

Supplementary Information for

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

Jitendra Singh^{1*}, Deepti Singh², Sebastian Sippel³, Erich Fischer¹

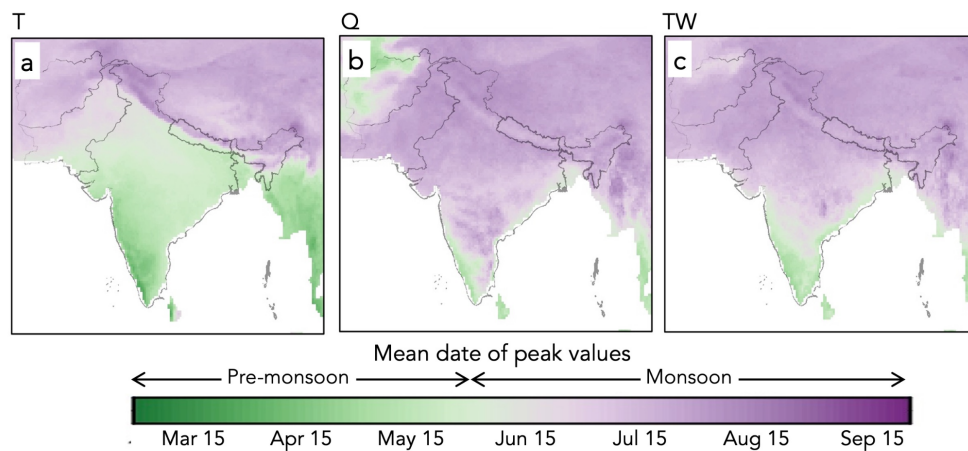
¹Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland

²School of the Environment, Washington State University, Vancouver, WA, USA

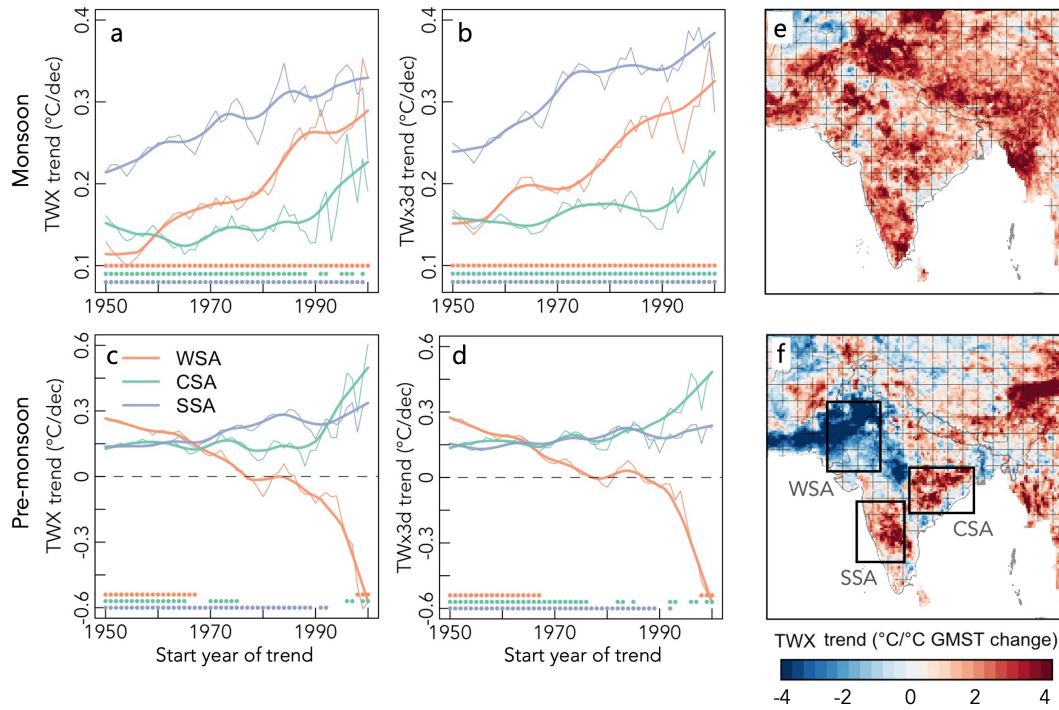
³Leipzig Institute for Meteorology, Leipzig University, Leipzig, Germany

