Weather's Effect on Atlantic Meridional Overturning Circulation and Climate Change

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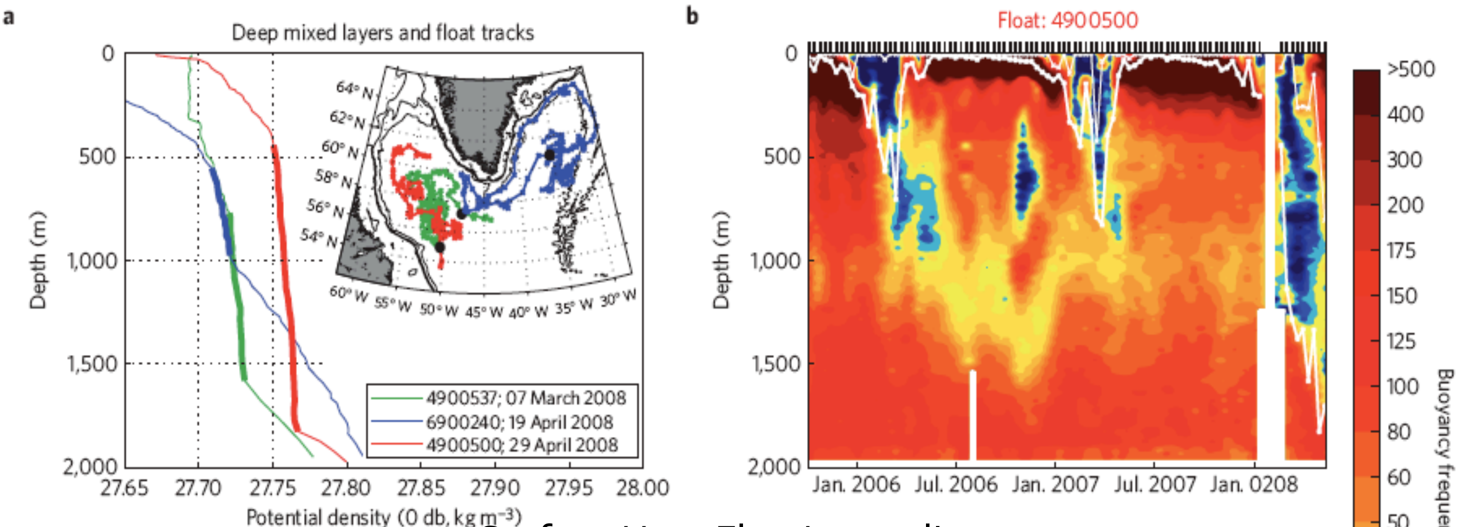
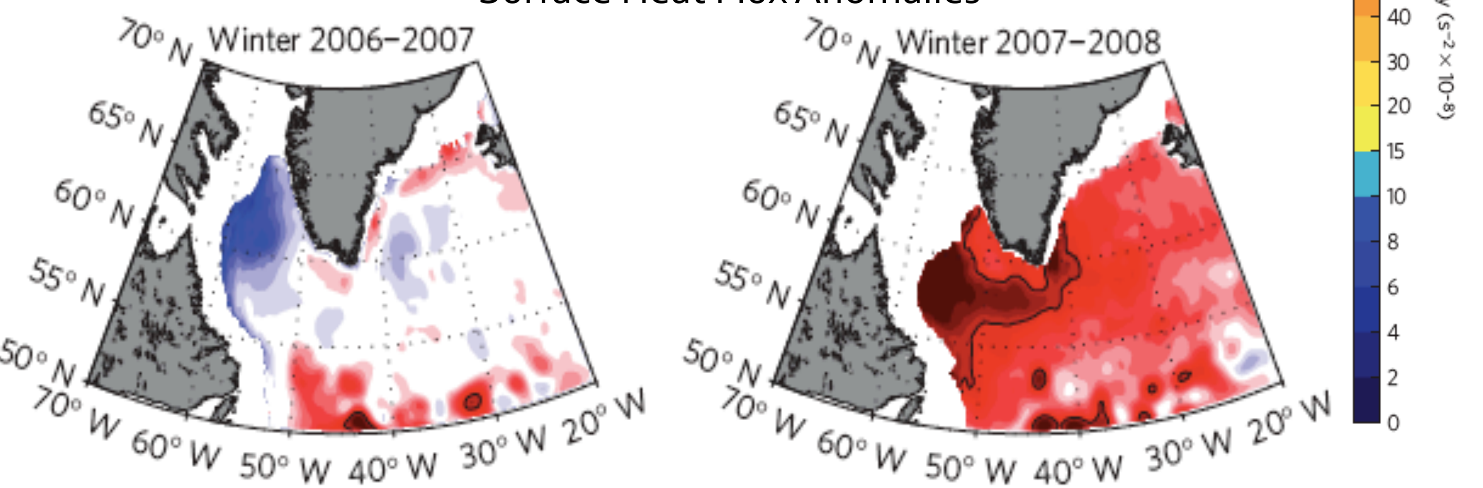
Observation of Labrador Sea Deep Convection



Surface Heat Flux Anomalies



Winter 2007/08 deep convection is much stronger than that in winter 2006/07, in spite of the weaker NAO index in 2007/8 than in 2006/7

A strong positive (to the atmosphere) surface heat flux anomaly is observed in winter 2007/08, but not in 2006/07

Våge et al. (2009)

Cold Air Outbreaks

Våge et al. (2009)

