Understanding
Atlantic Multidecadal Variability (AMV), AMOC, and Arctic Sea Ice

Presented by

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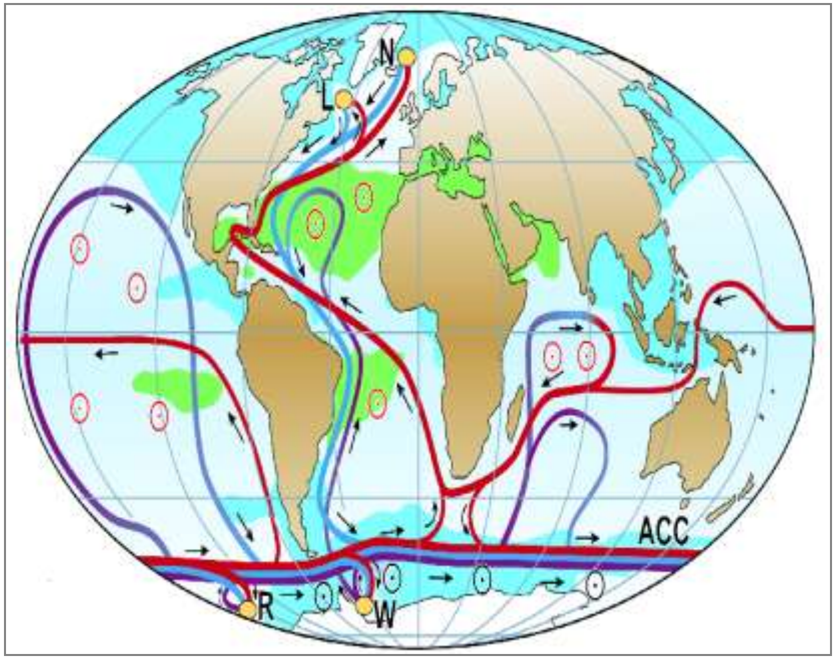
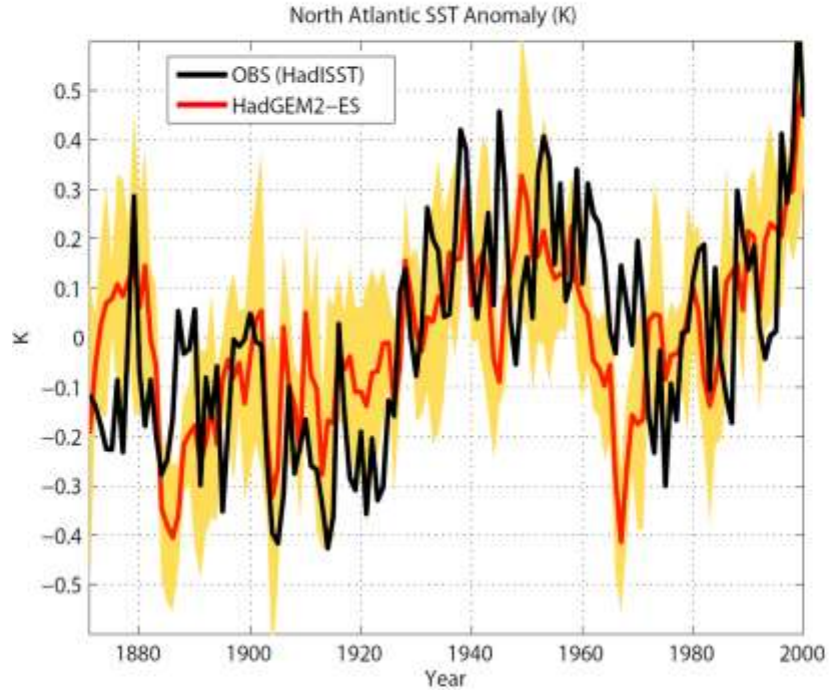
Mechanisms for Atlantic Multidecadal Variability (AMV)



