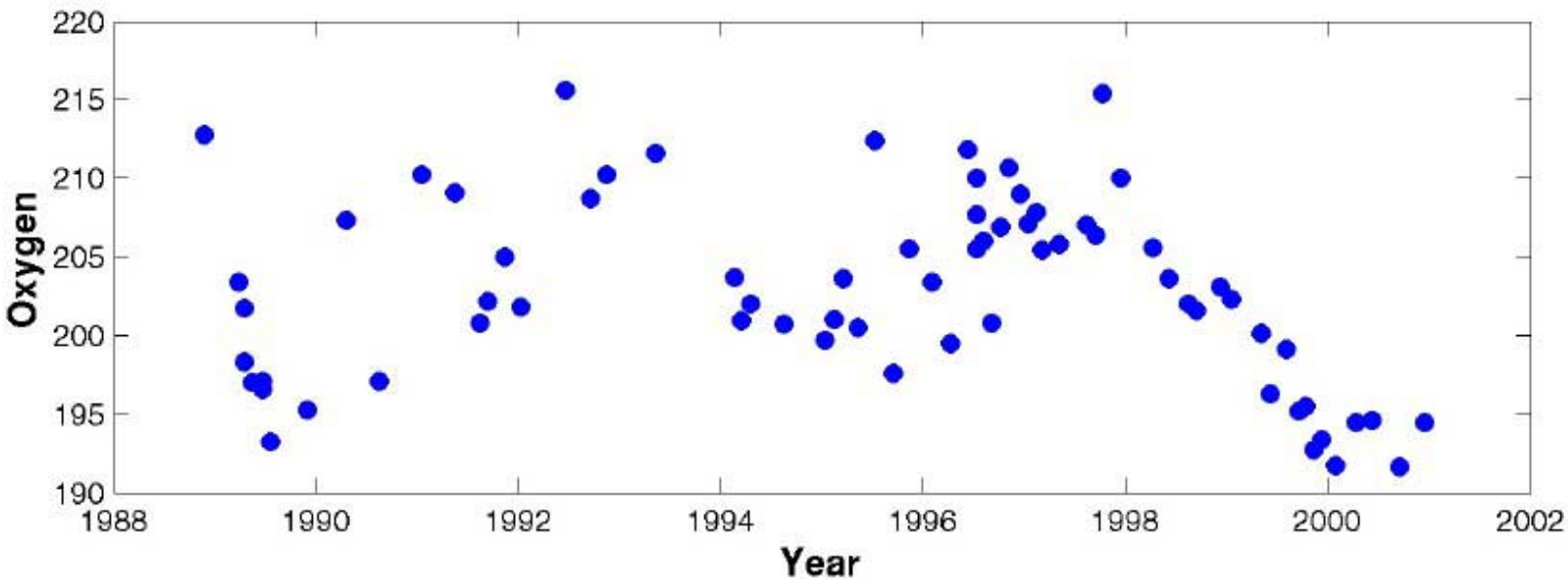


Source: Bates *et al.*, 2002

Increase in Remineralization Rate?