*Corresponding Author: jitendra.singh@env.ethz.ch

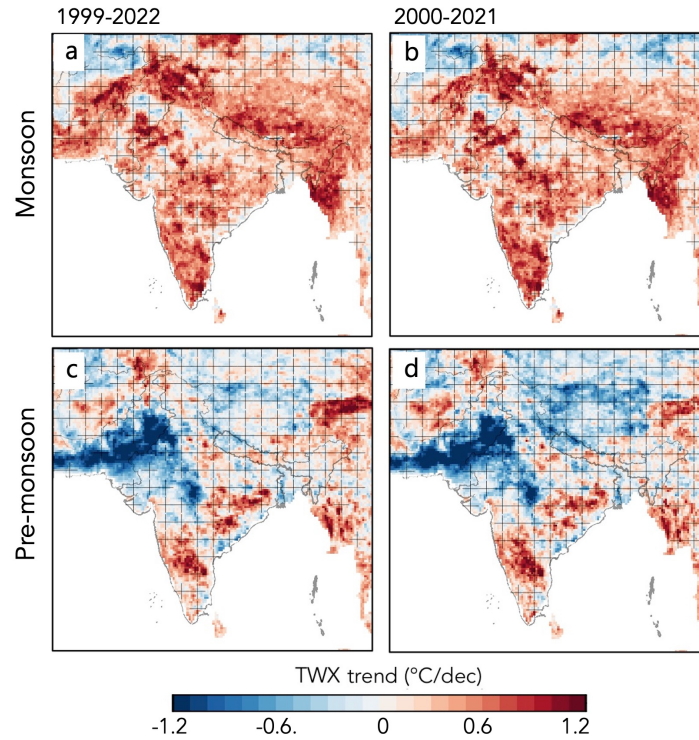
Supplementary Figures



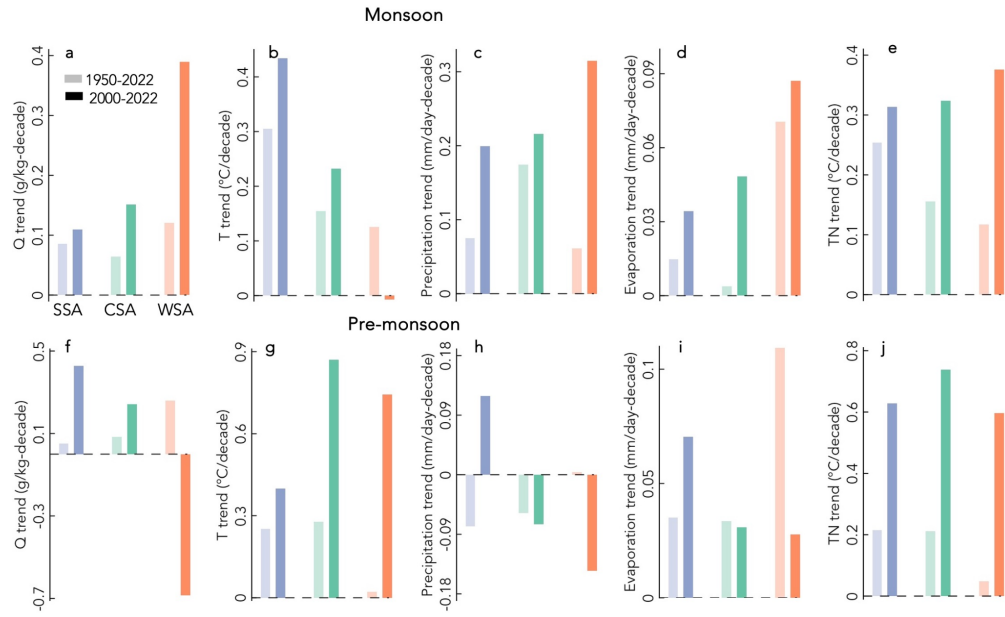
Supplementary Figure 1: Spatial pattern of time of occurrence of peak (a) temperature (T) (b) specific humidity (Q), and (c) wet bulb temperature (TW) in the climatology, defined over 1950 to 1979.



