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11A.4 VARIABILITY OF SURFACE RELATIVE HUMIDITY OVER TROPICAL WEST AFRICA

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1. INTRODUCTION

Our primary motivation for this study hinges on the important role surface relative humidity (RH) plays in the occurrence of meningococcal meningitis (hereafter MM) over tropical West Africa. Moisture flux, especially from the tropical South Atlantic Ocean (Hagos and Cook 2007), largely determines the RH levels, which modulate MM — a climate-driven, highly fatal and morbid disease, affecting nearly 250,000 people annually, with an average of 25,000 deaths. Knowledge of RH-MM relationship is currently being exploited as an effective strategy for reactive vaccination campaign, by channeling limited logistics and vaccines to most vulnerable targets (areas of low RH levels, typically less than 40% threshold) during the campaign period.

The focus of the study is twofold. First, we intend to investigate the surface RH variability, on seasonal to interannual time scales. Second, determine the dominant tropical Atlantic SST modes that modulate the surface RH variability. The outcome of this will provide an insight into the dynamical predictability of surface RH, a proxy for MM.

2. DATA AND METHODS

The data used for the research were monthly improved extended reconstructed sea surface temperature (ERSST; Smith and Reynolds 2004), and National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis (Kalnay et al. 1996). These have 0.5^{o} latitude x 0.5^{o} longitude and 2.0^{o} latitude x 2.0^{o} longitude, respectively, on global grids. Analysis was done for 1948-2010, consisting of 63 years of continuous data.

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First, surface RH climatology over Northern Hemisphere (NH) Africa was computed for 12 overlapping, three-month seasons to shed light on its seasonal cycle, using NCEP/NCAR reanalysis. This was followed by implementation of empirical orthogonal function (EOF) analysis on the RH and tropical Atlantic Ocean. Statistical separability of the dominant modes was obtained using the delta-test (North et al. 1982).Tropical Atlantic-RH co-variability was investigated using grid point correlations, at 99.9% confidence level. Also, the relationships between the temporal characteristics of the RH and the Atlantic were investigated using linear correlation analysis.

3. RESULTS

3.1 Surface RH Climatologies

The twelve surface RH climatologies, represented by the four standard NH seasons namely winter, spring, summer, and fall, are depicted in Fig. 1. Visual inspection reveals persistent surface RH lows and highs over West Africa and over the tropical Northern Atlantic, respectively. More especially the spatial extent of the lows over West Africa significantly varies from season to season, with the largest RH low field occurring in Dec-Jan-Feb (DJF) and the smallest in Jun-Jul-Aug (JJA), the latter being the West African Sahel monsoon season. This implies to some extent that the vulnerability to the disease is season-dependent or sensitive, on the assumption of MM dependence on RH.

3.2 EOF Analysis

Figures 2-5 show the EOF analysis results for the two variables for only winter (DJF) and spring (MAM) seasons. In both seasons, the percent total variances explained by the leading five modes for SST variability were 67.8 %(for DJF) and 70.2 % (for MAM). For the sake of brevity, the three leading modes with their percent variances shown on the top of the right hand side (RHS) of the panels are presented. The first mode in both seasons indicates a warming trend signal (Fig.2a, 3a). Their second modes also share similarity in having a characteristic, dimorphic tropical Atlantic SST anomaly pattern (ie, the interhemispheric SST asymmetry — the tropical Atlantic Dipole Mode: TADM) as well as interannual oscillations in their time series (Figs. 2b, 3b). However, their third modes show dissimilar spatial patterns even though their temporal characteristics are dominated by interannual variability (Figs .2c, 3c). DJF SST EOF 3 mode is encapsulated in a quadrupole-like pattern with bands of SST anomalies of alternating signs. The corresponding MAM SST EOF 3 mode depicts a tripole-like pattern with negative anomalies sandwiched by the positive anomalies.

