Mean and Variability of the Tropical Atlantic in CCSM4

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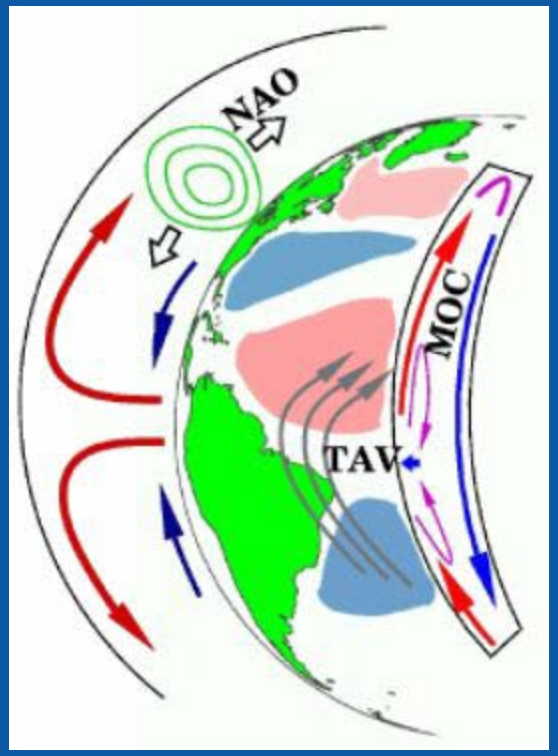
Under review by Journal of Climate

Atlantic CLIVAR (Hurrell, Visbeck et al. 2006, J Clim)



Source: Atlantic CLIVAR

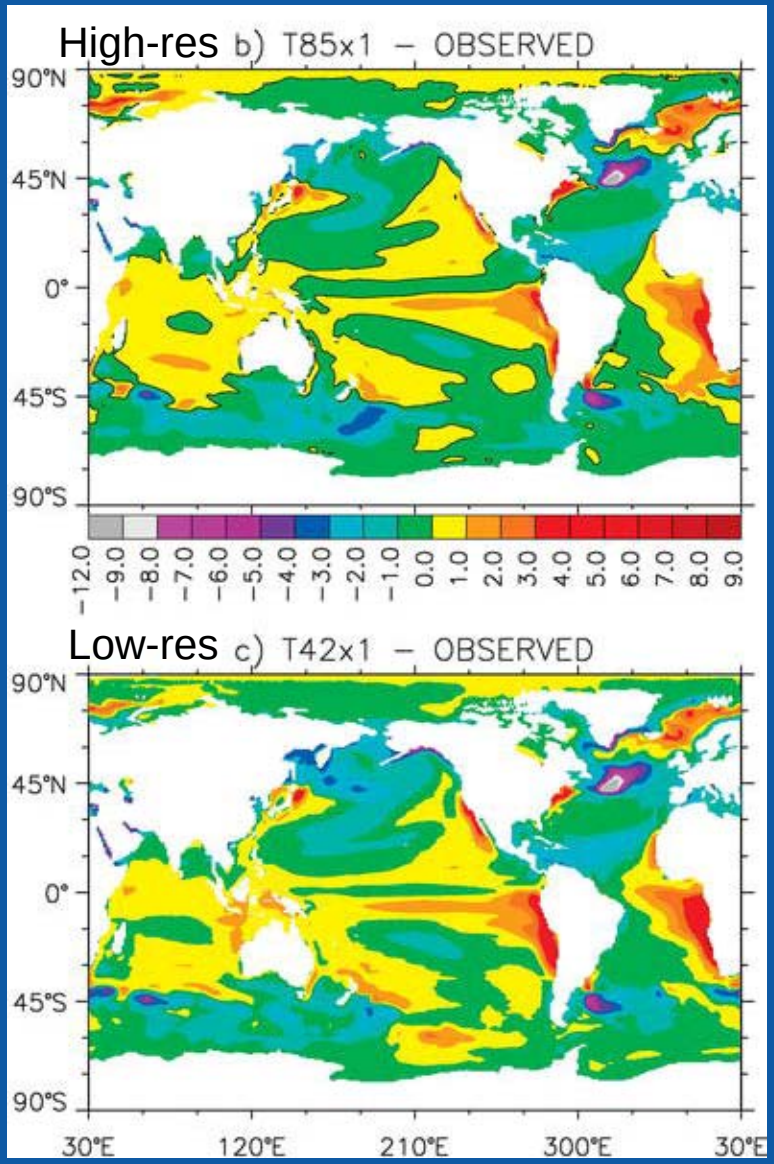
- North Atlantic Oscillation (NAO)
- Tropical Atlantic Variability (TAV)
- Meridional Overturning Circulation (MOC)

The Intra-Americas Sea (IAS):
Gulf of Mexico and Caribbean Sea

Source: IASCLIP VAMOS

Known biases in tropical Atlantic coupled simulations are:

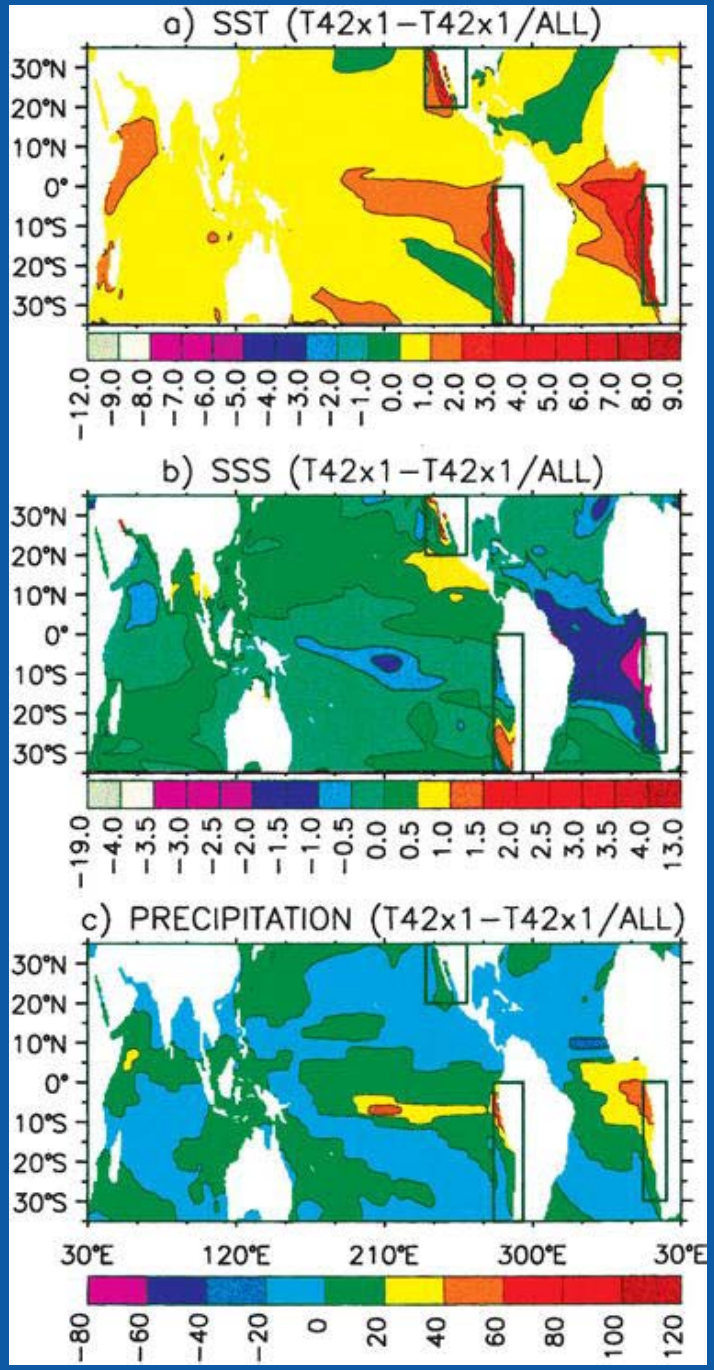
- Warm bias in the southeastern tropical South Atlantic
- Cold Intra-Americas Warm Pool
- Weaker easterlies over the equatorial Atlantic



Large and Danabasoglu 2006, JCLIM

Large and Danabasoglu (2006) showed impact of “fixing” bias

- Restored ocean temperatures and salinities to World Ocean Atlas down to ~500m within “upwelling” regions.



Data Sets:

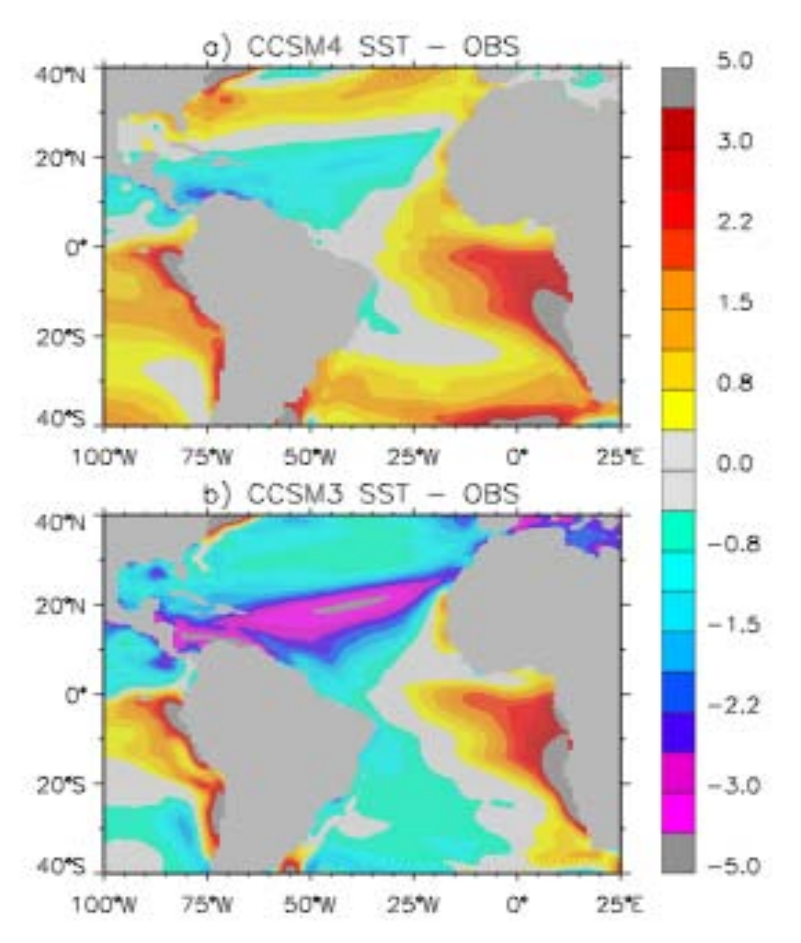
- CCSM4 Simulations:
  - 20th century ensemble members 1-5
    - File names: b40.20th.track1.1deg.[005 - 009]
    - Only different initial conditions
    - Forced by time series of solar output, greenhouse gases, several aerosols, and volcanic activity.
  - Control run: used ~100 years (863-959)