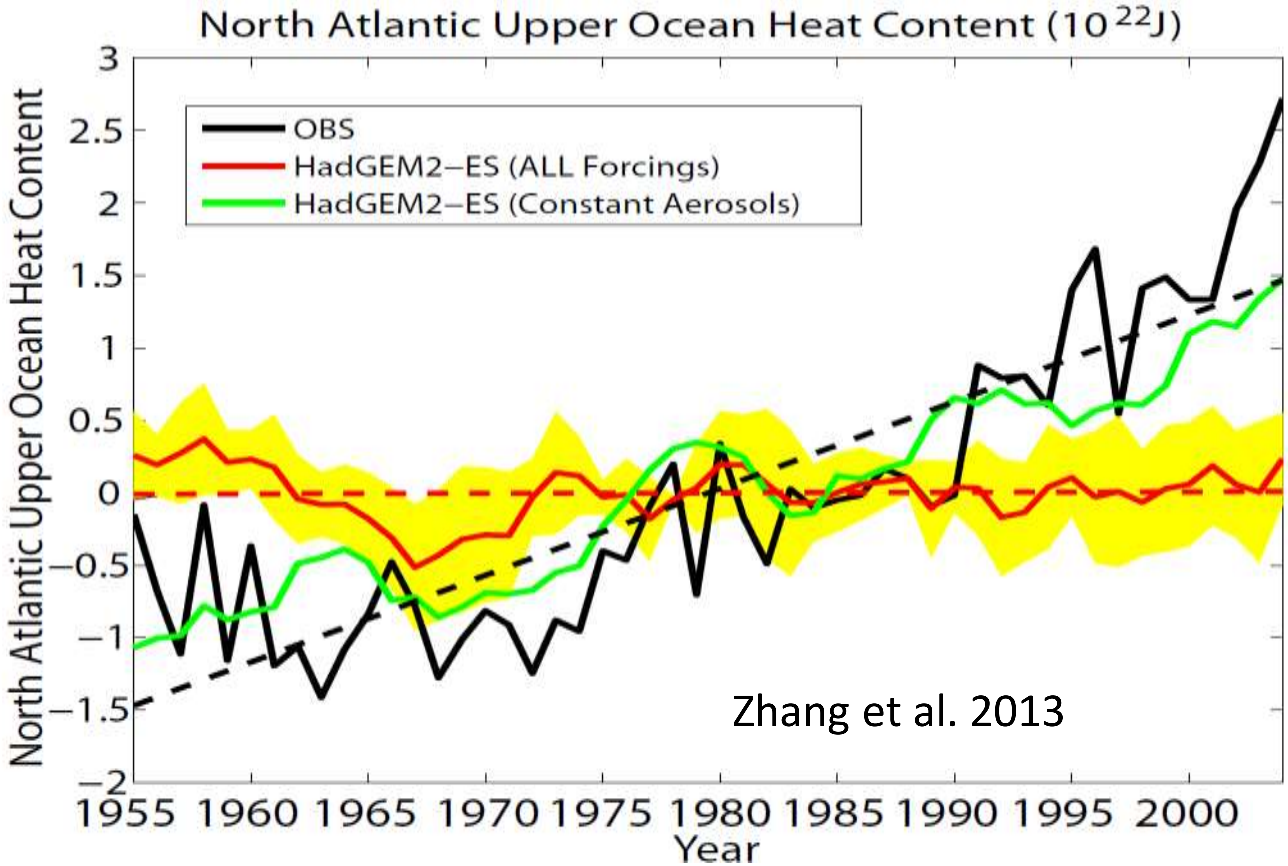


Atlantic Meridional Overturning Circulation (AMOC) (Adapted from Booth et al. 2012)

- The AMV is often thought to be linked to AMOC variability (Delworth et al. 1993; Latif et al. 2004; Knight et al. 2005; Zhang, 2007, 2008)

