



## Emergence of strong trends in humid heat intensity and duration in recent decades over South Asia

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The far-reaching impacts of humid heat extremes on public health and ecosystems underscore a necessity for a comprehensive investigation. South Asia is a global hotspot where humid heat reaches some of the highest levels globally in a densely populated region, and climatologically highly interesting since temperatures typically peak in the pre-monsoon period, and humid heat only several weeks later during the monsoon period. This study examines the historical trends in humid heat extremes, and their underlying drivers and mechanisms during the pre-monsoon (Mar-May) and monsoon (June-September) seasons over South Asia. Our findings reveal a notable surge in the warming trends of humid heat extremes since 2000, exhibiting a rate exceeding twice that of observed long-term trends since 1950 in the monsoon season across South Asia. During the pre-monsoon season, short-term trends (trends since 2000) exhibit diverse regional patterns, indicating cooler heat extremes in western South Asia, while the rest of the region experiences increasing trends in heat extremes. This contrasts with the consistent and regionally coherent long-term warming trends in humid extremes since 1950 across South Asia.

We further show that the seasonal evolution of daily maximum wet-bulb temperature in South Asia is closely linked with humidity levels, indicating that the occurrence of high humidity events governs the timing of humid heat extremes. During the monsoon season, higher humidity in Southern and Central South Asia occurs ~2 weeks earlier since 2000 compared to the climatological period (1950-1979). This elevated humidity aligns with several  $\square$  higher temperatures occurring earlier in the season, intensifying humid heat extremes. In western South Asia, changing humidity trends notably impact humid heat extremes: rising trends intensify them during the monsoon season, while declining trends cool pre-monsoon extremes. Further, we show that precipitation variability modulates humidity levels and, thereby, the intensity of humid heat extremes over western South Asia. Moreover, our study notes a significant increase in the duration of monsoon season humid heat extremes, expanding from ~2 days in the 1950s to several weeks in recent decades across South Asia. This prolonged and sustained occurrence is predominantly associated with consistent and high humidity levels. The emergence of such strong trends emphasizes the need to expedite adaptation and mitigation measures to align with the substantial escalation in humid heat intensity and duration.

