Atlantic Multidecadal SST Variability in CMIP3 and CMIP5 models and related global impacts

Ting, Mingfang; Camargo, Suzana; Kushnir, Yochanan; Li, Cuihua
Cooperative Institute for Climate Applications and Research
Lamont-Doherty Earth Observatory, Columbia University

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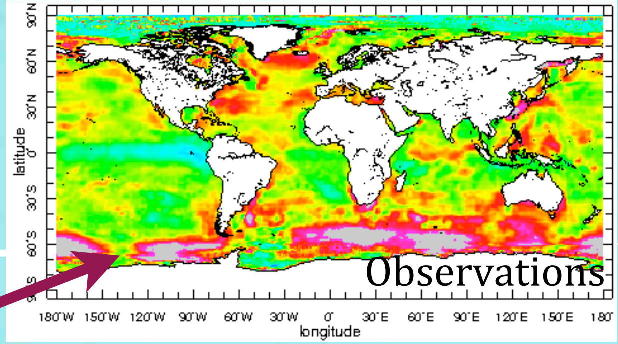
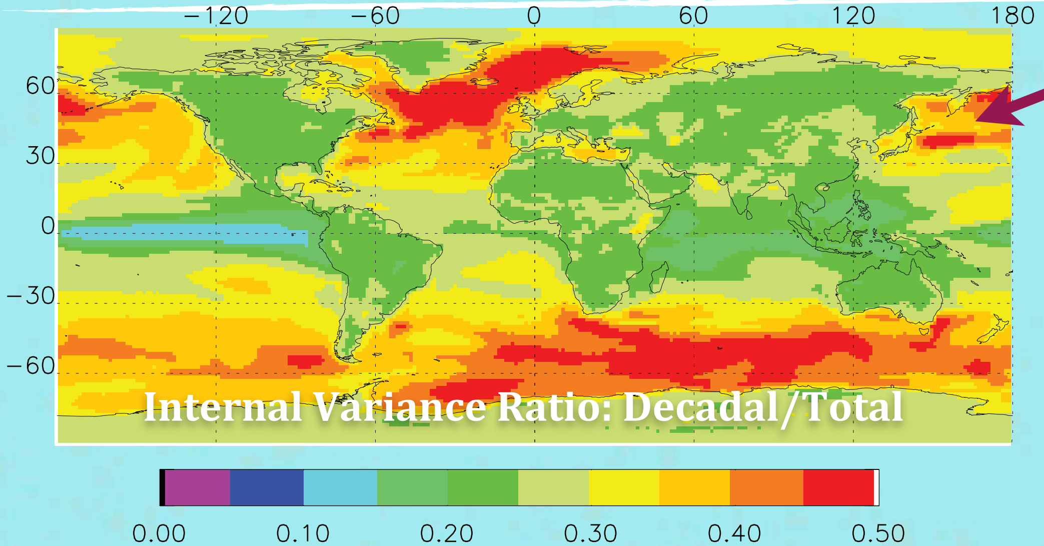
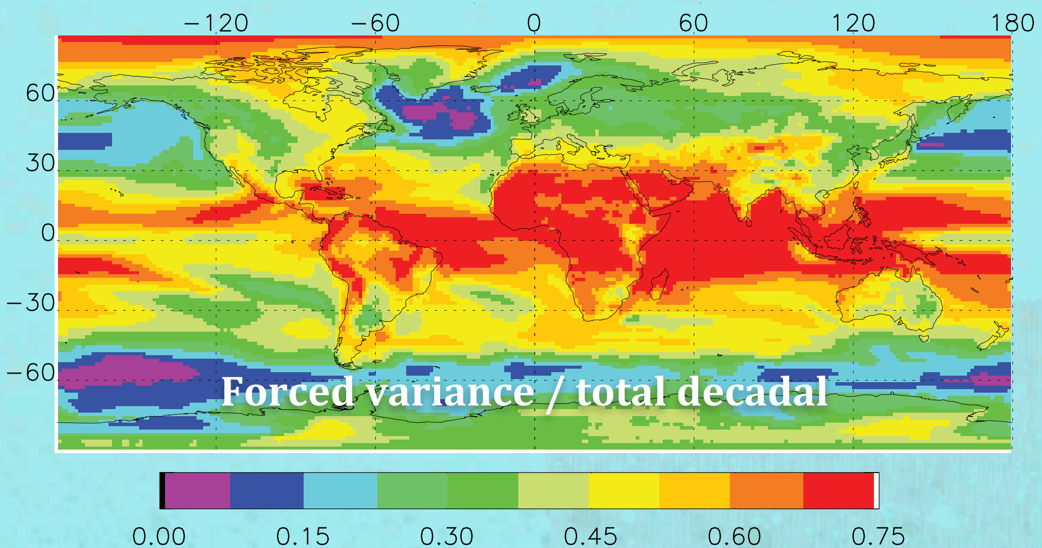
Outline

- Is AMV (of SST) a robust low-frequency mode in CMIP5 models?
    - *How do forced and internal long-term Atlantic SST variability compare?*
    - *What is the impact of AMV on global climate?*
    - *What can we learn from comparing observed and simulated AMV?*
- How did AMV and external forcing influence tropical Atlantic hurricane potential intensity during the 20th century?