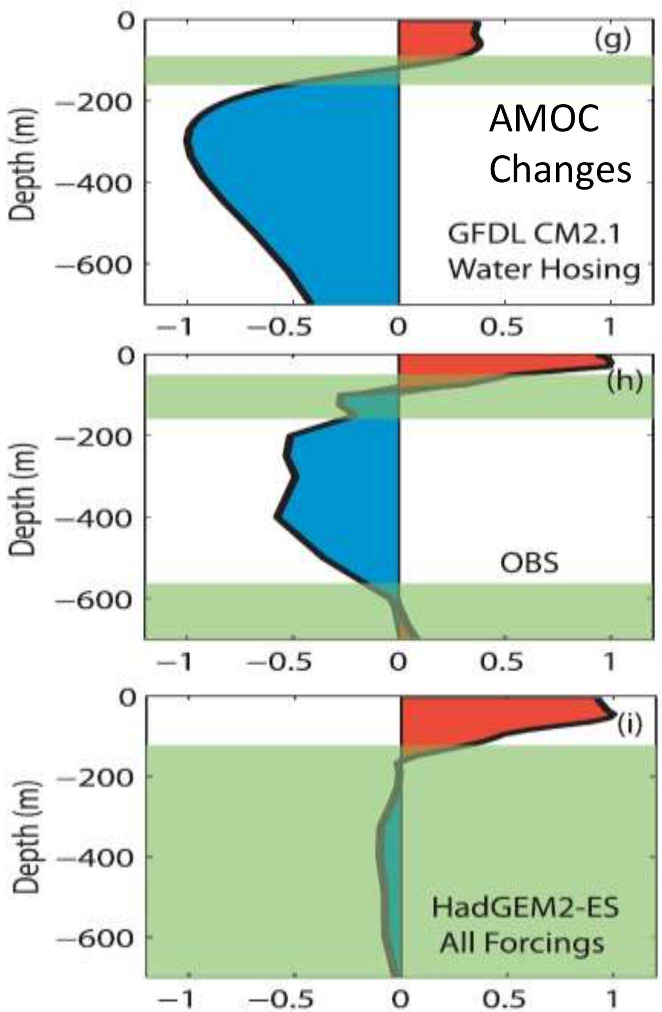
- A recent modeling study (Booth et al. 2012) suggested that aerosols are a prime driver of the observed AMV

Aerosol Effects and Upper Ocean Heat Content



- Observations show substantial warming trend in the North Atlantic upper ocean heat content
- All-forcing simulations used in Booth et al. (2012) show no warming trend
- The discrepancy is mainly due to anthropogenic sulfate aerosols and the indirect effects of sulfate aerosols are strongly overestimated

Anti-Correlated Multidecadal Variations in Tropical North Atlantic (TNA)