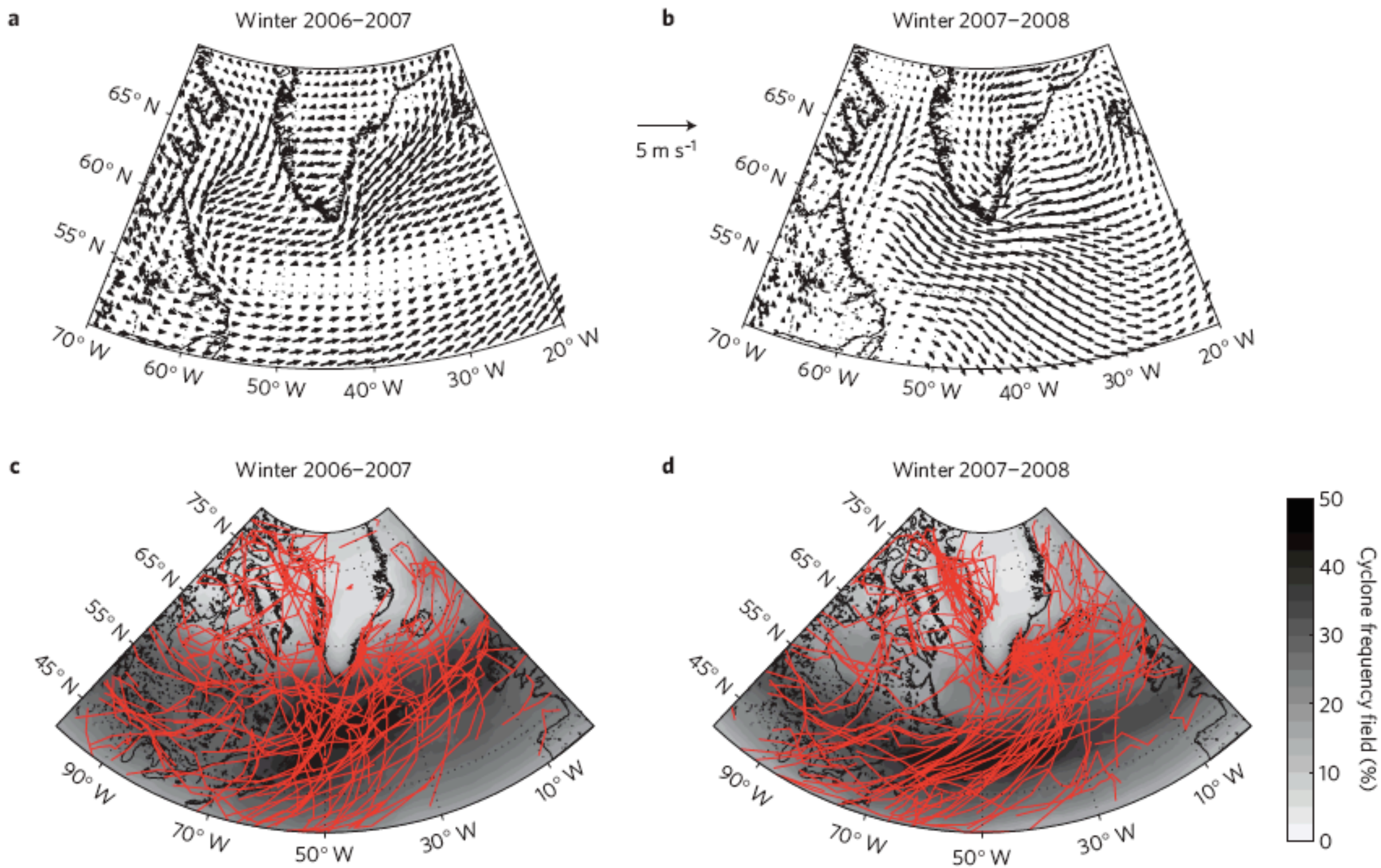
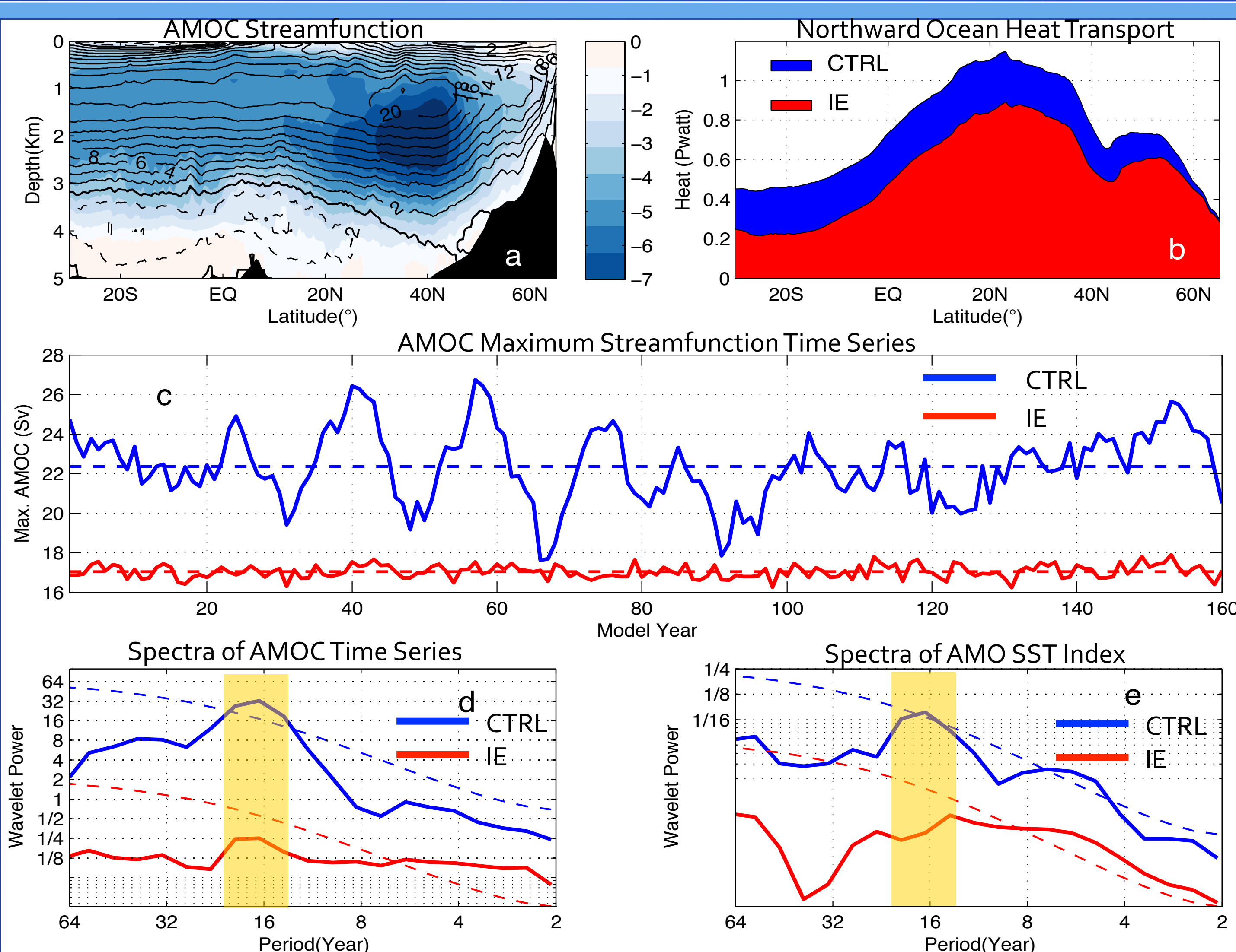


