Understanding the AMOC-AMV Linkage and Associated Climate Impacts

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4th Summer School on Theory, Mechanisms, and Hierarchical Modeling of Climate Dynamics: Atlantic Variability and Tropical Basin Interactions at Interannual to Multi-Decadal Time Scales

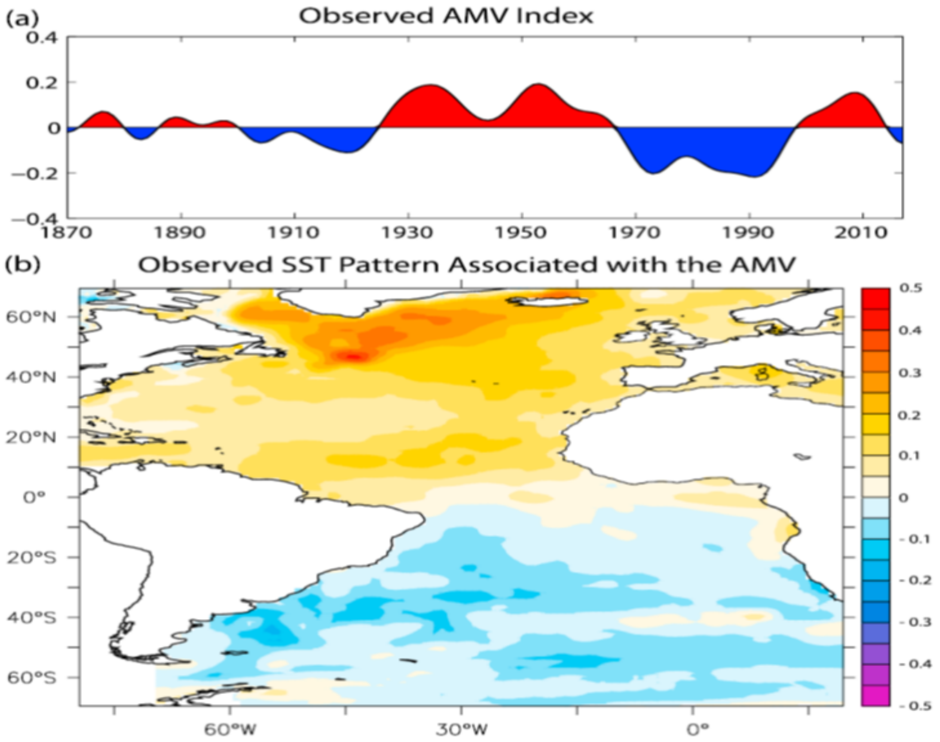
August 3, 2023

Outline

- Observed key elements of AMV
- AMOC fingerprints and the AMOC-AMV linkage
- Multivariate nature of AMV
- Climate Impacts of multidecadal AMOC variability and AMV
- Modelling biases of the AMOC-AMV linkage and associated climate impacts

Introduction - Atlantic Multidecadal Variability

Atlantic Multidecadal Variability (AMV) has impacts on many regional climate phenomena (ITCZ position, Sahel/India monsoon, Atlantic hurricane, North Atlantic Oscillation, North American/European heat waves and drought, Pacific climate variability, and Arctic sea ice) (Zhang et al. 2019)



Zhang et al. 2019, Reviews of Geophysics

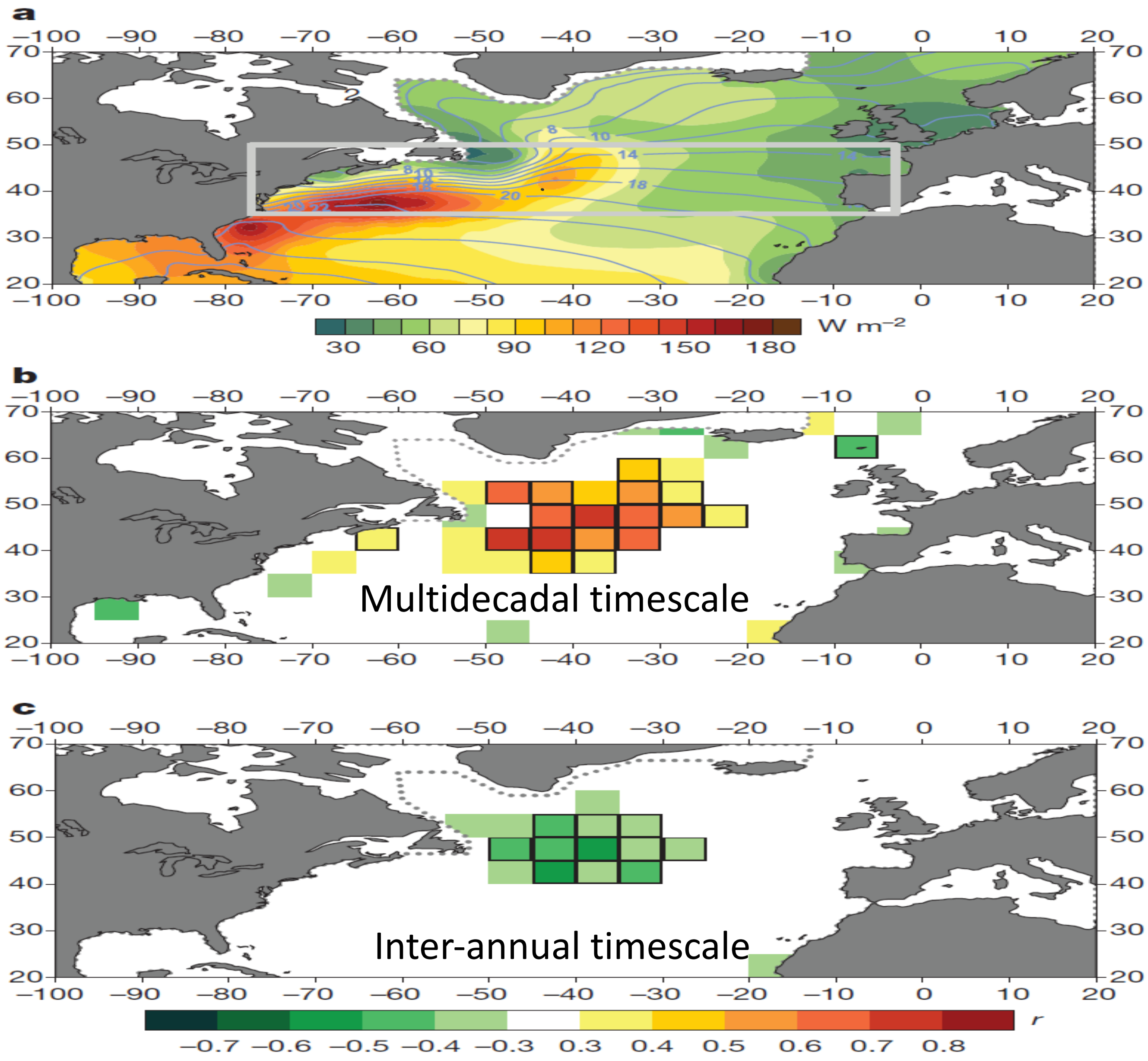
- The observed AMV exhibits a dipole SST pattern over the Atlantic
- The subpolar AMV SST signal propagates into the tropical NA along a horseshoe pathway
- The observed positive AMV is associated with more heat flux released from mid-latitude NA into the atmosphere and vice versa
- There is high coherence among observed AMV-related subpolar NA SST, SSS, upper ocean heat/salt content, and anti-correlation between AMV-related tropical NA surface and subsurface temperature

The observed key elements of AMV are crucial for evaluating proposed AMV mechanisms

AMV ≠ NASST Anomaly

AMV: multidecadal timescales, multivariate phenomenon, unique to the Atlantic, with the global mean signal removed

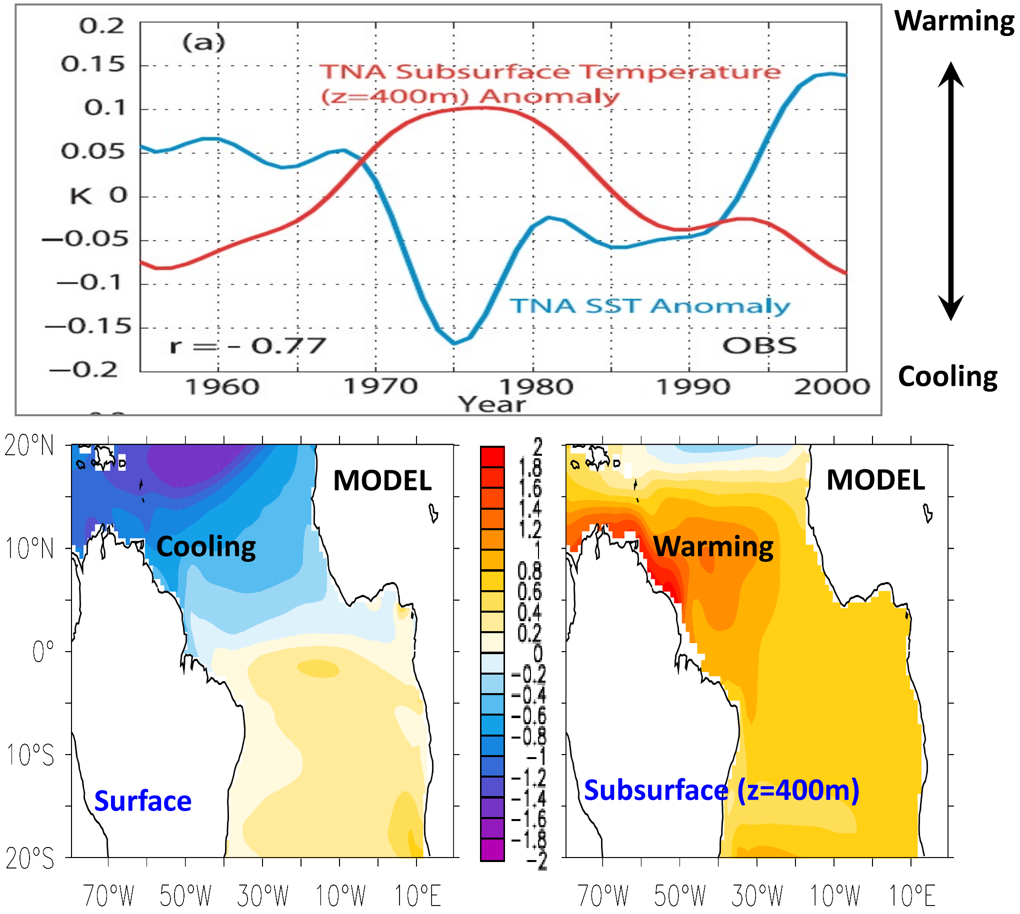
NASST Anomaly: all timescales, including global mean signal and inter-annual SST variability induced by North Atlantic Oscillation



Correlations between SST and surface turbulence heat fluxes
Gulev et al. 2013, Nature

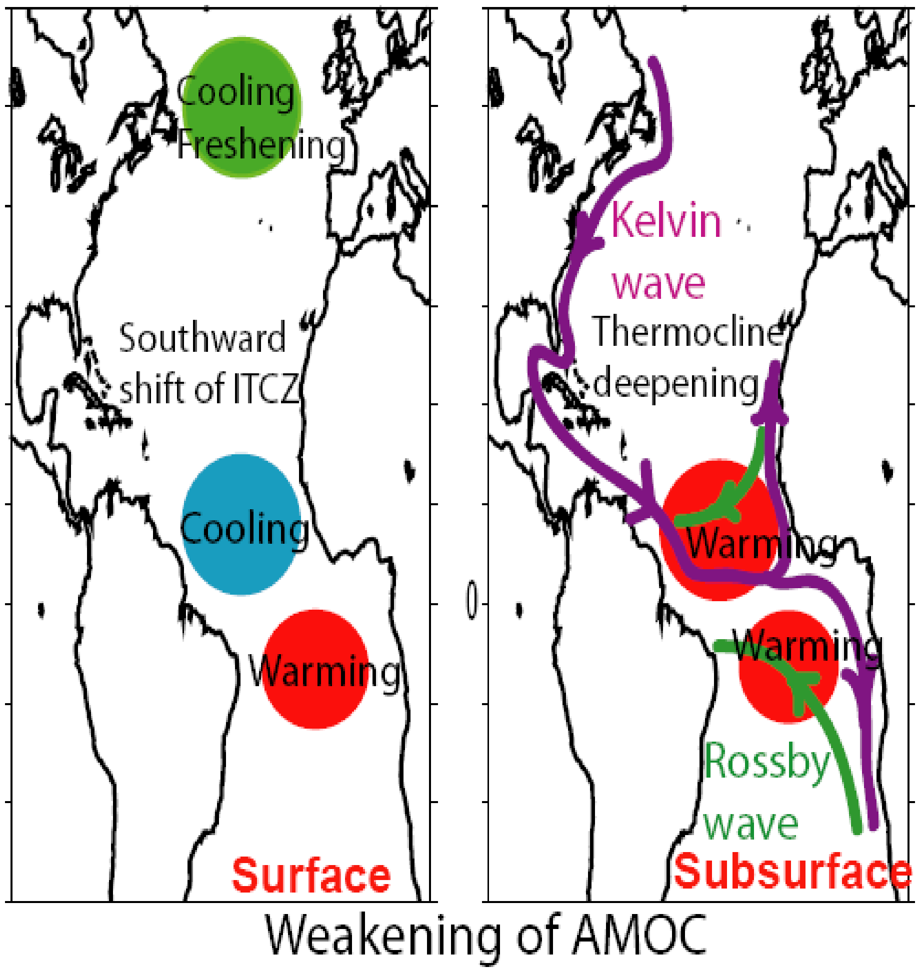
The observed positive AMV is associated with more heat flux released from mid-latitude NA into the atmosphere and vice versa, supporting Bjerknes' hypothesis (1964) and early observational/modeling studies suggesting that multidecadal AMOC variability plays an active role in the observed AMV (Folland et al. 1986; Deser & Blackmon, 1993; Delworth et al. 1993; Schlesinger & Ramankutty, 1994; Kushnir, 1994; Enfield & Mestas-Nuñez, 1999; Delworth & Mann, 2000; Latif et al. 2004)

The observed anti-correlated variations between TNA surface and subsurface temperature



Ocean temperature anomaly due to the weakening of AMOC

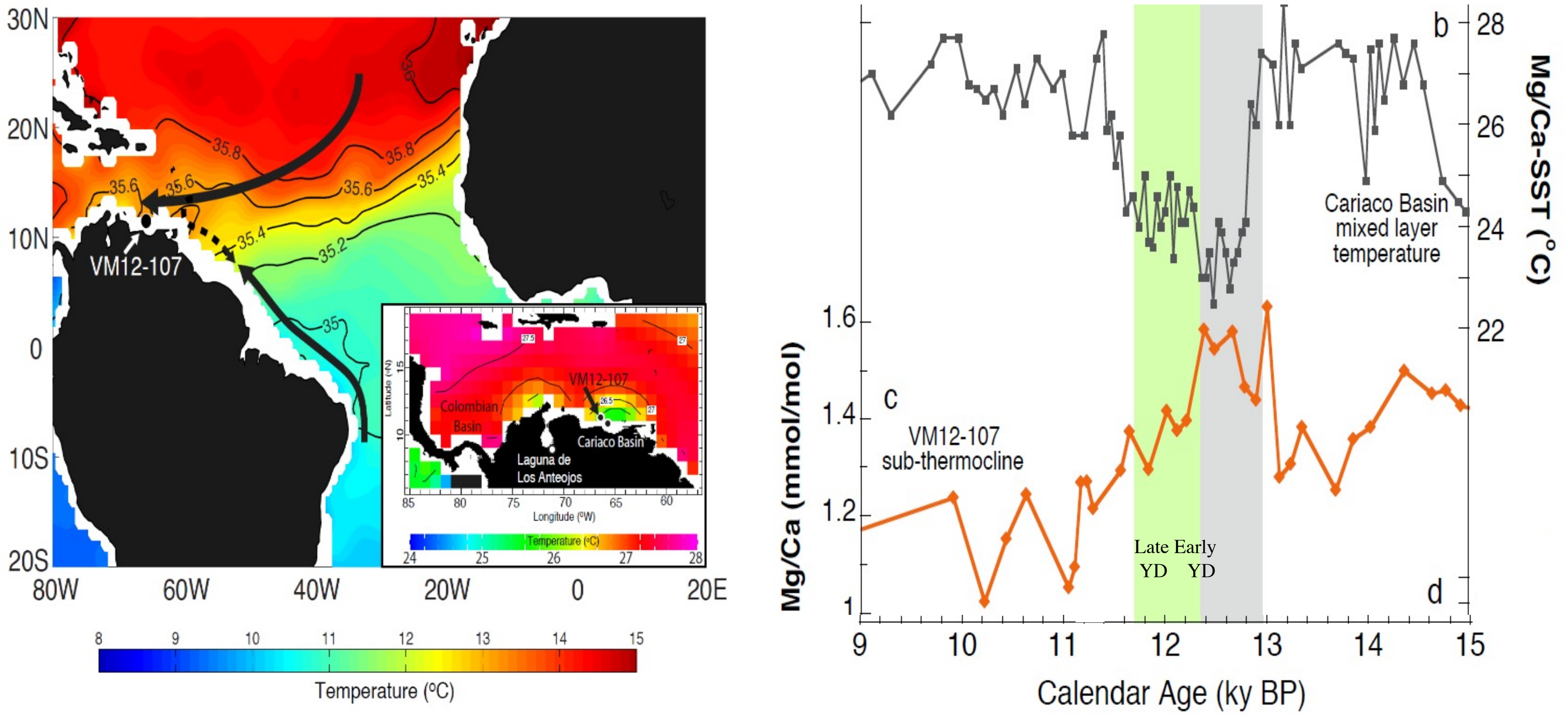
GFDL CM2.1 water hosing experiment



Zhang, 2007, GRL

- The anticorrelation between TNA surface and subsurface temperature has been identified as a tropical AMOC fingerprint, indicating the important role of AMOC in the observed tropical AMV signal
- The AMOC induced anti-correlated TNA surface and subsurface temperature variations are also found in many climate models (Wang and Zhang, 2013)

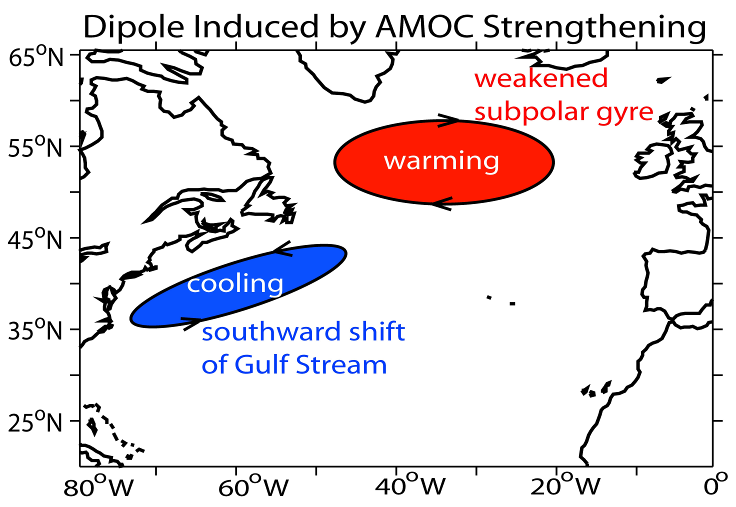
Anticorrelated Tropical North Atlantic (TNA) Surface and Subsurface Temperature



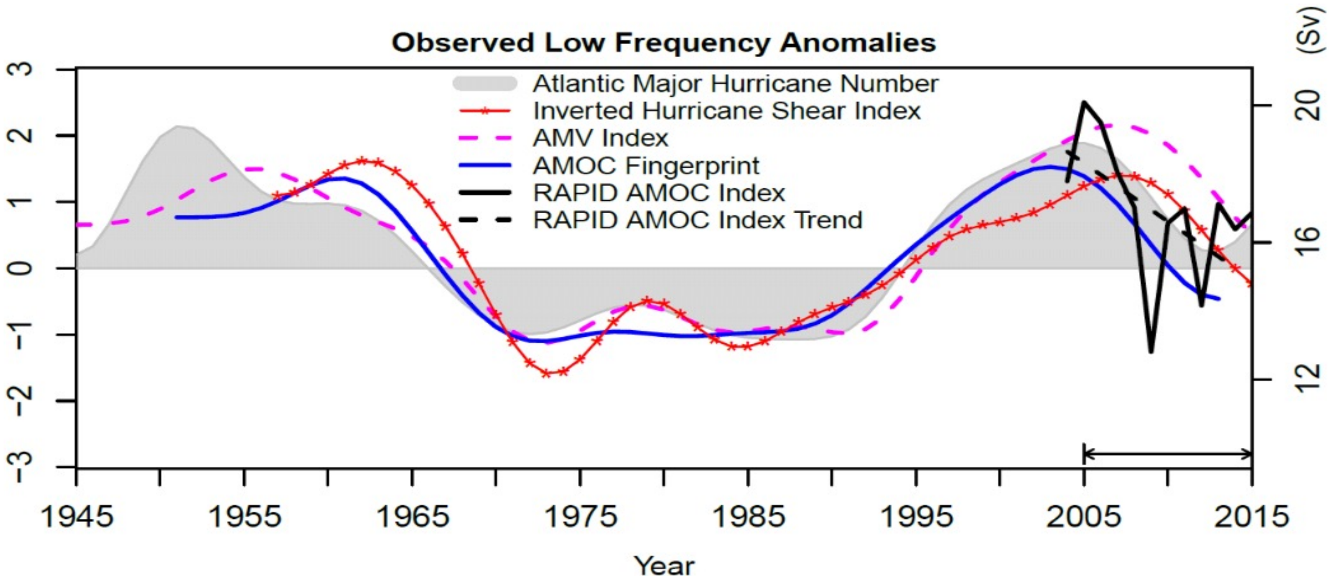
Schmidt et al. 2012, PNAS

High-resolution temperature records of the last deglacial transition from a southern Caribbean sediment core indeed show anticorrelated TNA surface and subsurface temperature changes, with warmer subsurface temperature corresponding to colder surface temperature during the Younger Dryas, a period with a much weaker AMOC

Observational and Modeling Evidence for the AMOC-AMV Linkage



Zhang, 2008, GRL



Yan, Zhang, and Knutson, 2017, Nature Communications

- The leading mode of extratropical NA upper ocean heat content variations (opposite variations in the subpolar gyre and the Gulf Stream region) has been identified as an extra-tropical AMOC fingerprint (Zhang, 2008)

- The reconstructed multidecadal AMOC variations are coherent with the observed AMV index, supporting a close AMOC-AMV linkage (Zhang, 2008; Yan et al. 2017)

