Links Between the Deep Western Boundary Current, Labrador Sea Water Formation and Export, and the Meridional Overturning Circulation

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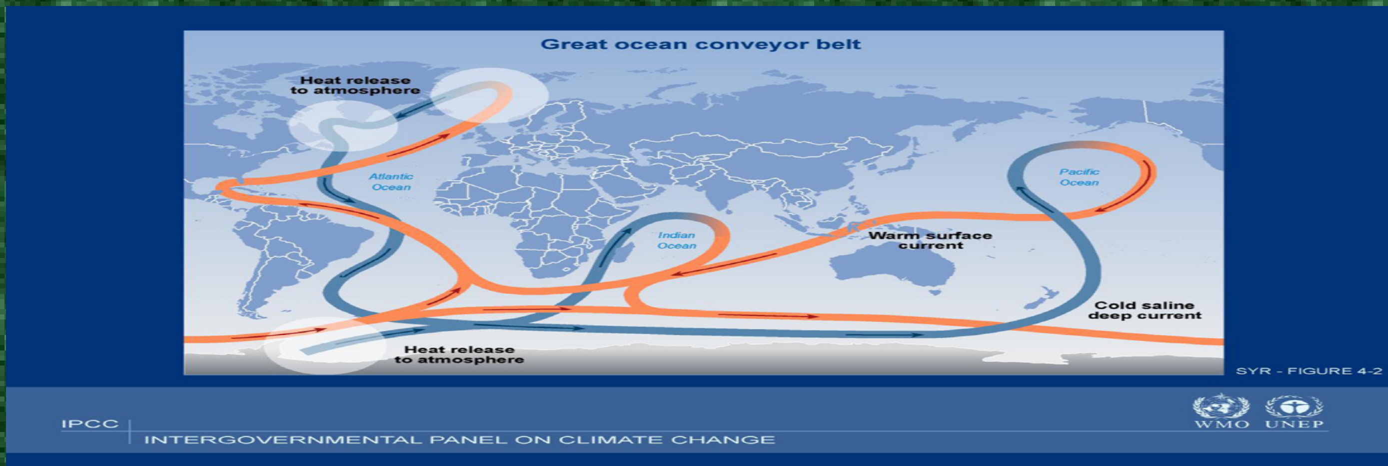
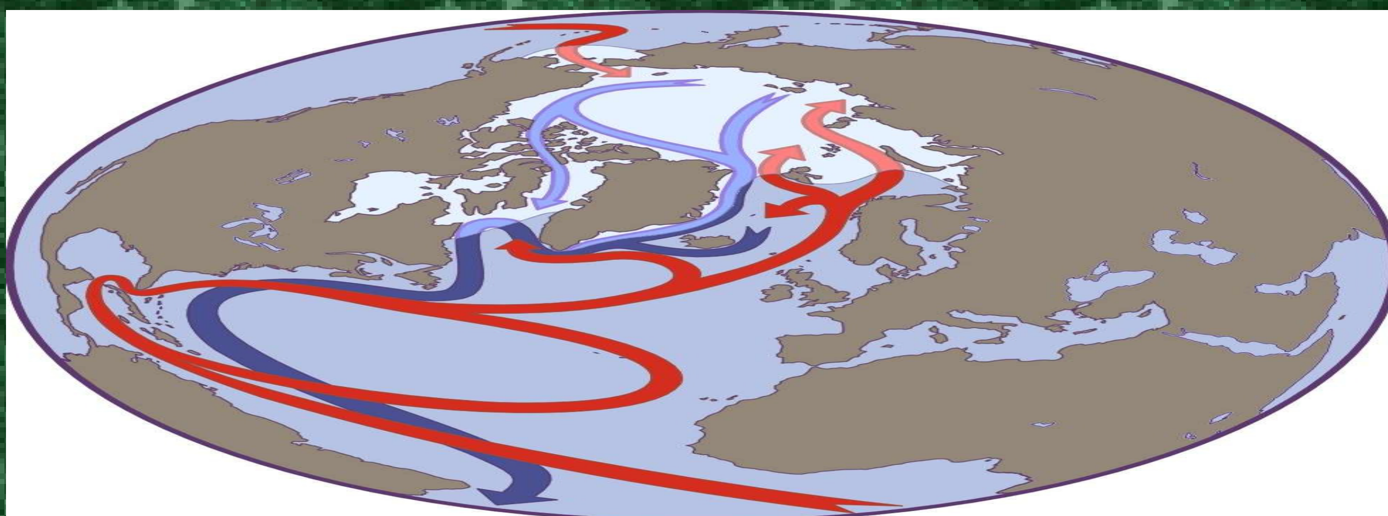
Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)
NSERC CRSNG People. Discovery. Innovation.
GOAPP Global Ocean-Atmosphere Prediction and Predictability

Introduction

- Atlantic Meridional Overturning Circulation (AMOC)
- Data
  - Labrador Sea climatology and triad analysis, 1949-1999
  - Spectral nudged modelling experiments
- Labrador Sea Water Formation
  - Volume Rate of Change
  - Instanteous kinematic approach
- Transport in the Deep Western Boundary Current
- Links to the AMOC
- Summary

