Climate Impacts of Atlantic Multidecadal Variability: Perspectives and Future Challenges

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"AMOC Variability: Dynamics and Impacts"

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Climate Impacts of AMOC-AMV

- Sea level, sea ice cover
- Surface temperature around the North Atlantic basin
- Precipitation over North and South America, Africa, and Indian monsoon region
- Atlantic hurricanes, other extreme events(?)
- Atmospheric Circulation (NAO, storm tracks)
- Fisheries
- Biogeochemistry

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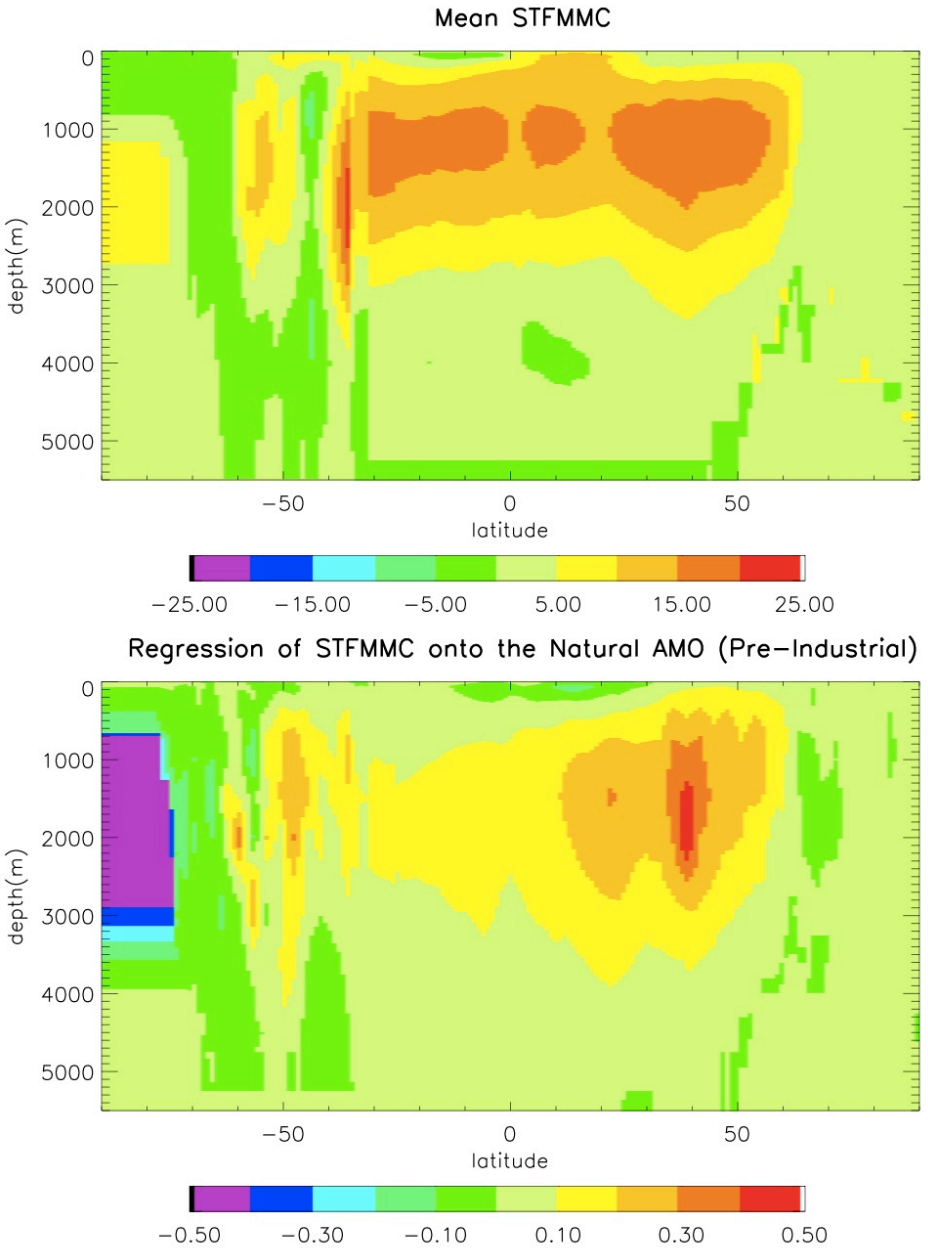
Outlines

- Forced versus internal multidecadal variability in CMIP5 models: to what extent is observed 20th Century Atlantic multidecadal variability externally forced?
- Is AMV a robust low-frequency mode under various external forcing conditions, from pre-industrial to 21st C scenarios, in terms of its spatial and temporal characteristics?
- Climate Impacts of the tropical and extratropical North Atlantic components of the AMV?
- Interaction between Atlantic and Pacific basins
- Future Challenges

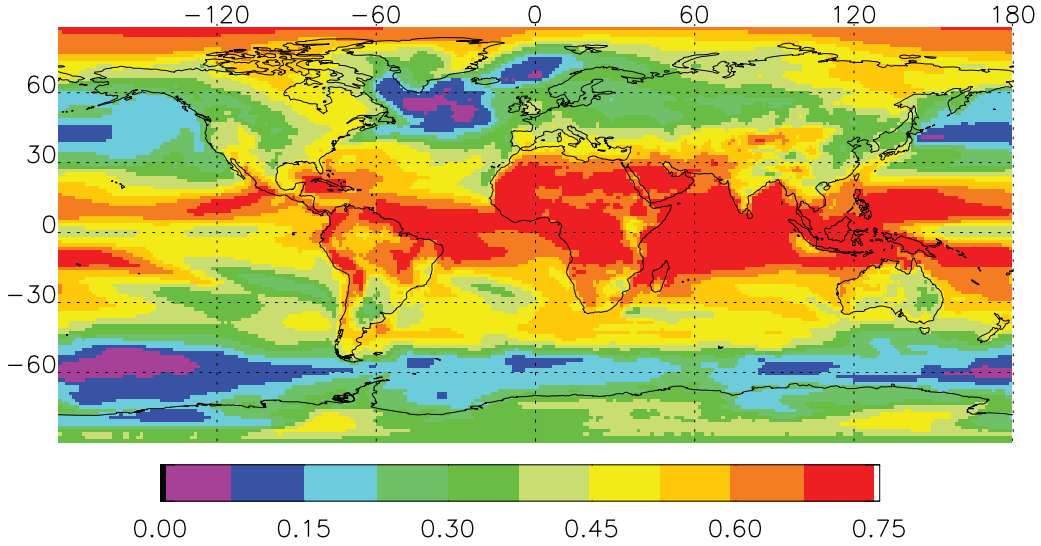
Atlantic Meridional Overturning Streamfunction

AMV and AMOC

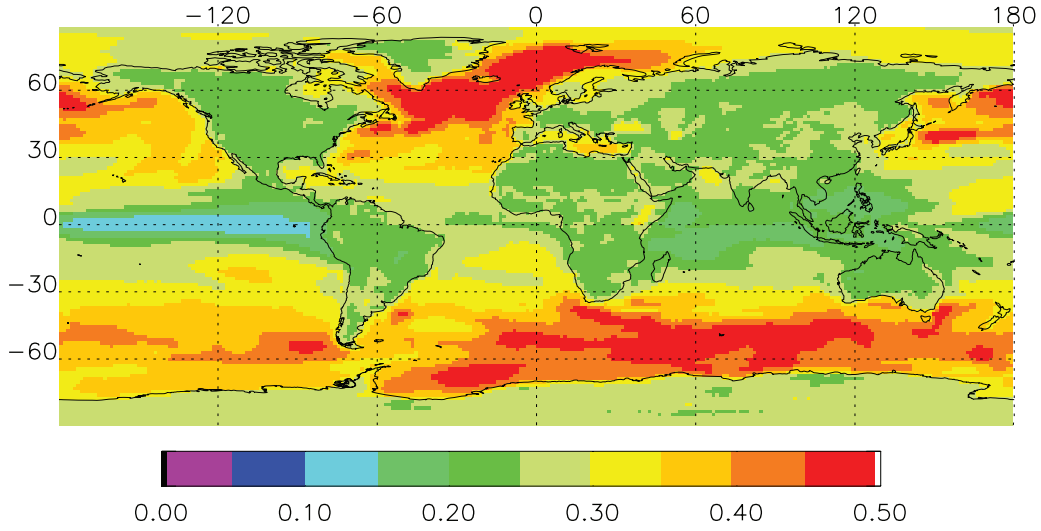


Why do we care about the climate impacts of the North Atlantic SST?

Forced Variance Ratio: Forced/(Forced + Decadal)



Internal Variance Ratio for Ts: Decadal/Total



$$r = \frac{\sigma_F^2}{\sigma_T^2} = \frac{\sigma_a^2 - \frac{1}{N-1}\sigma_I^2}{\sigma_I^2 + \sigma_F^2}$$

$$\sigma_a^2 = \frac{1}{M}\sum_m \left(\frac{1}{N}\sum_n Ts_{mn} - \frac{1}{MN}\sum_m \sum_n Ts_{mn} \right)$$

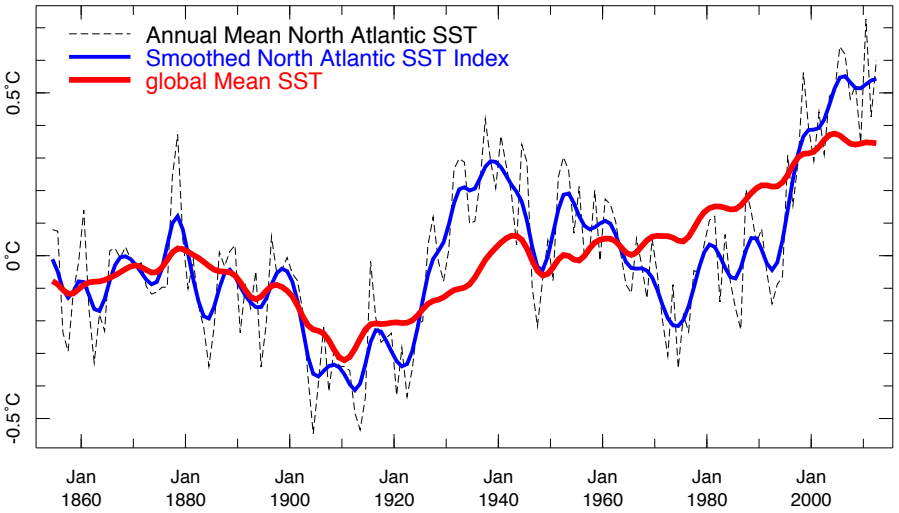
M-years, N-ensemble members

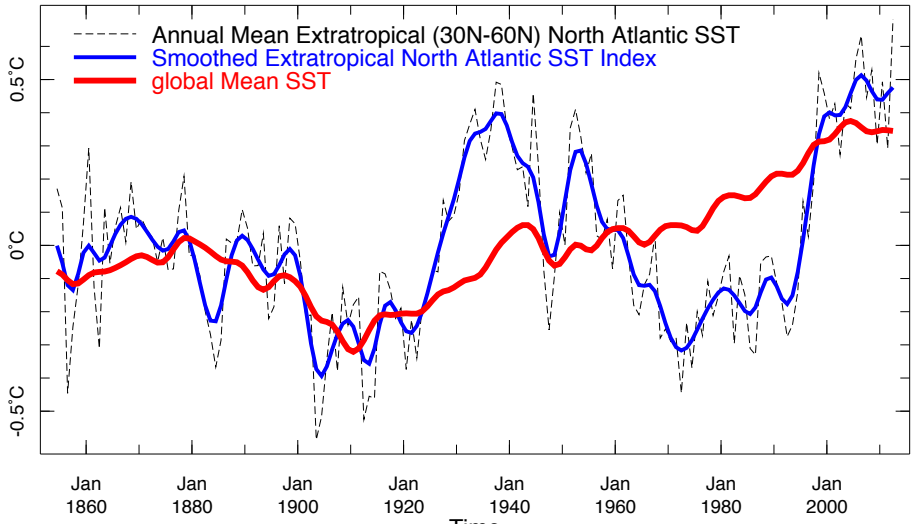
σ_I^2 : internal variance estimated from pre-industrial run (CMIP5)