- The inferred AMOC decline during 2005-2015 by the fingerprint is consistent the observed cooling trend in subpolar NA (Robson et al. 2016) and the directly observed AMOC decline from the RAPID program (Frajka-Williams et al. 2016; Smeed et al. 2018)

Evolution of the Extra-tropical AMOC Fingerprint

Southward propagation of AMOC anomaly

↓

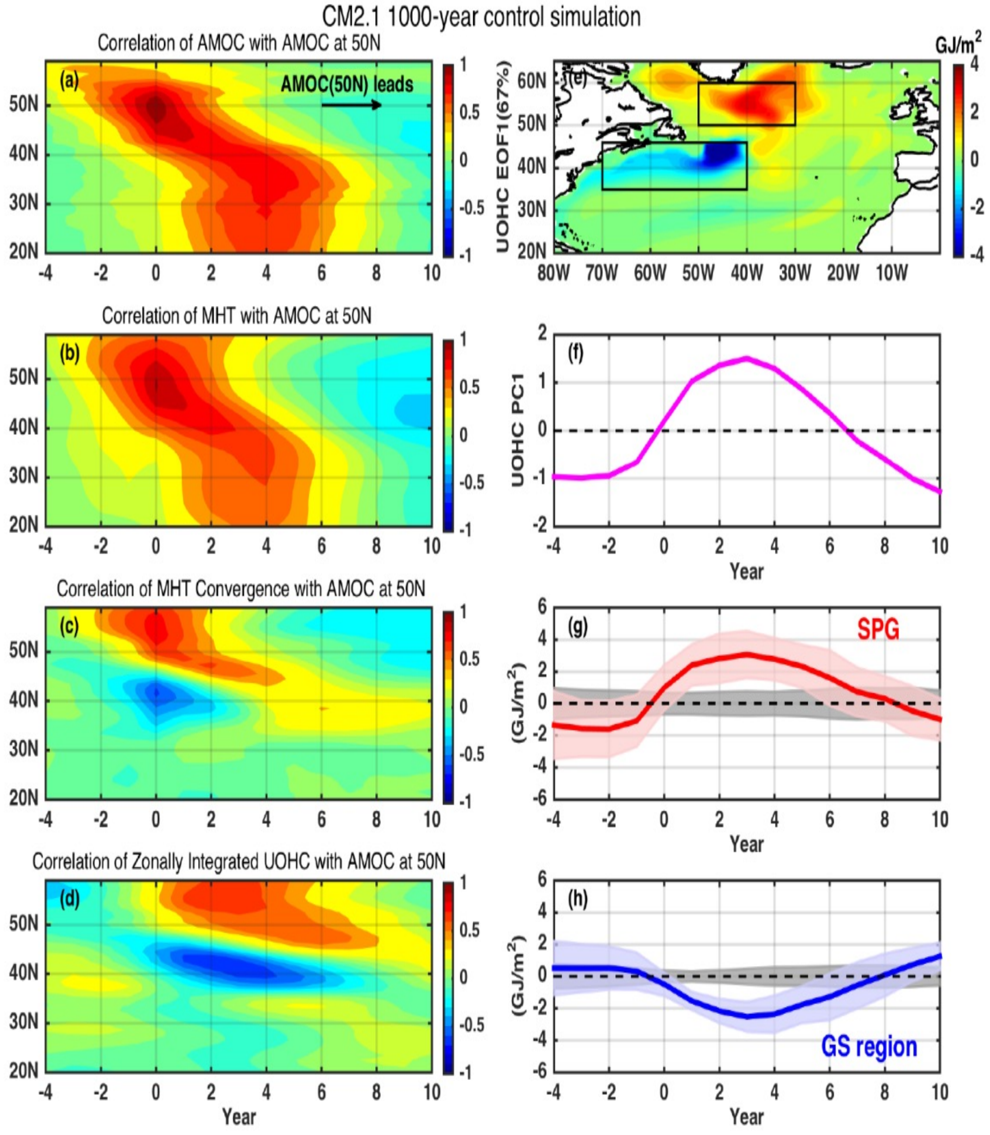
Southward propagation of MHT anomaly

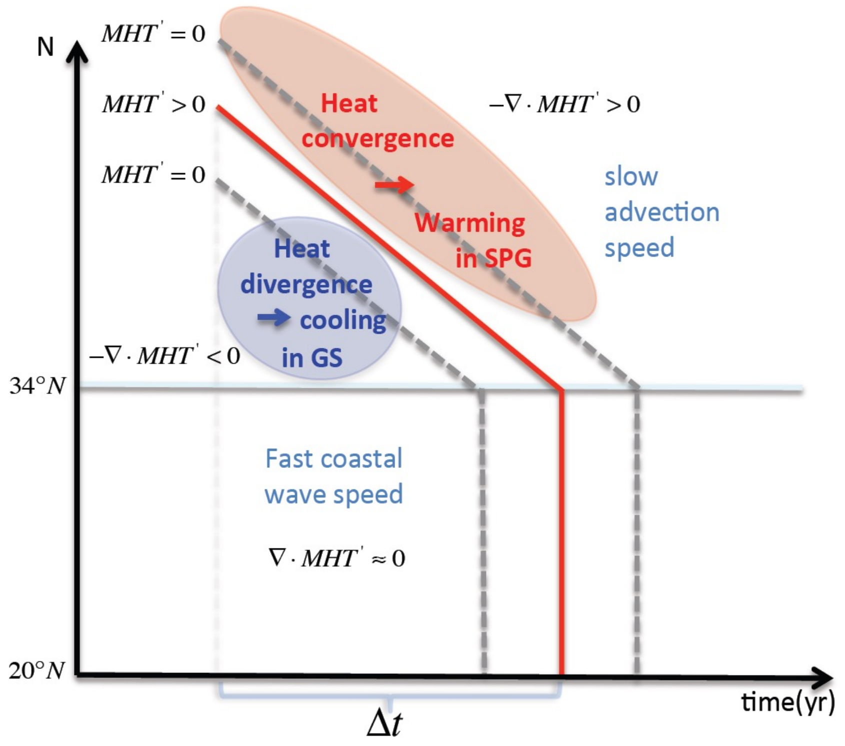
↓

MHT convergence in SPG and divergence in GS

↓

Warming in SPG and cooling in GS

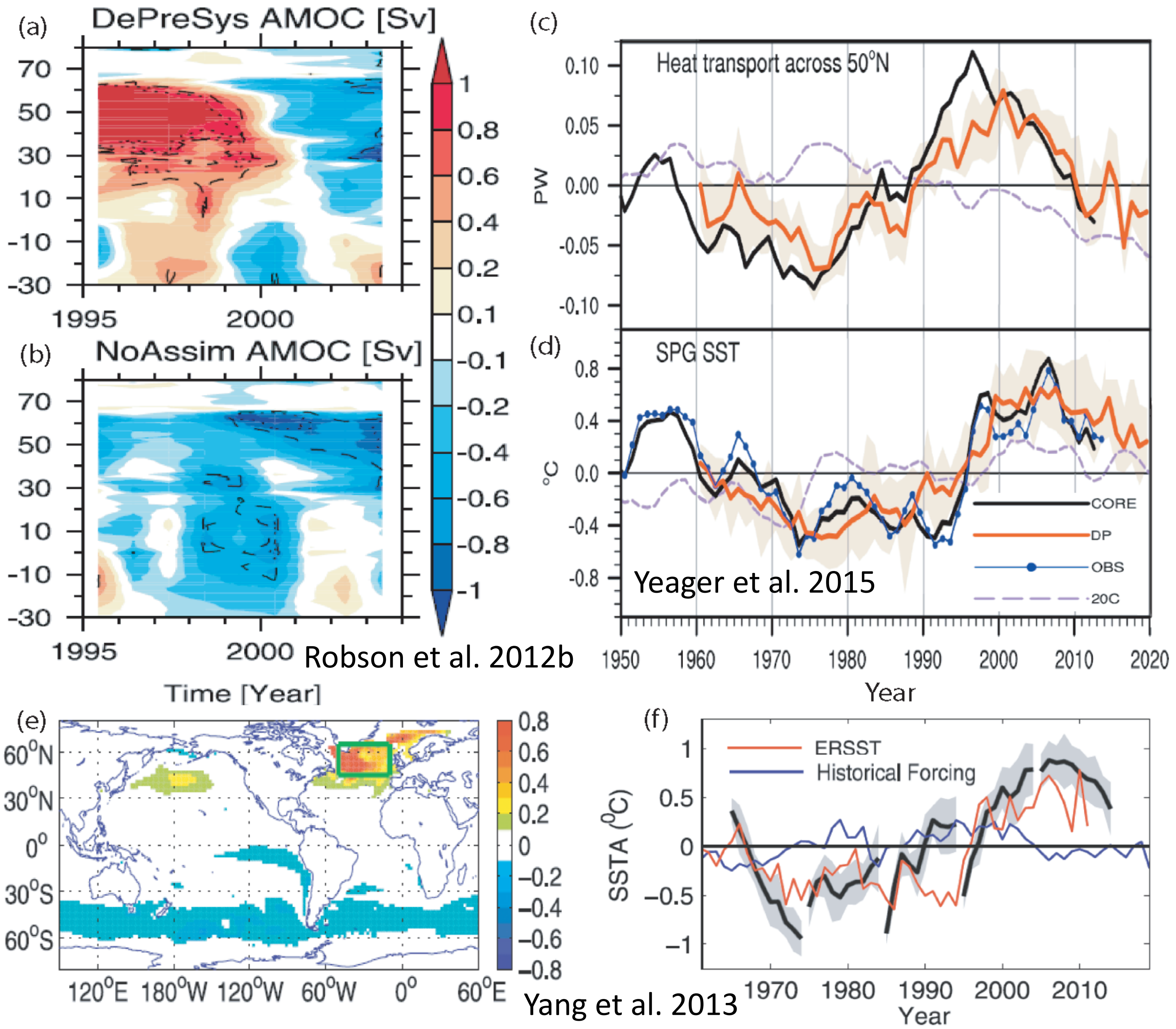




The slow propagation of AMOC anomaly is crucial for enhanced decadal predictability of SPG and GS temperature, consistent with enhanced decadal predictions of the AMOC fingerprint and the AMV signal obtained by initializing AMOC anomalies at northern high latitudes in decadal prediction experiments (e.g. Robson et al. 2012; Yeager et al. 2012; Yang et al. 2013)

Zhang and Zhang, 2015, GRL

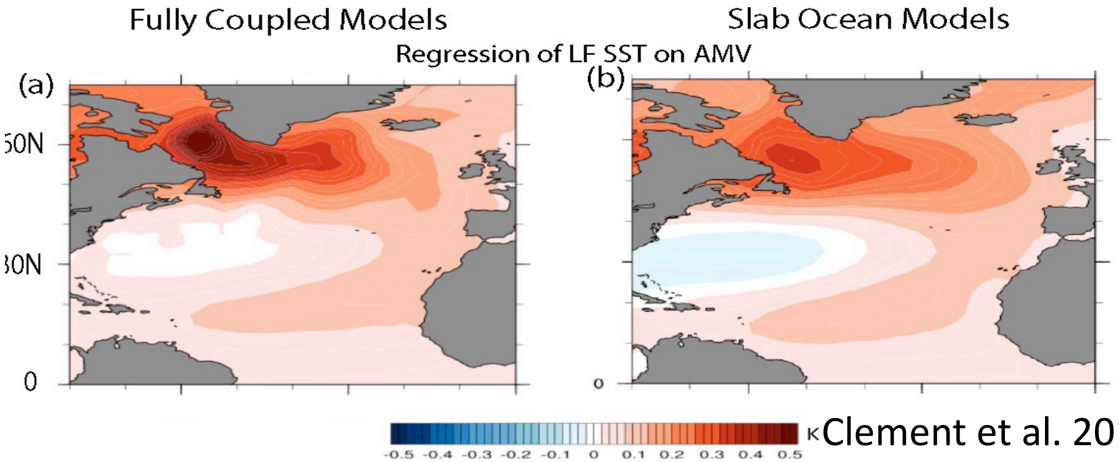
Relationship between AMOC, AMV and Atlantic Decadal Predictability & Prediction



Many decadal prediction experiments initialized with observed ocean states exhibit a positive AMOC anomaly at northern high latitudes in the mid-1990s, hence simulate an increase in ocean heat transport into subpolar NA and successfully predict the observed decadal warming shift in subpolar NA (e.g. Robson et al. 2012; Yeager et al. 2012; Yang et al. 2013)

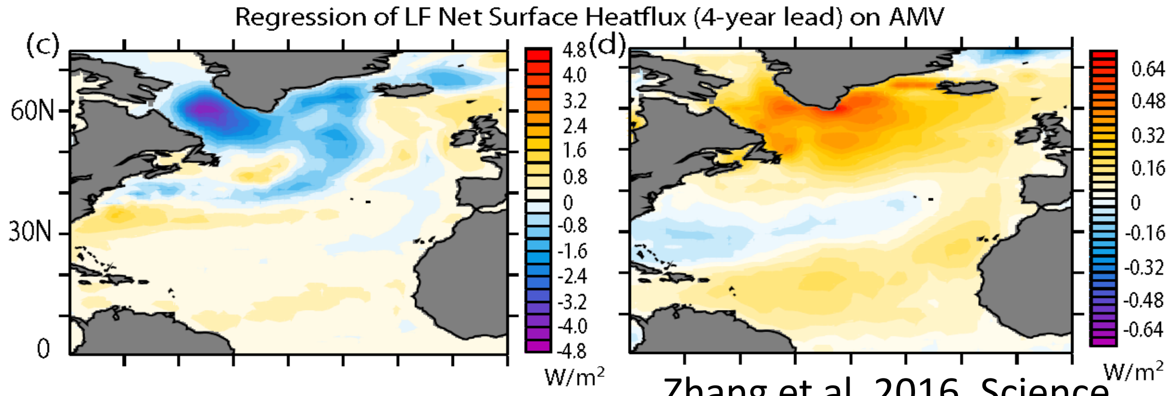
In contrast, uninitialized hindcasts with prescribed changes in external radiative forcings do not simulate the positive AMOC anomaly at northern high latitudes, thus are not able to predict the observed postive AMV shift, suggesting the critical role of AMOC in AMV and associated Atlantic decadal predictions

Hypotheses for AMV Mechanisms without an Essential Role for the AMOC



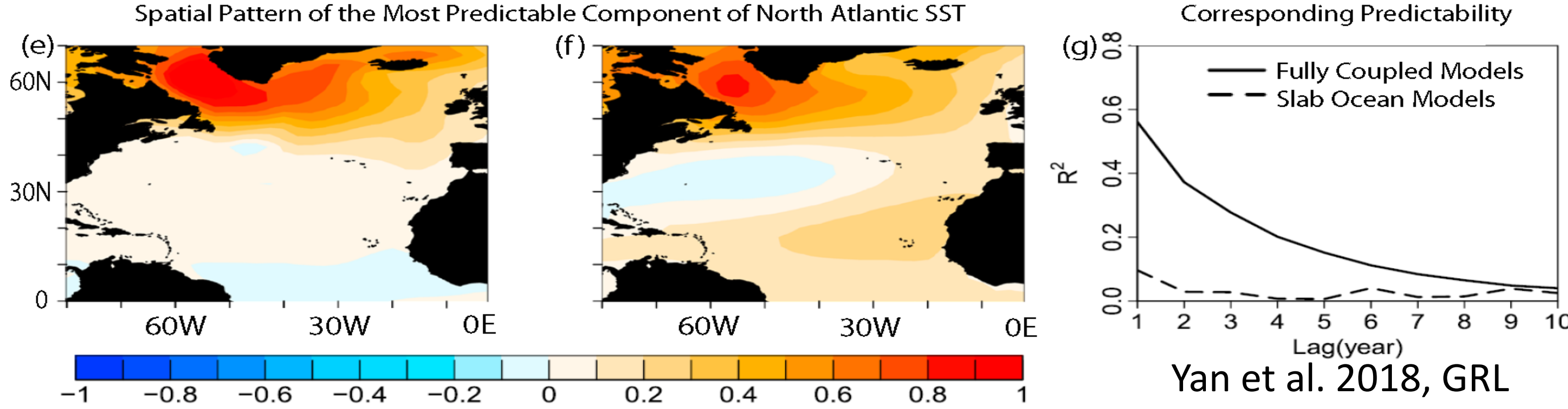
Clement et al. 2016, Science

AMV has been proposed as a red noise response of NA SST to stochastic atmospheric forcing without a role of ocean dynamics, because NA SST patterns associated with AMV and spectra of basin-averaged NA SST are similar in fully coupled models with ocean dynamics and in slab ocean models without ocean dynamics



Zhang et al. 2016, Science

In contrast to slab ocean models, in fully coupled models multidecadal net downward surface heat flux anomalies have a negative correlation/regression with AMV over subpolar NA due to anomalous ocean heat transport convergence, consistent with observations



Yan et al. 2018, GRL

The red noise mechanism found in slab ocean models cannot explain many observed key elements of AMV and implies no decadal predictability other than short persistence

The most predictable component of NA SST persists much longer with much higher predictability in fully coupled models than in slab ocean models, due to the important role of ocean dynamics

A Simple Conceptual Model for SST Anomalies

$$\rho c_p h \frac{\partial T'}{\partial t} \approx F'_{Net} + F'_O \approx -\lambda_A T' + f'_A - \lambda_O T' + f'_O$$

$$F'_{Net} \approx -\lambda_A T' + f'_A$$

$$F'_O \approx -\lambda_O T' + f'_O$$

λ_A: net surface heat flux damping rate, λ_O: oceanic damping rate

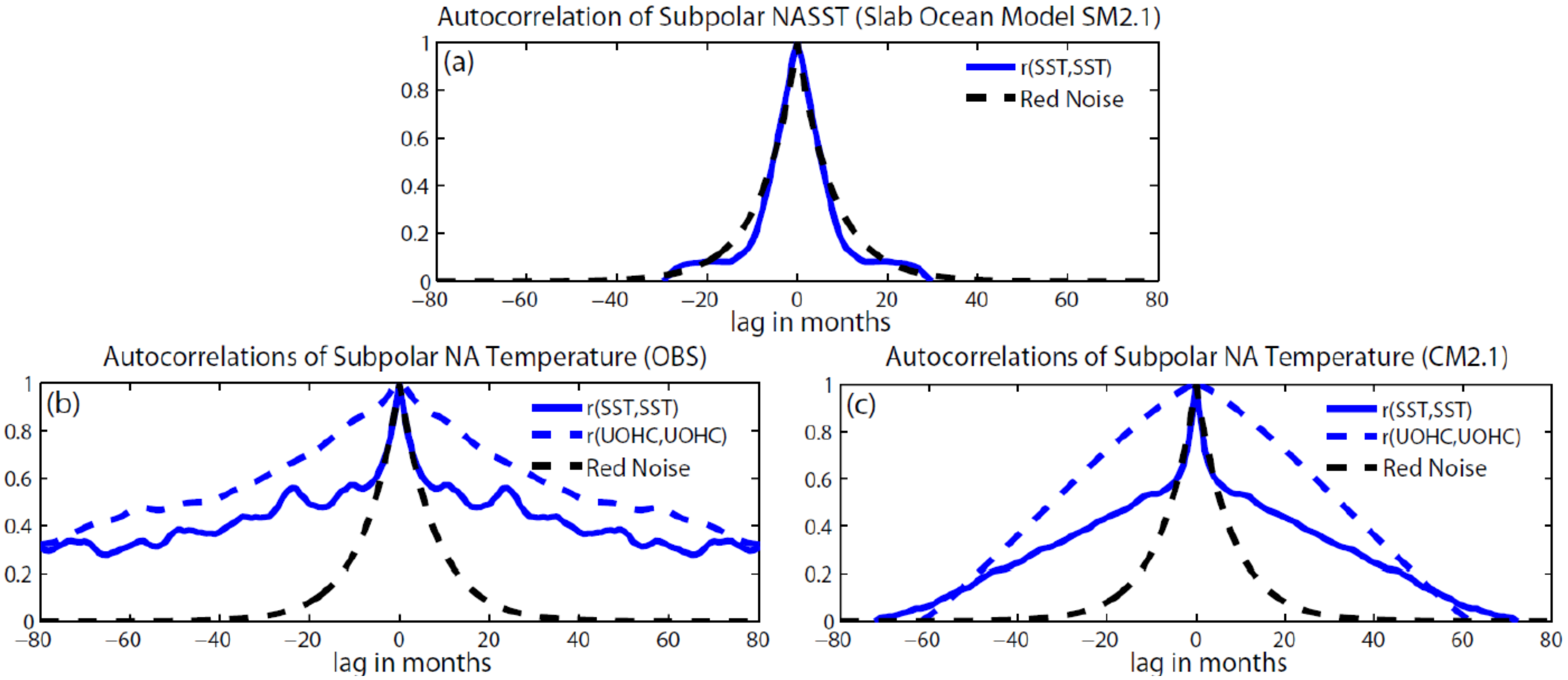
$$\frac{cov(f'_O, T')}{cov(f'_A, T')} \approx \frac{\lambda_O - \frac{r(F'_{Net}, T')\sigma_{F'_{Net}}}{\sigma_{T'}}}{\lambda_A + \frac{r(F'_{Net}, T')\sigma_{F'_{Net}}}{\sigma_{T'}}}$$

The correlation/regression between F'_{Net} and T' at low frequency are key indicators for the relative roles of oceanic vs. atmospheric forcing

- For both observations and CM2.1, $\frac{cov(f'_O, T')}{cov(f'_A, T')} \gg 1$, f'_O has a dominant role for low frequency Subpolar NASST anomalies associated with the AMV