The number of leading modes for surface RH DJF and MAM seasons were five and three, respectively. These explained 54.7 % and 43.7% of total variability, respectively. The first two modes for the two seasons are presented. The individual contributions of the modes are similarly shown on the top of the RHS of the panels (Figs. 4, 5). The DJF surface RH EOF 1 mode (Fig. 4a) exhibits a tripolar anomaly pattern with the center of action of the anomalies over land having positive loadings ensheathed by negative loadings. This mode is related to MAM tropical Atlantic SST EOF 3 (r=+0.41), suggesting the latter as a potential predictor. The temporal variability associated with DJF RH EOF 1 mode is decadal-like (Fig. 4a). The DJF surface RH EOF 2 mode (Fig. 4b) also exhibits a tripolar pattern with alternating bands of RH anomaly. Similarly, its time series shows decadal-like variability. This mode is associated with DJF tropical Atlantic SST EOF 3 (r=+0.46). MAM RH EOF 1 and 2 time series are anti-correlated with MAM tropical Atlantic SST EOF 3 (r=- 0.38) and DJF tropical Atlantic EOF 3 (r = -0.45) time series, respectively, suggesting the latter as a potential predictor.

RH-SST co-variability, investigated by grid point correlations between tropical Atlantic SST anomalies and the first two RH EOF time series for the two seasons are displayed in Fig. 6. All are mainly characterized by positive correlations. Figure 6a shows that DJF surface RH EOF 1 is modulated by climatic signals in the subtropical, equatorial and eastern Atlantic SST anomalies. On the contrary, the EOF 2 is seen to be related to a remote but small scale signal in the northwestern subtropical North Atlantic (Fig. 6b). MAM surface RH EOF 1 modulation is quite similar to the DJF mode 1, except for a more prominent signal in the southwestern South Atlantic (Fig. 6c), whereas MAM surface RH EOF 2 is related to remote but small scale subtropical North Atlantic SST anomalies over northern Africa (Fig. 6d).

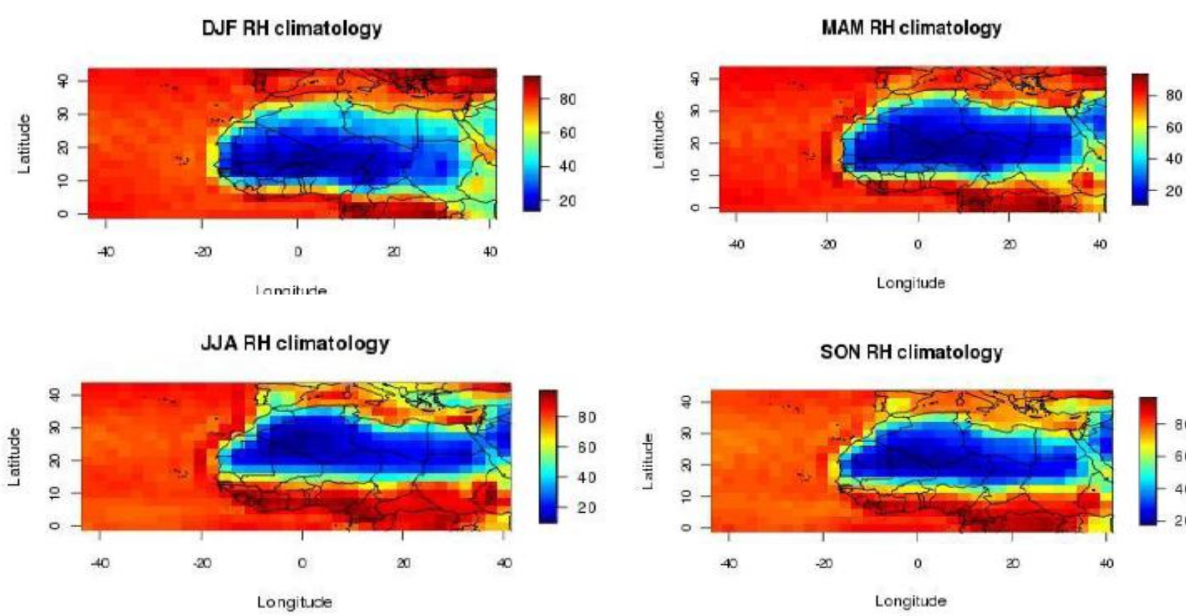

Figure 1. NH Africa seasonal surface RH climatologies.

