Hydroclimate Impacts of Atlantic Multidecadal Variability in CMIP5 Models

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Oct. 17, 2012

Atlantic Sector Climate Variability over the Last Millennium and the Near-Term Future

Lamont-Doherty Earth Observatory

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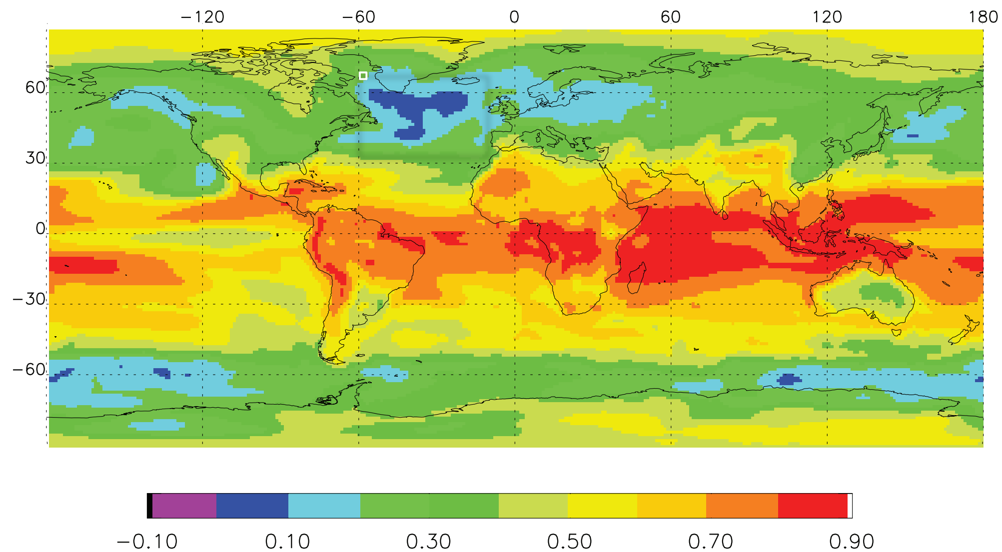
20th Century Forced to Total Variance Ratio

CMIP3 (Ting et al., 2009, J Clim.)

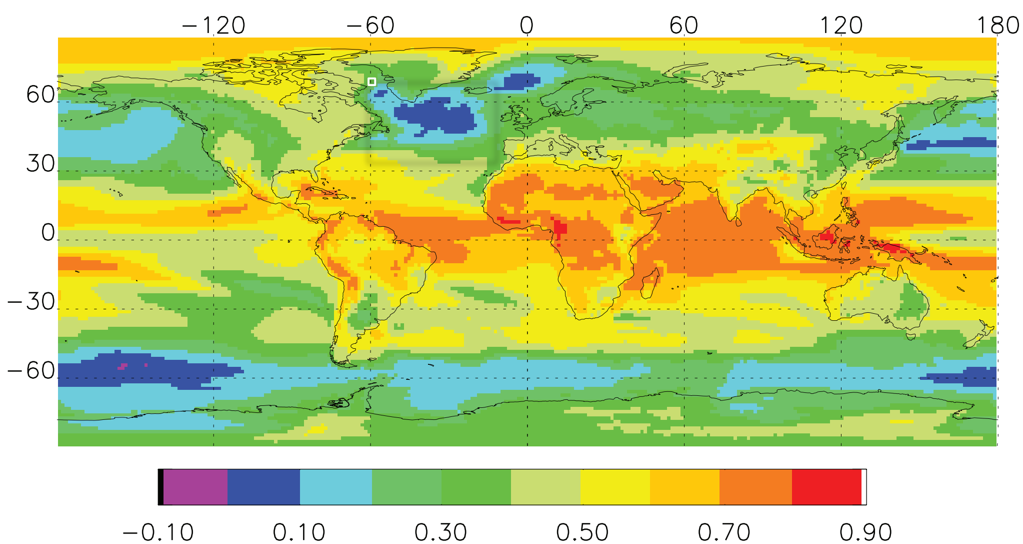


$$r = \frac{\sigma_F^2}{\sigma_T^2} = \frac{\sigma_a^2 - \frac{1}{N-1}\sigma_I^2}{\sigma_I^2 + \sigma_F^2}$$

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

M-years, N-ensemble members

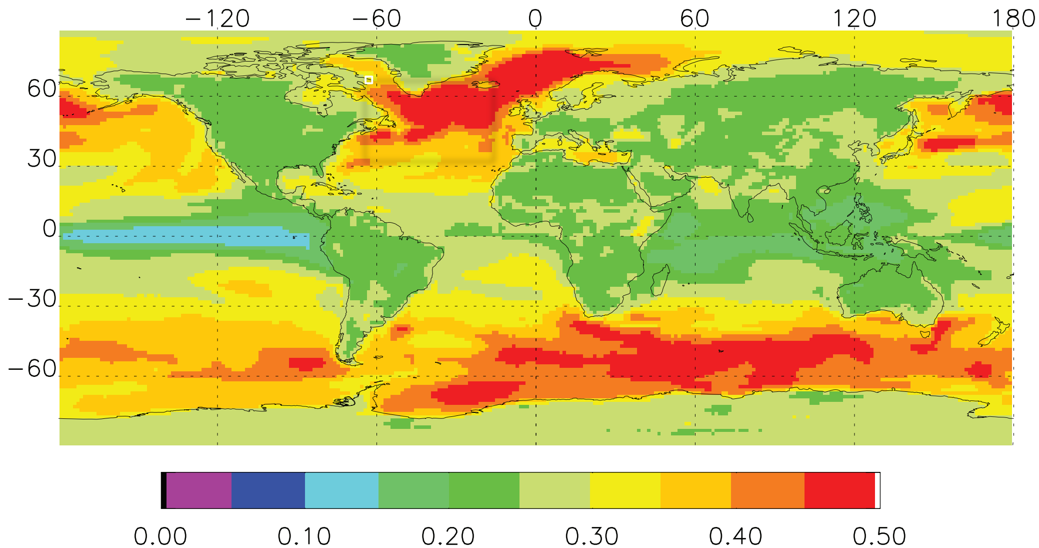
CMIP5 Models



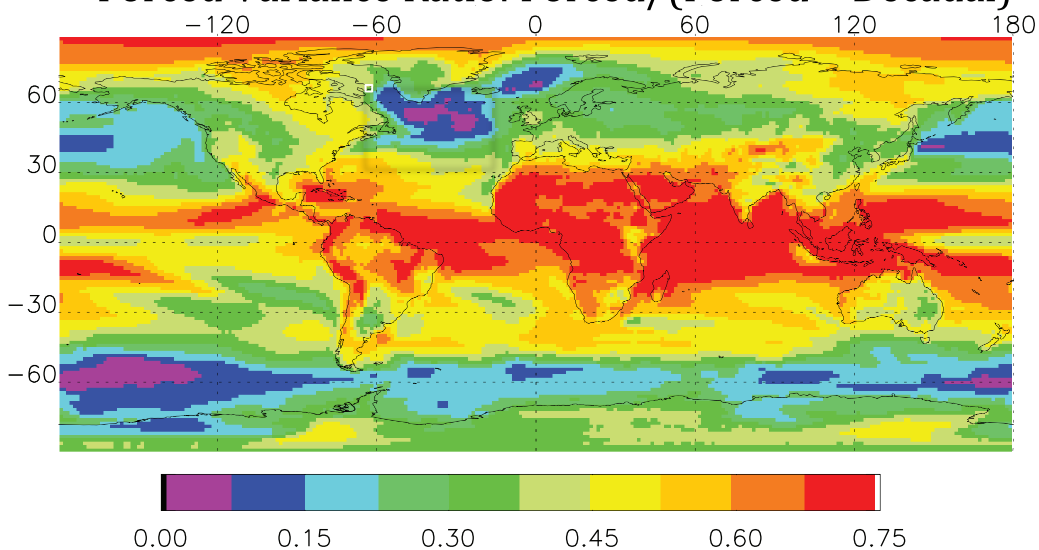
σ_I^2 : internal variance estimated from either the deviations from ensemble mean (CMIP3) or pre-industrial run (CMIP5)

Internal Decadal vs. Forced Variability

Internal Variance Ratio for Ts: Decadal/Total



Forced Variance Ratio: Forced/(Forced + Decadal)



- The North Atlantic, North Pacific, and the Southern Oceans are regions of high internal decadal and longer time scale variability.
- Decadal and longer time scale variability is relatively weak over land.
- Externally forced variance to total variance ratio is low in regions of high decadal internal variability

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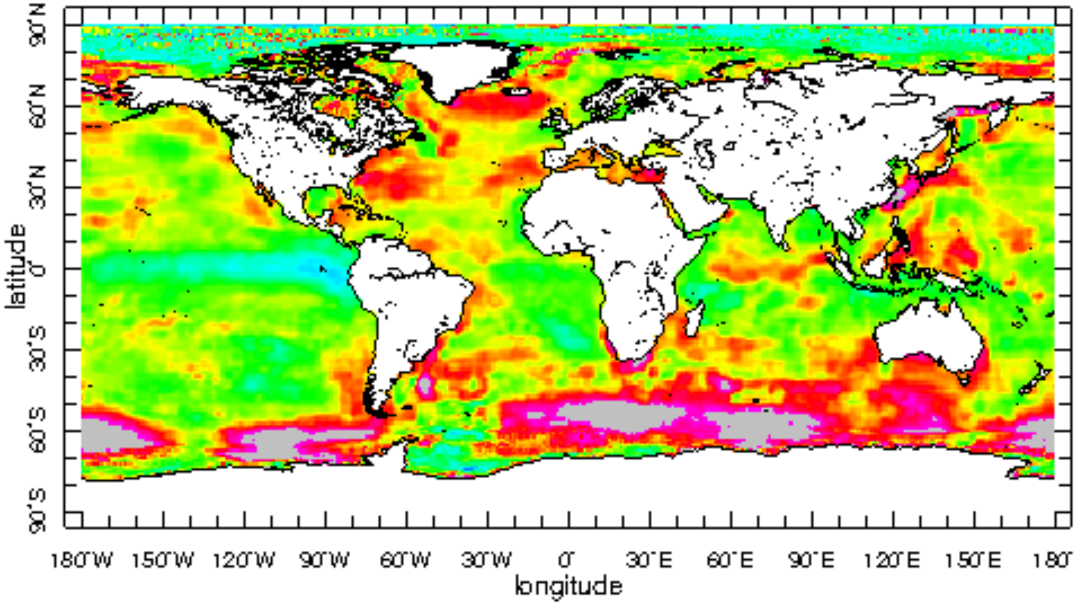
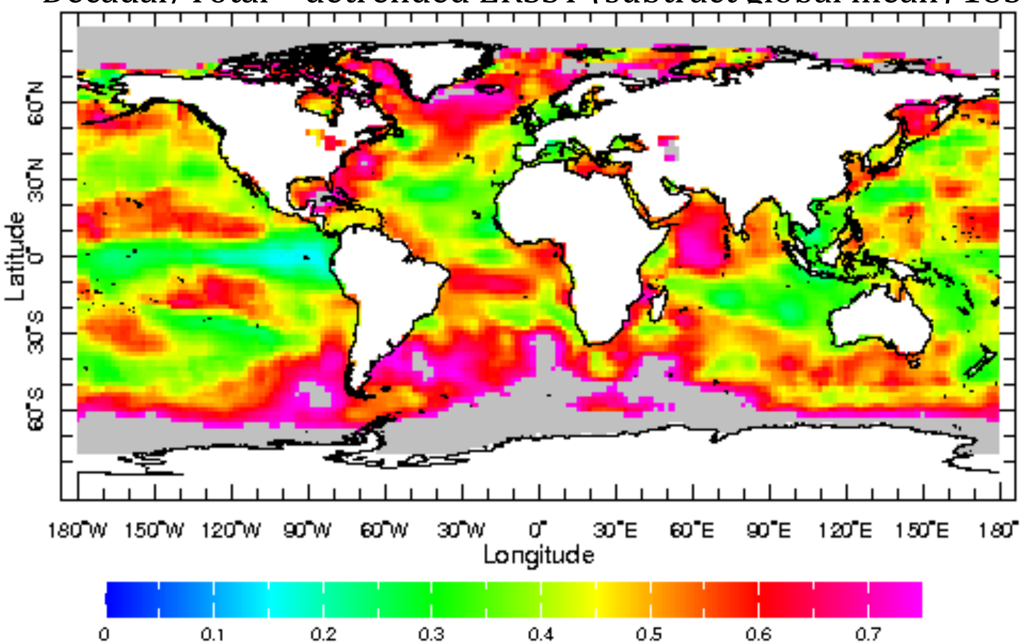
Decadal/Total – detrended HadiSST, 1870-2006

