# The Link Between Variations in Sea Level and Circulation in the North Atlantic

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**Acknowledgements: COMDA[1],CONCEPTS[2] and GOAPP[3]**

[1] Centre of Ocean Model Development for Applications, DFO

[2] Canadian Operation Network for Coupled Environmental PredicTion Systems, partnership of DFO-EC-DND, Universities, Mercator-Ocean

[3] Global Ocean-Atmosphere Prediction and Predictability, CFCAS research network

# Motivation

- **Focus on inter-annual and decadal variations**
- **Sea Level, Gyre & Meridional Overturning Circulation**
- **Understanding forcing mechanisms:**
  **-- roles played by wind and buoyancy forcing**
- **Explore the link: Sea level vs circulation**

# 1° Global Model Simulations

- Spin-up: 10-years
  CORE “normal-year” forcing (climatology)

- FULL (Control): 47-years
  CORE forcing 1958-2004

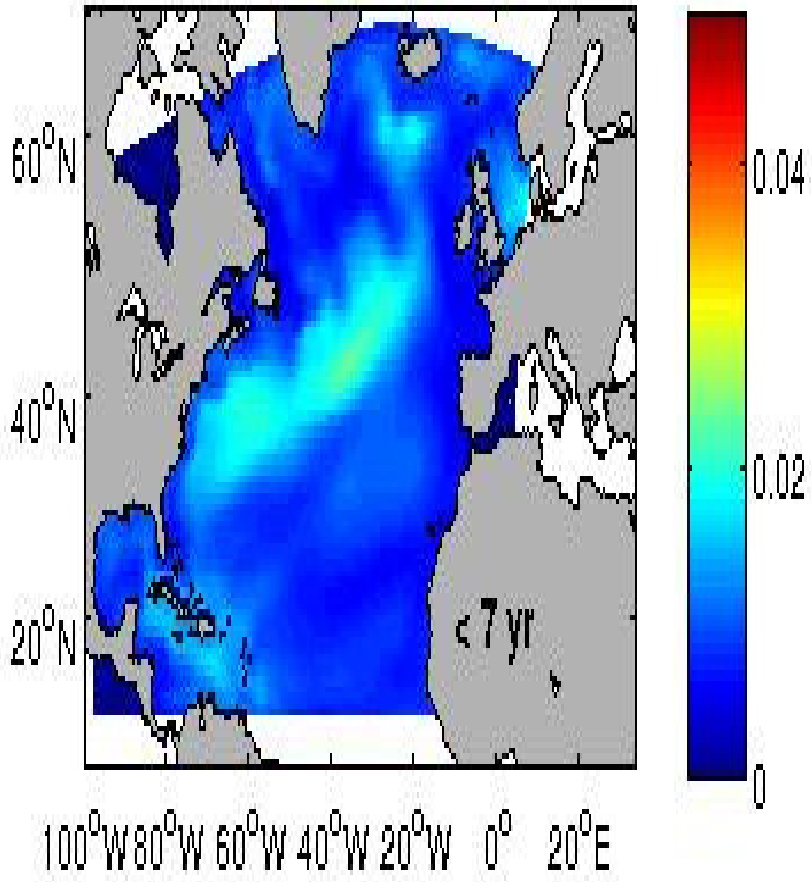
- Sensitivity runs:
  HEAT: wind stress set to climatology
  WIND: buoyancy flux set to climatology

# Analyses

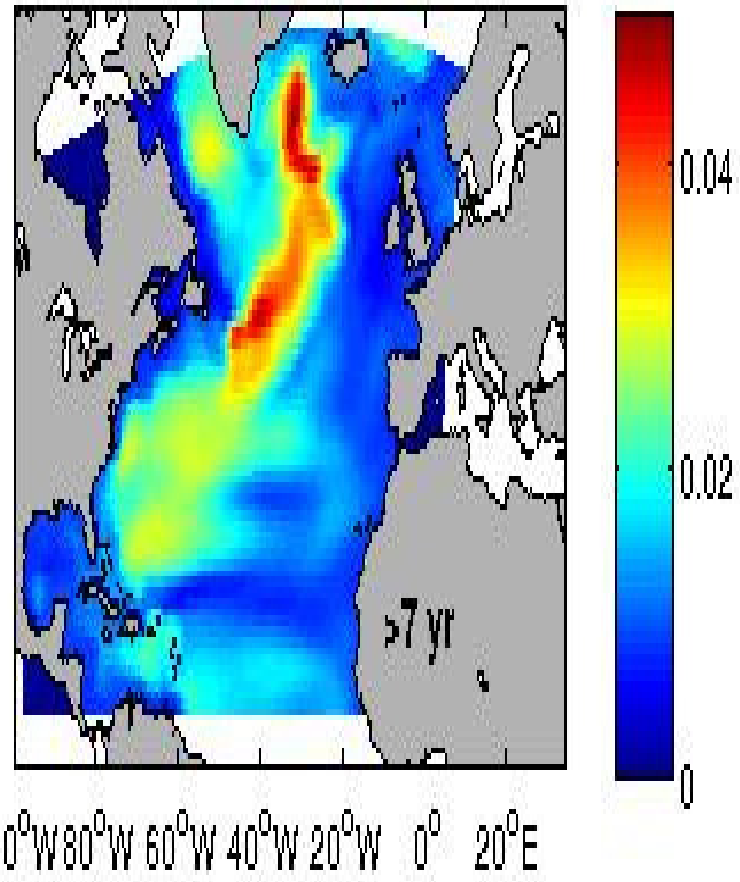
- Annual time series, linear trend removed
- Time filtering:
  Interannual (< 7 yrs); Decadal (> 7 yrs)
- Variance: roles of wind and buoyancy forcing
- EOFs
- Correlation