Zhang, 2017, GRL

Decadal Persistence of Subpolar NASST Anomalies

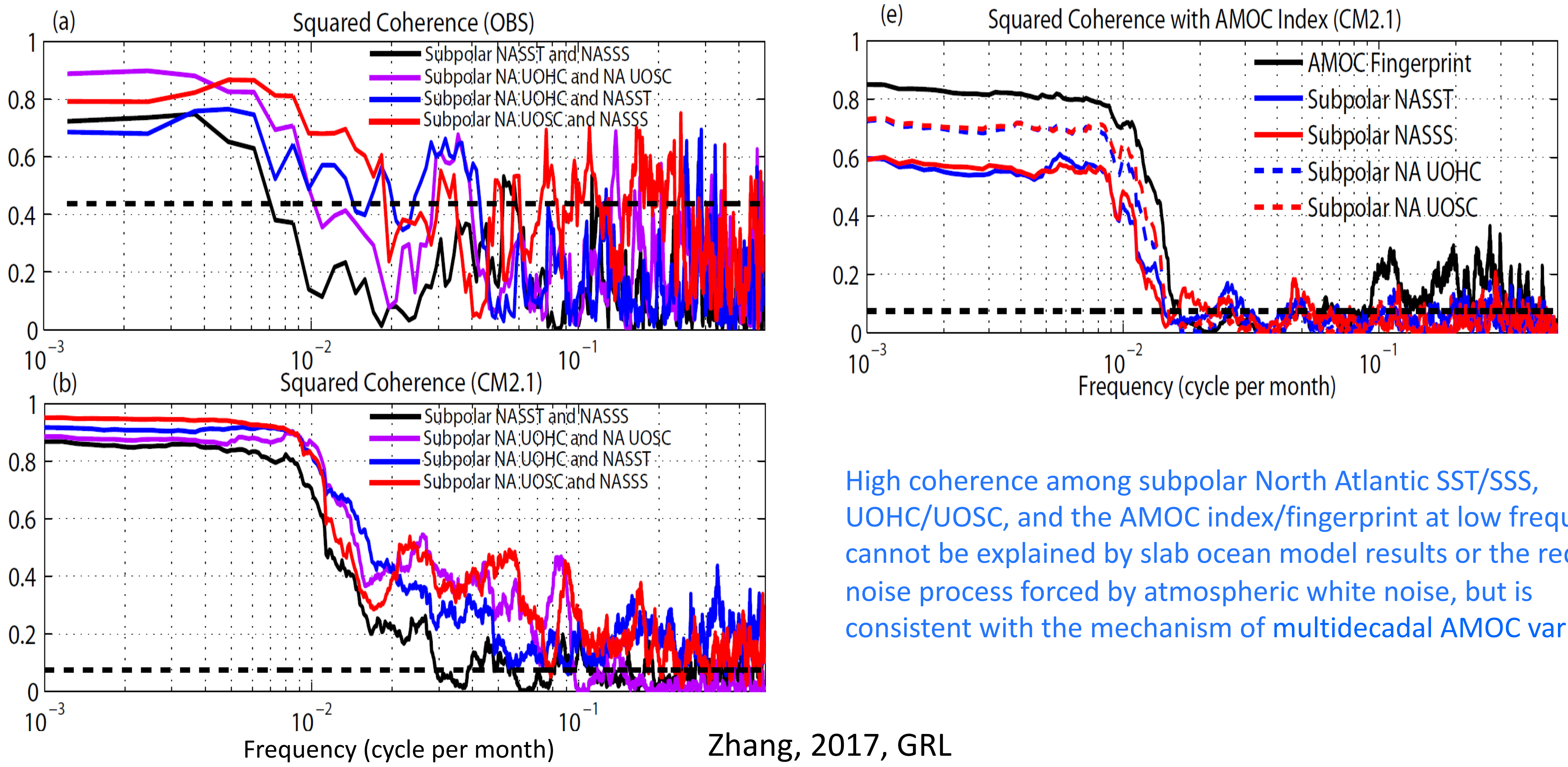


Zhang, 2017, GRL

- The observed and GFDL CM2.1 simulated decadal persistence of subpolar NASST anomalies associated with AMV will lead to a much higher decadal predictability than that obtained from slab ocean models or the red noise process
- Multidecadal AMOC variability is a major source for the decadal persistence in the subpolar North Atlantic SST anomalies associated with AMV

Coherent Multivariate Nature of AMV

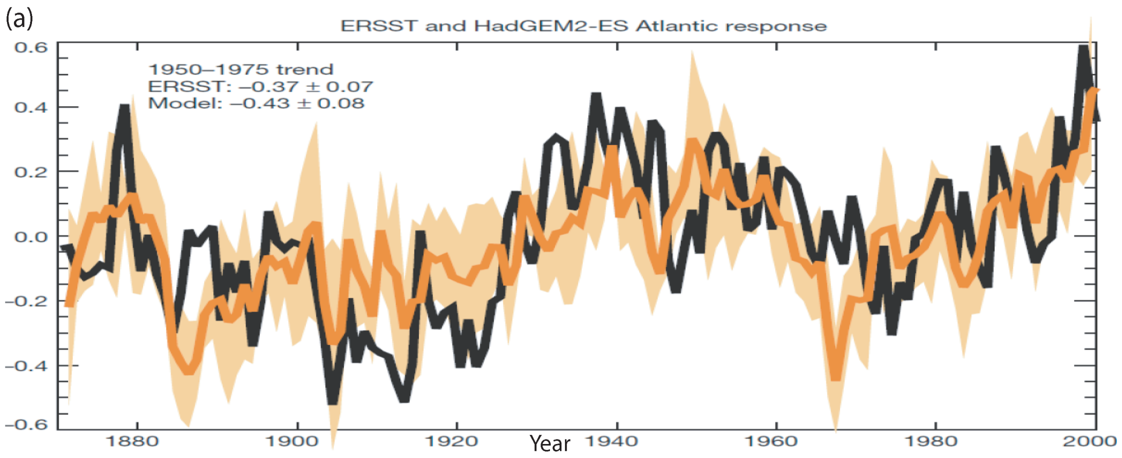
The observed AMV is associated with coherent variations among the subpolar North Atlantic SST, SSS, and upper ocean heat/salt content (UOHC/UOSC). The high coherences only occur at low frequency and not at high frequency



High coherence among subpolar North Atlantic SST/SSS, UOHC/UOSC, and the AMOC index/fingerprint at low frequency cannot be explained by slab ocean model results or the red noise process forced by atmospheric white noise, but is consistent with the mechanism of multidecadal AMOC variability

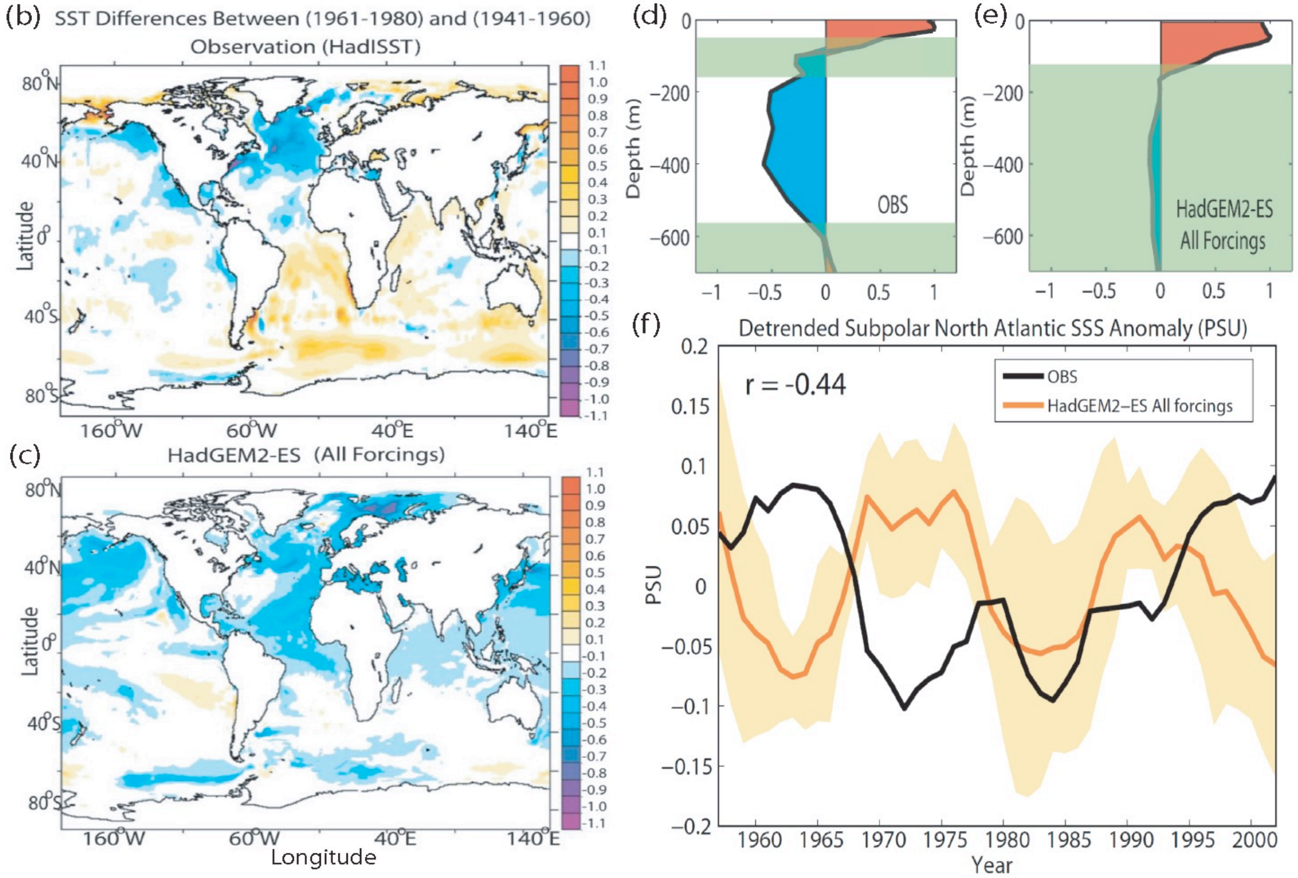
Zhang, 2017, GRL

Hypotheses for AMV Mechanisms without an Essential Role for AMOC



Anthropogenic aerosols have been implicated as the prime driver of the observed AMV, because basin-averaged NA SST anomalies in externally forced simulations including aerosol indirect effects is similar to observations

Booth et al. 2012, Nature



The aerosol mechanism is inconsistent with many observed key elements of AMV

The simulated externally forced multidecadal SST signal is not unique to the Atlantic, but also appears in many other ocean basins and represents a global scale response to external forcings

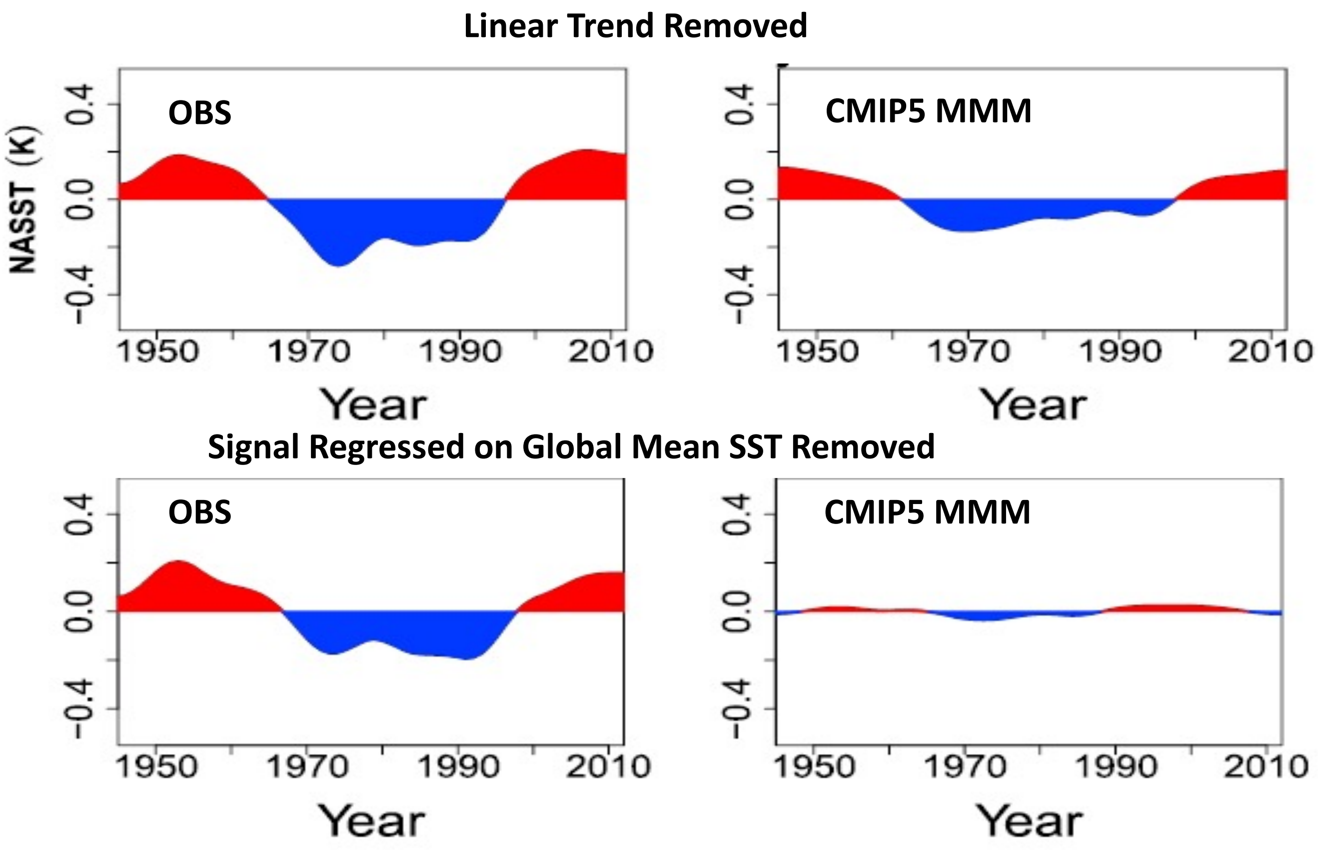
The simulated response to anthropogenic aerosols does not explain the observed anticorrelation between multidecadal tropical NA surface and subsurface temperature

The simulated detrended subpolar NA SSS anomalies are quite different from that observed

Zhang et al. 2013, JAS
Zhang et al. 2019, Reviews of Geophysics

Issues with the Aerosol Mechanism of AMV

The aerosol mechanism of AMV (e.g. Booth et al., 2012) is based on the resemblance of the linearly detrended basin-wide SST-based AMV index between observations and modeled externally forced response in historical simulations

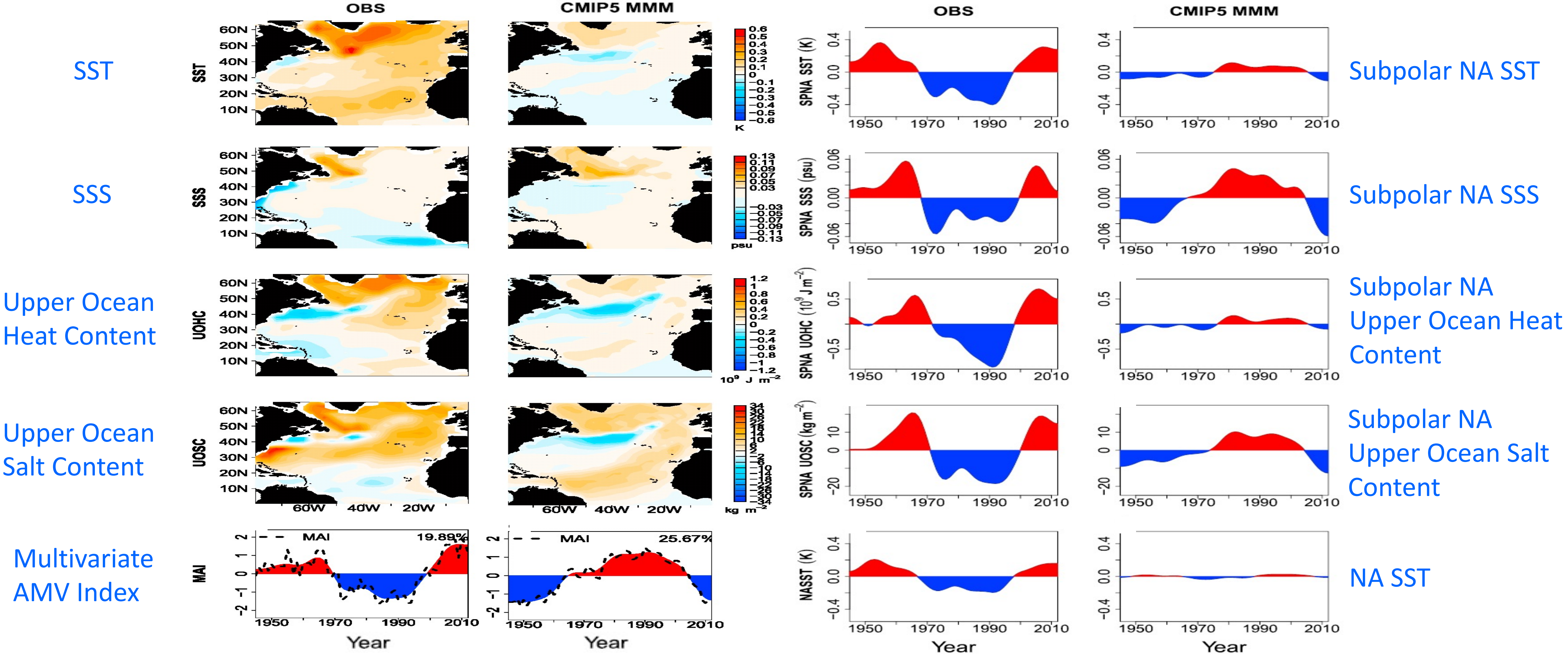


Yan, Zhang, and Knutson, 2019, GRL

- The resemblance between linearly detrended observed and CMIP5 forced basin-wide SST-based AMV indices is an artifact of linear detrending
- When the signal associated with global mean SST is removed, such resemblance disappears: the CMIP5 MMM simulated AMV index is much smaller, whereas the observed AMV index remains pronounced

Multivariate AMV Index (MAI)

Signal Regressed on GLobal Mean SST Removed (Nonlinear Detrending)

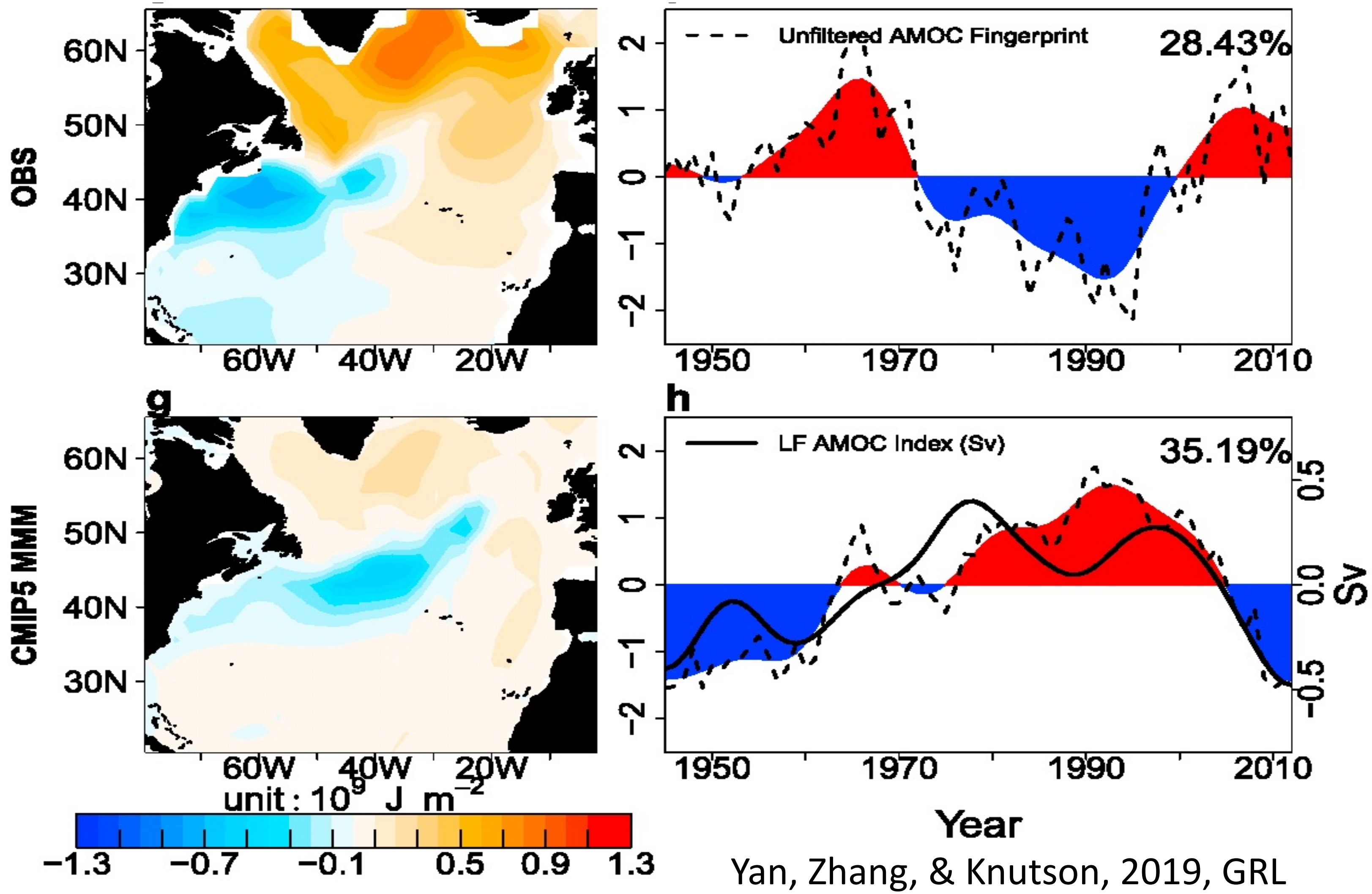


Yan, Zhang, and Knutson, 2019, GRL

- Multivariate EOF analysis has been applied to obtain a Multivariate AMV Index (MAI), defined as the normalized leading principal component of combined detrended NA SST, SSS, upper ocean heat and salt content anomalies to reflect the observed multivariate nature of AMV
- The CMIP5 externally forced multivariate AMV index (MAI) and multidecadal signal in the subpolar NA SST, SSS, upper ocean heat and salt content disagree strongly with that observed

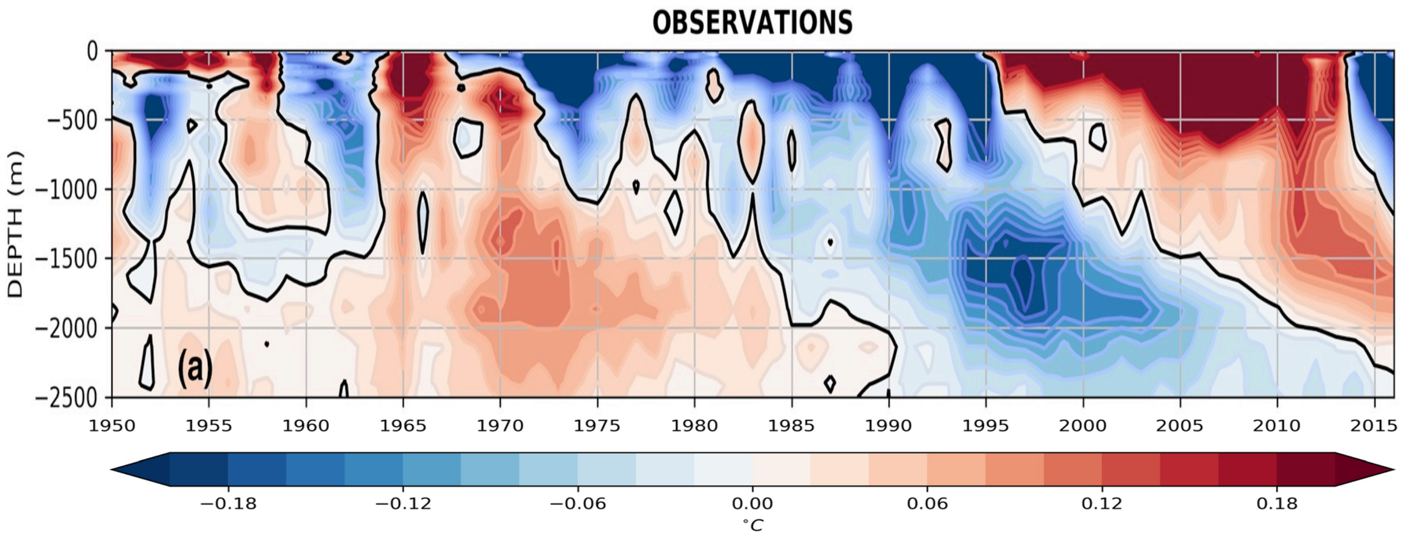
Extra-tropical AMOC Fingerprint (Observed vs. CMIP5 Externally Forced Response)

