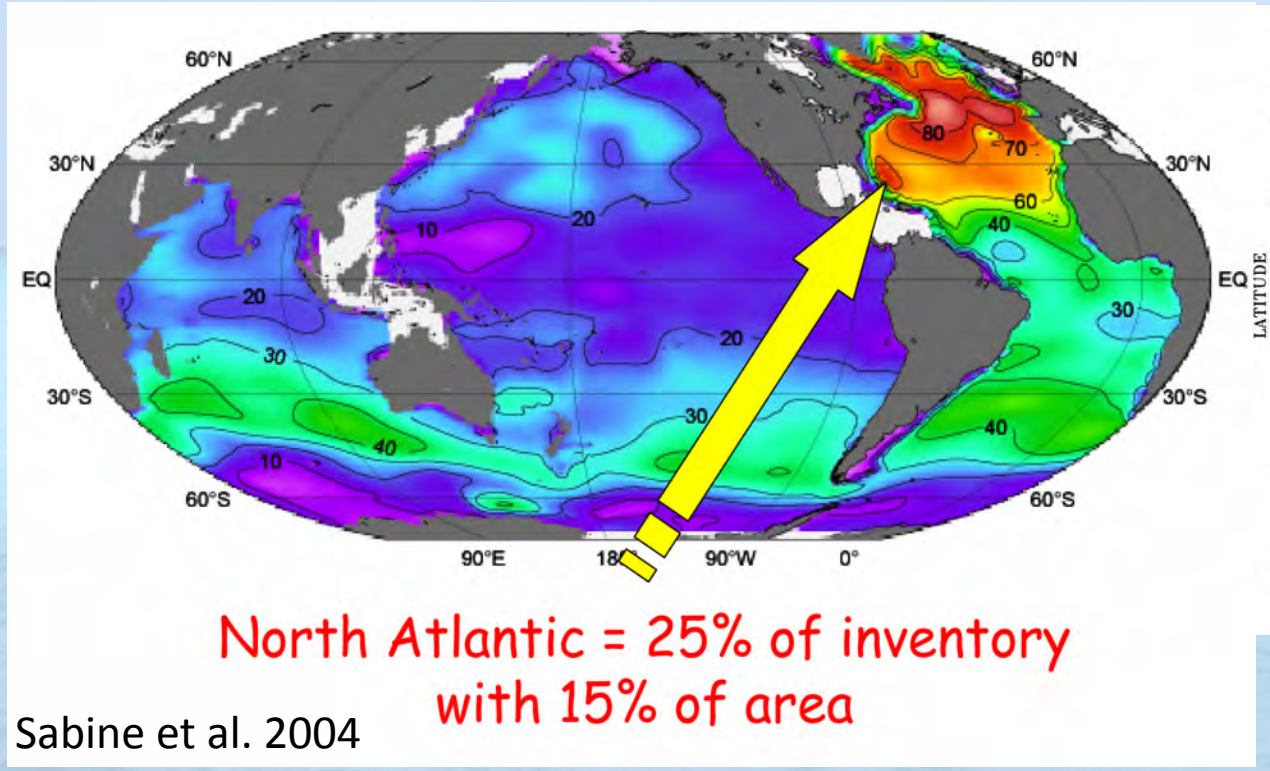
Decadal Variations of the Atlantic Meridional Overturning Circulation (AMOC) and CFC-11 in the Subtropical North Atlantic

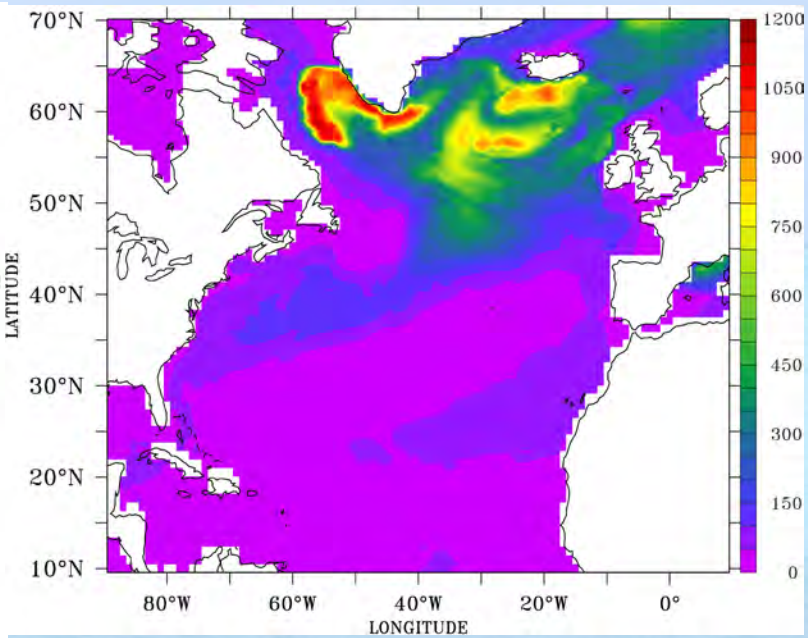
Dongxiao Zhang[1], Michael J. McPhaden[2], Wei Cheng[1], Rainer Bleck[3]

1. JISAO/University of Washington
2. NOAA/Pacific Marine Environmental Laboratory
3. NOAA/Earth System Research Laboratory

Formation of NADW and the DWBC responsible for the deep penetration and high inventory of anthropogenic CO_2 and CFCs in the North Atlantic

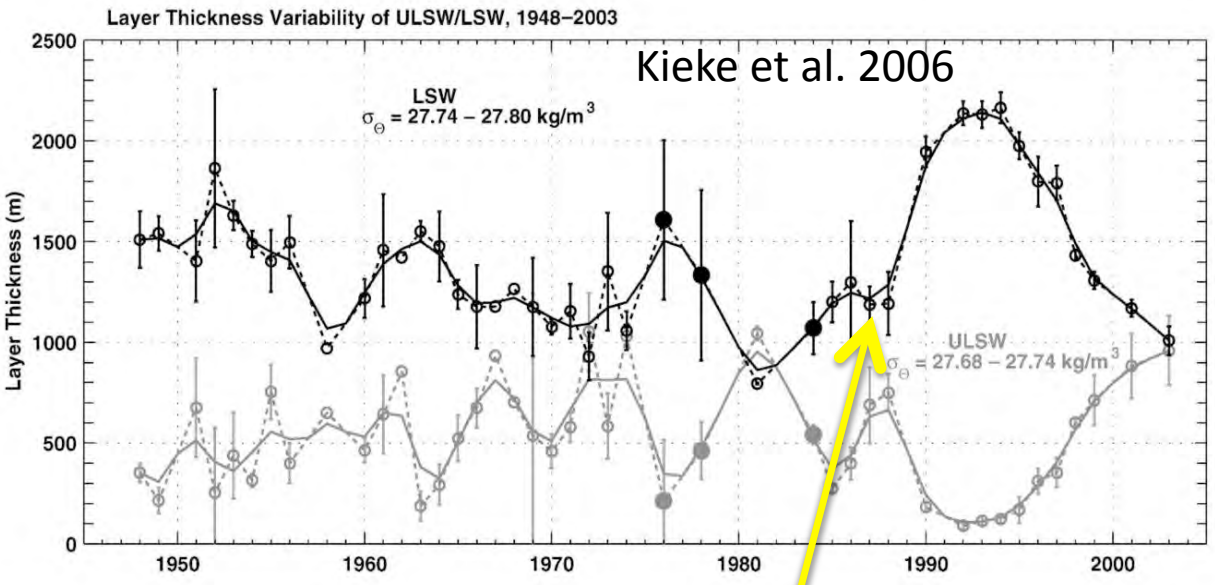


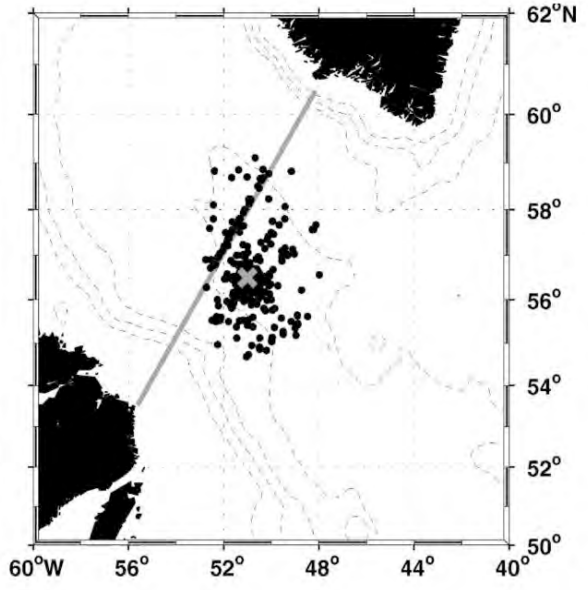
Sabine et al. 2004

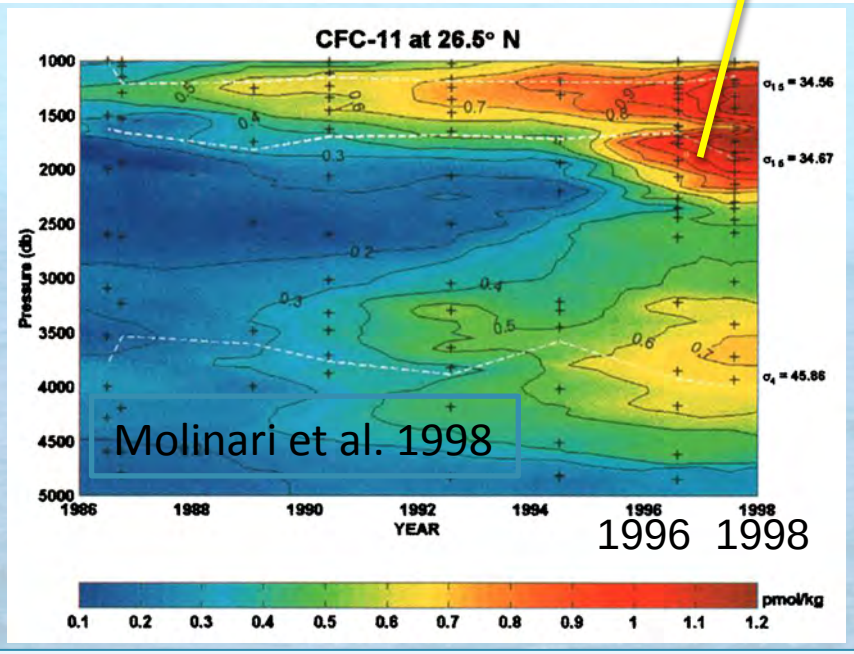


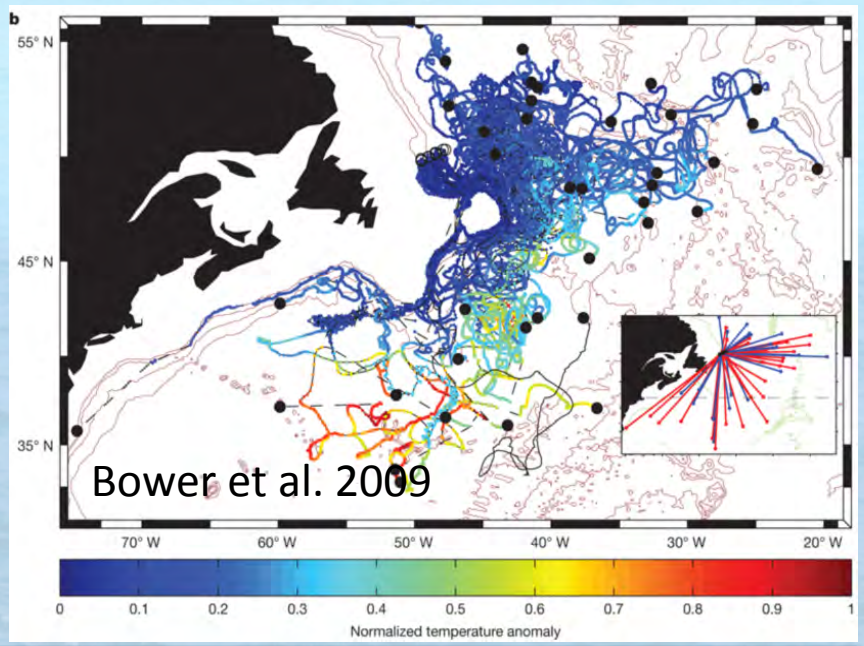
Modeled Winter Mixed Layer Depth

What is the decadal variability of tracer transport from deep convection regions to the subtropics, and how is it related to changes of ocean circulation?







