North Atlantic Sea Surface Salinity as a Predictor of Sahel Precipitation

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Introduction

Moisture originating from the ocean is the ultimate water sources for terrestrial precipitation. Globally, the largest moisture source regions are located in the subtropical oceans, where the evporation is enhances due but precipitation is depressed due to the presence of subtropical high pressures. Consequently, evporation excesses precipitation by 1-3 meters at a yearly basis, resulting in a net export of moisture from the subtropical oceans (Fig. 1).

As moisture exsits the subtropical oceans, it leaves an imprint on sea surface salinity (SSS). The subtropical oceans are characterize as the saltest regions in the open ocean (Fig. 1). Studies have shown that SSS is sensitive to the changes in freshwater flux and can thus gauge the intensity of the oceanic water cycle (Schmitt 2008; Durack *et al.* 2012).

Given the close relationship between salinity and oceanic water cycle and the importance of oceanic moisture supply to terrestrial precipitation, we are motivated to explore whether SSS in the subtropical oceans can be utilized as a predictor of terrestrial precipitation.

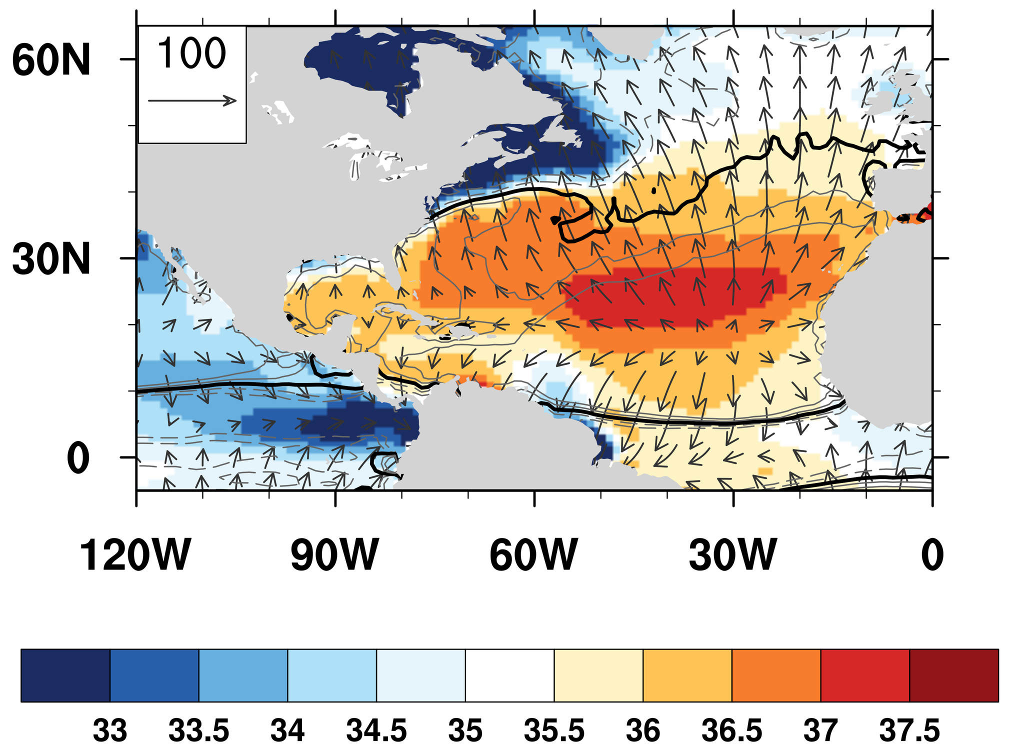


Fig. 1 | Springtime climatology (1950-2009) of SSS (shaded, unit: PSU), moisture flux divergence (thin contours, unit: mm day^{-1}) and the divergent component of moisture flux (vectors, unit: Kg m^{-1} s^{-1}) over the North Atlantic. The solid bold contour is the moisture flux divergence = 0 isoline. The thin solid (dashed) contours are the moisture flux divergence >0 (<0) isolines. The contour intervals are 1 mm day^{-1}.

Data and Methods

Salinity Data: EN4 (Objectively analyzed, monthly, 1950-2009)

Precipitation: NOAA PREC/L (monthly, 1950-2009)

Atmospheric Reanalysis: NCEP/NCAR (6-hrly; 1950-2009)

Singular Value Decomposition (SVD):

SVD analysis was applied to the covariance matrix between springtime (March-April-May; MAM) SSS and monsoon-season (June-September, JJAS) precipitation to extract the spatiotemporal mode that maximize the covariance between SSS and precipitation.