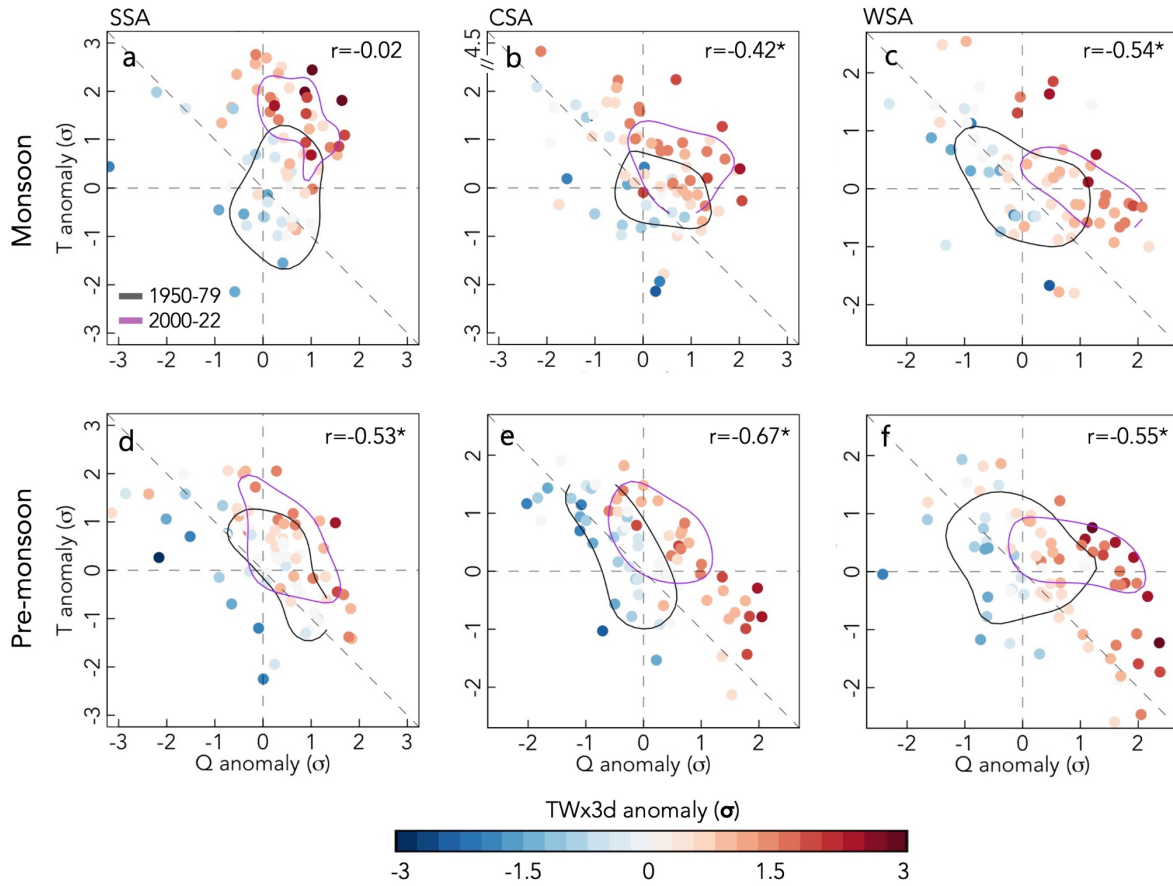
Supplementary Figure 2: Temporal evolution of trends in humid heat extremes. (a, b) Moving trends in TWX (seasonal maximum of daily maximum TW) and TWx3d (3-day maximum of daily maximum TW) over Western South Asia (WSA), Central South Asia (CSA), and Southern South Asia (SSA), respectively. The dots located at the bottom of each panel denote statistically significant trends at a 10% significance level. (c, d) Similar to (a,b) but for the pre-monsoon season. (e,f) Spatial pattern of TWX trends relative to changes in global-mean surface temperature (GMST) during 2000-2022.