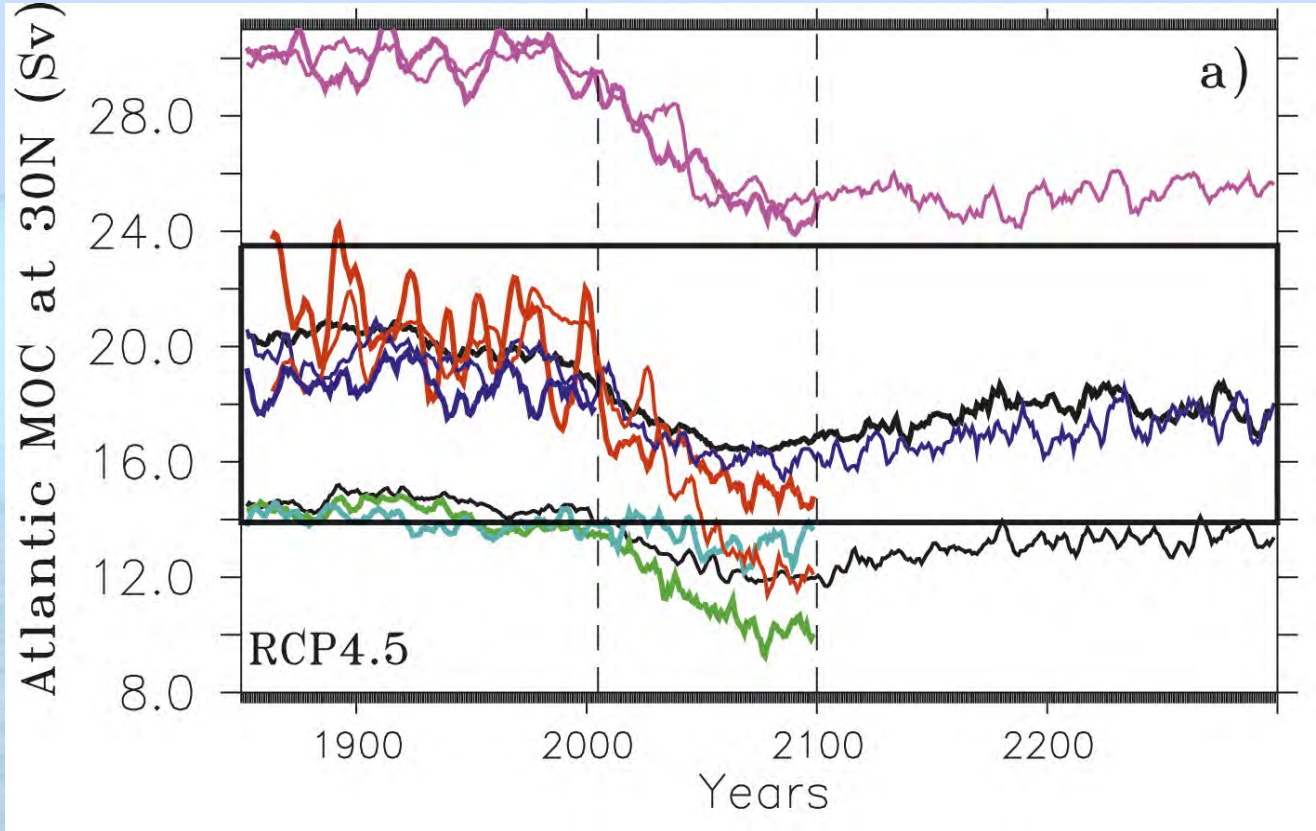


Purpose: to investigate if/how variations of CFC-11 in LSW along the pathway to the subtropics are related to decadal variability of AMOC and Labrador Sea ventilation

Challenges in understanding the decadal variability of AMOC

- Lack of long term observation of AMOC (RAPID ~ 10 years)
- Inconsistent AMOC state and variability in different models

CMIP5 models



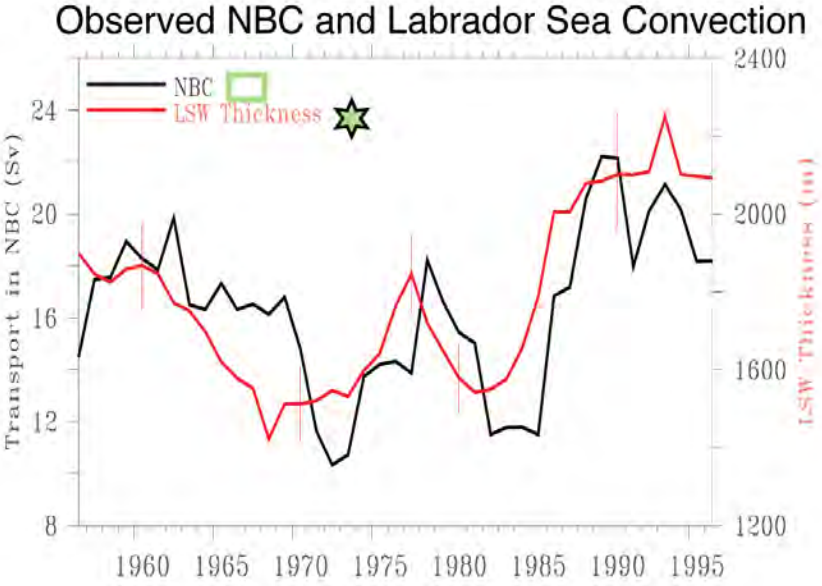
Cheng et al. 2013

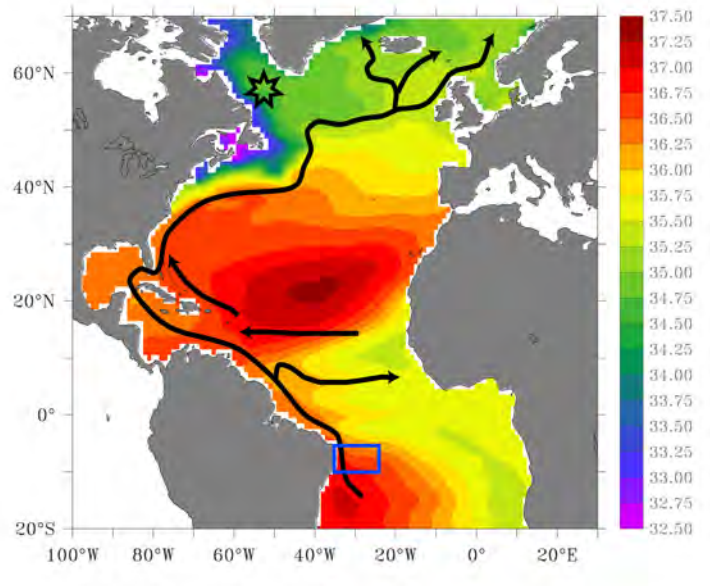
Approach:

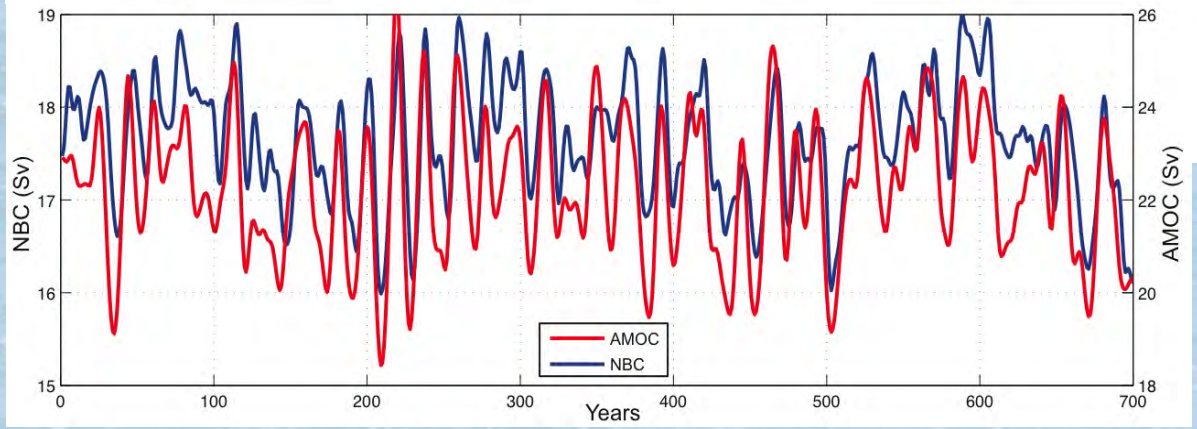
- using observation to validate and guide model development
- using model to explain observation

Observations:

- AMOC transport (Apr. 2004 - Mar. 2014) at 26°N by US-UK RAPID Program (http://www.rapid.ac.uk/rapidmoc/)
- Labrador Sea Deep Convection Index (Curry et al. 1998; Kieke et al. 2006)
- Historical North Brazil Current transport (Zhang et al. 2011)
- CFC11 observed during WOCE and CLIVAR Repeat Hydrography







Zhang et al. 2011

HYCOM Model Setting

- Global HYCOM (Bleck 2002), but on newly developed σ_1 coordinate (traditionally on σ_2)
- 1°×1°cos(latitude): 360×387 horizontal mesh with 30km resolution near North Pole; 46 vertical layers.
- Large and Yeager (2008) Interannual CORE II (1948-2009):

  5 cycles of the 62-year forcing as spin-up
- During the 6th cycle:

  forcing is extended with NCEP/CFSR (2008-2015);

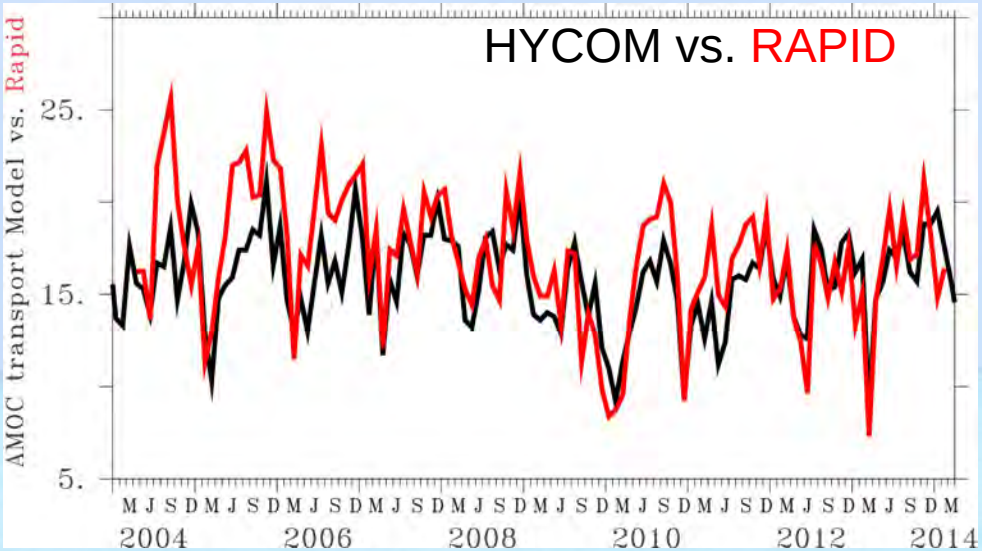
  CFC-11 uptake follows OCMIP2 (Dutay et al. 2002):