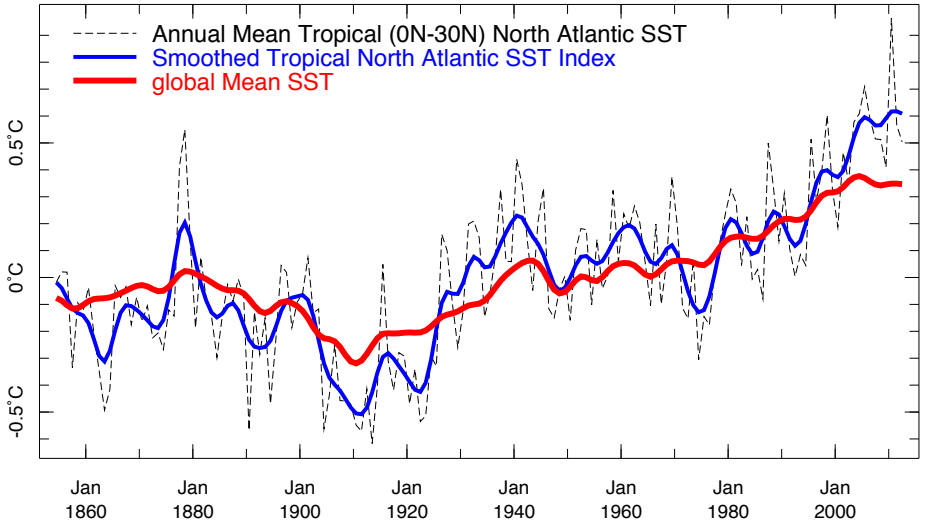
North Atlantic is a region of relatively low forced variability and high in decadal variability – high potential predictability

To what extent is 20th Century North Atlantic multidecadal variability externally forced?

ERSST, 1854 - 2012







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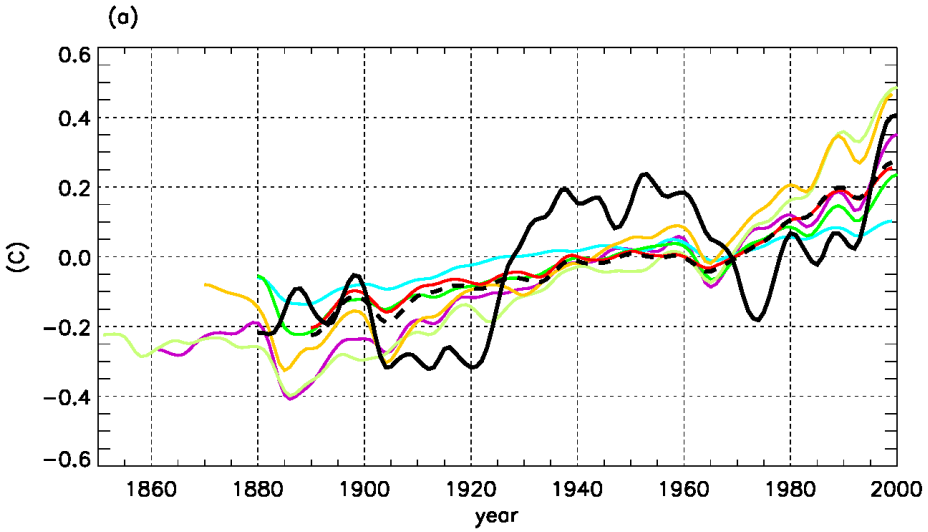
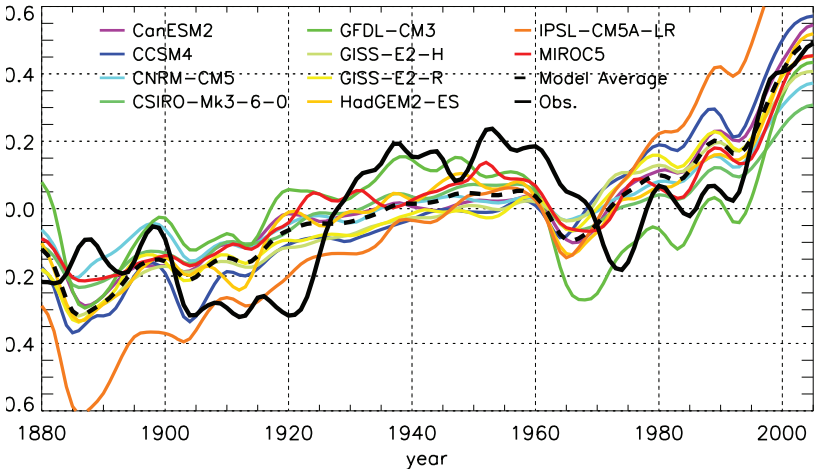
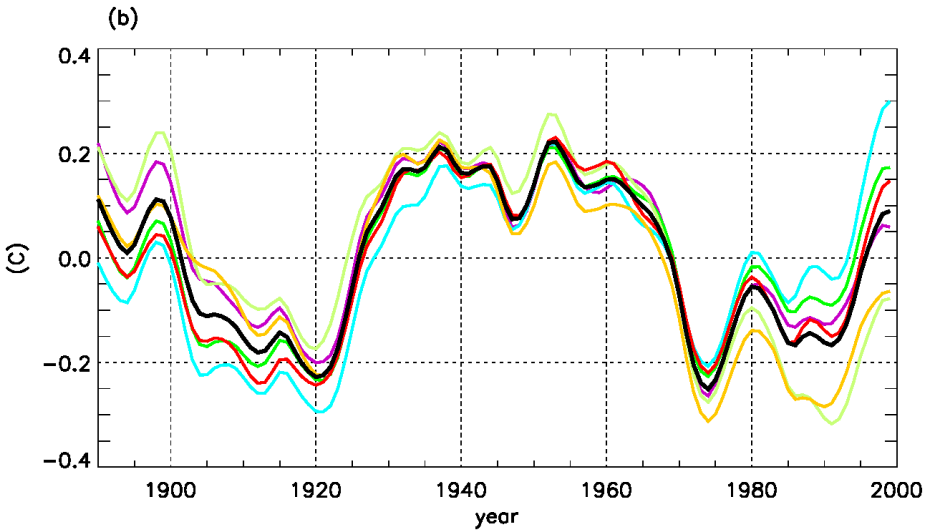
Ting et al., 2009, updated for CMIP5