Internal vs. externally forced variability





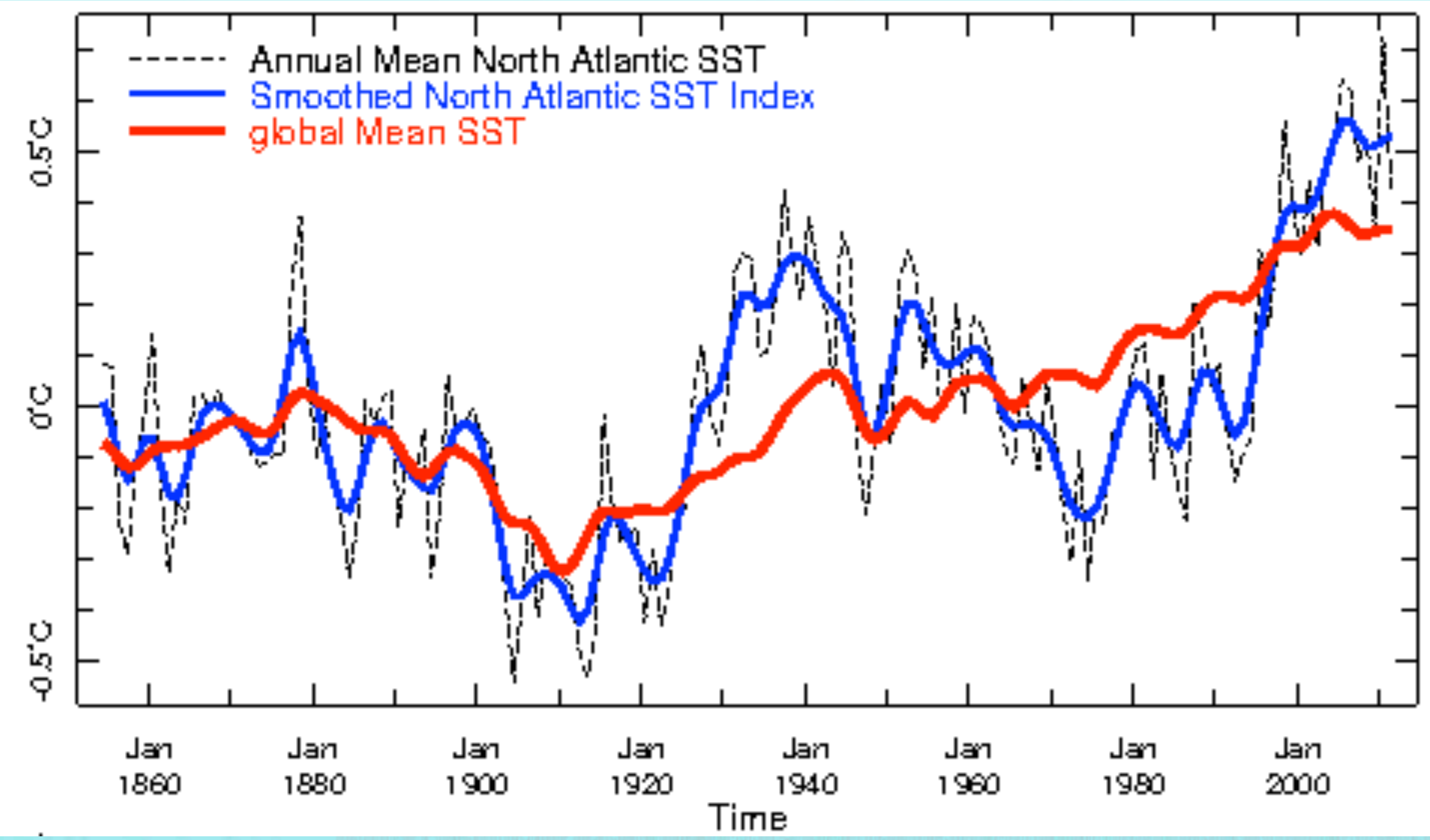


- The North Atlantic, North Pacific, and the Southern Oceans are regions of high internal decadal variability.
- Decadal and longer time scale variability is relatively small over land.
- Externally forced variance to total variance ratio are low in regions of high decadal internal variability

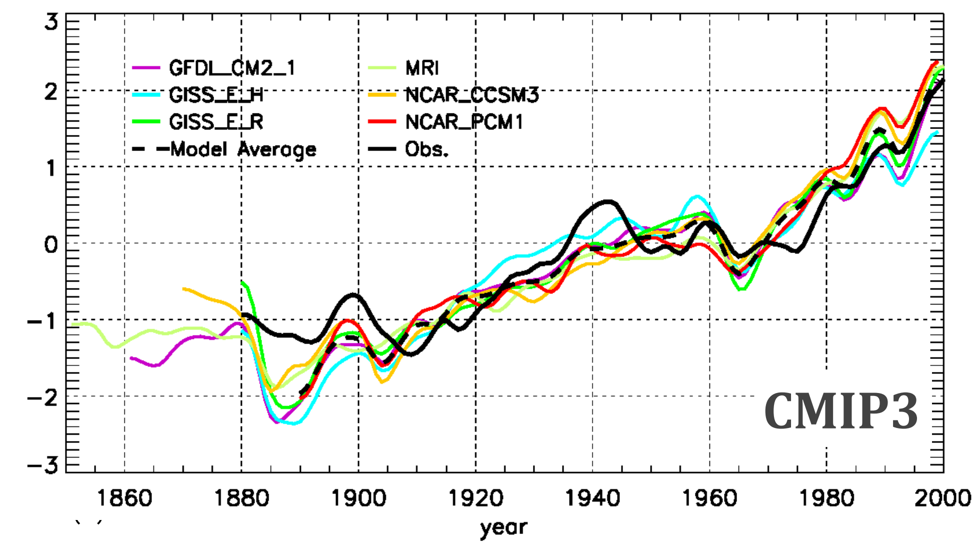
(CMIP5 model output; top figure is derived from pre-industrial integrations; bottom: ANOVA of models with multiple integrations)

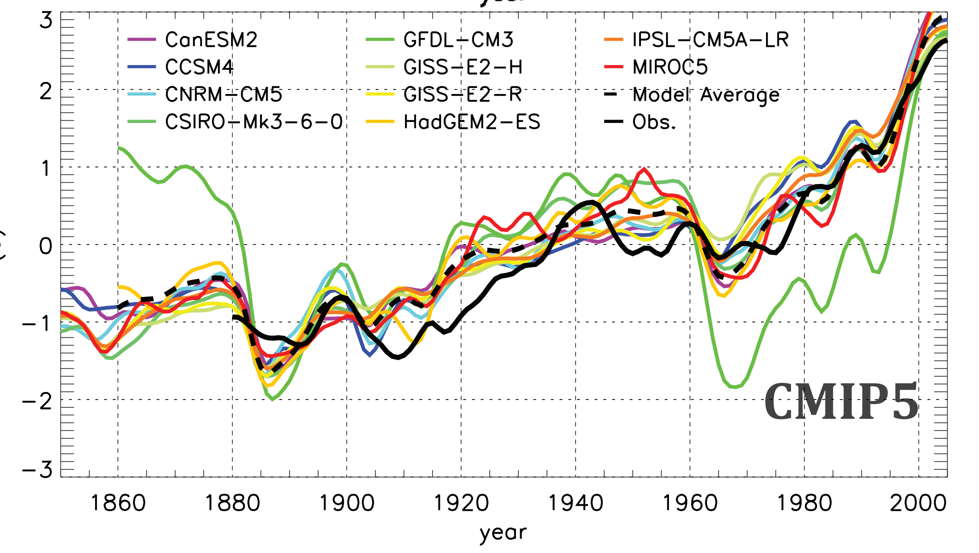
20th Century North Atlantic Multidecadal Variability natural or externally forced?