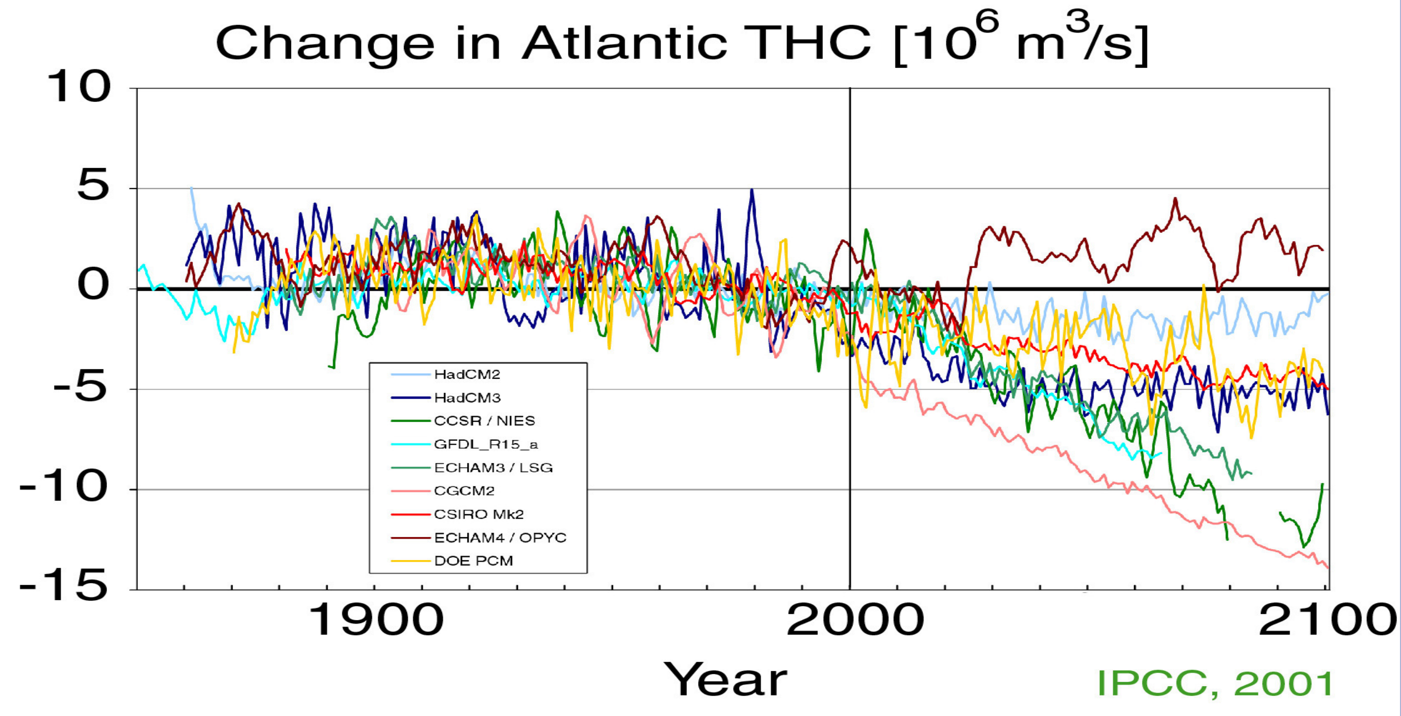
Meridional Overturning Circulation



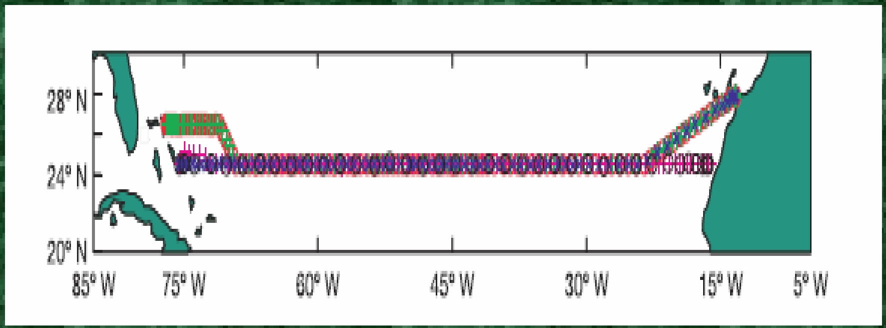


Taken from Holloway, 2003

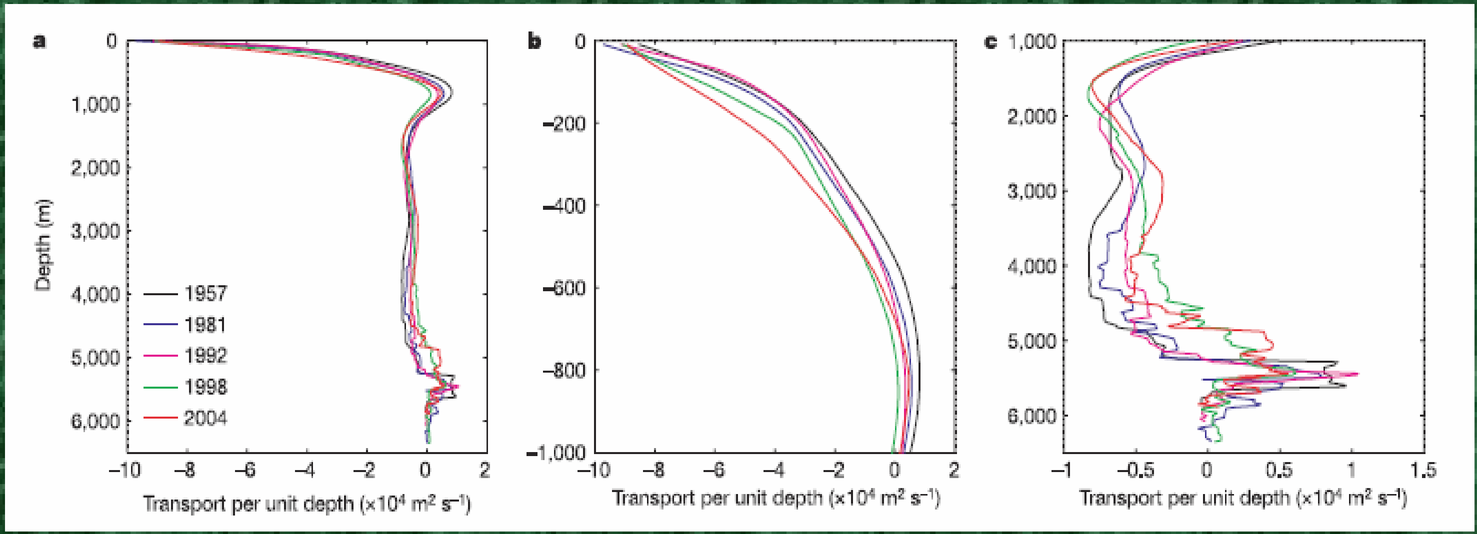
MOC Variability



Suggestion for Observed Weakening of MOC



Both: Bryden et al., 2005



Climatological Analysis

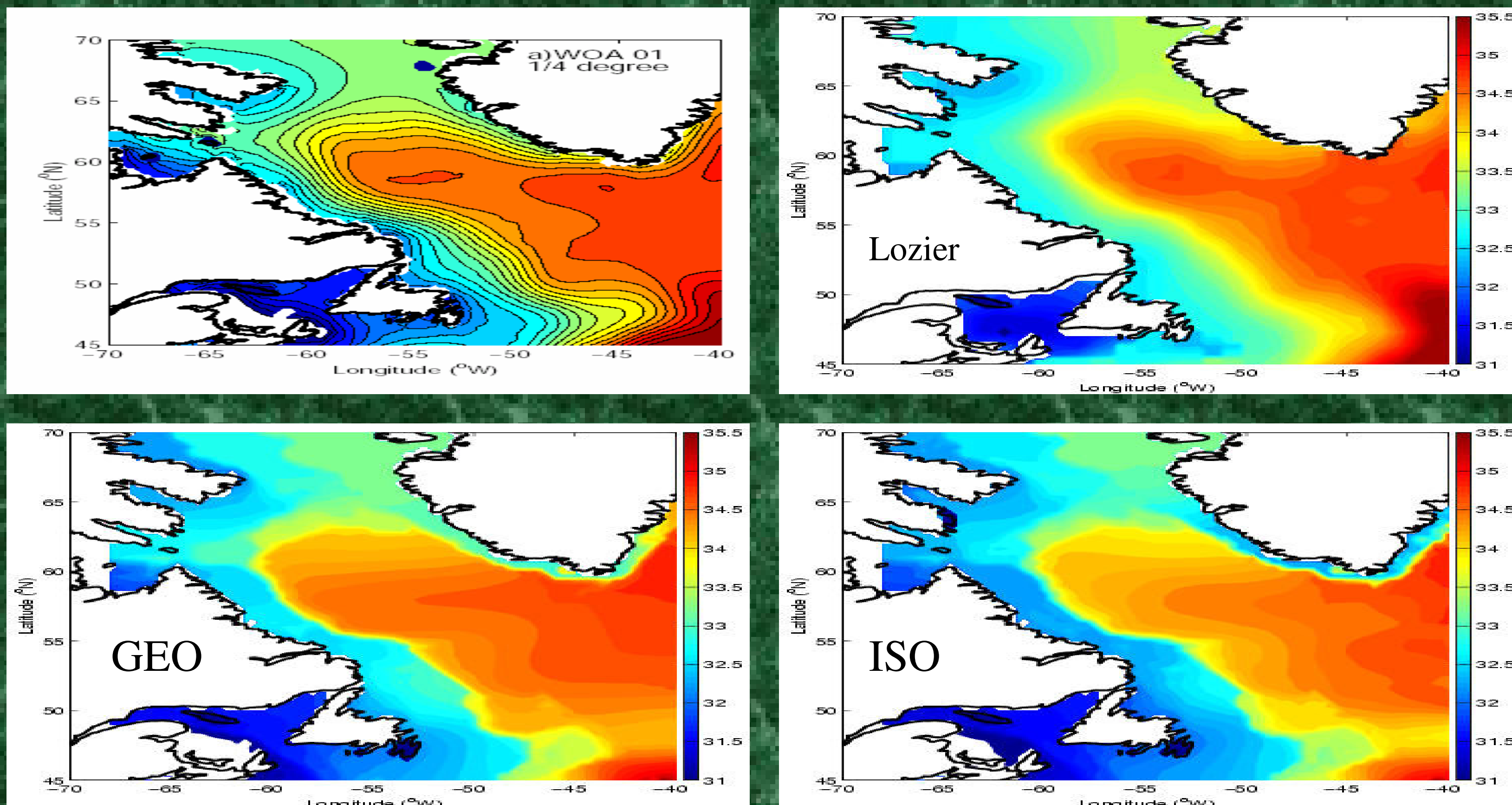
- Region: 45-70N; 40-70W
- 1/3 degree resolution
- Based on data in MEDS database, 1910-present – Temperature and Salinity
- Objective Analysis using Iterative Difference-Correction Scheme
  - Modified by polynomial weighting based on bottom depth
  - Three search radii: 500, 300 and 150 km
- Vertical Binning
  - Isopyncal Coordinates (46 isopyncal surfaces)