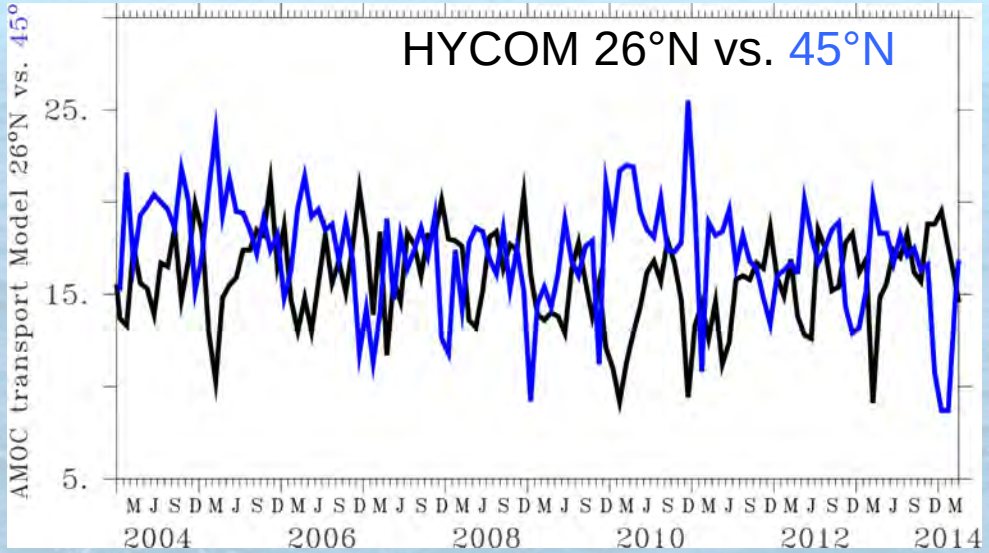
  F= Kw (Csat – Csurf)=F(winds, ice-cover, SST, SSS, CFC11 air)

  CFC11 air -- regularly updated by Dr. John Bullister at PMEL,

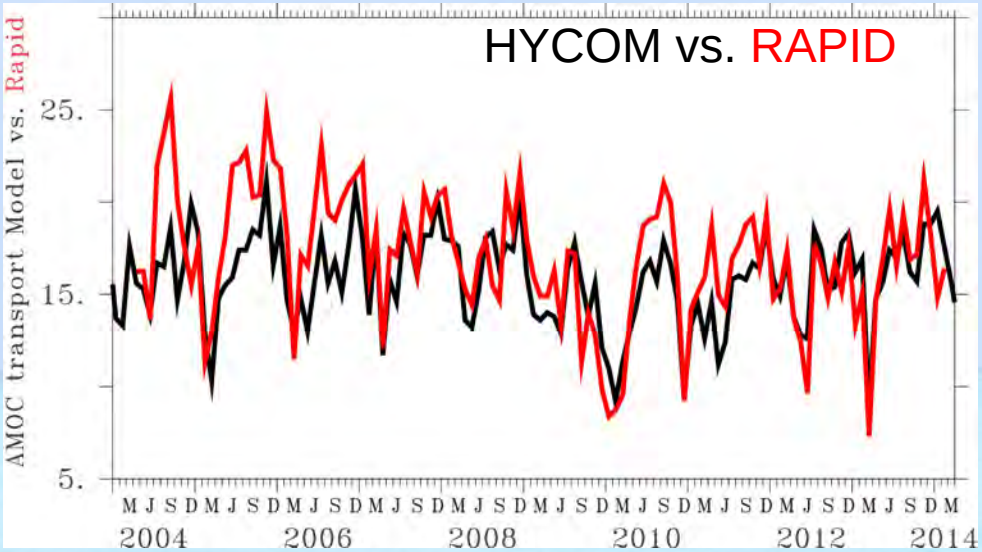
  http://cdiac.ornl.gov/oceans/CFC_ATM_Hist2015.html