NOAA ERSST, 1854 - 2011

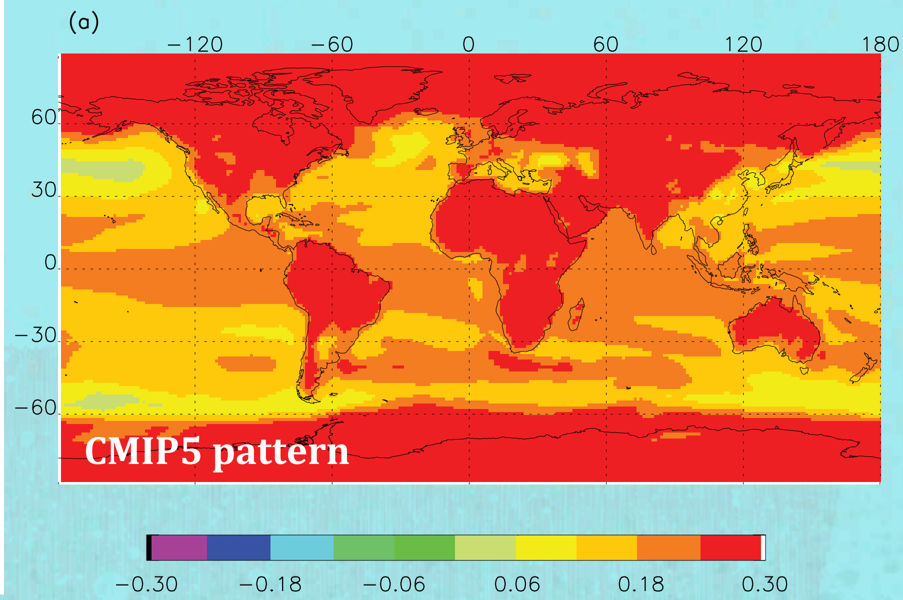


Externally forced 20c variability





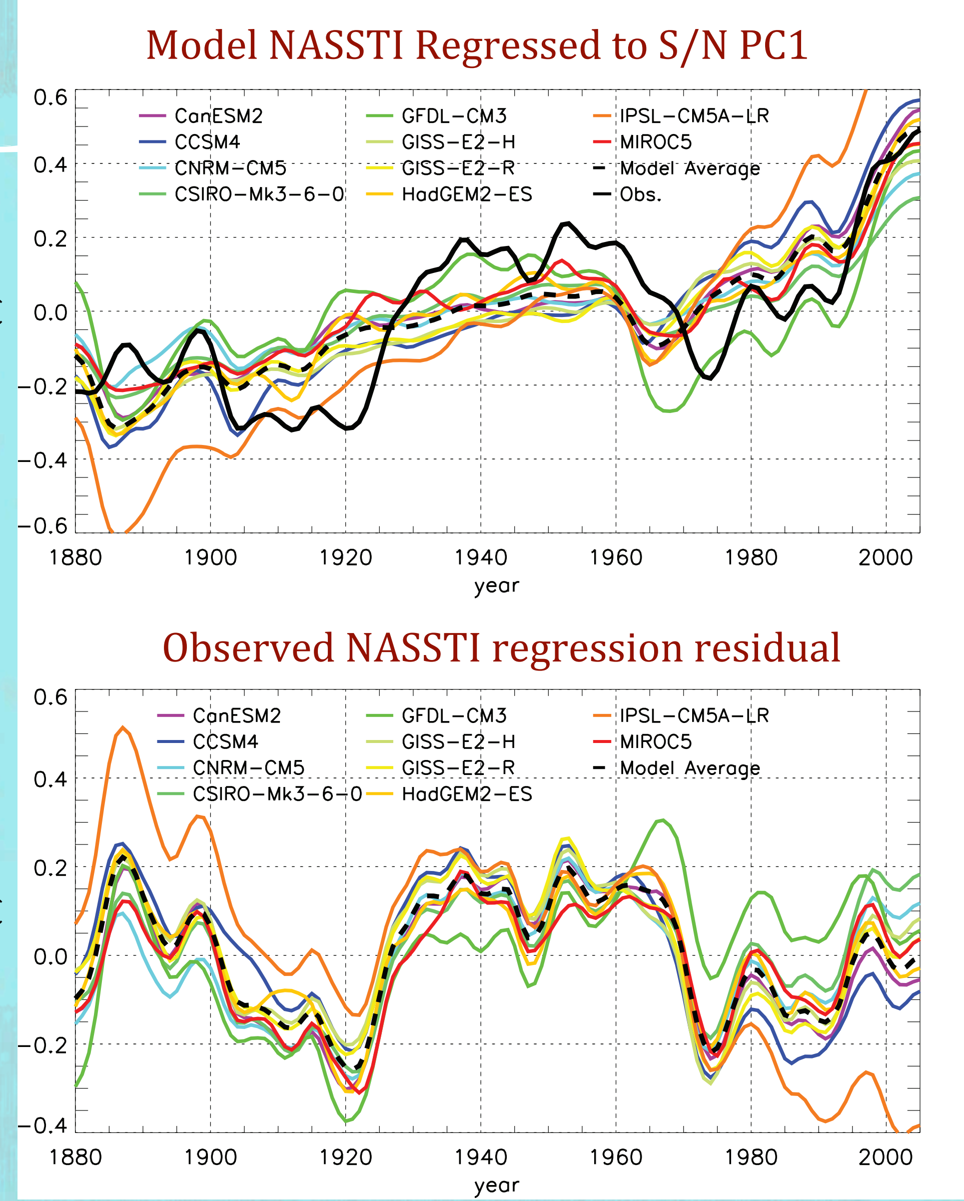
- left: S/N maximizing PC1of 9 CMIP3 models [*Ting et al., 2009*] compared to results from a similar analysis applied to CMIP5 models.
- CMIP5 models display larger spread around the mean.

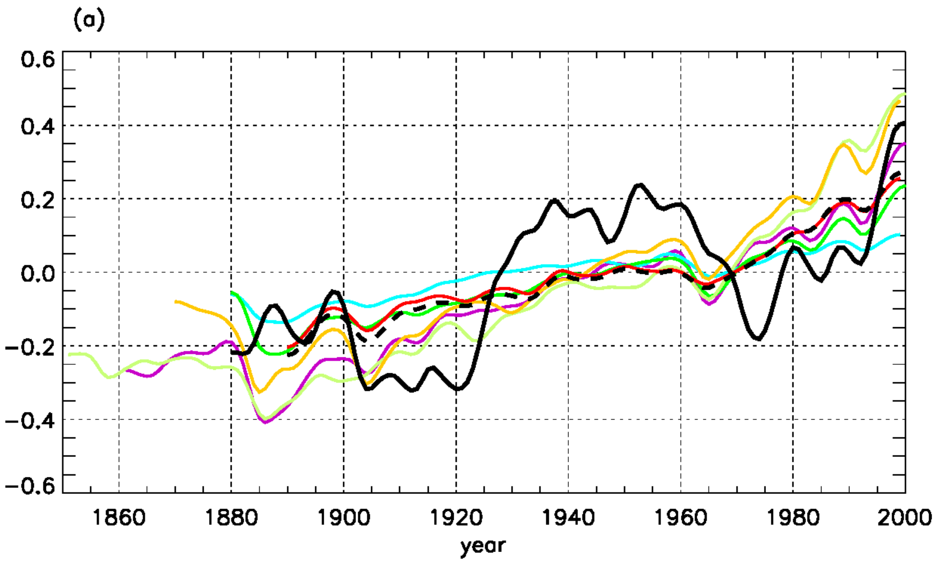


AMV: Internal variability or externally forced?