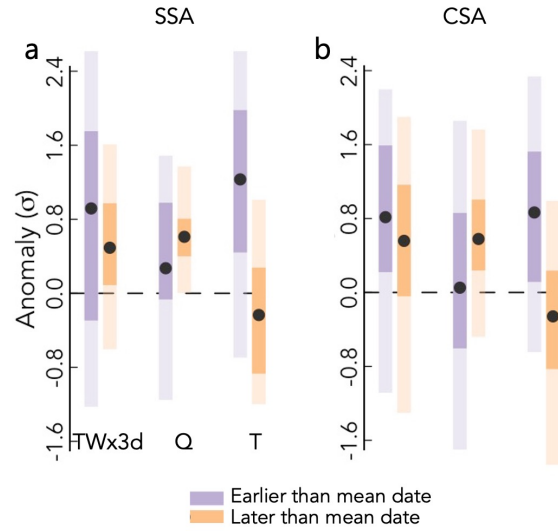
Supplementary Figure 3: Spatial distribution of trends in humid heat extremes. (a, b) Trends in TWX, defined as seasonal maximum of daily maximum TW, during 1999-2022 and 2000-2021, respectively, in the pre-monsoon season. The black rectangle in (a) indicates the extent of Western South Asia (WSA), Central South Asia (CSA), and Southern South Asia (SSA). (c, d) Similar to (a, b), but for the monsoon season. Hatching indicates an insignificant trend at a 10% significance level. The trends and their significance are estimated using Theil-Sen's slope estimator.



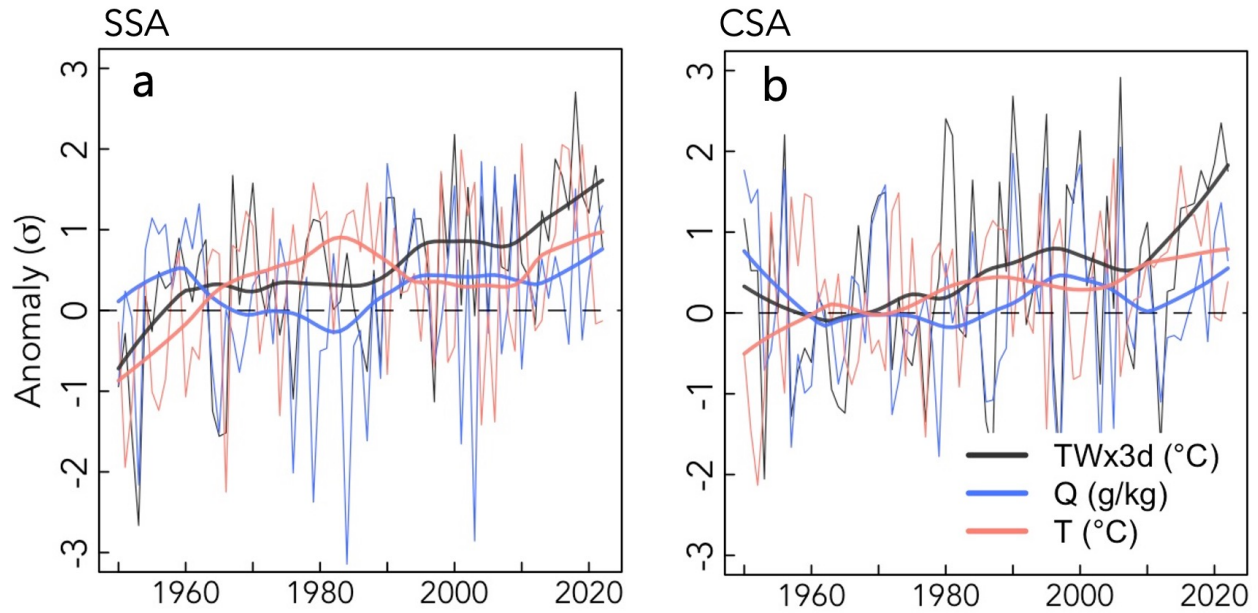
Supplementary Figure 4: Trends in specific humidity (Q), temperature (T), precipitation and evaporation and nighttime temperature (TN). Q, T, evaporation and TN is averaged over the 3-days when TWx3d occurs.