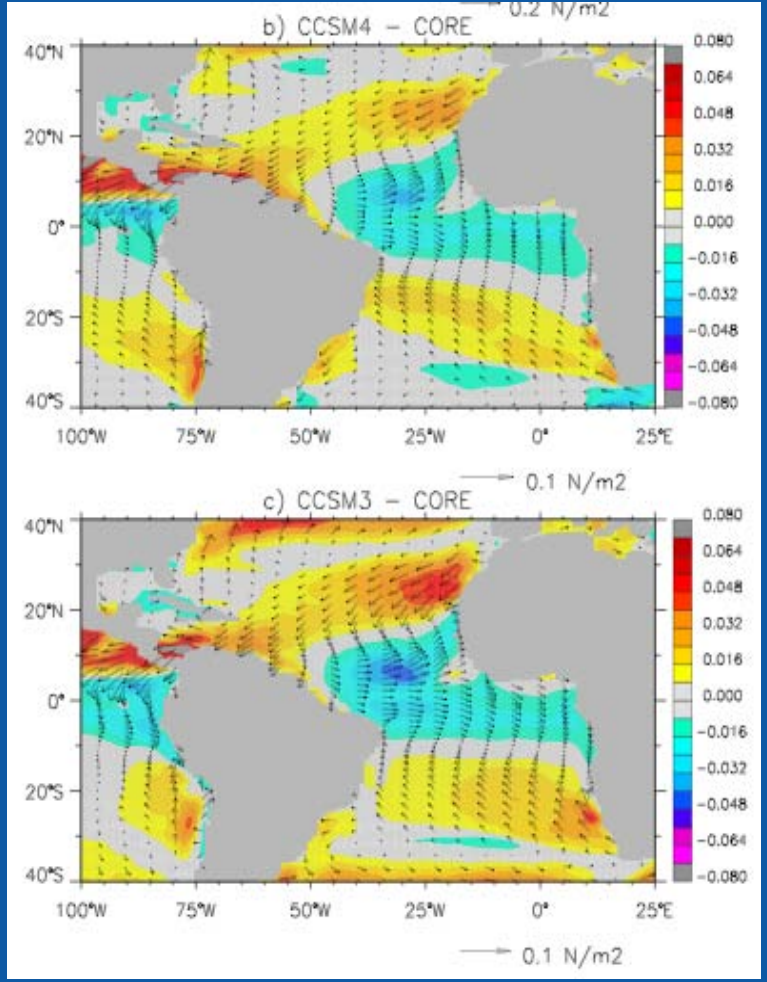
- Fourth cycle of POP simulation forced by Interannual "CORE" Forcing (Large & Yeager, 2009)

- Observational data sets:
  - SSTs: Hurrell et al.; ERSST
  - CORE-based wind stress
  - Subsurface temperature: Ishii et al (2006)

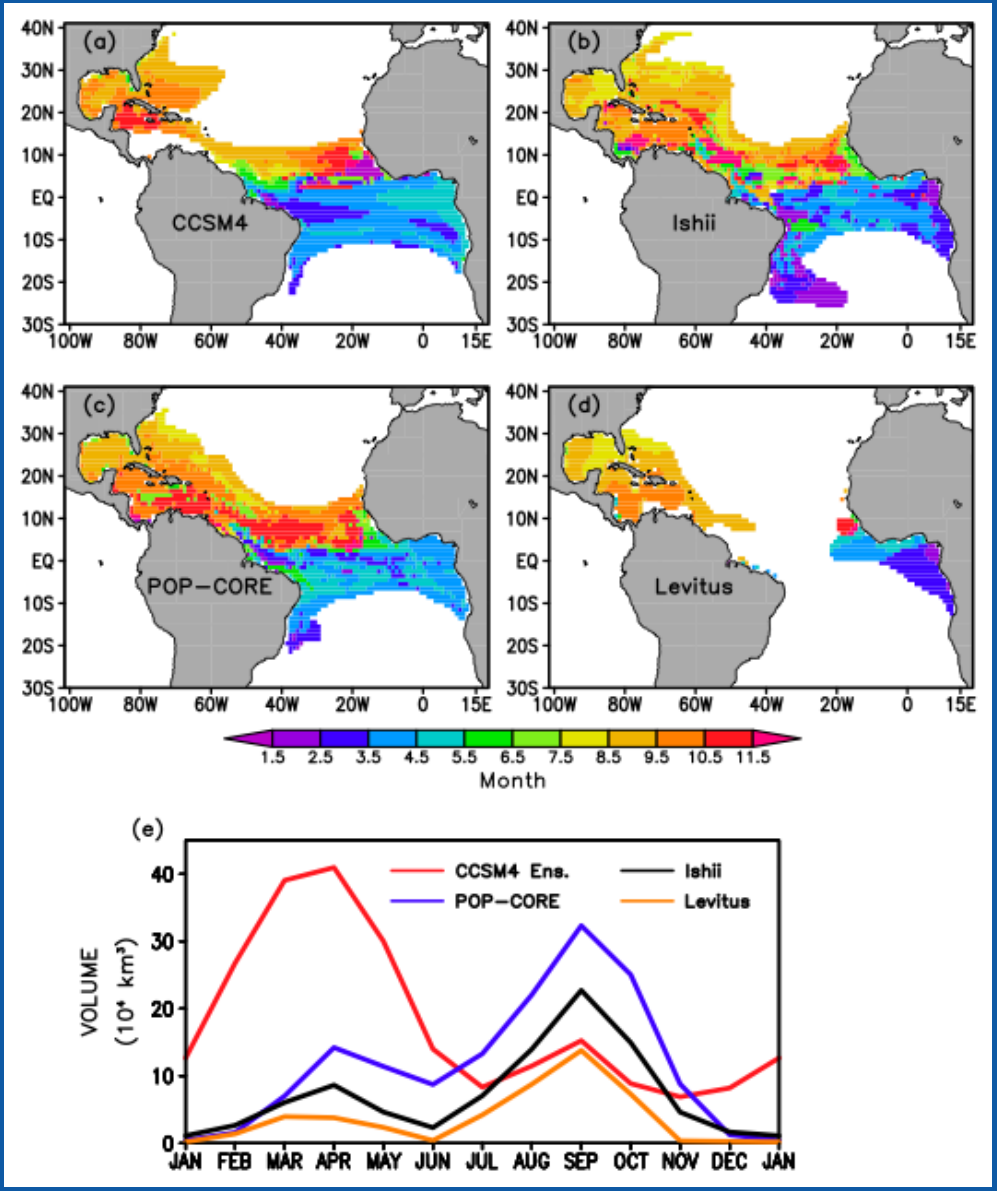
Differences (Model-Obs) in SST and wind stress are still existent

- The tropical North Atlantic (TNA) SSTs have improved
- Even though the equatorial zonal wind stress has improved, the TSA SSTs are significantly different from observations





