M20 #1330

Role of Air-Sea-Land Interactions in Tropical Atlantic Seasonal Cycle

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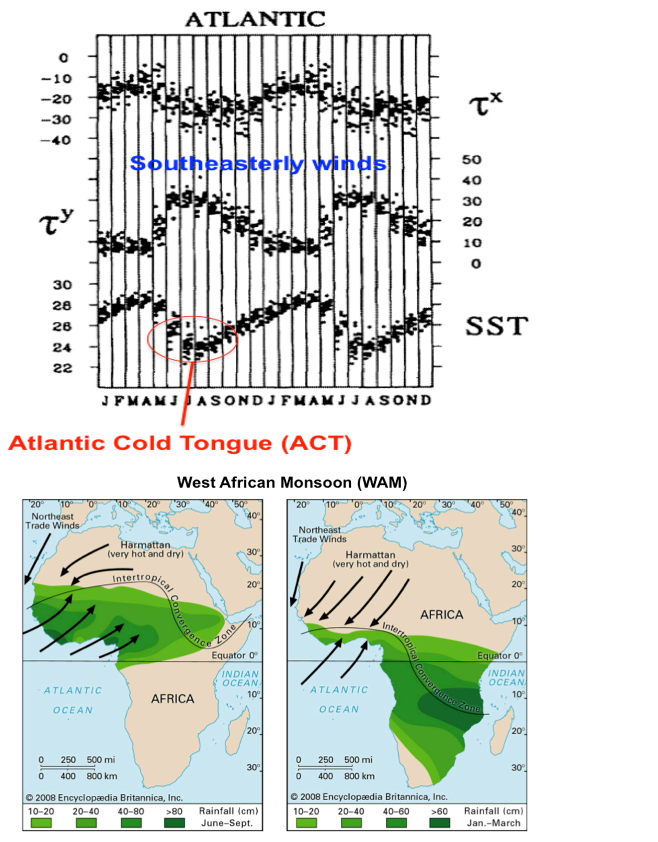
1. Motivation

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 the eastern tropical Atlantic (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).
We have performed different sensitivity experiments with an Atmospheric General Circulation Model (AGCM) forced by SSTs to study the relevance of the impact of the SST on the tropical Atlantic atmospheric low-level flow.



2. Experimental setup for the AGCM runs

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

ClimSST	MeanSST	EqmeanSST
Full Sea Ice Coverage		
Seasonally varying SST everywhere	Time independent SST everywhere	Time independent SST at the equatorial Atlantic (10S-5N)
Eliminates interannual variability Retain the SC	Eliminates SC	Eliminates SC only at EqAtlantic

3. Methodology

- Subjective comparison of the AGCM atmospheric output variables.
- Statistical study of the properties of the Joint Distribution of climSST and eqmeanSST run values
- Maximum Covariance Analysis (MCA) -> Ocean-atmosphere and land-atmosphere covariability patterns.

Case A) ***climSST - meanSST run***	Case B) ***meanSST run***	Case C) ***climSST - eqmeanSST run***
$(SST,[U,V,PRECT])_{climSST-meanSST}$	$(LST,[U,V,PRECT])_{meanSST}$	$(SST,[U,V,PRECT])_{climSST-eqmeanSST}$
Ocean - atmosphere	**Land - atmosphere**	**Equatorial ocean - atmosphere**

