# RESPONSE OF AFRICAN EASTERLY WAVES TO A CHANGING CLIMATE


## ABSTRACT

The northward migration of the Intertropical Convergence Zone (ITCZ) is a significant feature of the West African (WA) monsoon. An accurate simulation of ITCZ migration is essential for the realistic representation of WA precipitation in global coupled models. This study employs the energetics and dynamics framework with a subset of Coupled Model Intercomparison Project Phase VI (CMIP6) models to investigate the bias in the simulated WA precipitation. Models were found to simulate more local positive (negative) shortwave cloud radiative forcing (SWCRF) in the Southeastern Atlantic Ocean (over the African continent). The effect of the excess local SWCRF is linked to the stagnation of the ITCZ latitudinal migration and the associated biases in the asymmetry index of precipitation. In the models, there is more (less) moist static energy in the lower (mid and upper) troposphere than in the reanalysis. The worst models have a stronger bias, especially over land. The vertical transport of moisture is confined to the boundary layer in the worst model ensemble. In most cases, the high-resolution coupled models show substantial northward migration of the ITCZ compared to the low-resolution models. Furthermore, the best performing models capture local circulation and energetic processes more accurately than the worst-performing models. Chapter 3 investigates the contribution of African easterly waves (AEWs) to precipitation in the current climate. AEW influences the precipitation variability over West and Central Africa, as seen from the study. This makes the tracking of AEW an important feature to estimate, using dynamical means and quantifying its current and future variability. An ideal threshold for tracking AEW in climate models and reanalysis is proposed as the 90th percentile of vorticity values. With these threshold values, the Lagrangian technique successfully identifies AEW, which is reliable and comparable to previous methods. The AEW tracks using the Lagrangian tracking method were found to be comparable with the archives of Belanger, the reference tracked datasets in this study. Using the three skills score criteria, the results of the Lagrangian method were found to match about 60-70% with ERA5 tracks, 85-98% with MERRA2 tracks, and ERA-Int with ~98% from all three tracking levels.

Though the study quantified matches between the archived tracks, nonmatches are not quantified since the algorithm significantly captures AEW evolution and propagation characteristics in both reanalysis and CMIP6 models. These results suggest high confidence in the applicability of the algorithm for tracking point-wise atmospheric synoptic features such as AEW from all kinds of datasets with varying temporal and horizontal resolutions. The similarity in the evolution of waves in CMIP6 models compared to ERA5 composites indicates an improvement in the dynamical coupling of convection with AEW in most of the high-resolution CMIP6 models, except for the low-resolution models. However, the simulated convection in the high-resolution models appears to be weaker than that in ERA5, as seen in the days before day-0 composites, and overestimated in the low-resolution models. The precipitation rate is higher in the tracks at 600 hPa (Southern tracks) than in the tracks at 850 hPa (Northern tracks), in agreement with previous studies. The tracks at 700 hPa and 850 hPa from the bandpass filtering method suggest that the waves may not be specifically different from each other, instead, they may be a feature of the same wave that merges or splits.

The response of AEW to climate change and their contribution to future extreme precipitation using CMIP6 models are investigated. First, the future changes in precipitation characteristics are quantified before investigating the changes in the AEW tracks and their influence on future precipitation and extremes. The median and maximum ITCZ positions are projected to migrate northward in the future, with the median at ~7.7°N and the maximum at ~7.9°N, respectively. The tendency for a northward shift of the ITCZ in response to climate change suggests future changes in

precipitation patterns. During the JJAS season, the interhemispheric asymmetry (IA) in the models is projected to broaden, while future trends in the precipitation asymmetry index (PAI) do not show significant changes from the historical patterns. Secondly, the counts of AEW in the future are higher in the 600 hPa than in the 700 hPa and 850 hPa levels, respectively. The percentage increase in future AEW counts varies among the models. For instance, the percentage change in AEW counts ranges from 12% to 50% in most models except for MRI-ESM2-0, with a 20% decrease in July, while MIROC6 simulates a more than 100% increase in June. In the future climate, the complex interaction between hydrological processes and atmospheric dynamics may be impacted by changes in the AEW in the region. Models project an increased lifetime

and decreased phase speed in the future climate. The projected decrease in the phase speed of AEW may have potential implications for the formation and intensity of the waves in the future over the continent. When the AEW slows down, the momentum and energy of the waves decrease, leading to less organized and weaker intensities of the waves as they propagate. This may have potential implications for the representation of weather patterns such as localized onset and cessation of rainfall and even extreme events such as heavy precipitation and flooding.

**KEYWORDS**: African Easterly Waves, Monsoon, Climate change, Lagrangian tracking method, Intertropical convergence zone, precipitation extremes