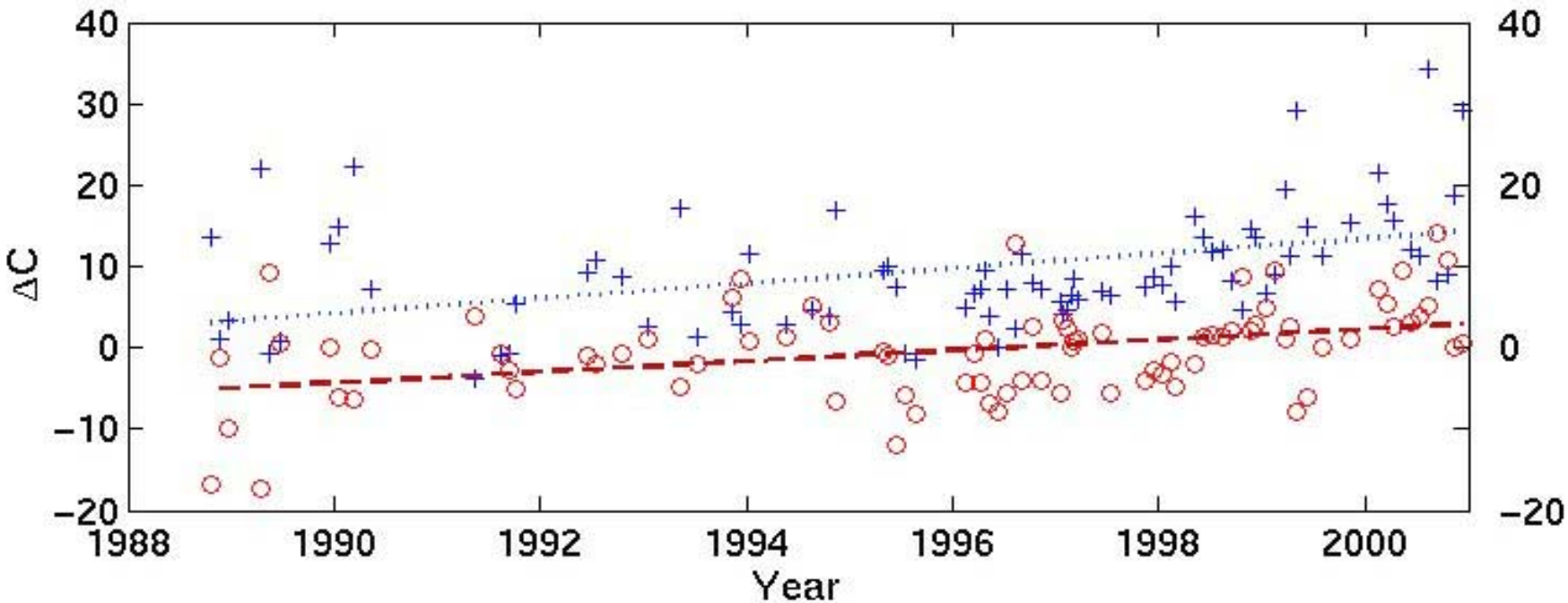
DO -0.58 ± 0.22 µmoles kg^{-1} yr^{-1} (r^2= 0.27)
Nitrate -0.02 ± 0.02 µmoles kg^{-1} yr^{-1}(r^2= 0.15)
Phosphate -0.00 ± 0.00 µmoles kg^{-1} yr^{-1} (r^2= 0.13)
[Temperature +0.003 ± 0.004 °C yr^{-1} Salinity +0.002 ± 0.000 yr^{-1}]

- **STMW TCO_2 changes <u>not</u> due to remineralization (i.e., decrease in DO) or sampling of older water.**



Increase in Remineralization Rate?