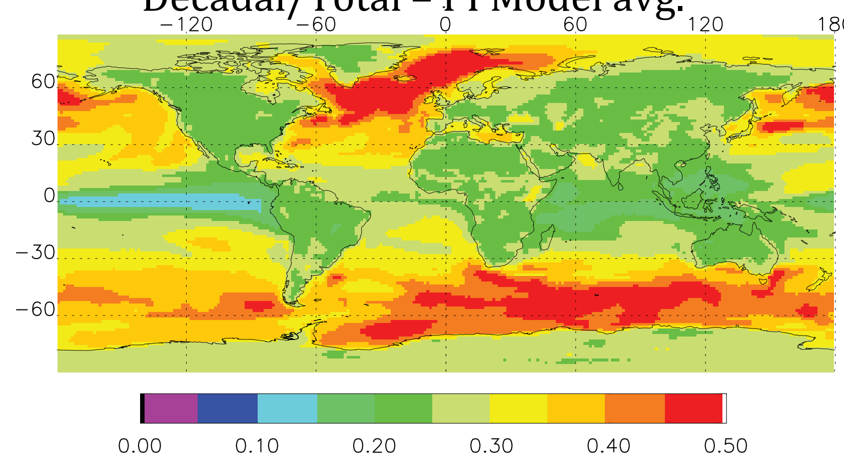


Observed ratio: Decadal variance/Total Variance

Decadal/Total – detrended ERSST (subtract global mean) 1854-2011



Decadal/Total – PI Model avg.



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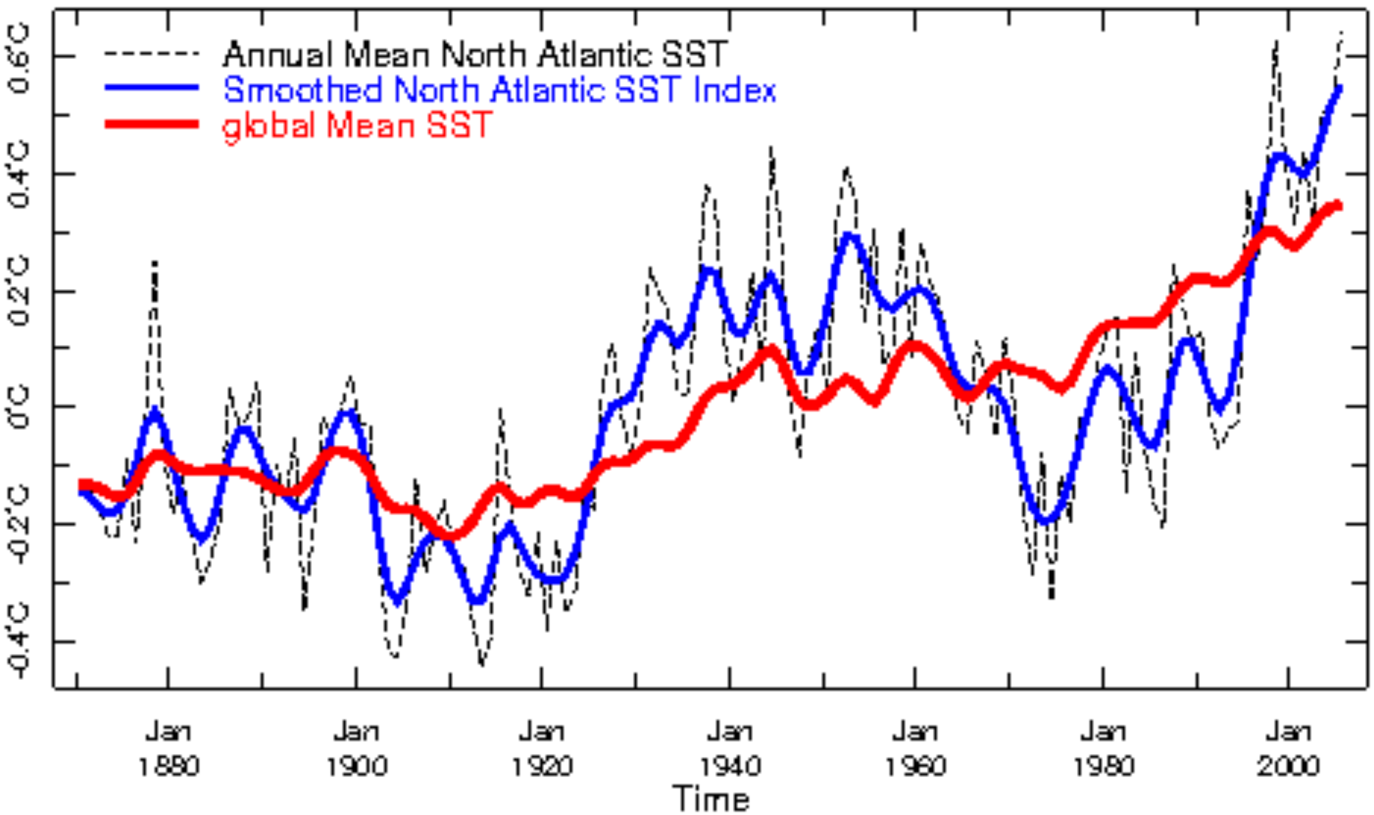
To what extent is 20th Century North Atlantic multidecadal variability externally forced?

HadiSST, 1870 - 2006



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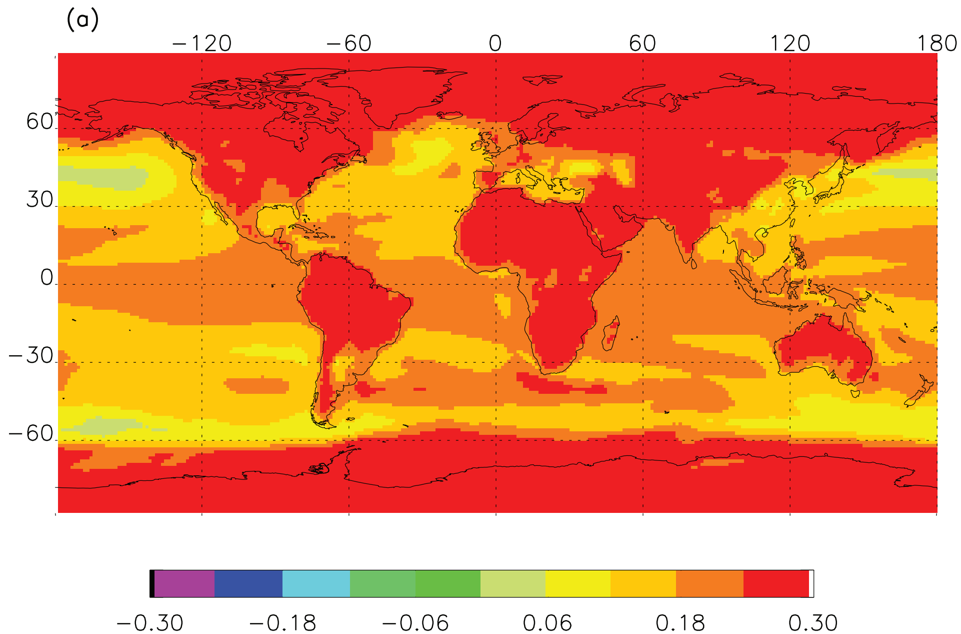
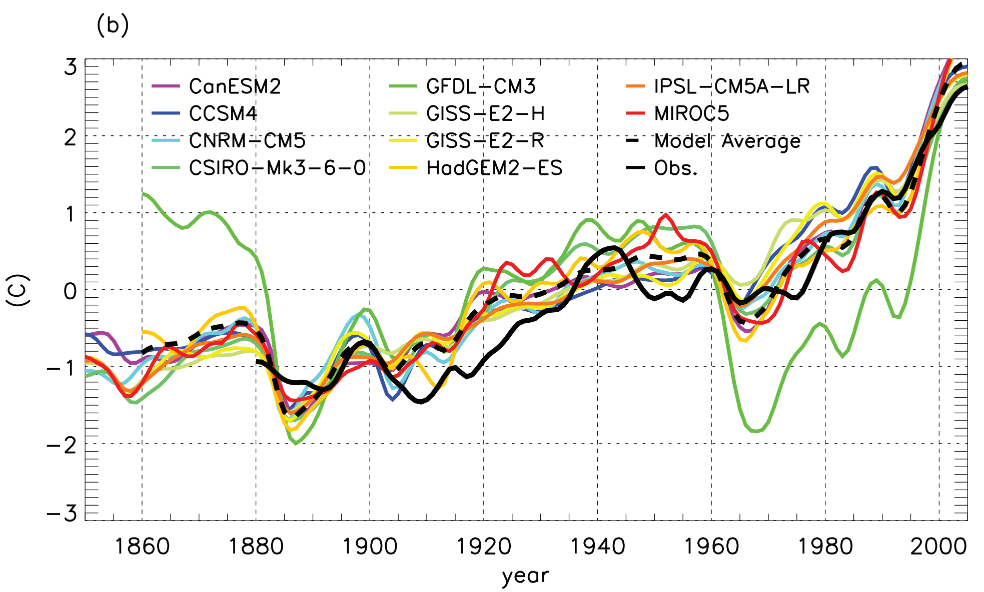
Signal-to-Noise Maximizing EOF Analysis (Ting et al., 2009)