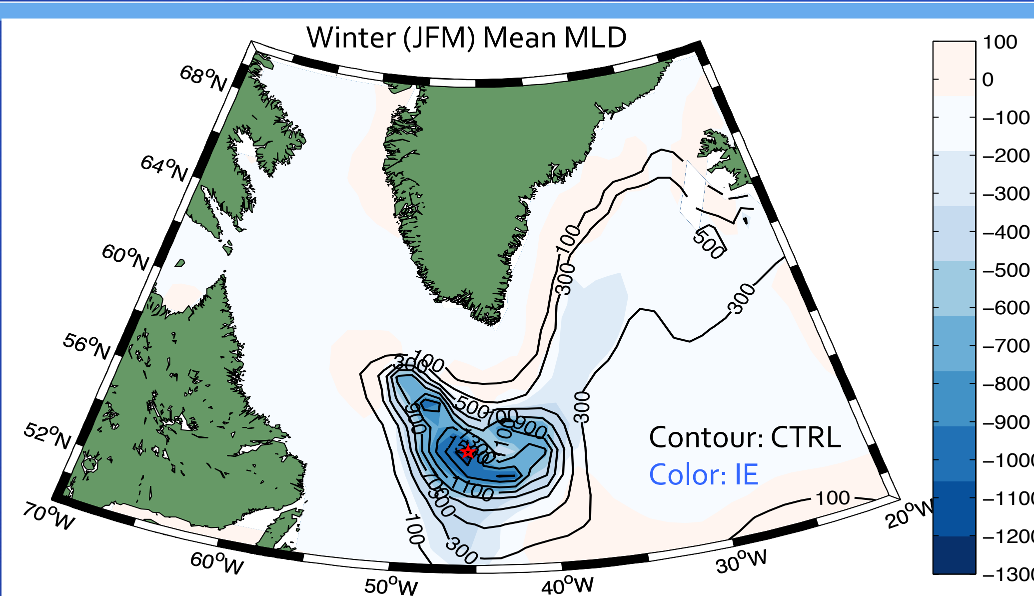
Figure 5 | Wind anomalies and storm properties for the two high-NAO winters of 2006–2007 and 2007–2008. a,b, NARR surface wind vector anomalies (m s^{-1}, every 21st vector) relative to the 2000–2007 base period. **c,d**, Storm tracks (red lines) and cyclone frequency field (grey shading).

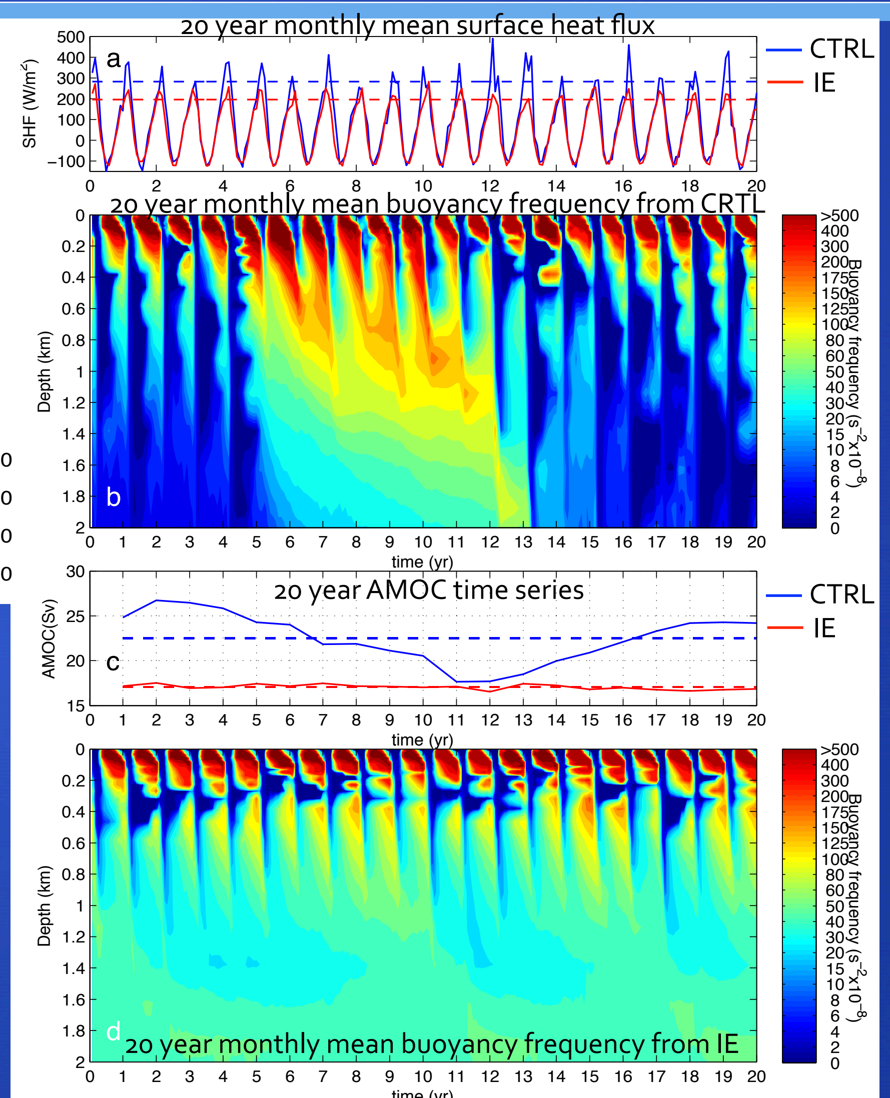
CCSM3 CTRL vs IE Simulation



By ensemble-averaging (6 members) surface fluxes, IE coupling weakens internally generated atmospheric variability, including Atlantic storm track variability. As a result, AMOC mean strength and variability are both significantly reduced. The northward ocean heat transport in the Atlantic is reduced by ~ 0.2 PW.