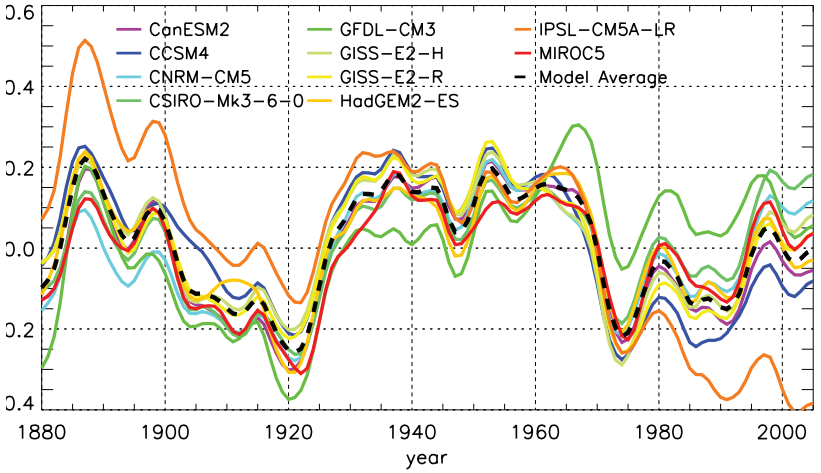


NASSTI Regressed to S/N PC1





NASSTI regression residual



upward trend in CMIP 5 NASST

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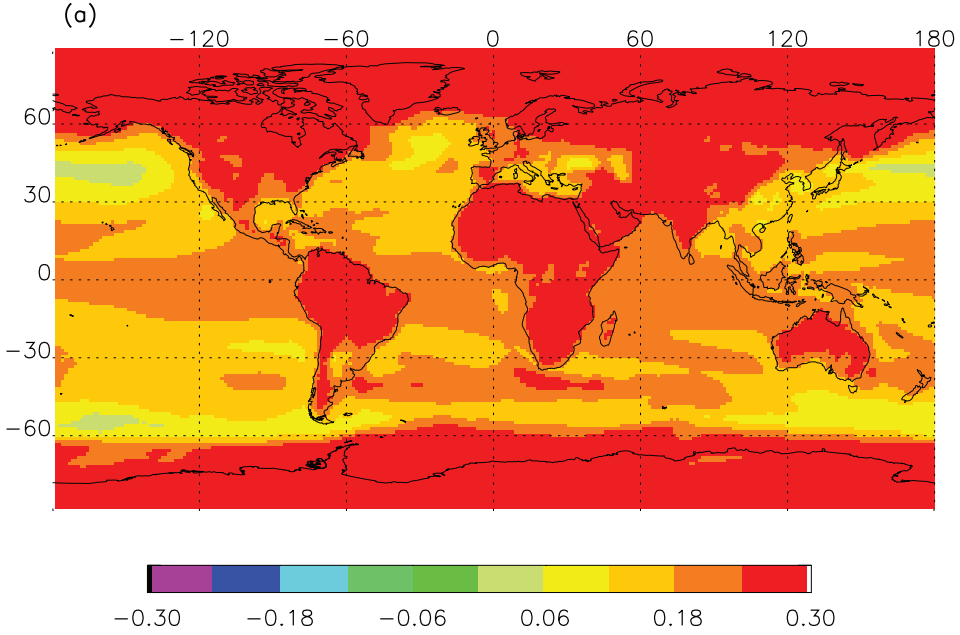
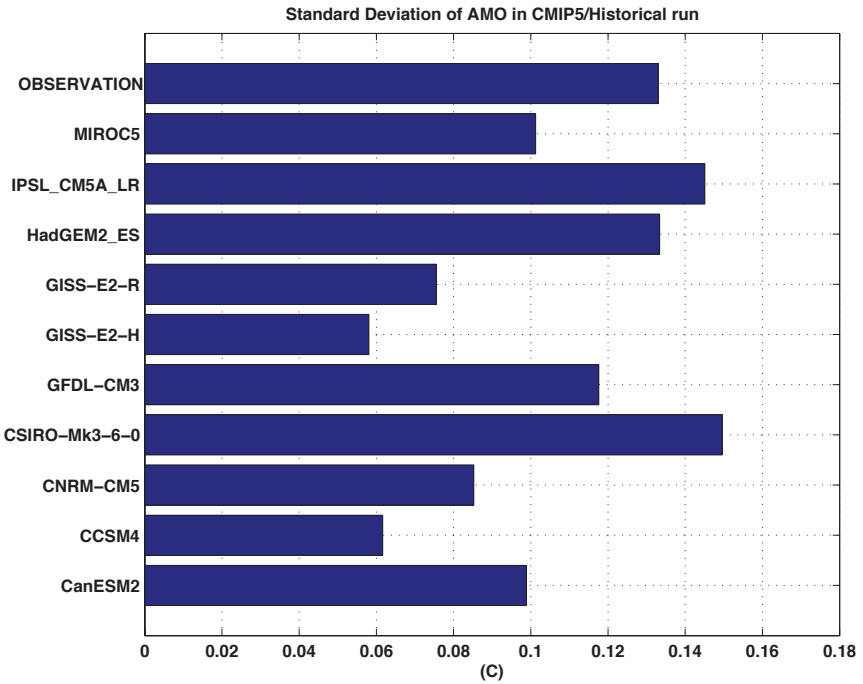
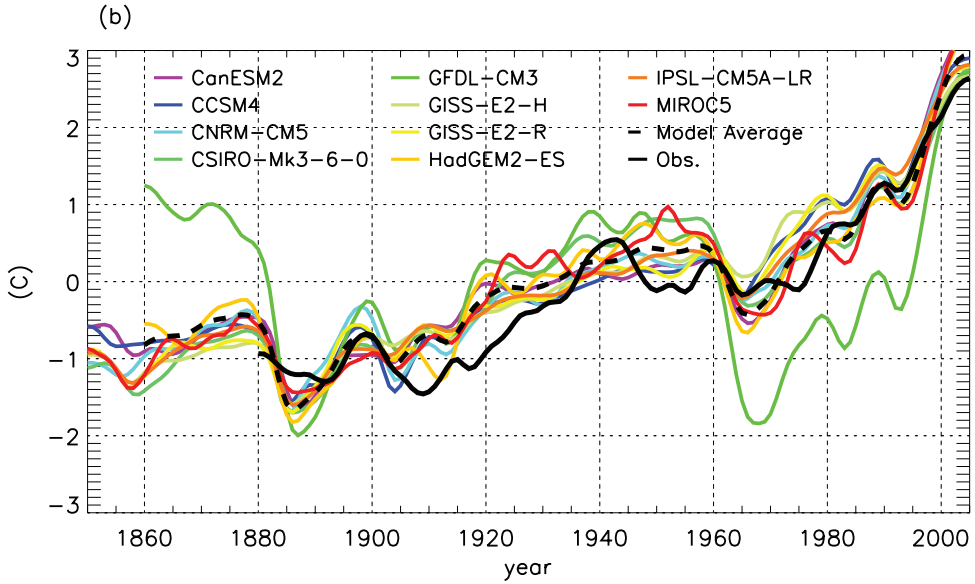
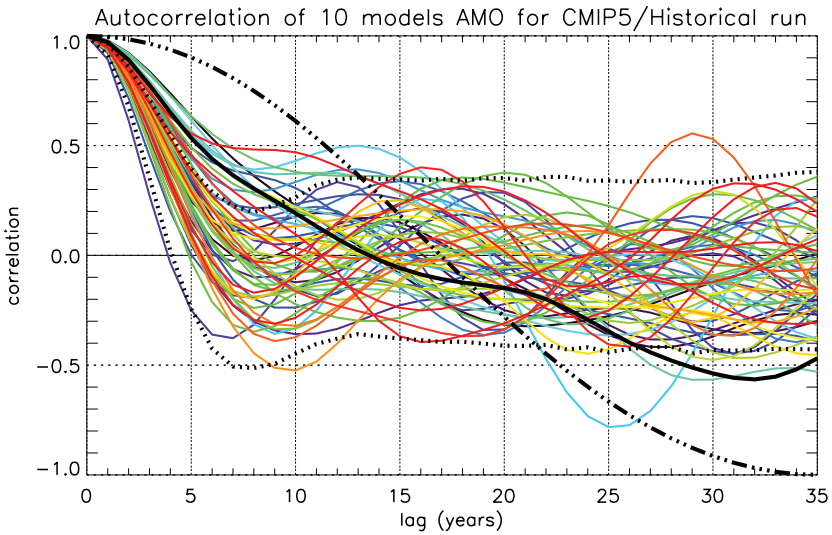
Forced vs. Natural Atlantic SST Variability in CMIP5

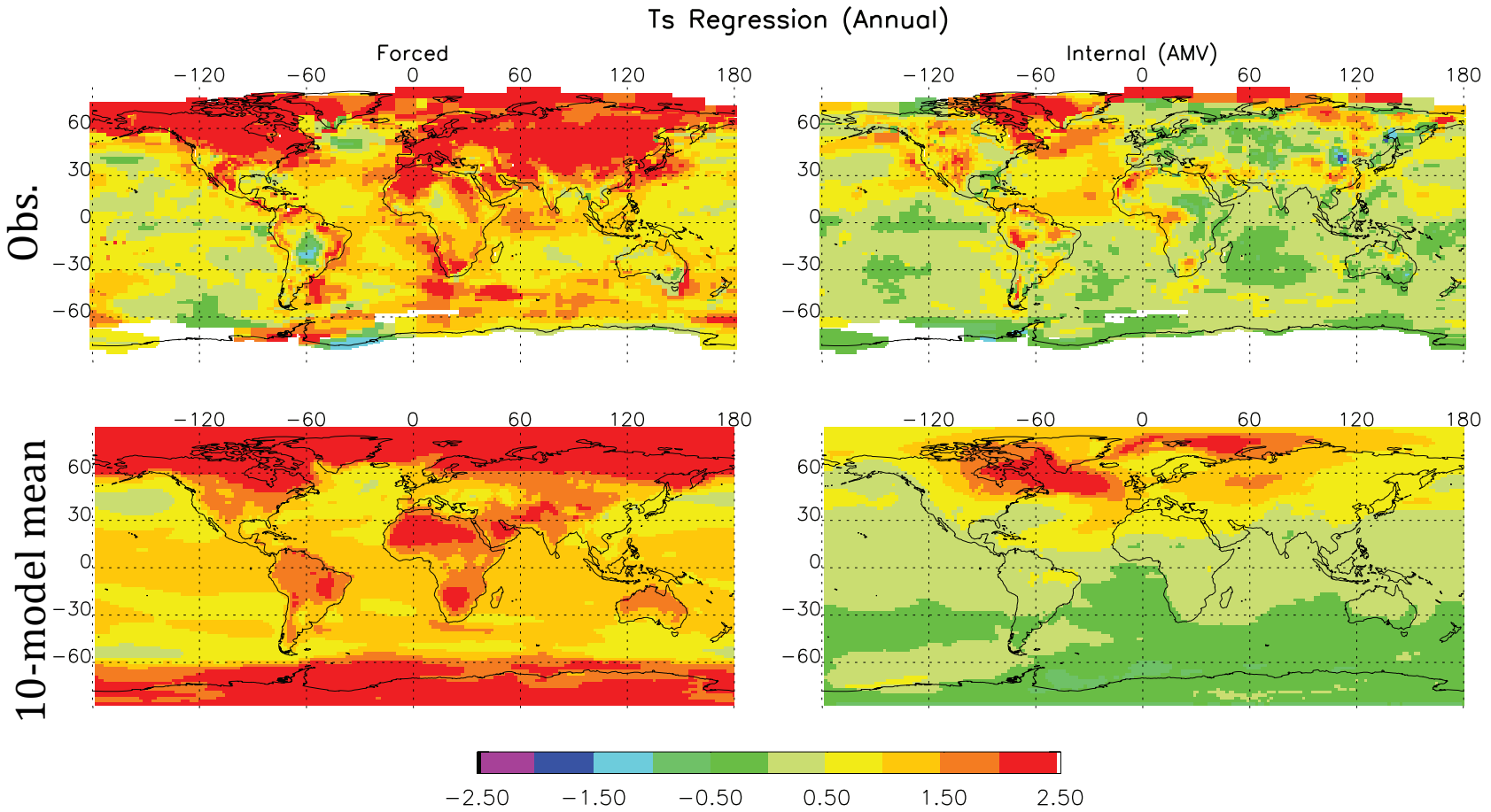








Are forced and internal AMV distinct in its spatial structure?