- Allen and Smith, 1997; Venzke et al., 1999; Chang et al., 2000
- Apply EOF analysis to deviations from ensemble average to determine the spatial structure of the internal modes of variability
- Apply a spatial pre-whitening transformation based on the internal EOFs to remove the spatial correlations in the internal atmospheric variability (i.e., "climate noise") contained in the ensemble average



Regression of global surface temperature and PC1, averaged over ten CMIP5 models



S/N maximizing PC1 of the CMIP5 historical simulations + observed global mean SST

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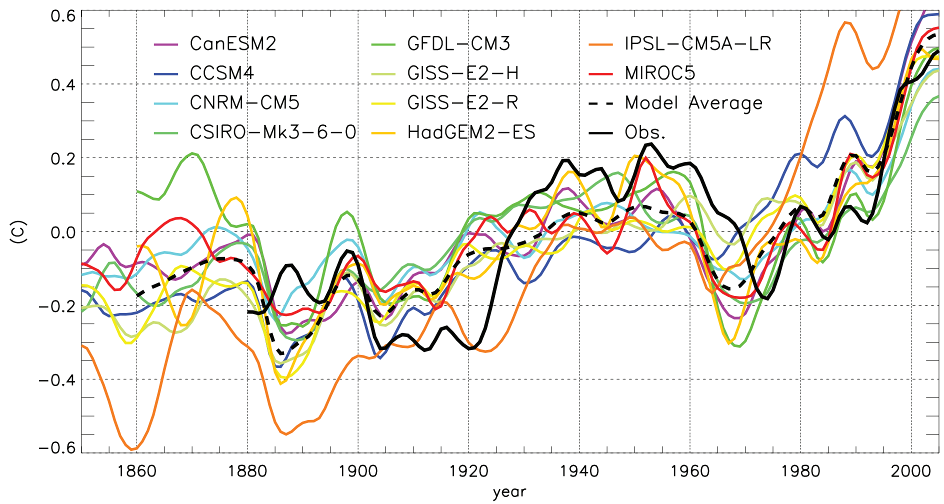
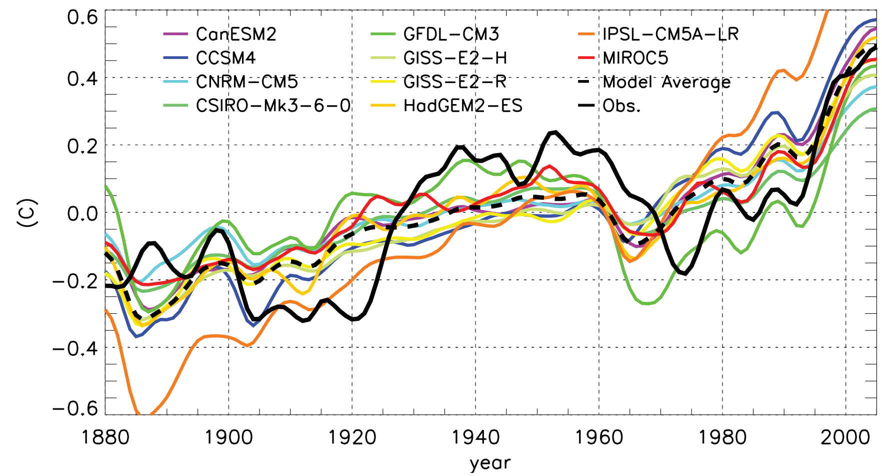
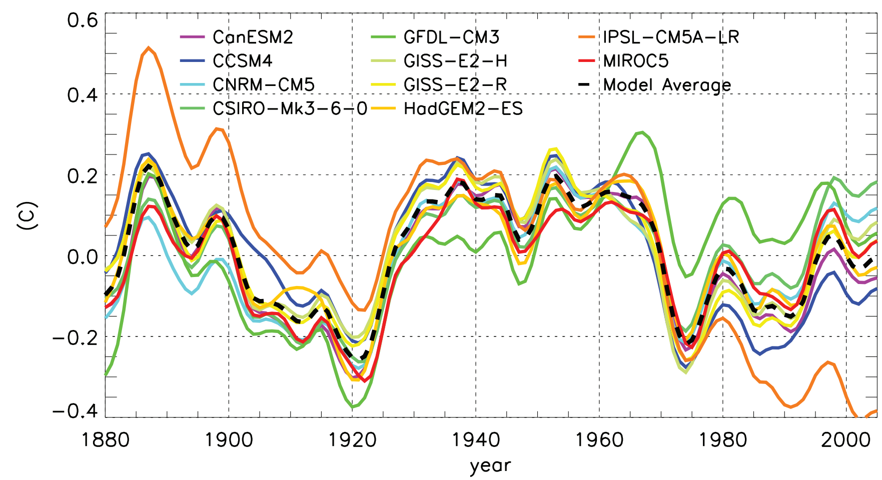
Ensemble averaged NASSTI



Model NASSTI Regressed to S/N PC1



Observed NASSTI regression residual



- Externally forced signals in CMIP5 models do not show the abrupt ups and downs in NASST as observed
- Observed trend in last 30 years or so matches well with the forced upward trend in CMIP5 NASST

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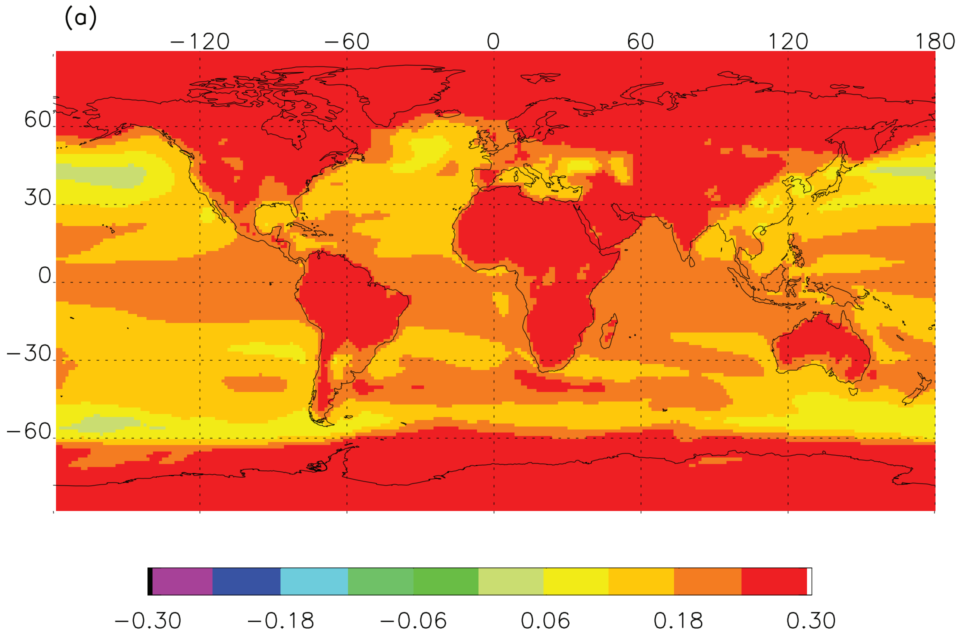
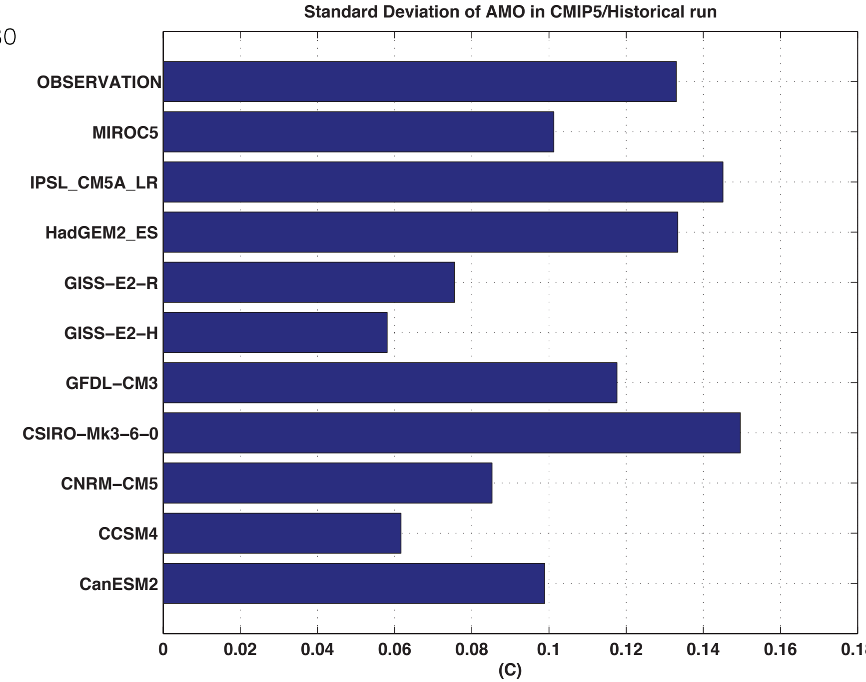
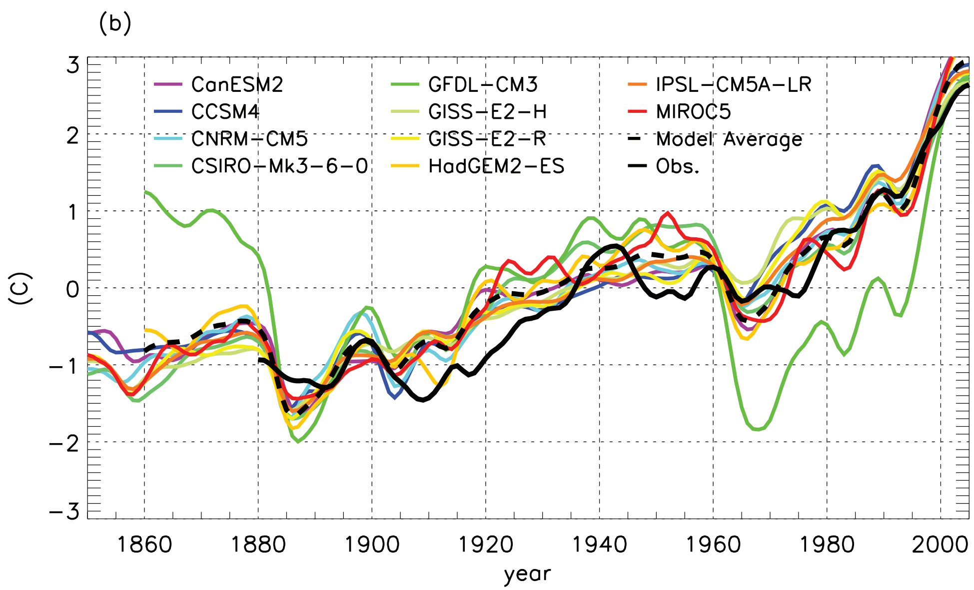
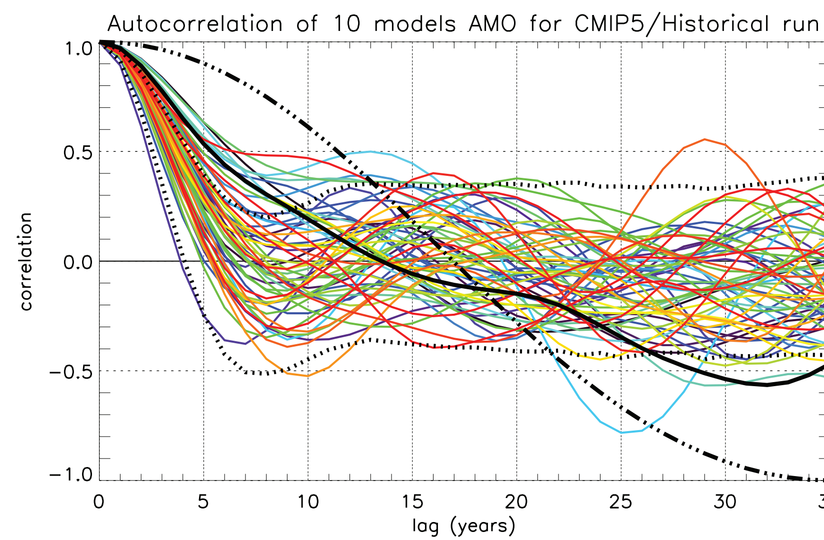
Forced vs. Natural Atlantic SST Variability in CMIP5