Deep Convection in CTRL and IE

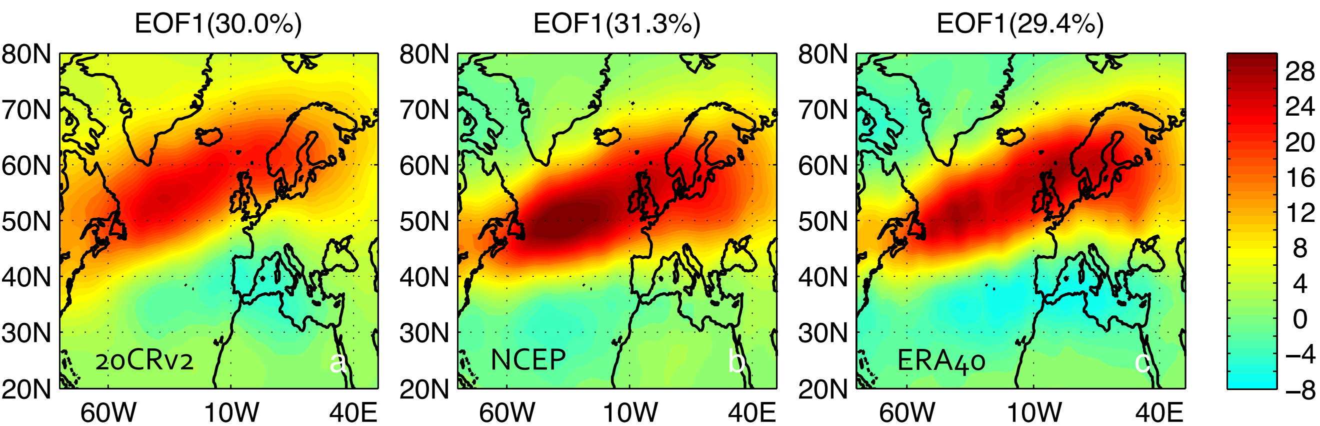


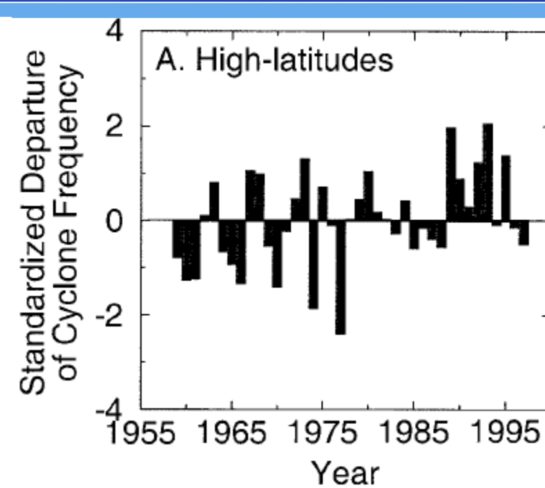


- Winter mean MLD in the Labrador Sea deep convection region is significantly reduced by more than 1000 m in IE
- Large changes in surface heat fluxes occur in winter season with a reduction of winter mean net surface heat flux in IE by more than 30% (~87 Wm^{-2})

Storm Track Changes During the 20th Century

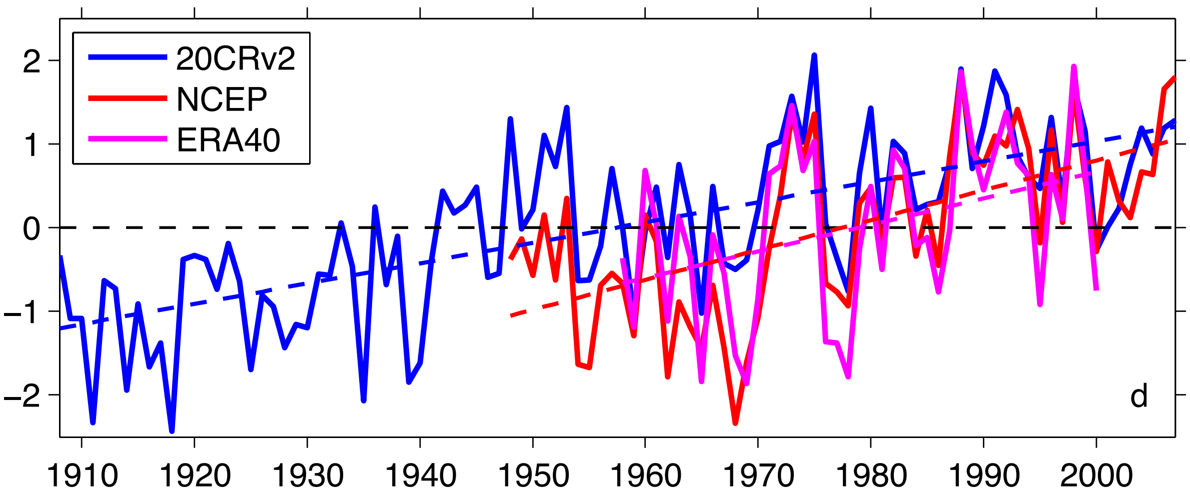
EOF Analysis of 2-8 day bandpass filtered winter v-wind at 300 mb