# SSH Variability (rms in m) from FULL Run

## Inter-annual

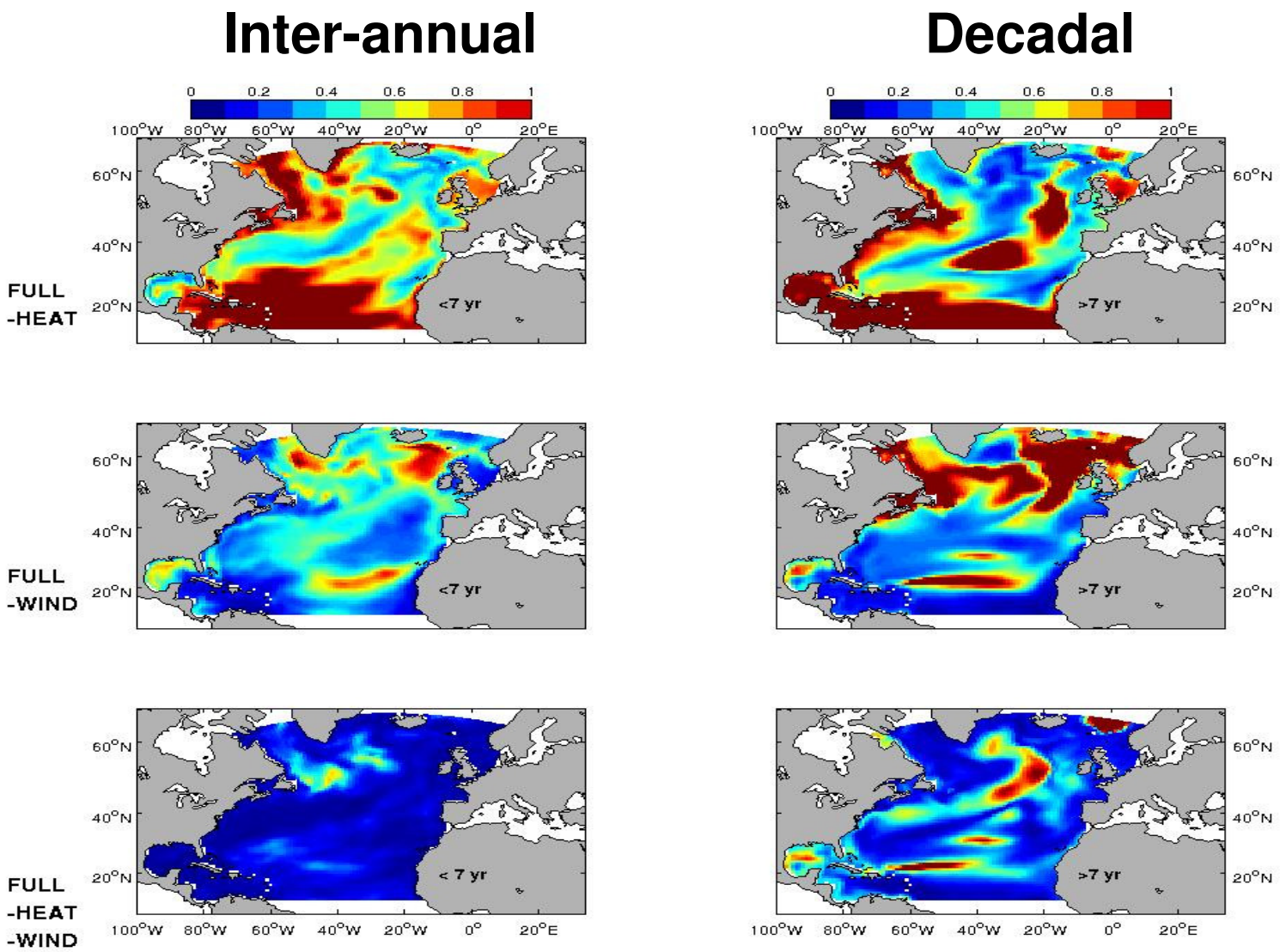



## Decadal

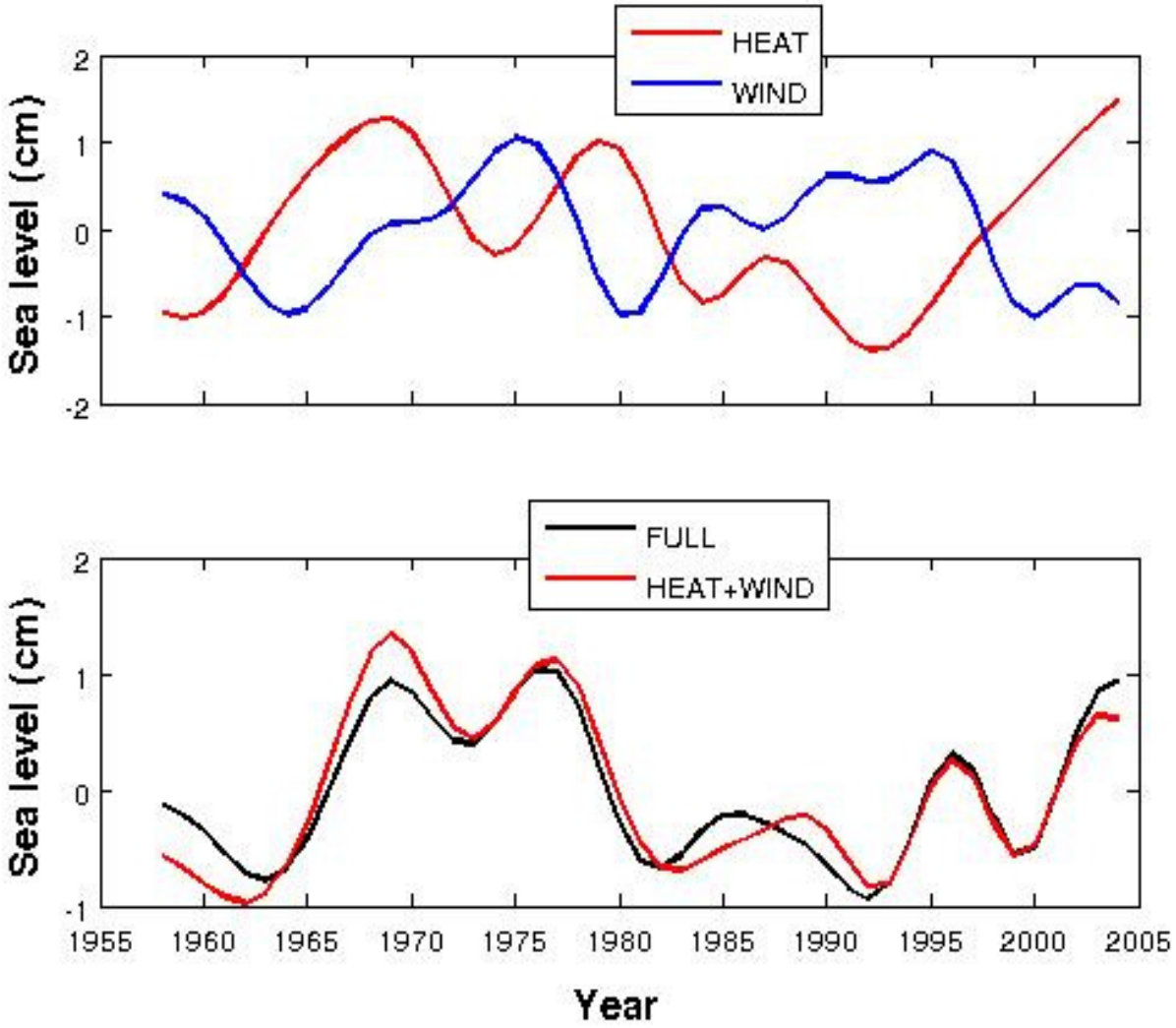


# SSH Variance Explained by Forcing

$$\gamma^2 = \mathrm{var}(X - Y)/\mathrm{var}(X)$$