Signal Regressed on Global Mean SST Removed (Nonlinear Detrending)

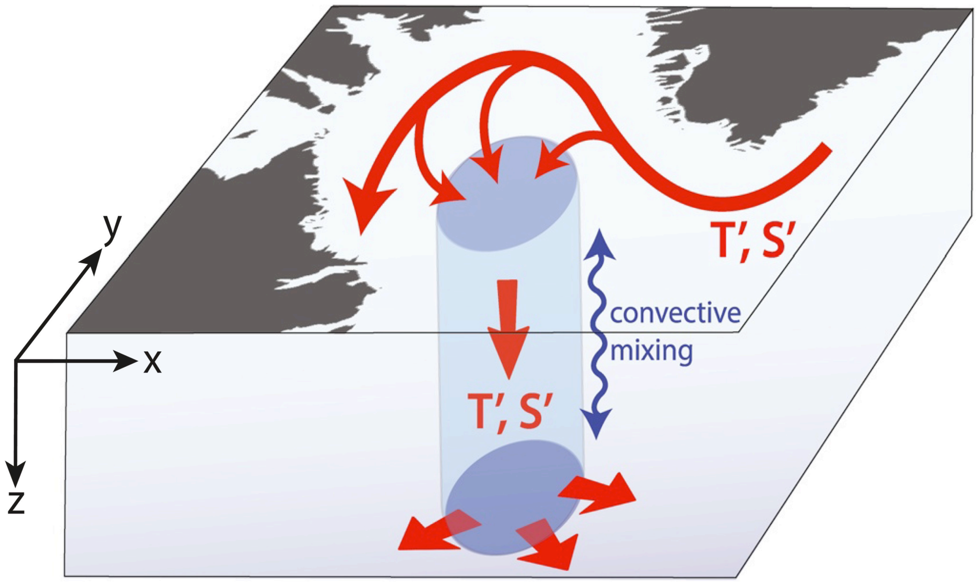


Yan, Zhang, & Knutson, 2019, GRL

The modeled externally forced AMOC index/fingerprint, which is in phase with the externally forced multivariate AMV signal, is also very different from observations



Desbruyeres et al. 2020, GRL

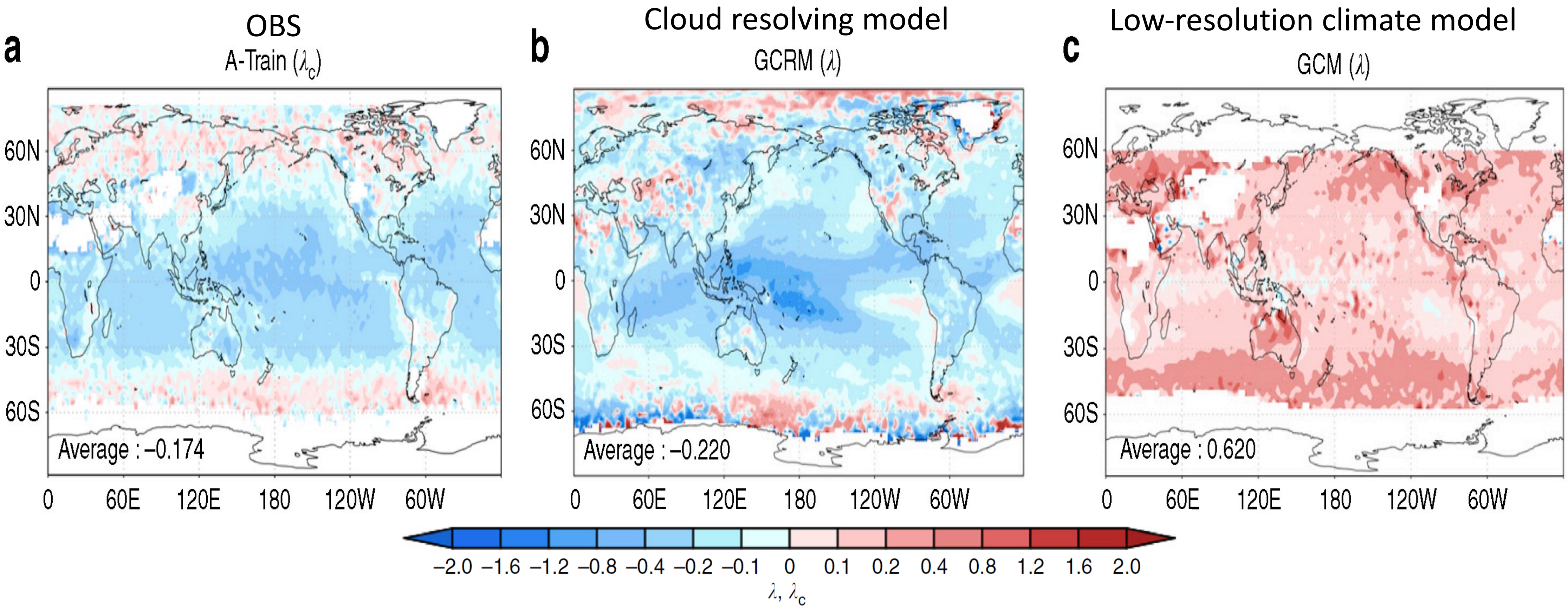


Thomas and Zhang, 2022, GRL

- The AMV-related multidecadal variability is also found in the observed deeper subpolar NA temperature (Polyakov et al. 2010; Hodson et al. 2014; Kim et al. 2018; Desbruyeres et al. 2020; Thomas and Zhang, 2022)
- It has been suggested that the AMV-related upper subpolar NA temperature anomalies propagate downward through boundary vertical advection and diffusion (Desbruyeres et al. 2020)
- The AMV-related upper subpolar NA temp/salinity anomalies are also advected/mixed into the central Labrador Sea, then vertically mixed down into the deeper ocean through deep convection and spread into the deeper subpolar NA (Thomas and Zhang, 2022)

Issues with the Aerosol Mechanism of AMV

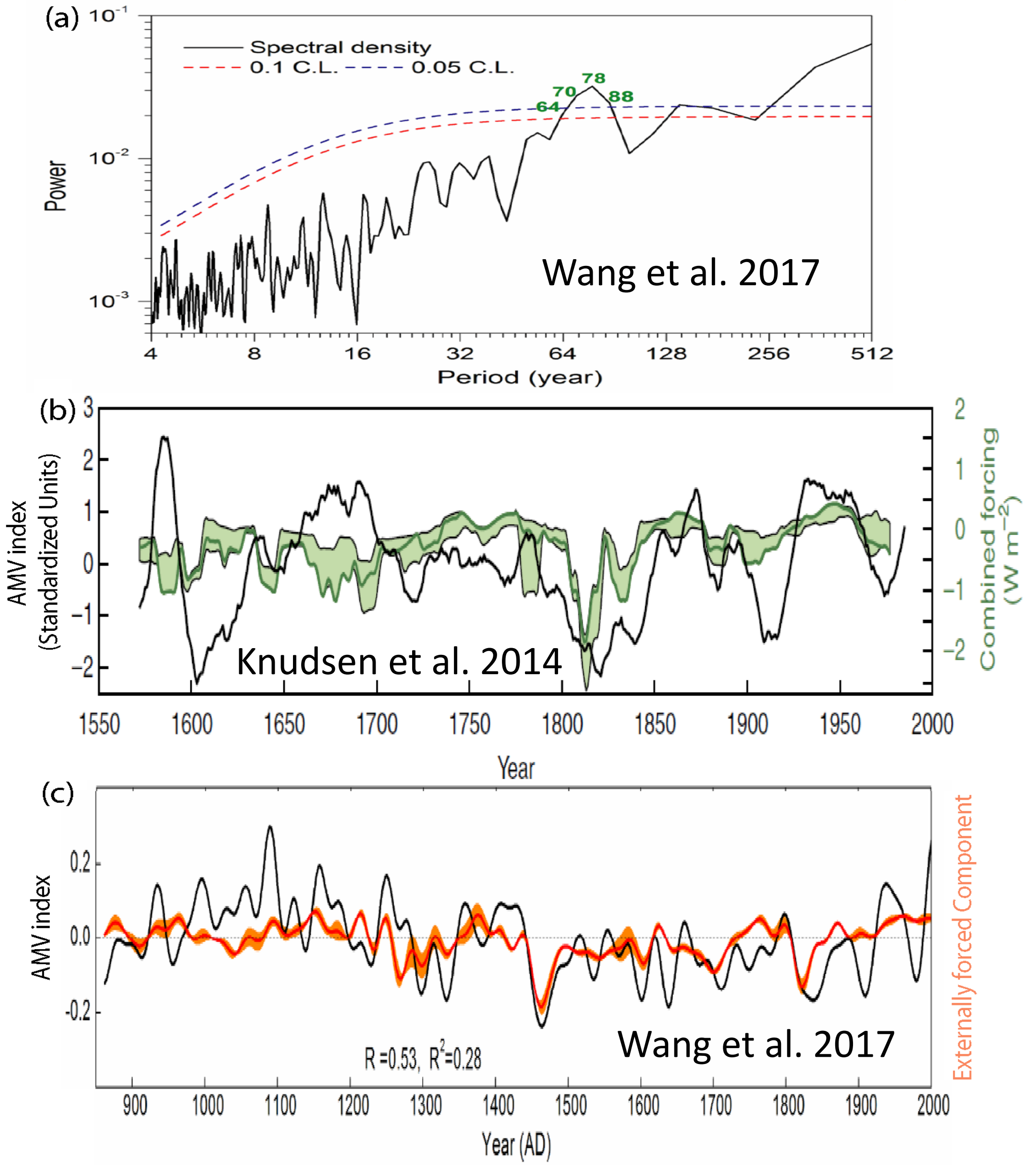
Recent satellite observations and cloud-resolving models (Sato et al. 2018; Toll et al. 2019) suggest that the sign of the second aerosol indirect effect should be negative, i.e. opposite to that simulated in low-resolution climate models, and the net aerosol indirect effects have been overestimated in many climate models



Response of the liquid water path to the perturbation of the aerosol number concentration

Sato et al. 2018, Nature Communications

Paleoclimate Evidence of AMV



Zhang et al. 2019, Reviews of Geophysics

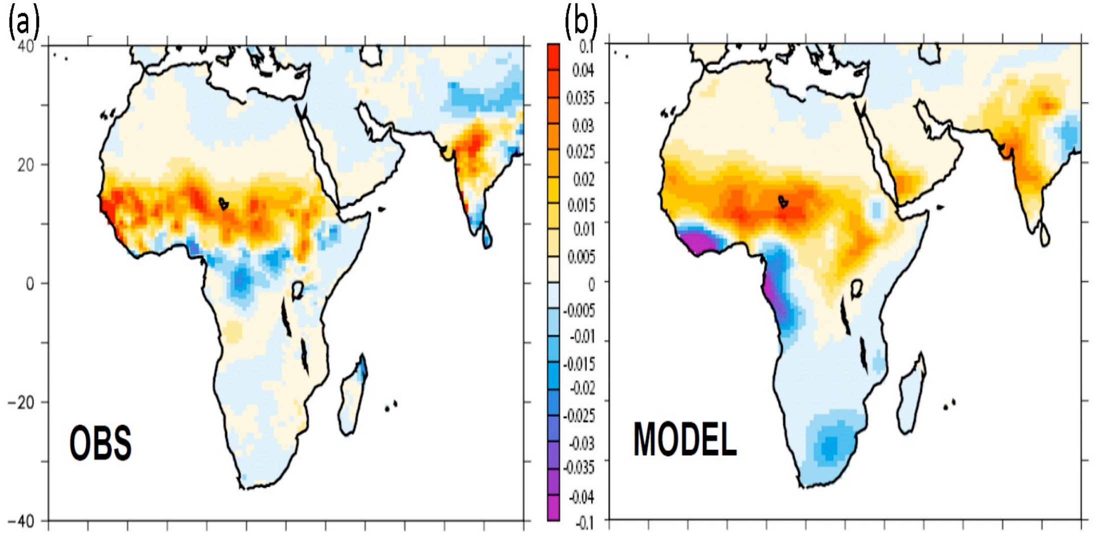
Paleo reconstructions largely indicate that AMV is a phenomenon that existed prior to the instrumental period, with enhanced power at multidecadal timescales significantly above a red noise background and not dominated by solar and volcanic forcing

Climate Impacts of Multidecadal AMOC Variability and AMV

Impact on ITCZ

Statistical analyses of observations suggest that AMV is correlated with multidecadal fluctuations of ITCZ position and Sahel summer rainfall (e.g. Folland et al. 1986)

Summer (JJAS) precipitation anomalies associated with AMV

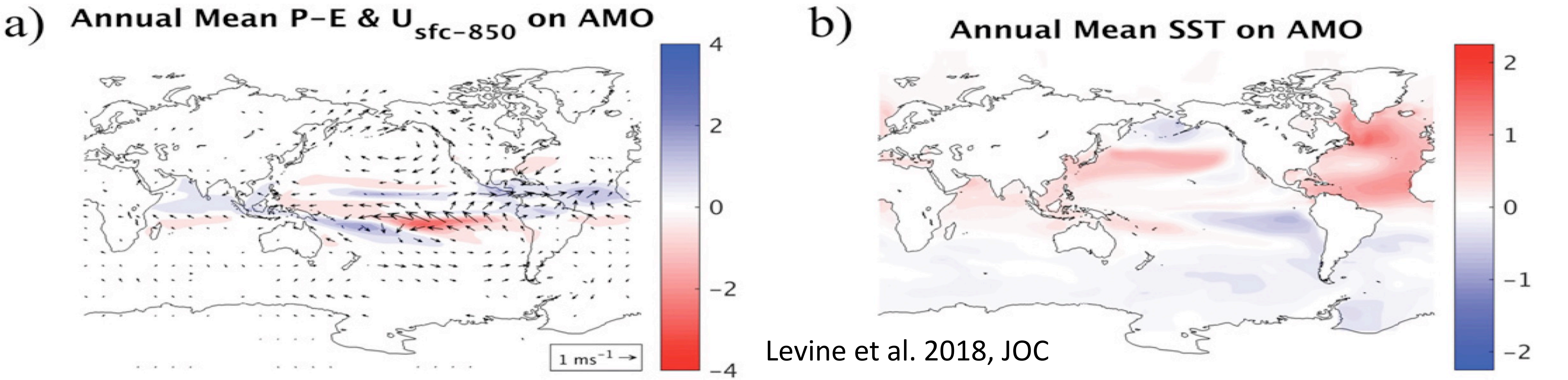


Zhang and Delworth, 2006

The causal linkage between AMV and ITCZ shifts is associated with changes in AMOC-induced Atlantic heat transport and compensated atmospheric heat transport across the equator, consistent with coupled climate model simulations of ocean-atmosphere heat transport compensation and ITCZ shift induced by an abrupt AMOC change

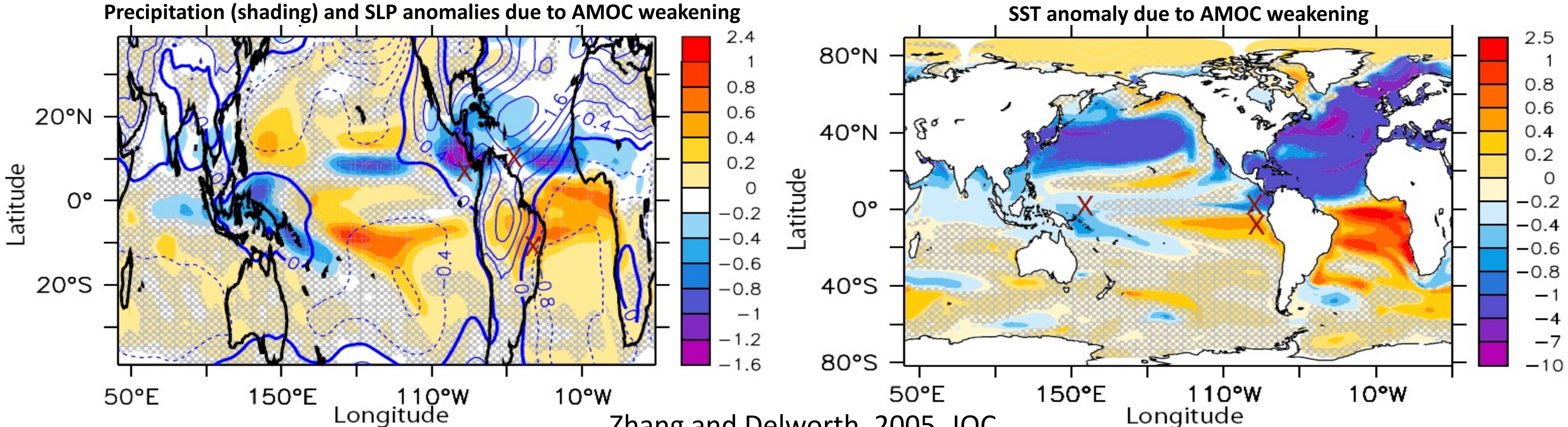
Similar impacts on ITCZ are also found in recent modeling studies (e.g. Ruprich-Robert et al., 2017; Levine et al. 2018)

Impact of AMV on Multidecadal Fluctuations of ITCZ



Levine et al. 2018, JOC

A positive AMV phase leads to a northward shift of the ITCZ in both the Atlantic and Pacific in coupled model simulations with the North Atlantic SST restored to the AMV signal



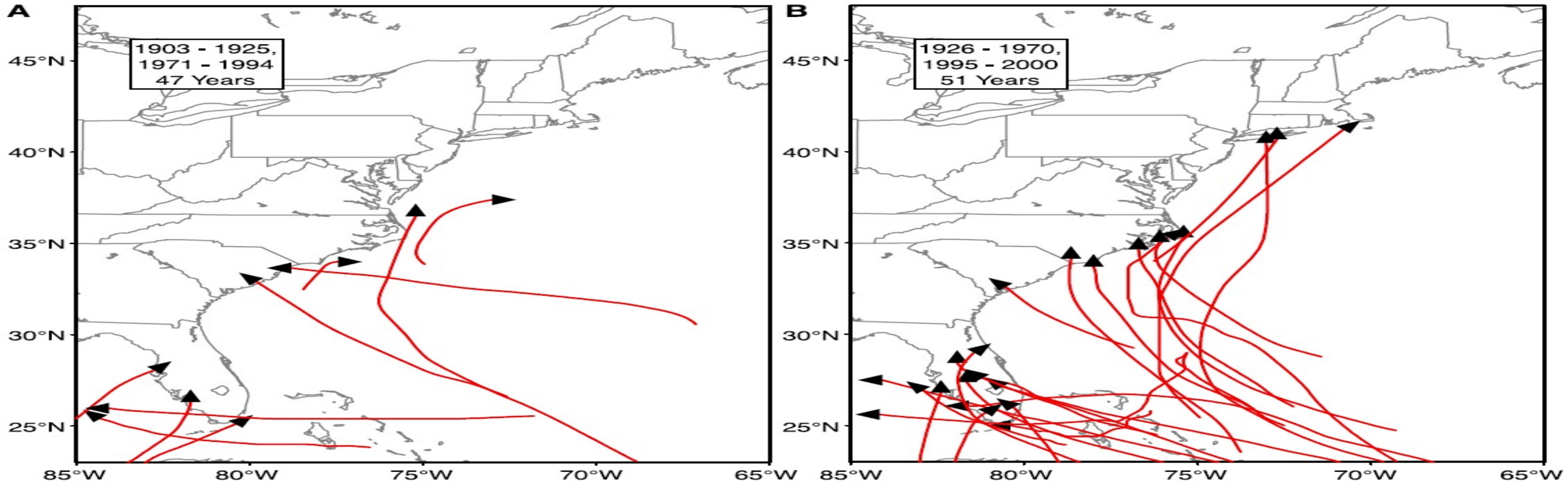
Zhang and Delworth, 2005, JOC

A substantial weakening of the AMOC leads to a southward shift of ITCZ in both the Atlantic and Pacific in water hosing experiment

Impact of AMV on Atlantic Hurricane Activity

Negative AMV Phase

Positive AMV Phase

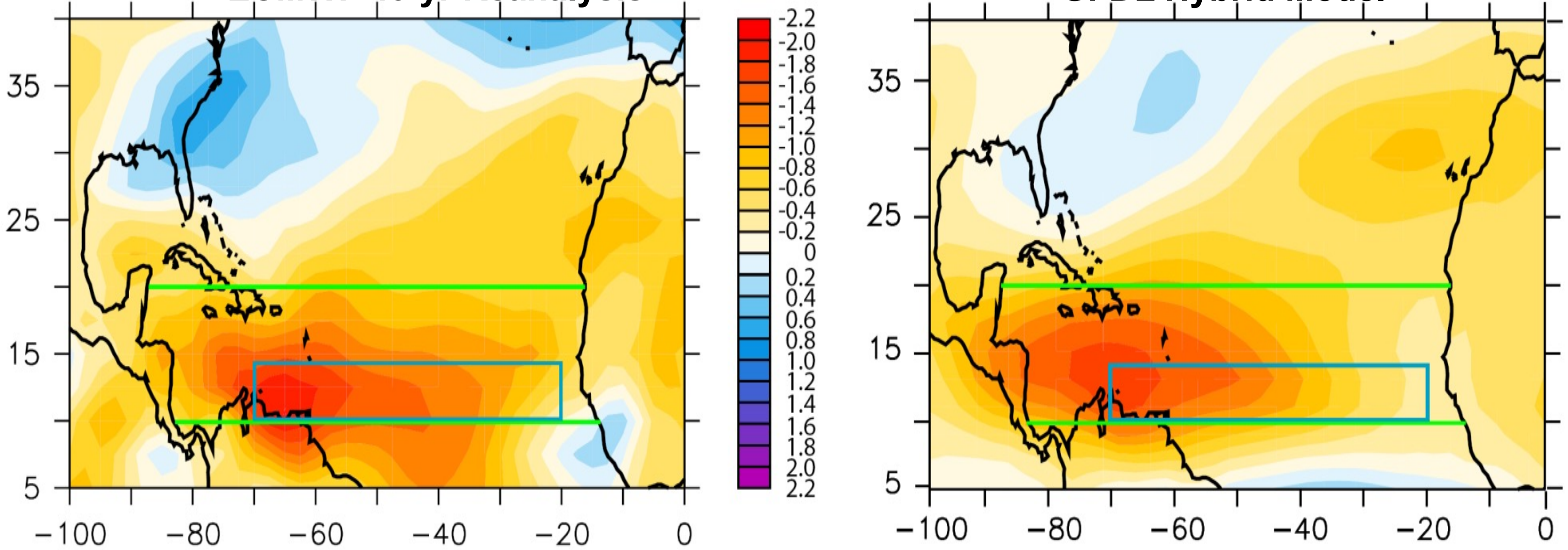


Contrast of U.S. east coast major hurricane landfalls during the negative (left) and positive (right) AMV phase