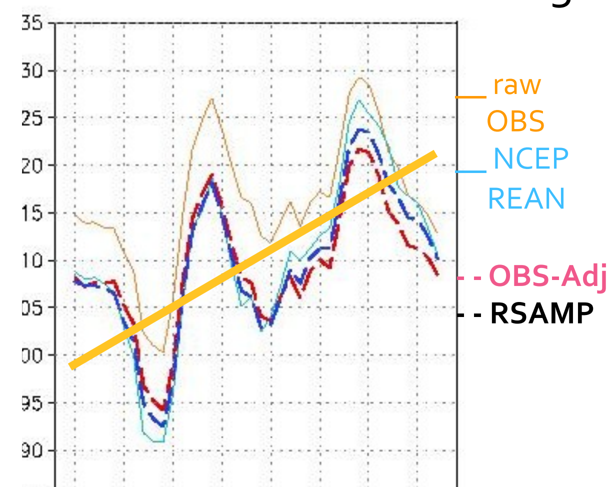


McCabe et al. (2001)

PC1 Time Series of Atlantic Storm Track

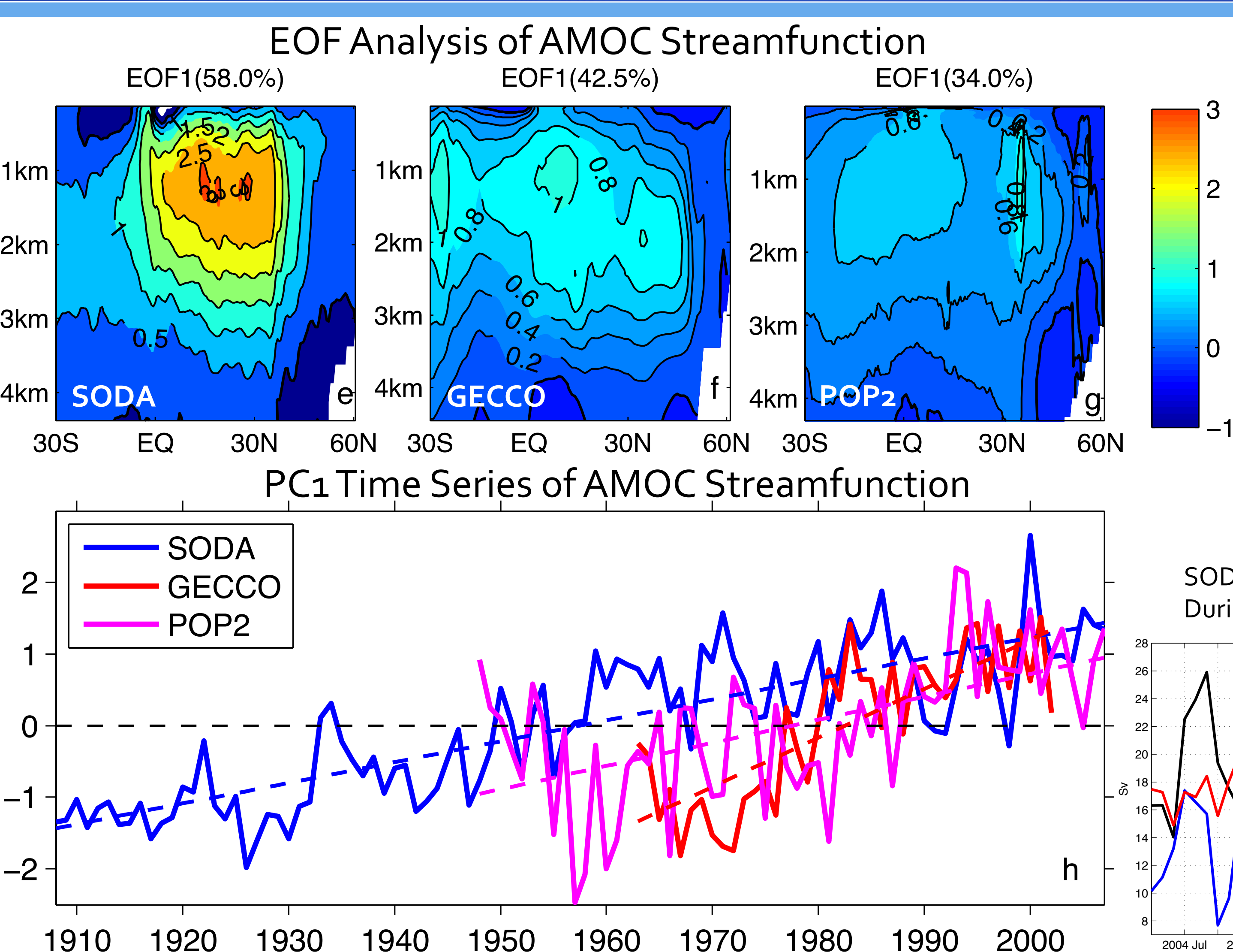


Atlantic Storm Track Change



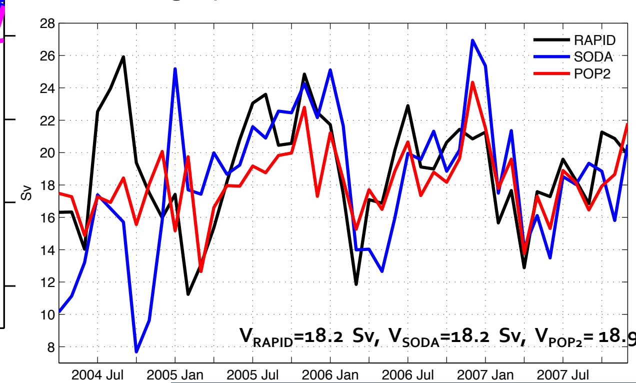
Chang (2007)

Have Storm Track Changes Had an Impact on AMOC During 20th Century?