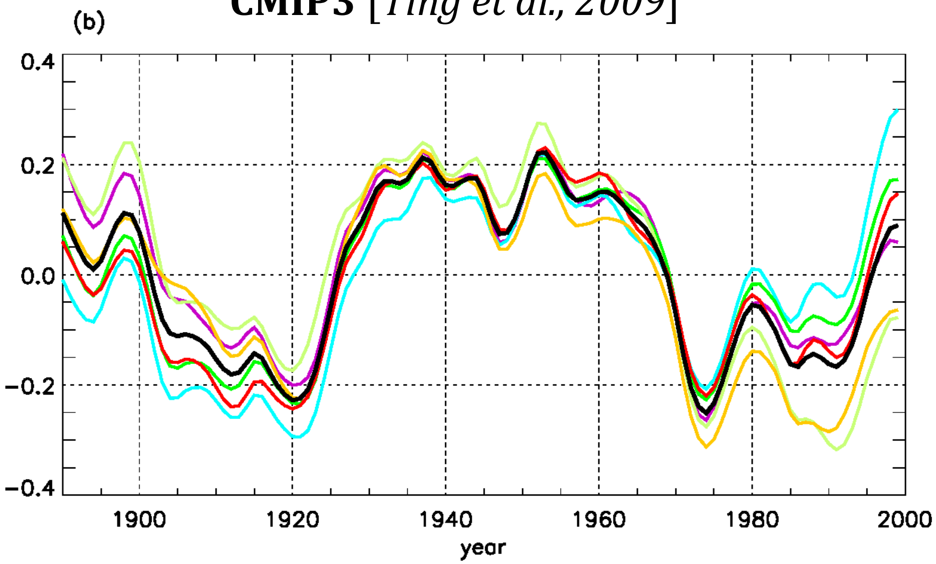
- North Atlantic SST average (NASSTI) is used as a measure of AMV.
- We separated NASSTI into forced and internal components using S/N maximizing EOF analysis and linear regression analysis.
- An internal "oscillation" stands out in observations particularly by its abrupt phase changes around 1930 & 1970.
- CMIP5 analysis attributes more of the observed NASSTI trend in last ~30 years (particularly after 1990) to anthropogenic frocing.

CMIP5



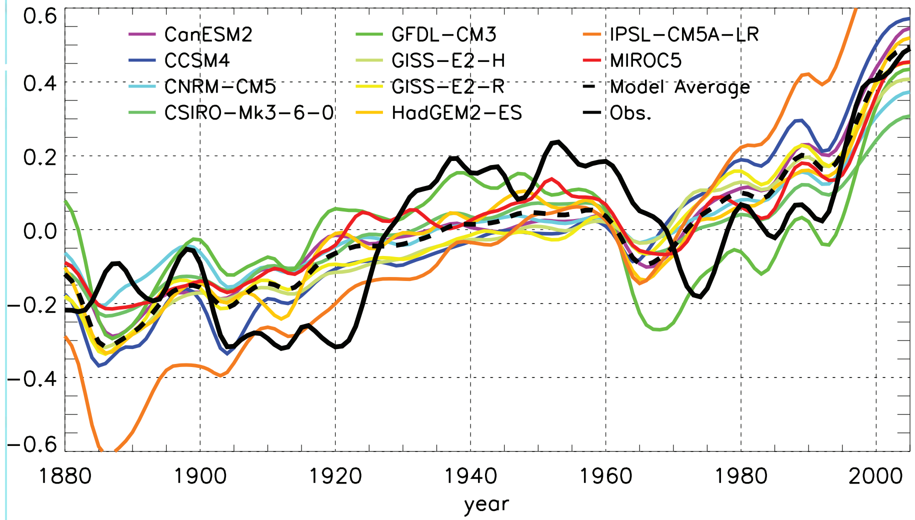


CMIP3 [*Ting et al., 2009*]