Temperature biases extend beneath surface

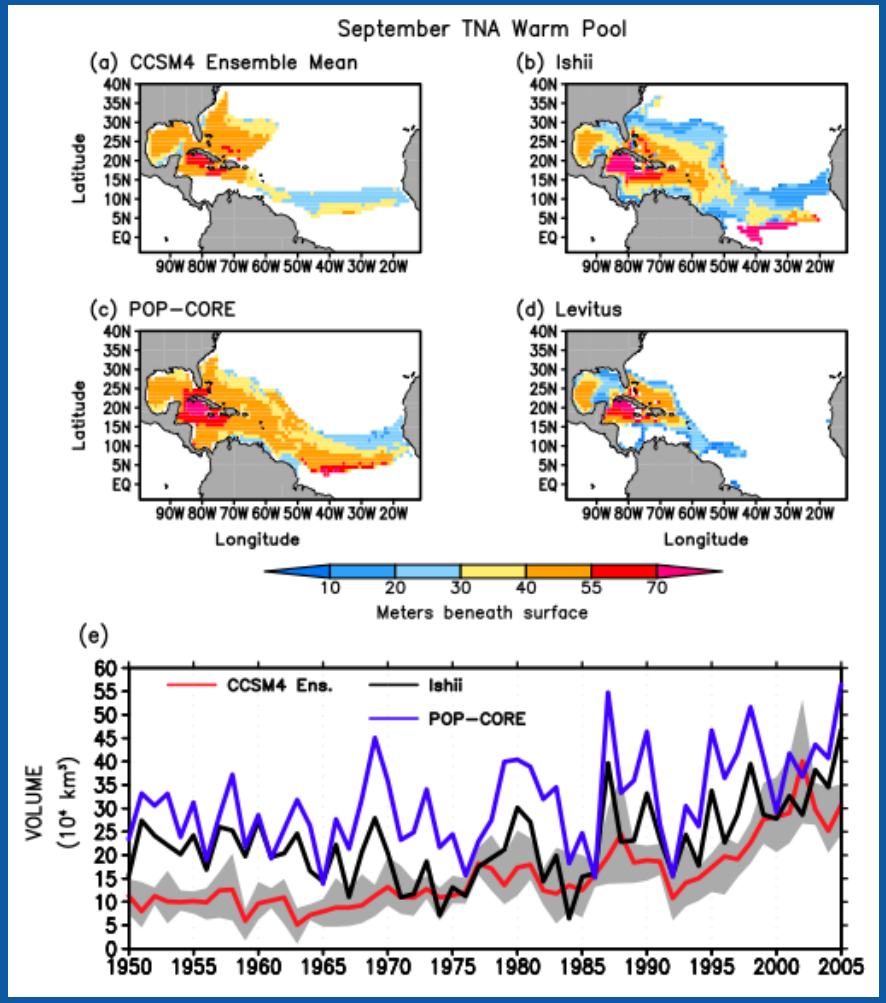


- Seasonal cycle of maximum depth of 28.5° C isotherm
- The Tropical South Atlantic is staying too warm during the boreal spring.
- The CCSM4 warm pool volume in TSA is four times that from observations.

