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Classification of Atmospheric Circulation Patterns That Trigger Rainfall Extremes in the Sudan-Sahel Region

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A better understanding of the rainfall variability and extremes in tropical regions is crucial for the development of improved statistical and numerical approaches used for climate research and weather prediction. In this study, we present a novel fuzzy rule-based method for classifying atmospheric circulation patterns relevant to heavy rainfall in the Sudan-Sahel region over West Africa. In the first step, we determine large-scale atmospheric patterns to describe important seasonal features of the West African Monsoon like the movement of Saharan Heat Low over the African continent. In the second step, meso-scale monsoon patterns are classified to better describe rainfall variability and extremes during the monsoon period. In addition to a comprehensive predictor screening using more than 30 variables at different atmospheric levels, a detailed sensitivity analysis is performed, which aims to improve the transferability of the classification approach to an independent dataset. Furthermore, crucial aspects of the methodological development of fully automatic classification approaches are addressed. Using mean sea level pressure and stream function fields (700hPa) as final predictor variables, we identified 23 circulation patterns as robust solution to represent key atmospheric processes and rainfall variability in the study region. The two wettest patterns are distinguished by an enhanced Saharan Heat Low and cyclonic rotation near the study region, suggesting the presence of a tropical wave trough and triggering about 50% of the rainfall extremes on 6.5% of the days. The identified atmospheric circulation patterns are currently used to develop a variety of improved statistical approaches for this challenging region, such as pattern-dependent bias correction, geostatistical interpolation, and simulation.