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Monsoon Onset Response to Warming in Idealized GCM and CMIP6 Simulations

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GCMs robustly project a delay in the timing of the global monsoon onset and tropical precipitation intensification with warming. However, a closer look at the response of different monsoon regions shows less consistency. To better understand how monsoons will respond to a warming climate, with a particular focus on the timing of monsoon onset, we use a hierarchy of climate models, starting from idealized aquaplanet simulations all the way to CMIP6 projections, to identify the robust and uncertain changes and investigate the underlying mechanisms. Our idealized work covers two sets of simulations: 1) aquaplanet runs with a uniform mixed layer depth (MLD) in a wide range of climates, from colder to warmer than the current climate, and 2) simulations with an idealized saturated zonally symmetric continent extending from 10^{o}N to the North Pole in a similar range of colder to warmer climates. Monsoon onset is determined using a change point detection method on the cumulative moisture flux convergence (MFC) (or net precipitation), which robustly links monsoon onset to changes in the large-scale monsoonal circulation. The idealized uniform MLD aquaplanet simulations show a robust progressive delay of monsoon onset, consistent with results reported in the literature. Analyses of the atmospheric energy budget suggest this delay is due to the increased atmospheric latent heat capacity with warming. Interestingly, this delay is not evident in the simulations with the idealized saturated continent. Mechanisms are explored by analyzing changes in the energetics and dynamics of the tropical circulation and related monsoonal precipitation. CMIP6 projections in different monsoon regions are investigated to determine if mechanisms exposed in the idealized simulations can shed some light on the differing monsoon onset responses in more complex climate models.