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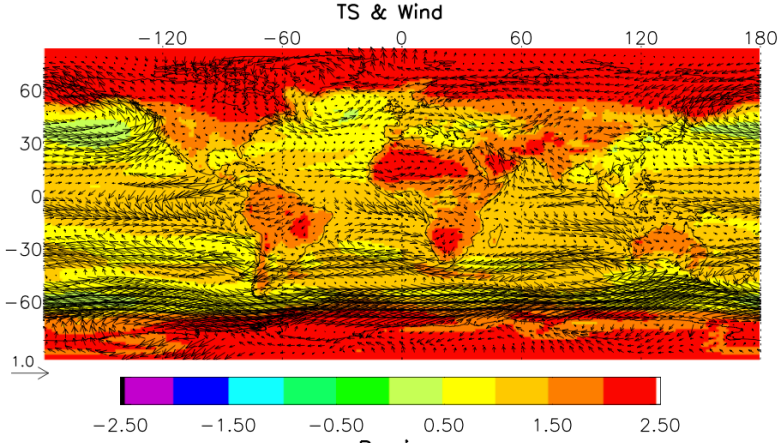
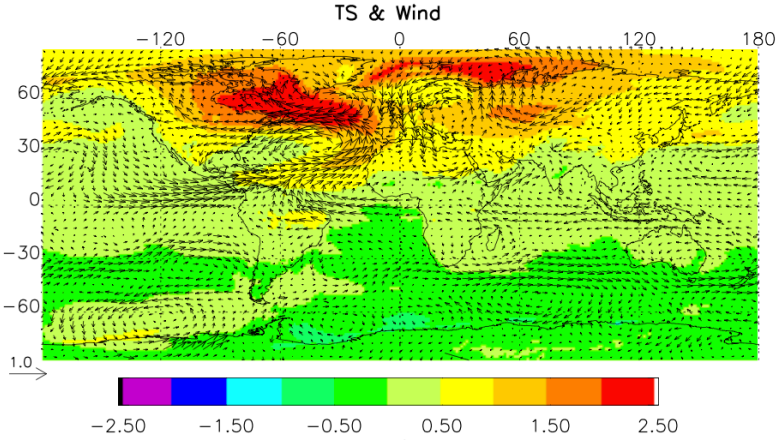
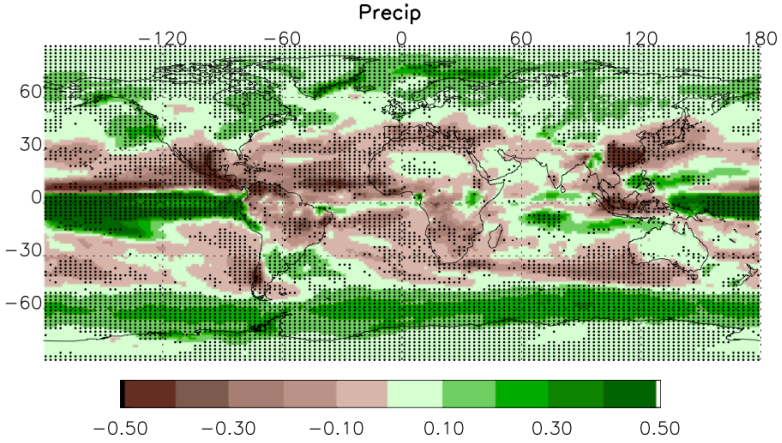
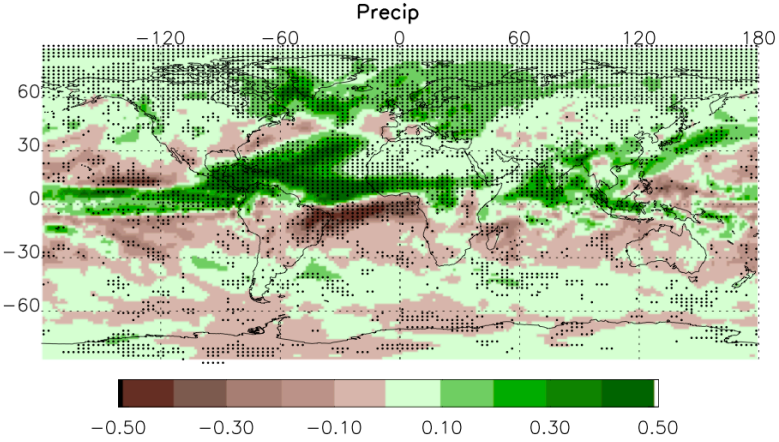
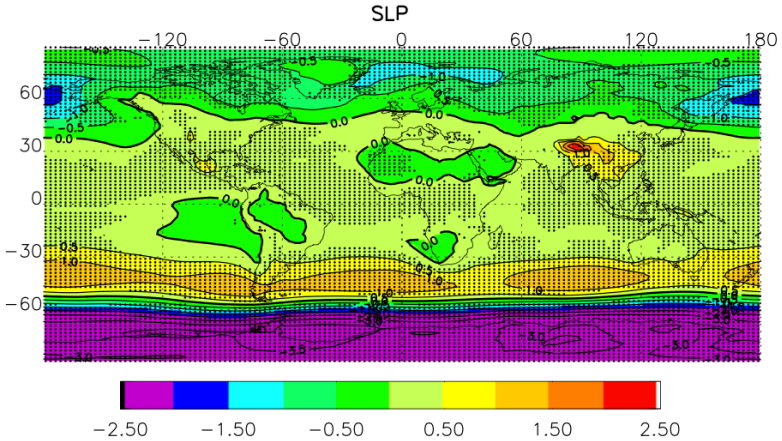
Forced (left) vs. Internal (right) Atlantic Variability

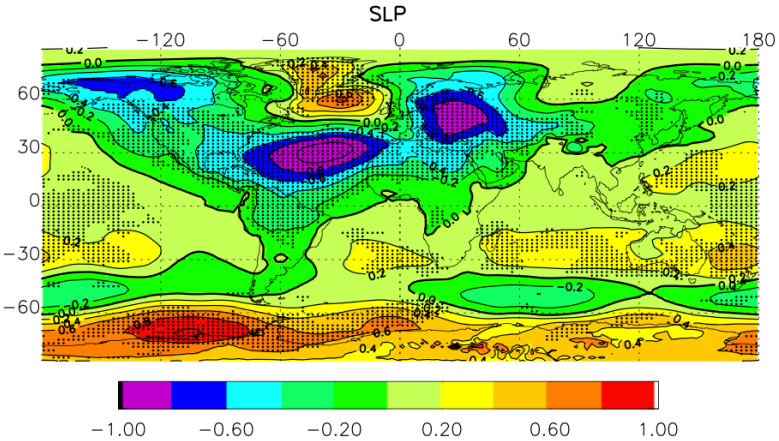


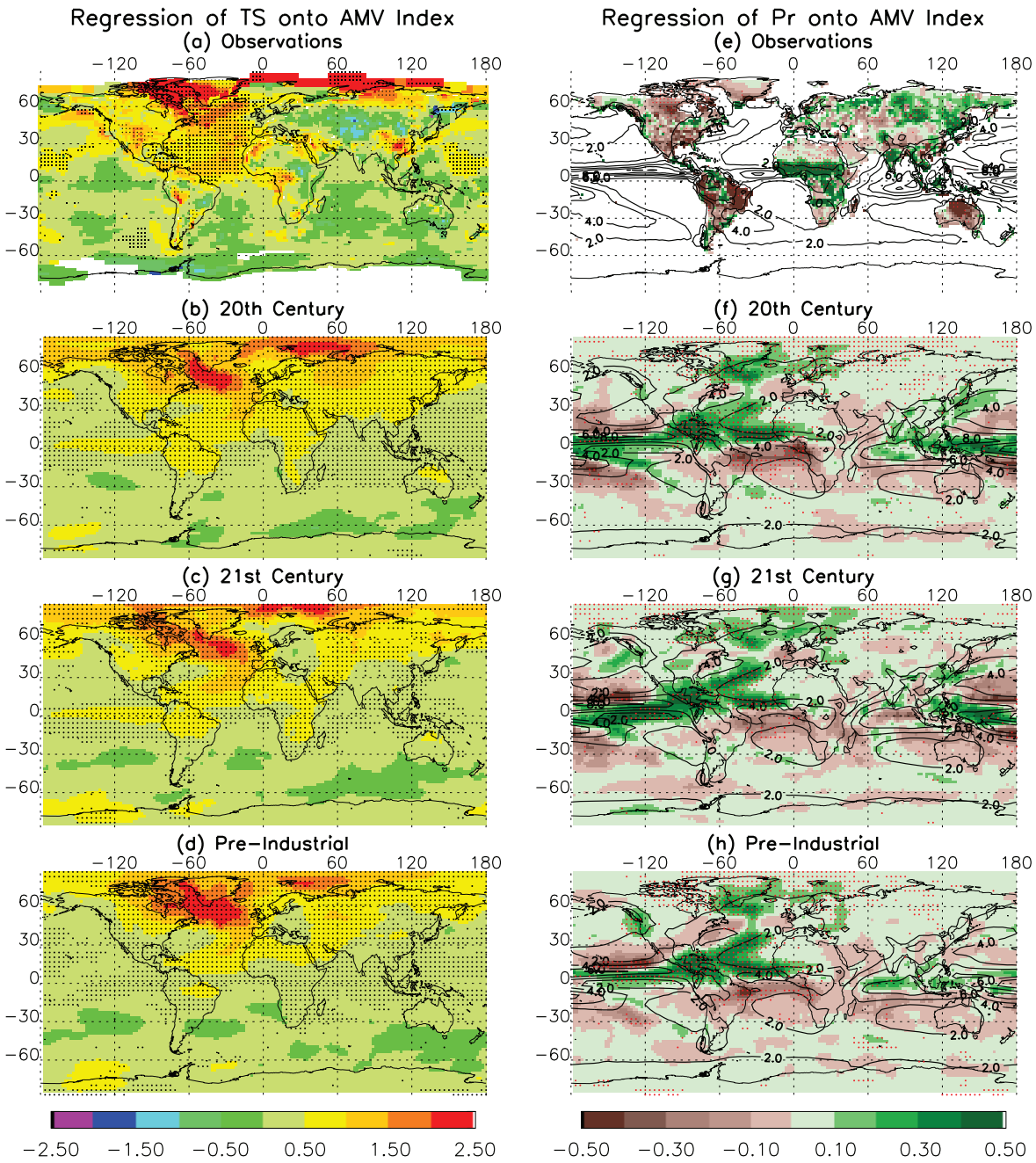












Robust AMV Patterns and Climate Responses in CMIP3

Ting, M., Y. Kushnir, R. Seager, and C. Li (2011): Robust features of Atlantic multi-decadal variability and its climate impacts, Geophys. Res. Lett., 38, L17705, doi: 10.1029/2011GL04871