4. Results: Simulation of the SC

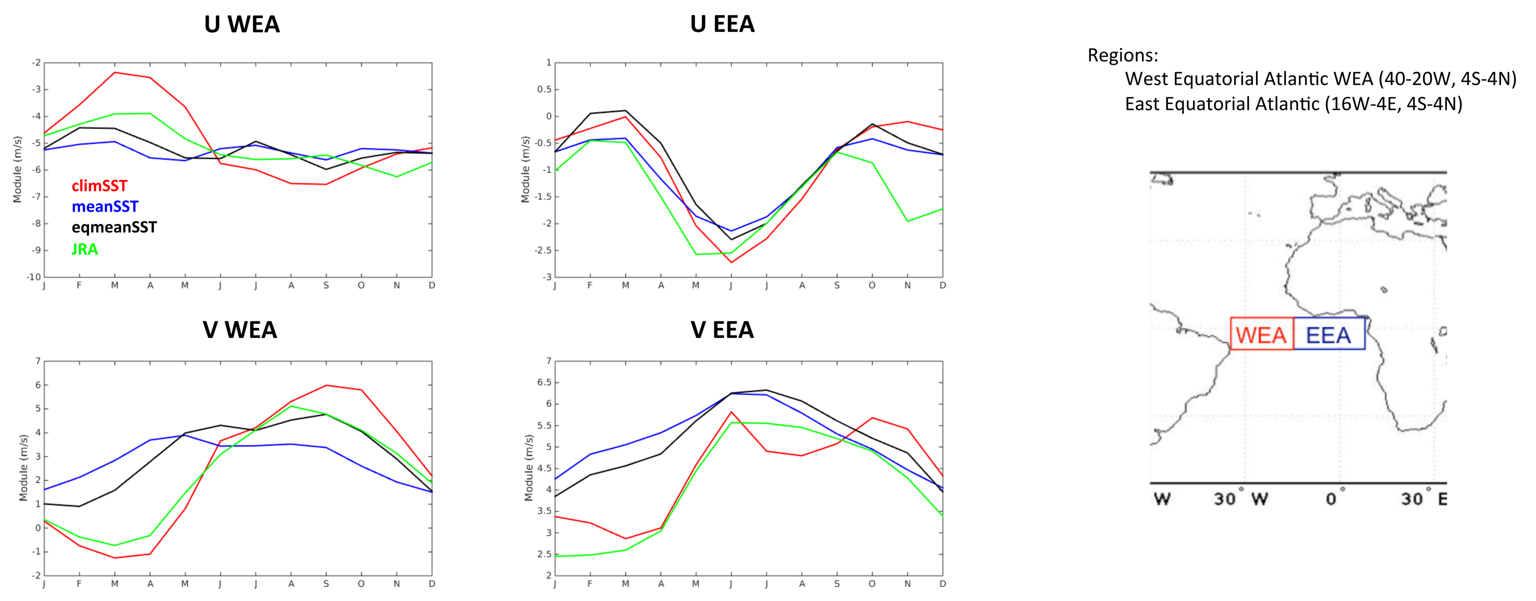


Fig. 1. Seasonal cycle of the surface winds. Zonal component (top) and meridional component (bottom) in the EEA (left) and WEA (right) regions. The results for the different experiment runs are shown in colors: climSST (red), meanSST (blue), eqmeanSST (black) and JRA reanalysis data (green).

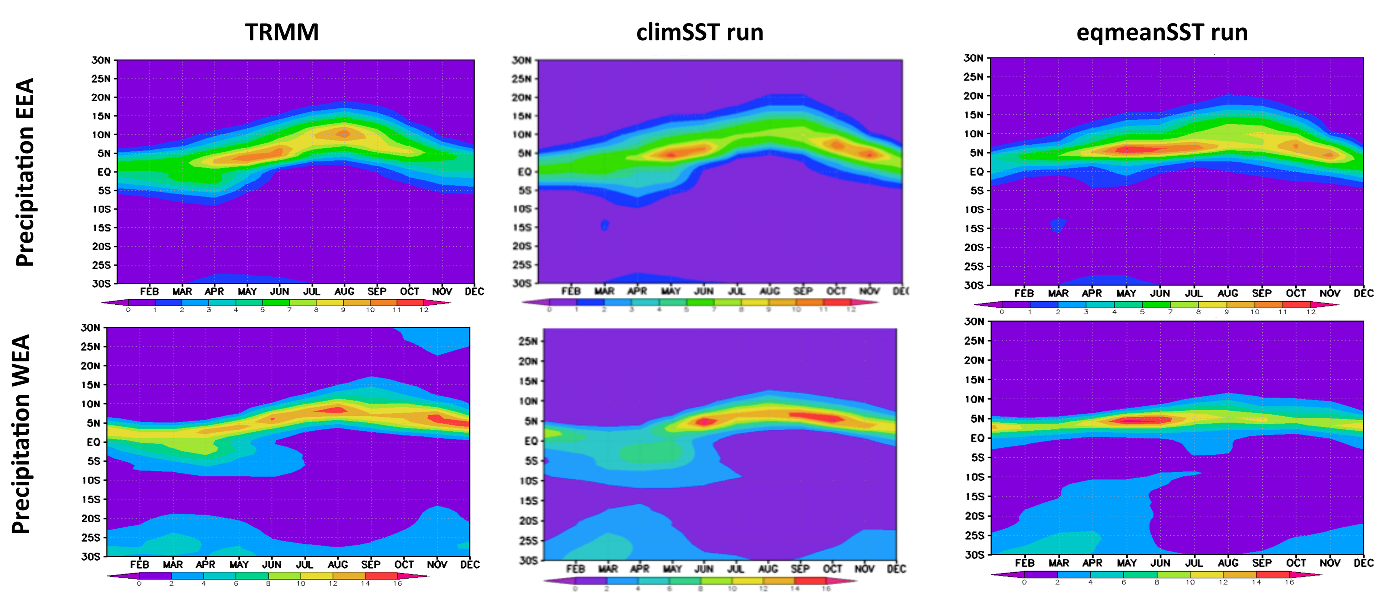


Fig. 2. Seasonal cycle of the precipitation in EEA (top row) and WEA (bottom row) regions. The results shown correspond to TRMM dataset (left), climSST run (center) and eqmeanSST run (right).