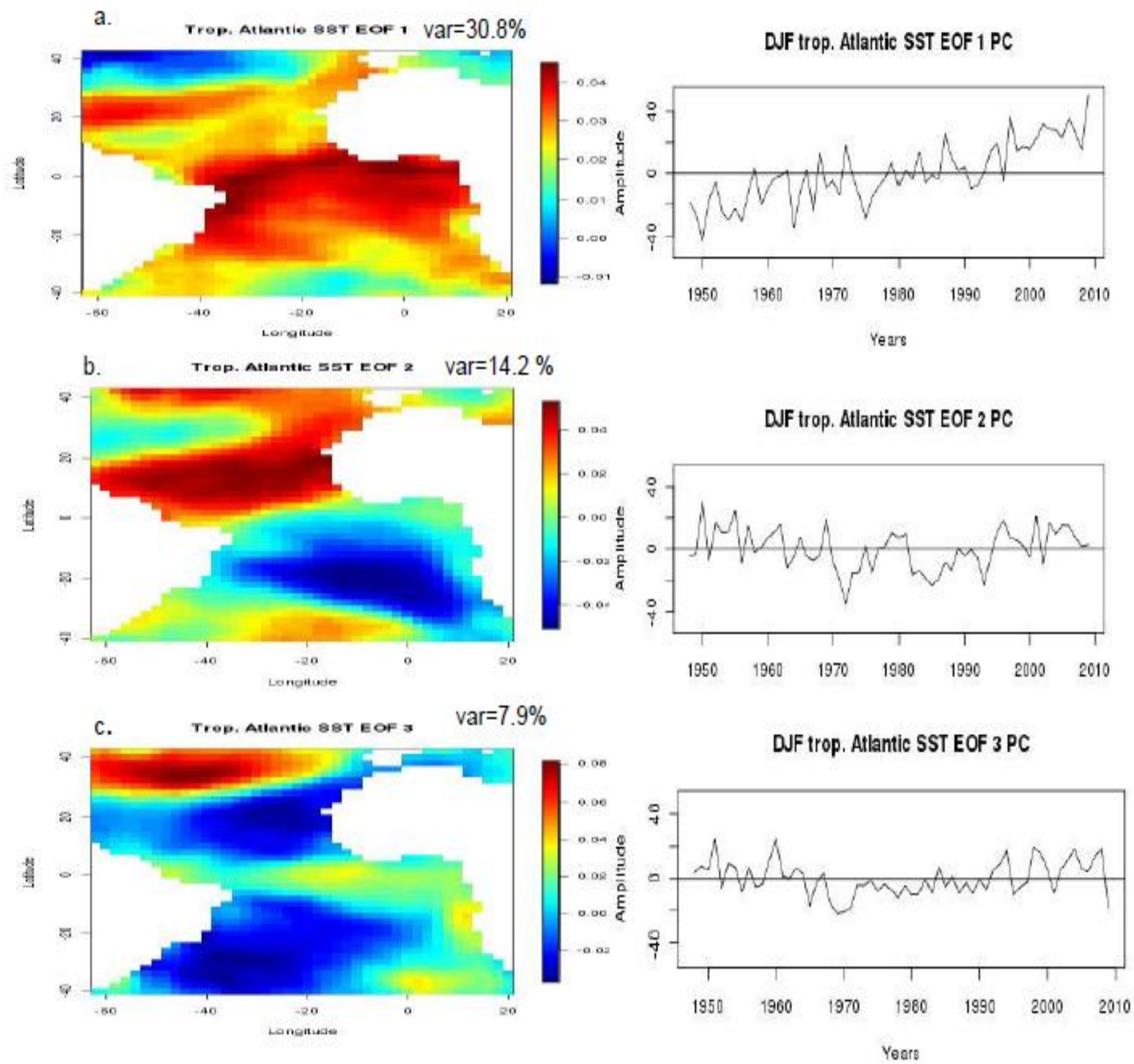

Figure 2. DJF tropical Atlantic SST EOF modes.