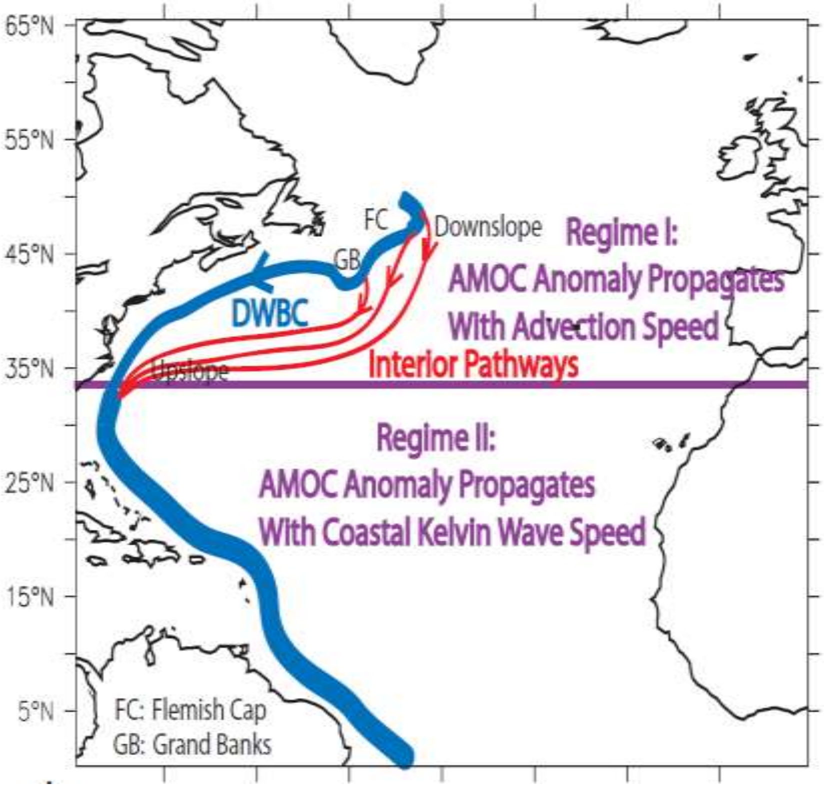


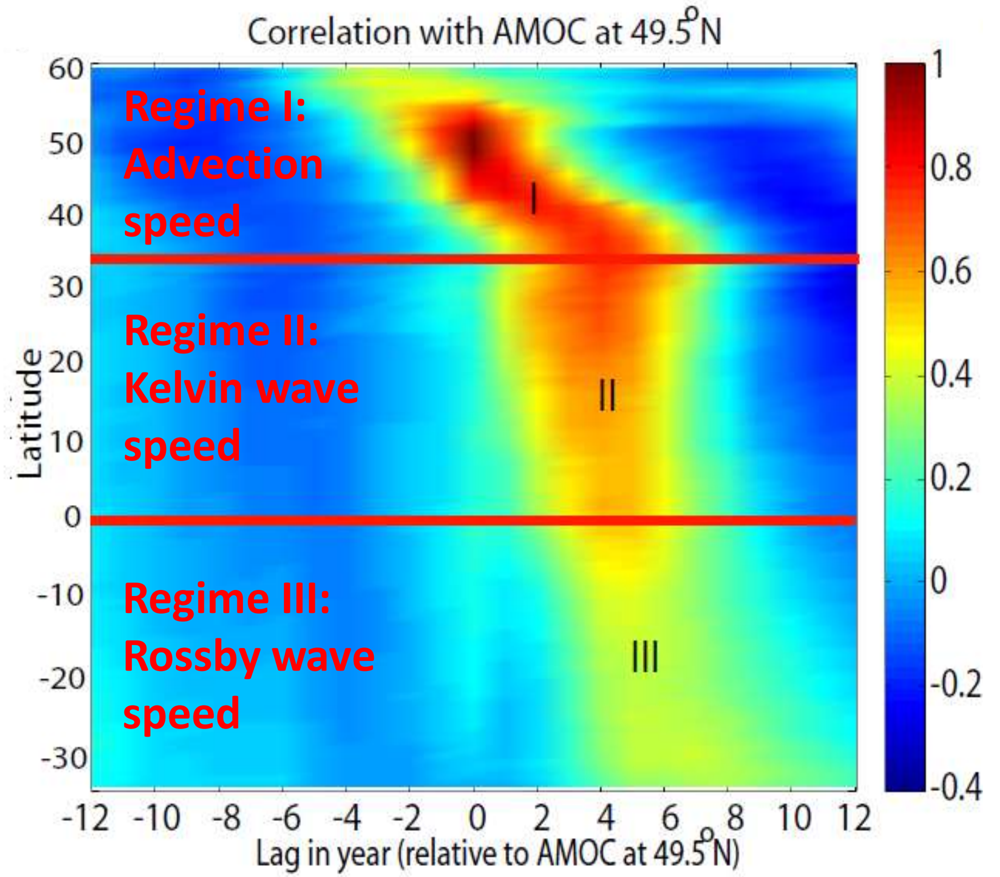
Zhang et al. 2013

- The anti-correlated variations are seen for both observations and in model simulations of AMOC changes, but not in the simulation (HadGEM2-ES) used in Booth et al. 2012

- The aerosol mechanism cannot account for the observed anticorrelated multidecadal TNA SST and subsurface temperature variations

