Role of Ocean-Atmosphere-Land Interactions in Tropical Atlantic Seasonal Cycle

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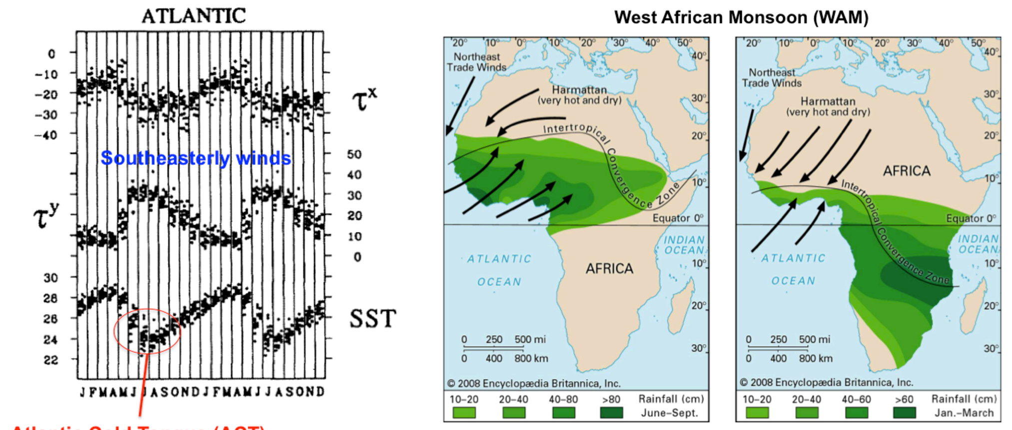
1. Motivation

The seasonal cycle (SC) of the equatorial eastern Atlantic sea surface temperature (SST) is characterized by a rapid cooling from April to July, coinciding with the onset of the West African summer Monsoon (WAM) and followed by a slow warming that lasts much longer (Mitchell and Wallace, 1992).

Some authors suggest that the monsoon is the main driver of the atmospheric variability in annual timescales in eastern TA (Philander and Li, 1997) and that the SC of the SST plays a minor role, while others highlight a significant influence of the equatorial SST cooling on the African monsoon (Okumura and Xie, 2004).



Atlantic Cold Tongue (ACT)

We have performed different sensitivity experiments with Norwegian Earth System Model (NorESM) atmospheric component with SSTs as forcing to study the relevance of the impact of the SST on the TA atmospheric low-level flow.

2. Experimental setup for the ACGM runs

- Version 4.0 of the Community Atmospheric Model (CAM4) low-top, 1.25°x0.9° and 26 vertical layers.
- 2 experiments with SST and SIC as boundary conditions.
- Historical run: from Jan 1982 to Dec 2013.

CTL run	No SC run
Clim SST	Fixed SST
Full Sea Ice Coverage	
Seasonally varying SST Eliminates Interannual Variability Retain the SC	Time independent SST Eliminates SC

3. Methodology

- Subjective comparison of the AGCM atmospheric output variables
- Study of the properties of the Joint Distribution of CTL run and No SC run values: $p(y_i, o_j) = \Pr\{y_i, o_j\} = \Pr\{y_i \cap o_j\}; \quad i = 1,\dots,I; \quad j = 1,\dots,J;$
- Maximum Covariance Analysis (MCA) -> Find the covariability patterns between the ocean, atmosphere and land.

Case 1) ***CTL run***	Case 2) ***CTL - NoSC run***	Case 3) ***NoSC run***
$(SST,U)_{CTL}$	$(SST,U)_{CTL-NoSC}$	$(TS,U)_{NoSC}$
$(SST,V)_{CTL}$	$(SST,V)_{CTL-NoSC}$	$(TS,V)_{NoSC}$
$(SST,PRECT)_{CTL}$	$(SST,PRECT)_{CTL-NoSC}$	$(TS,PRECT)_{NoSC}$
Ocean+Land	**Ocean**	**Land**