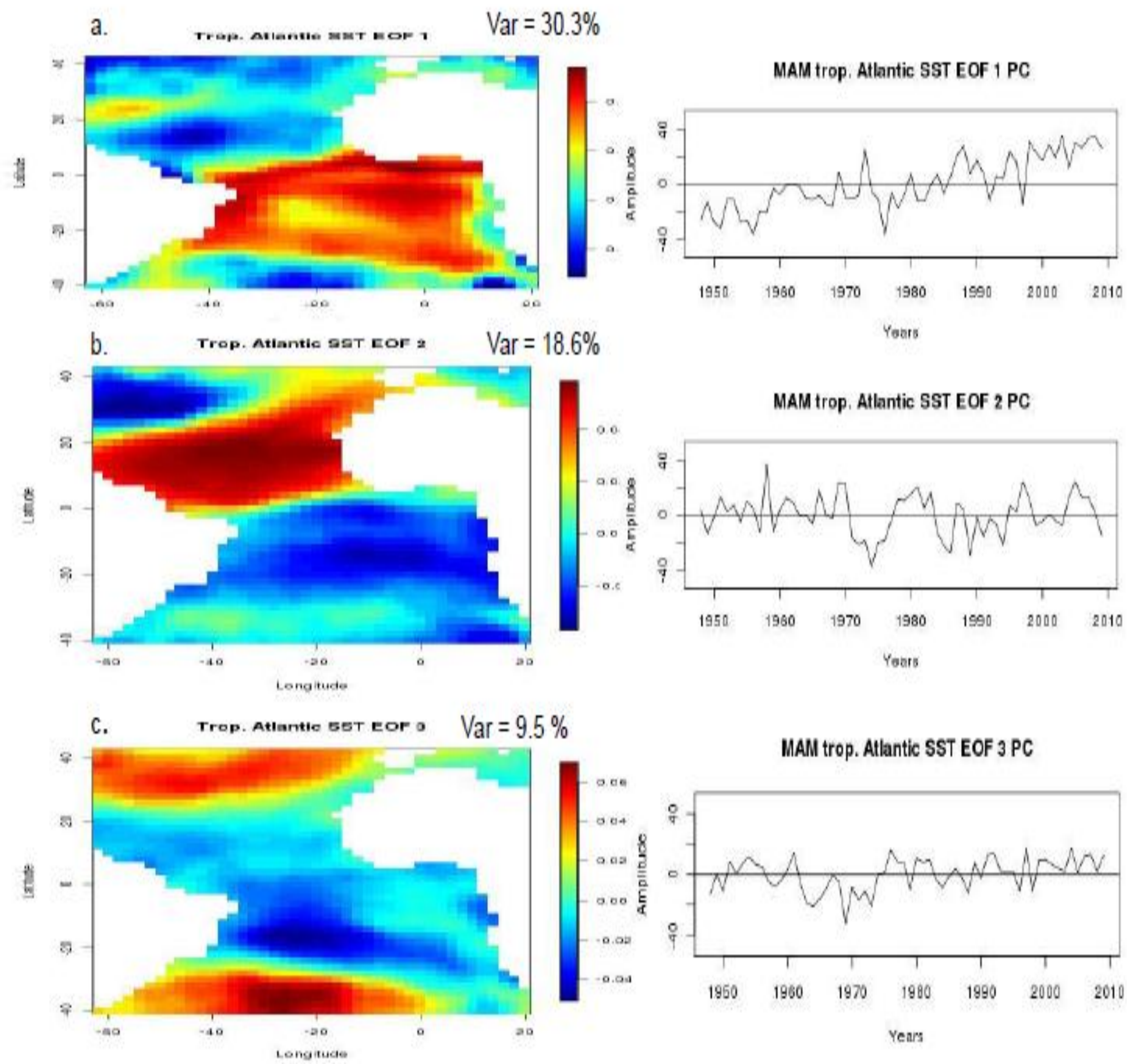

Figure 3. As in Figure 2 except for MAM season.