Kulan and Myers, 2009

Climatological Study

- Time varying Triads also produced
  - Triads based on overlapping running means
    - E.g. 1970 uses data from 1969-1971
- Climatological Data merged with Levitus and/or Lozier climatologies for rest of sub-polar gyre
- Assimilated into regional model of the Sub-Polar Gyre
  - Technique: Spectral Nudging – 10 day damping timescale
  - Mean is controlled but neither annual cycle nor eddies significantly damped
  - Allows model to adjust T and S fields to fix mis-matches between velocity and density fields
  - Each year run repeatedly for 5 years to allow for ‘nudging to stablize’
  - Also, a 5 year run with the long-term mean climatology and perpetual year forcing run

30 m salinity



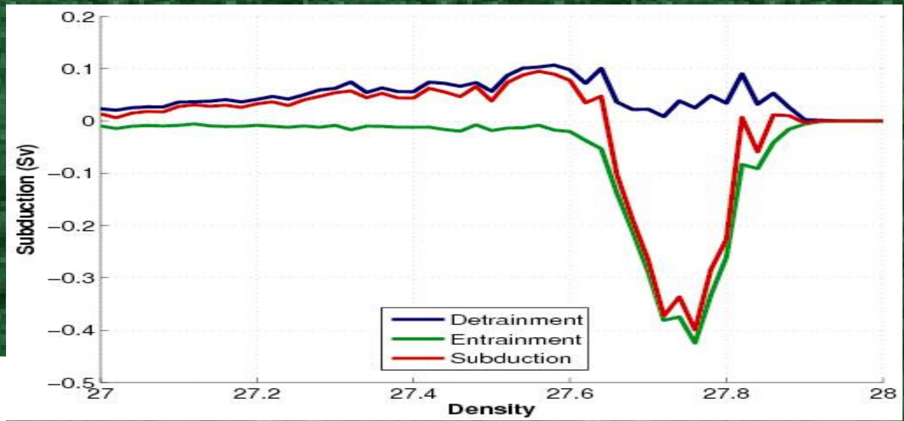
Kulan and Myers, 2009

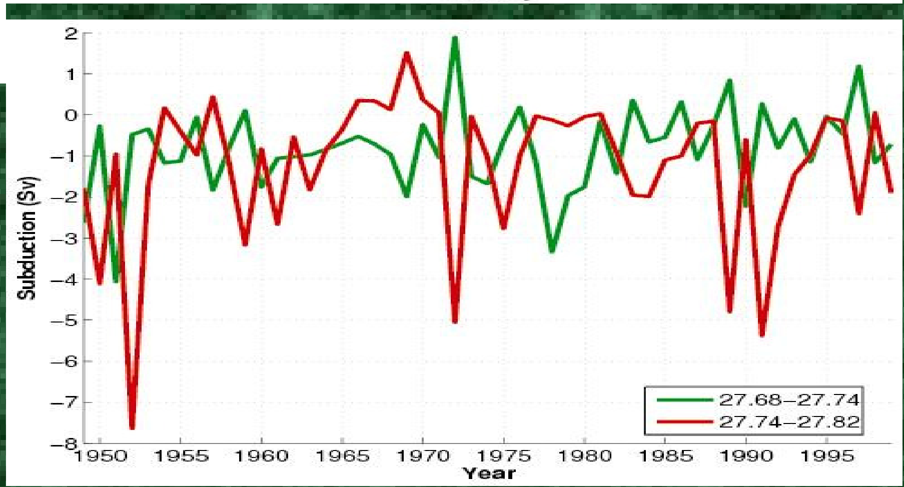
Labrador Sea Water Formation

$$S(\mathbf{x}, t) = -\left[\frac{\partial h}{\partial t} + \nabla \cdot (\mathbf{u}h)\right],$$

$$S(\sigma, t) = -\int_{A_S(\sigma,t)} \left[\frac{\partial h}{\partial t} + \nabla \cdot (\mathbf{u}h)\right] dA,$$

$$\overline{S}(\sigma) = -\frac{1}{\Im}\int_0^{\Im} \left\{\int\int_{A_S(\sigma,t)} \left[\frac{\partial h}{\partial t} + \nabla \cdot (\mathbf{u}h)\right] dA\right\} dt,$$





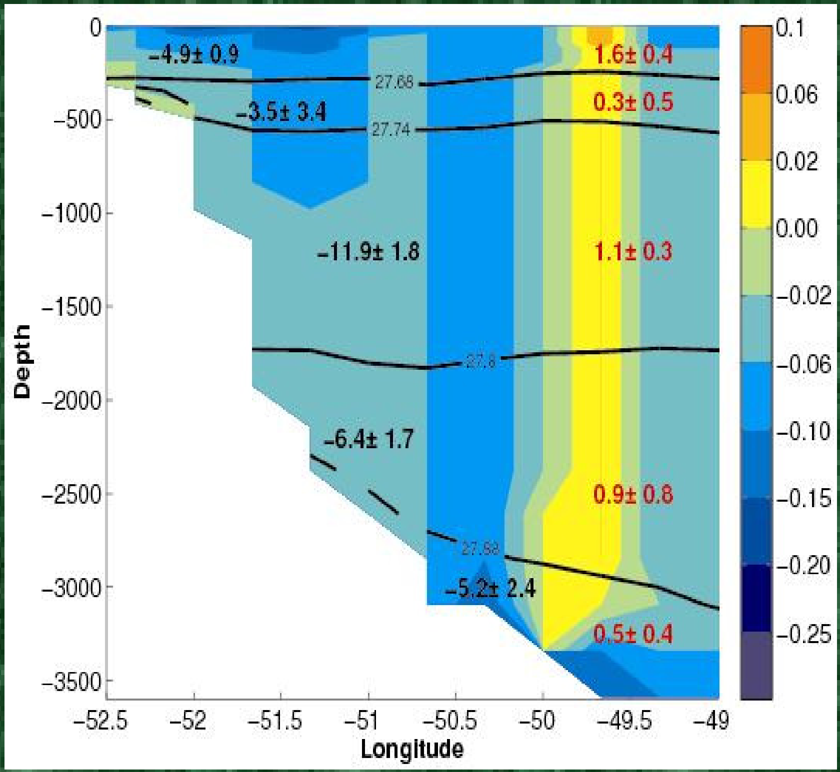
- Subduction based on:
  - I) ML retreat
  - II) Convergence of horizontal transport into ML
  - S > 1 subduction
  - S < 1 entrainment into ML
    - Later transferred into interior through deep convection