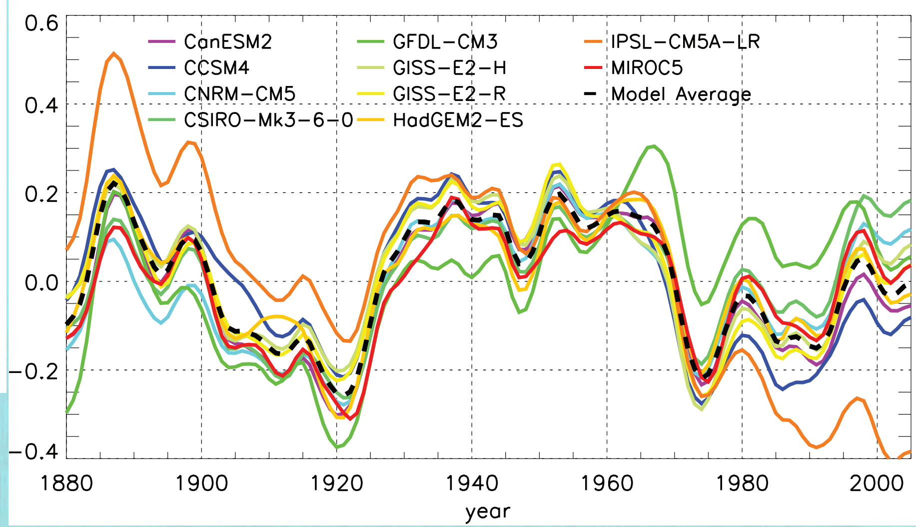


CMIP5

Model NASSTI Regressed to S/N PC1



Observed NASSTI regression residual

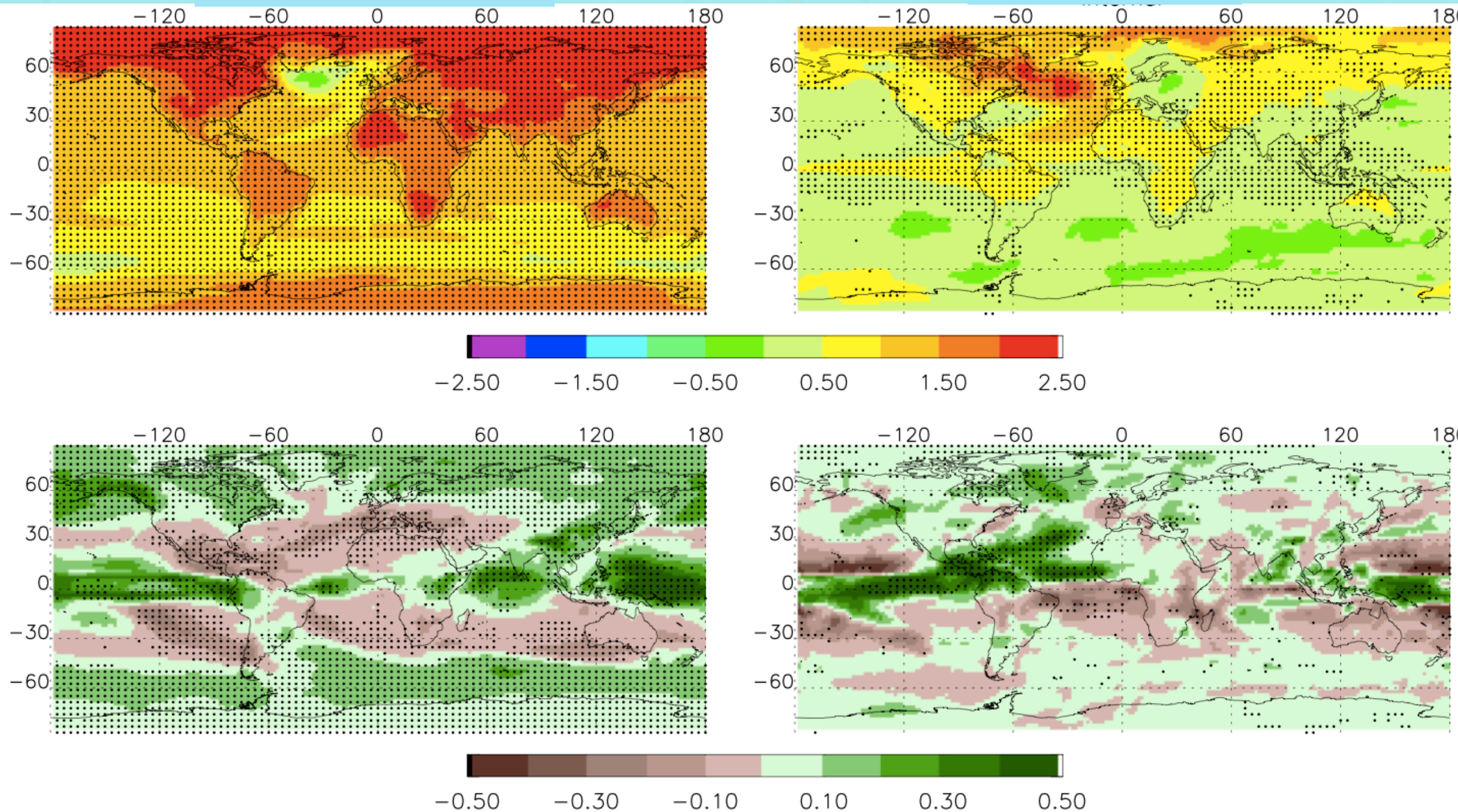


(particularly after 1990) to anthropogenic frocing.

CMIP3 20th century variability

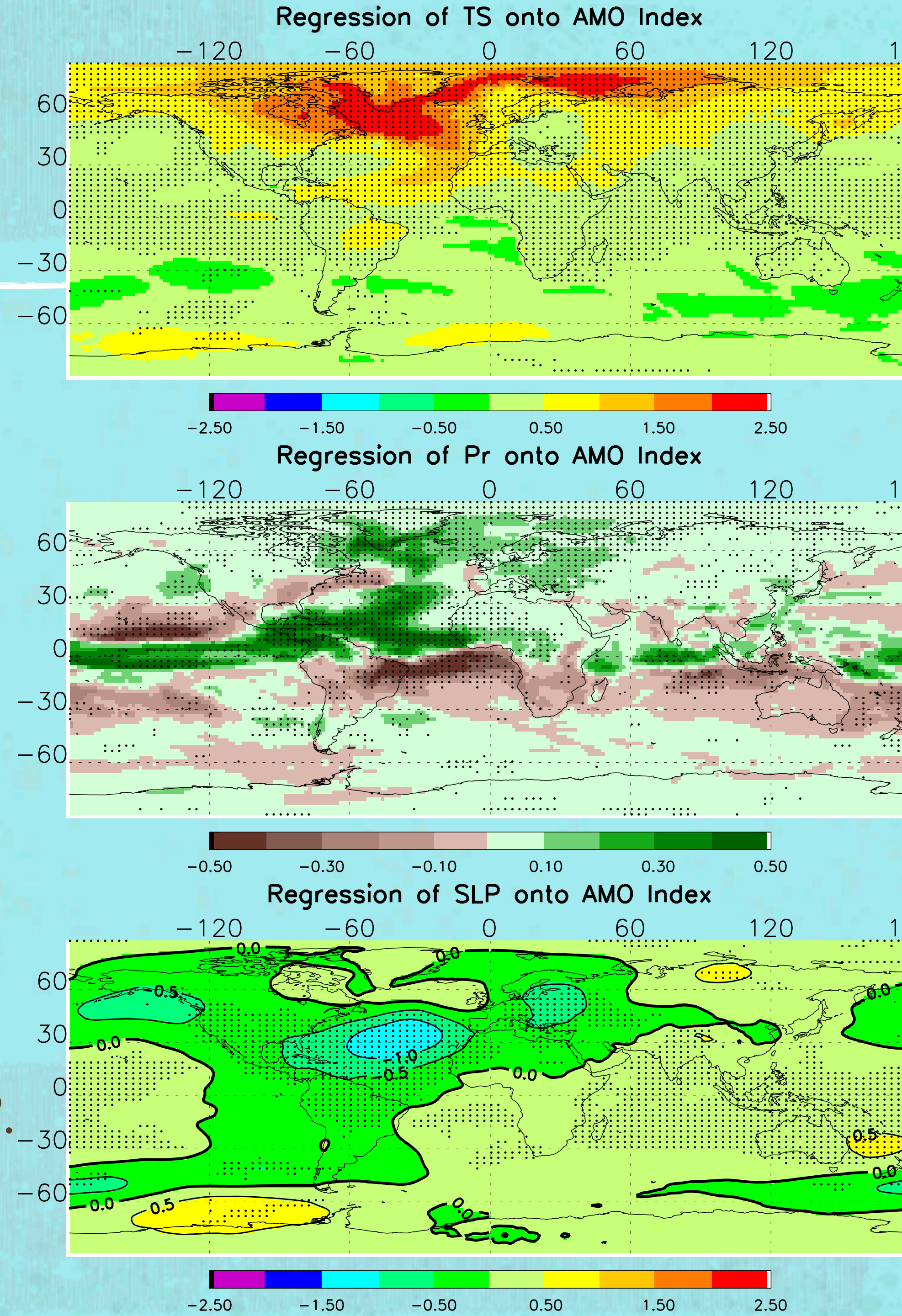
Ting et al. [*2009; 2011*]