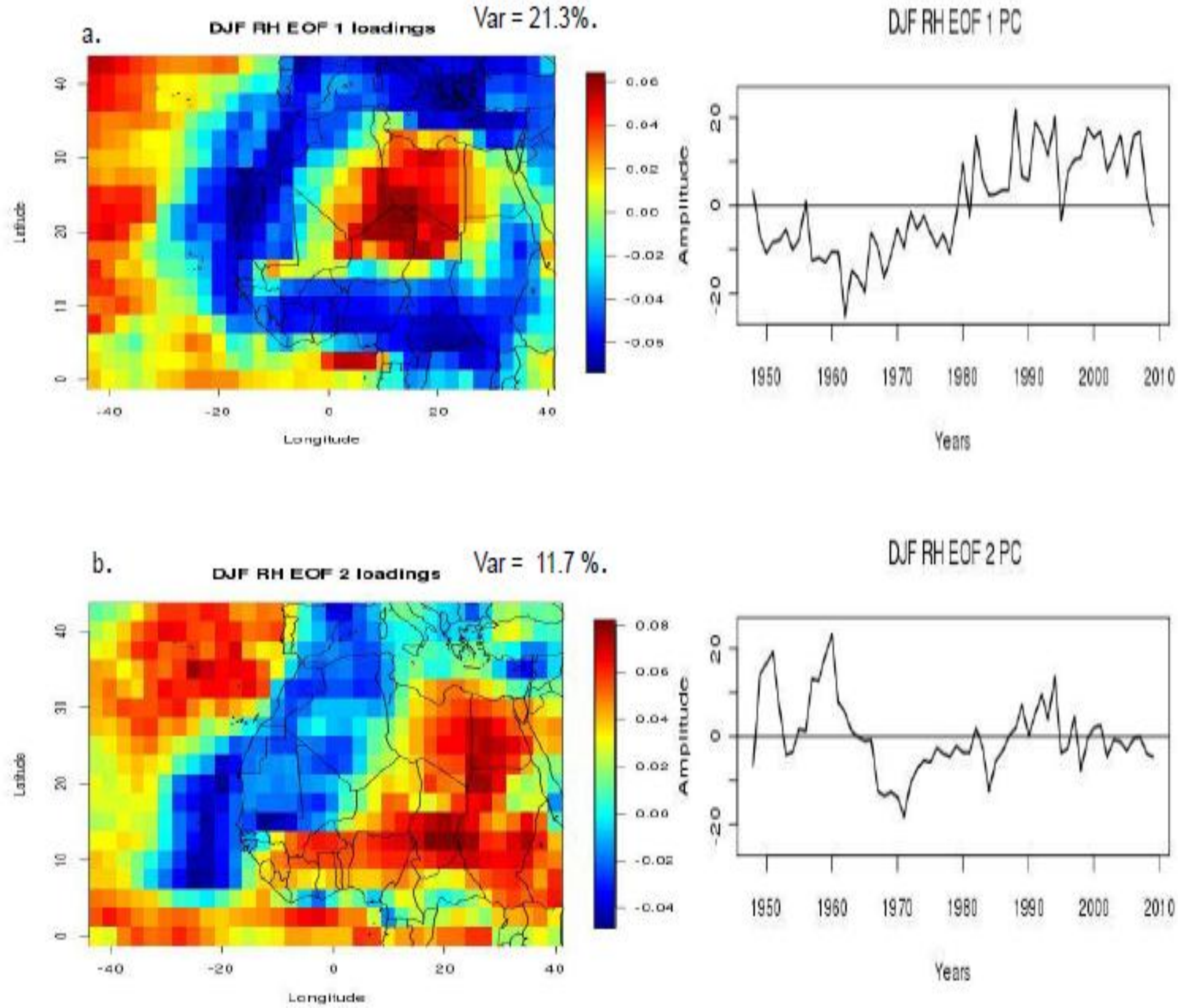

Figure 4. DJF surface RH EOF modes.