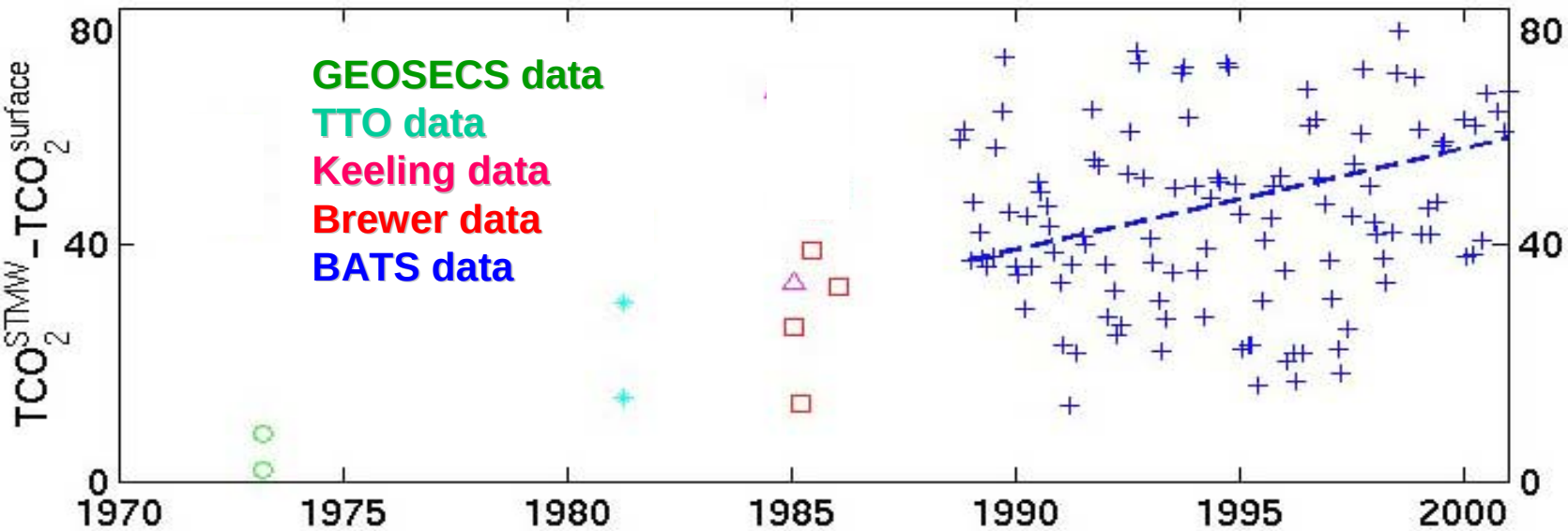
ΔC	**+2.22** (µmoles kg^{-1} yr $^{-1}$)
ΔC_{ant}	+**0.90** (µmoles kg^{-1} yr $^{-1}$)
ΔC_{gasex}	+**1.19** ± 0.26 (µmoles kg^{-1} yr $^{-1}$) (r^2= 0.47)
ΔC_{bio}	+**0.28** ± 0.12 (µmoles kg^{-1} yr $^{-1}$) (r^2= 0.25)



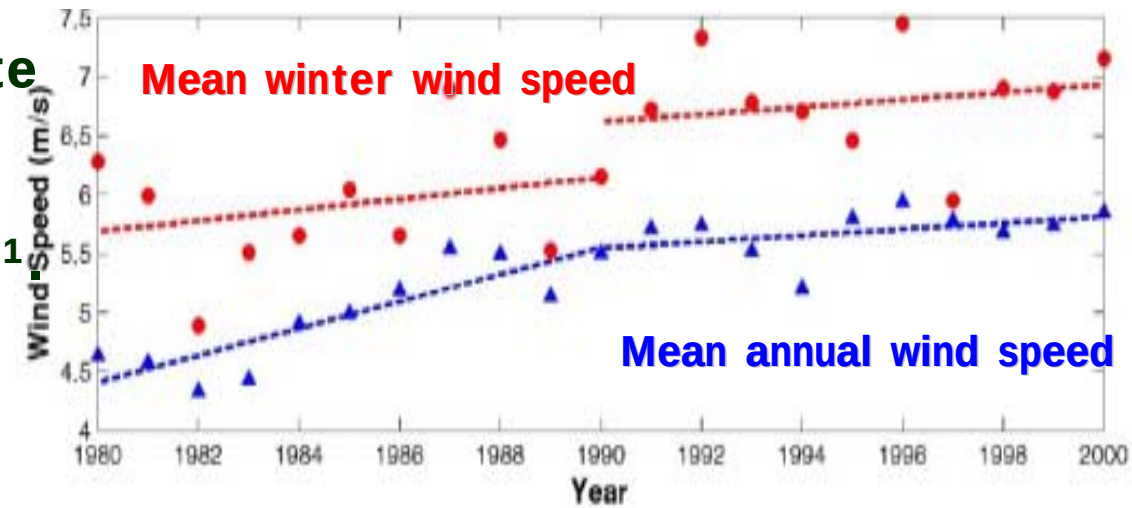
- **Low DC_{bio} values indicate that biological processes did not contribute much to the +2.2 µmoles kg^{-1} yr $^{-1}$ change in STMW TCO_2**

Source: Bates *et al.*, 2002

Increased Gas Exchange?