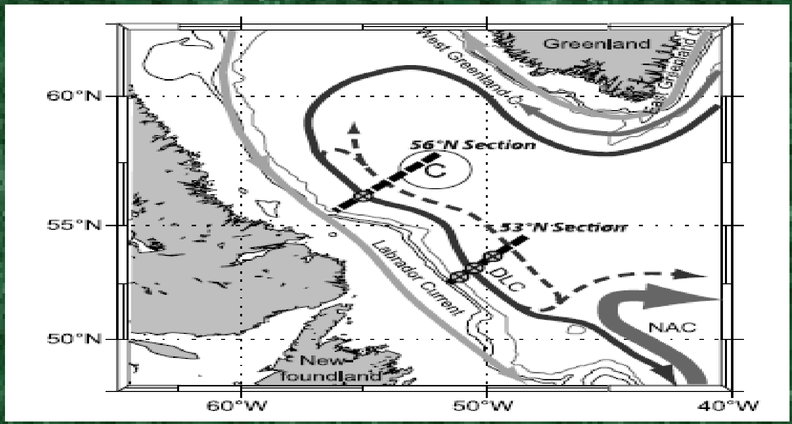
Mean: 1.2 Sv (27.74-27.82) and 0.8 Sv (26.68-27..74)

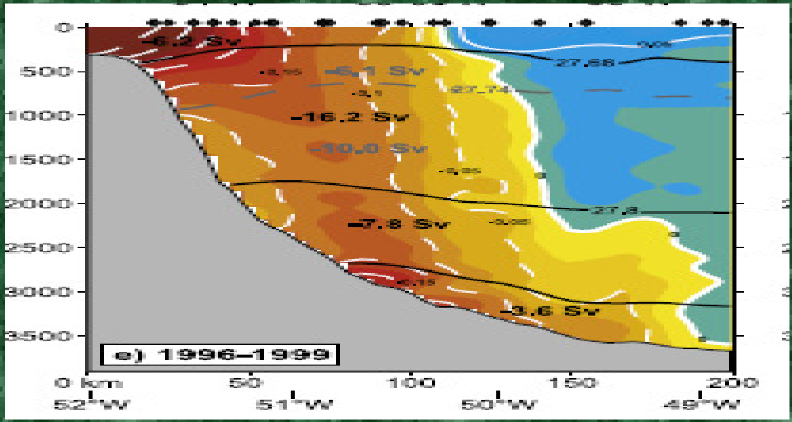
Export in DWBC at 53N

Dengler et al, 2006

1996-1999



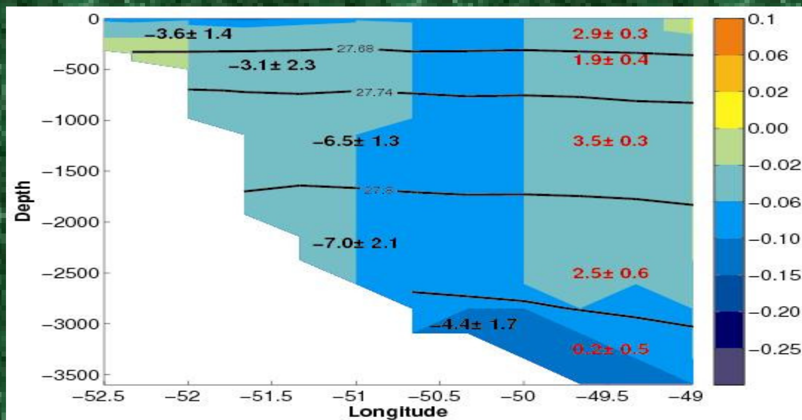


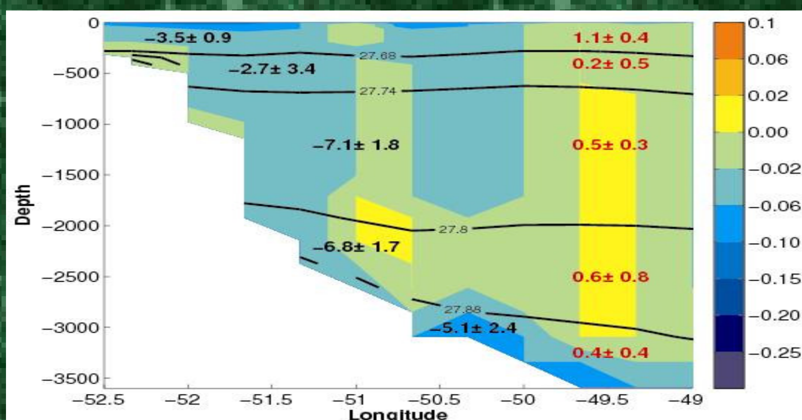


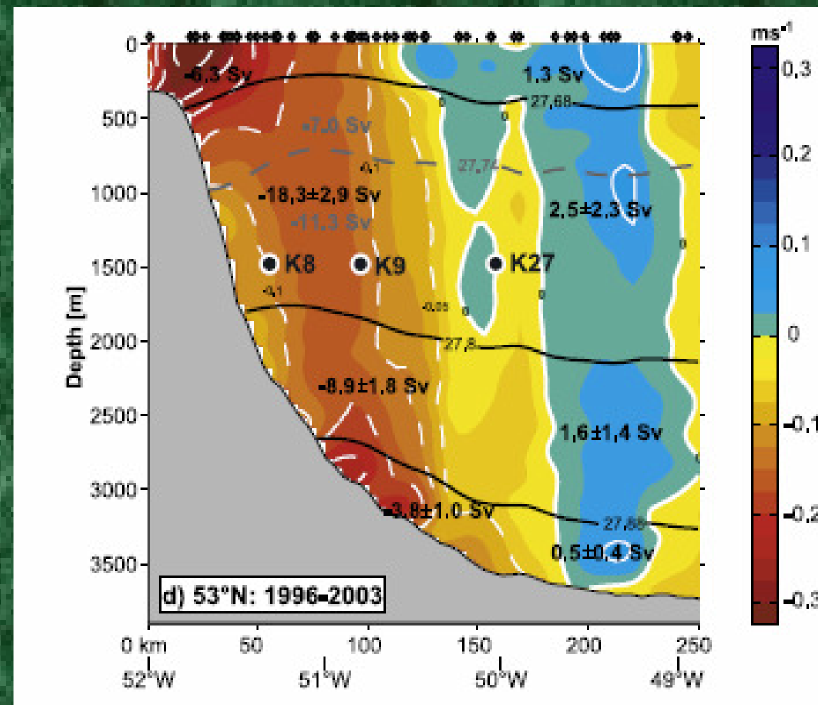
Export in DWBC at 53N

Mean Exp.