Externally forced **AMV-related**



AMV in CMIP5 models

- Regression of surface T, precipitation, and sea level pressure on NASSTI pooling 23 pre-industrial CMIP5 models.
- Robust features are assessed based on model agreement (stipples). There is large consensus in model Ts patterns and less in associated Pr and SLP.

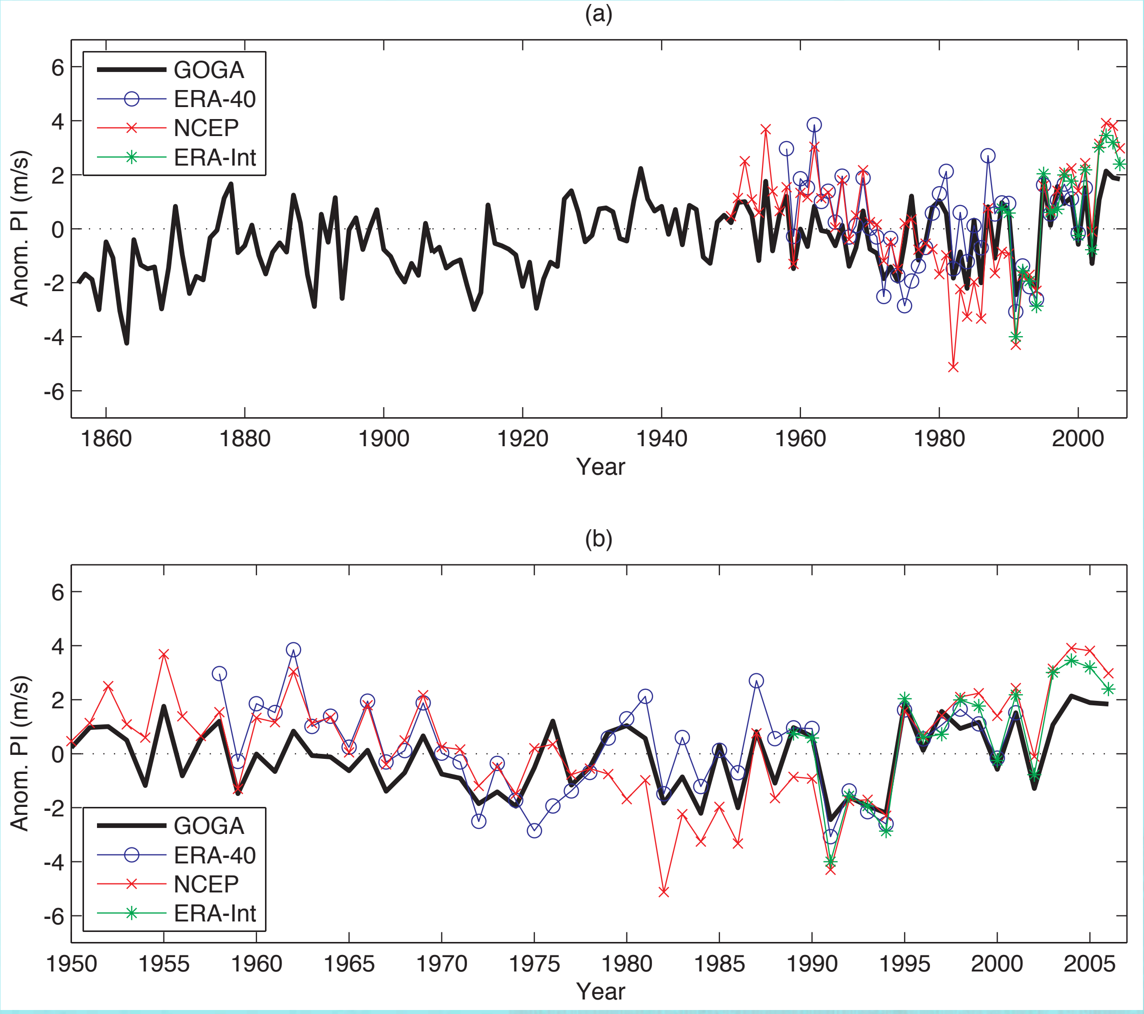


20th century variations of Atlantic hurricane PI

Camargo et al. [*submitted*]