# SSH Decadal Variations: Labrador Shelf




**Decadal variations:**

**•WIND & HEAT tend to play opposite roles (effects of Ekman and steric height)**

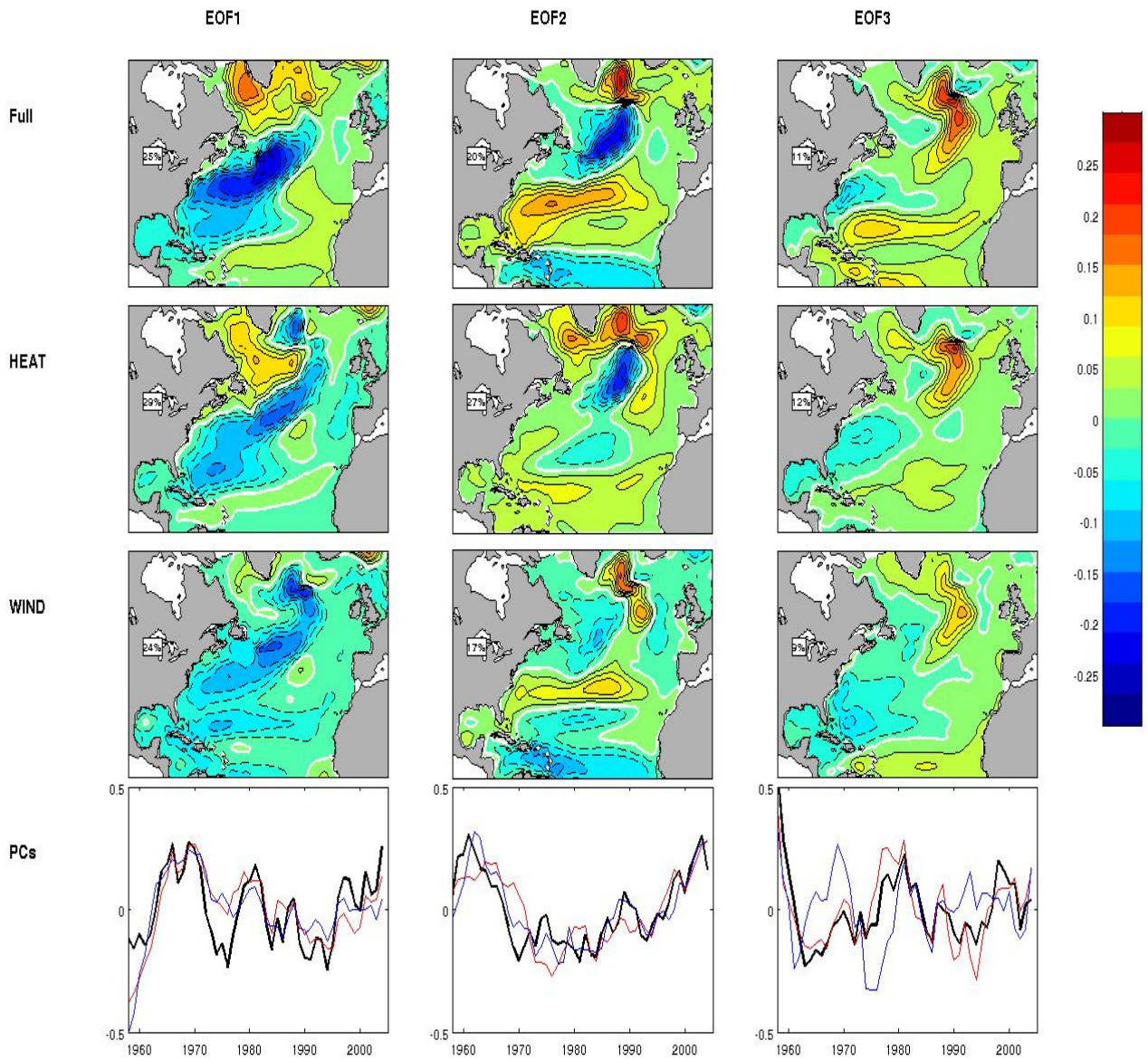
**•FULL solution nearly equals linear combination**