Goldenberg et al. 2001, Science

ECMWF 40-yr Reanalysis

GFDL Hybrid Model

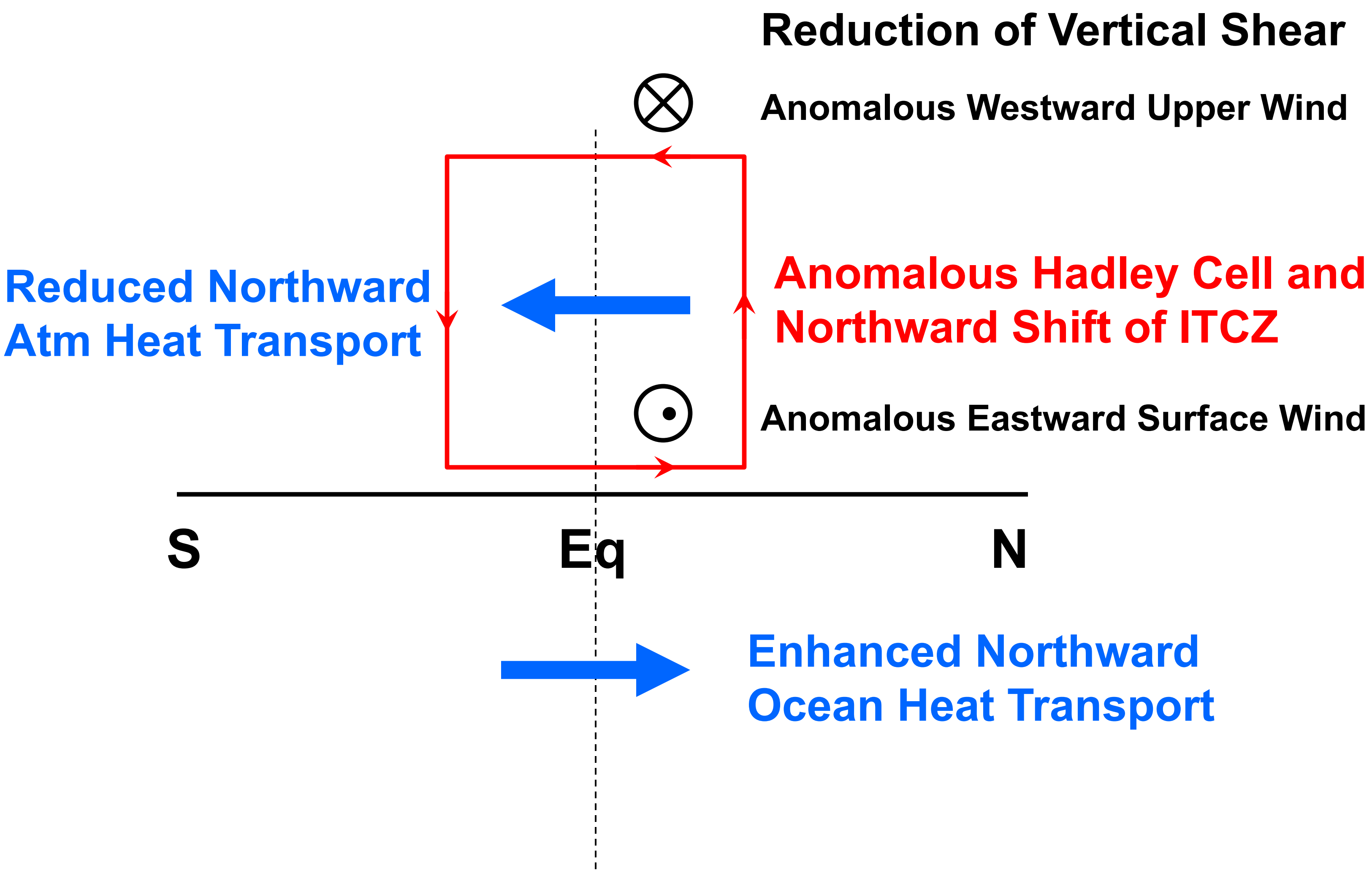


Regression of hurricane season vertical shear of zonal wind (m/s) on the AMV index

A positive AMV phase leads to a reduction of the vertical shear over the tropical North Atlantic Main Development Region (MDR) for hurricanes

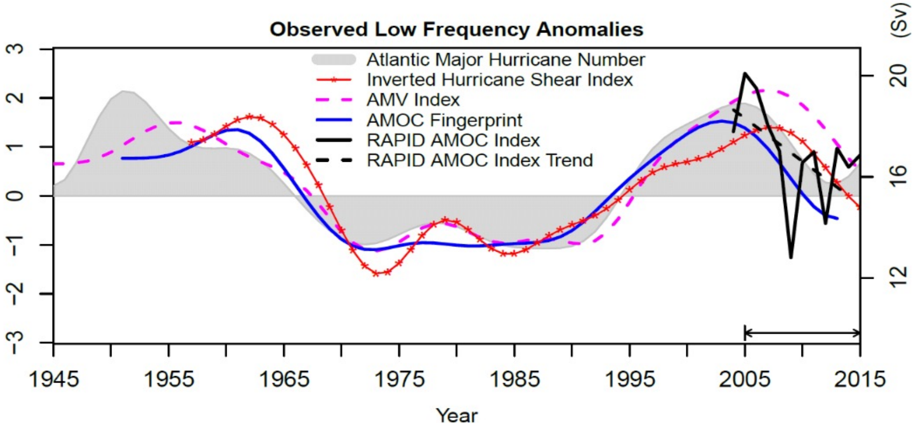
Zhang and Delworth, 2006, GRL

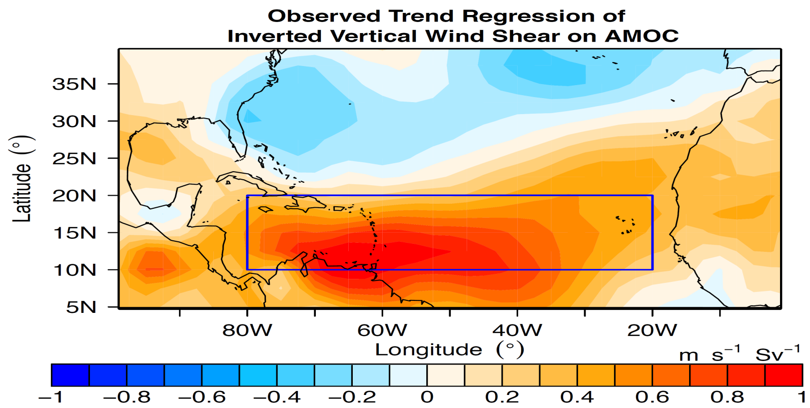
Schematic Diagram



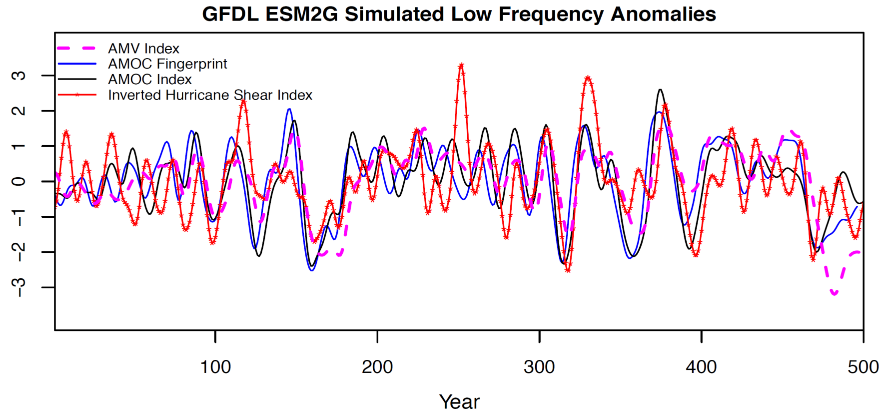
The positive AMV phase (associated with a stronger AMOC)

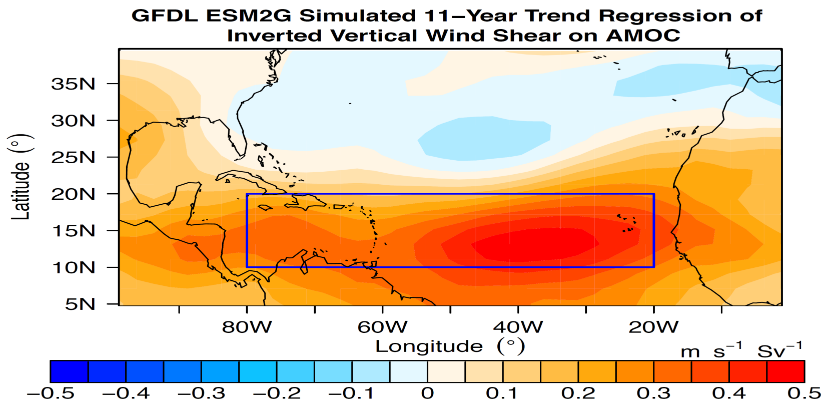
Impacts of AMOC on Atlantic Major Hurricane Frequency





Observations show coherent multidecadal variations among the Atlantic major hurricane frequency, AMOC fingerprint, AMV index, and inverted vertical wind shear index. The observed decline of the Atlantic major hurricane frequency during 2005–2015 is associated with the directly observed AMOC weakening from the RAPID program



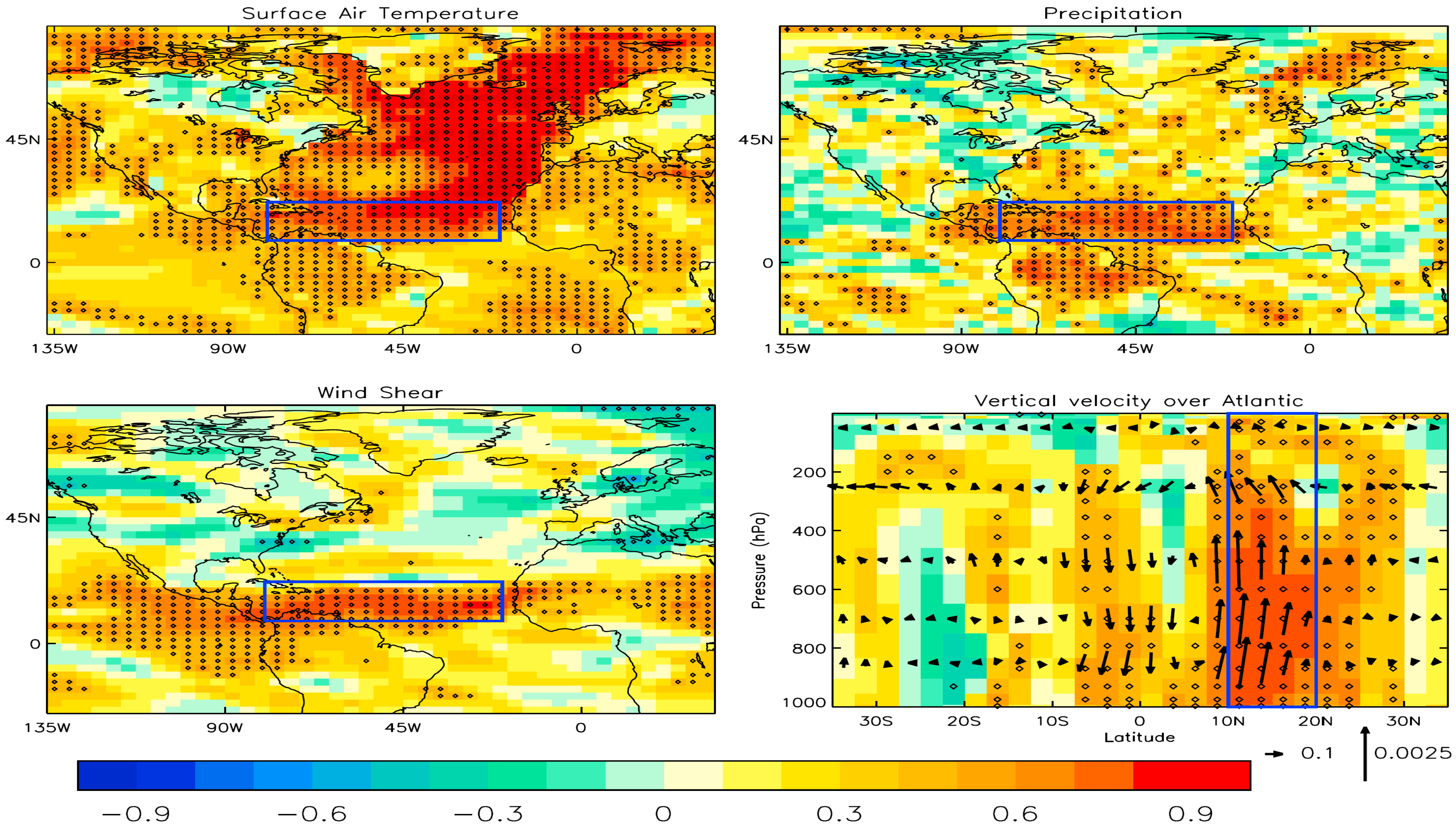


GFDL-ESM2G control simulation has similar coherent variations among AMOC Index/fingerprint, AMV index, and inverted vertical wind hear index, supporting an important role of the AMOC in AMV and multidecadal variability of Atlantic major hurricane frequency

Yan, Zhang, and Knutson, 2017, Nature Communications

Multi-year Predictability of Tropical Atlantic Atmosphere Driven by the Subpolar North Atlantic Ocean

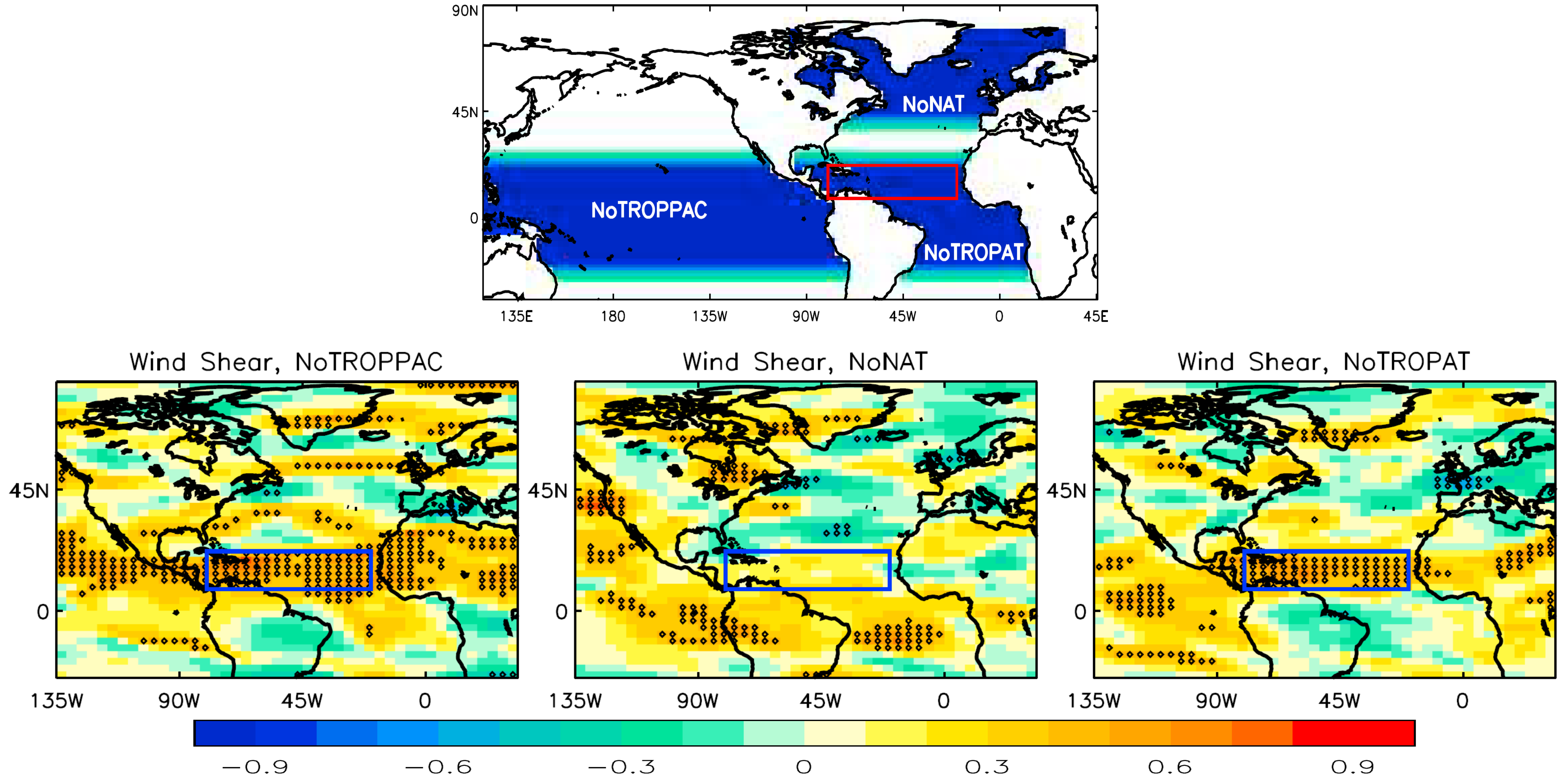
Anomaly correlations for Years 2-6 ensemble means of the perfect and the initialized forecast experiments using HadCM3



The North Atlantic Subpolar Gyre is identified as a key driver of skills in predicting the tropical Atlantic atmosphere, including tropical precipitation, wind shear, vertical velocity, and storm numbers

Dunstone et al. 2011, GRL

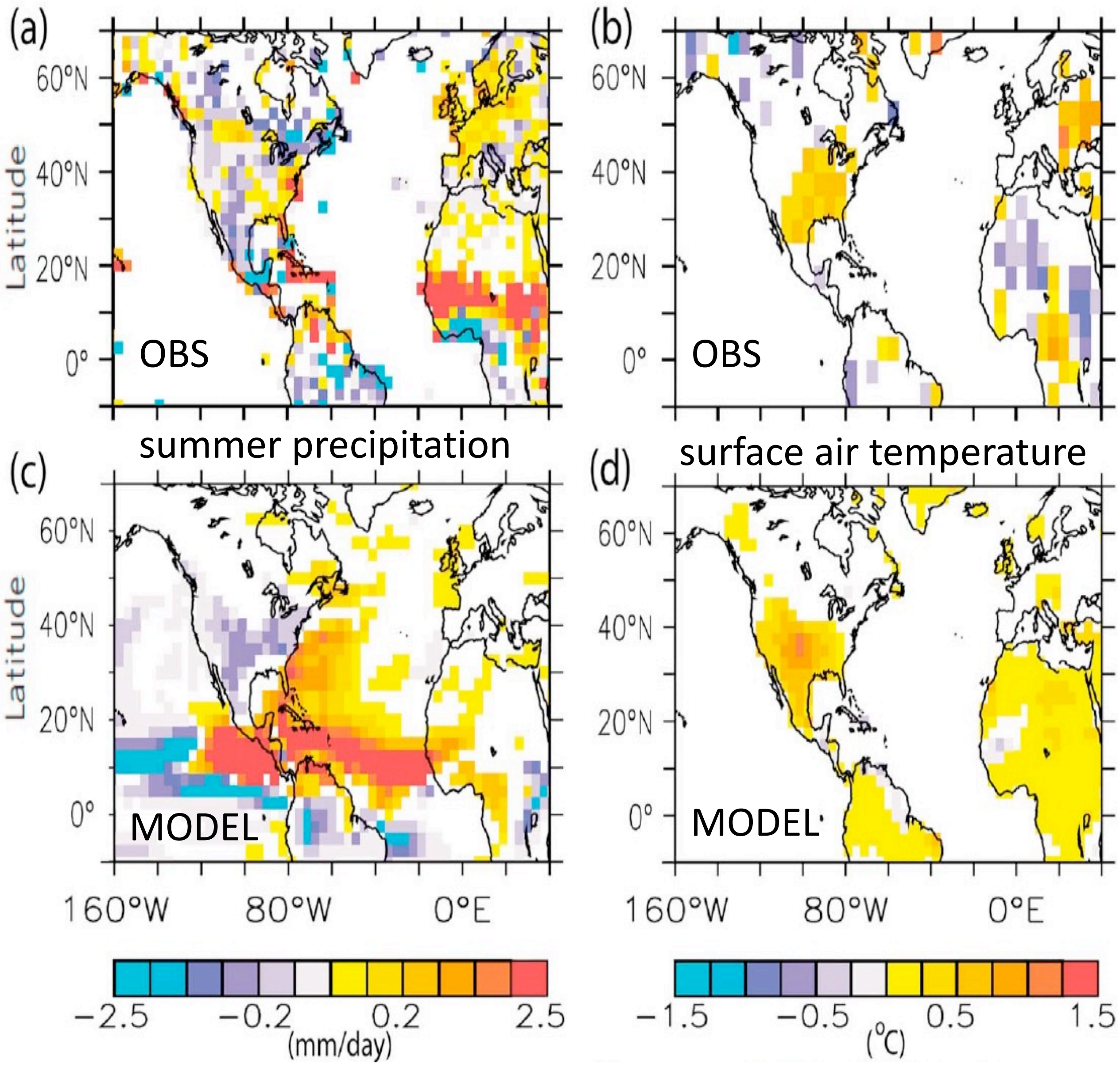
Multi-year Predictability of Tropical Atlantic Atmosphere Driven by the Subpolar North Atlantic Ocean



The multiyear predictability skill of vertical wind shear over the MDR is lost when ocean is not initialized in the extratropical North Atlantic, but remains when ocean is initialized in the extratropical North Atlantic but not initialized in the tropical Atlantic or the tropical Pacific