- **Monsoonal behaviour in EEA in absence of seasonality in the SST but the onset is missed.**
- **The seasonality of the SST is more relevant in the WEA than in the EEA.**
- **The precipitation seasonal cycle in EEA is captured without variability in equatorial SSTs.**
- **No seasonal march of the ITCZ along the whole equatorial Atlantic when we eliminate the SC in the SST everywhere (not shown). The extra-equatorial SSTs are important for the development of the monsoon.**

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 = climSST run C = eqmeanSST run

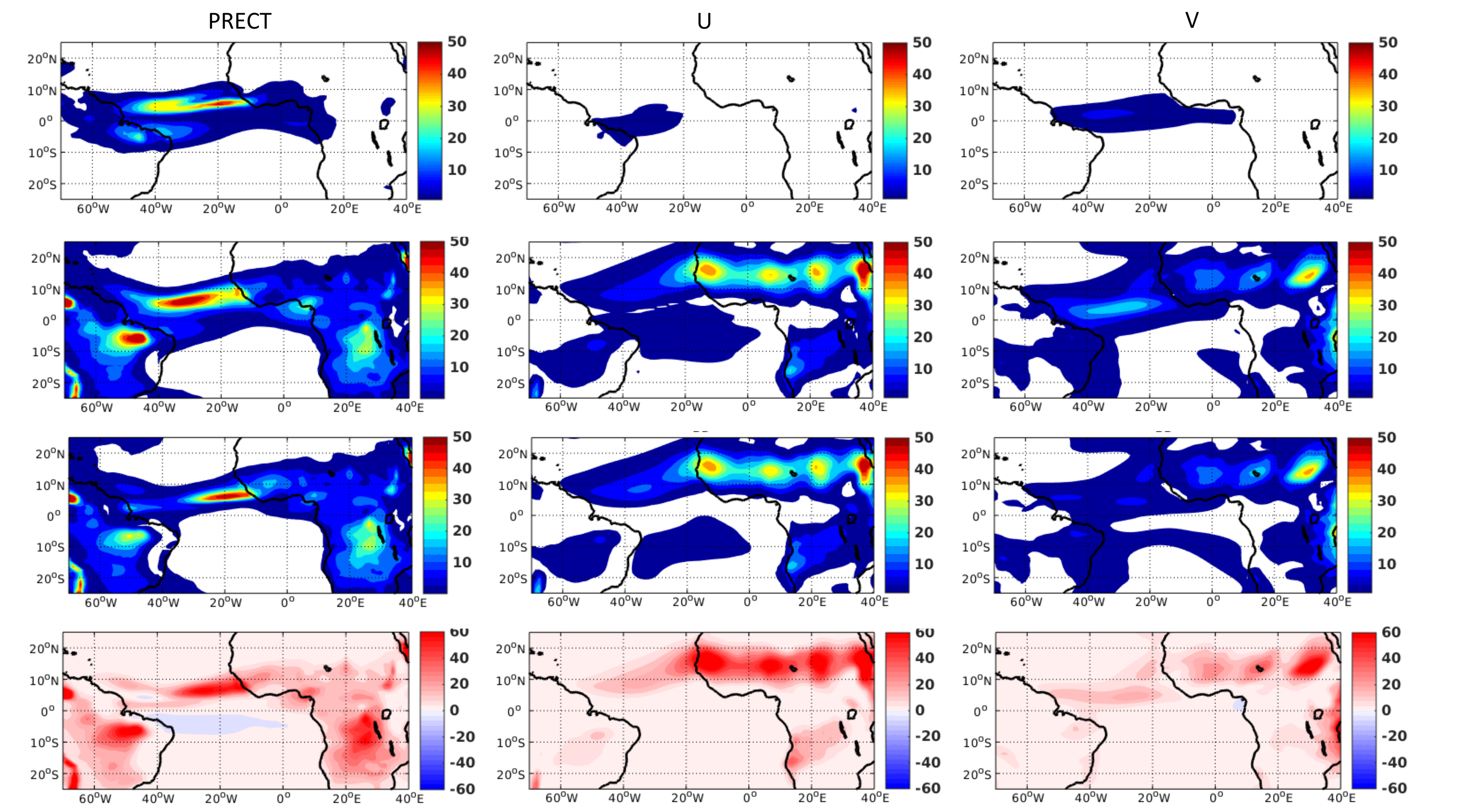


Fig. 3. Terms contributing to the mean square error between the climSST run and eqmeanSST run of the precipitation (left column), zonal (center column) and meridional (right column) winds. Total MSE (first row), standard deviation of climSST (second row) and eqmeanSST (third row) runs and covariance (fourth row).

- **Large MSE in precipitation and V along the equatorial Atlantic.**
- **The contribution of the BIAS to the MSE is rather small (not shown).**