# MOC Variations (rms in Sv)

## Inter-annual

## Decadal

# EOFs of Sea Levels

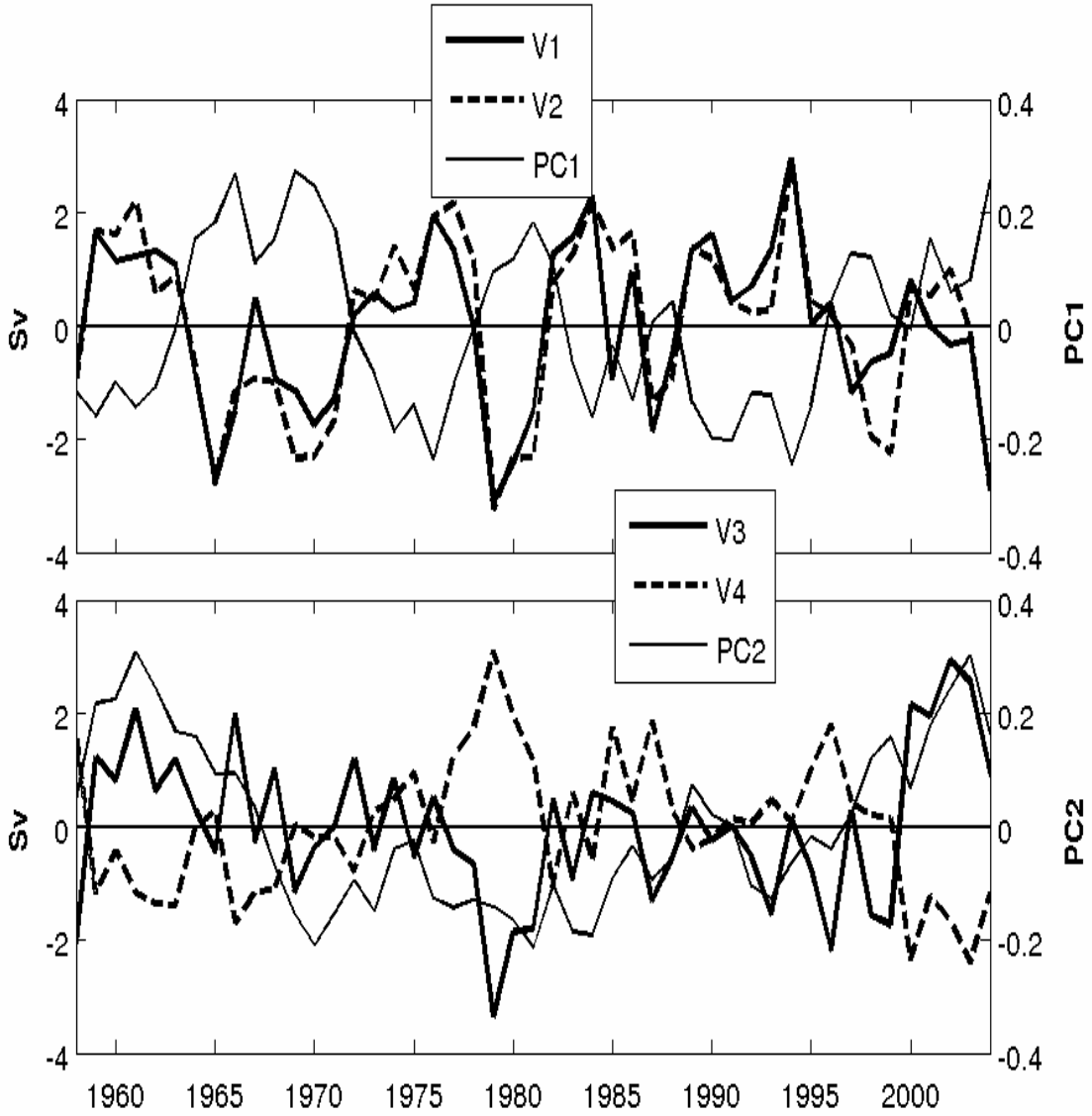


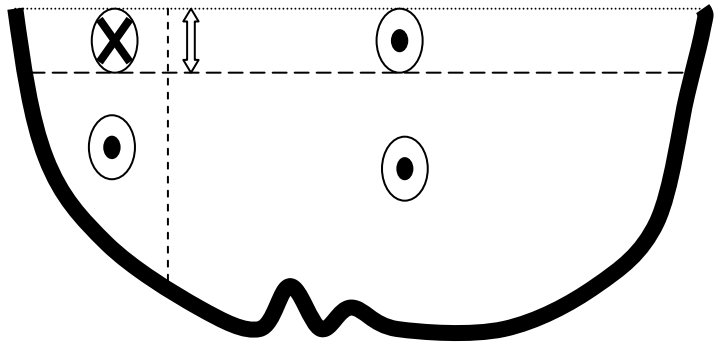

- **Dominated by low-frequency (decadal) variations**

**In each mode both HEAT and WIND forcing are important; but with different centers of action**

# Mid-latitude Gyre Circulation

## SSH EOF1 "center of action" near 38°N,50°W



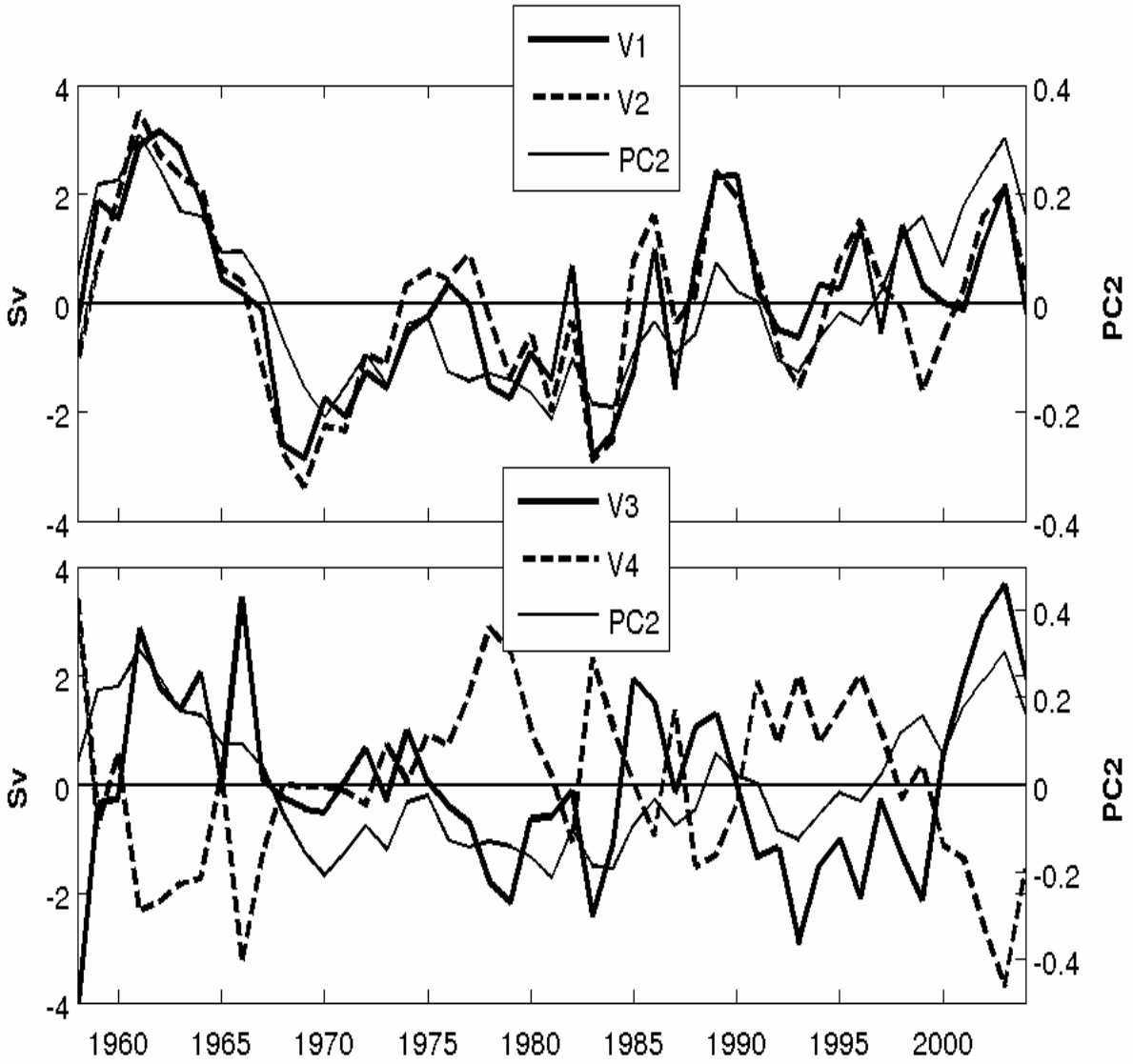



- Upper 1000 m gyre has high correlation (-0.73, -0.65) with PC1 of SSH

- Deep circulation correlates with PC2 of SSH (0.55, -0.58)