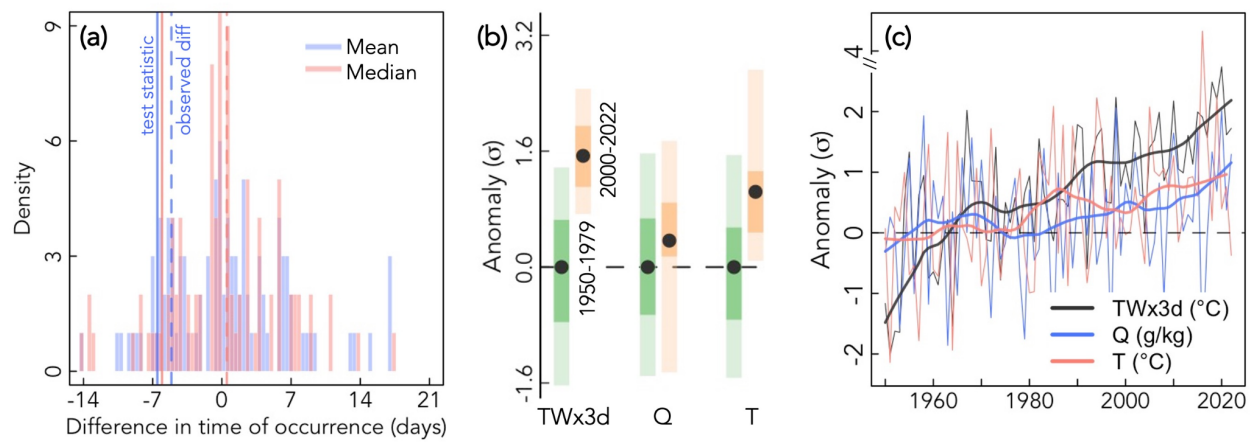
Supplementary Figure 5: Interaction between T and Q. (a,b,c) Joint distribution of T and Q, and its link with TWx3d in the monsoon season over Southern South Asia (SSA), Central South Asia (CSA) and Western South Asia (WSA), respectively. Dot colors indicate TWx3d anomalies corresponding to the simultaneous occurrence of T and Q. Black and purple contour lines illustrate the joint kernel distribution of T and Q over 1950-1979 and 2000-2022, respectively. (c,d,e) Similar to (a,b,c) but for the pre-monsoon season.



Supplementary Figure 6: Distribution of TWx3d, Q, and T. (a) The distribution of TWx3d and the associated Q and T occurring earlier and later the mean date of TWx3d events in the monsoon season over Southern South Asia (SSA). Dark and light colors represent the 25th-75th percentile and 5th-95th percentile ranges, respectively. (b) Same as (a), but for Central South Asia (CSA).



Supplementary Figure 7: Smoothed time series of TWx3d, Q and T during the pre-monsoon season.
 (a) Anomaly of TWx3d, Q, and T relative to the climatological period (1950-1979) over Southern South Asia (SSA). Q and T are averaged over a 3-day period coinciding with maximum TWx3d occurrences. Thin line represents the actual anomalies in standard deviations, while thick lines denote the 11-year smoothed anomalies. (b) Same as (a) , but for the Central South Asia (CSA).



Supplementary Figure 8: Same as Figure 5, but for Central South Asia (CSA).