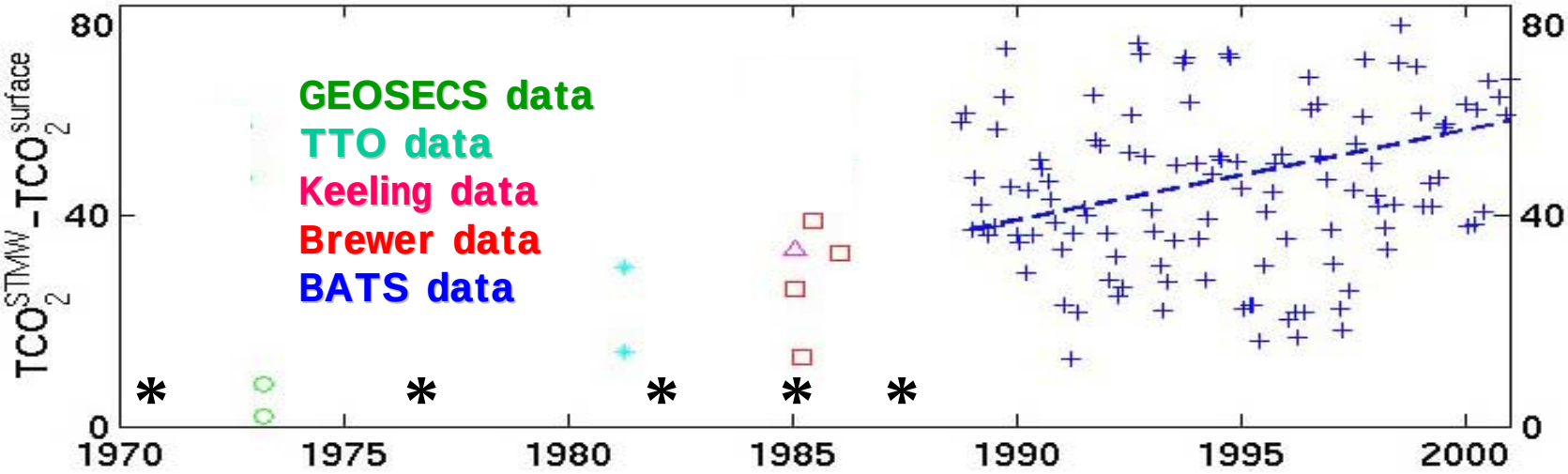


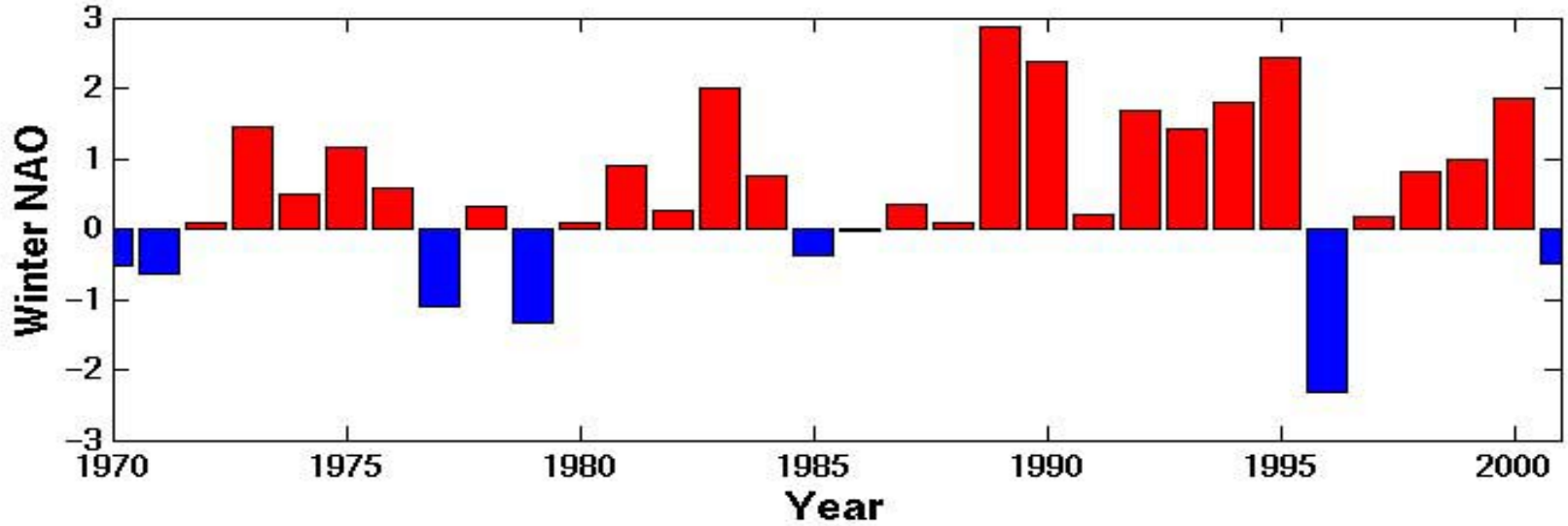
CO_2 gas flux at the site of STMW formation should increase STMW by 2-3 µmoles kg^{-1} yr^{-1}



- **Higher winter wind speeds in 1990's compared to 1980's**

Variability of Carbon Storage?