Dengler et al, 2006

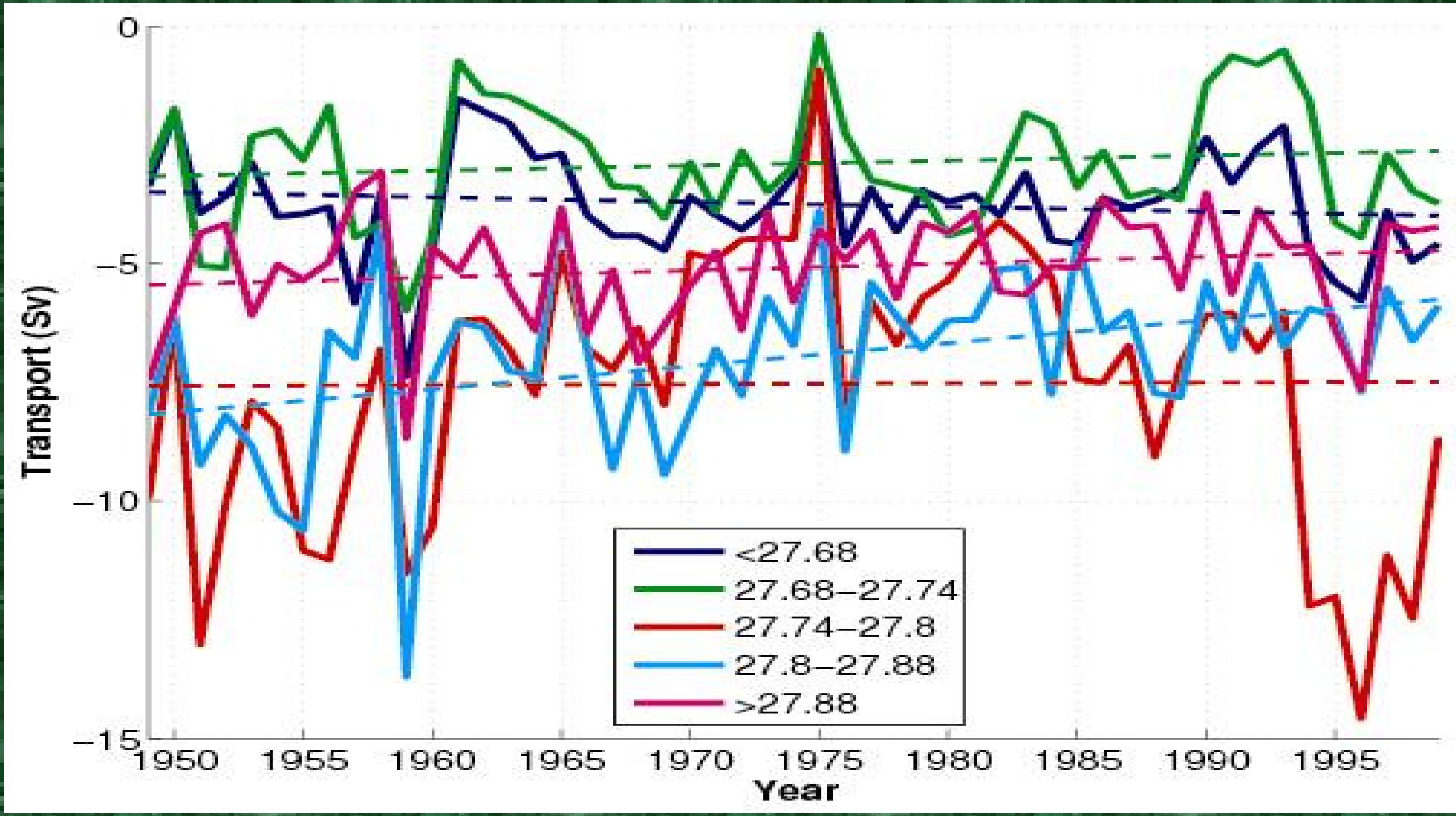






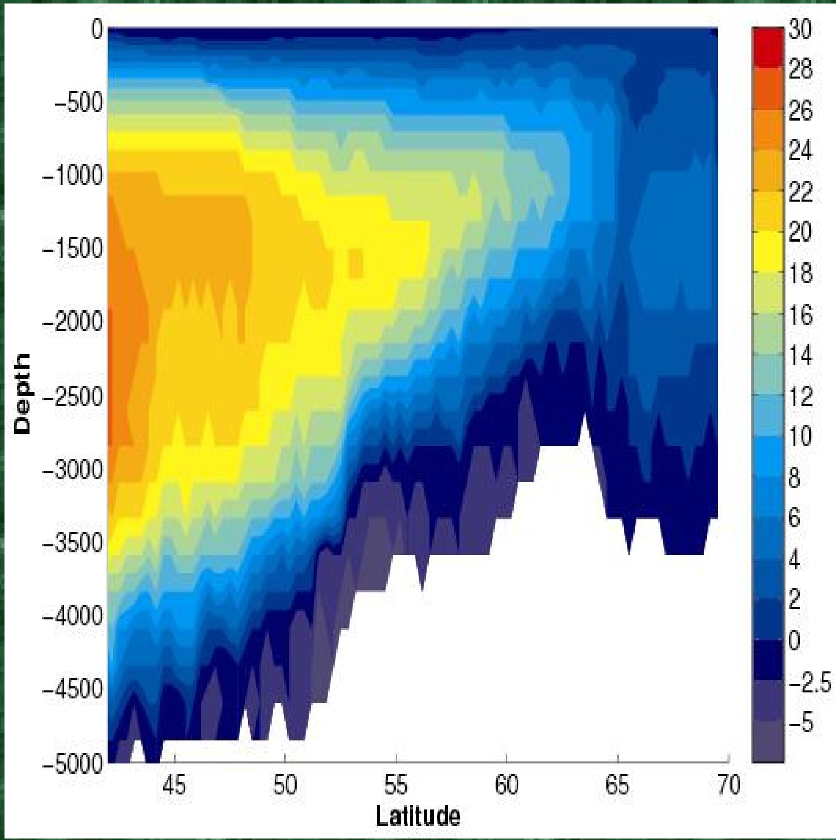
Long-term mean based on inter-annual experiments