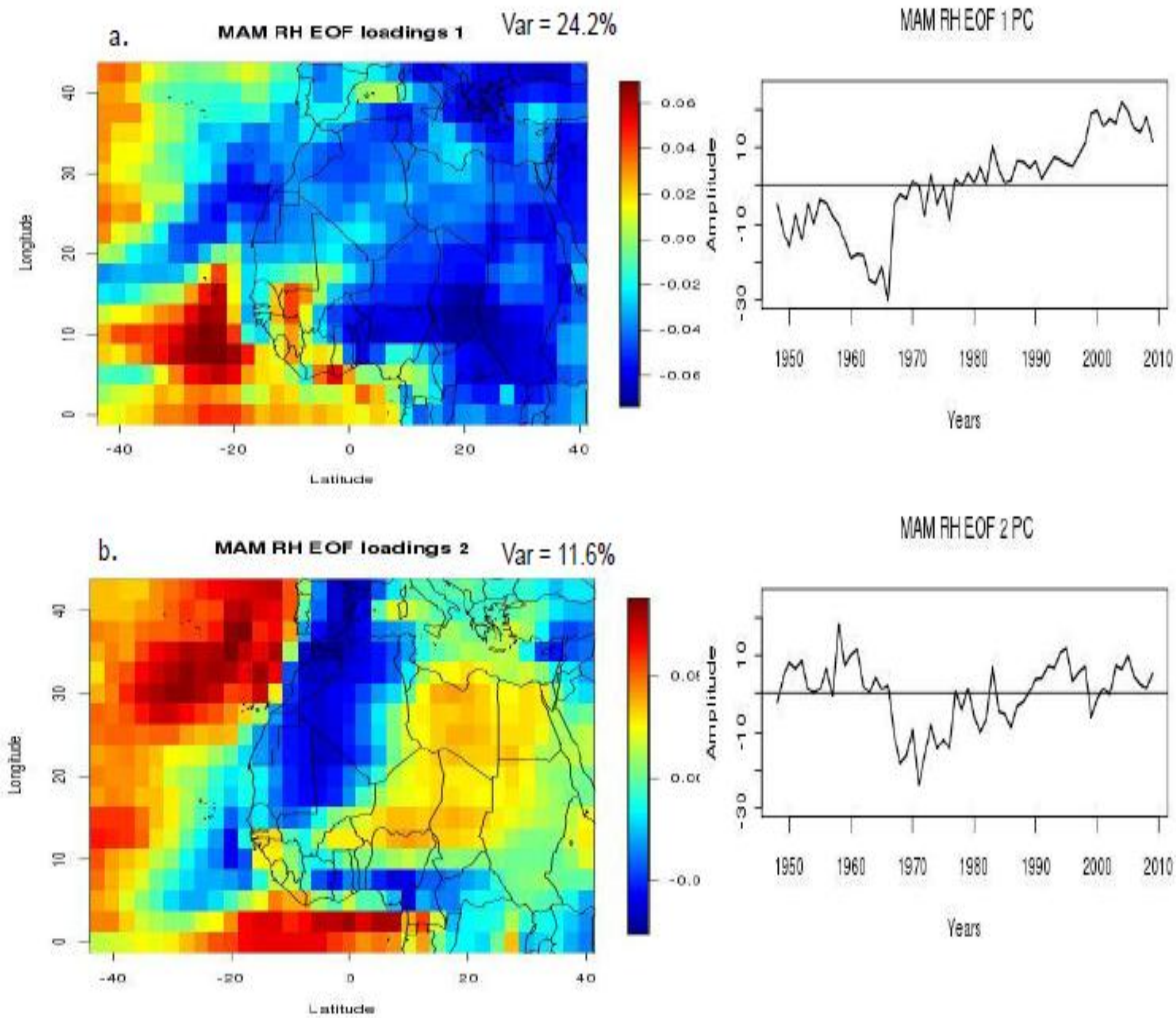

Figure 5. As in Figure 4 except for MAM season.