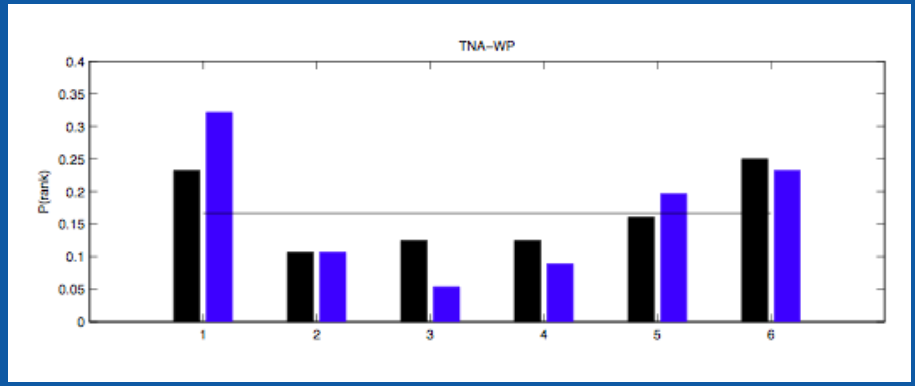
Interannual Variability

Cold bias also impacts the TNA warm pool

Depth of the 28.5˚ C isotherm



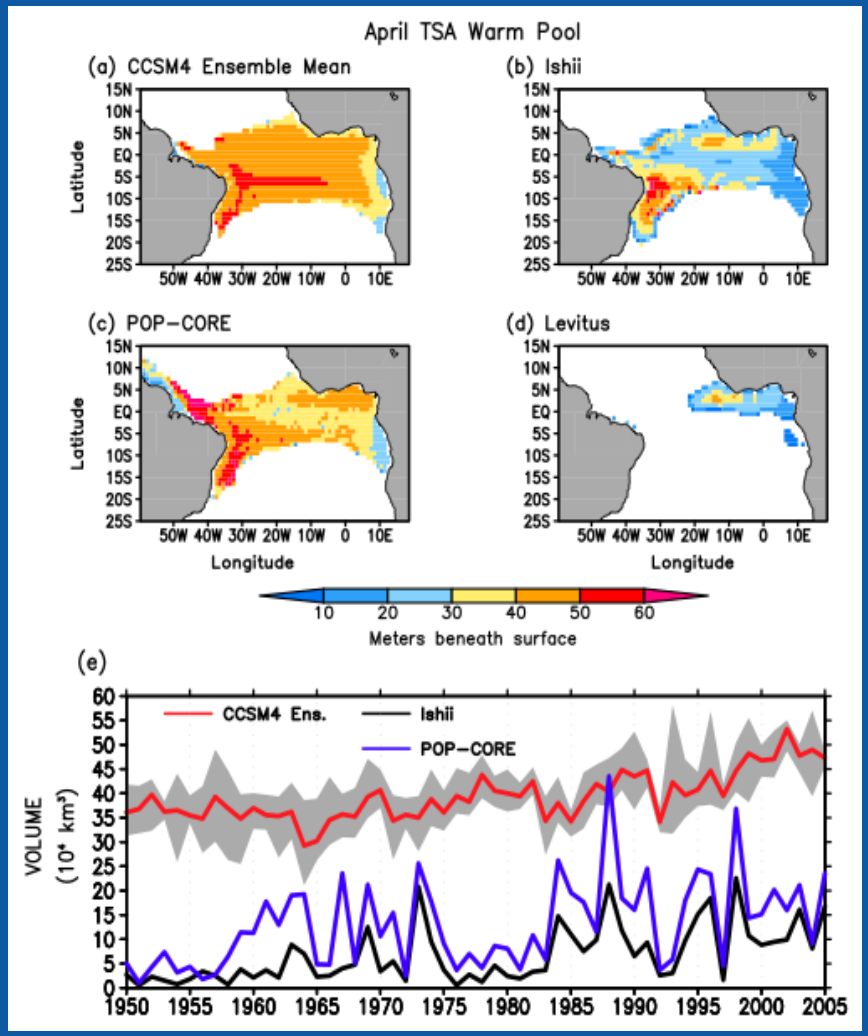
Rank histogram of warm pool metric



Blue is POP CORE-forced
Black is observational estimate

Warm bias also impacts the TSA warm pool

Depth of the 28.5˚ C isotherm



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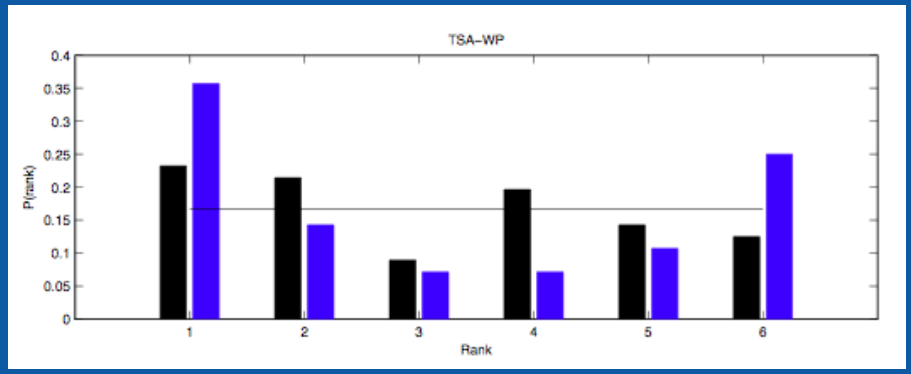

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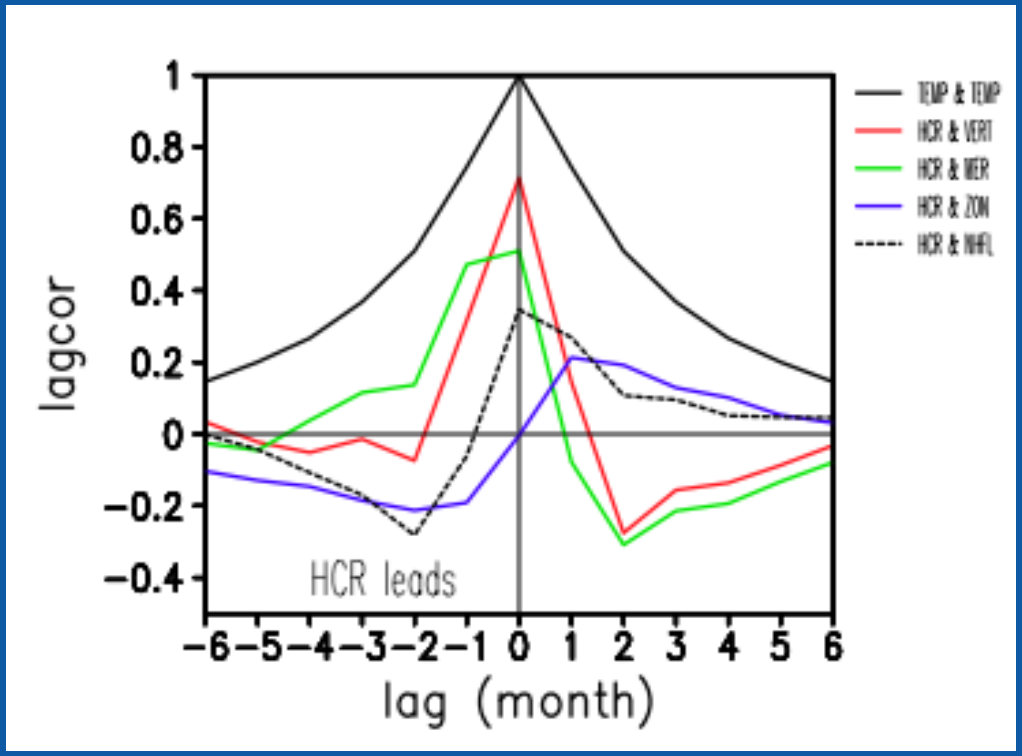
At interannual timescales, in Benguela region, vertical advection contributes the most to heat content rate of change



Based on control run

- Time scale of Benguela Niños is 4 months

~50% of HCR variance is due to local upwelling

~25% is explained by anomalous meridional advection

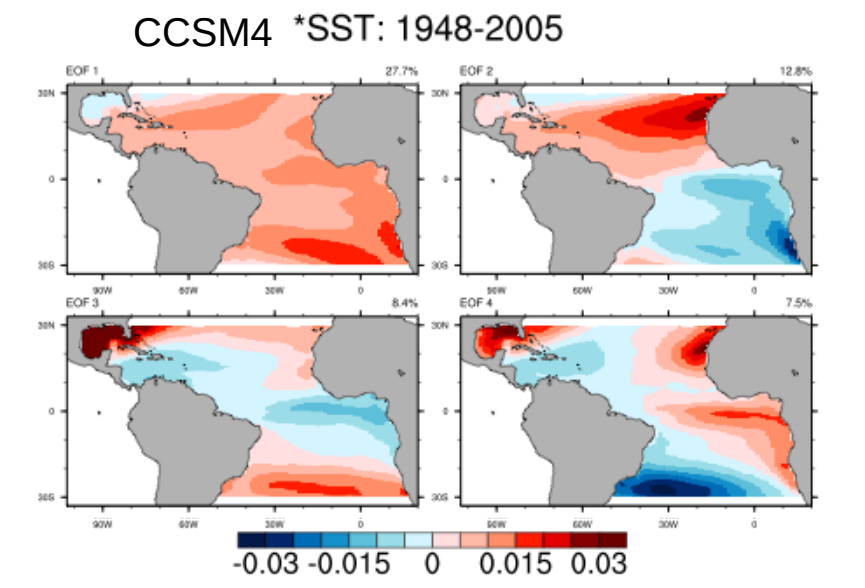
~10% is explained by anomalous surface flux

Instantaneous zonal heat advection is weak

Red or Green?

