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A global climatology of the kinematical skeletons organising subtropical and tropical convergence zones

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Large-scale mixing in the atmosphere redistributes moisture as organised bands or filaments. In some tropical and subtropical monsoon regions, a substantial part of rainfall happens under moisture and cloud bands commonly referred to as convergence zones. Recent regional studies have shown that such large-scale filaments or bands of moisture and rainfall form along or in the neighborhood of mixing features known as attracting ``Lagrangian Coherent Structure'' (LCSs) - material skeletons associated with strong attraction of air parcels. However, there are still no global climatologies to support more general conclusions about the spatiotemporal relationships between mixing and precipitation and the impact of large-scale mixing on monsoons. In this study, we investigate how mixing features determine the subseasonal and seasonal rainfall variability in tropical and subtropical regions around the globe. We characterise mixing by computing the Finite-time Lyapunov Exponent (FTLE), a measure of Lagrangian deformation among neighbouring parcels, on ERA5 reanalysis data between 1980 and 2009. Attracting LCSs are identified as ridges of the FLTE. We also employ diagnostic Eulerian variables such as mean sea level pressure and mass meridional streamfunction to associate mixing with general circulation features. On the seasonal scale, we show that the strength of mixing and the frequency of LCSs modulates rainfall under the African, American and Asian convergence zones and the ITCZ. On the subseasonal scale, we focus on the influence of the Madden-Julian oscillation and the North Atlantic oscillation on the mixing regime of the Atlantic and East Pacific; we show how these oscillations control horizontal mixing as to suppress or enhance precipitation variability over the American monsoons. This first long-term global climatology of mixing and LCSs quantifies the often overlooked role of Lagrangian kinematics on the hydrological cycle and provides a powerful process-based diagnostic to investigate mechanisms of rainfall variability that does not require region-specific considerations.