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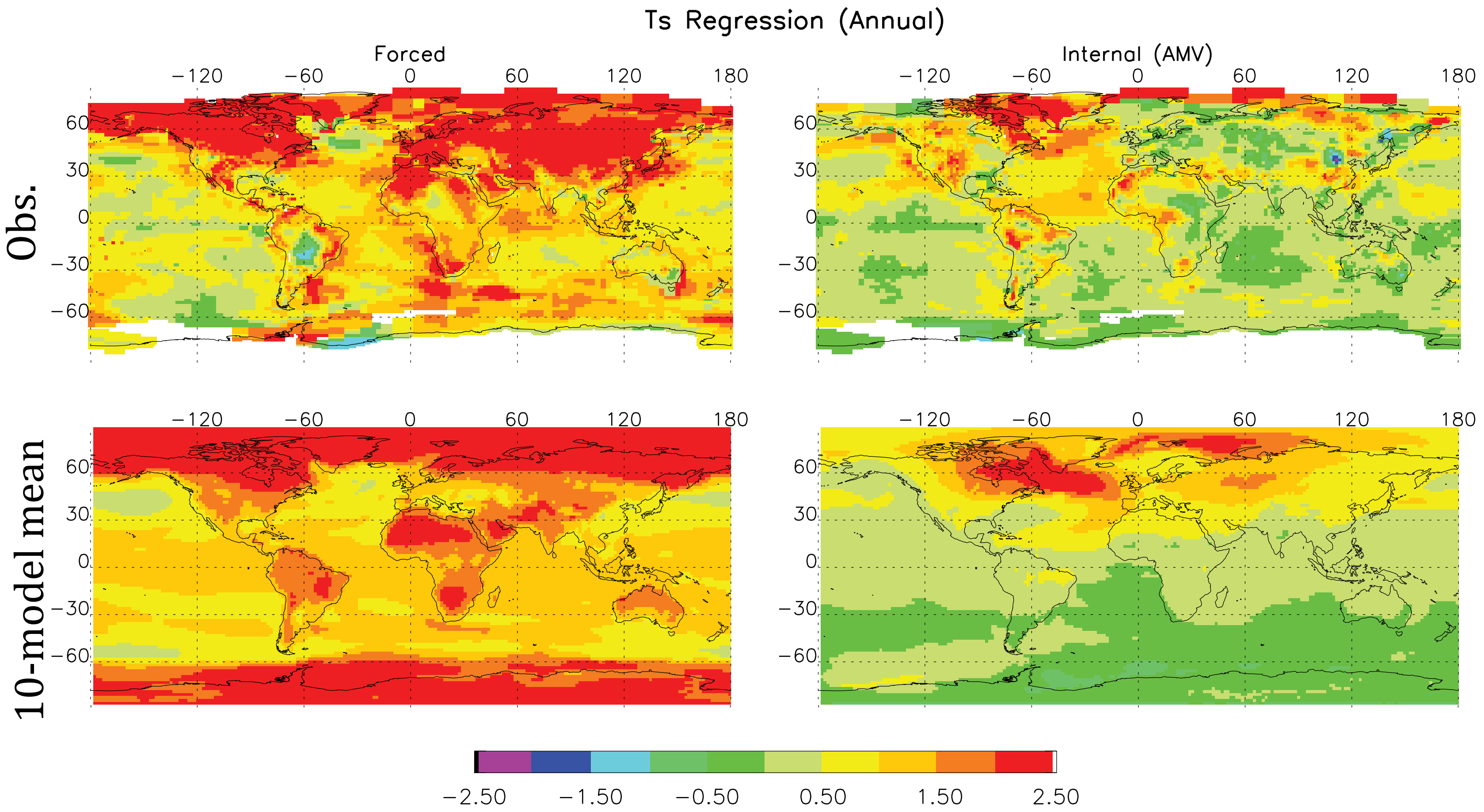
Are forced and internal AMV distinct in its spatial structure?