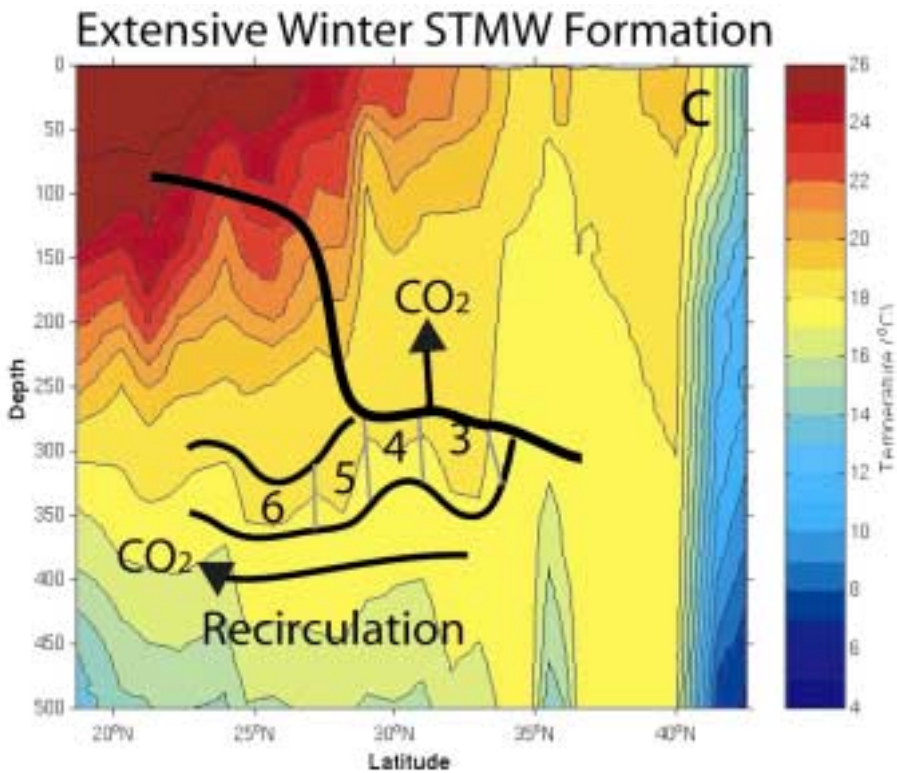
* Extensive ST MW

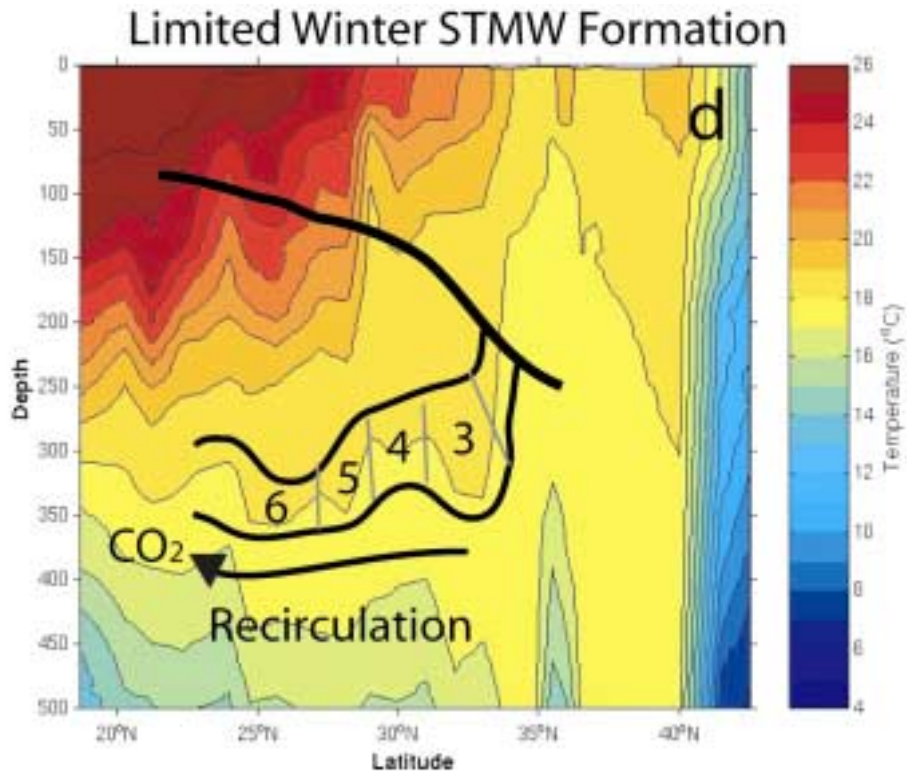
NAO-ve State

NAO+ve State

1960's, 1970's, early 1980's: CO_2 in STMW redistributed

Post 1987: CO_2 transferred to ocean interior





Short-term CO_2 sink ~1-4 years

Long-term CO_2 sink >10 years

Conclusions:

- **Apparent coupling between modes of climate variability such as NAO and CO_2 uptake and storage in the subtropical gyre.**
- **Since 1988, ~0.6-2.8 Pg (10^{15} g) of extra CO_2 has accumulated within the gyre STMW layer. This represents a longer term oceanic sink of CO_2 (>10 years) in the 1990's compared to earlier decades, and 3-11% of global ocean flux?**

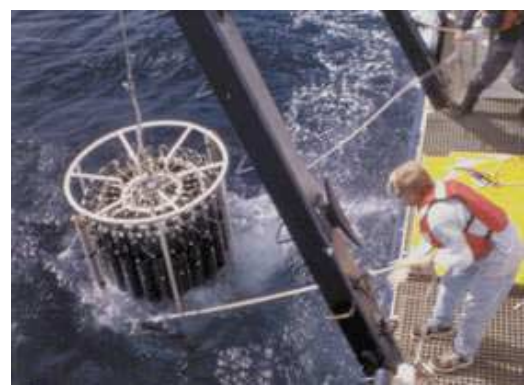


Image Source: BBSR

Acknowledgements:

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National Science Foundation
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