Meridional Coherence of AMOC Variability

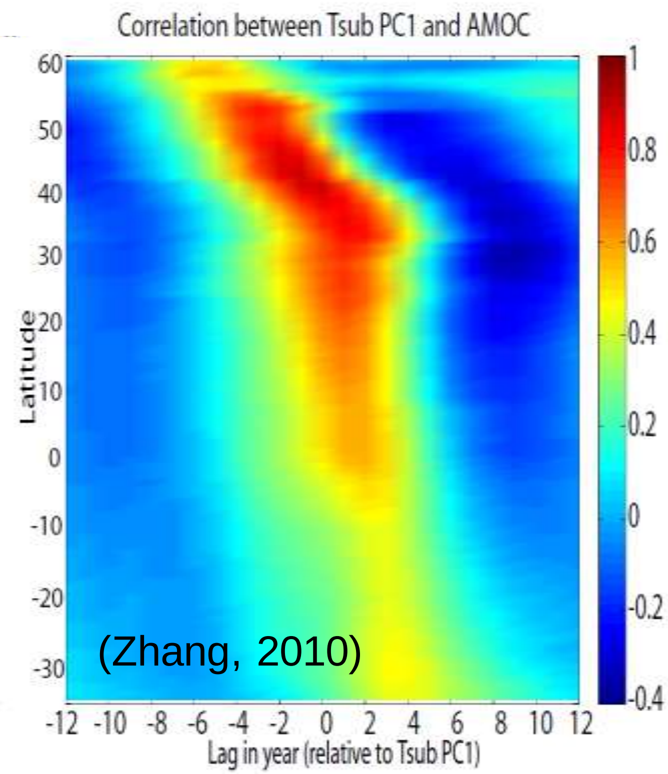


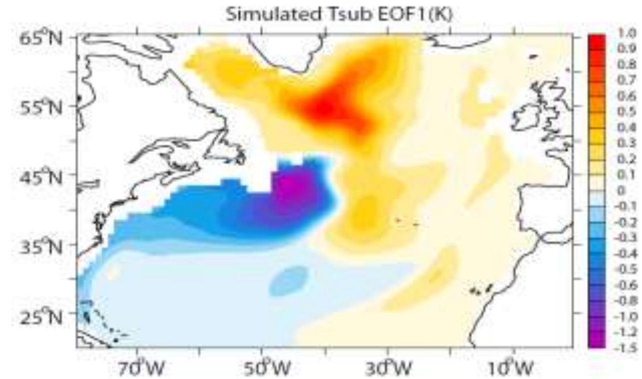


Zhang, 2010

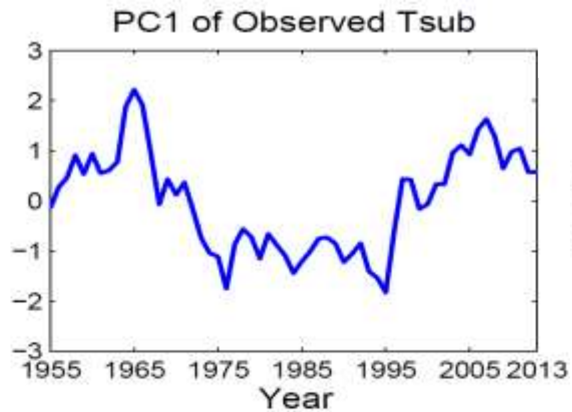
- Due to the existence of interior pathways, AMOC variations in Regime I propagate with the slow advection speed
- Subpolar AMOC variations lead subtropical AMOC variations by several years

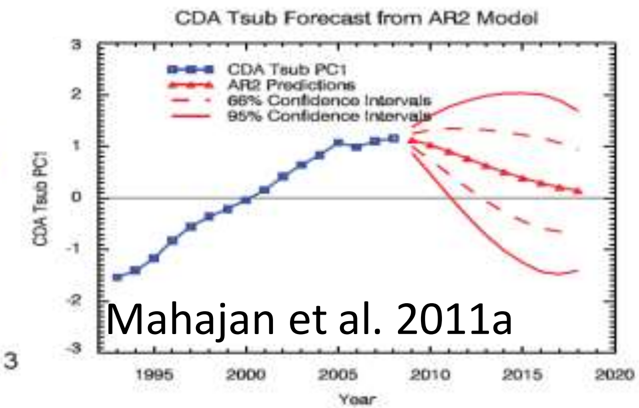
Linkage to AMOC Fingerprint and Decadal Prediction





AMOC Fingerprint
(leading mode of Tsub)