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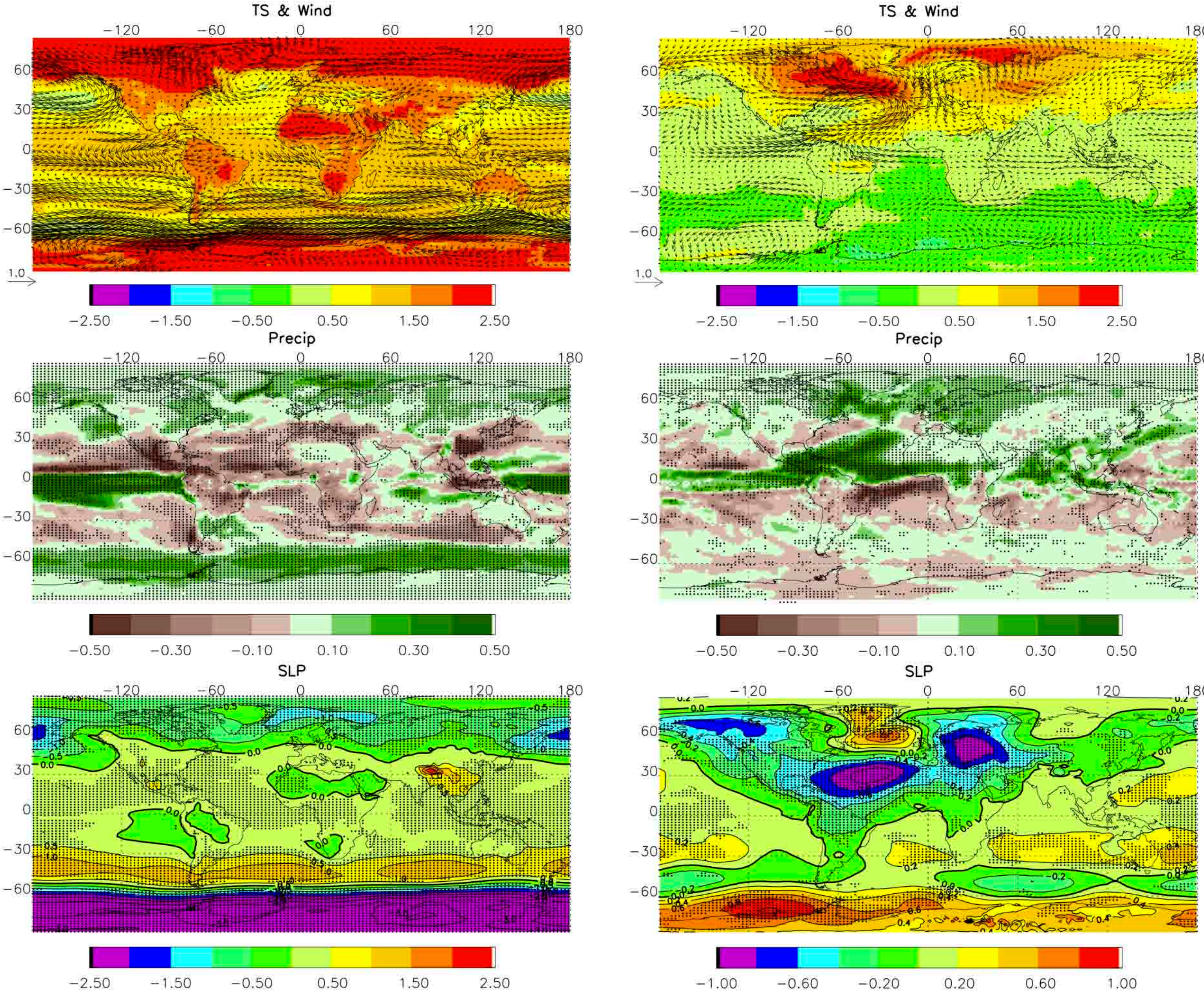
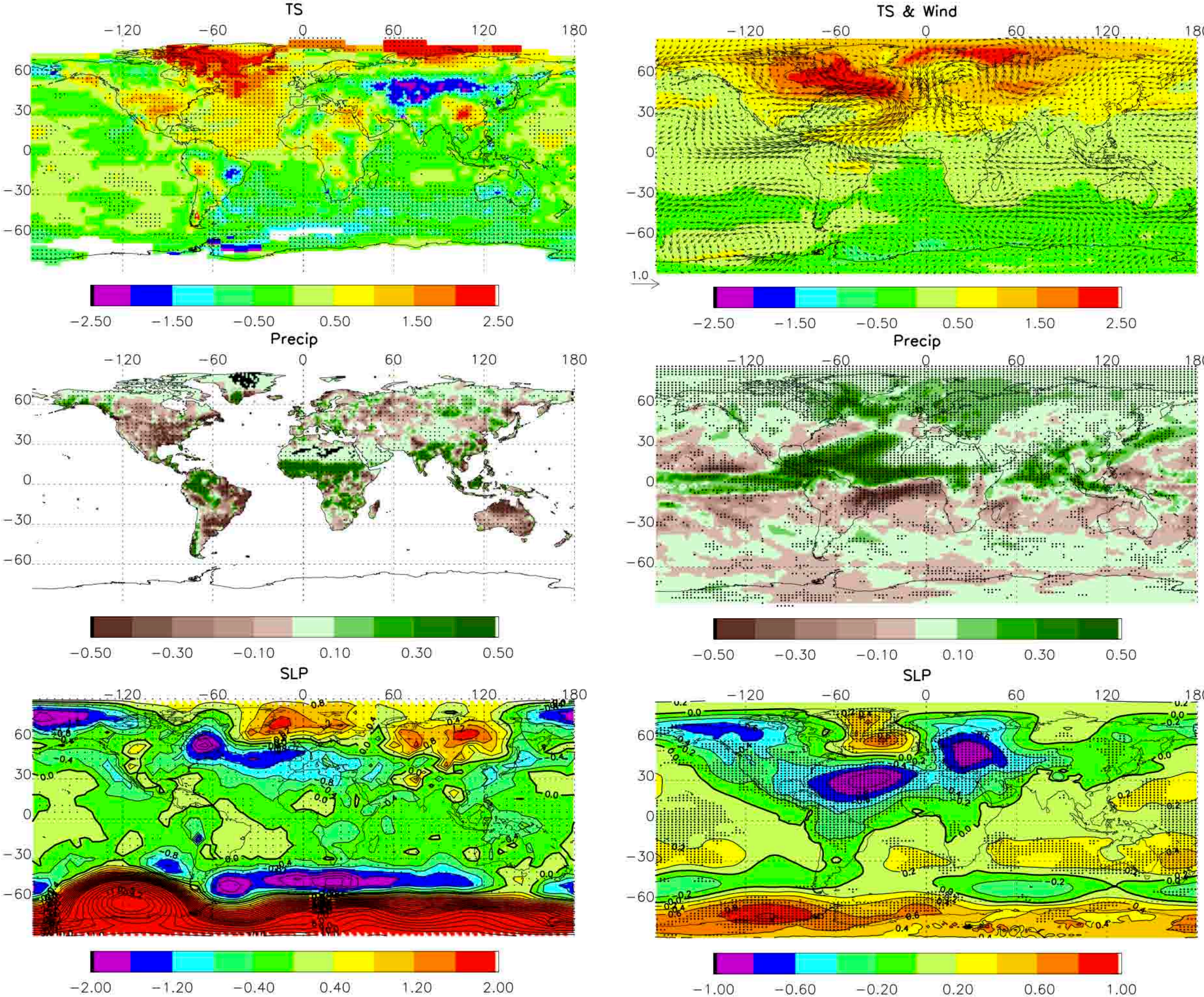
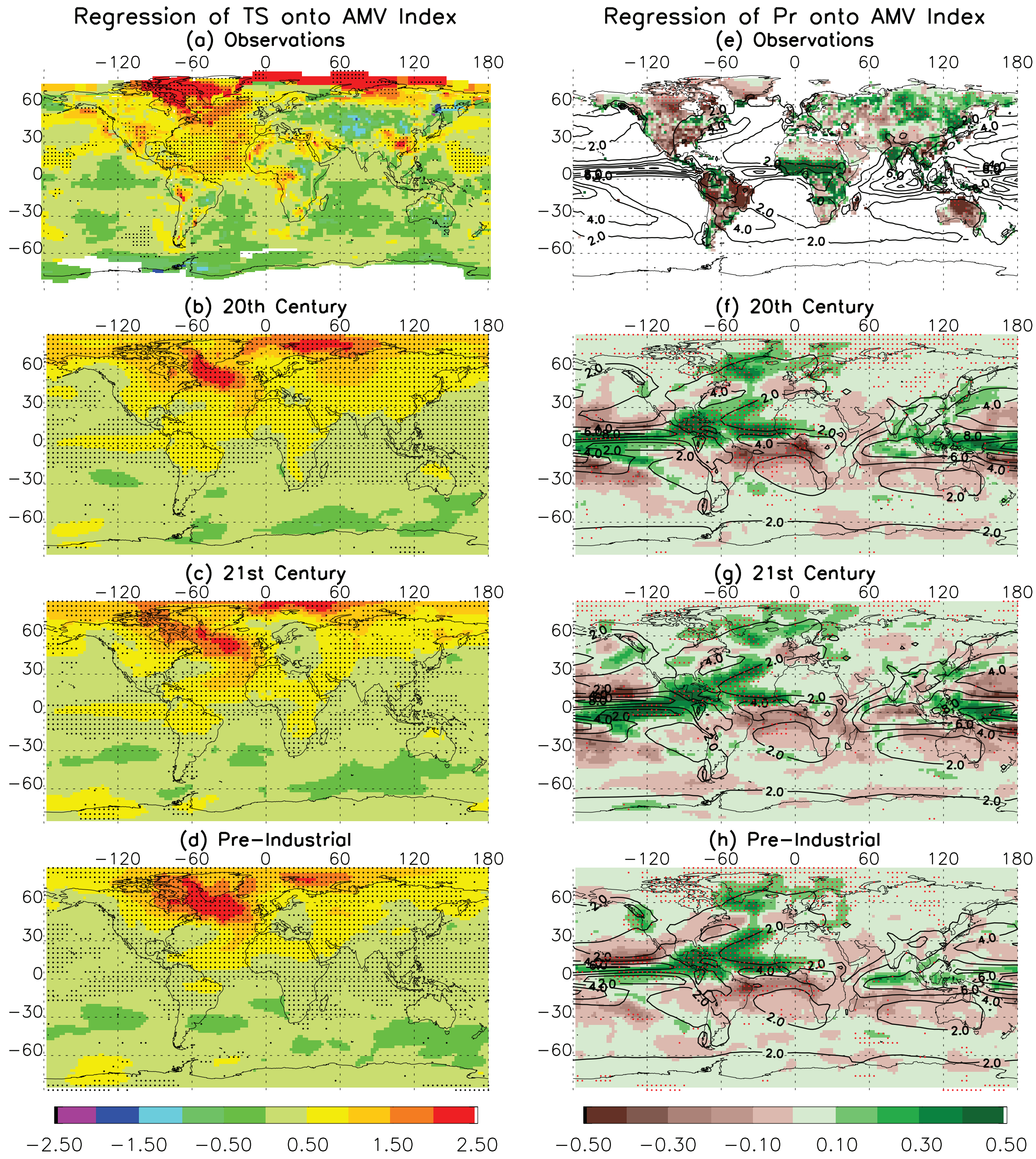
Forced (left) vs. Internal (right) Atlantic Variability



AMV regression for Observation (left) and CMIP5 Historical (right)



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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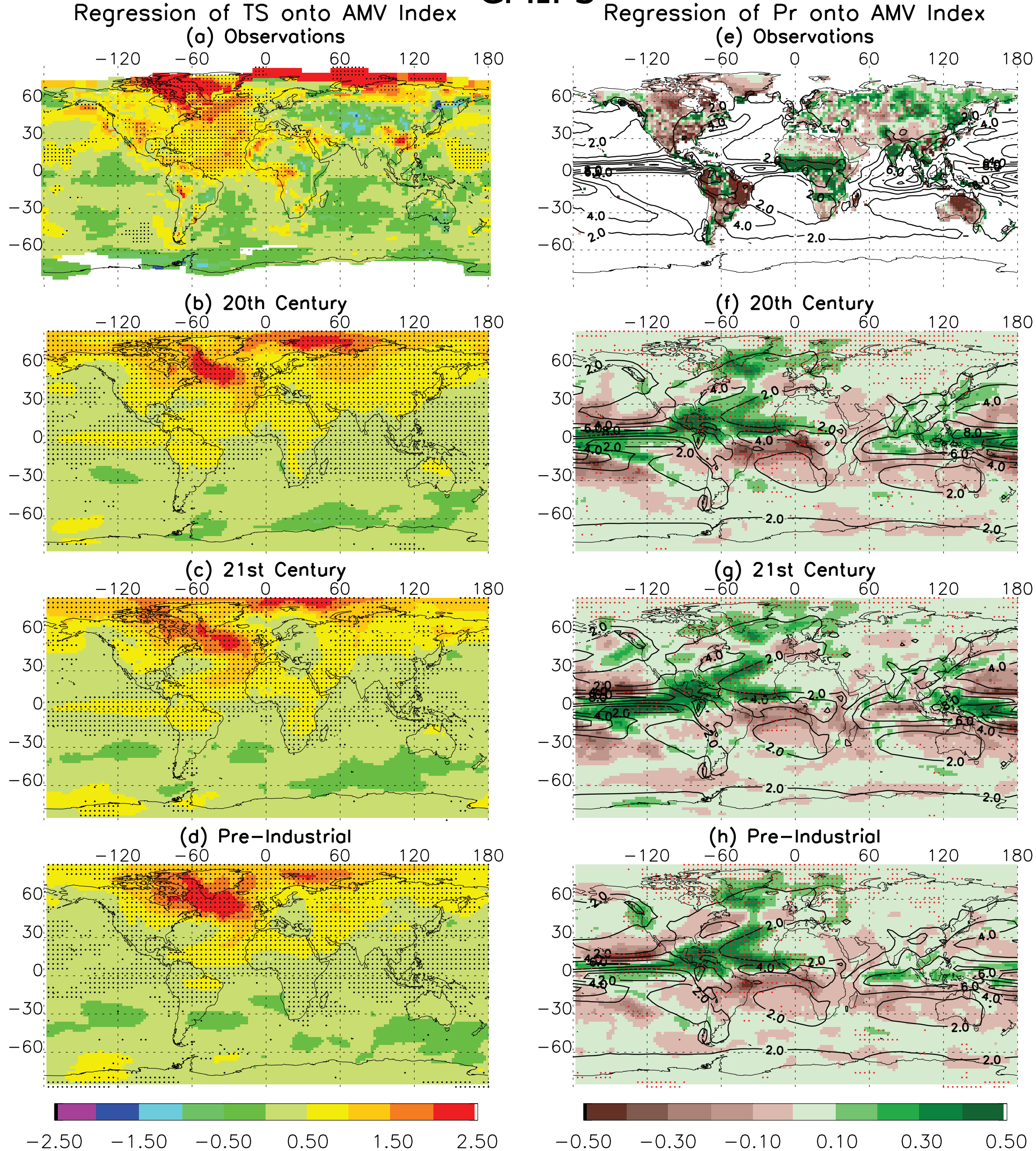
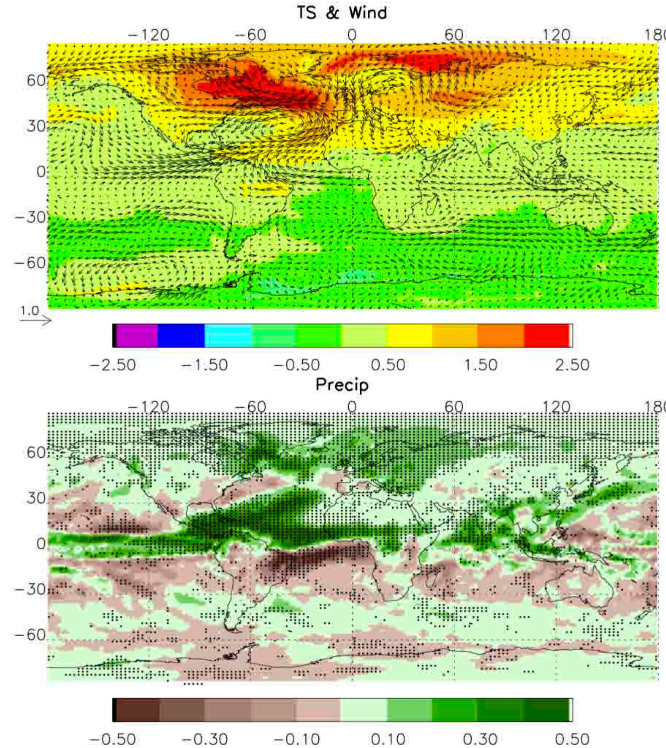
CMIP3