Dunstone et al. 2011, GRL

Impact on Climate over Europe and North America

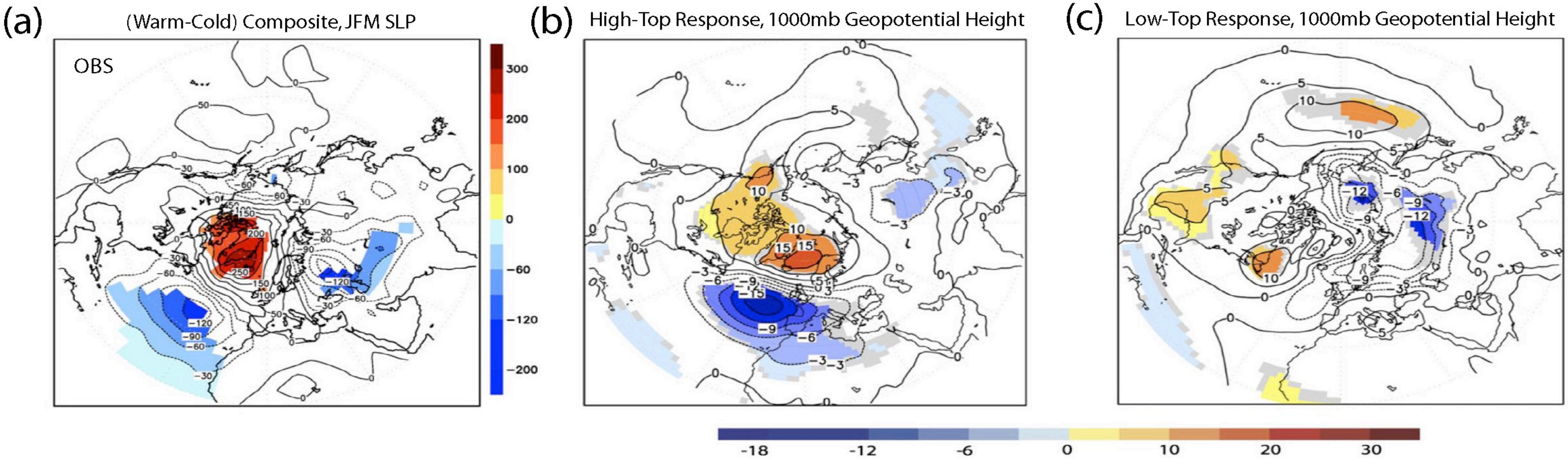


Sutton and Hodson, 2005, Science

The positive AMV can lead to warmer and wetter summers over western Europe, warmer and drier summer climate over central North America in both observations and AGCM experiments

Fully coupled models with strong positive correlations between AMV and multidecadal surface turbulent heat flux anomalies over the midlatitude NA can simulate a warmer summer over Europe during the positive AMV phase; in contrast, the positive AMV simulated in slab ocean models cannot lead to a warmer summer over Europe (O'Reilly et al., 2016)

Impact on Winter North Atlantic Oscillation



Omrani et al. 2014

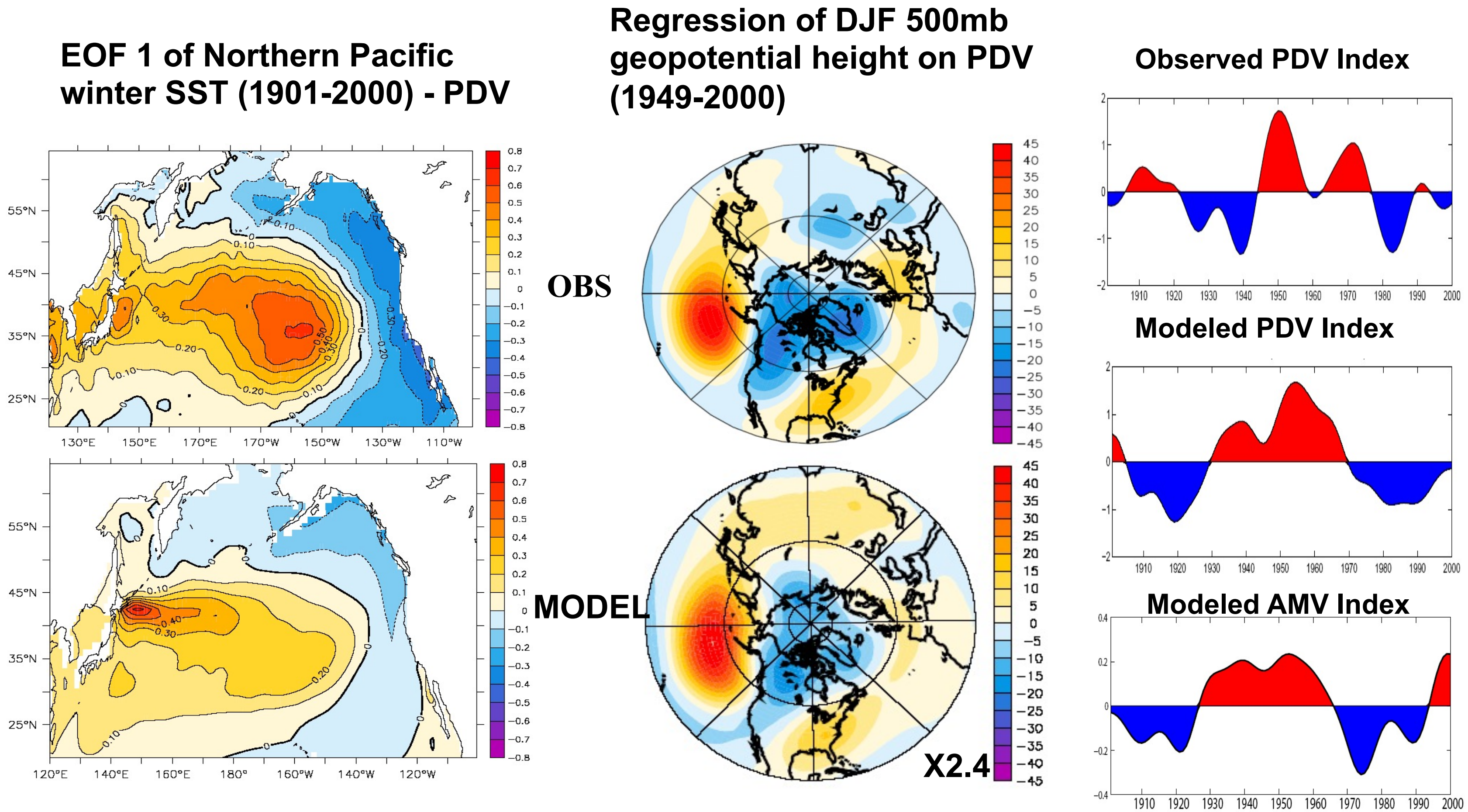
- AGCM experiments suggest that a positive AMV can induce a negative winter NAO response with an amplitude comparable to that observed (Omrani et al. 2014; Peings and Magnusdittir 2016)

- A realistic winter NAO response to AMV exists in a high-top AGCM with well-resolved stratosphere but not in a low-top AGCM that has poorly resolved stratosphere and inhibits upward propagation of planetary waves (Omrani et al. 2014)

- The simulated amplitude of winter NAO signal associated with AMV in coupled models is much weaker than that observed (Ting et al. 2014; Peings et al. 2016), due to the underestimated internal AMV signal and associated surface turbulent heat flux anomalies (Peings et al. 2016), consistent with the underestimation of internal multidecadal winter NAO in many climate models (Kravtsov, 2017; Wang et al. 2017; Kim et al. 2018; Simpson et al. 2018; Xu et al. 2018)

Impact of AMV on Pacific Low-Frequency Variability

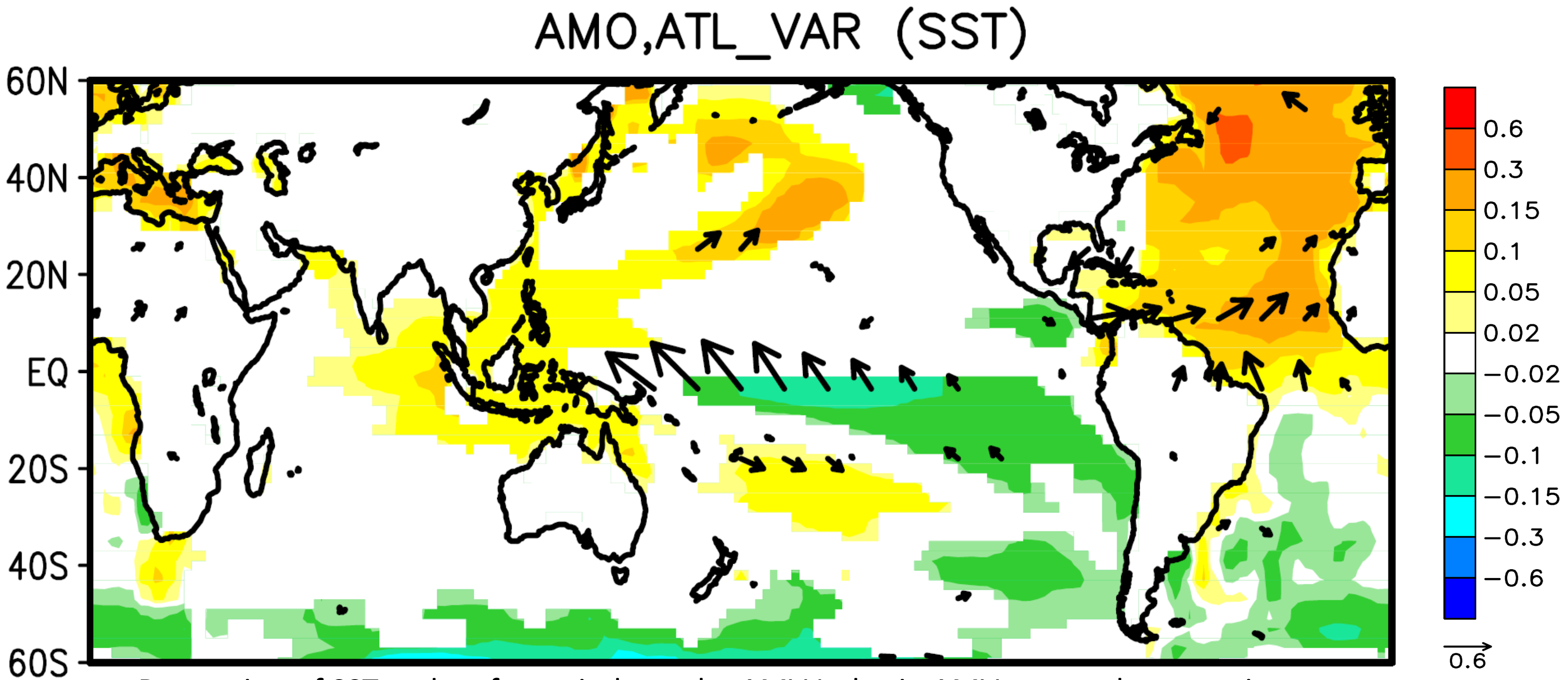
- Can the AMV influence the Pacific Decadal Variability (PDV) ?



Zhang and Delworth, 2007, GRL

Modeling results suggest that AMV can contribute to the PDV and Pacific/North American (PNA) pattern, and provides a source of multidecadal variability to the North Pacific

Impact of AMV on Pacific Low-Frequency Variability



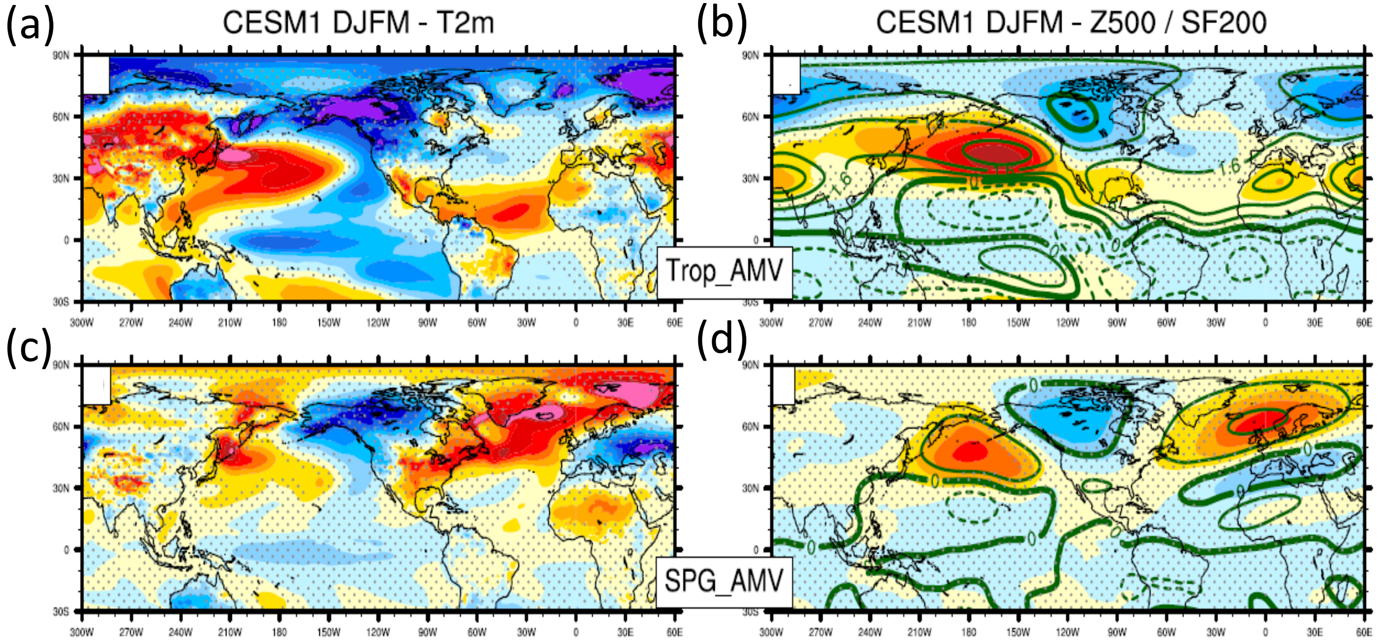
Regression of SST and surface winds on the AMV Index in AMV pacemaker experiments

Kucharski et al. 2015, Climate Dynamics

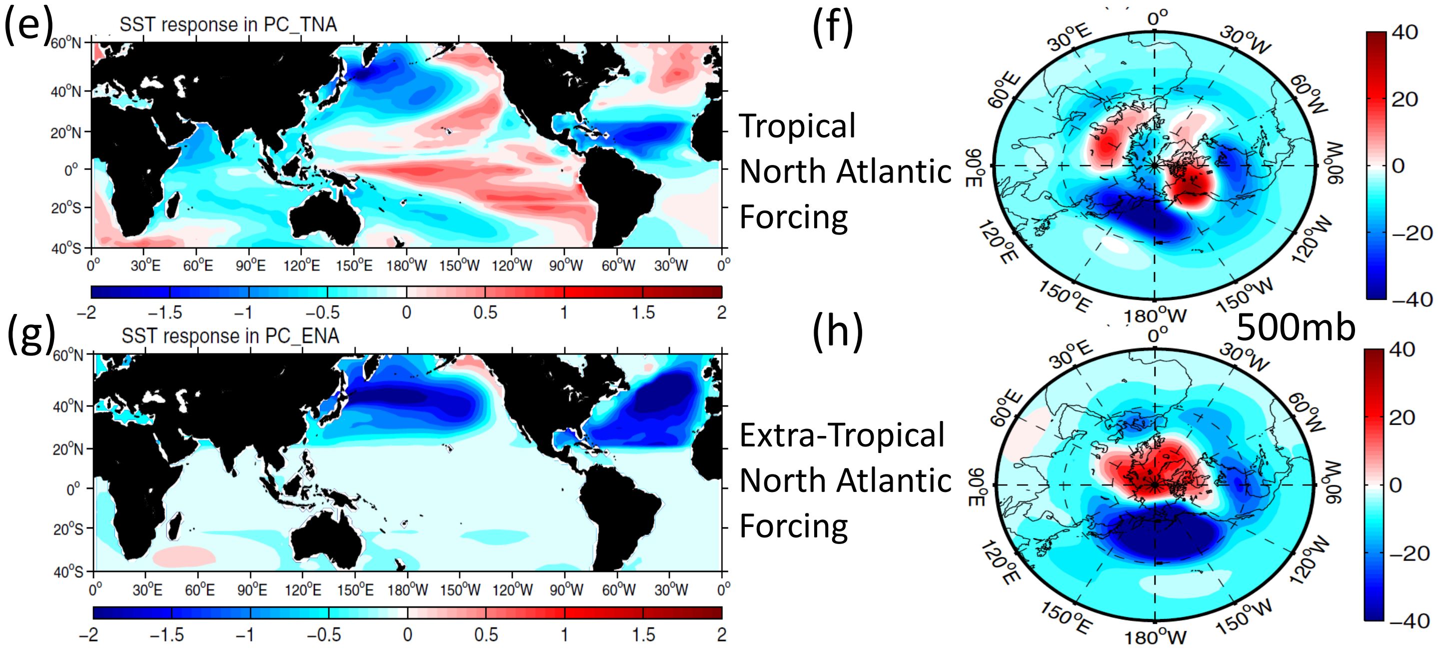
- Many recent modeling studies (e.g. Kucharski et al. 2015; Ruprich-Robert et al. 2017) show that AMV also has significant impacts on the low-frequency ENSO-like variability in the tropical South Pacific

- A positive AMV leads to stronger trade winds/Walker circulation and La Niña-like cooling over the tropical South Pacific similar to changes induced by the AMOC weakening but with an opposite sign (e.g. Dong and Sutton, 2002; Zhang and Delworth, 2005)

Impact of AMV on Pacific Low-Frequency Variability

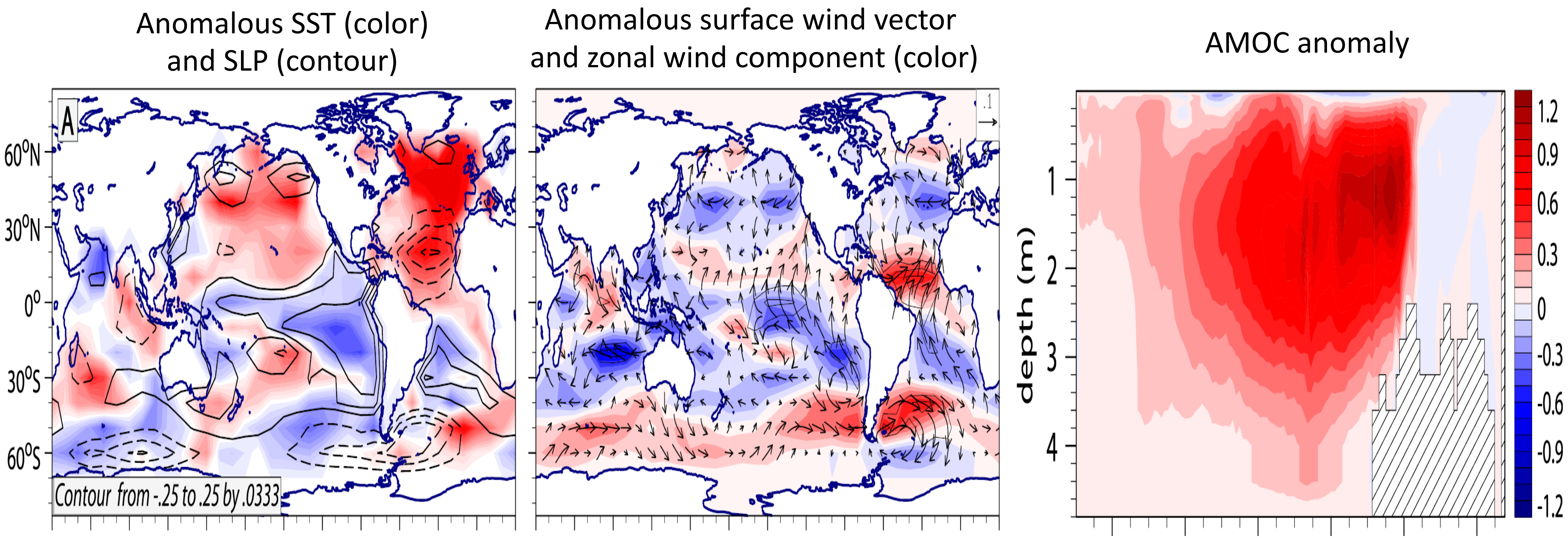


A recent modeling study (Ruprich-Robert et al. 2017) suggests that the tropical AMV forcing dominates the response in both the tropical and North Pacific, consistent the responses to the AMOC weakening (Okumura et al. 2009)



In a coupled simulation forced by the mean-state cold SST bias in either the tropical or extratropical North Atlantic, there is cooling over the North Pacific associated with the PNA pattern, so both tropical and extratropical SST biases contribute to the teleconnection (Zhang and Zhao, 2015)

Impact of AMV on Pacific Low-Frequency Variability

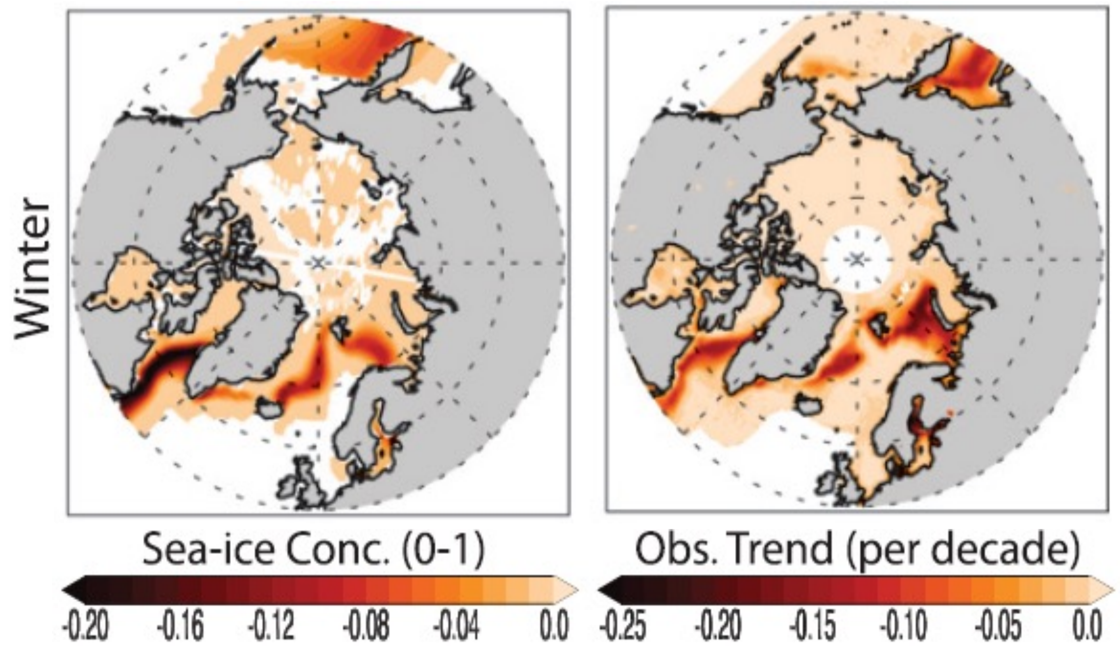


Barcikowska, Knutson, and Zhang, 2017

- Multichannel singular spectrum analysis (MSSA) applied jointly to SST, SLP, and surface winds in a coupled model (CSIRO Mk3.6.0) reveals a global scale multidecadal mode, resembling AMV and associated impacts over the Pacific (e.g. a positive AMV is associated with stronger trade winds/Walker circulation and La Niña-like cooling over the tropical South Pacific)
- This mode is closely linked to the simulated multidecadal AMOC variability, suggesting an important role of the AMOC in this interbasin teleconnected multidecadal mode