# Mid-latitude Gyre Circulation (cont'd)

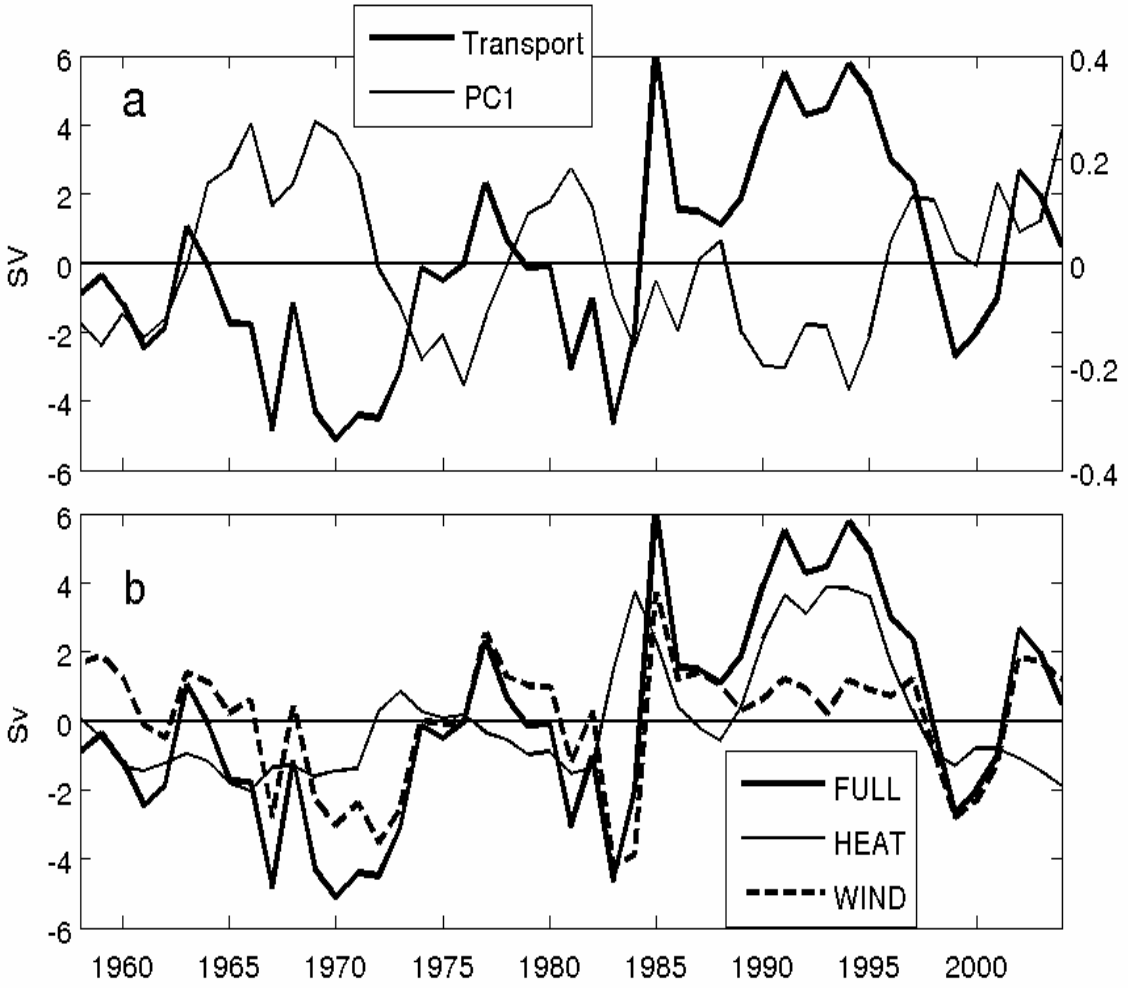
## SSH EOF2 "center of action" near 32°N,60°W




**Correlation with PC2 of SSH:**

- **(0.77, 0.70) for upper 1000 m**
- **(0.53, -0.62) for deep layer**

# Transport of Subpolar Gyre (Labrador Coast to Bravo)




- **Correlation 0.80 with PC1 of SSH; consistent with Hakkinen & Rhines (2004)**

- **HEAT and WIND forcing both important; upper layer is more HEAT driven; WIND more important in deep layers**