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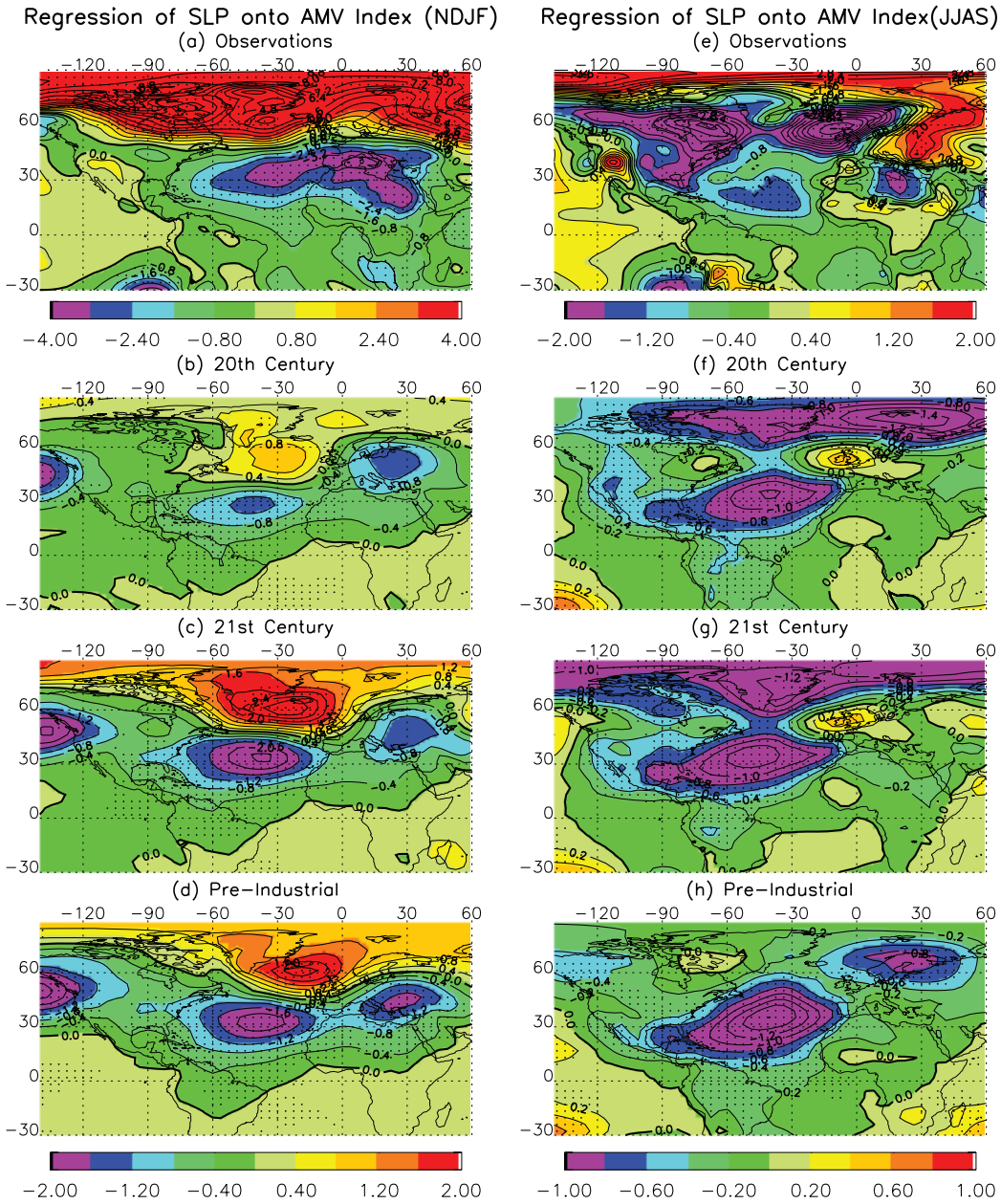
AMV SLP in Winter(left) and Summer (right)

Ting et al., 2013



- Positive AMV is associated with a negative NAO phase in winter
- During summer, the most prominent signal in sea level pressure is a weaker Bermuda high (low pressure anomalies)
- These are robust across all external forcing scenarios

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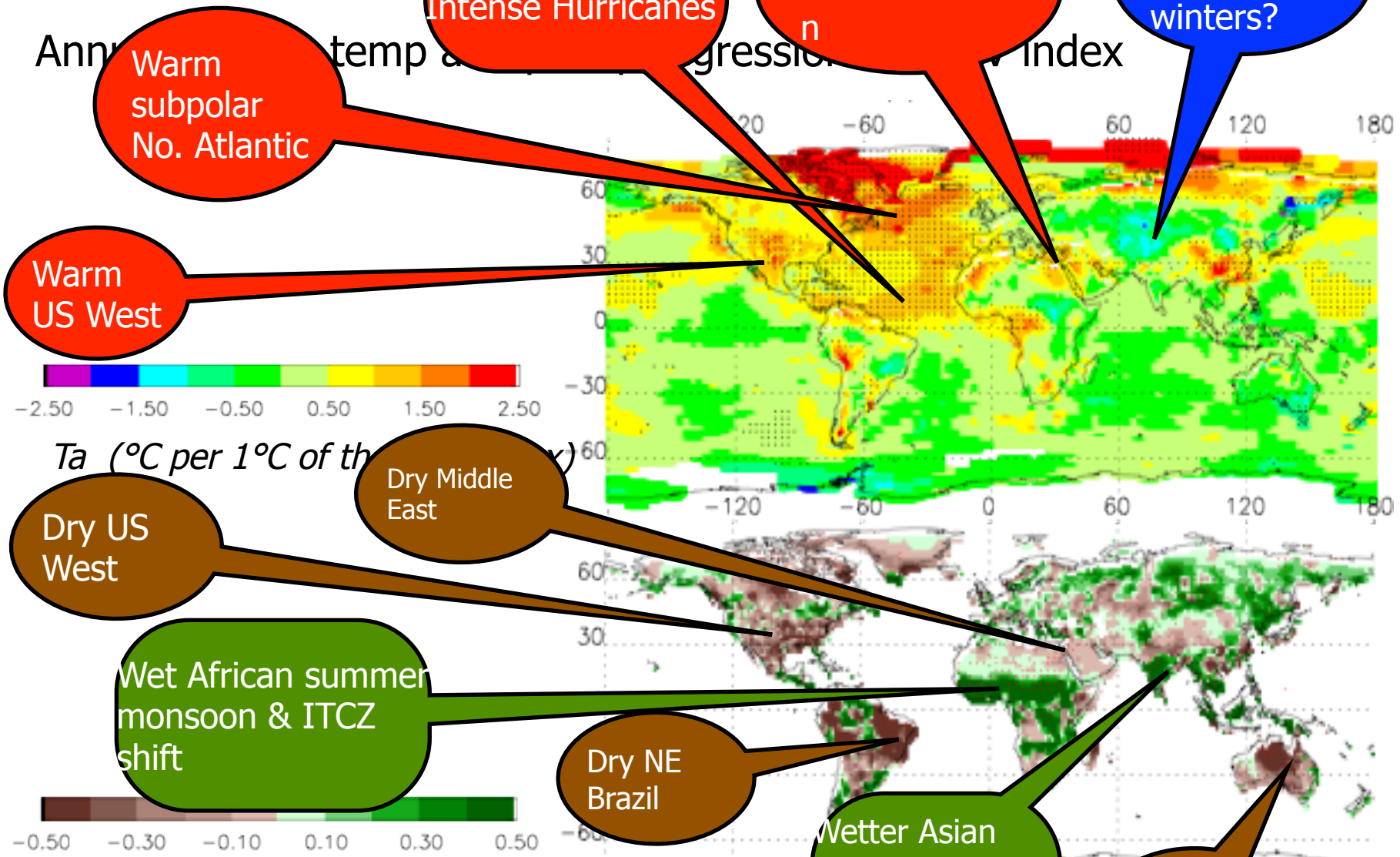

Ting et al (2009)

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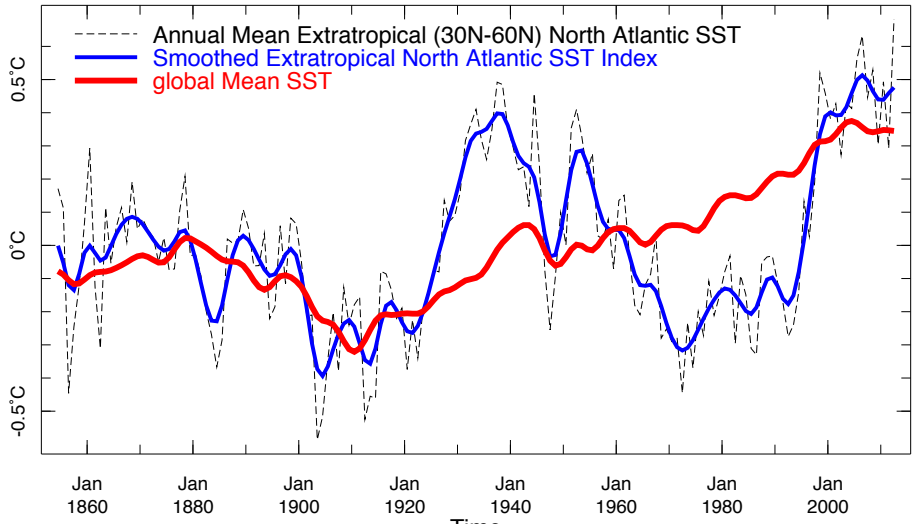
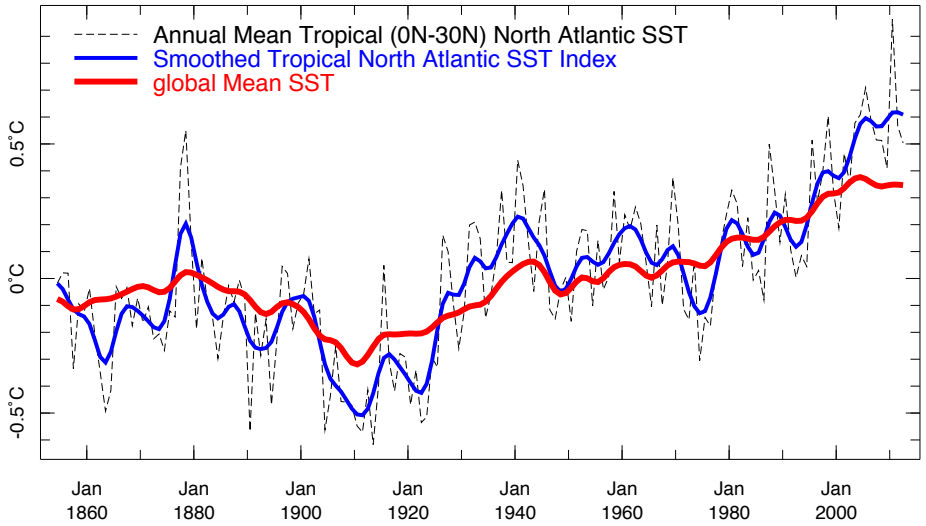
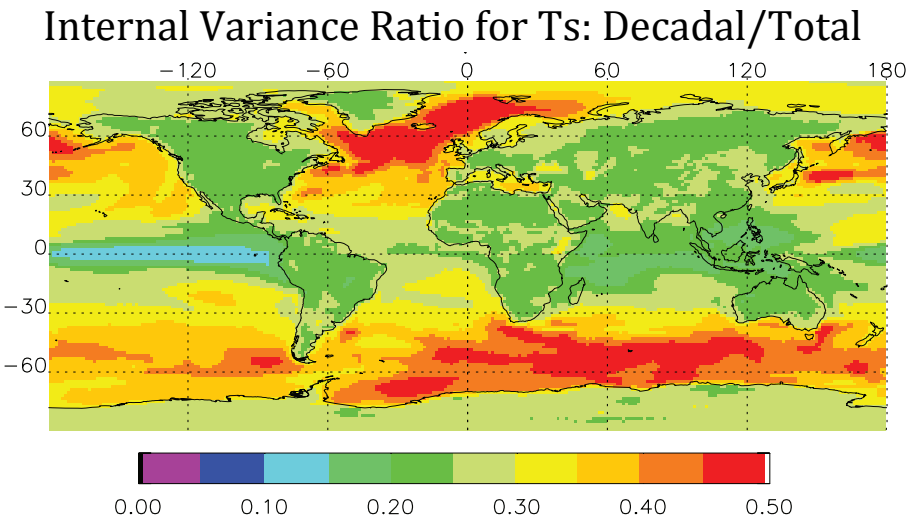
What is the relative importance of tropical and extratropical AMV on climate?