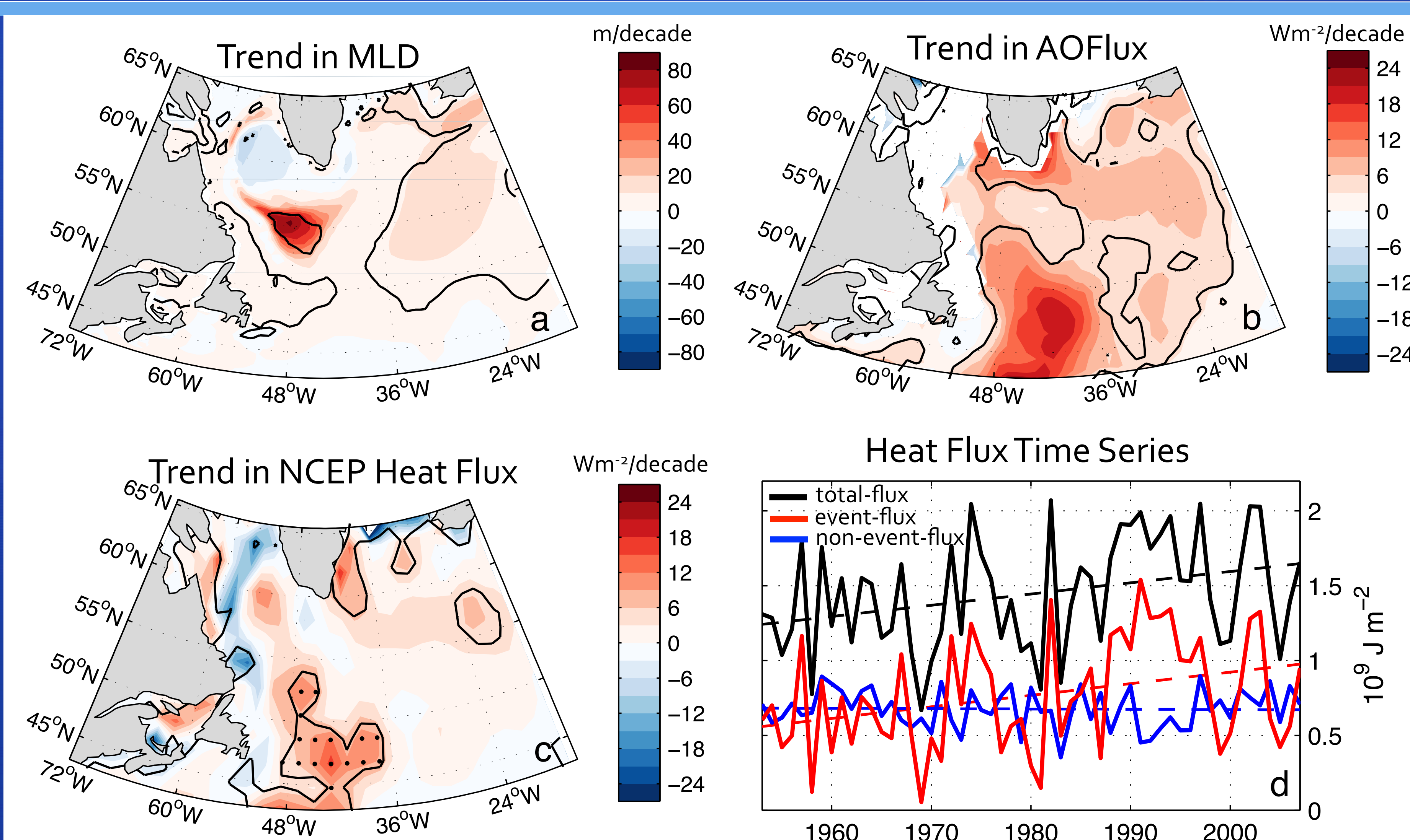


SODA, GECCO&POP2 all show an increasing trend in AMOC

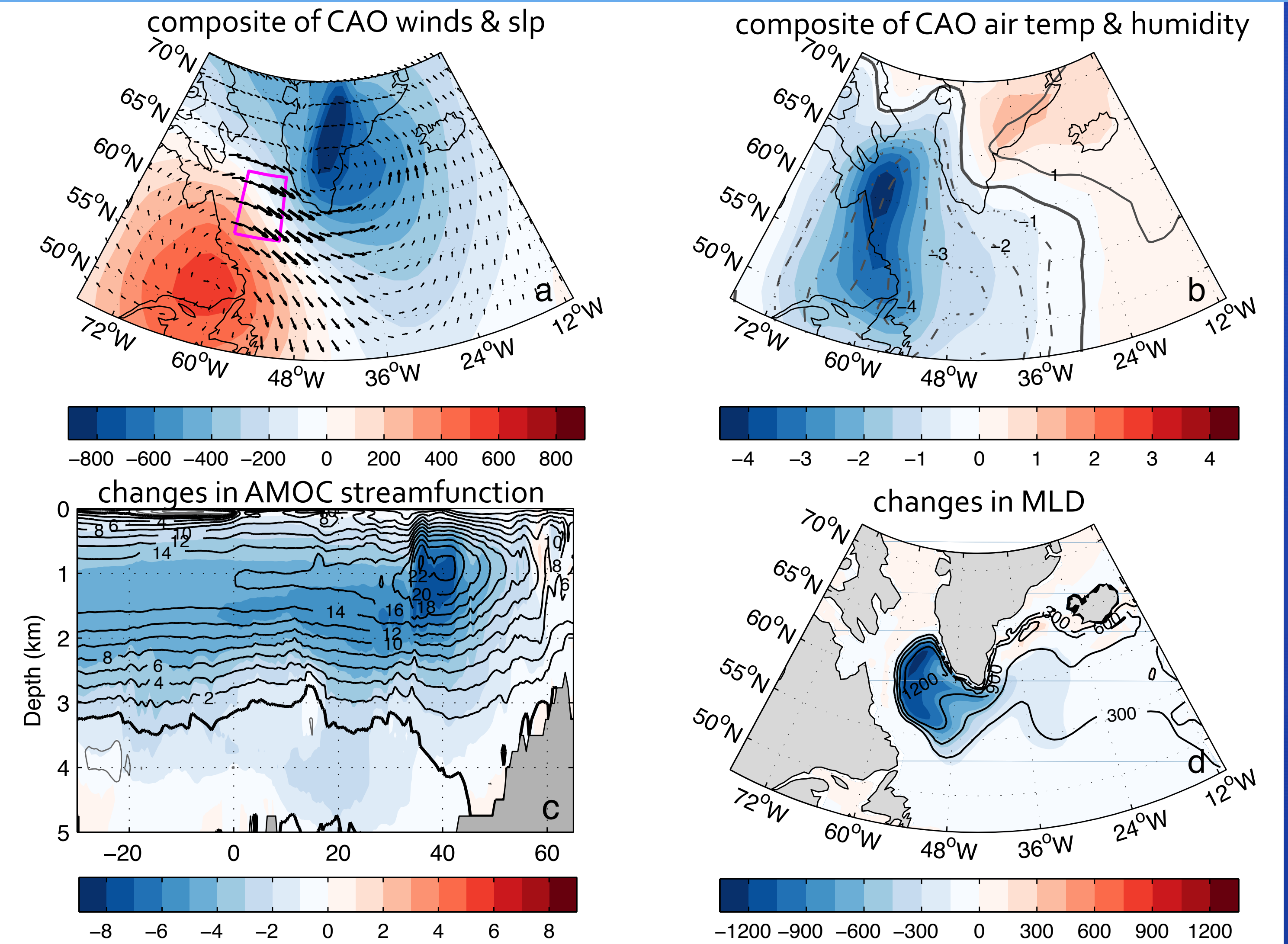
SODA&POP2 vs RAPID along 26.5N During April 2004 –December 2007