4. Results: Study of the SC

Surface winds

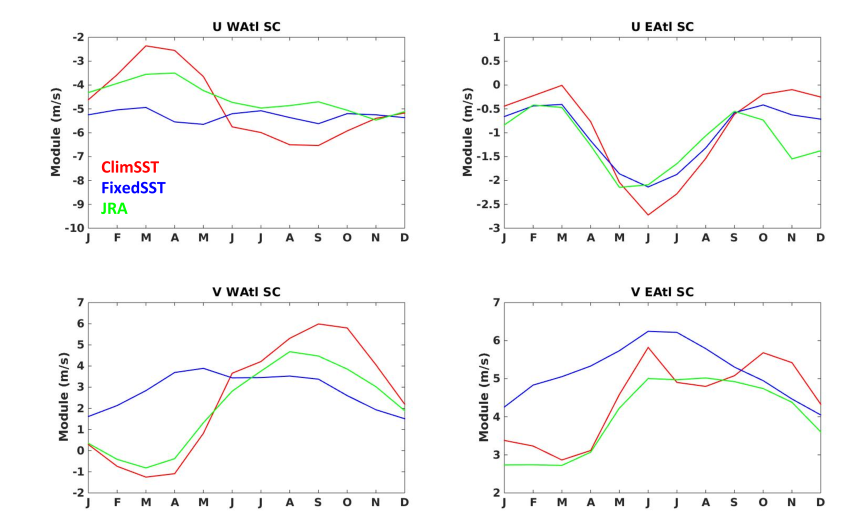
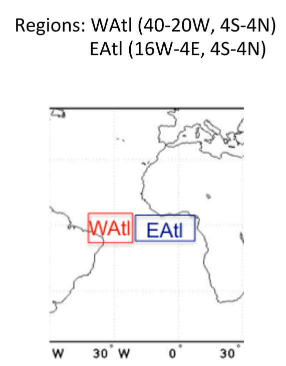


Fig. 1. Seasonal cycle of the surface winds. Zonal component (top) and meridional component (bottom) in the East Atlantic (left) and West Atlantic (right) regions. The results for the different experiment runs are shown in colors: climSST (red), fixedSST (blue) and JRA reanalysis data (green).



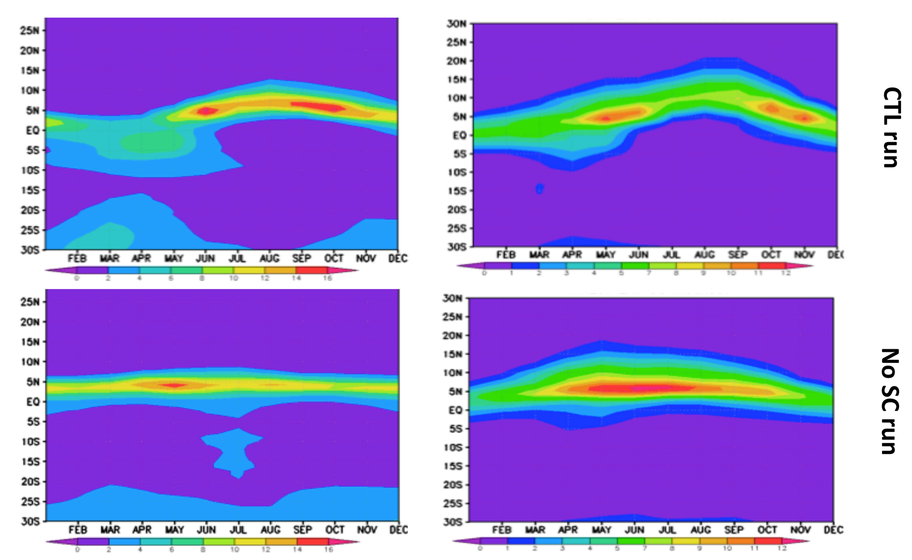


Fig. 2. Seasonal cycle of the precipitation. East Atlantic (top) and West Atlantic (bottom) regions. The CTL run and the No SC run results are shown in the left and right columns, respectively.