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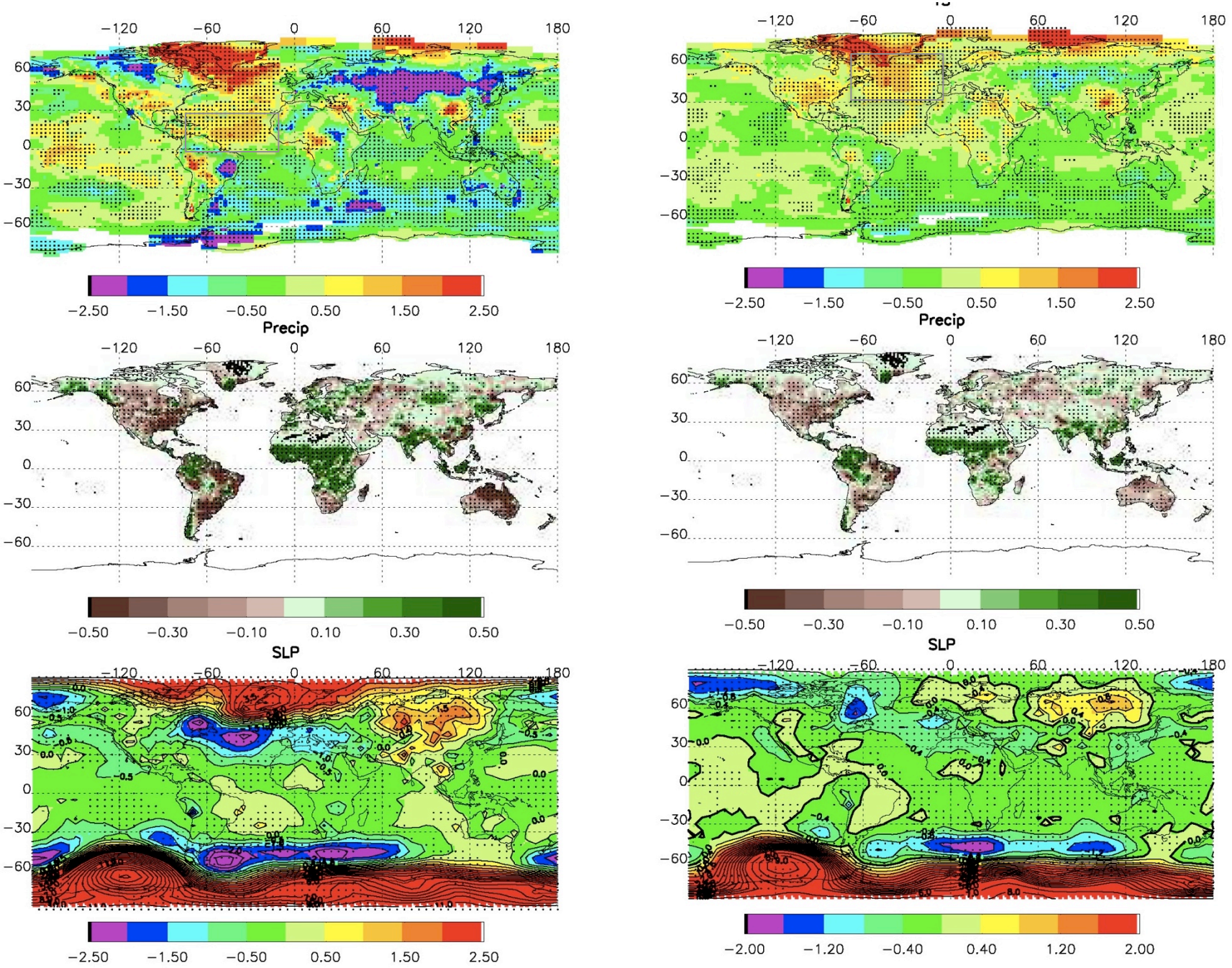
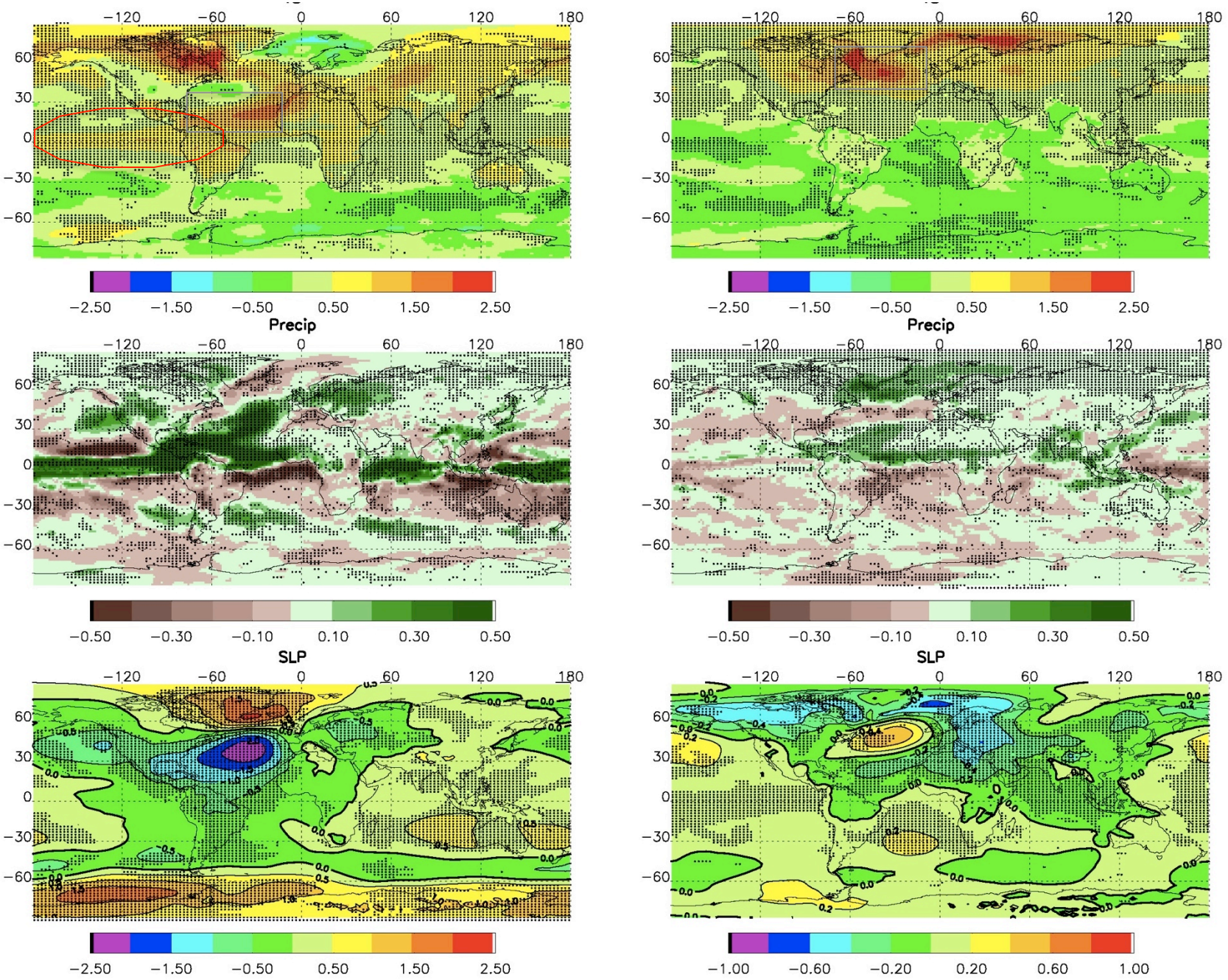
Obs. Tropical (left) vs Extratropical (right) SST Impacts

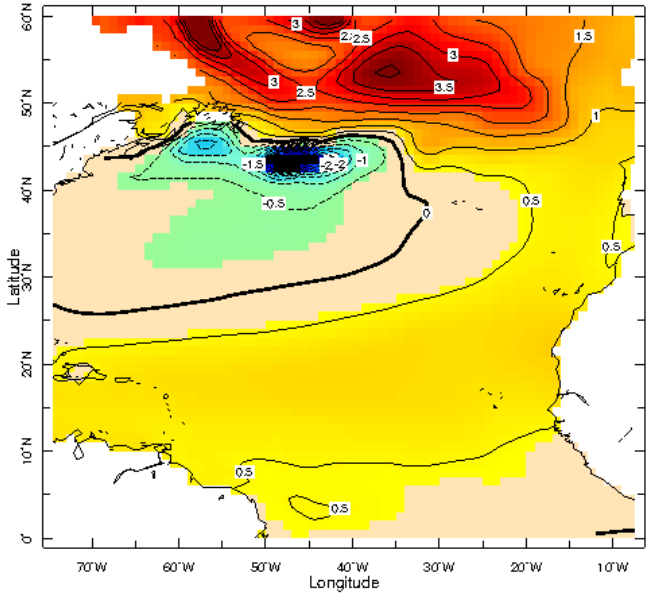


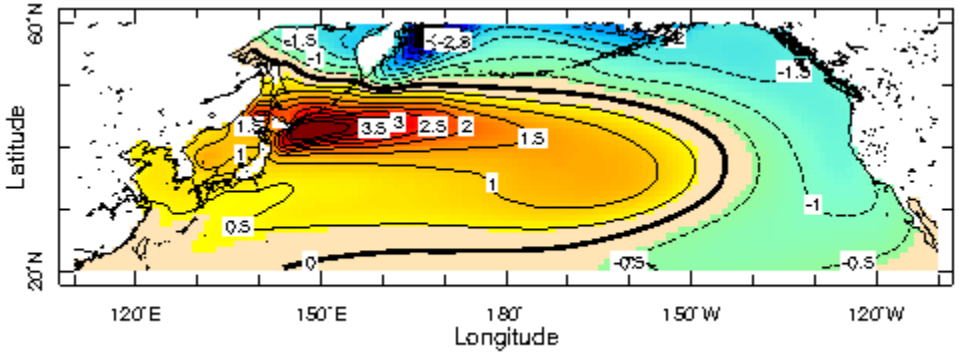
CMIP5 Historical Tropical (left) vs Extratropical (right) SST Impacts