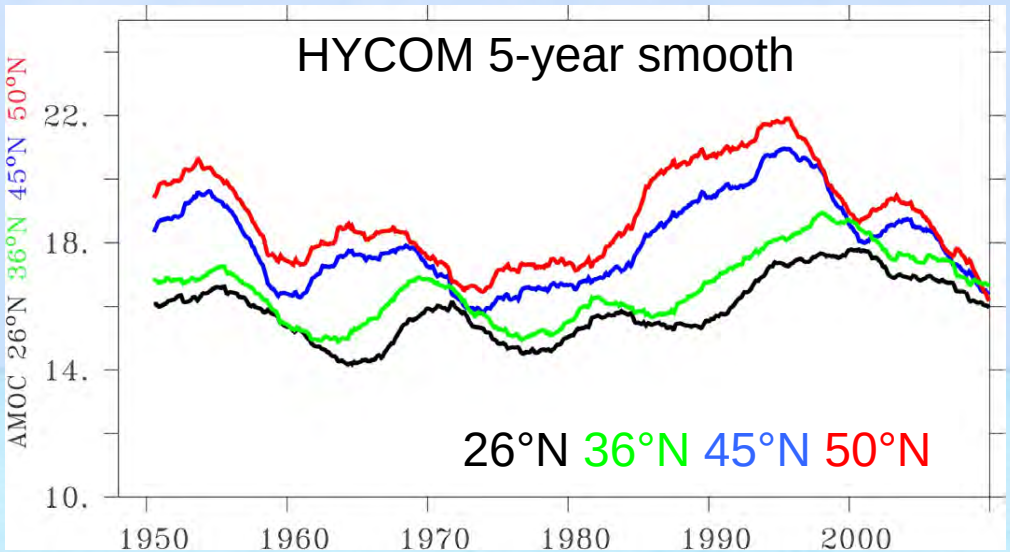
AMOC Transport

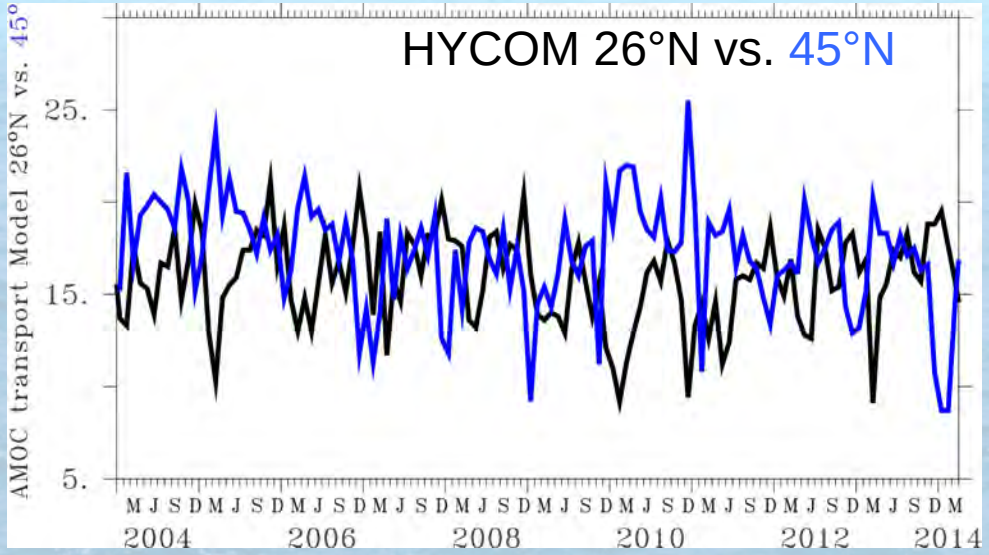


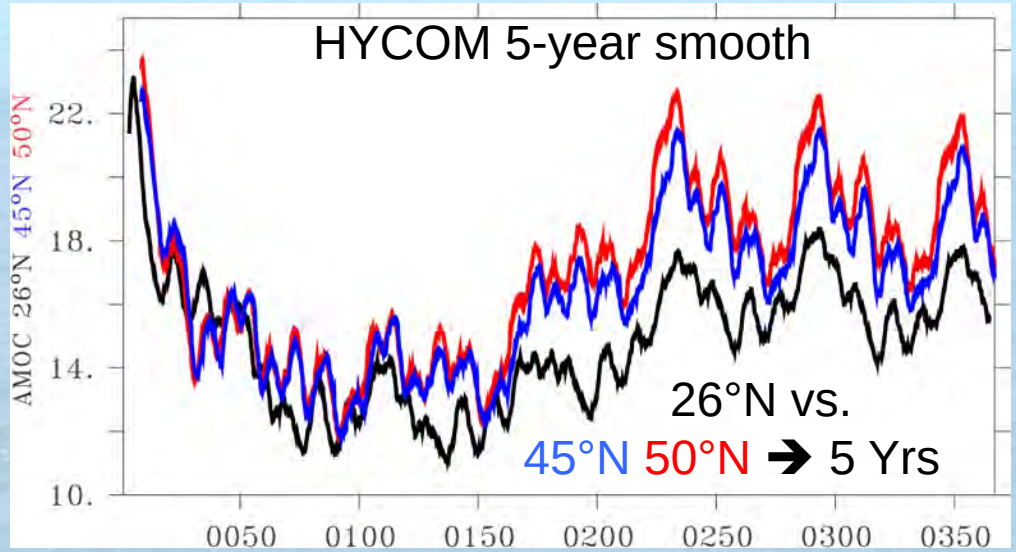


AMOC Transport



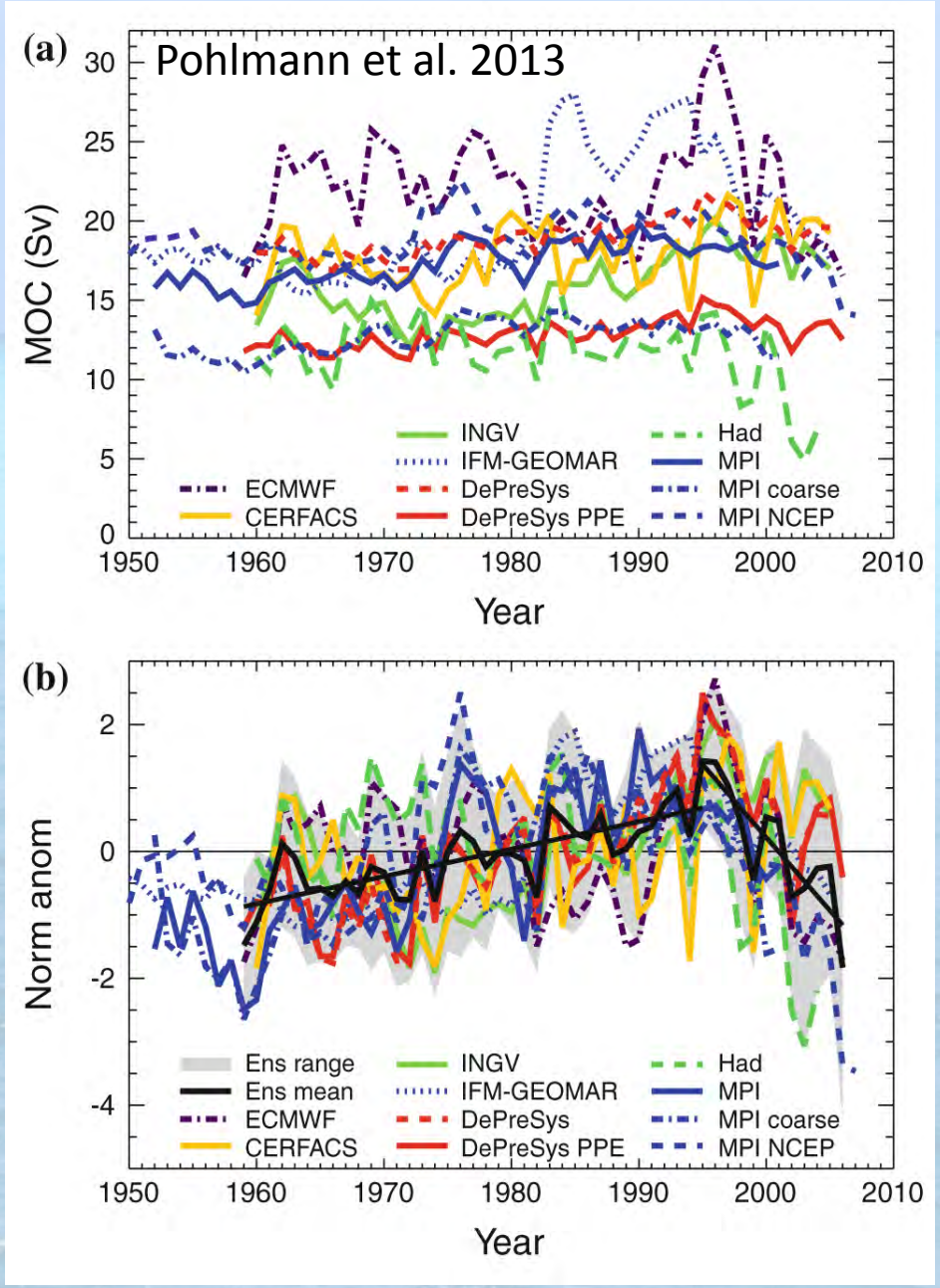


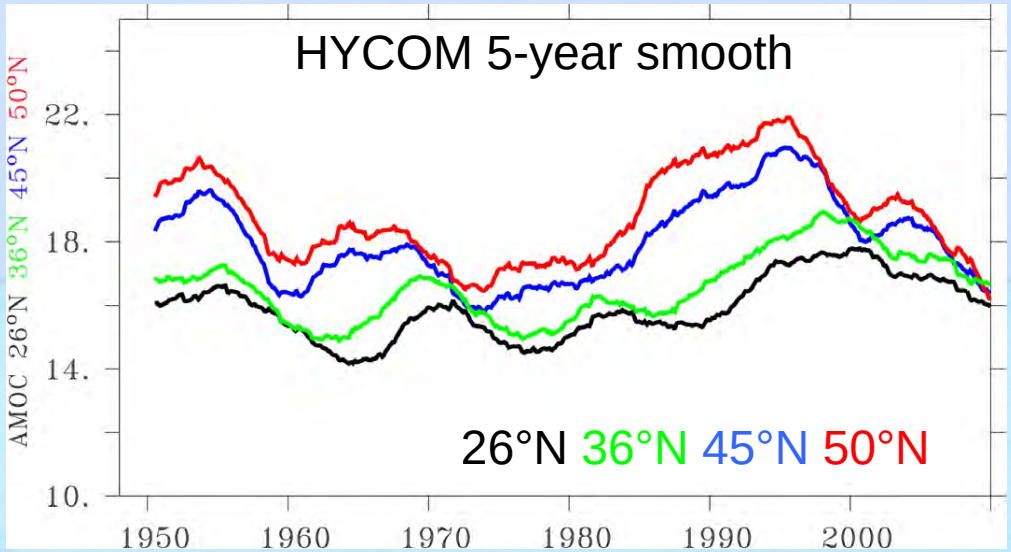


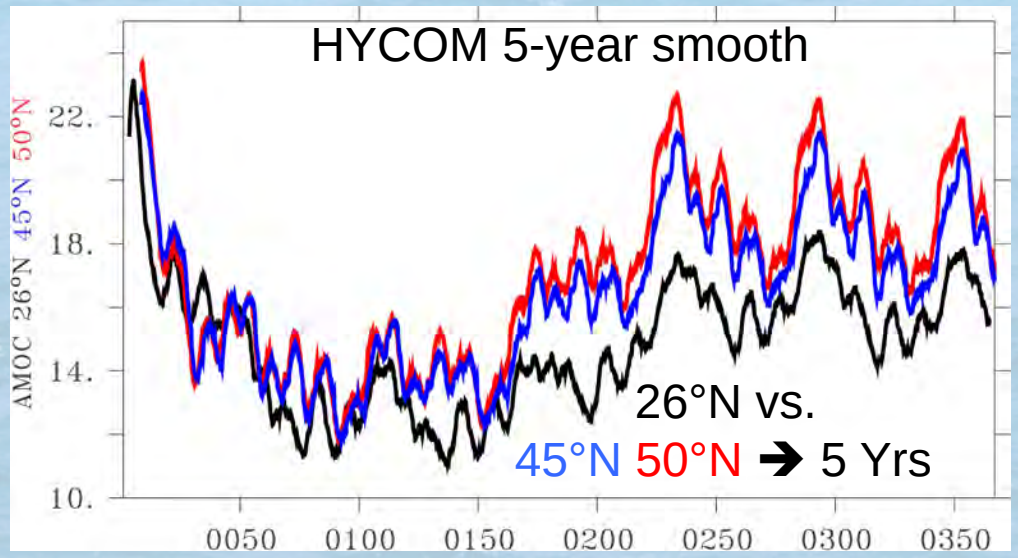