Composite Analysis:

Mositure flux and soil moisture content were composite upon the SSS over the key areas of the subtropical oceans to study the physical processes that correlate monsoon-season precipitation to pre-season SSS variablity.

Random Forest Regression/Prediction:

Random Forest prediction model (Breiman 2001) was constructed to assess the predictive skills using SSS as a rainfall predictor. The results have also been tested using the multiple linear regression model (Li *et al.* 2016).

Results

Increased springtime SSS in the subtropical North Atlantic is followed by excessive monsoon-season precipitation in the African Sahel.

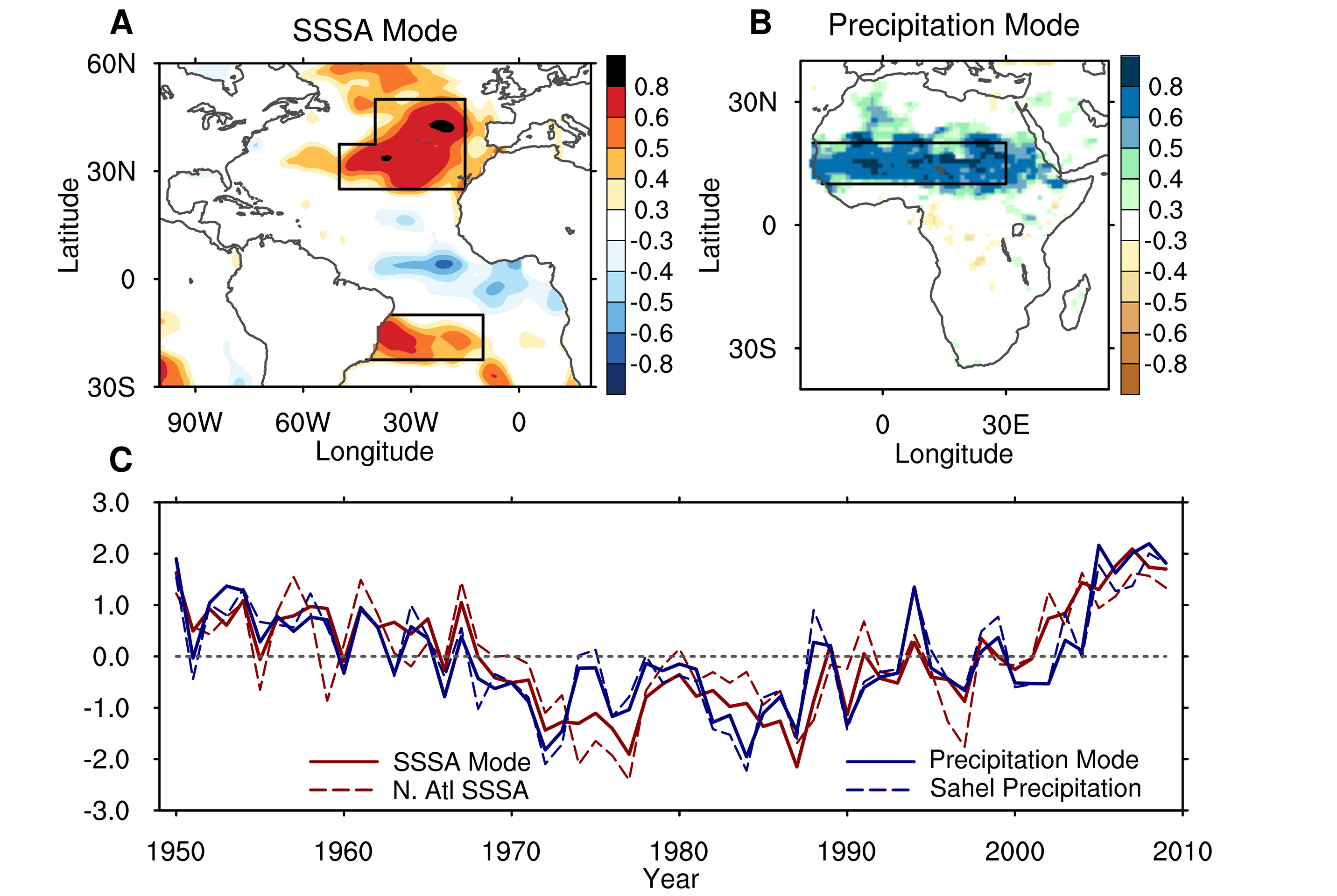


Fig. 2 | Springtime Atlantic SSSA and Sahel monsoon-season rainfall. (A) The leading SVD mode of springtime (MAM) Atlantic SSSA and (B) JJAS African precipitation. (C) shows the time series of the first SVD modes of SSSA (solid red curve) and precipitation (solid blue curve), as well as the normalized MAM SSSA in the North Atlantic region (dashed red curve) and JJAS Sahel Precipitation (dashed blue curve).

The 3-month time delay is likely bridged by the memory of soil moisture and its positive coupling with the inflow of atmospheric moisture flux.