- **EqmeanSST run less variability than climSST run and the ITCZ is constrained to a narrower band along the equator.**
- **High covariance in the regions where ocean contribution is negligible.**

  - **Where does the SST have a bigger impact on the atmosphere?**

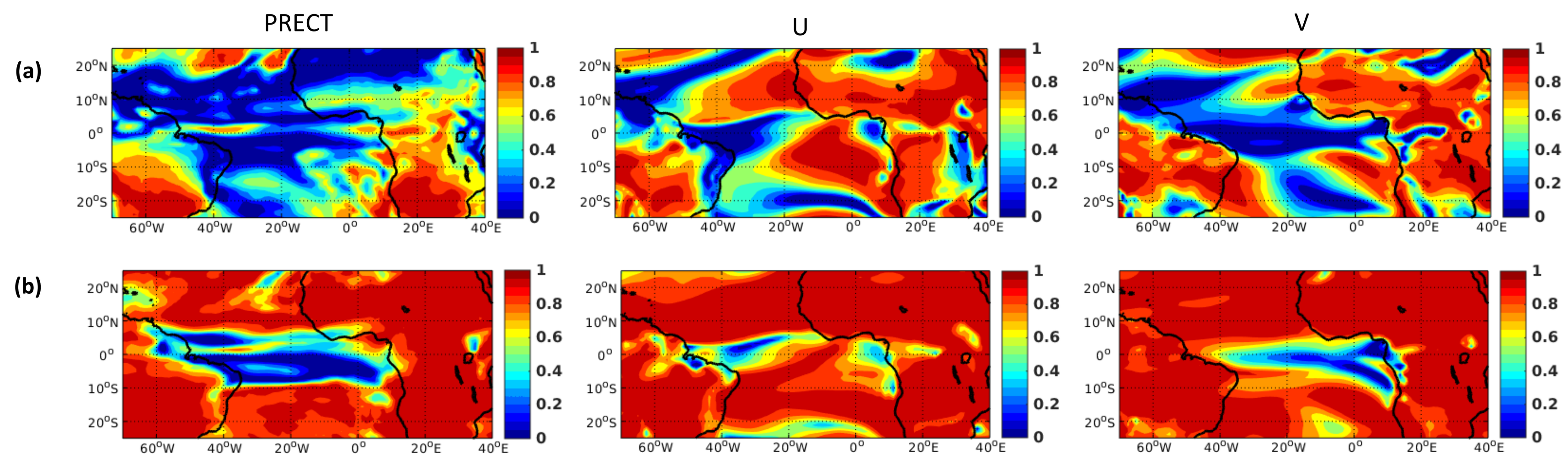


*Fig. 4. **(a)** Squared correlation coefficient between the climSST and meanSST runs for precipitation (left column), zonal (center column) and meridional (right column) winds. **(b)** Same as (a) for the climSST and eqmeanSST runs. This statistical quantity accounts for the amount of the variance explained by the SST with red (blue) shading representing the regions with low (high) variance explained by the SST seasonal cycle.*

- **SST main trigger of the precipitation along equatorial Atlantic.**
- **SST considerable impact over West African continental Precipitation.**
- **Low-level winds controlled by SST except for the zonal wind in EEA region**
- **Remote SSTs play a relevant role in the seasonality of equatorial Atlantic atmosphere.**