Comparison with Ocean Data Assimilations

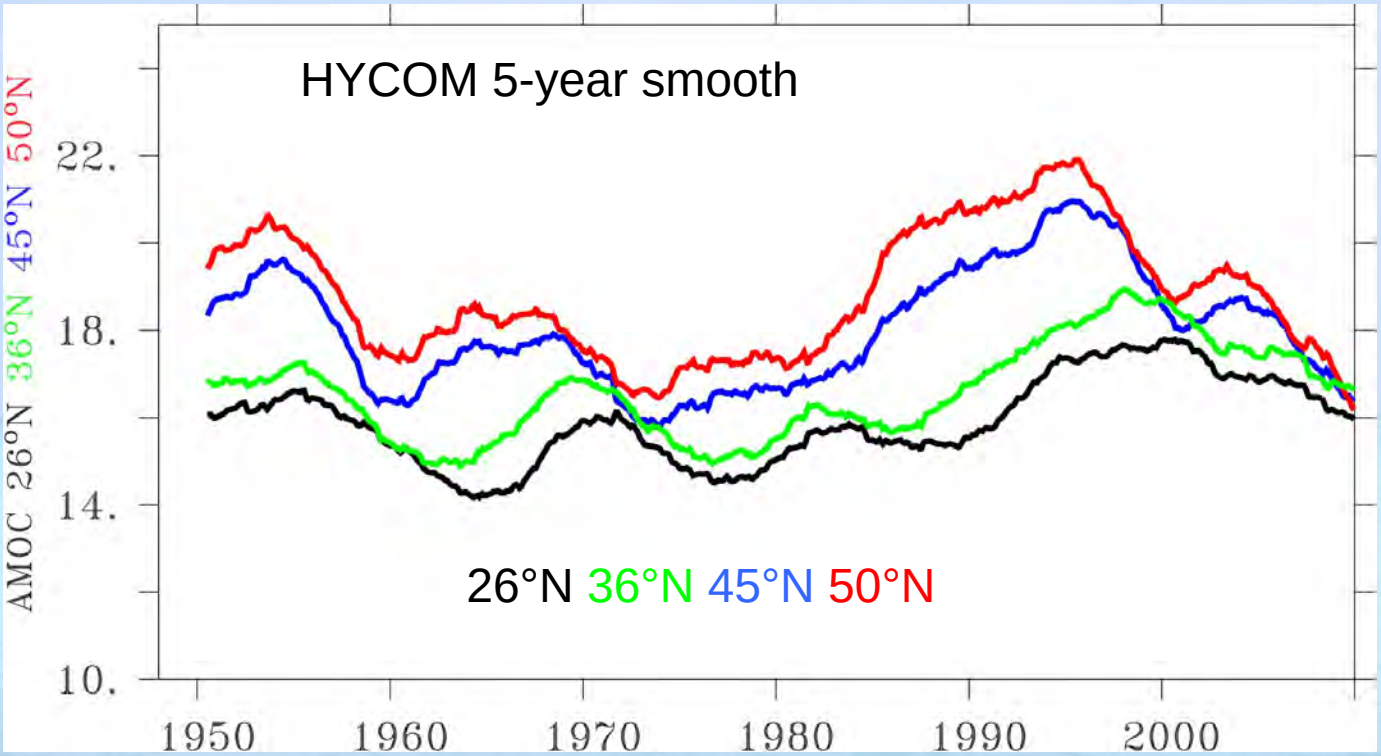
45°N

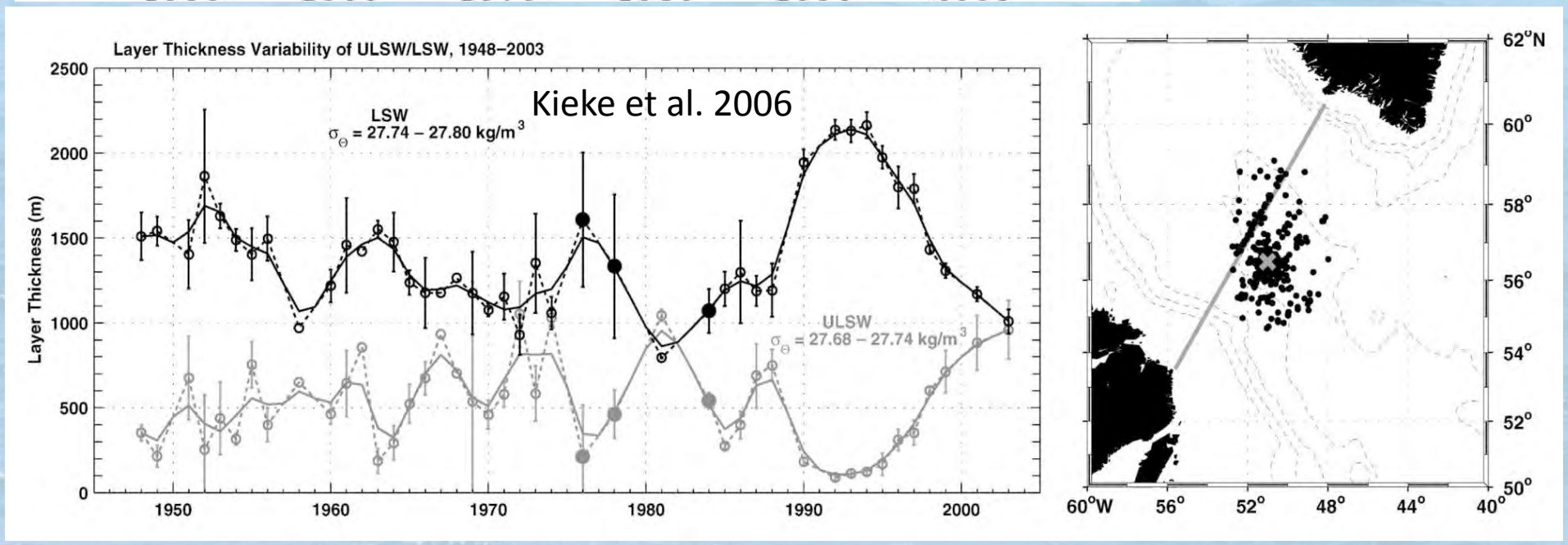




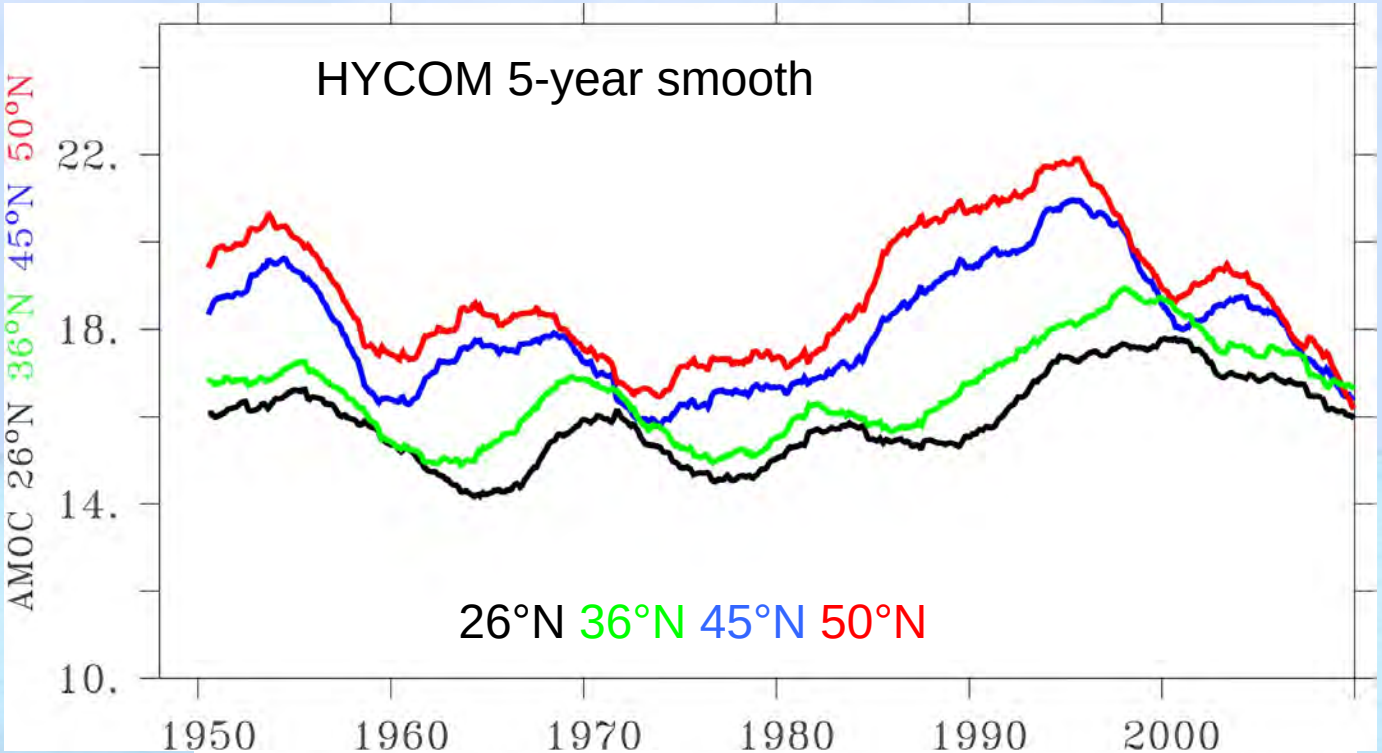


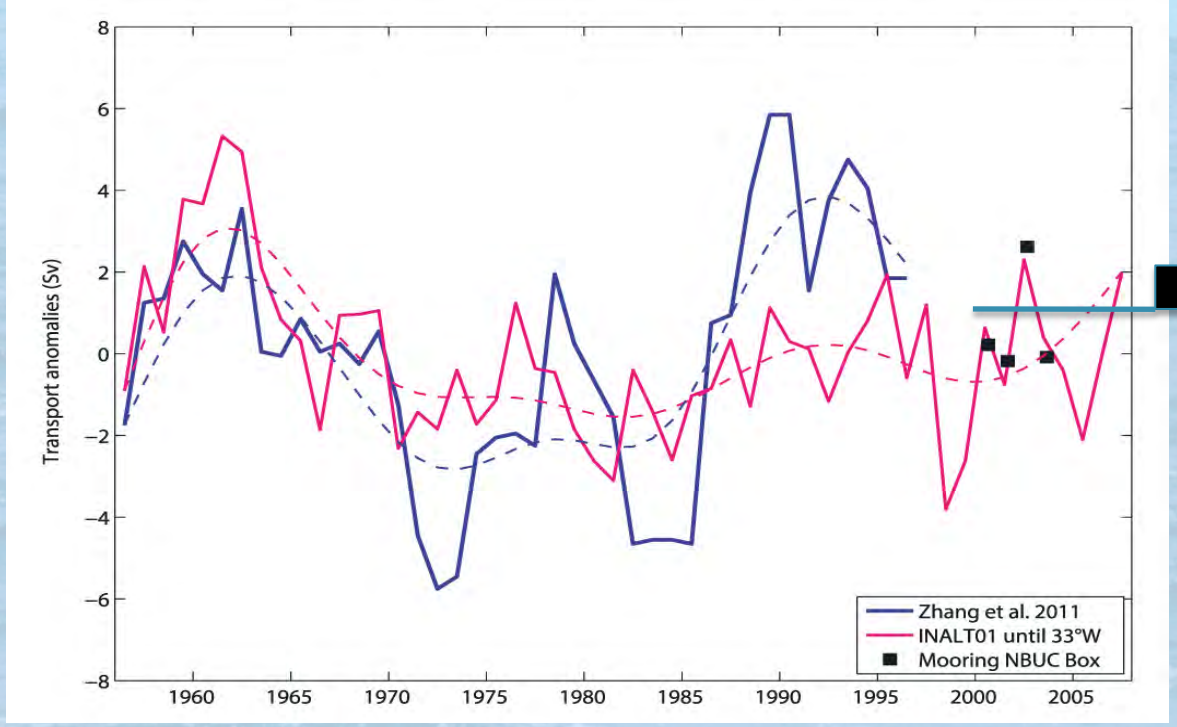
Model AMOC transport vs. observed LSW thickness





