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Inconsistent Fast and Slow Responses of East Asian Summer Monsoon Precipitation Forced by Black Carbon

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The East Asian summer monsoon (EASM) region, teeming with anthropogenic black carbon (BC), lacks clarity on the fast and slow responses of EASM precipitation and other atmospheric water cycle processes to BC forcings. Through CESM1 simulations with an atmospheric water tracking (AWT) method, fast atmospheric adjustments and slow SST (sea surface temperature)-meditated responses of EASM to BC are found inconsistent, and the summertime precipitation anomaly exhibits a “positive-negative” and “negative-positive” meridional pattern, respectively. Quantitative AWT results highlight the dominant influences of BC-induced atmospheric dynamics adjustments in shaping the EASM precipitation anomaly pattern. The impacts of moisture transport by the southwesterlies mainly from tropical Indian Ocean overweigh those of surface evaporation changes, governing both fast and slow precipitation responses. Tropospheric warming from high BC concentrations over northern East Asia in the fast response creates a positive anomaly in the meridional temperature gradient at the lower level of the East Asian Subtropical Westerly Jet (EASWJ) center. This weakens the EASWJ, leading to significant upper-level convergence at 200 hPa and anomalous descending motion north of 30°N, which reduces precipitation over North China, while causing compensatory ascending motion and low-level convergence south of 30°N, thereby enhancing precipitation over South China. Conversely, BC-induced SST warming in the Indo-Pacific Warm Pool generates a negative meridional temperature gradient anomaly and strengthens the EASWJ, leading to an opposite slow precipitation response pattern. Overall, the total EASM responses manifests as a "wetter-drier-wetter" meridional precipitation pattern, aligning with the main structures of inter-decadal summer precipitation anomalies in recent observations.