Rotated or Unrotated?

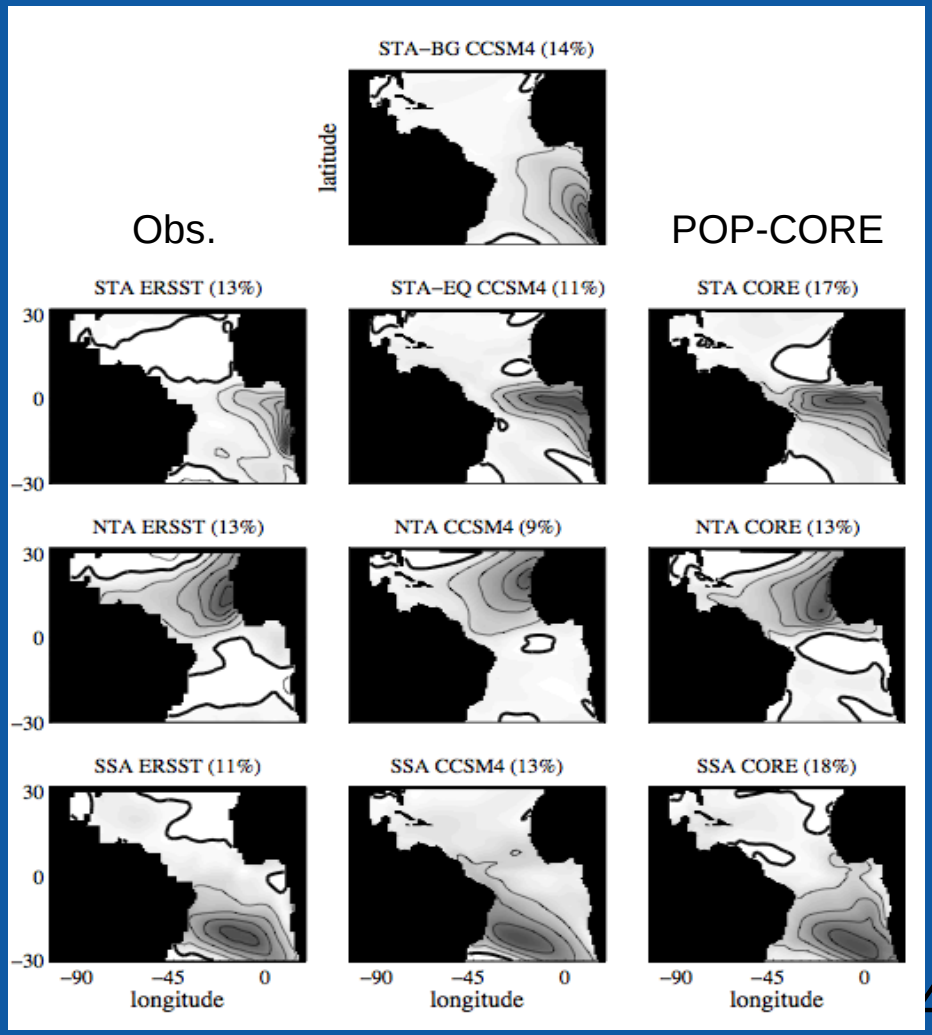
Unrotated EOFs



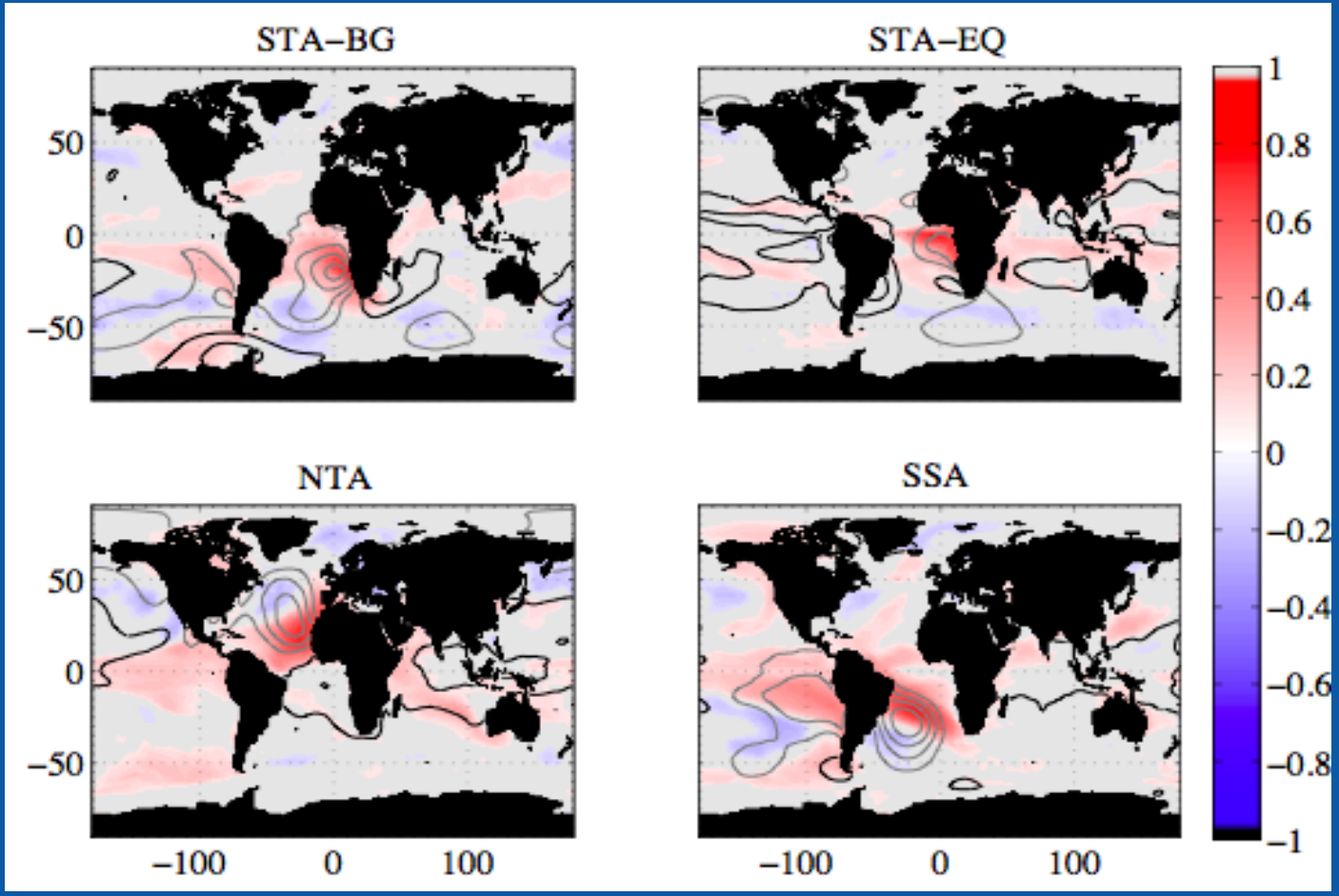
EOFs computed from detrended, area-weighted SST anomalies w.r.t. seasonal cycle between 30° N and 30° S.