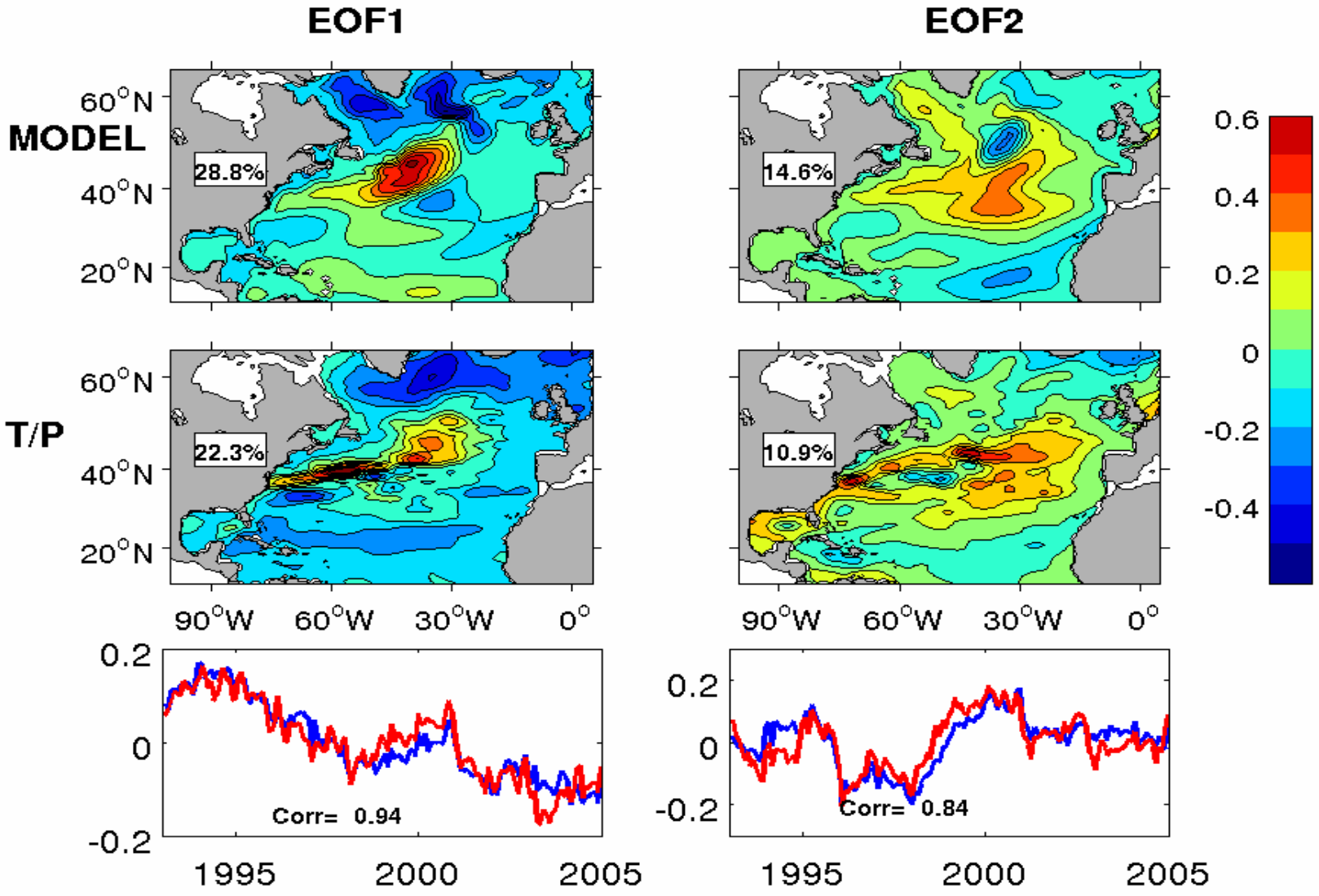
# Summary

- 1°global model applied for understanding inter-annual and decadal variations in NA
- Decadal variations of SSH and MOC: simulations suggest increasing importance of HEAT in sub-polar region; importance of WIND in mid-latitudes (interesting opposite roles for SSH on Labrador shelf)
- PC1 of SSH corresponds to volume transports of sub-polar gyre and of the upper layer in “inter-gyre” region
- PC2 of SSH corresponds to mid-latitude gyre, in both upper and deep layers
- No significant correlation between SSH and MOC variations is identified.

# Backup Slides

# Sea Levels 1993-2004

(monthly data, de-seasonalized)

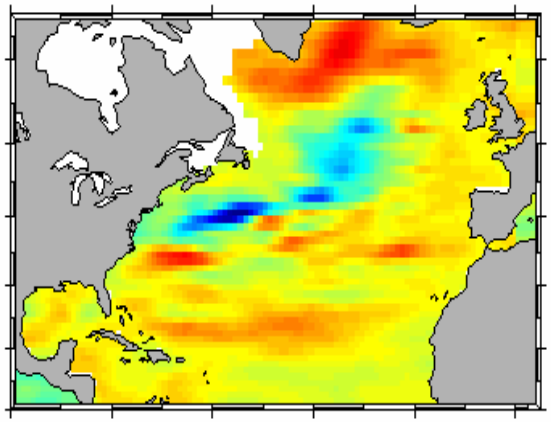


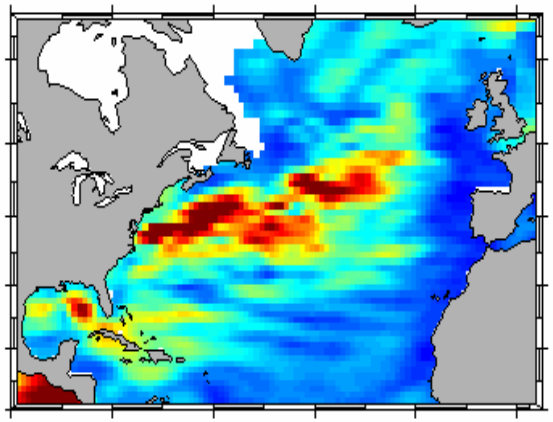
# Sea Levels 1993-2004

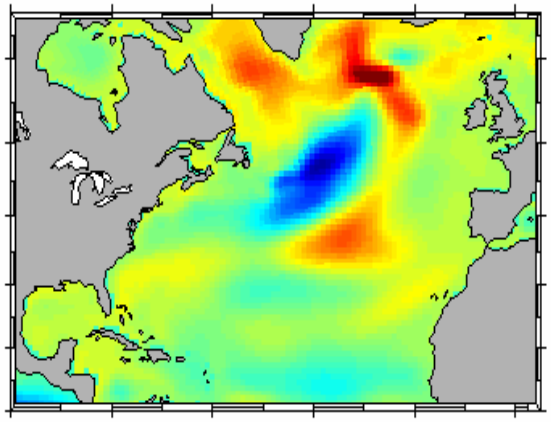
**Trend (m/yr)** **Standard Deviation (m)**