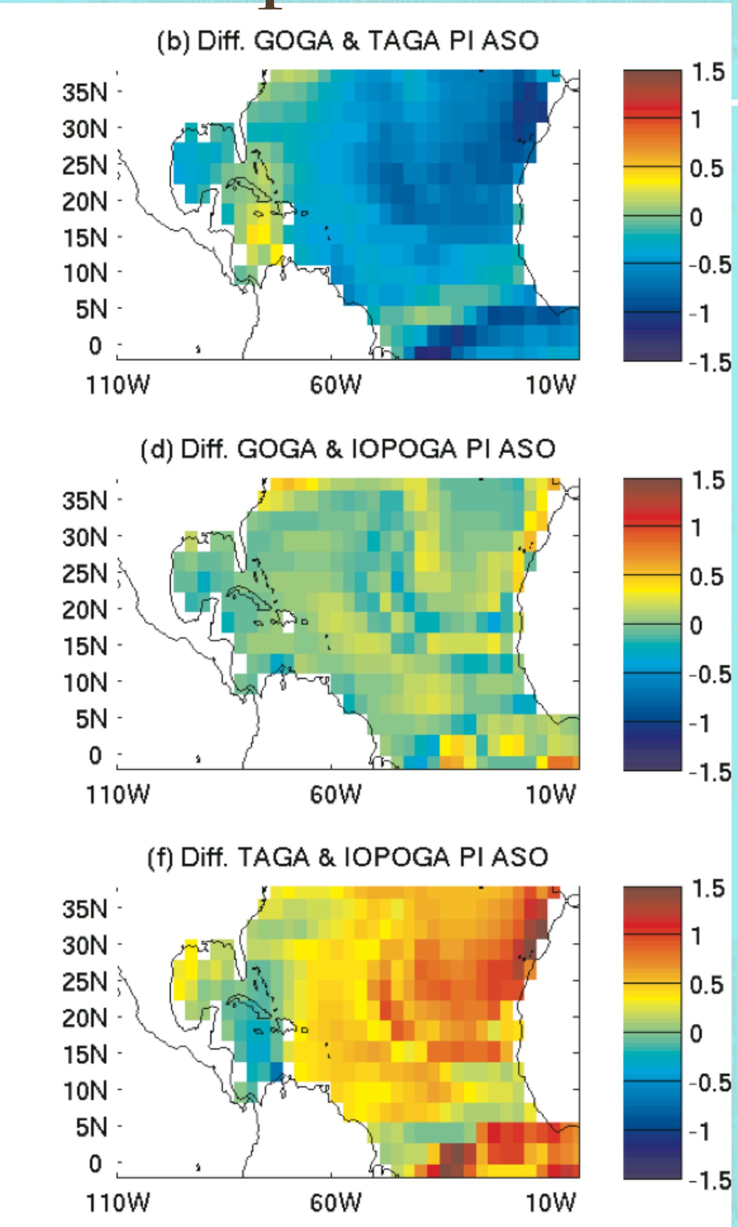
- Study the impact of Atlantic tropical storm potential intensity (PI, which depends on local SST and local atmospheric thermodynamic properties) using ensembles of an SST forced AGCM (CCM3).
- Contrast the influence of externally forced SST with that due to internal, multidecadal SST variability (AMV).
- Evaluate and compare the impact of local SST variability on atlantic PI to that due to SST variations elsewhere.
- We use realistic SST variations in different segments of the tropical (30°S-30°N) oceans: Atlantic only (TAGA), Pacific only (POGA) and Pacific + Indian (IOPOGA). SST variations elsewhere are limited to the climatological annual cycle.
- SST are realistically varying from 1856-2006.

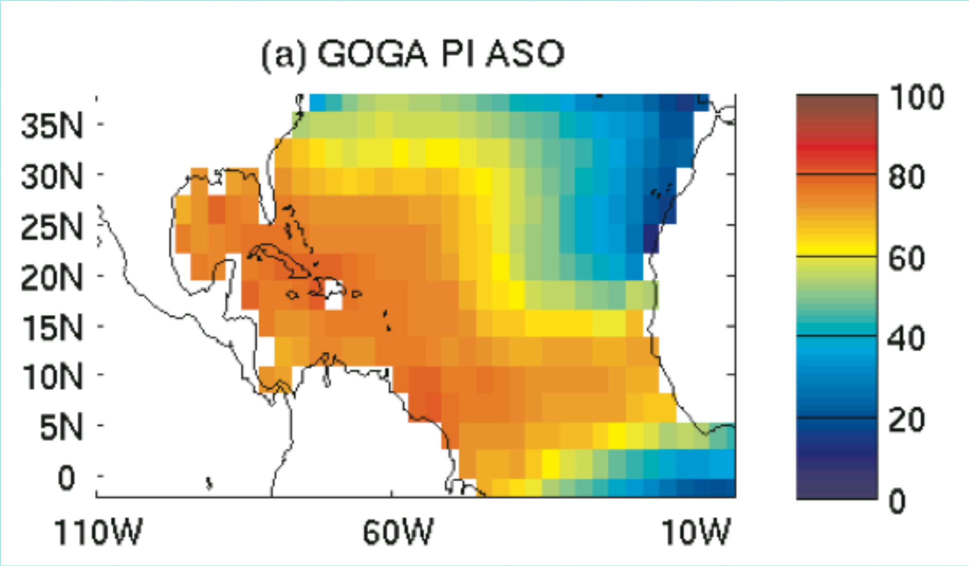
Temporal variability of MDR PI



Anomalous PI (m/s) averaged in the North Atlantic tropical storms Main Development Region (MDR) per JJASON season in the GOGA ensemble mean and reanalyses: 1856-2006 (top panel), and in the period 1950-2006 (bottom panel)

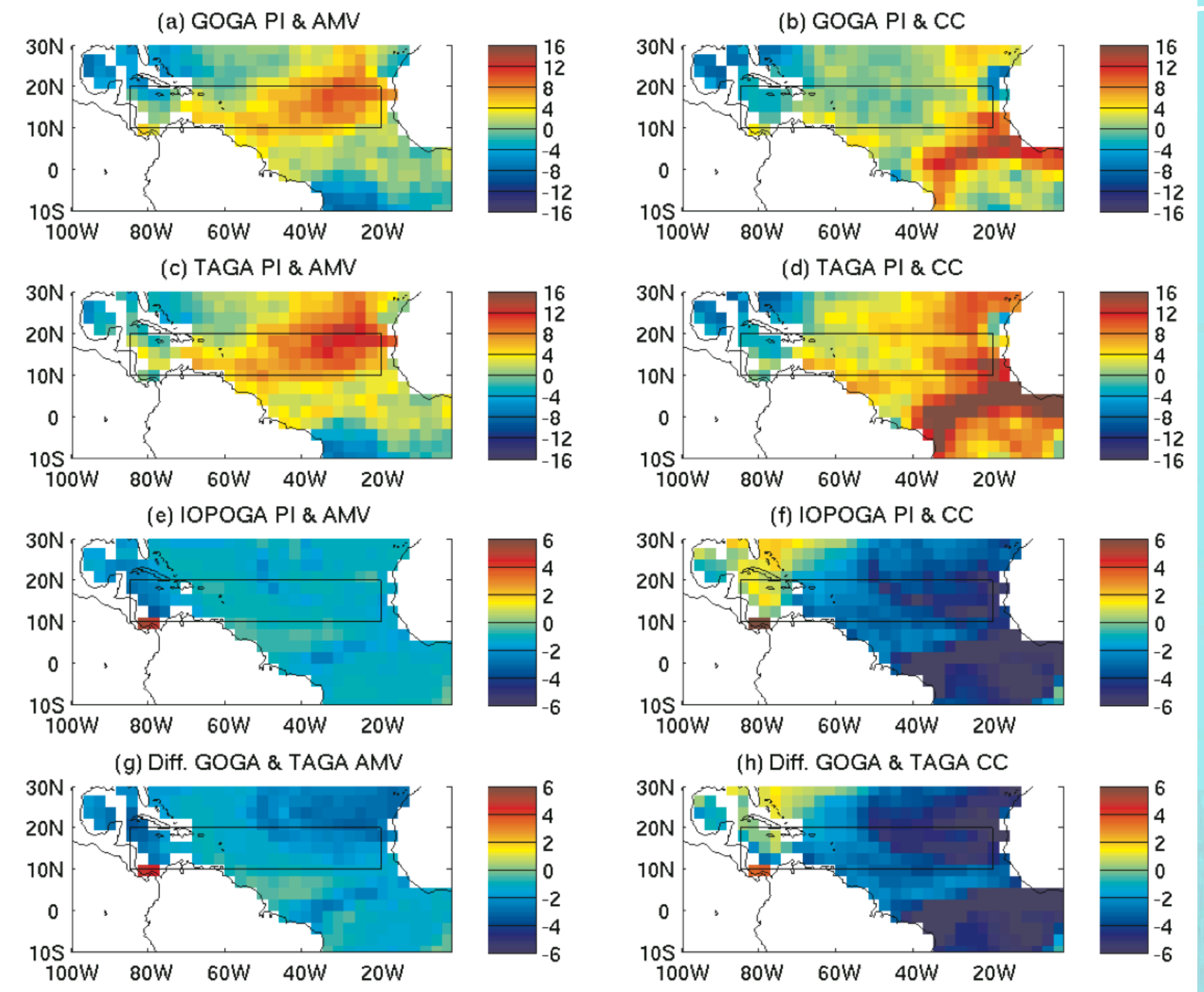
Tropical Atl. PI response to remote forcing 1





