UNDERSTANDING THE ZONAL VARIABILITY IN CMIP6 PROJECTIONS OF SAHELIAN PRECIPITATION

Emmanuel O. Audu[1], Ross D. Dixon[1], Ismaila Diallo[2]

[1] Department of Earth and Atmospheric Science, University of Nebraska-Lincoln, USA

[2] Department of Meteorology and Atmospheric Science, The Pennsylvania State University, University Park, PA 16802, USA

1. Introduction

The uncertainty in model projections of future precipitation across the Sahel has persisted across many generations of Earth System Models (ESMs), with some models predicting drying and others moistening across this region. These discrepancies in future projections pose a challenge for stakeholders and decision makers. Many projections of Sahel precipitation found in the ESMs show a zonal dipole in the sign of precipitation pattern, with moistening across the Central and Eastern Sahel and drying projected for the Western Sahel. However, it remains unclear why some models produce the zonal dipole and others do not.

2. Objective

In this study, we seek to understand why some of the current state-of-art CMIP6 models produce this zonal contrast and others do not, along with to investigate and better understand the variability in the transition region for models that produce the dipole.

3. Data and Methods

We used the monthly data from 43 fully coupled CMIP6 models for two different periods: the historical simulation (1900 – 2014) and the SSP585 future scenario (2015 - 2100) of the July, August, September (JAS) of the West African Monsoon Season. The Sea Surface Temperatures (SSTs) and Precipitation region used in this work are similar to those in Park et al., 2015 and Monerie et al., 2023. We developed the E-W indices by averaging Sahel Precipitation change meridionally from 10°N – 20°N and plotted this mean across longitudes. The location of transitioning from drying to moistening (Figure 1(b)) is the index for each of the models.

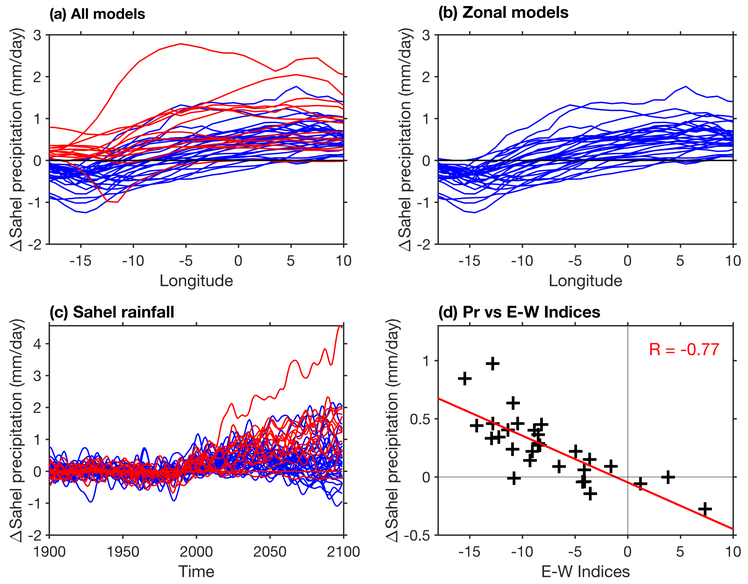
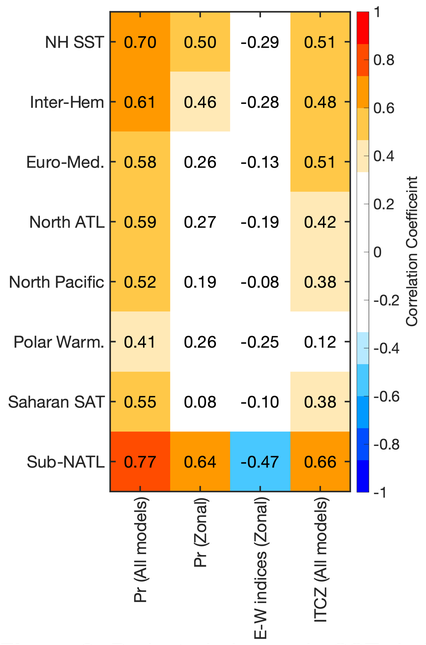


Figure 1: The JJAS mean change in Sahel rainfall plotted zonally (a) and (b). The anomalies (c) and relationship with E-W indices (d)

KEY POINTS:

- E-W indices and Sahelian precipitation are strongly negatively correlated
- Models that transition further to the east tend to project drier conditions across the Sahel

4. Relationship between SST, Pr, and E-W indices



KEY POINTS:

- Strong positive relationship between SSTs and Sahel rainfall change for all model ensemble
- For zonal models only, the correlation with SSTs indices is either weaker or insignificant.
- Except for sub-NATL, regional and global SSTs does not explain a significant variance in the E-W model transition

Figure 2: Projected change in SSTs indices correlated against the changes in Sahel precipitation for all models, zonal models, E – W indices, and Atlantic ITCZ

5. Difference between zonal and non zonal models

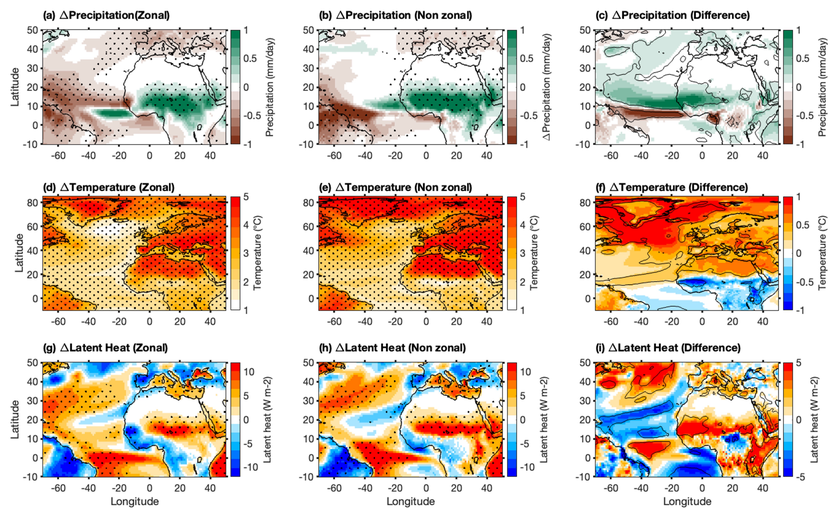


Figure 3: Composite plots of JAS mean change in precipitation, surface temperature, and latent heat flux between the twentieth and twenty-first centuries for zonal (29 models) and non-zonal models (14 models)

KEY POINTS:

- There is a statistically significant difference between the zonal and non zonal models not just across land but across the entire tropical Atlantic
- The zonal models tend to simulate the Atlantic ITCZ position farther to the south while the non zonal model tend to position it relatively to the north

6. Correlation between Atlantic ITCZ and Sahel precipitation

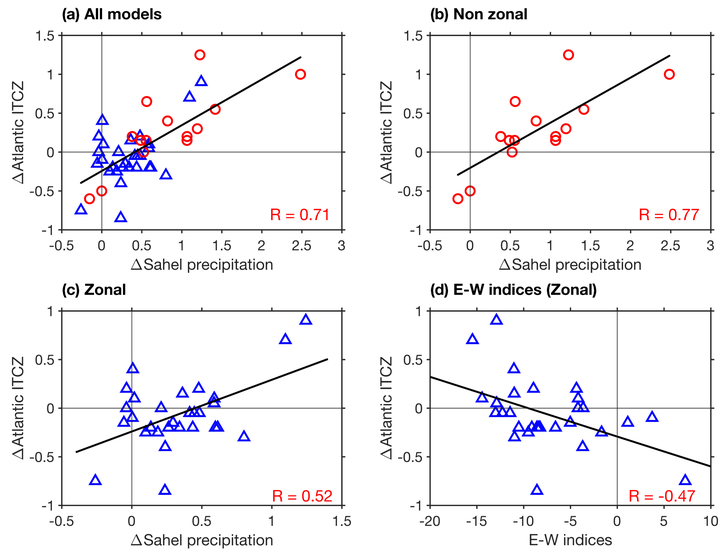


Figure 4: The relationship between the JAS shift in the Atlantic ITCZ and the change in Sahel precipitation

KEY POINTS:

- The relationship between the shift in Atlantic ITCZ and Sahel rainfall is weaker for zonal models (figure 4c)
- The non zonal models tend to produce a northward shift in the Atlantic ITCZ

7. Conclusions

- Our newly defined E-W indices explain a large proportion of the uncertainty in projected Sahel precipitation change
- Removing non-zonal models from the ensemble results in weaker correlations between SST change and Sahel precipitation change
- Models that simulate the zonal dipole pattern tend to produce a southward shift in the Atlantic ITCZ

References:

Park et al., 2015, https://doi.org/10.1038/ncomms6985.

Monerie et al., 2023, https://doi.org/10.1029/2023JD038712.