Model AMOC transport vs. observed NBC transport



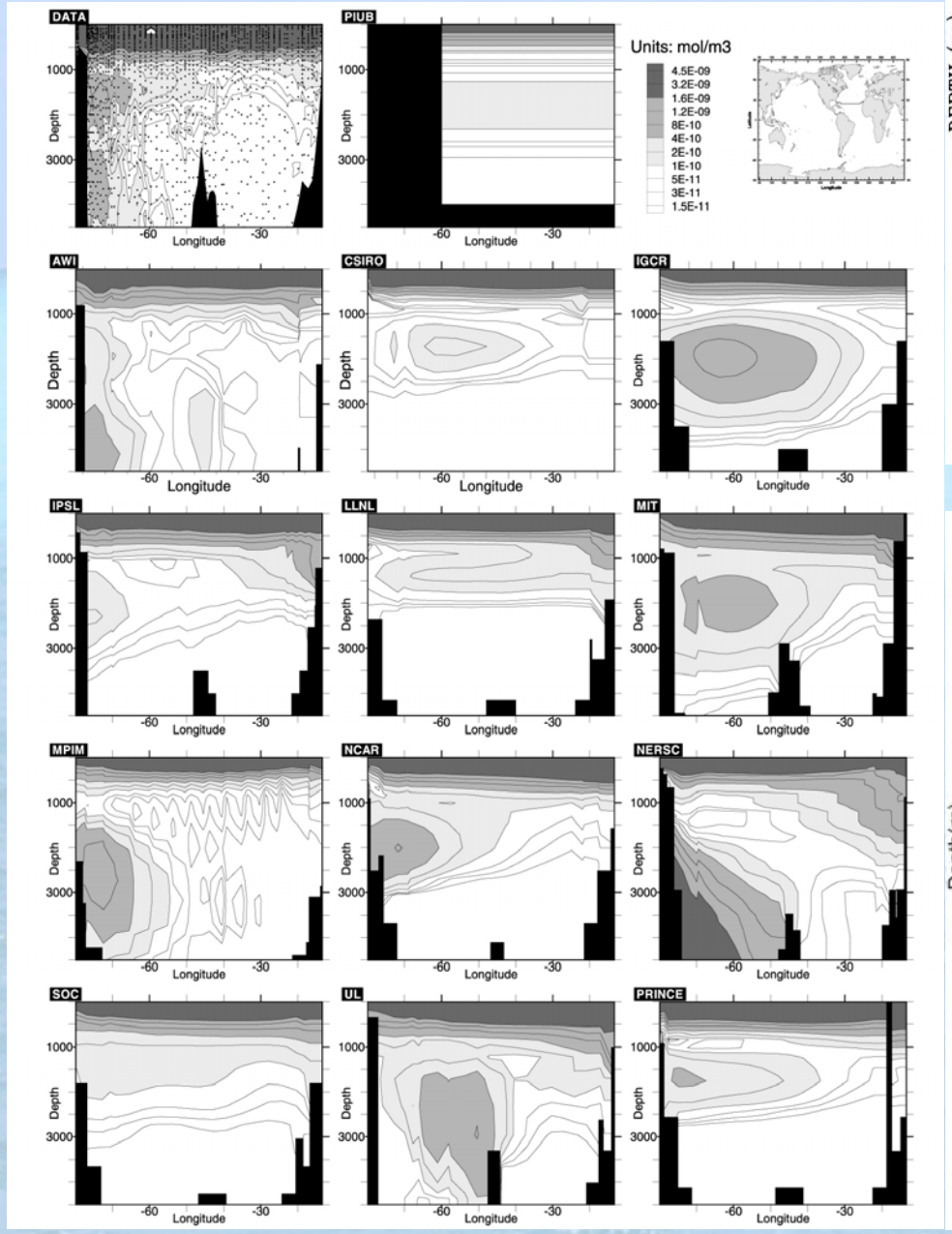


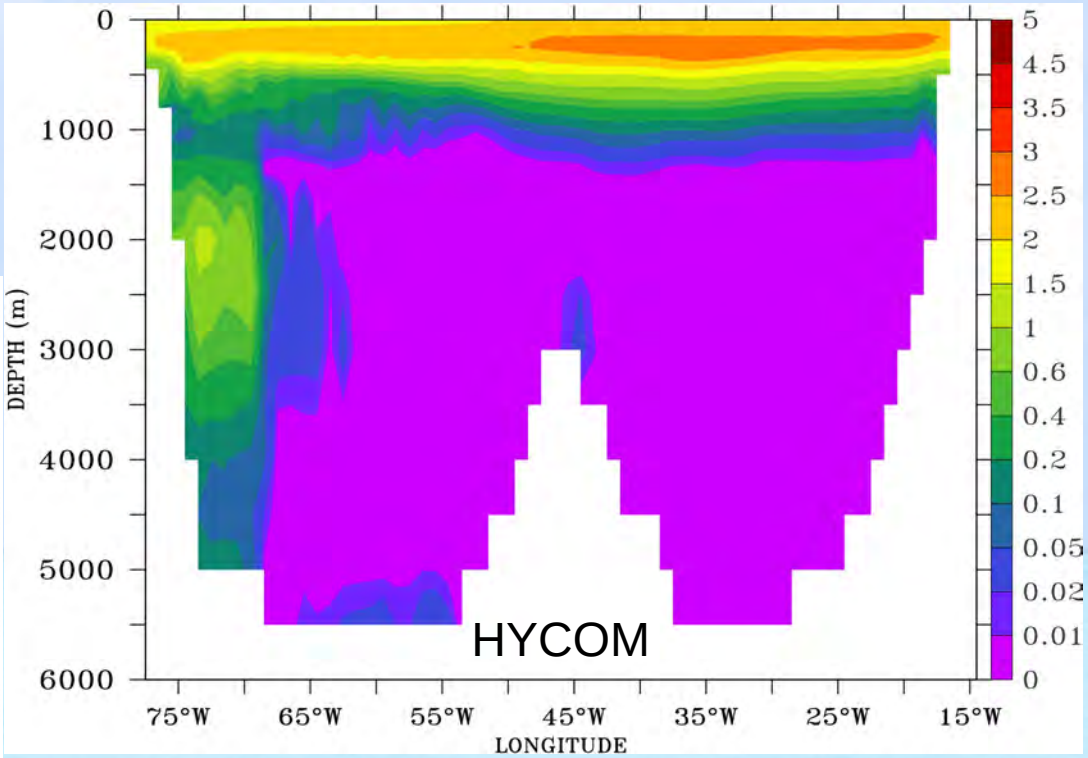
2013

Hummels et al. 2015

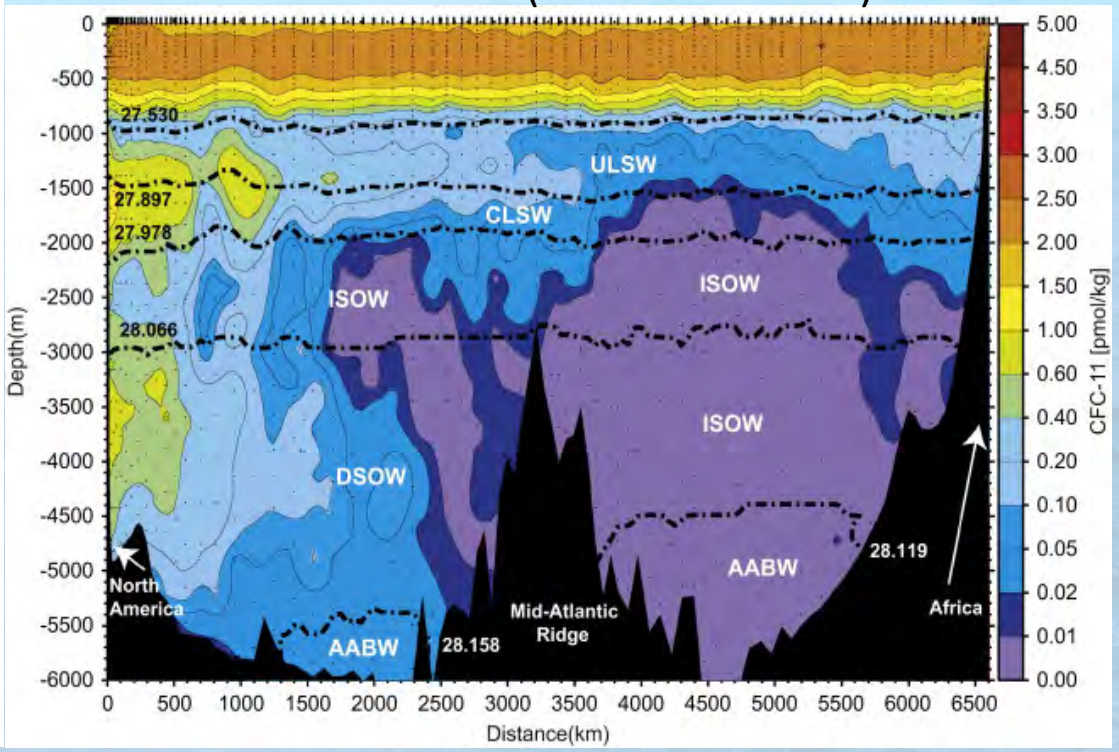
Modeled and Observed CFC-11 at 24.5°N in Feb. 1998 during WOCE

Dutay et al. 2002

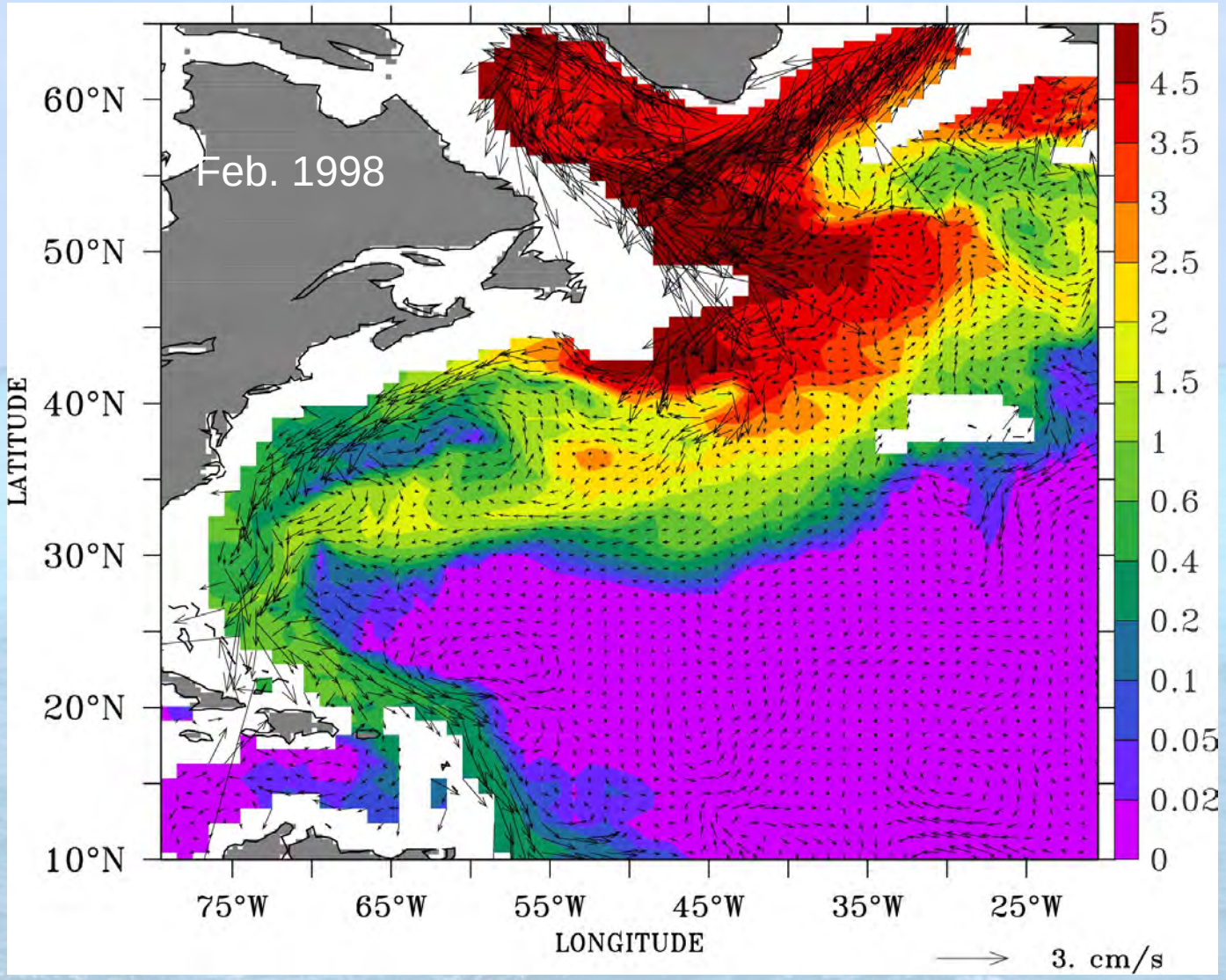




WOCE section (Lebel et al. 2008)