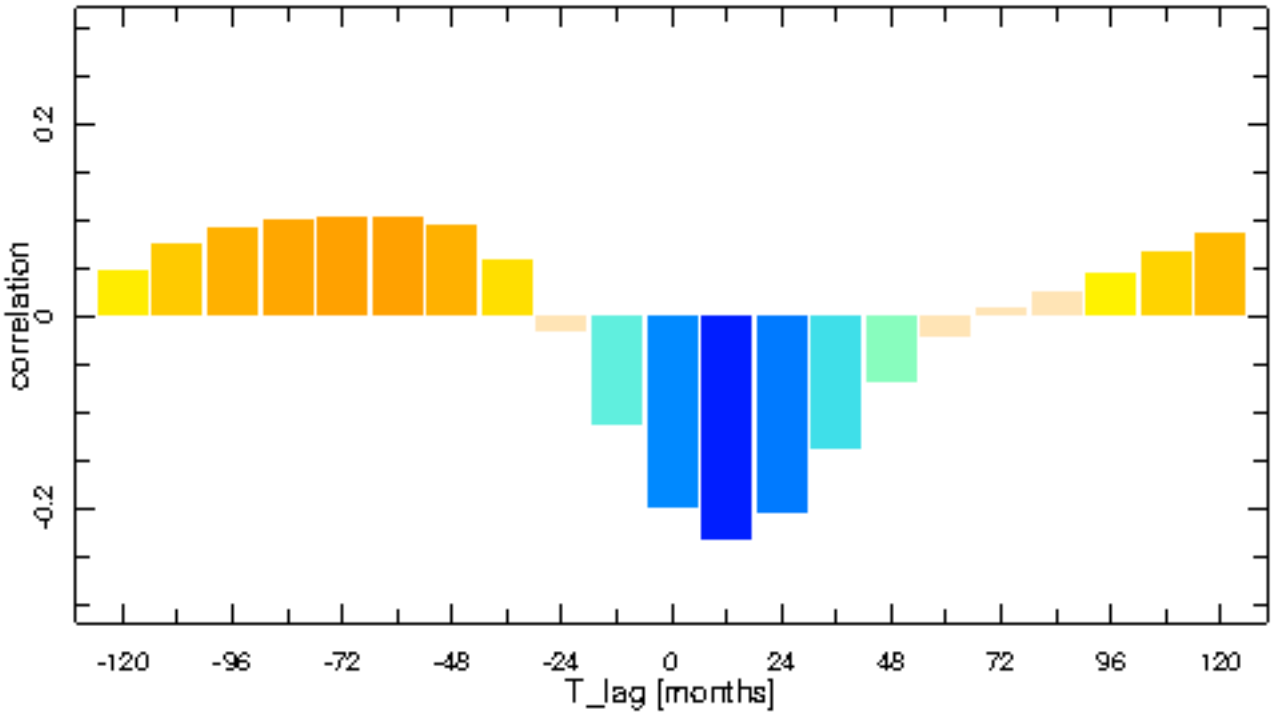


Are CMIP5 models over-representing the inter-basin interaction?

- Use 500 years of NCAR CCSM4 (CMIP5) pre-industrial control run
- First EOF of decadal filtered SST in Atlantic and Pacific is AMV and PDO like.
- First EOF of SLP in Atlantic and Pacific basins are NAO and PNA like.
- There are indications of tropical Pacific forcing the NAO and then AMV-like SST pattern

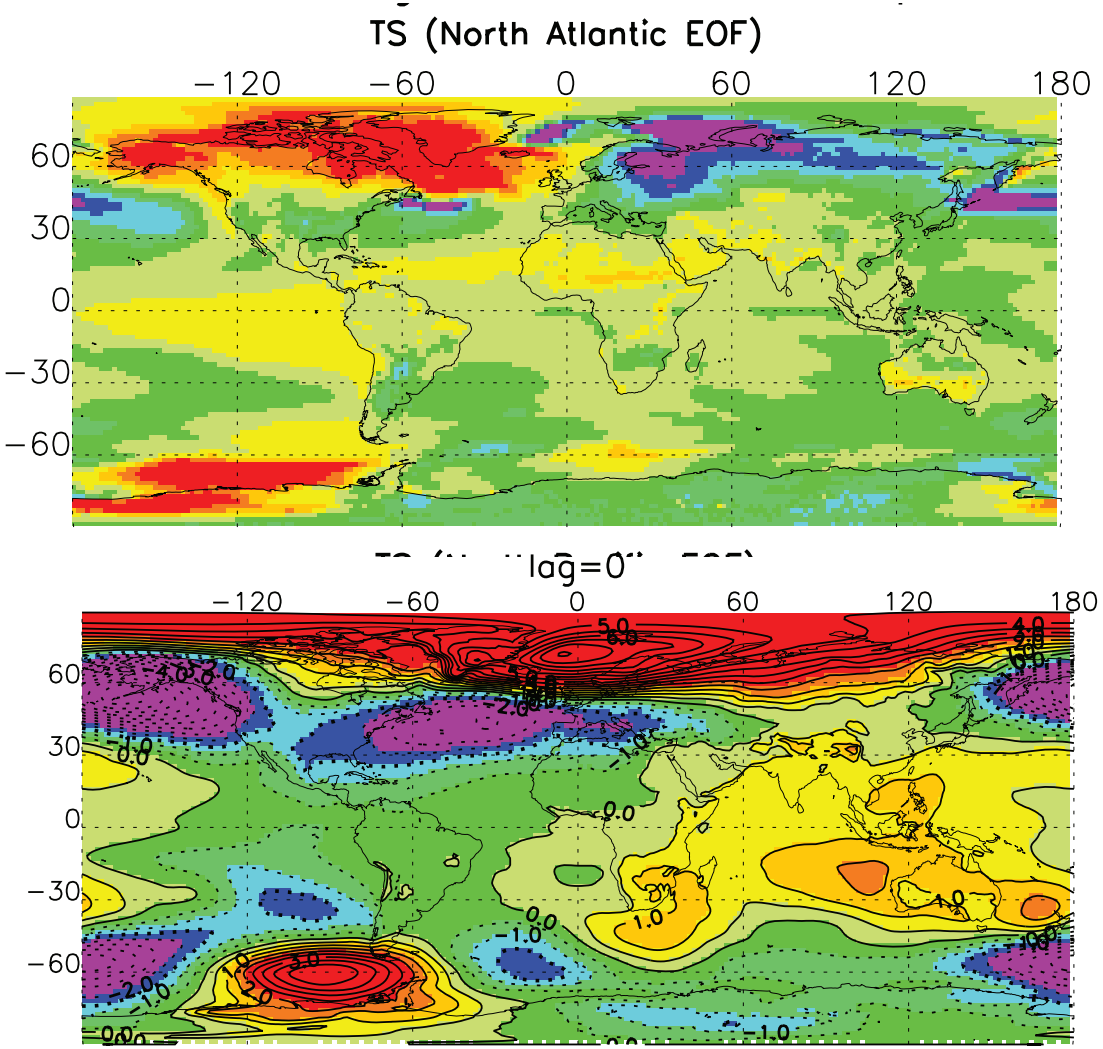






In CCSM4, the Atlantic mode is significantly correlated with the North Pacific mode with the Pacific leads the Atlantic by 1 year.

Regression of global Ts (left) and SLP (right) onto PC1 of North Atlantic (top) and North Pacific (bottom) EOF1



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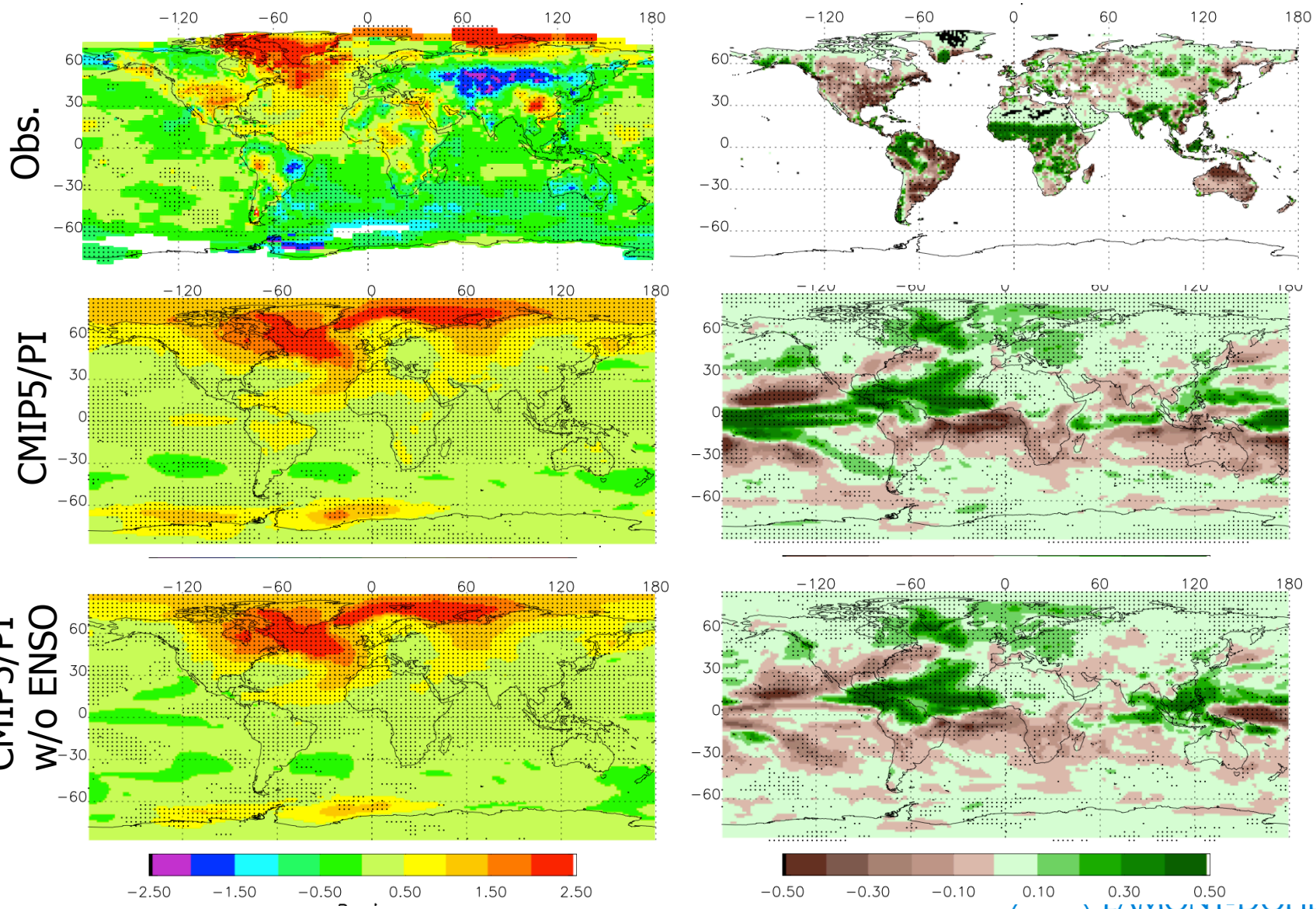
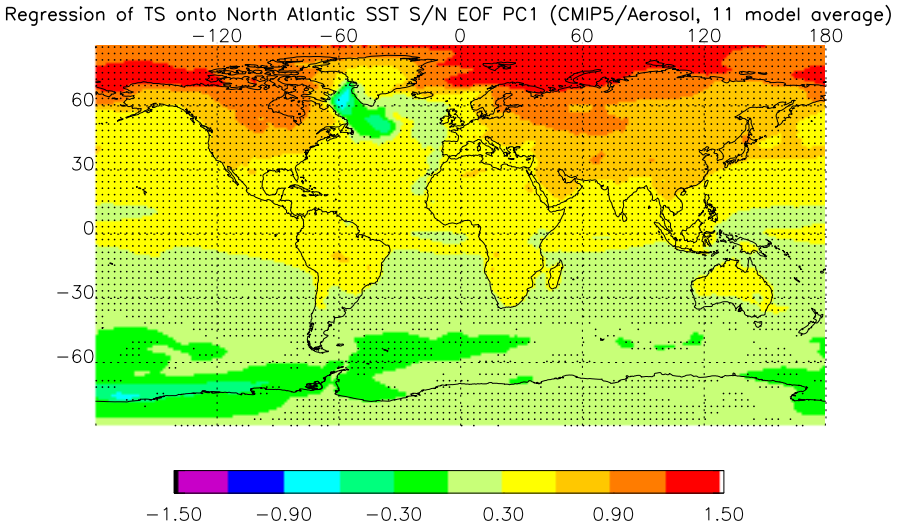
AMV Impacts With and Without Decadal ENSO