CMIP5 Historical



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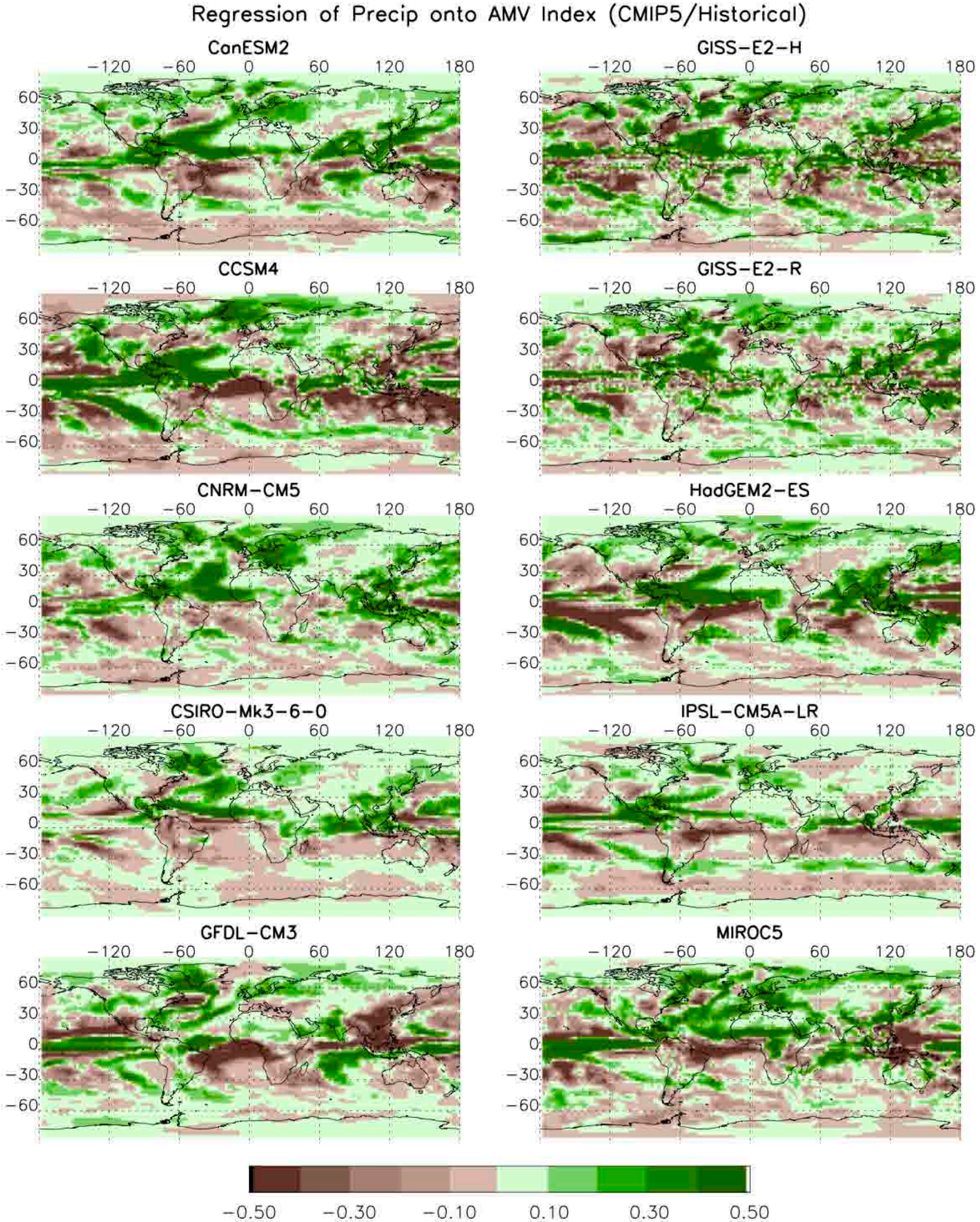

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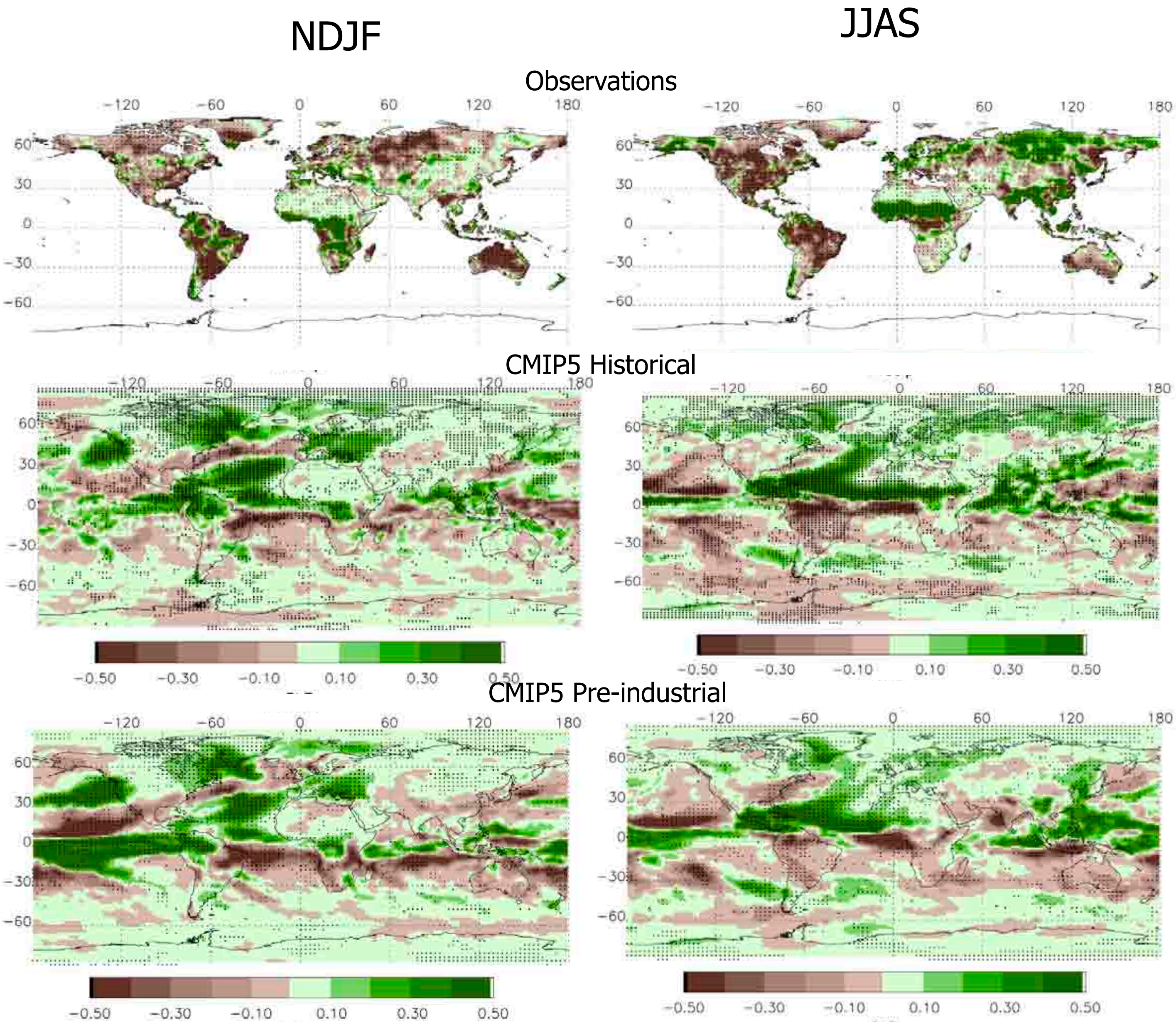
Questions

- What are the roles of subpolar and subtropical AMV SST anomalies in impacting hydroclimate?
- What role does decadal ENSO play in hydroclimate impacts of the AMV?
- Seasonality?



- Observed North American drying associated with positive AMV mainly in summer.
- Models show much less North American drying than in observations
- Robust rainfall signal in Sahel rainfall in summer for both observations and models
- Northeast Brazil dries more in JJAS in observations, but in models, more drying seen in NDJF

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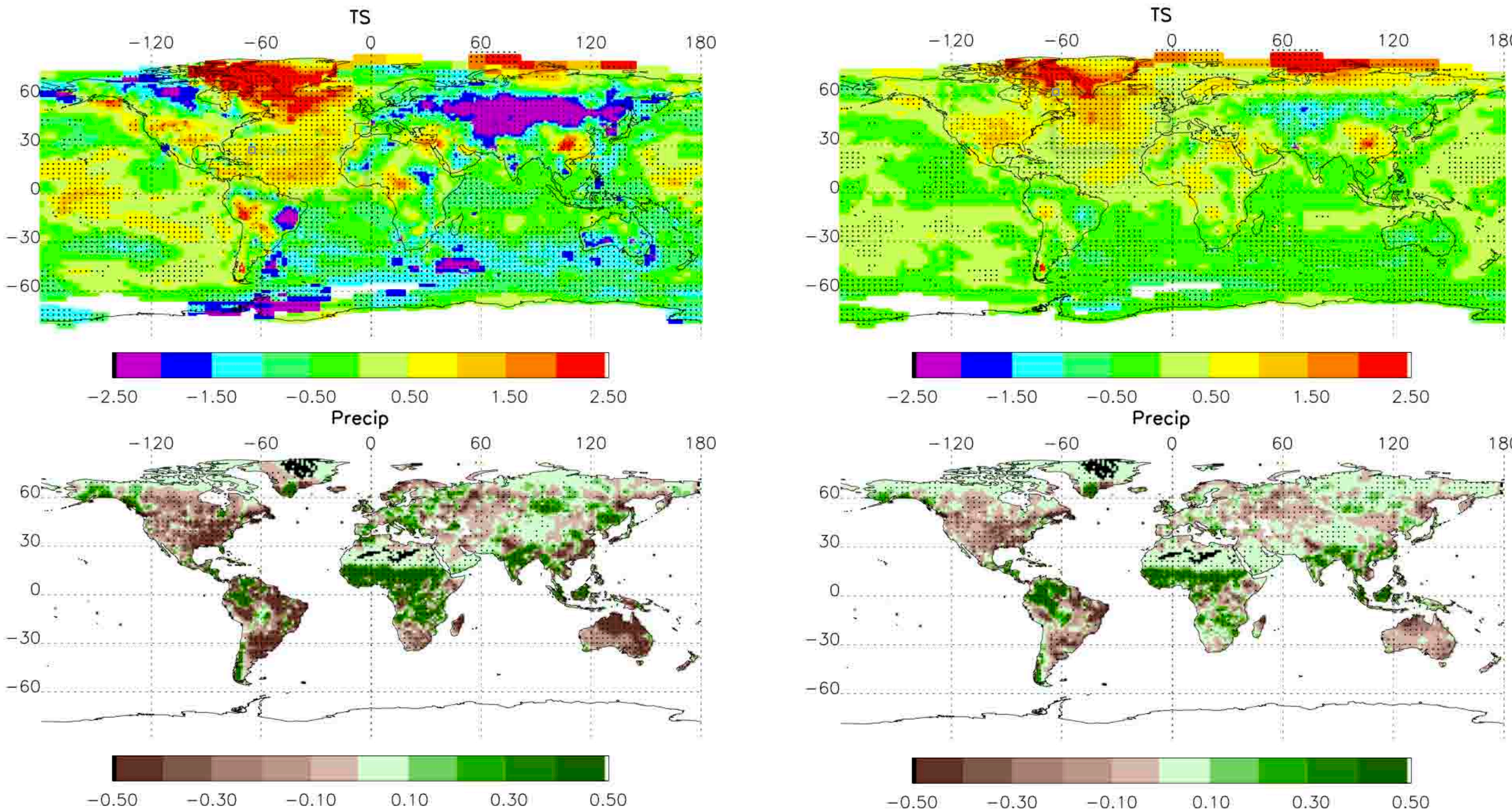
Obs. Subtropical (left) vs Subpolar (right) SST Impacts