Modeled CFC-11 and currents at 1800m



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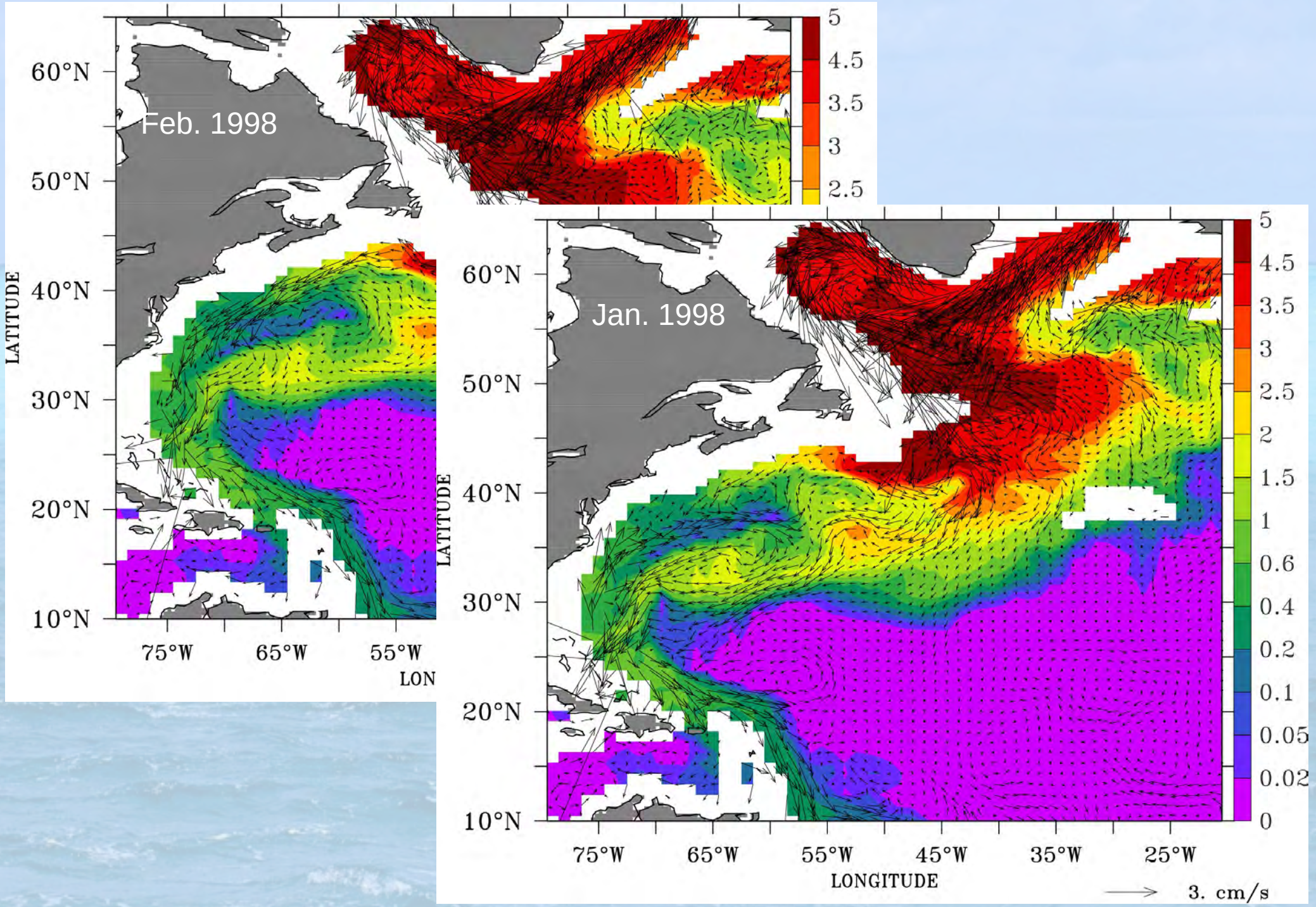
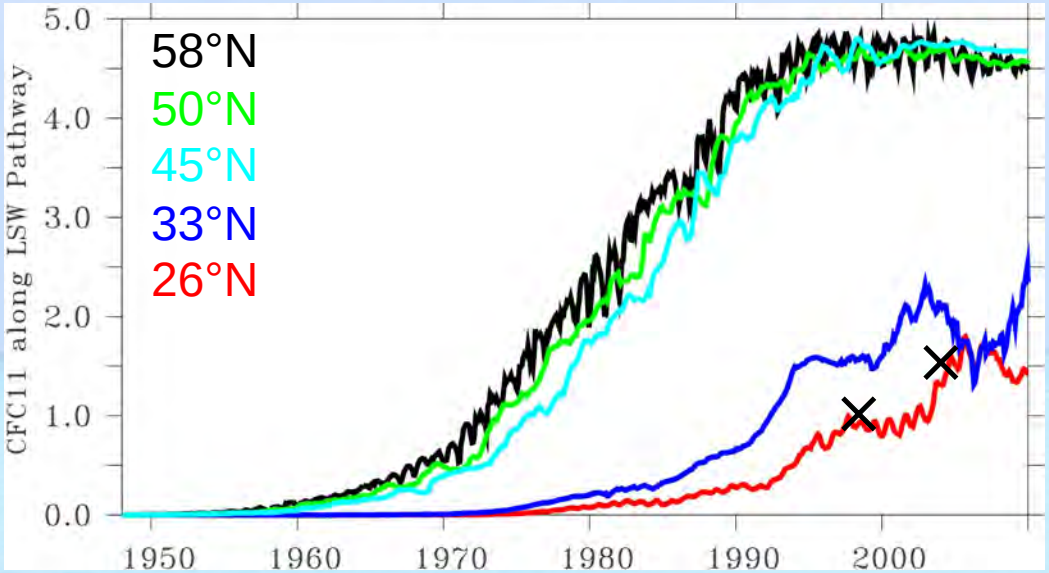
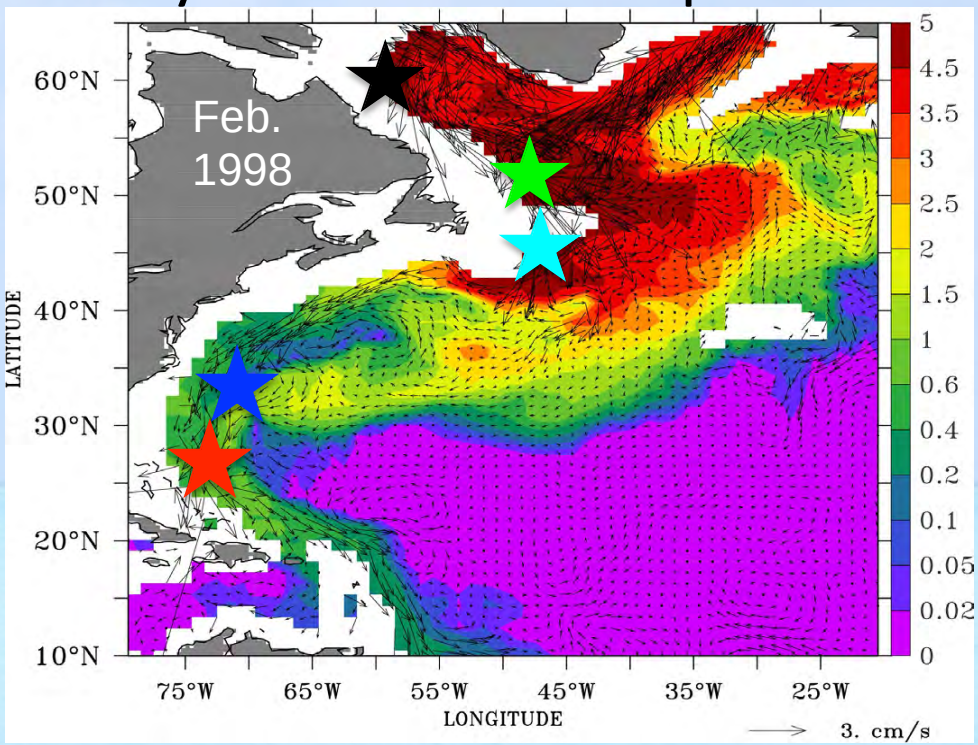
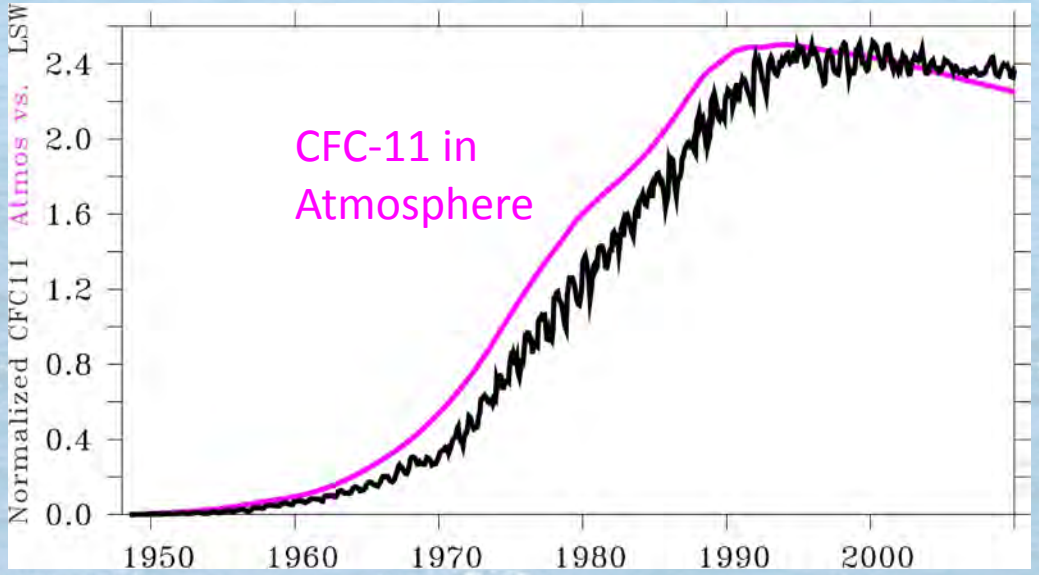


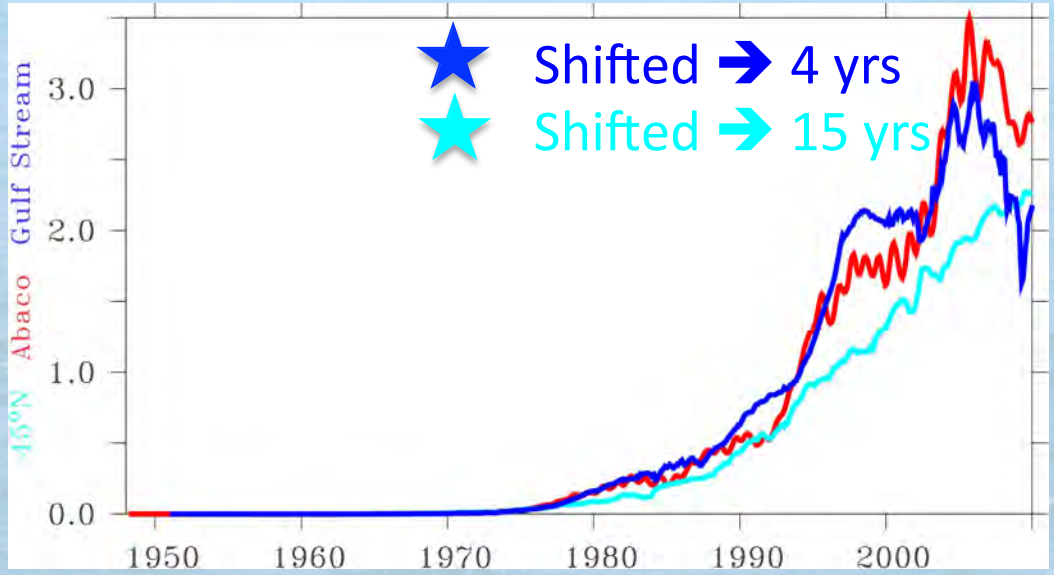
Modeled CFC-11 along LSW pathways into the subtropics