Model SST variability similar to variability in SST observations

Rotated EOFs

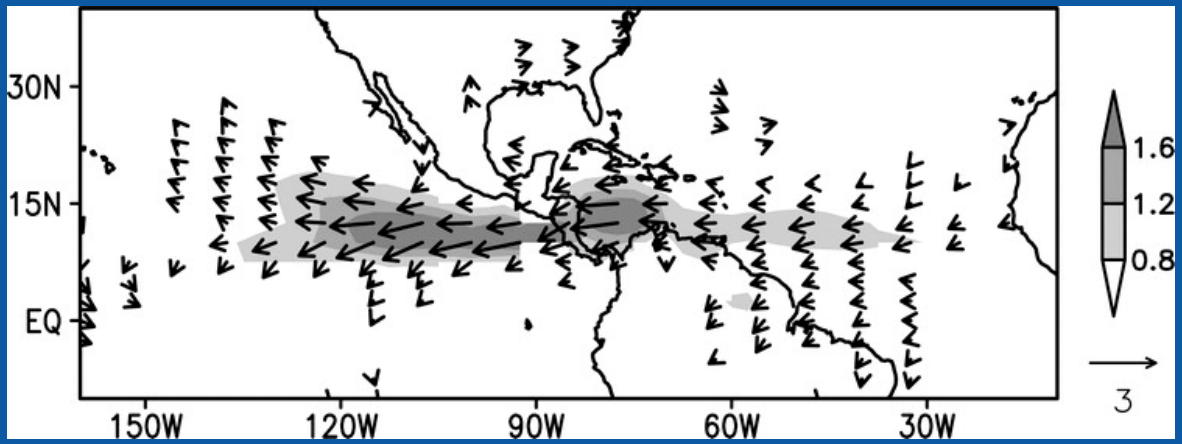


No dominant relationship with ENSO



- Correlation between rPCs (time series) and SST (shaded) and SLP (contoured)
- The STA-EQ is anti-correlated with the tropical Pacific

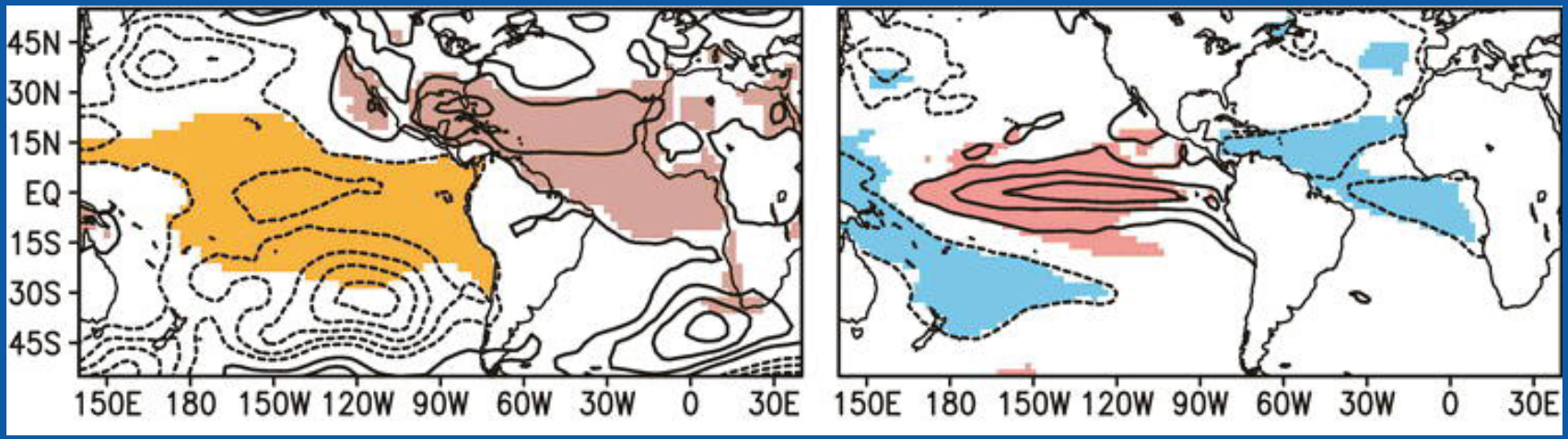
The Caribbean low-level jet is influenced by inter-basin pressure gradients