- Observed subtropical and subpolar AMV SST impacts on precipitation very similar
- Subtropical AMV dominates over all regions
- No clear ENSO signal in the tropical Pacific

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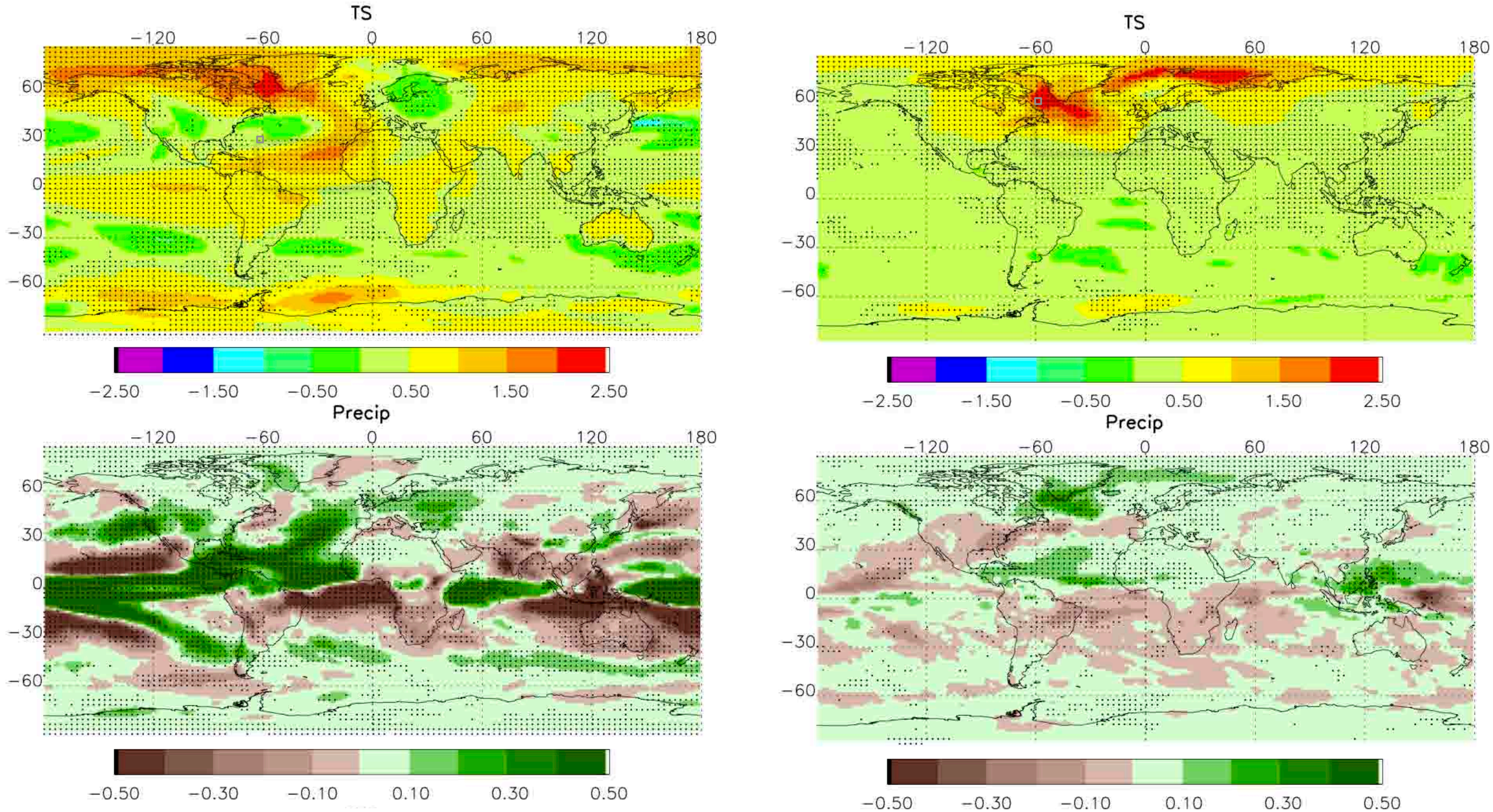
CMIP5 Pre-Industrial Subtropical (left) vs Subpolar (right) SST Impacts



- Very little connection between subpolar AMV and tropical Atlantic SST
- Large El Nino signal in tropical Pacific associated with subtropical AMV
- Lack of North American drying in models due to subtropical AMV

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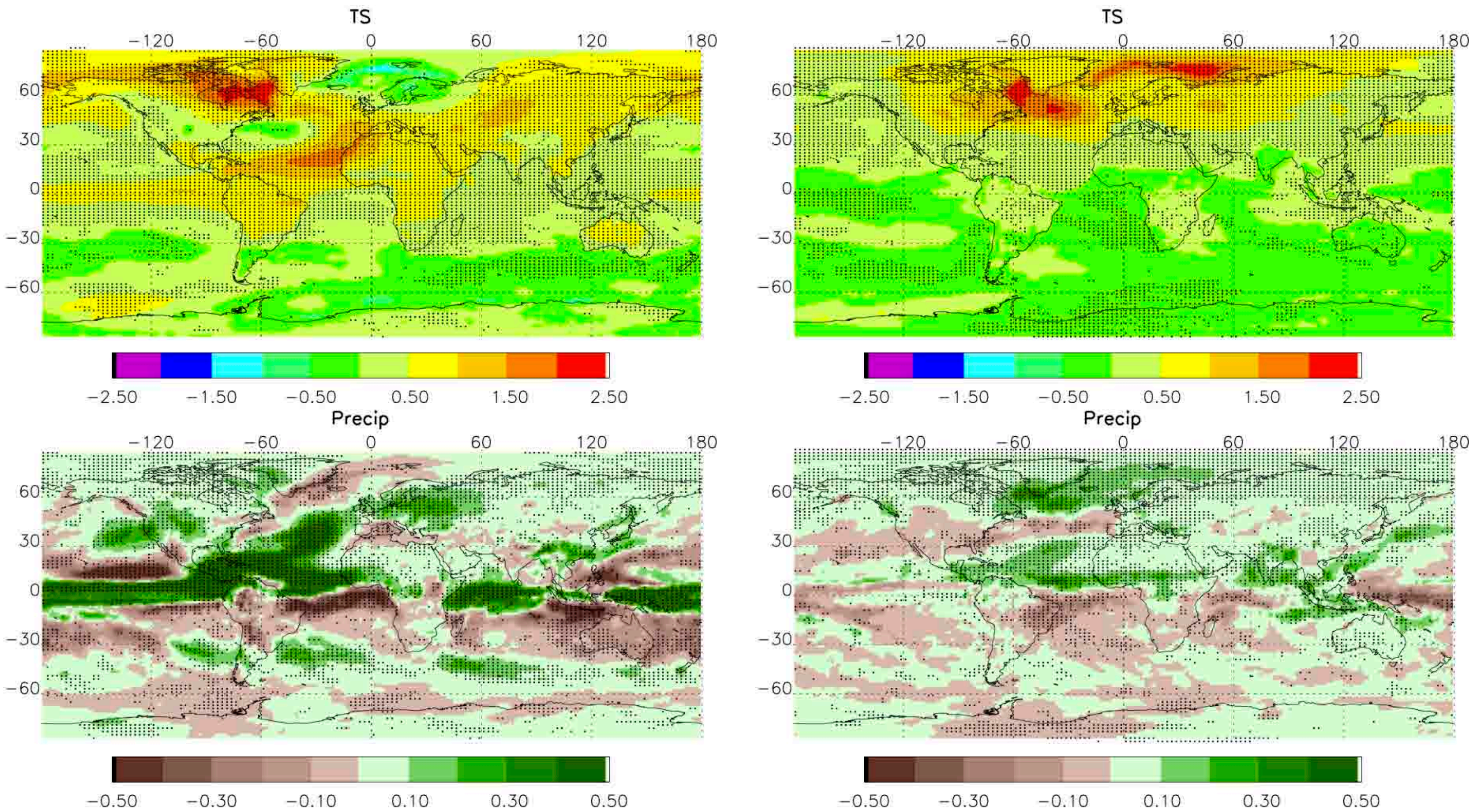
CMIP5 Historical Subtropical (left) vs Subpolar (right) SST Impacts