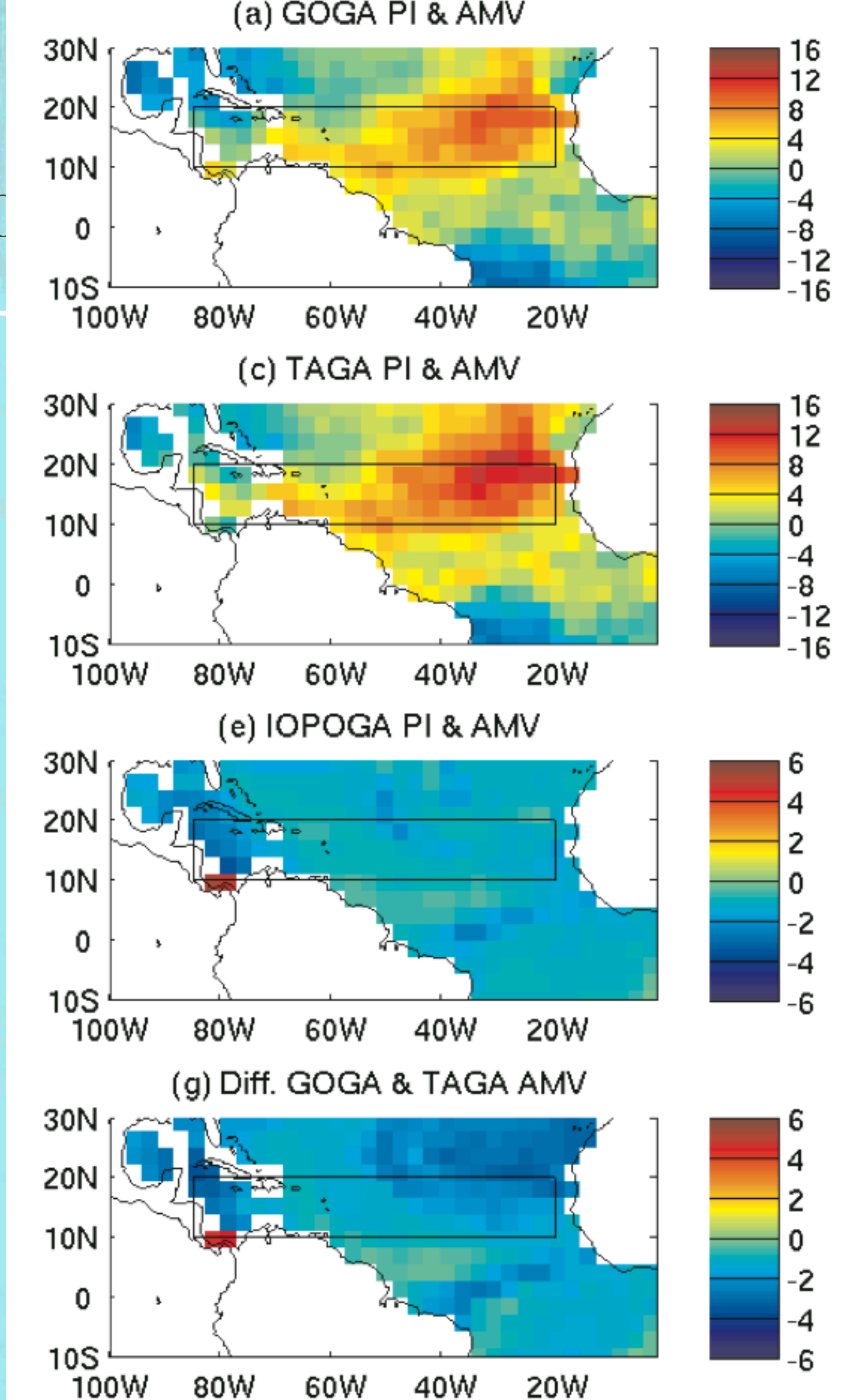
Ensemble mean, 1856 - 2006 climatological PI (m/s) for the peak hurricane season ASO in the tropical Atlantic for (a) GOGA simulation. Differences between climatological PI in ASO for (b) GOGA and TAGA, (d) GOGA and IOPOGA, (e) TAGA and IOPOGA.

Impact of local and remote forcing on internal and external Atlantic PI variability



Regression of anomalous ASO PI (m/s) on AMV (left panels) and climate change (CC) indices (right panels). Regression pattern of AMV and GOGA (a), TAGA (c), and IOPOGA (e) . Regression pattern of CC index and GOGA (b), TAGA (d), and IOPOGA (f). The difference between the PI regression patterns in GOGA and TAGA are shown in (g) and (h) for the AMV and CC patterns, respectively. The region of the main development region (MDR) is indicated by the black box.

c emote forcing tlantic PI variability



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Summary

- Analysis based on CMIP3 and CMIP4 models indicate AMV is a robust low-frequency mode of internal climate variability.
    - *AMV is centered in the North Atlantic but influences climate on a global scale, noticeably in the tropics (ITCZ).*
    - *Modeled AMV SST largely agrees with observed estimate and inter-model agreement is high. There is more divergence in precipitation and atmospheric links.*
- Tropical Atlantic hurricane PI depends on the variability of local conditions (SST) relative to those in the entire tropical region [*Vecchi and Soden, 2007; Vecchi et al., 2008*]
- AMV is an important component of 20th century changes in tropical Atlantic PI.