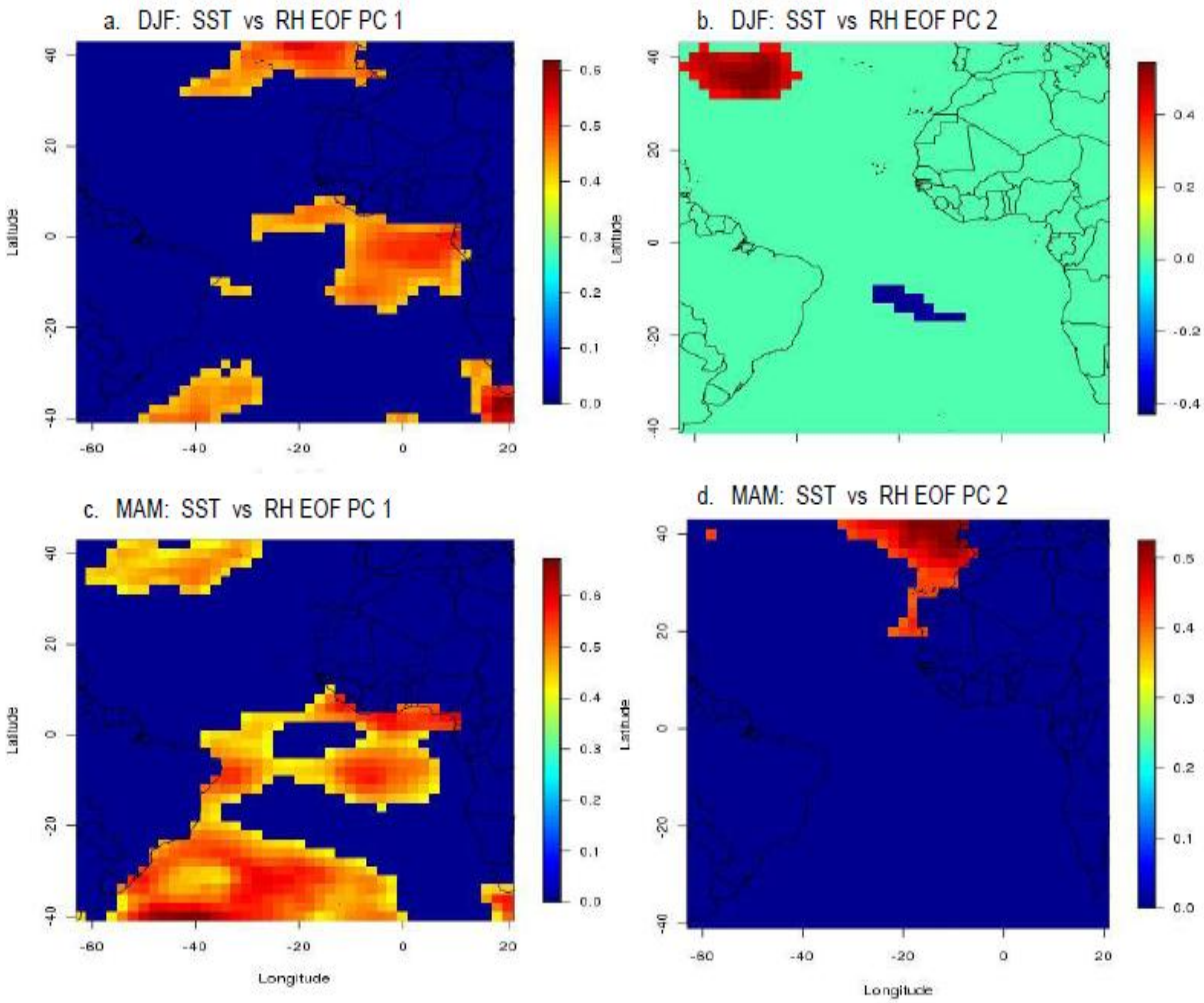

Figure 6. Seasonal tropical Atlantic SST-RH covariability. In panels a, b, c, and d, dark blue or green areas over the ocean are statistically insignificant at 99.9% confidence level. On land, dark blue or green colors are default background colors, and should be ignored.

4. CONCLUSIONS

The study has revealed that surface RH lows are persistent features over tropical West Africa. The largest spatial extent of the lows occurs in the NH winter and the smallest occurs in NH summer. This suggests that RH is sensitive to season.

The RH-SST co-variability is mainly characterized by positive correlation pattern, suggesting that RH over West Africa is modulated by tropical Atlantic SST variability. DJF RH EOF 1 is mainly related to SST variability in the subtropical, equatorial and eastern Atlantic. A similar observation is made for MAM RH EOF 1, but with a more prominent SST signal associated with it in the southwestern South Atlantic. The RH EOF 2 time series for both seasons are linked to remote but small scale SST variability in the subtropical North Atlantic: DJF RH EOF2 (northwestern SST) vs MAM RH EOF 2 (SST over northern Africa).

Temporal linear correlations show that DJF RH EOF 1 series is related to NH spring (MAM) tropical Atlantic SST EOF 3 time series. This lagged correlation suggests the spring season SST variability as a potential predictor. However, DJF RH EOF 2 time series is linked to DJF tropical Atlantic SST EOF 3 time series. MAM RH EOF 1 and 2 time series are anti-correlated with MAM tropical Atlantic SST.EOF 3 and DJF tropical Atlantic EOF 3 time series, respectively, with the latter as a potential predictor.

In future, the dynamical predictability of the dominant surface RH modes, on seasonal to interannual time scales, will be investigated.

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