6. Results: Covariability patterns using MCA

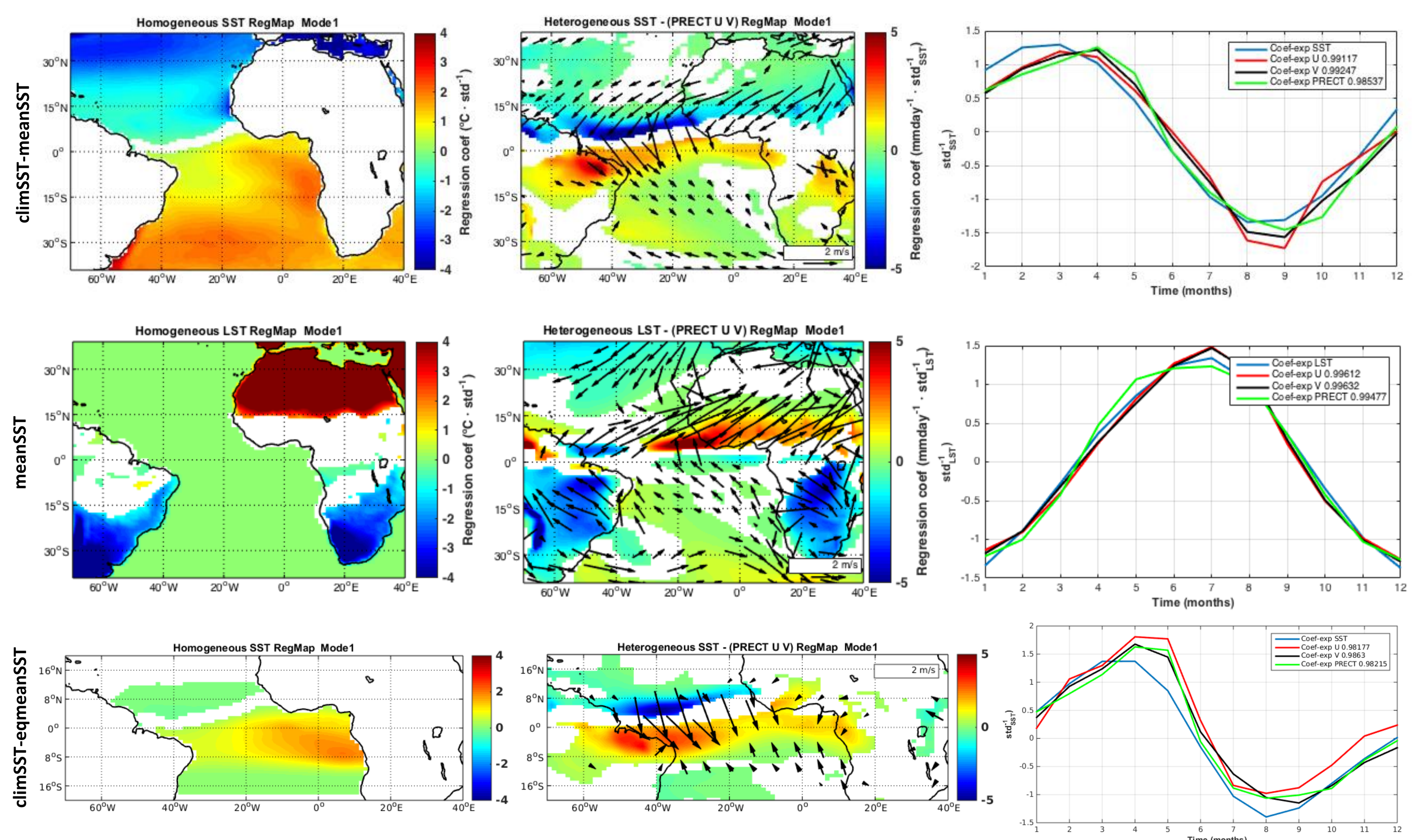


Fig. 5. Regression homogeneous and heterogeneous maps showing the Maximum Covariance Analysis modes for the atmosphere-ocean, atmosphere-land pairs of variables. Different cases are shown: climSST-eqmeanSST (first row), meanSST (second row) and climSST-eqmeanSST (third row). Statistically non-significant values are shown in white. Only the 1st mode explaining most of the covariance (above 96%) is shown. Positive and negative values are shown in red and blue shading, respectively.

- **Both SST and LST show an inter-hemispheric gradient driven by the seasonal march of the sun.**
- **SST controls precipitation over the equatorial Atlantic ocean.**
- **Land is the main driver of the monsoonal southerly winds and associated precipitation over west Africa.**
- **The equatorial SSTs impact onto the atmosphere is predominantly local.**
- **The impact of equatorial SSTs on precipitation and low-level winds is larger at west equatorial Atlantic.**

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.