Impact of AMOC on Multidecadal Arctic Sea Ice Variability

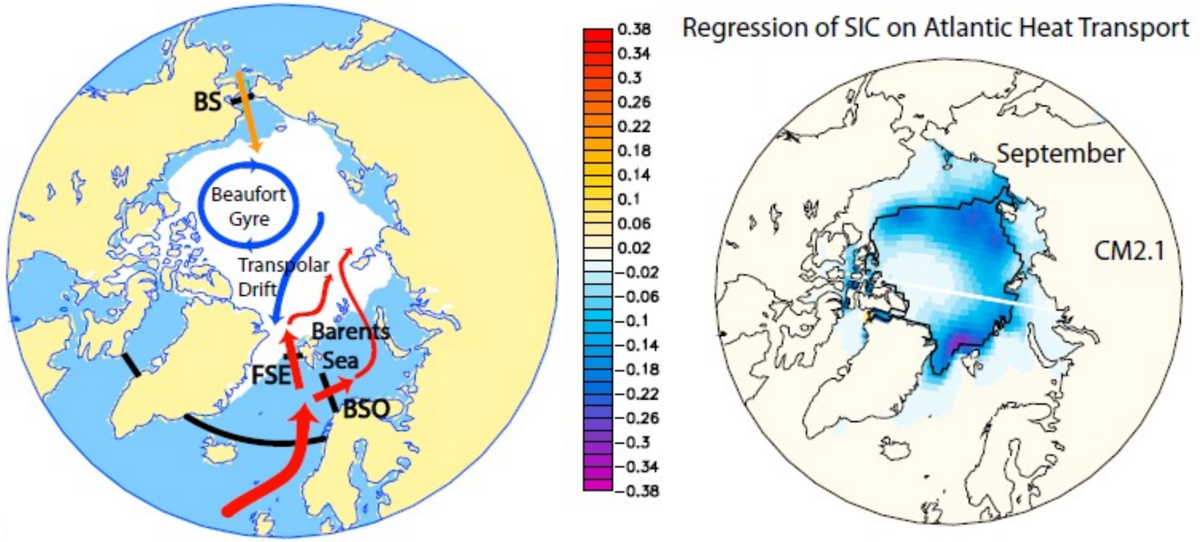
Modeled SIC Regression on AMV | Observed SIC Trend

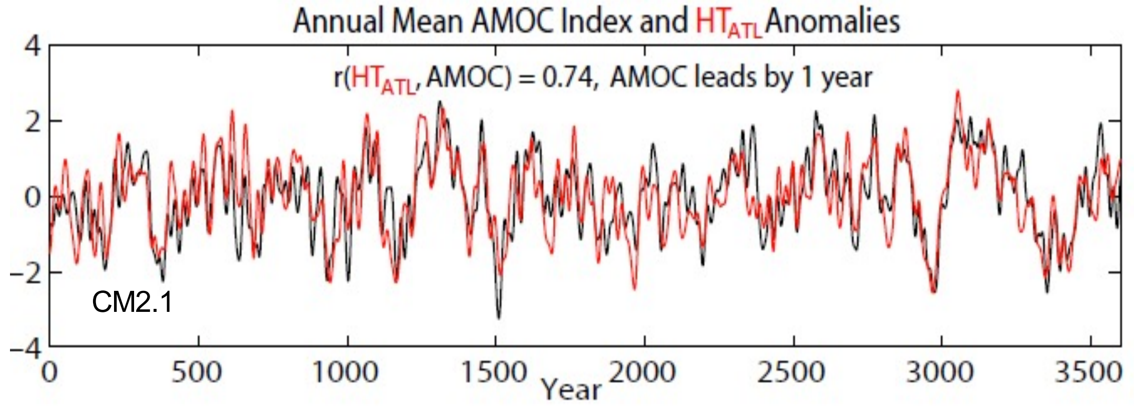


Mahajan, Zhang, and Delworth, 2011, JOC

GFDL CM2.1 control simulation

The simulated multidecadal winter Arctic sea ice decline is associated with an intensified AMOC and a positive AMV, and resembles observed winter Arctic sea ice decline pattern over recent decades

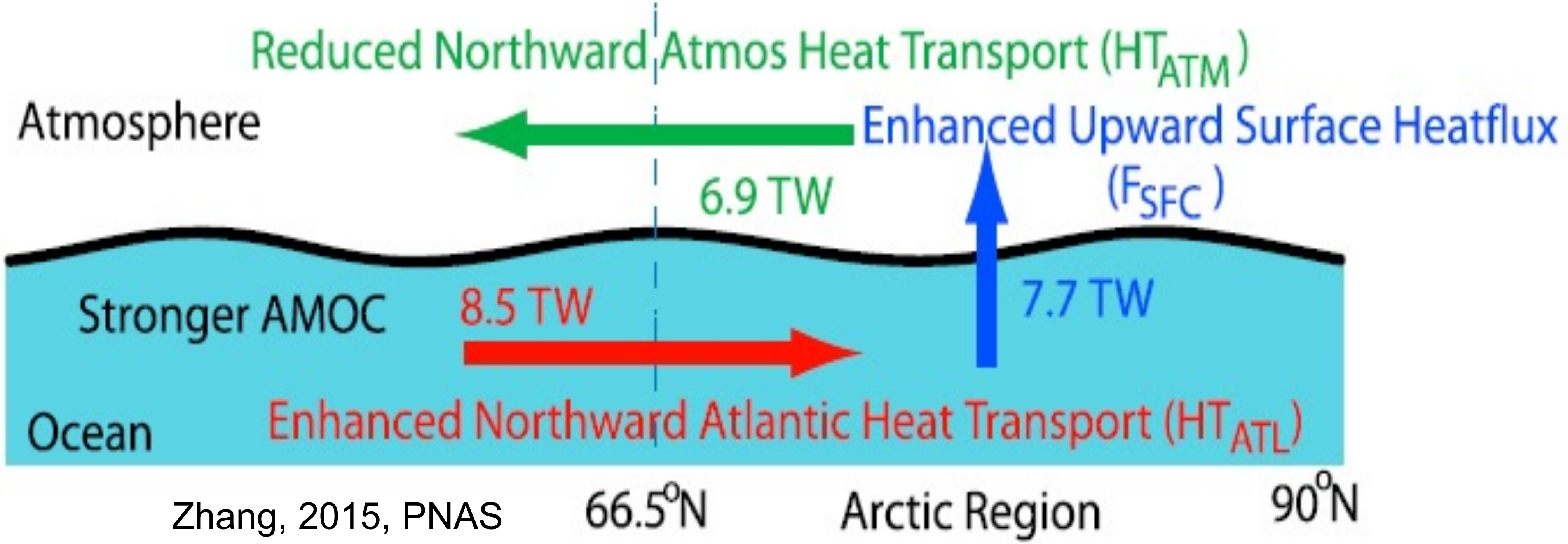




Zhang, 2015, PNAS

Modeling studies suggest that AMOC and associated Atlantic heat transport is a key player for low-frequency Arctic sea ice variability

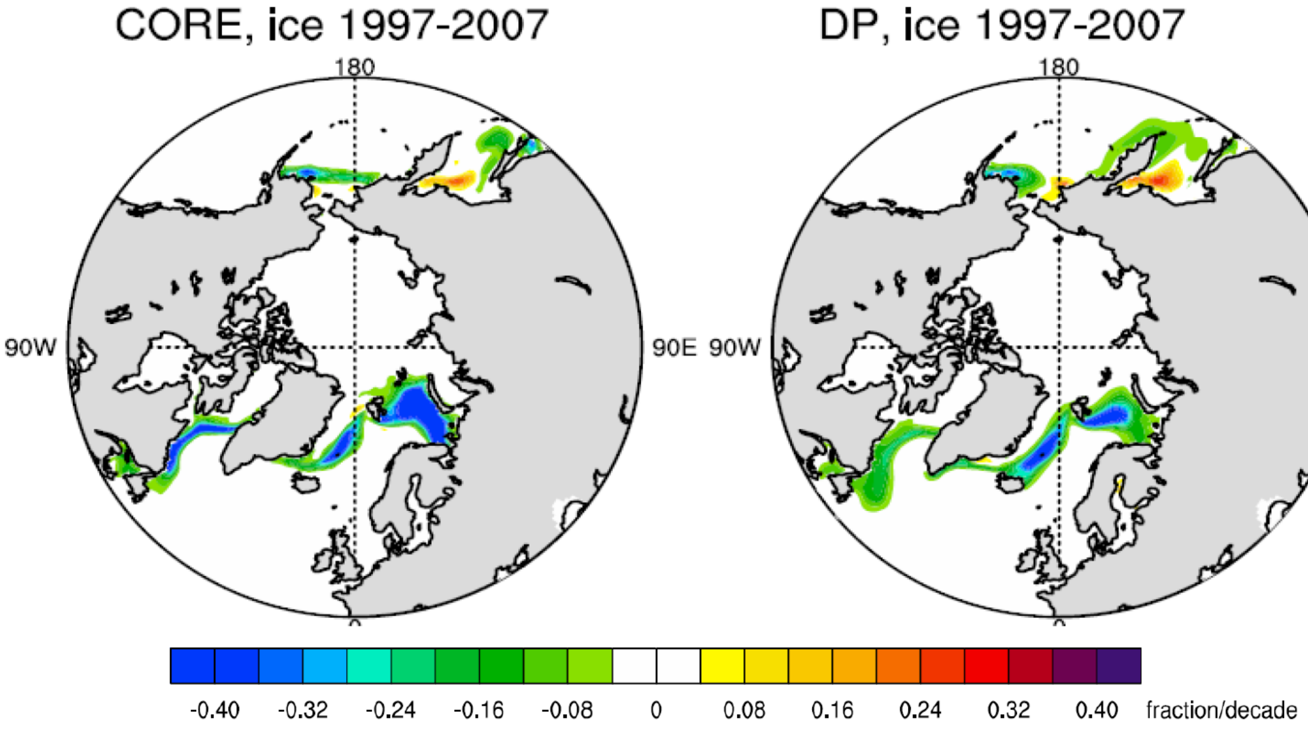
Impact of AMOC on Multidecadal Arctic Sea Ice Variability



Zhang, 2015, PNAS

- The Bjerknes compensation (Bjerknes, 1964) has been found at decadal time scale (e.g. Shaffrey & Sutton, 2006; Jungclaus & Koenigk, 2010)
- At multidecadal and longer time scales, the coherences among HT_{ATL}, Arctic SHF, and inverted HT_{ATM} are much higher than those at decadal time scale
- Changes in HT_{ATM} are forced by anti-correlated changes in HT_{ATL} thus provide a negative feedback to Arctic sea ice variations

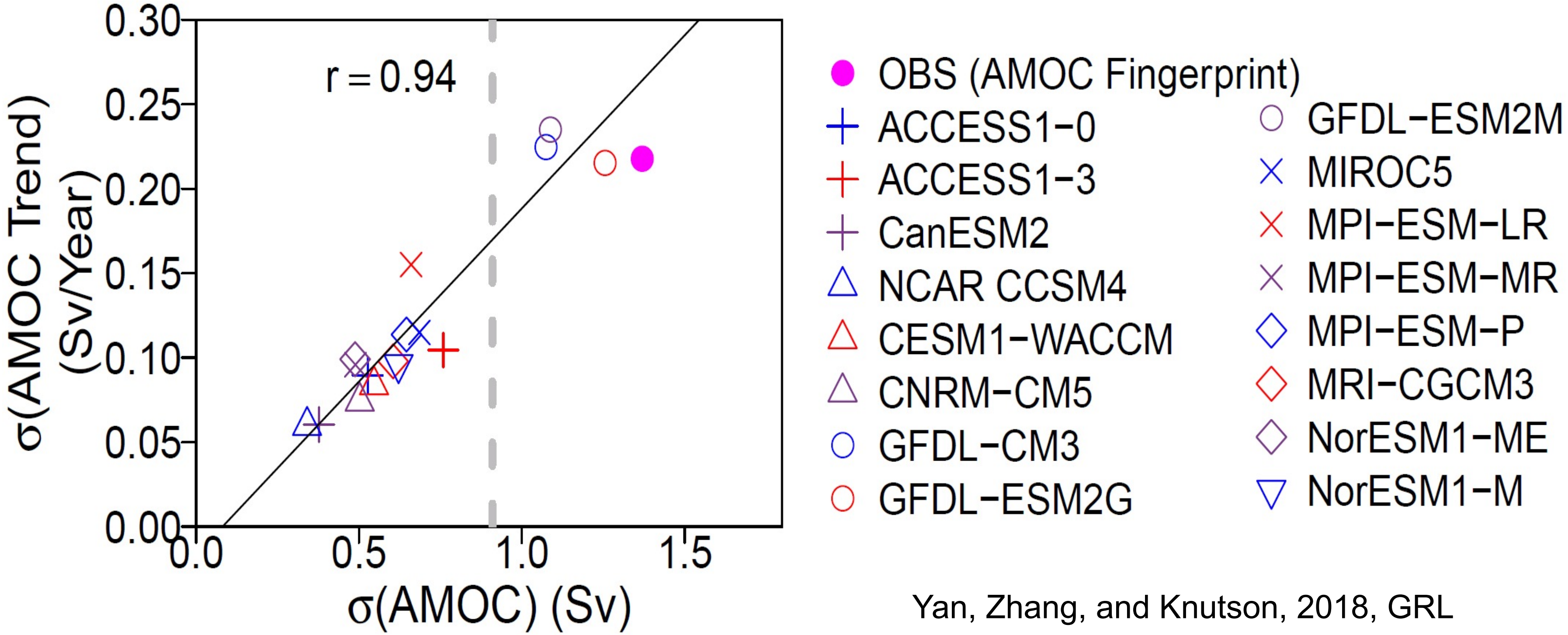
Predictive Impact on Winter Arctic Sea Ice



The predicted decadal winter Arctic sea ice decline since the late 1990s is very similar to that simulated in the OGCM hindcast due to a strengthening in the AMOC and associated Atlantic heat transport

Yeager et al. 2015

Modelling Biases of the AMOC-AMV linkage and Associated Climate Impacts



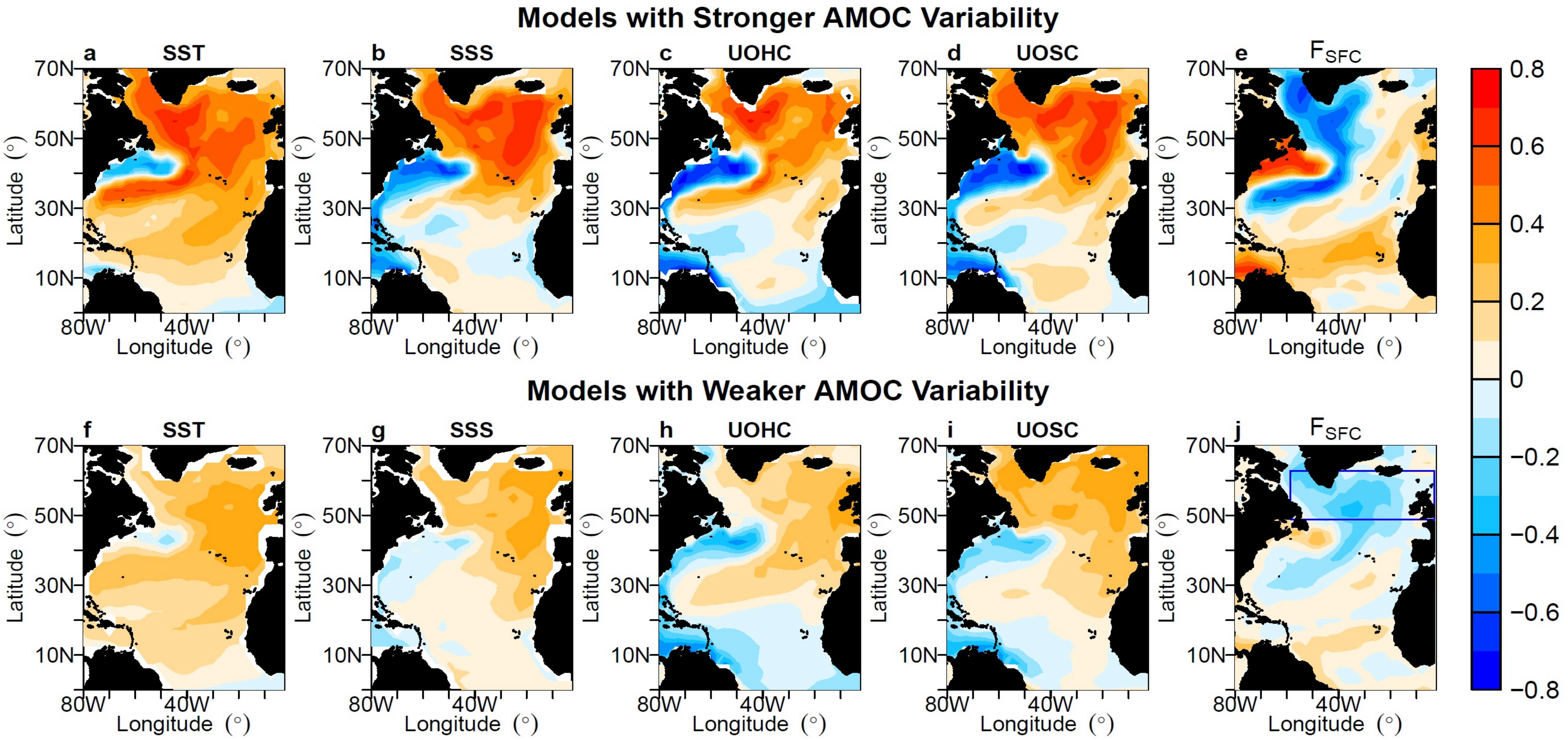
Yan, Zhang, and Knutson, 2018, GRL

Scatterplot of standard deviations of decadal AMOC trends vs. amplitudes of low-frequency AMOC variability (i.e. standard deviations of the 10-year low-pass filtered AMOC anomalies) across CMIP5 control simulations

- Most coupled models underestimate amplitudes of multidecadal AMOC variability, leading to the underestimation of the AMOC-related climate impacts and Atlantic decadal predictability

- The underestimated multidecadal AMOC variability amplifies the relative role of external radiative forcing or stochastic atmospheric forcing in AMV (Kim et al. 2018)

AMOC-AMV Linkage is Underestimated in Many CMIP5 Models



Correlations with AMOC

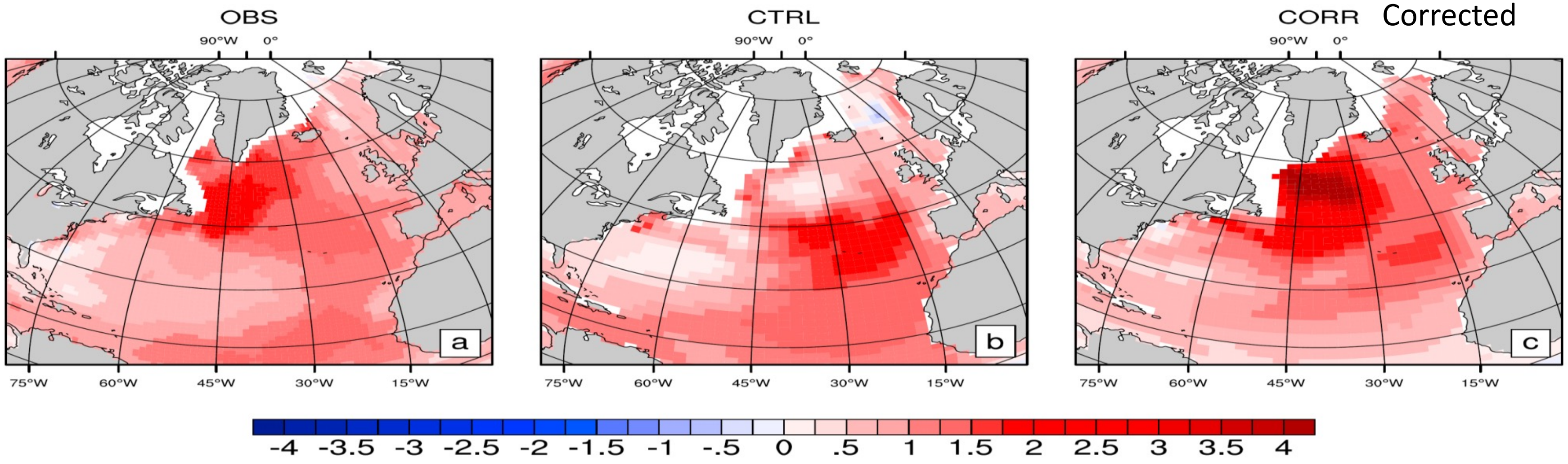
Yan, Zhang, and Knutson, 2018, GRL

The correlation between the AMOC and AMV-related subpolar signal in SST, SSS, upper ocean heat/salt content, and net downward surface heat flux is much stronger (weaker) in models with relatively stronger (weaker) multidecadal AMOC variability