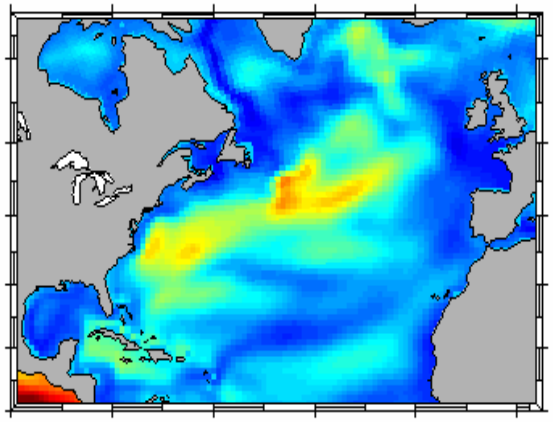
**Obs**

**Model**





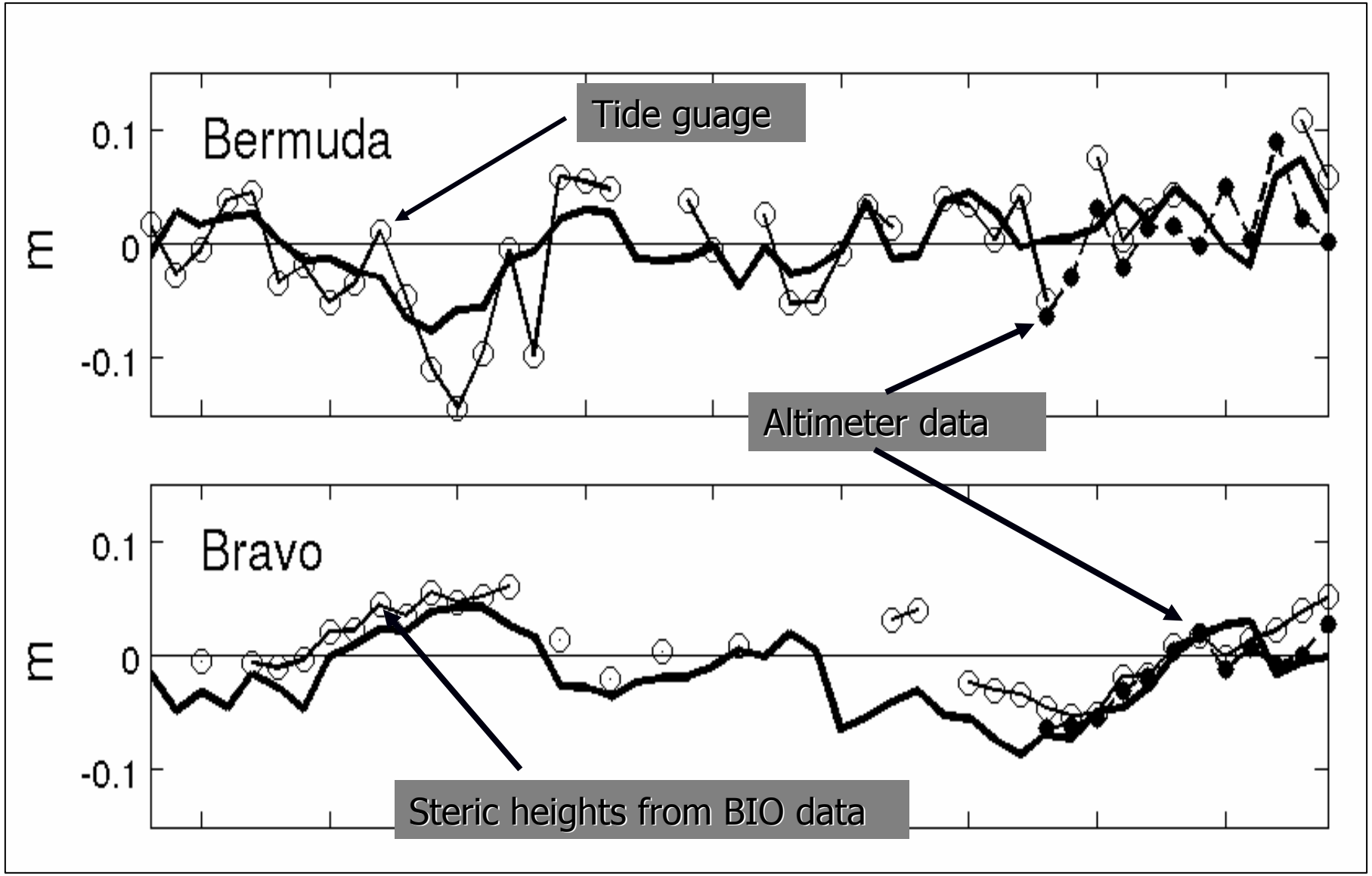




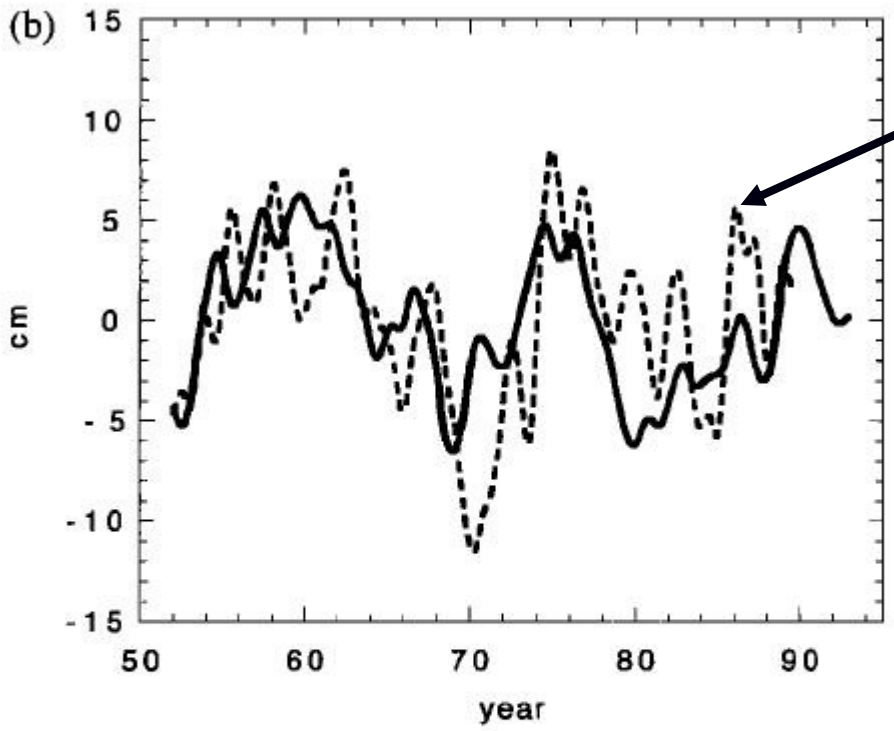


**Note that a 1º model doesn't capture the eddy variability**

# Annual Mean Sea Level & Steric Height 1958-2004



# Comparison with Hakkinen (2001) at Bermuda




Tide guage

**Figure 3b from Hakkinen (2001)**

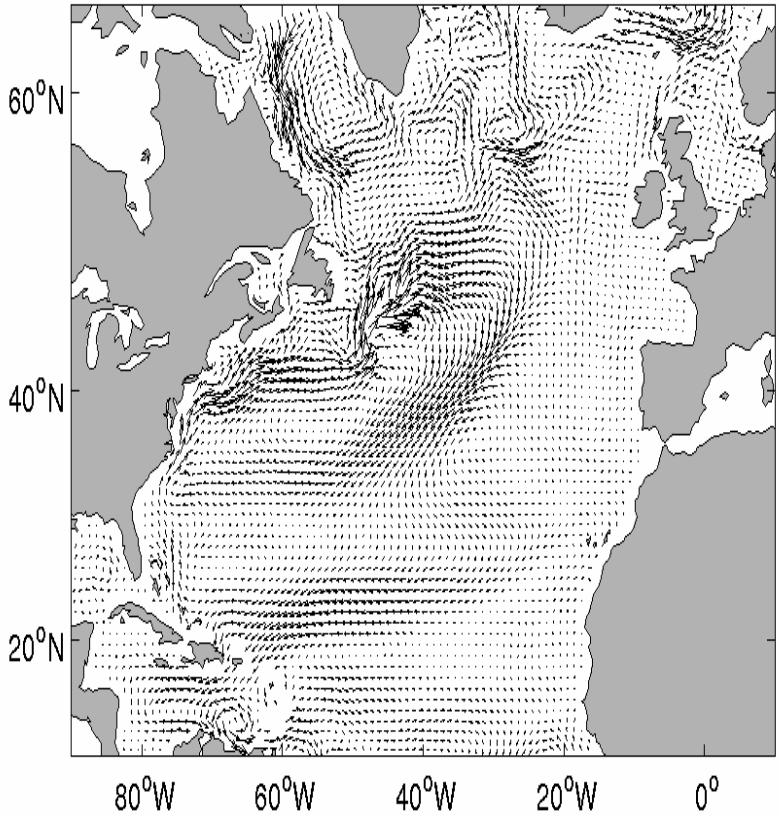
Low-pass-filtered (37-point Hanning filter) sea level at Bermuda (in cm). Dashed line is tide gauge data (from the Florida State Sea Level Center), and solid line is the model data.