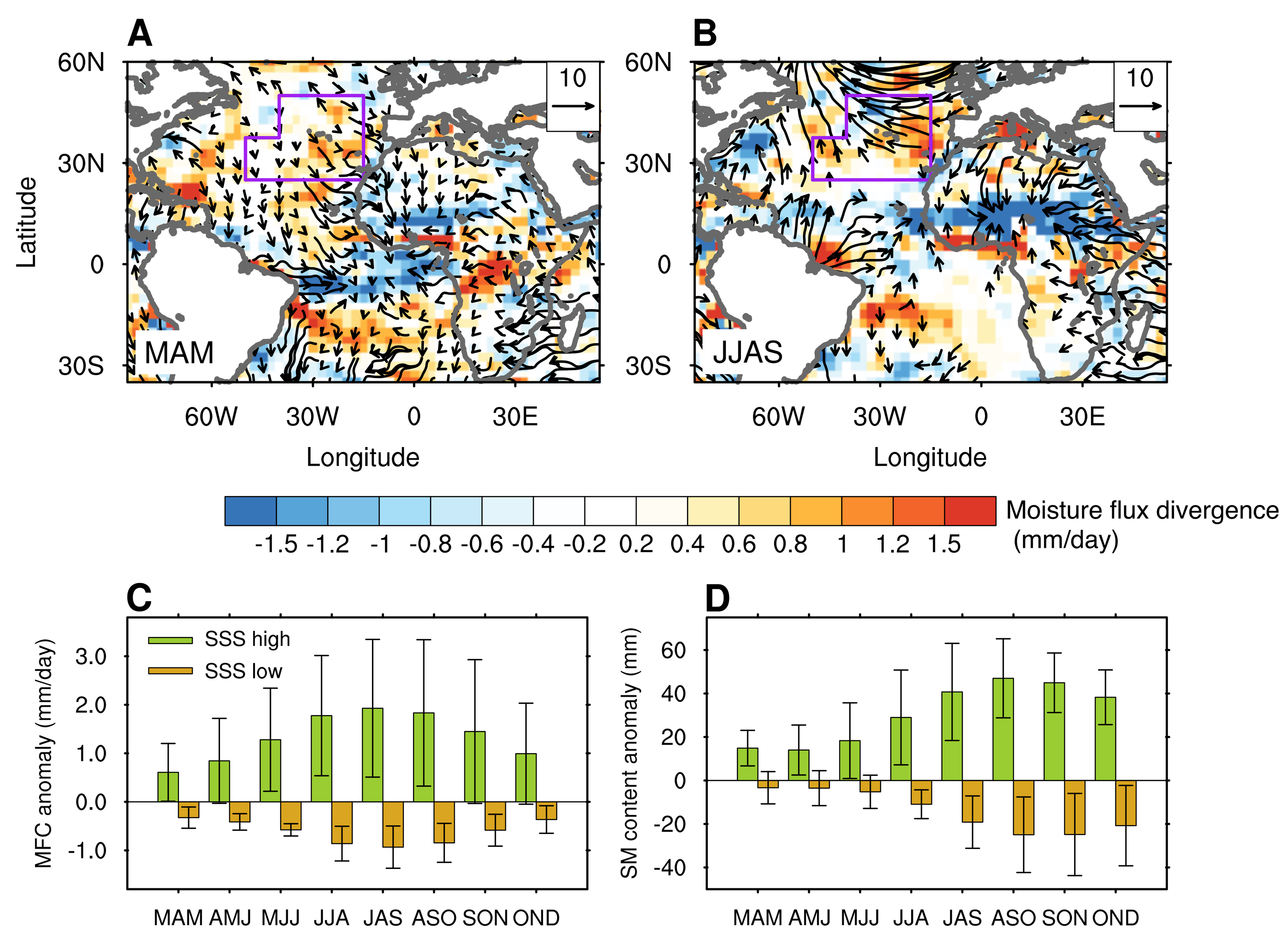


Fig. 3 | **Mechanisms linking springtime SSSA and Sahel monsoon-season precipitation.** Moisture flux divergence anomaly (shaded; mm day^{-1}) and the divergent component of moisture flux (vectors; Kg m^{-1} s^{-1}) composites upon North Atlantic SSSA: (A) is the MAM composite, and (B) is JJAS composite. Vectors are only shown for moisture flux anomalies significant at the 0.05 level according to a Hotelling t-squared test; (C) moisture flux convergence anomaly and (D) soil moisture content anomaly over the Sahel composited on springtime North Atlantic SSSA. The error bars denote the upper and lower bound of soil moisture or moisture flux convergence anomaly defined by one standard deviation.

North Atlantic salinity outperforms SST-based predictors in seasonal forecasts of monsoon precipitation in the African Sahel.