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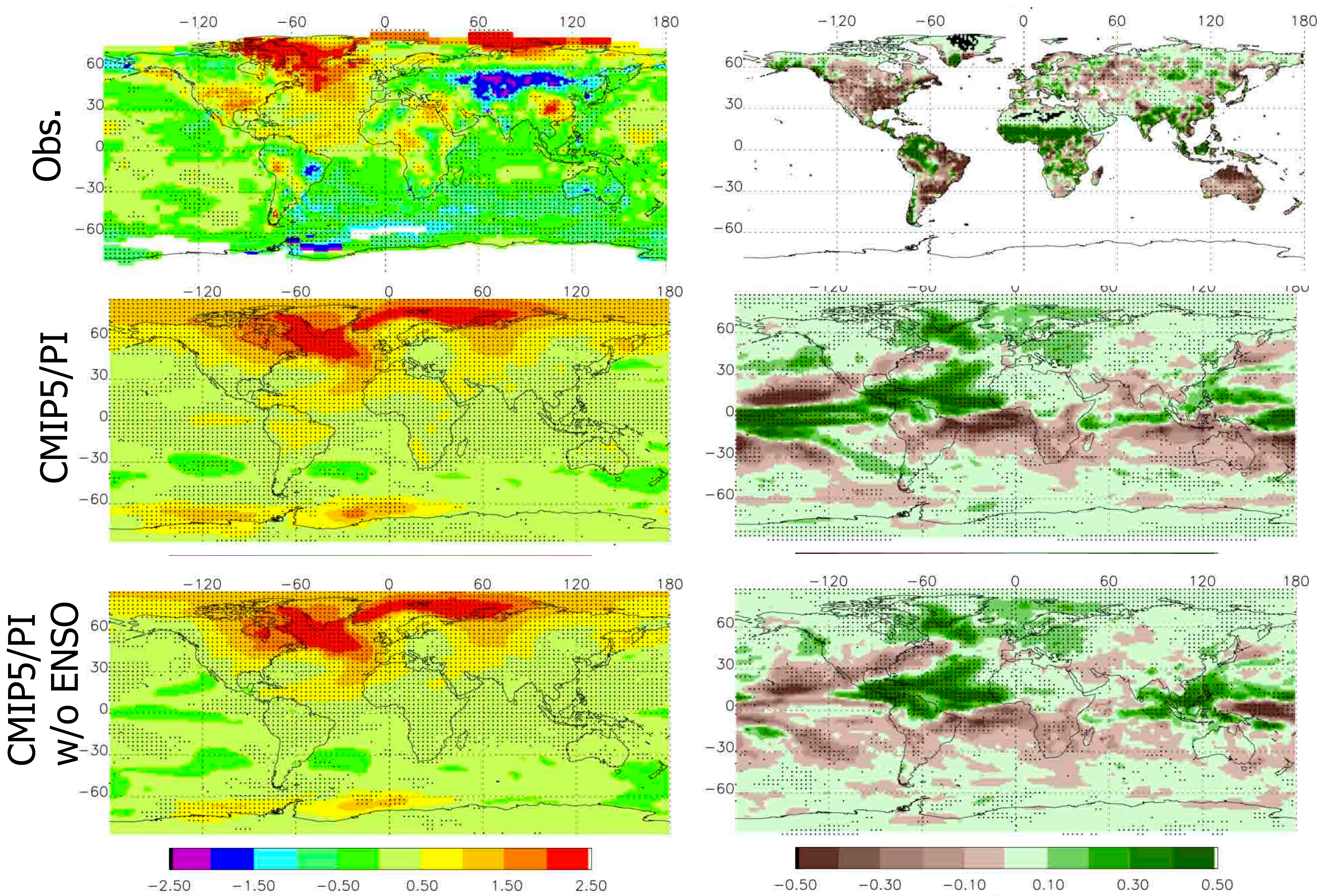
AMV Impacts With and Without Decadal ENSO



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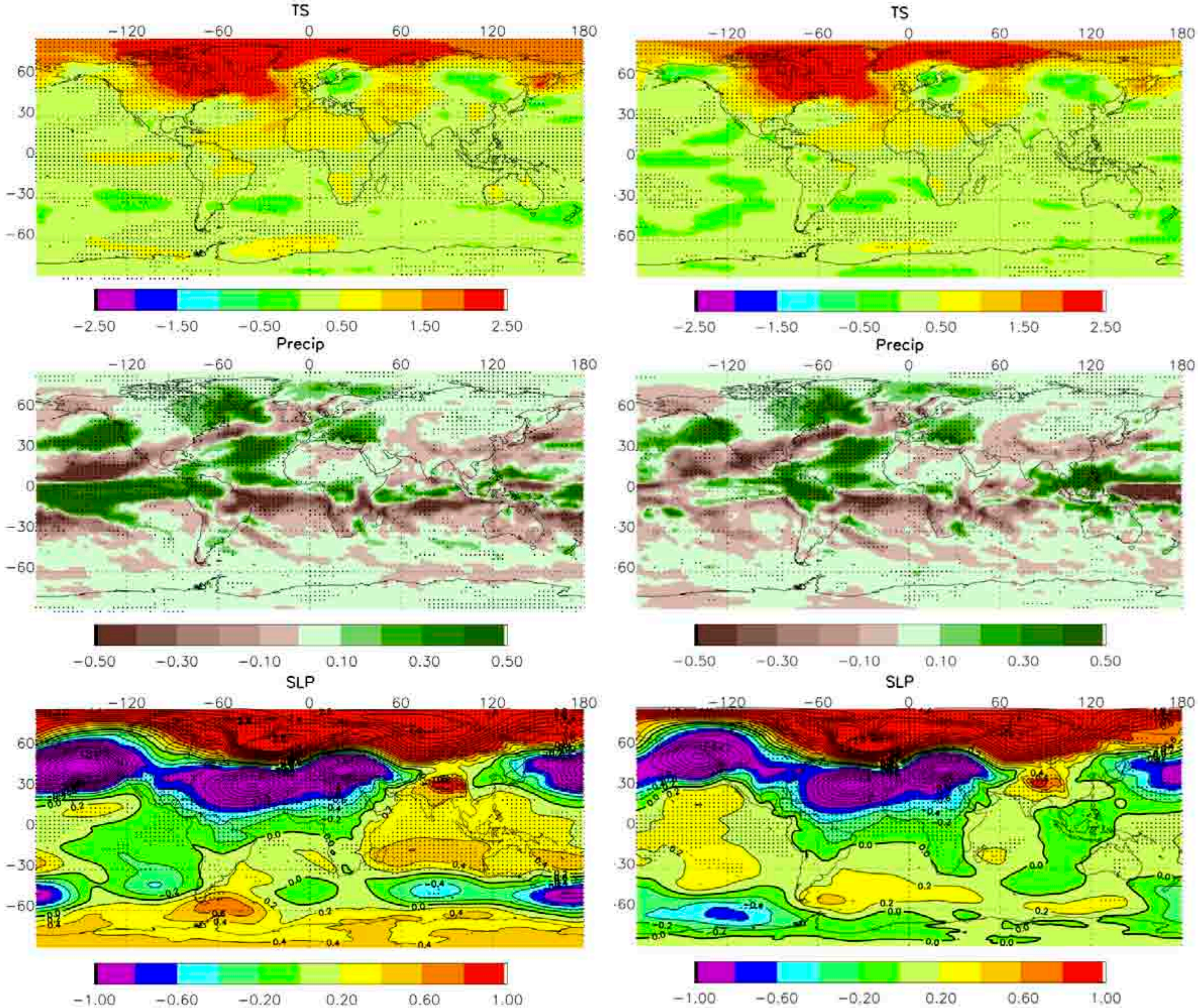
NDJF AMV Impacts With (left) and Without (right) Decadal ENSO



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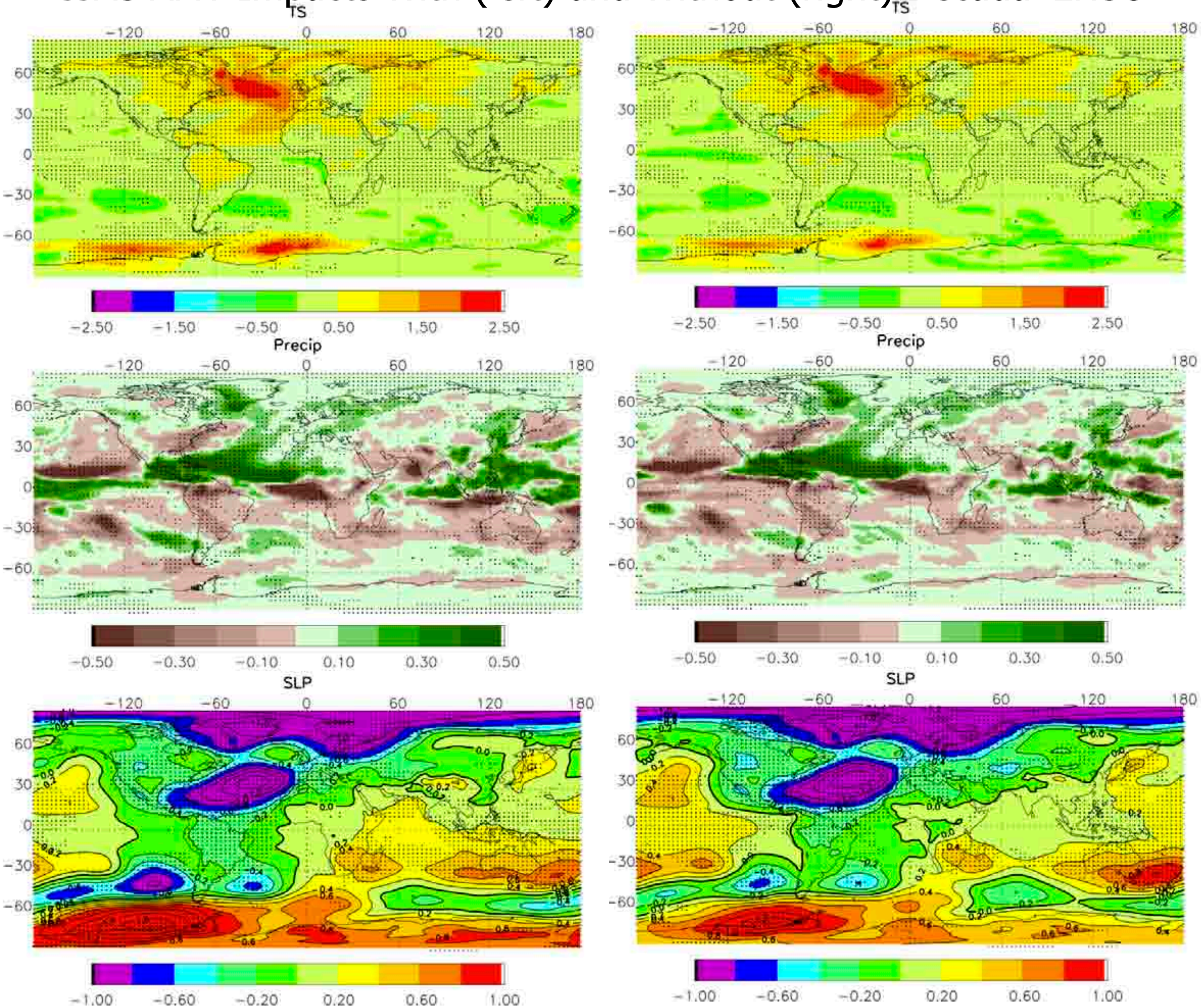
JJAS AMV Impacts With (left) and Without (right) Decadal ENSO



Summary

- North Atlantic, North Pacific and the Southern Oceans are regions of high decadal and longer SST variability.
- The North Atlantic decadal and multidecadal SST variability has distinct forced and natural component.
- The 20th Century observed North Atlantic multidecadal SST variability can be attributed to a pattern associated with global climate change and a component due to internal coupled ocean-atmosphere variability.
- CMIP3 and CMIP5 models show robust SST spatial patterns and climate responses, which are shown to be insensitive to external radiative forcing.
- ENSO decadal variability plays a more dominant role in CMIP5 models pre-industrial runs compared to observations. Removing decadal ENSO brings the Atlantic SST pattern closer to observations and improves the precipitation responses over the Indian monsoon region and the US SW, but not over the Sahel.
- Decadal ENSO influences are mainly in the northern winter season, whereas the removal of decadal ENSO didn't change significantly the precipitation responses.

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