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Mapping km-scale global extreme rainfall onto mesoscale convective systems lifecycle, frequency and dynamics

Benjamin Fildier[1], Maxime Carenso[1], Rémy Roca[2], and Thomas Fiolleau[2]
[1]Laboratoire de Météorologie Dynamique, Ecole Normale Supérieure, Paris, France
[2]Laboratoire d'Études en Géophysique et Océanographie Spatiales (Université de Toulouse III, CNRS, CNES, IRD), Toulouse, France

Mesoscale convective systems are the building block of tropical precipitation, as more than 40% of global precipitation and more than 80% of extreme rainrates are produced by these organized systems. However, when investigating the sensitivity of global rain extremes, the behavior and morphology of organized storm systems are typically ignored and corresponding dynamics are instead interpreted using the textbook framework of a convecting parcel. Indeed, despite rich observational and case studies describing the internal dynamics and structures of MCSs, no conceptual framework exist to this day to bridge the gap between global hydrologic sensitivity and MCS behavior.

This work introduces new approaches to link extreme precipitation rates in the tropics to the occurrence, internal dynamics and lifecycle of individual MCSs. Individual storms are idenditifed based on by the Lagrangian tracking algorithm TOOCAN which tracks storm anvils over their lifecycle, and which has been applied to satellite observations and to global storm resolving models in the DYAMOND experiment. We first use this rich dataset to develop a numerical interface that maps the occurrence of extreme precipitation rate onto the MCS cloud shield. We then introduce a novel conceptual framework to decompose the sensitivity of precipitation extremes to the change in storm occurrence and change in internal dynamics within this cloud shield.

Results are threefold. We demonstrate a robust phasing in the timing of global extreme rainrates within the storm lifecycle, robustly occurring at 25-30% of the storm's lifetime for the models and regions analyzed. The analytical decomposition confirms that in a given climate state, variability in the heaviest rainrates across regions mostly occur through changes in MCS frequency, rather than changes in their efficiency at producing rain. We finally argue that the sensitivity of extremes to climate state may occur through both a change in occurrence and a change in internal MCS dynamics.