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Extremes in South African Rainfall: Mean Characteristics and Seamless Variability Across Multiple Timescales

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Rainfall extremes are of major and increasing importance in semi-arid countries and their variability has strong implications for water resource and climate impacts on the local societies and environment. Here, we examine extremes intraseasonal descriptors (ISDs) in austral summer rainfall (November–February) over South Africa (SA). Using daily observations from 225 rain gauges, ERA5 reanalysis and satellite estimates (TRMM-3B42), we propose a novel typology of wet extreme events based on their spatial fraction, thus differentiating large- and small-scale extremes. Long-term variability of both types of extreme rainfall events is then extensively discussed. The relationship between these two types of rainfall extremes and different modes of climate variability is further explored at multiple timescales. At low-frequency modes, rainfall extremes are assessed at interannual (IV: 2−8 years) and quasi-decadal (QDV: 8−13 years) timescales which are primarily associated with El Niño Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO) respectively. At high-frequency modes, rainfall extremes are evaluated with synoptic-scale variability related to seven convective regimes of Tropical Temperate Troughs (TTTs: 3–7 days) and intraseasonal variability associated with eight phases of the Madden-Julien Oscillation (MJO: 30–60 days).

The results demonstrate that using 7% of spatial fraction simultaneously exceeding the local threshold of the 90th percentile produces remarkable results in characterizing rainfall extremes into large- and small-scale extremes. Austral summer total rainfall is found to be primarily shaped by large-scale extremes which constitute more than half of the rainfall amount under observation, and nearly half in ERA5. Observation (ERA5) shows an average of 8 ± 5 (20 ± 7) days per season associated with large-scale extremes, which are comprised in 5 ± 3 (10 ± 3) spells with an average persistence of at least 2 days. Overall, we find a strong dependence of total rainfall on the number of wet days and wet spells that are associated with large-scale extremes. We also find that large- and small-scale extremes are well-organized and spatially coherent yet extreme conditions during small-scale events are found sporadic over the region, contrasting with large-scale events for which extreme conditions are found over a larger and coherent region.

Teleconnections with global SSTs confirm that La Niña conditions favor overall wet conditions and

wet extremes in SA. The frequency of large-scale extremes is consistently related to warmer SSTs in the North Atlantic while their link with warmer Indian and tropical South Atlantic Ocean found stronger without ENSO influence. At low-frequency timescale, risk ratio assessment shows that the frequency (total rainfall) of large-scale extremes is significantly modified by IV (QDV) timescale. We note strong variations in the frequency (total rainfall) of large-scale (small-scale) extremes when IV timescale lies in strong positive phase (i.e., +0.5 standard deviation). At high-frequency timescale, the synoptic-scale variability associated with TTT events, are mostly responsible for changes in large-scale extremes as nearly 75% of such events occur during early to mature TTT regimes (3−5) whereas small-scale extremes were found equiprobable during all synoptic regimes. A risk ratio assessment suggests that the probability of large-scale extremes in TTT regime 5 significantly enhance (suppress) during MJO phases 6−8 (1−2).