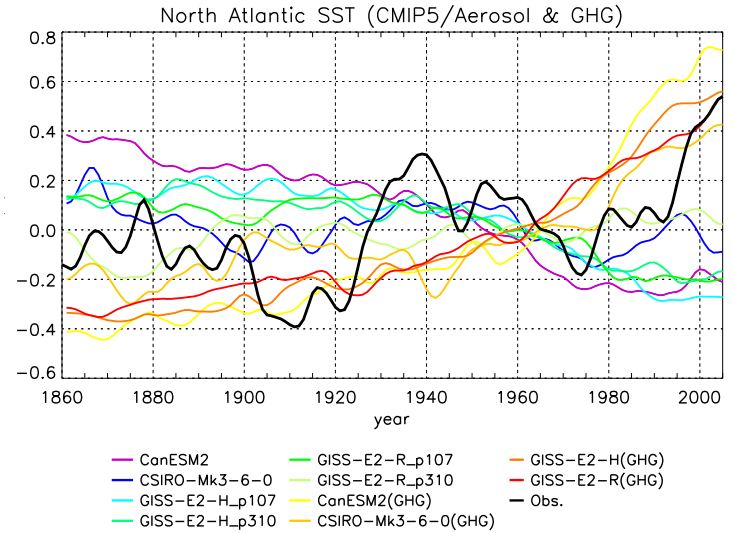


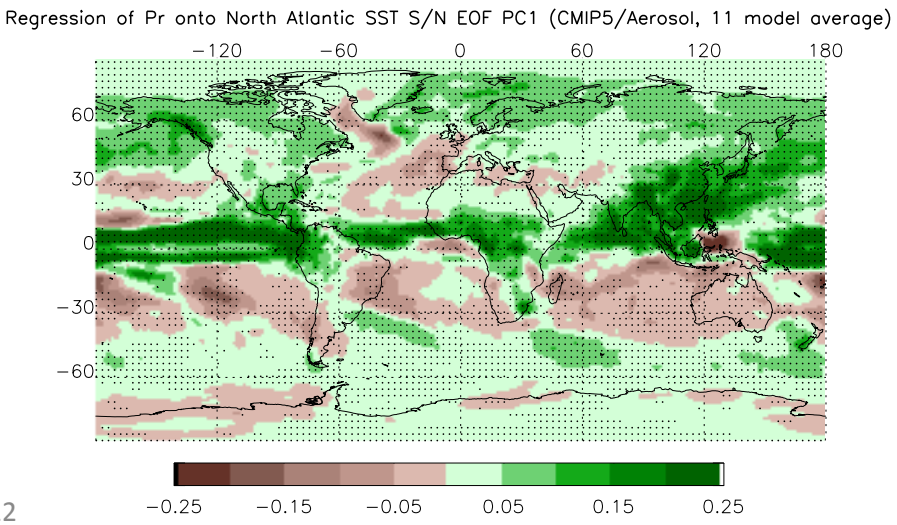
Future Challenges

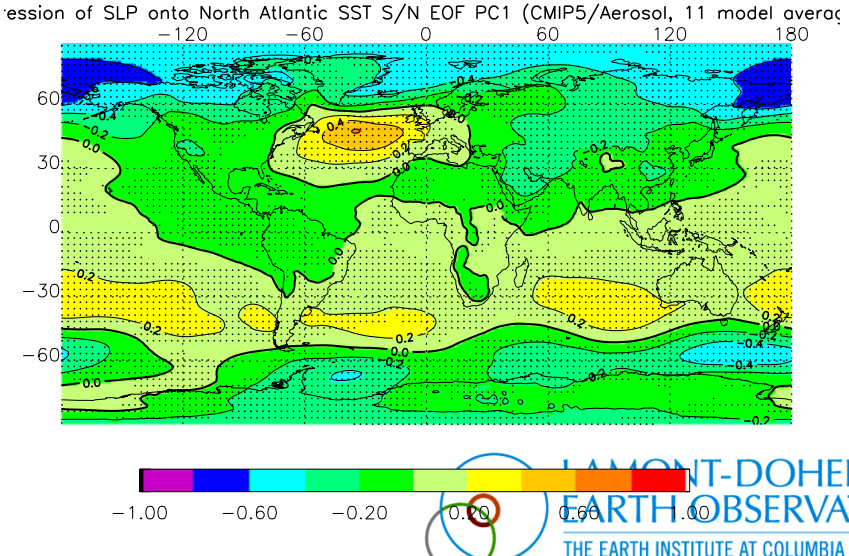
- Could observed AMV in the historical period be forced by aerosols? Is the observed time scale of AMV (~60 yrs) a result of aerosol forcing?
- The source of multi-decadal SST variability originates from the SPG, yet the atmosphere responds mainly to the tropical component of the AMV in most of the CMIP5 models. What is the physical mechanism linking the tropical and subpolar AMV? What determines the horseshoe pattern?
- Is the horseshoe SST pattern a statistical artifact?
- Are CMIP5 models overemphasizing the decadal ENSO impacts on AMV?
- Given the large inter-model spread in terms of temporal scale and climate impacts, is the multi-model mean approach the best way to move forward?
- Are there any climate impacts that we haven't explored, such as AMV impacts on extremes?

CMIP5 Historical Aerosol-only Forcing Simulations

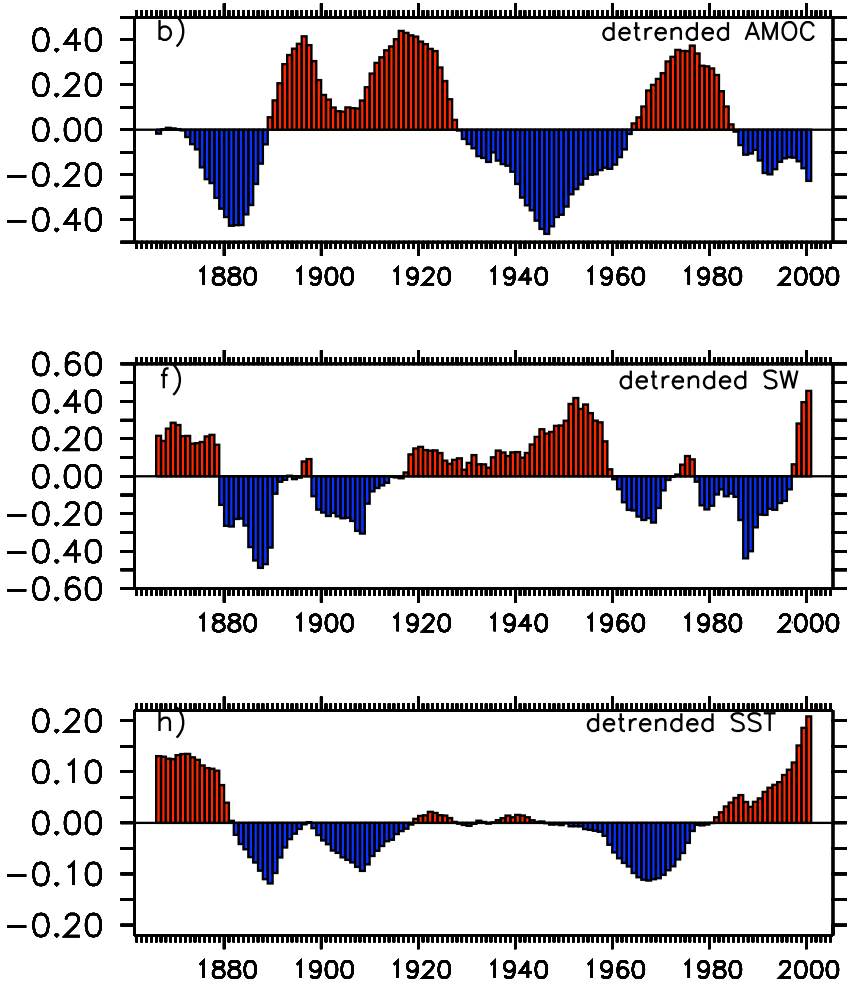


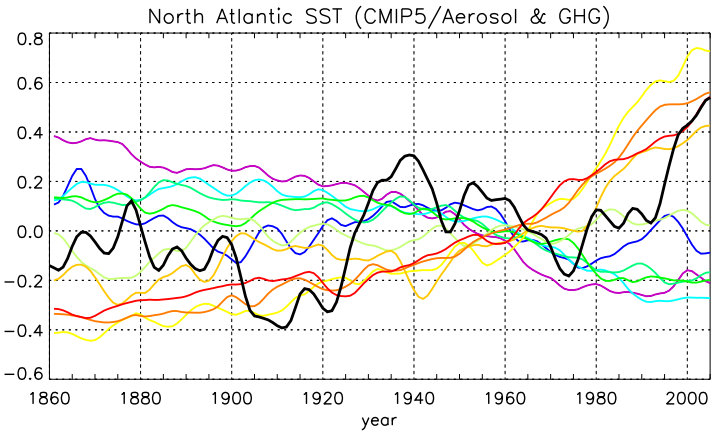






CMIP5 multi-model mean multidecadal SST





From Wei Cheng's talk

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