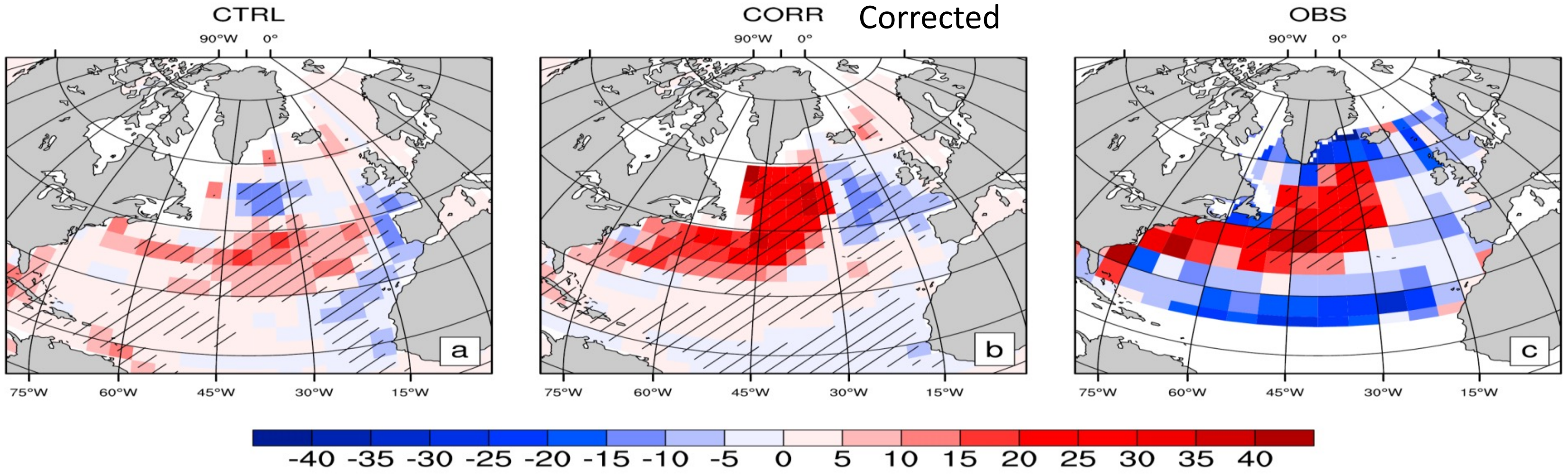
Most climate models underestimate amplitudes of multidecadal AMOC variability, leading to the underestimation of the AMOC-AMV linkage

Modelling Biases on the Pattern/Amplitude of AMV-related SST and Turbulence Heat Flux

AMV SST pattern



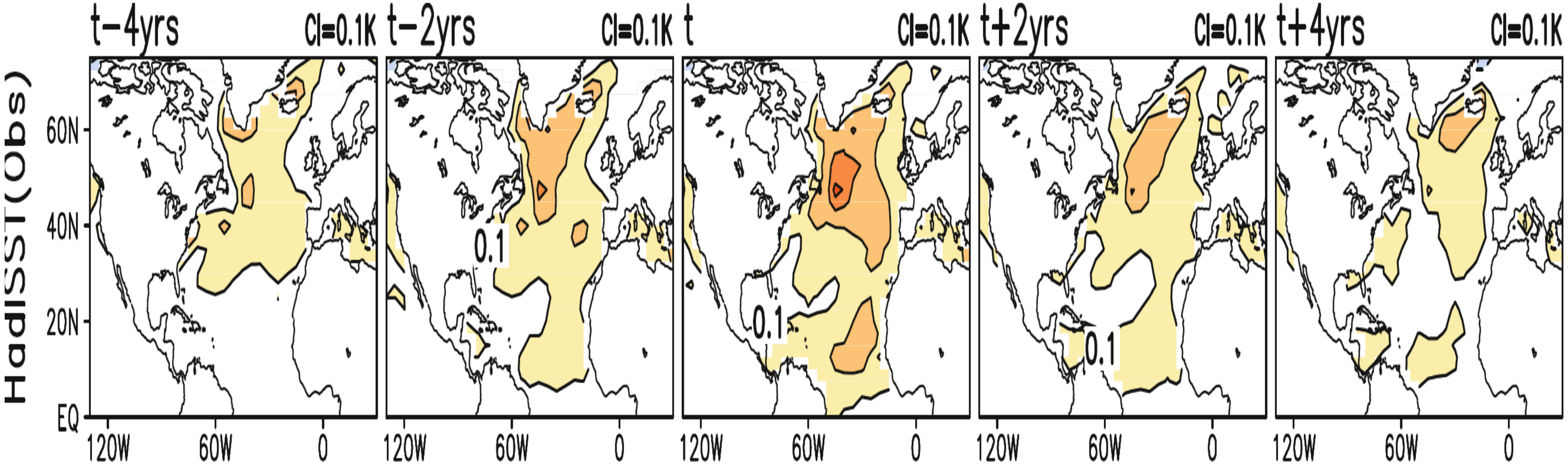
Turbulence heat flux anomalies associated with AMV



Drews and Greatbatch, 2016, GRL Kiel Climate Model

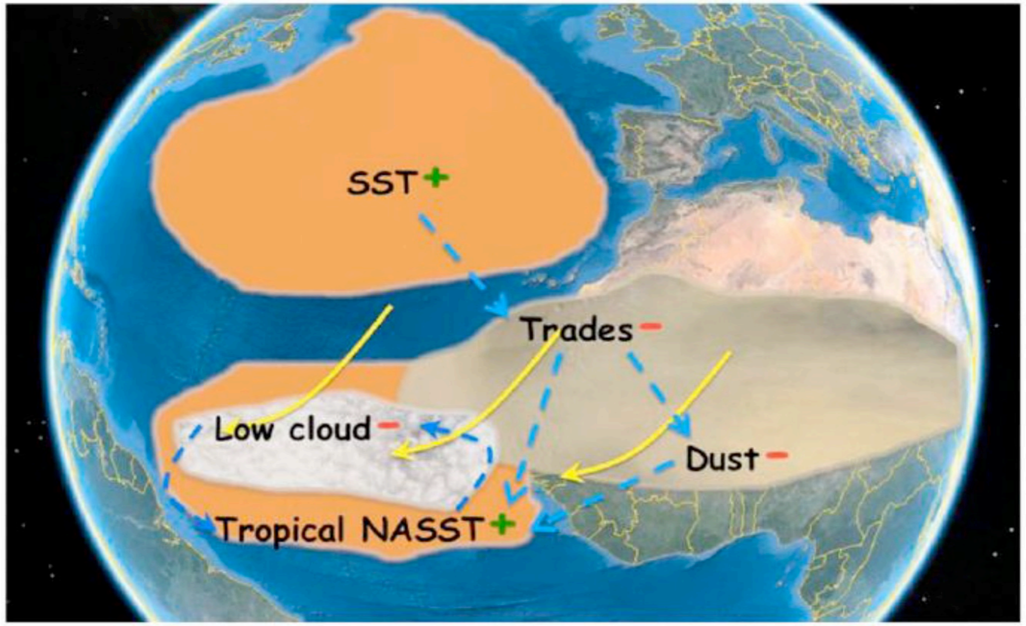
Climate model with corrected mean state North Atlantic Current (NAC) pathways can simulate more realistic pattern/amplitude of AMV and associated surface turbulence heat flux anomalies induced by AMOC variability (Drews and Greatbatch 2016; 2017)

Modelling Biases on Teleconnections between Subpolar and Tropical AMV SST Signal



Evolution of the Observed AMV SST Signal

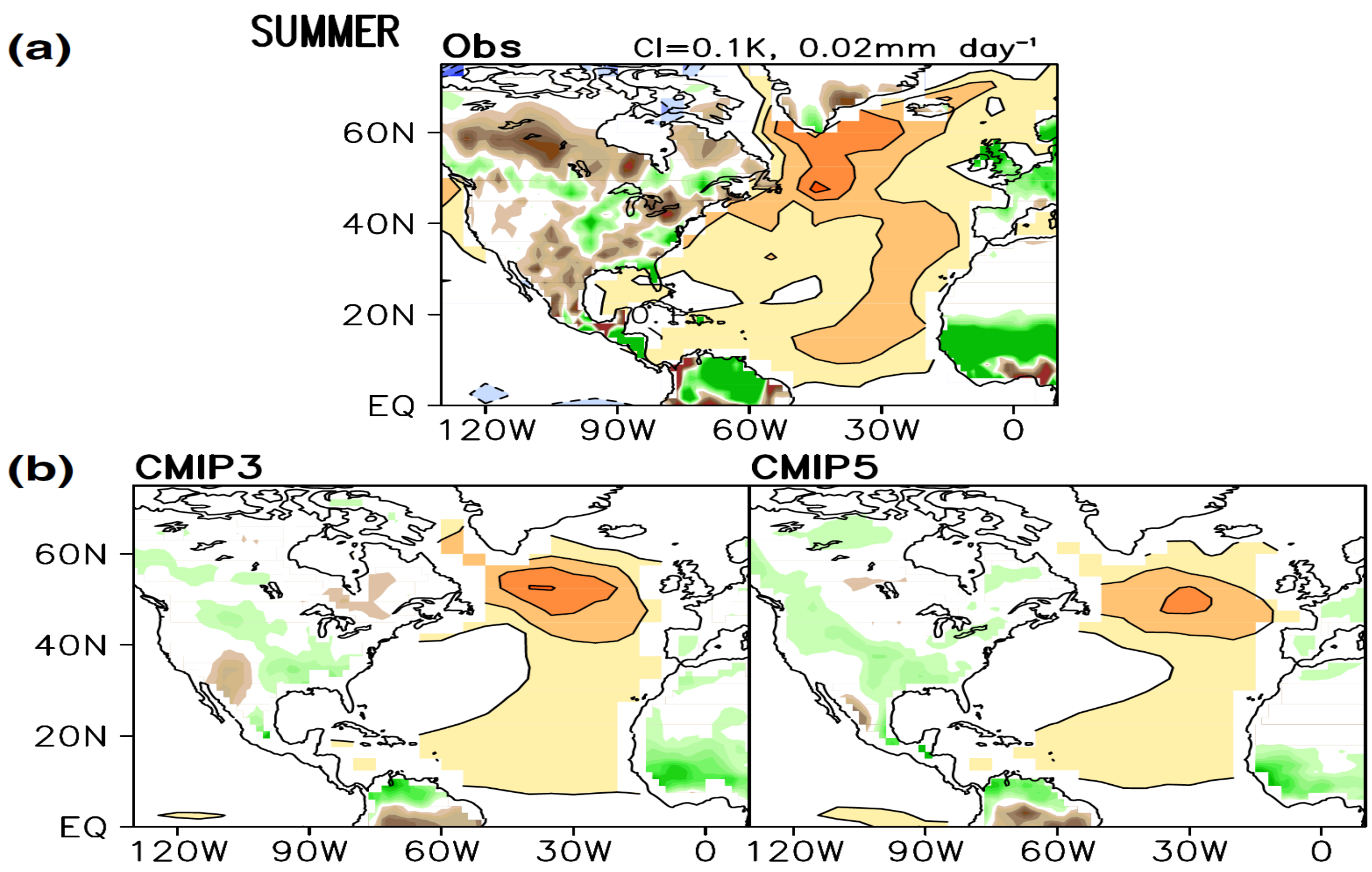
Ruiz-Barradas et al. 2013
Climate Dynamics



Observational and modeling studies suggest that coupled air-sea feedbacks, such as wind-evaporation-SST feedback, cloud feedback, and dust feedback, are essential for the propagation of the subpolar AMV SST signal to the tropical NA along the horseshoe pathway (e.g. Smirnov & Vimont, 2012; Wang et al., 2012; Yuan et al. 2016; Bellomo et al., 2016; Brown et al., 2016)

Most current climate models lack the critical trade wind speed response to the subpolar AMV signal and lack the positive low cloud feedback over the tropical NA, contributing to the much weaker than observed teleconnections between subpolar and tropical AMV SST signal

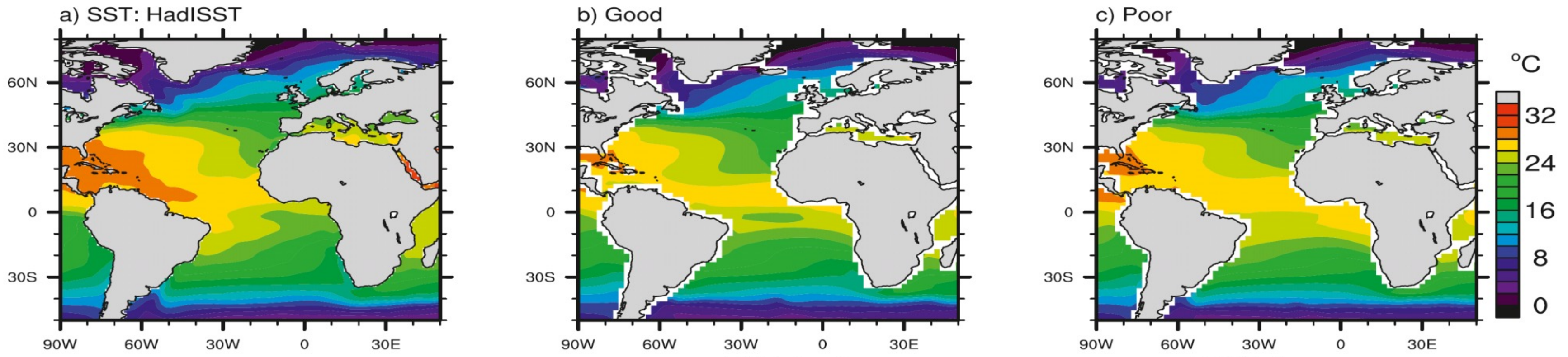
Yuan et al. 2016, GRL



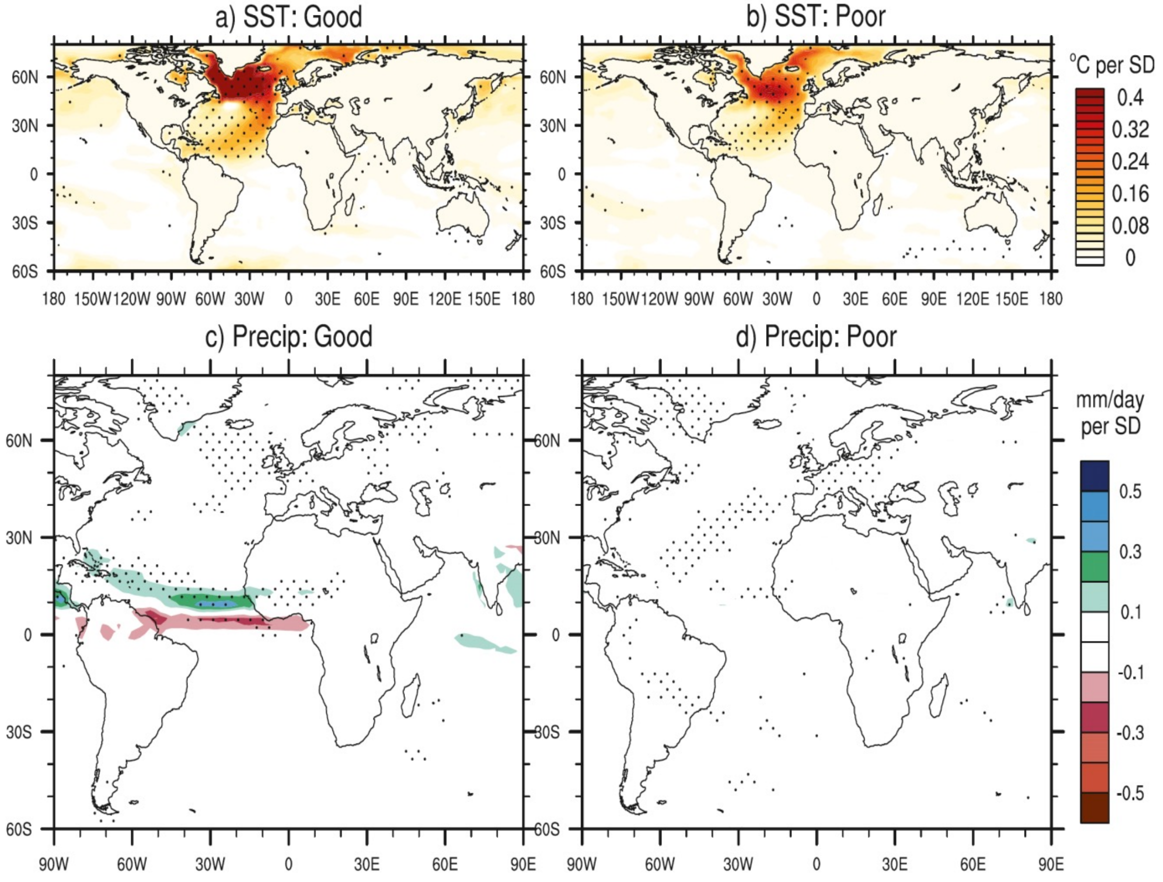
Ruiz-Barradas et al. 2013, Climate Dynamics

Most CMIP3 and CMIP5 coupled models underestimate the tropical AMV SST signal and associated ITCZ shift

Mean State SST Bias in Tropical North Atlantic and Impact of AMOC/AMV on ITCZ

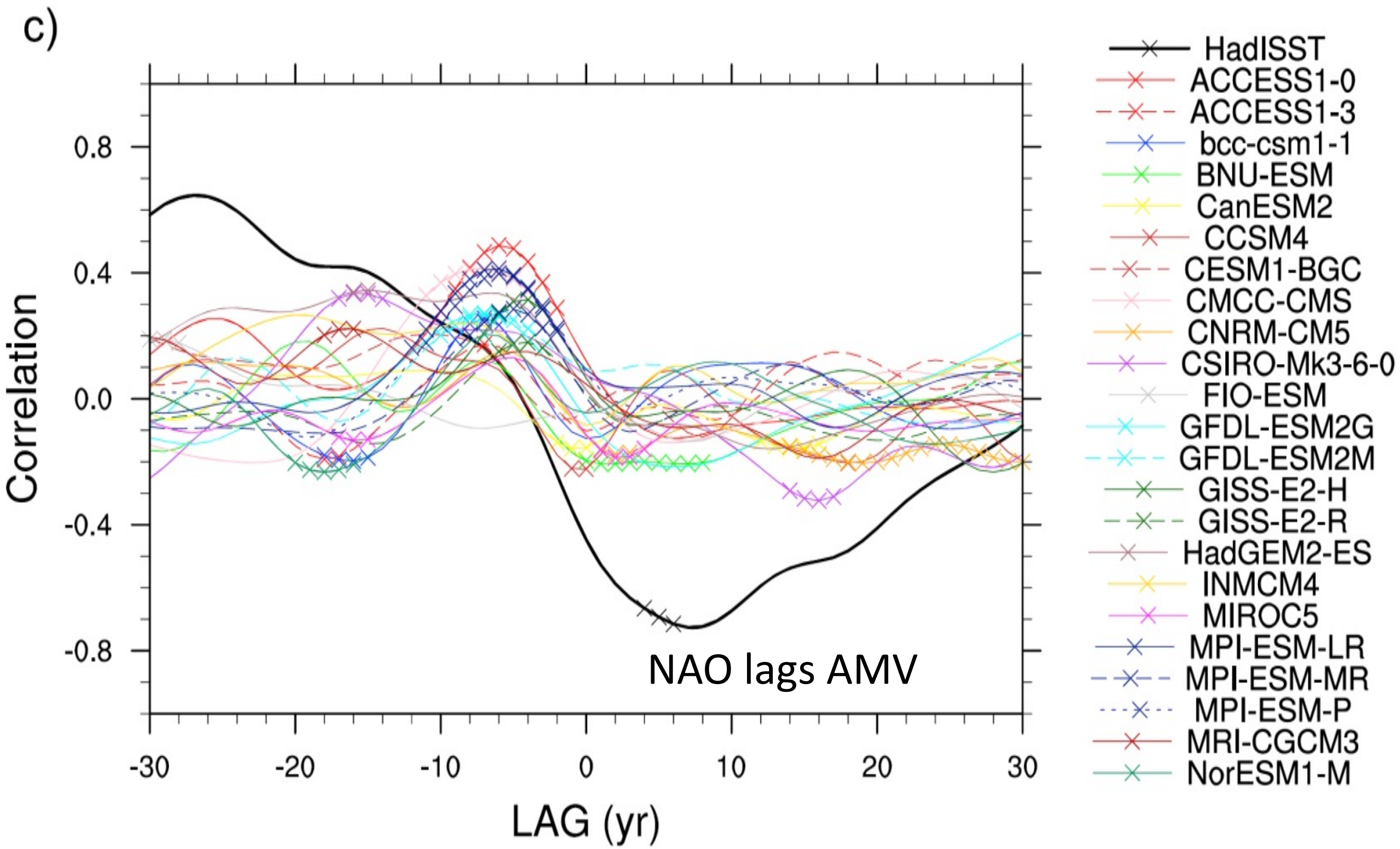


Martin et al. 2014,
Journal of Climate



Climate models with less mean state SST bias in tropical North Atlantic, can simulate better the linkage between the AMOC variability/subpolar AMV SST signal and the tropical AMV SST signal/associated ITCZ shift (Martin et al. 2014)

Modelling Biases on the Impact of AMV on Winter NAO



Correlations between the AMV index and the decadal winter NAO index in CMIP5 models and in observations (black)

Peings et al. 2016, JGR-Atmospheres

Observations show that the observed AMV leads the anti-correlated decadal winter NAO by several years. Coupled climate models underestimate the internally generated AMV signal and its associated impact on winter NAO

Summary

- The AMOC-AMV linkage is consistent with all observed key elements of AMV and underlies the enhanced decadal prediction skills of AMV
- Multidecadal AMOC variability is a key contributor to the subpolar AMV SST signal and should not be neglected
- Coupled air-sea feedbacks in response to changes in the subpolar NA are important for the propagation of AMV SST signal from the subpolar to the tropical NA
- The observed AMV is a multivariate phenomenon unique to the Atlantic, and it is critical to use multivariate metrics to understand the underlying mechanisms
- Externally forced SST response is not unique to the Atlantic. The resemblance between linearly detrended observed and modeled externally forced SST-based AMV indices is an artifact of linear detrending
- The hypothesis that changes in external radiative forcing or stochastic atmospheric forcing is the primary driver of AMV disagrees with many observed key elements of AMV
- Many climate models underestimate multidecadal AMOC variability, thus underestimate the AMOC-AMV linkages and associated decadal predictability/climate impacts

Reviews of Geophysics

REVIEW ARTICLE
10.1029/2019RG000644

Special Section:
Atlantic Meridional Overturning Circulation: Reviews of Observational and Modeling Advances

A Review of the Role of the Atlantic Meridional Overturning Circulation in Atlantic Multidecadal Variability and Associated Climate Impacts

Rong Zhang[1], Rowan Sutton[2], Gokhan Danabasoglu[3], Young-Oh Kwon[4], Robert Marsh[5], Stephen G. Yeager[3], Danial E. Amrhein[6], and Christopher M. Little[7]

Synthesis of ~480 studies from the climate community

- Essential role for the AMOC, associated ocean heat transport, and heat flux released from the ocean in many AMV-related climate impacts (e.g. ITCZ, Sahel/Indian monsoons, Atlantic Hurricanes, ENSO, PDV, NAO, climate over Europe, North America, and Asia, Arctic sea ice and surface temperature, and hemispheric mean surface temperature)

- Various climate linkages associated with AMV (e.g. linkages with the ITCZ, Western African Monsoon, climate over Europe, North America, Asia, and Arctic, Northern Hemisphere mean surface temperature) are also imprinted in paleo proxy records