Variability in DWBC at 53N

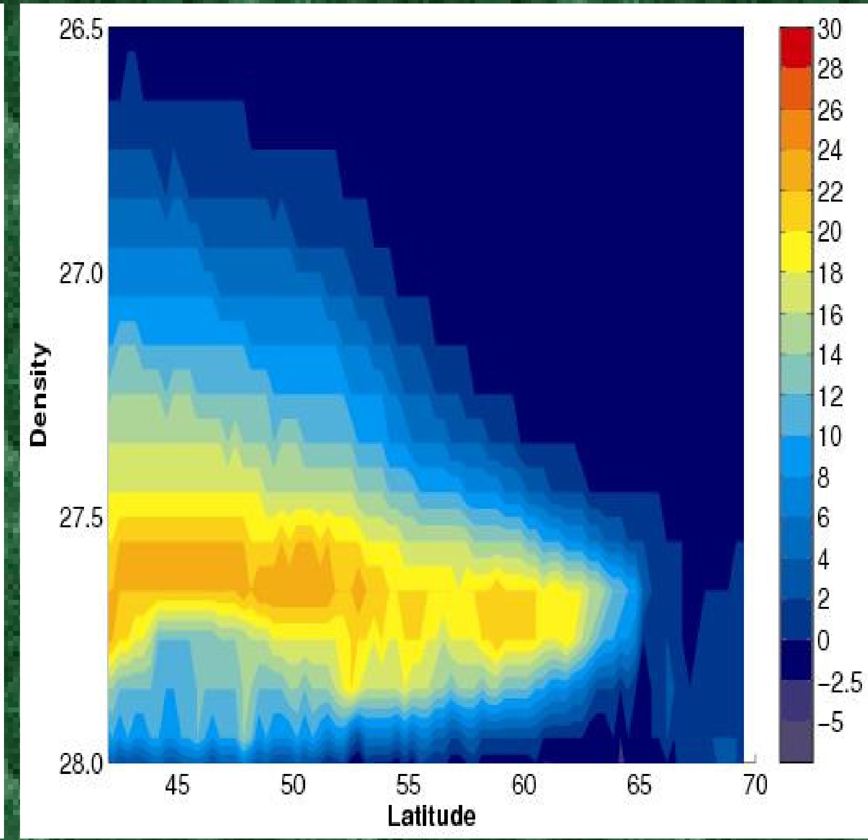


Reduction of 1.7 Sv over 1949-1999 in ISOW, DSOW layers

Historical Reanalysis MOC



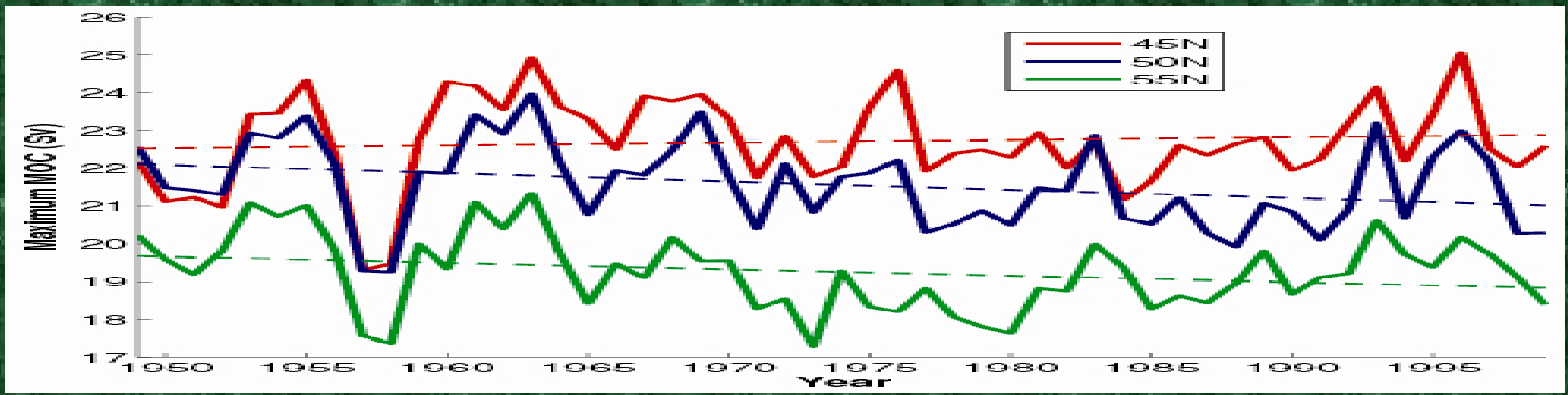
Depth Space

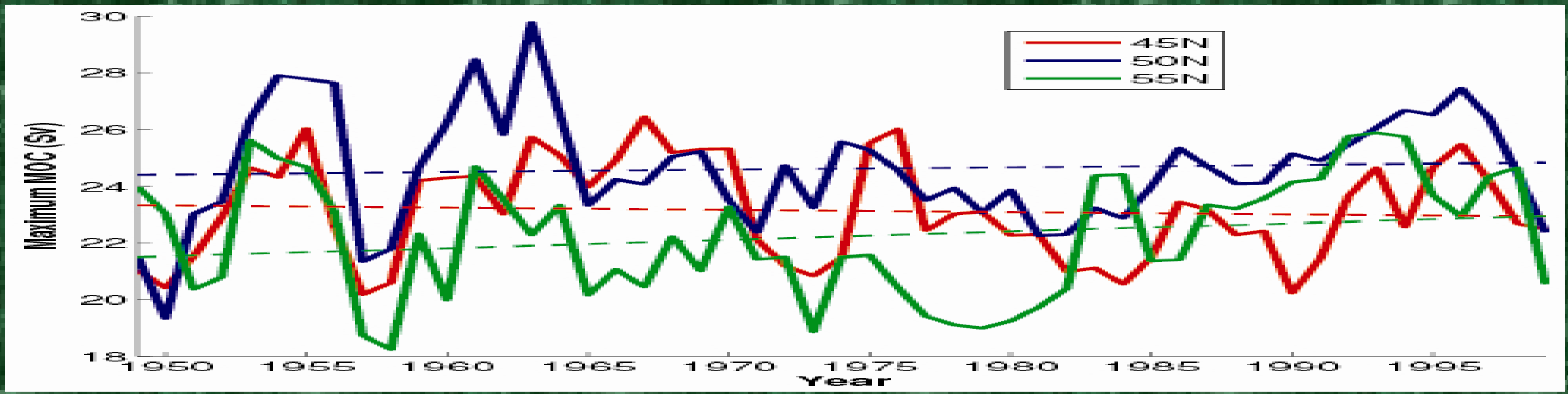


Density Space

Maximum MOC Variability

Depth space





Density Space

Correlations between depth and density space: 0.82, 0.61, 0.71 at 55N, 50N, 45N

Summary - MOC

- Variability well correlated in depth and density space
- Potential decline in depth space
  - But NOT in density space
- MOC correlated with LSW volume, with 0.3-0.5, maximum at a lag of 6-7 years
- MOC correlated with LSW formation (kinematic approach), with 0.3-0.4, max at a lag of 4-6 years
- MOC correlated with LSW transport in DWBC at 53N, with 0.3-0.5, max at lags of 7-8 years
- MOC strongly correlated with DWBC transport at 53N
  - 0.69-0.77 in depth space at short lags
  - 0.45-0.63 in density space at short lags
    - Difference related to the fact a decline not seen in density space??

Final Summary

- Long term LSW formation rates 1-2 Sv
  - Periods of strong formation inter-spaced with little formation
- Apparent decline in DWBC strength with time
- Much variability, but no change in LSW transport
- LSW Variability does impact the MOC and its variability
- But DWBC variability had a bigger impact on MOC variability
- Decline in DWBC strength over 1949-1999
- MOC Decline over same period - ????
- Results need a full uncertainity/error analysis to be robust