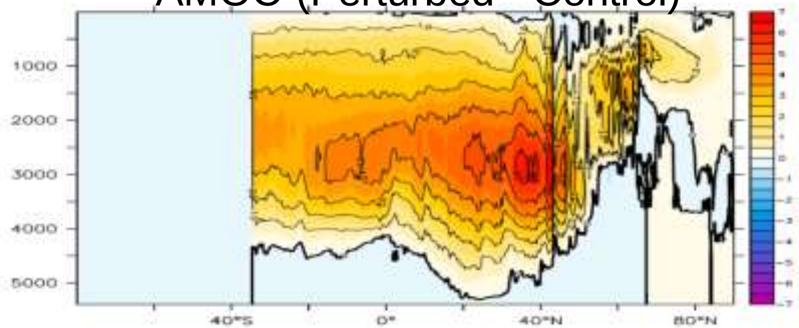


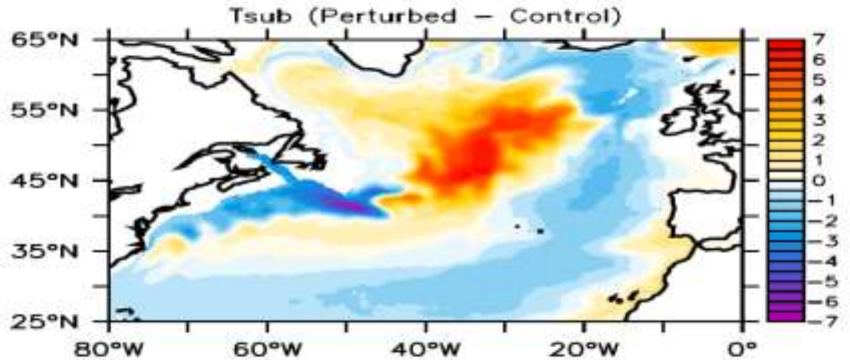


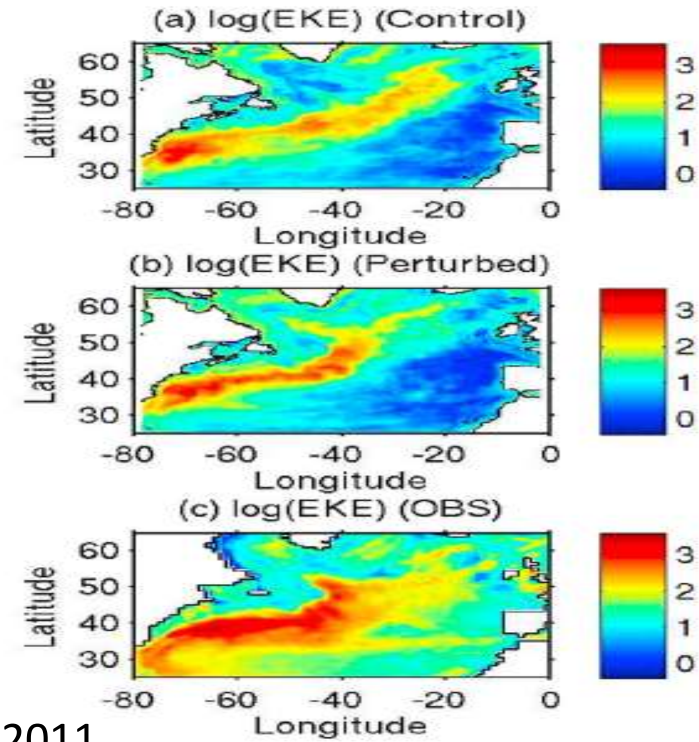
- A stronger/weaker AMOC at high latitude lead the AMOC fingerprint thus warming/cooling in subpolar gyre by several years, and contribute to enhanced decadal prediction skill in subpolar temperature
- A statistical prediction model is fit to the observed AMOC fingerprint and predicts a weakening of AMOC after 2008 (Mahajan et al. 2011a)

Nordic Sea Overflow and North Atlantic Ocean Circulation

AMOC (Perturbed –Control)







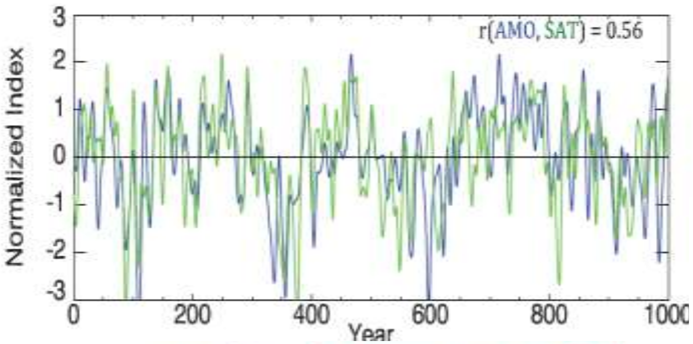
Zhang et al. 2011

The high resolution global coupled model (GFDL CM2.5) shows that a stronger Nordic Sea overflow leads to:

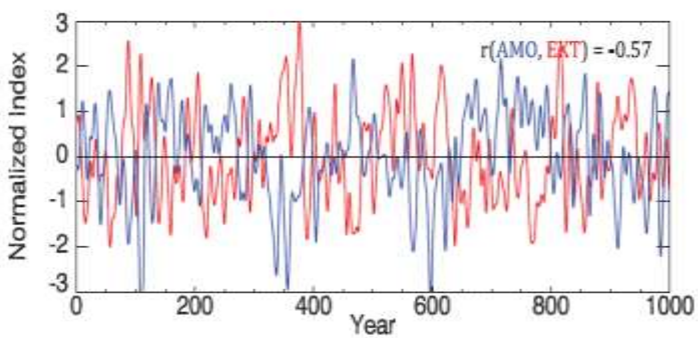
- A stronger and deeper AMOC, and contracted and weakened subpolar gyre
- Westward shift of North Atlantic Current and Southward shift of Gulf Stream
- A similar AMOC fingerprint (dipole pattern in Tsub) as in the coarse resolution model

Impact of AMV on Arctic Sea Ice Variability

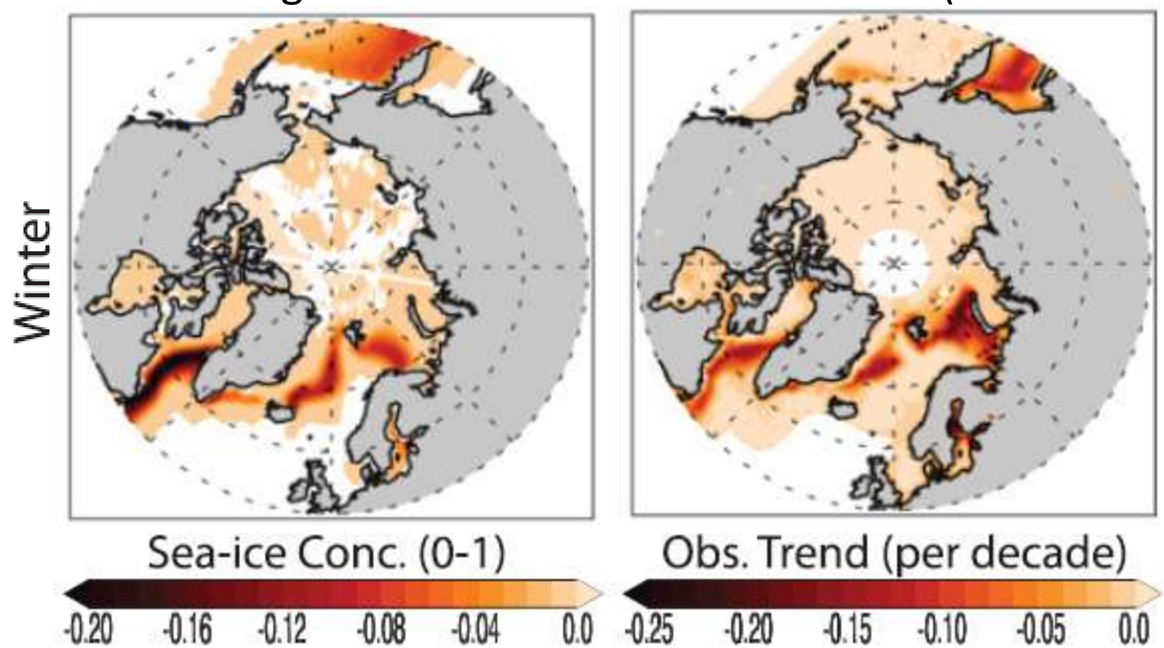
. Time-series: AMO index and Arctic Surface Air Temperature (SAT)



Time-series: AMO index and Arctic sea-ice extent (EXT)



Modeled Regression on AMV Observed Trend (1979-2008)