Analysis of POP2 Simulation



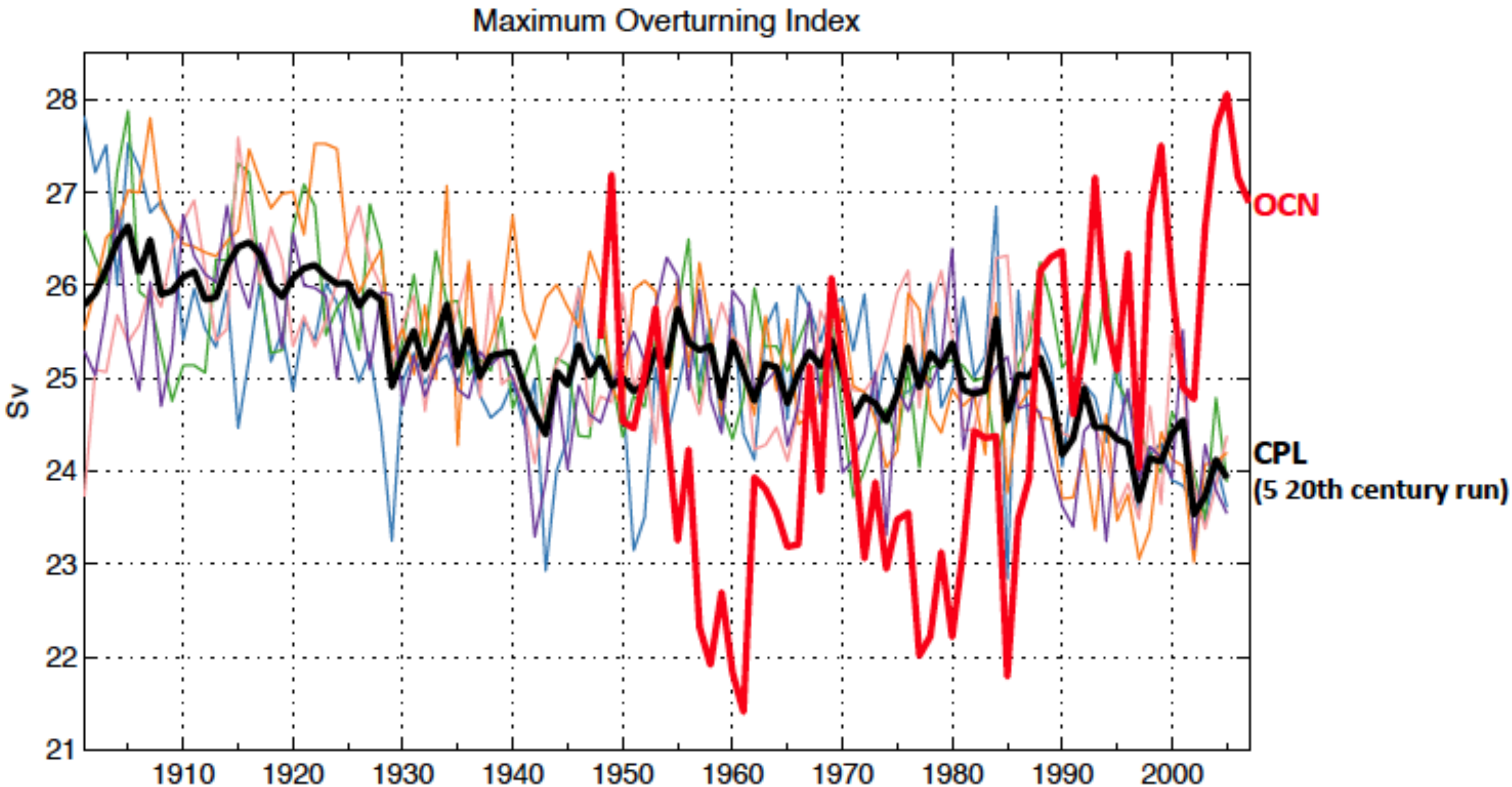
Cold-Air Outbreak (CAO) Removal POP2 Simulation