- **Monsoonal behaviour in absence of SC in the SST but the onset is missed.**
- **The seasonality of the SST is more relevant in the WAtl than in the EAtl.**
- **No seasonal march of the ITCZ when eliminating the SC in the SST.**

5. Results: Statistical understanding of the difference

- **Where is the error coming from?** $MSE = BIAS^2 + \sigma_b^2 + \sigma_c^2 - 2\sigma_b\sigma_c r_{bc}^2$ B = CTL run C = NoSC run

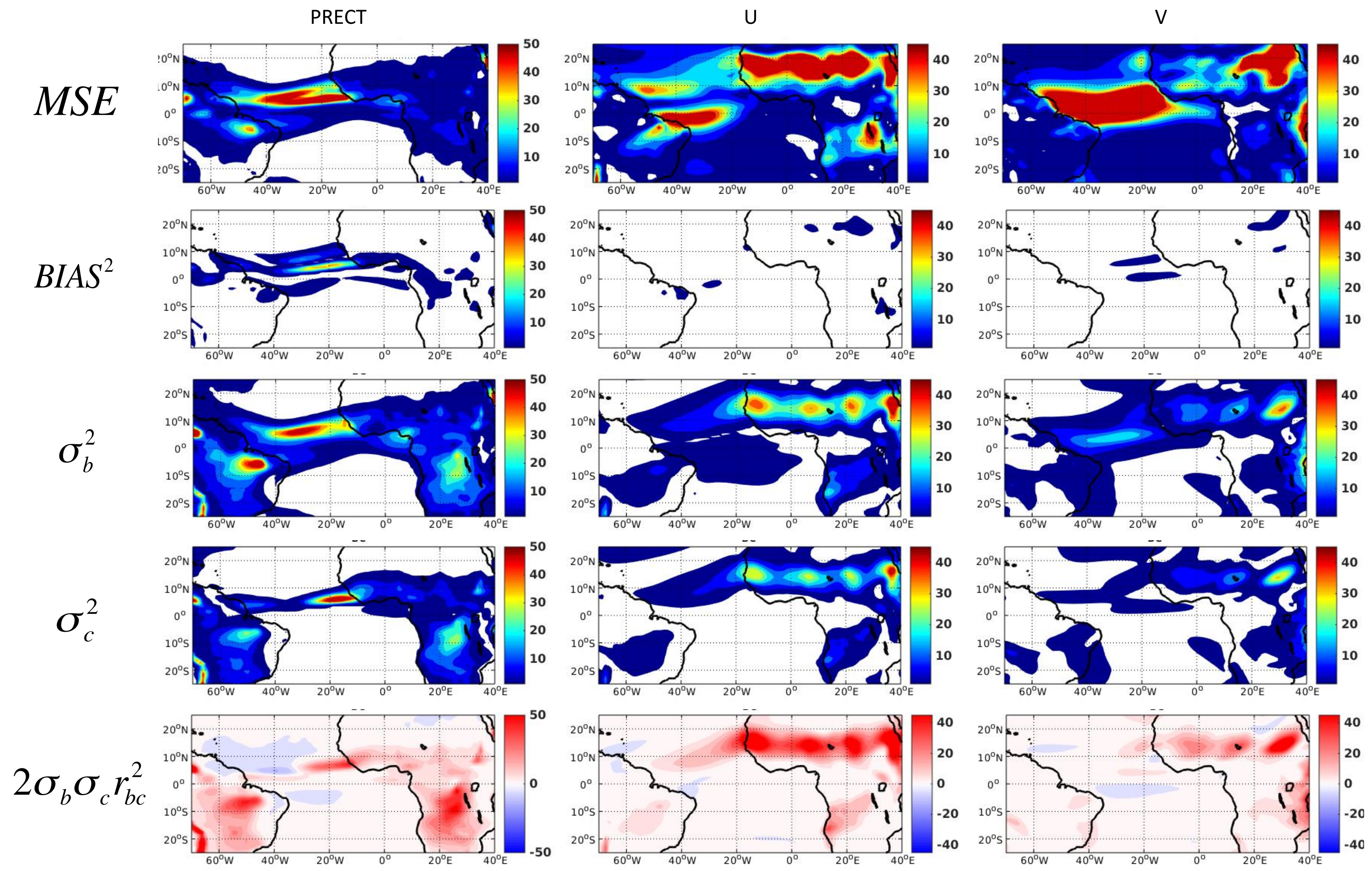


Fig. 3. Terms contributing to the mean square error between the CTL run and No SC run of the precipitation (left column), zonal (center column) and meridional (right column) winds. Total MSE (first row), bias (second row), standard deviation of CTL (third row) and NoSC (fourth row) runs and covariance (fifth row).