Mahajan et al. 2011b

- Winter Arctic sea ice in the Atlantic side declines with an intensified AMV/AMOC
- Similar spatial patterns suggest a possible role of the AMOC in the observed sea ice declining

Trends for Early 21st Century: Arctic Sea Ice vs. Global Mean SAT

We use 19 CMIP5 models' All-forcing experiments to do detection study for the observed summer Arctic sea ice trend in the early 21st century (Zhang and Knutson, BAMS, 2013)

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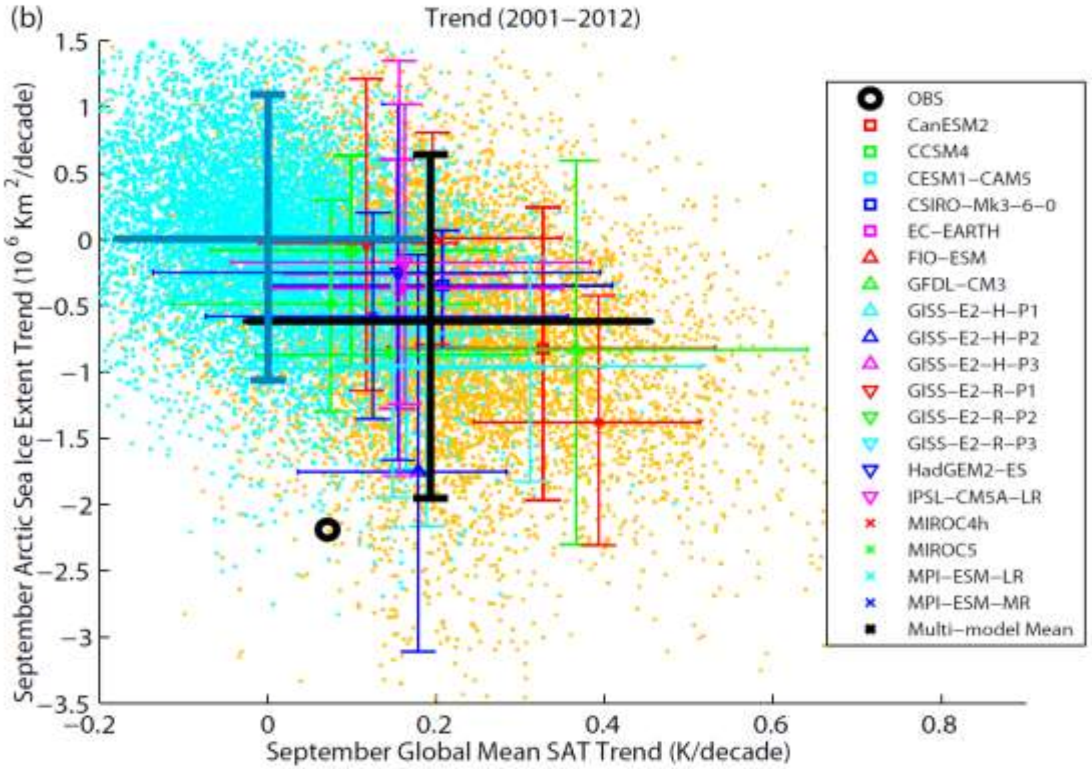

- The observed September Arctic sea ice extent decline trend lies outside the 5th to 95th percentile range of multi-model All-Forcing experiments
- The observed September global mean SAT warming trend during this hiatus period is not detectable

Summary and Discussions

- Quantifying the relative importance of AMOC variability vs. aerosol forcing on the AMV remains a key challenge

- A stronger/weaker AMOC can lead to the AMOC fingerprint thus warming/cooling in the subpolar gyre by several years due to the existence of interior AMOC pathways, and contribute to the enhanced decadal prediction skill in subpolar temperature

- An intensification of the AMOC is associated with a winter sea-ice decline in the Atlantic side of Arctic similar to that observed, suggesting the possible role of AMOC in the recent observed winter Arctic sea-ice decline

- The discrepancy in CMIP5 models with observed summer Arctic sea ice decline trend indicate several possibilities, such as the internal variability is underestimated in CMIP5 models or the observation represents an extreme rare scenario