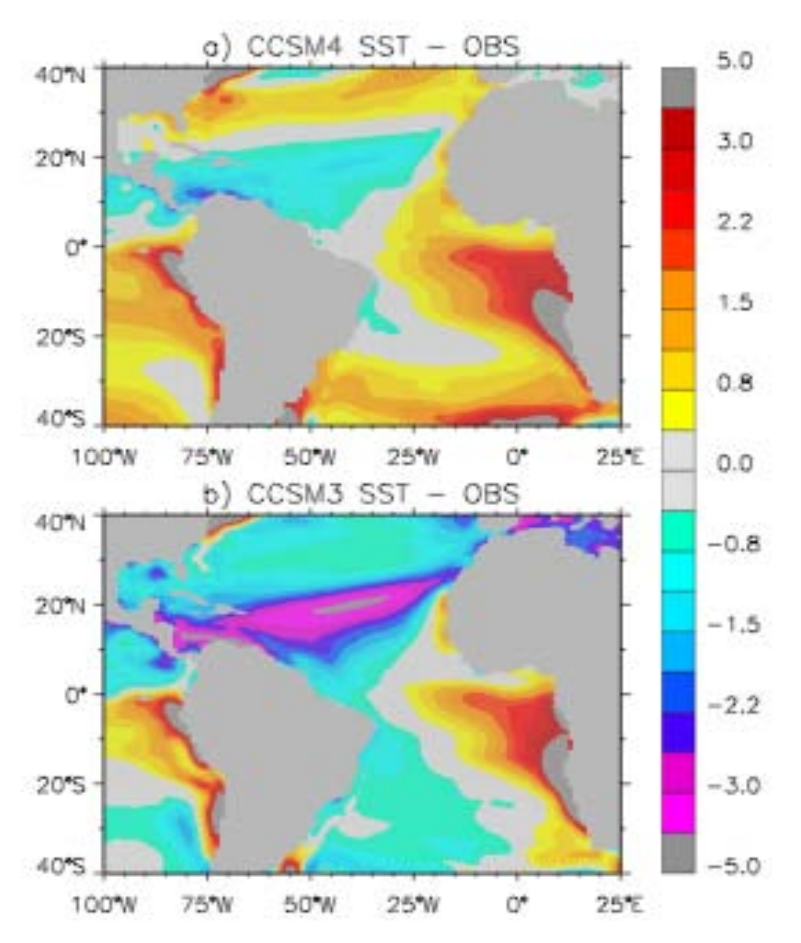
Munoz et al. 2008

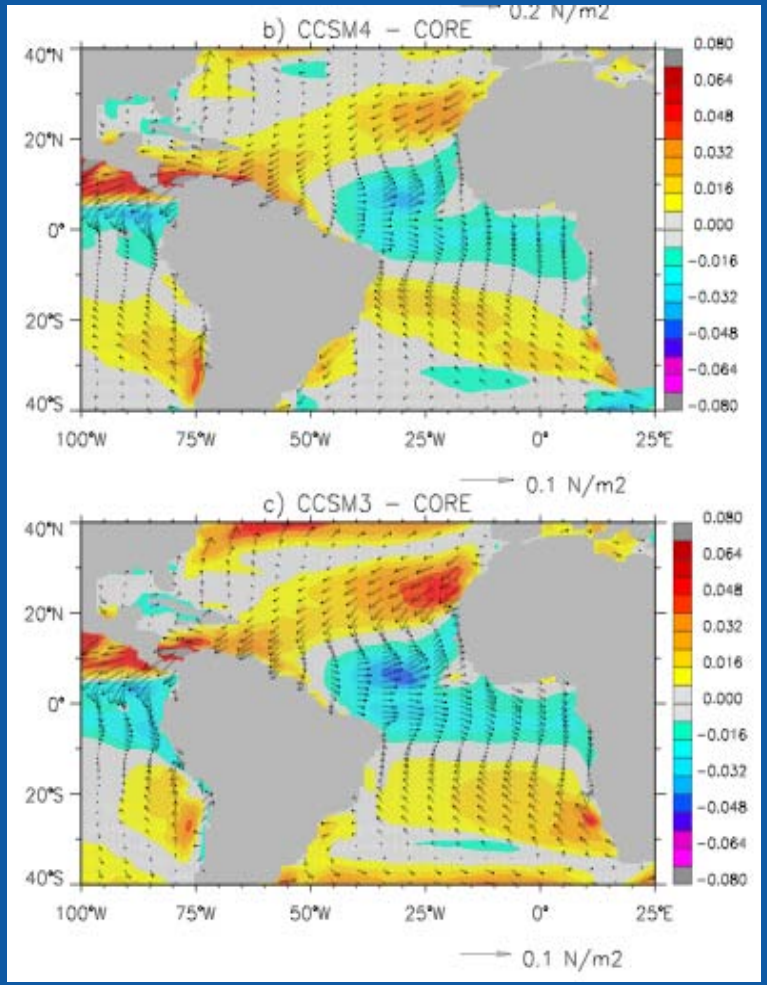
SLP

SST



Is the Caribbean easterly bias influenced by the gradient in SST bias between the TNA and the tropical Pacific?





Summary and Conclusions:

- CCSM4 still have biases in SST and wind stress very similar to those from previous versions.
- Yet, cold bias in tropical North Atlantic has ameliorated; as consequence "warm pool" exists (w.r.t. 28.5° C isotherm). TNA warm pool seems to have underdispersion in CCSM4.
- The warm bias in tropical South Atlantic is still present. Warm pool metric can also help in "assessing" the southeastern Atlantic temperature bias.
- There is a strong connection between temperature and wind biases in both the mean and the variability.
- One question is whether a bias in the mean will project onto a bias in the variability or vice versa.

Announcement

- Ocean Sciences 2012 session (#104) on:

  Improvements in Understanding Tropical Atlantic Climate Variability and Predictability: Past Behavior, Observations and Climate Models

Emerging topics:

- Tropical Atlantic relationship with adjacent monsoon systems (South American, African)
- The Atlantic Warm Pools as a key climatic feature
- Seasonal and inter-annual Atlantic predictability and outlooks
  - Hurricane seasonal outlooks in the Atlantic
- African dust plumes
- Stratus clouds in the eastern Atlantic

Recent reports by CLIVAR Atlantic Implementation Panel

- Problematic areas:
  - Lack of modeling activities as part of the Tropical Atlantic Climate Experiment (TACE) focus on the Eastern tropical Atlantic
  - Inadequate metrics to use in ocean synthesis intercomparsion project
  - Oceanic instrumentation of the Intra-Americas Sea

African topography