- **Large MSE in Precipitation and V along the equatorial Atlantic.**
- **The large BIAS in Precipitaion is consistent with the lack of seasonality in the NoSC run.**
- **No SC run less variability than CTL run and the ITCZ is constrained to a narrow band along the equator.**
- **U over Eatl well represented in NoSC run.**
- **High covariance in the regions where ocean contribution is irrelevant.**

6. Results: Covariability patterns using MCA

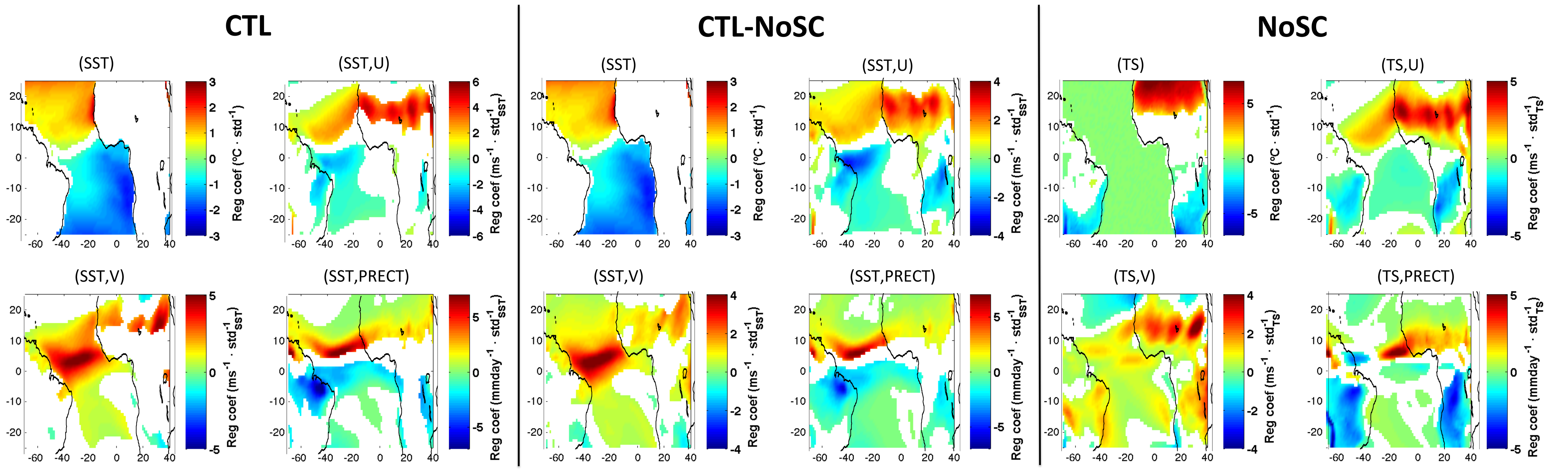


Fig. 4. Regression homogeneous and heterogeneous maps showing the Maximum Covariance Analysis modes of the JAS season average for the atmosphere-ocean, atmosphere-land pairs of variables. Different cases are shown: CTL (left), CTL-NoSC (center) and NoSC (right). Statistically non-significant values are shown in white. Only the 1st mode explaining most of the covariance (between 90-99%) is shown. Positive and negative values are shown in red and blue shading, respectively.

- **Both SST and TS show an inter-hemispheric gradient driven by the seasonal march of the sun.**
- **Land is the main driver of the monsoonal precipitation over west Africa but ocean also plays a role.**
- **Ocean SST contributes to push the rainband further north into the land in west Africa.**

References:

Mitchell, T. P., and J. M. Wallace, 1992: The annual cycle in equatorial convection and sea surface temperature. J. Climate, 5, 1140–1156.
Li, T., and S. G. H. Philander, 1996: On the annual cycle of the eastern equatorial Pacific. J. Climate, 9, 2986–2998.
Okumura, Y., & Xie, S. P. (2004). Interaction of the atlantic equatorial cold tongue and the african monsoon*. *Journal of Climate*, *17*(18), 3589-3602.