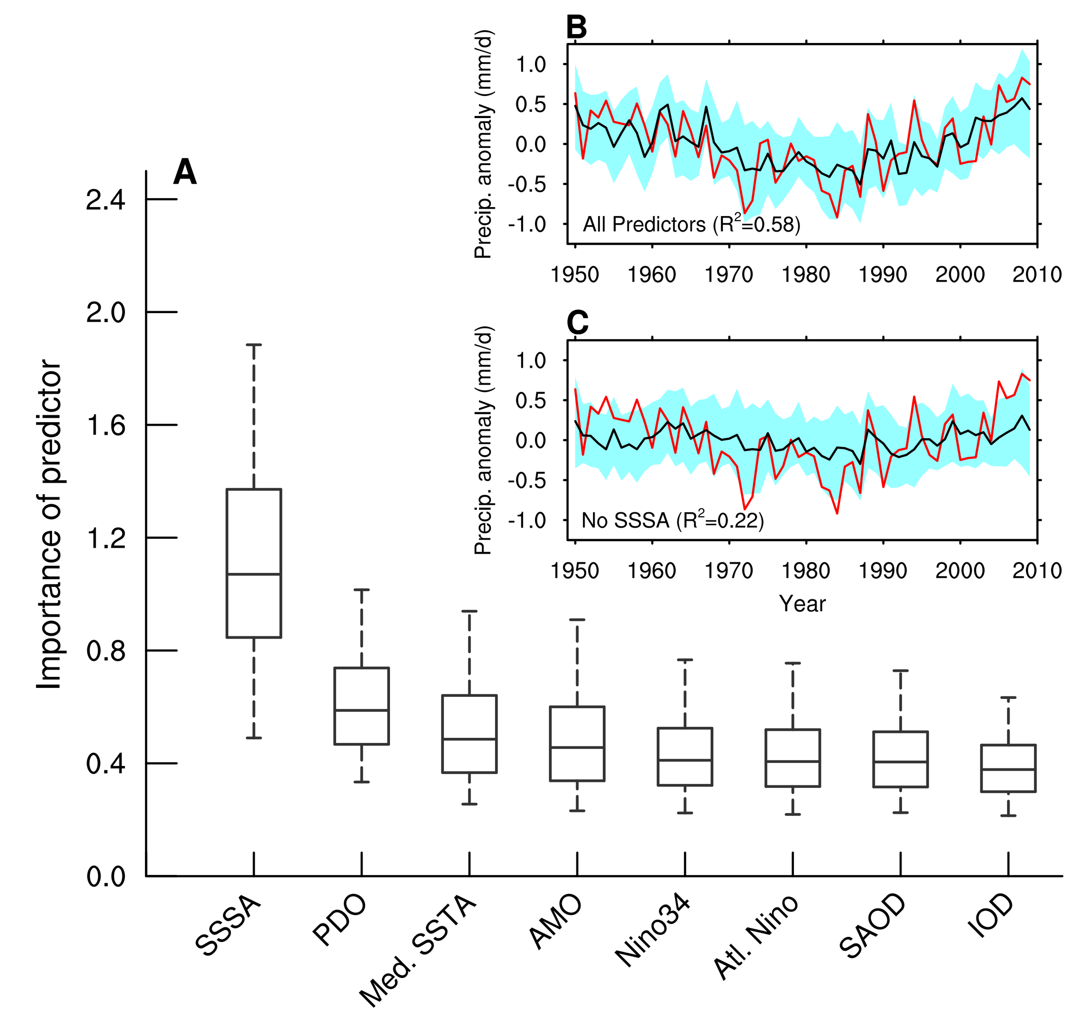
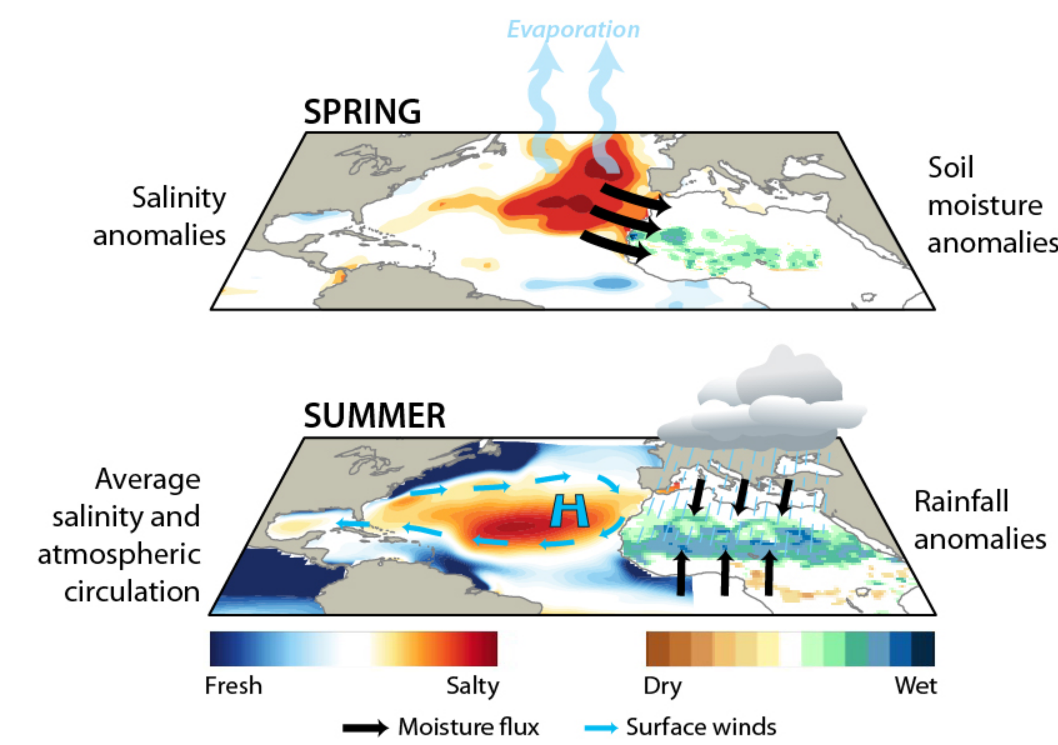


Fig. 4| **Sahel rainfall prediction using North Atlantic SSSA.** (A) Box-and-Whisker plot of the importance of predictors for Sahel monsoon-season precipitation according to the random forest algorithm. (B) and (C) are the precipitation anomaly (bold black curves) over the Sahel predicted by the random forest algorithm: B) is the prediction using the combination of all predictors including SSSA; and (C) is the prediction without SSSA. The blue envelope is the 95% confidence interval of the predictions. The red curve is the observed precipitation anomaly.

Conclusion

Springtime SSSA over the subtropical North Atlantic can be utilized as a physically meaningful predictor for Sahel precipitation during the summer monsoon season.



- Higher springtime SSS over the subtropical North Atlantic tends to be followed by above normal monsoon-season precipitation over the African Sahel.
- The physical mechanisms involve ocean-to-land moisture transport and a positive feedback between local soil moisture and atmospheric moisture flux.
- With the knowledge of springtime salinity in the subtropical North Atlantic, forecasts of Sahel monsoon-season precipitation can be significantly improved.

References

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