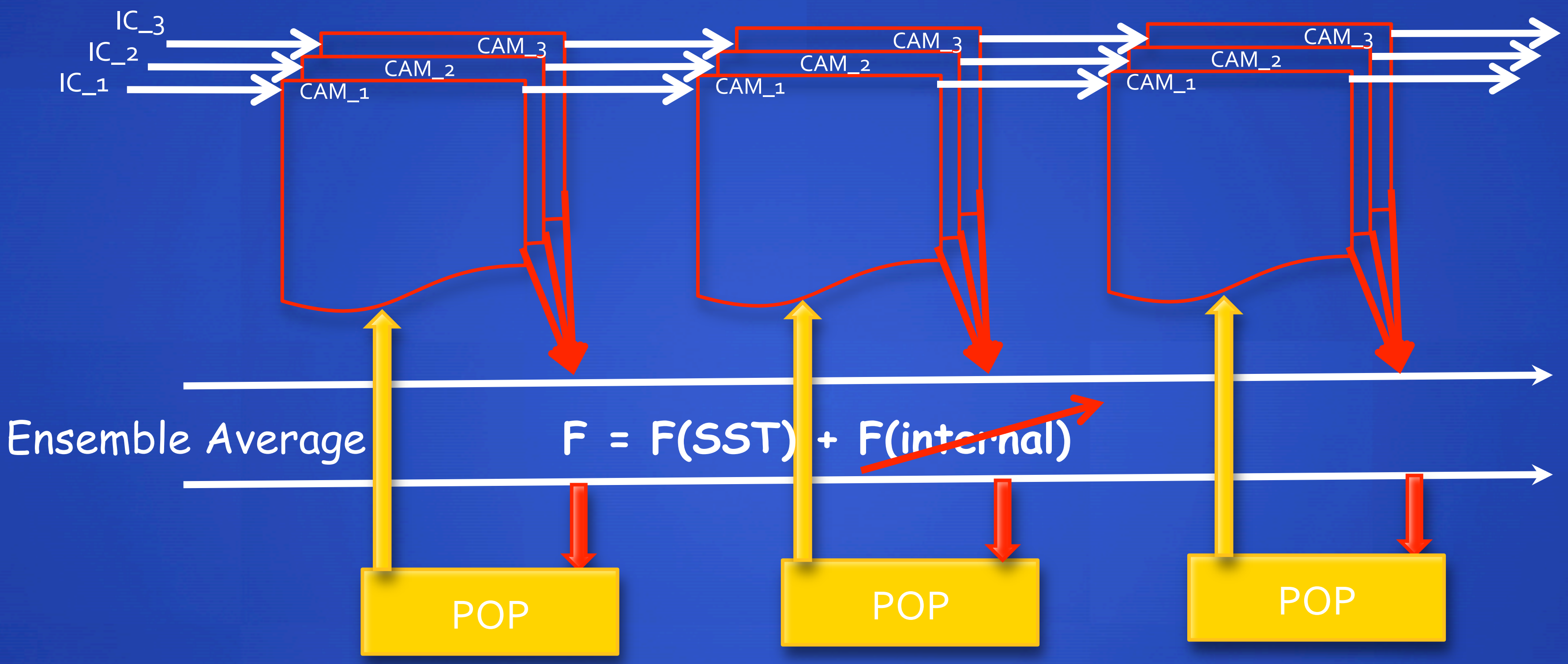
Summary

- Cold air outbreaks and synoptic winter storm events in the North Atlantic play an important role in sustaining AMOC strength and variability.
- Suppression of winter storm activities in CCSM3 leads to a major reduction in AMOC strength and variability.
- The strengthened North Atlantic storm track during the 20^{th} century in response to global warming may have contributed to long-term changes in AMOC strength.
- Future changes in AMOC strength depend on not only high-latitude surface buoyancy changes, but also storm track changes in response to future global warming.
- Day-to-day weather variability is an integral part of the climate system and should be realistically simulated by coupled climate models.

CESM1 AMOC vs POP2 AMOC



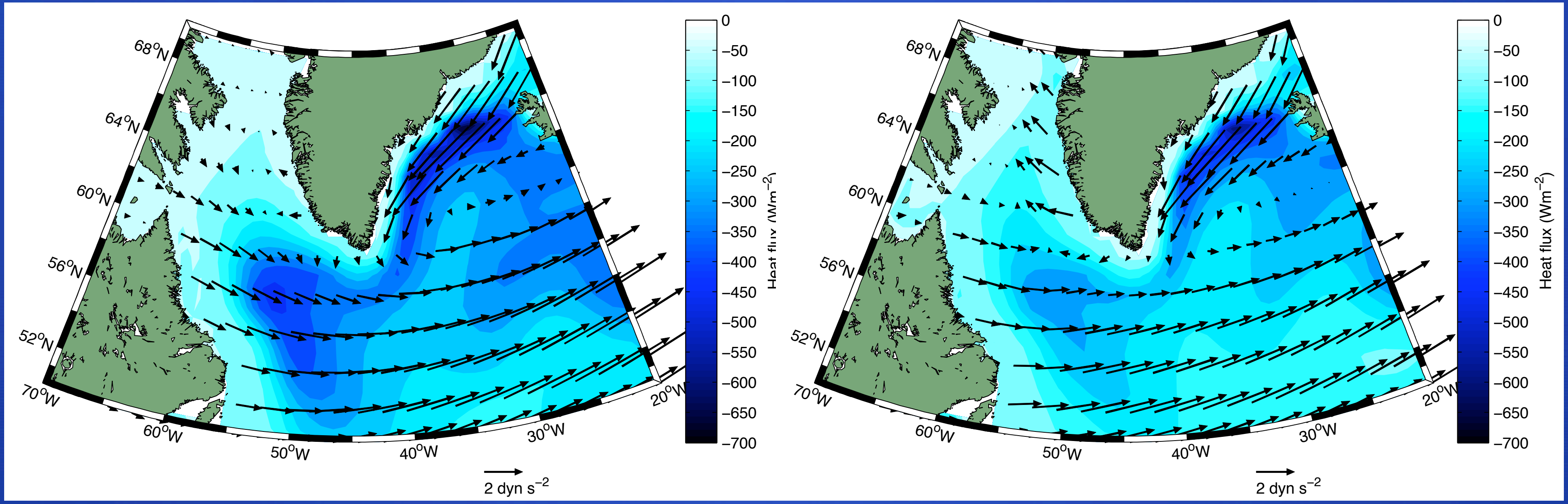
Interactive Coupled Ensemble (Kirtman and Shukla, 2002)



T85 CCSM3 IE Run

6 member-ensemble; close to 400 year simulation; last 160-year analyzed;
See Kirtman et al. (2009) for more detail.

Changes in Mean Winds and Q



Control Run

IE Run