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A Systematic Comparison of Tropical Waves over Northern Africa

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Low-latitude rainfall variability on the daily to intraseasonal timescale is often related to tropical waves, including convectively coupled equatorial waves, the Madden-Julian Oscillation (MJO), and tropical disturbances. Despite the importance of rainfall variability for vulnerable societies in tropical Africa, the relative influence of tropical waves for this region is largely unknown. This contribution presents the first systematic comparison of the impact of six types of tropical waves on precipitation over northern tropical Africa, including the associated changes to the horizontal circulation and vertical profiles of moisture and static stability. The study comprises the transition and full West African monsoon (WAM) seasons and used, apart from ERA-Interim, two satellite rainfall products, a dense rain gauge network, and upper-air soundings.

Composites of rainfall anomalies generally indicate the theoretical wave patterns, but some deviations exist, which might be related to the WAM and tropical-extratropical interactions. The different rainfall datasets show comparable modulation intensities in the West Sahel and at the Guinea Coast, varying from less than 2 to above 7 mm d-1 depending on the wave type. African Easterly Waves (AEWs) and Kelvin waves dominate the 3-hourly to daily timescale and explain 10−30% of the local rainfall variability. On longer timescales (7−20d), only the MJO and equatorial Rossby (ER) waves remain as modulating factors and explain up to one third of rainfall variability. Eastward inertio-gravity waves are comparatively unimportant. An analysis of wave superposition shows that lower-frequency waves (MJO, ER) in their wet phases amplify the shorter-frequency AEWs and mixed Rossby-gravity waves (MRG) and suppress them in the dry phase.

Tropical waves also influence the circulation patterns within the WAM system. The associated circulation patterns of the analyzed waves are roughly coherent with the theory. Deviations exist that might be related to the background flow and the rainbelt which serves as waveguide and is located 5°-10° to the north of the equator. Precipitation anomalies are accompanied by moisture flux convergence associated with the circulation patterns. Slow waves (MJO, ER) influence the moisture availability more than faster waves (MRG, Kelvin, AEWs). Rainfall in more imbalanced wave modes such as Kelvin, AEWs and MJO favor the meso-scale organization of precipitation, whereas more balanced wave modes such as ER and MRG tend to cause large-scale anomalies in total column water and quasi-geostrophic lifting. The rainfall modulation patterns of the MJO and ER wave reach deep into the subtropics and resemble tropical plumes. One month prior to the tropical plume, the significant MJO signal in the tropics is linked with a slowly propagating Rossby wave train in the Northern Hemisphere. The Rossby wave leads to a strengthening of the Saharan heat low and subsequently to an inflow of moist tropical air deep into the subtropics. In case of the ER wave, an extratropical Rossby wave precedes the ER signal in the tropics, indicating that subtropical dynamics can influence the WAM during the monsoon season. The results of the comprehensive study stress that more attention should be paid to tropical waves when forecasting rainfall over northern tropical Africa.