**Agreement considered to be "excellent" by Hakkinen.**

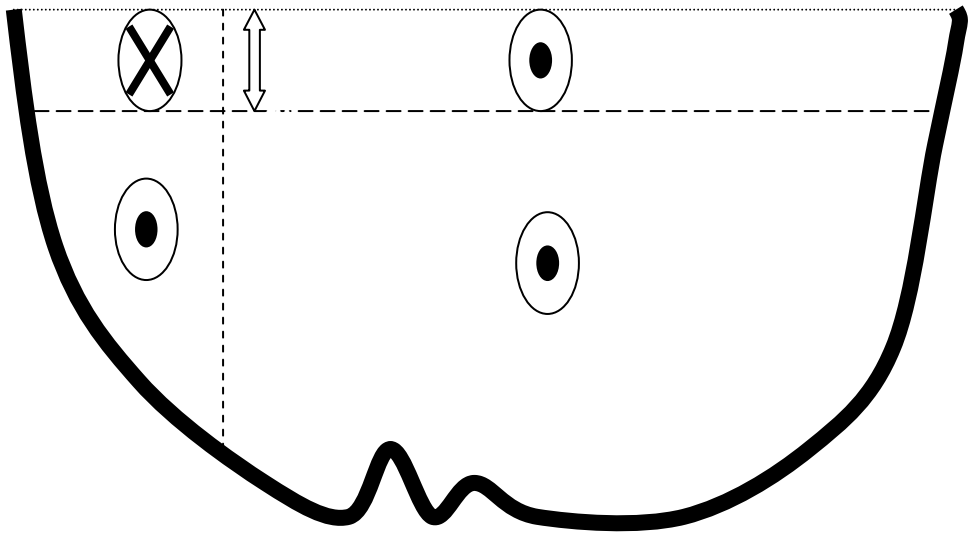
**Agreement between our Model & Obs at Bermuda is similar. (We think it's fare.)**

# EOF1 of SSH: Corresponding Variations in Sub-polar Gyre and Mid-lat "Anomalous Gyre"

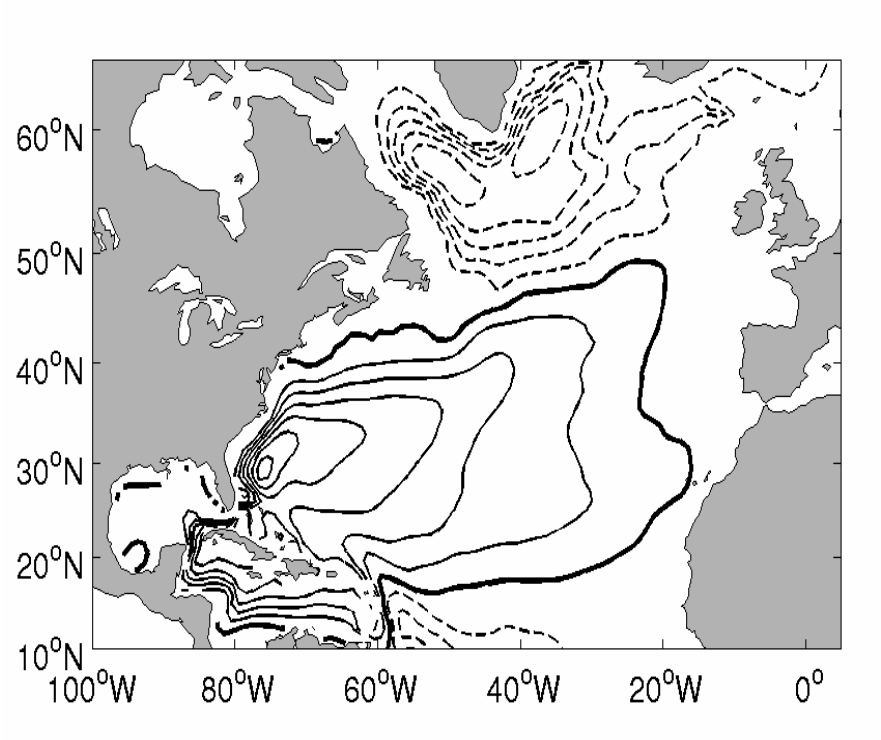
**"Geostrophic velocity" from EOF1 of SSH (Full)**

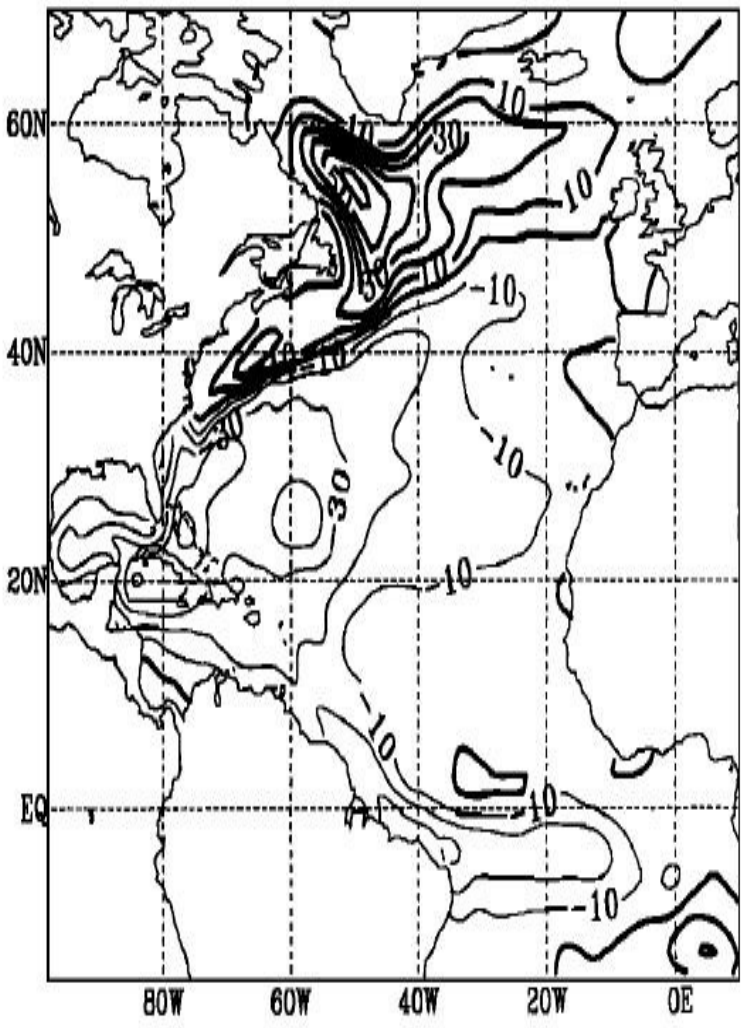



**Meridional transport, divided into sections**



# Barotropic Circulation: Time Mean Ψ




**Left: NEMO**
**Credible subtropical gyre;**
**Subpolar gyre 30 Sv**

**Right: Hakkienen 2001**
**Less ideal subtropical;**
**Subpolar 60 Sv**

# Link to the Atmospheric Forcing NAO & EAP