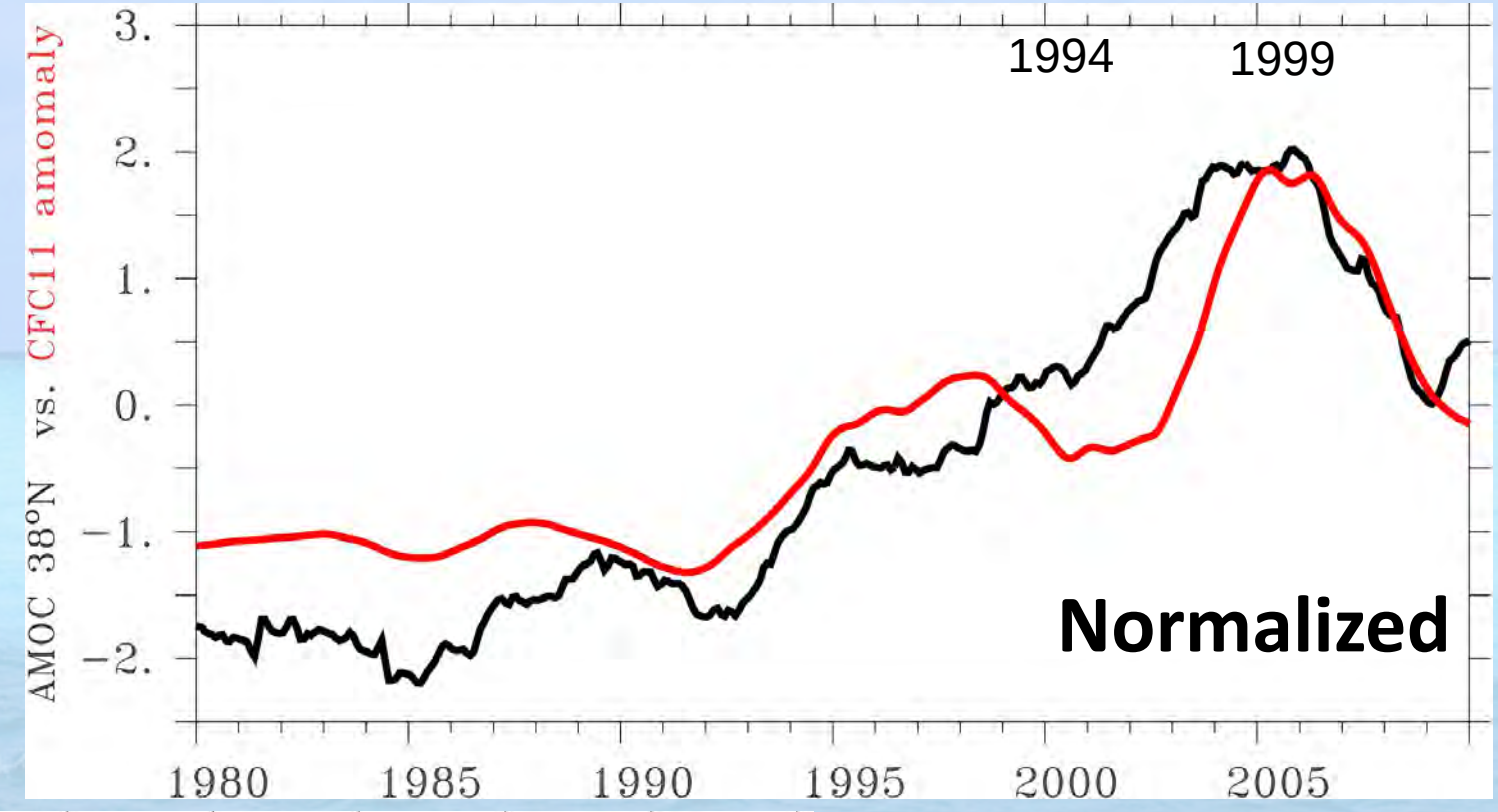


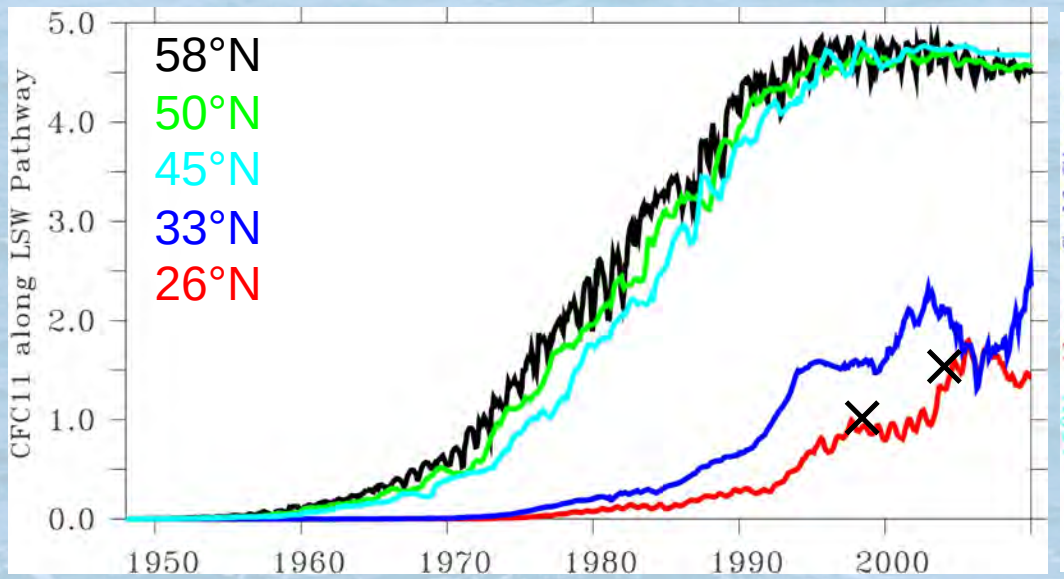
Normalized

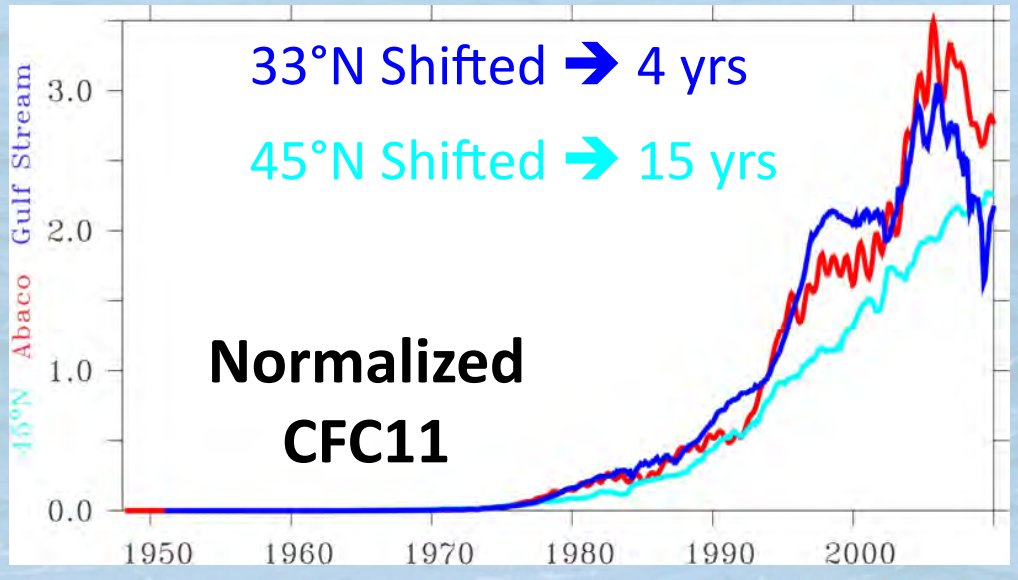


Normalized

CFC-11 anomaly at Abaco in the LSW layer vs. AMOC transport at 38°N (shifted ➔6 yrs)







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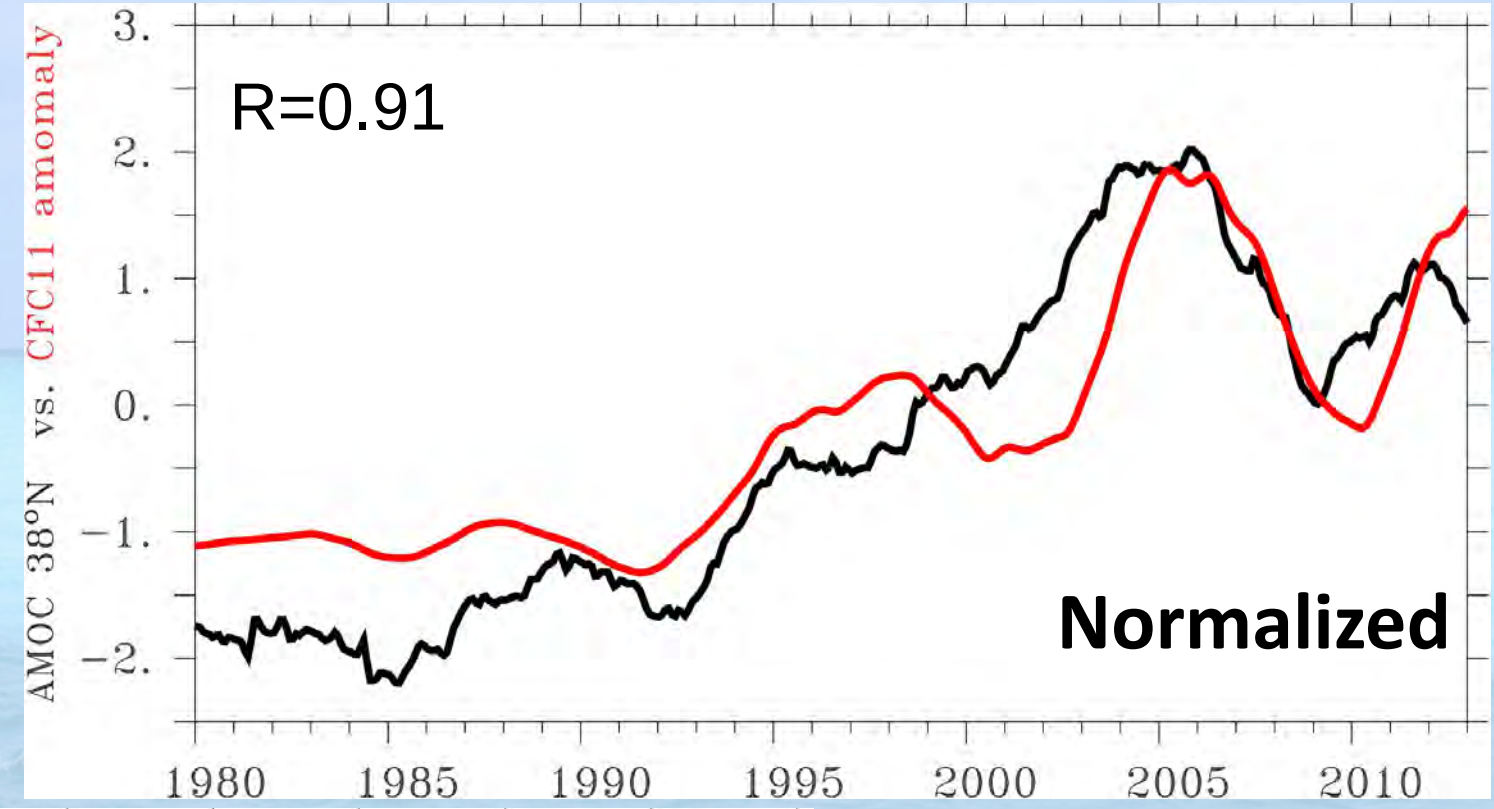

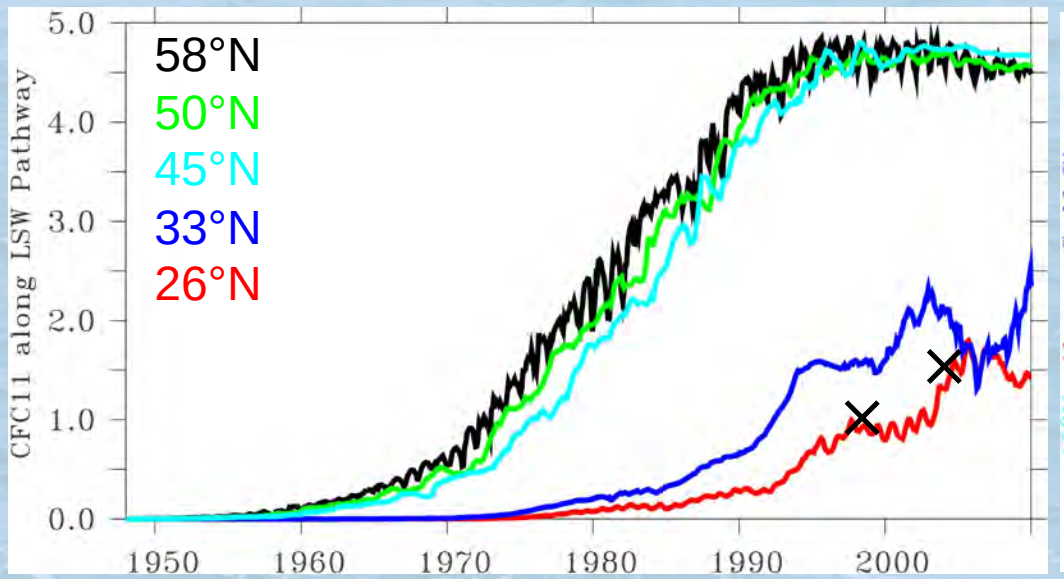

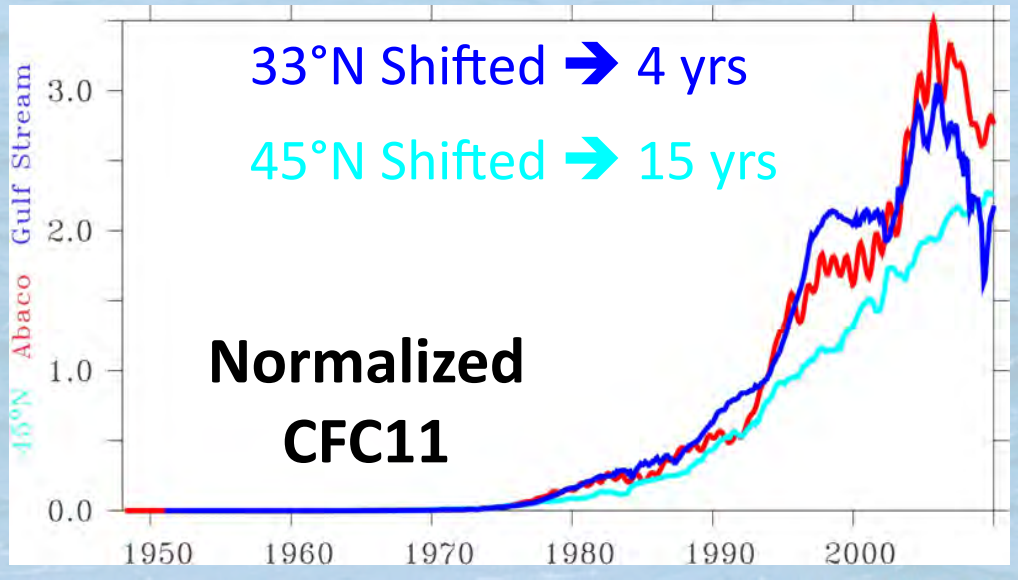

Conclusions

- Model and limited historical observations suggest that the slow-down of AMOC in the recent decade is preceded by a multi-decadal strengthening, and is part of the natural variability of AMOC, that follows the deep convection in the Labrador Sea.
- Both the western boundary and interior pathway contribute to the tracer transport from the Subpolar to Subtropical North Atlantic.
- The overall shape of the increasing CFC-11 time series in the Labrador Sea leads that east of Abaco in the DWBC by 18-20 years, suggesting an important role of mixing along the DWBC or interior pathway of LSW into the subtropical ocean.
- The decadal variation (anomalies from that overall increasing) of CFC11 in the DWBC of the subtropics, however, respond to the Labrador Sea Deep convection much faster, in about 10 years. This is through the AMOC decadal variation at the cross-over of Gulf Stream and DWBC, via v' d(tracer)/dy mechanism.