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Subseasonal Variability of Humid Heat During the South Asian Summer Monsoon

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Key Points:

- In contrast to dry heat, most extreme wet bulb temperature events in South Asia take place on rainy days during the monsoon season
- Local background specific humidity determines whether wet bulb temperatures are intensified by enhanced or suppressed precipitation
- Baseline moisture availability also influences whether early or delayed monsoon onset intensifies wet bulb temperature anomalies

Supporting Information:

Supporting Information may be found in the online version of this article.

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Abstract The South Asian summer monsoon strongly modulates regional temperature and humidity. While extreme dry heat peaks in the pre-monsoon season, recent literature suggests that extreme humid heat can continue to build throughout the monsoon season. Here we explore the influence of monsoon onset and subseasonal precipitation variability on the occurrence of extreme wet bulb temperatures (Tw) across South Asia. We find that extreme Tw events often occur on rainy days during the monsoon season. However, the influence of precipitation on Tw varies with the background climatology of surface specific humidity. In climatologically drier areas, positive Tw anomalies tend to occur when precipitation increases due to either early onset or wet spells during the monsoon. In contrast, in climatologically humid areas, positive Tw anomalies occur during periods of suppressed precipitation, including both delayed onset and dry spells during the monsoon.

Plain Language Summary The combination of high heat and humidity poses greater risks to human health, productivity, and well-being relative to elevated temperatures alone. South Asia has already experienced some of the most extreme humid heat observed on Earth. Typically, the highest temperatures in South Asia occur during the pre-monsoon season in March-May. While the precipitation and cloudiness associated with the summer monsoon reduce extreme air temperatures, the increased humidity can contribute to the occurrence of extreme humid heat events. Our research finds that a majority of extreme Tw events across South Asia happen on rainy days during the monsoon season. This is especially true for regions where surface humidity is typically low during the monsoon season, and Tw tends to be higher during heavier than usual precipitation spells and during years when the monsoon season starts earlier in the calendar year. In regions with high background surface humidity, however, Tw is more intense when there is less precipitation than usual or when the monsoon onset is delayed. These results help to identify additional times with high risk of heat stress for outdoor workers, and provide a new way of understanding how monsoon variations influence local humid heat.

1. Introduction

South Asia is a present-day hotspot for extreme humid heat, with the frequency and intensity of extremes projected to increase in the future. South Asia is one of the only areas to have reached a wet bulb temperature (Tw) beyond the theoretical threshold for human survival (Raymond et al., 2020), posing dire risks to human health and outsized socioeconomic impacts. In recent decades, increases in regional temperature and moisture have boosted the frequency of extreme humid heat events in South Asia (Rogers et al., 2021) and these trends are projected to continue with additional warming (Im et al., 2017; Li et al., 2020; Matthews et al., 2017; Mora et al., 2017; Murari et al., 2015; Saeed et al., 2021; Wang et al., 2021). In this region, humid heat extremes are driven by a variety of mechanisms. A partial list of such mechanisms includes moisture advection (Monteiro & Caballero, 2019), sensible heat flux (Raymond et al., 2021), proximity to warm water bodies (Im et al., 2017), large scale variability (Ivanovich et al., 2022; Speizer et al., 2022), and irrigation (Jha et al., 2022; Krakauer et al., 2020; Mishra et al., 2020), many of which can interact. Better understanding the relationships between monsoon precipitation and humid heat can help determine which types of meteorological drivers are associated with the highest risk for extremes, with potential to improve forecasting and model projections. These results can also help identify the dynamics of simultaneous or sequential rainfall and humid heat, which can cause compound extreme events with complex and understudied impacts on agriculture and human health (Zscheischler et al., 2018).

The South Asian summer monsoons are the main source of humidity and moisture to the region and strongly modulate local dry bulb temperatures (Tdry). Many of the factors driving extreme humid heat in South Asia are influenced by the summer monsoon. While Tdry tends to peak during the pre-monsoon season throughout the region (van Oldenborgh et al., 2018), recent work has suggested that the highest humid heat magnitudes often occur after monsoon onset in parts of South Asia (Raymond et al., 2020; Rogers et al., 2021). Differentiating between dry and humid heat extremes in this region is particularly important given their distinct impacts on plant and human health, respectively, which can both be detrimental to agricultural production (Diaz et al., 2023; Ting et al., 2023). Ivanovich et al. (2022) highlighted that elevated Tw during the June-August season in India is associated with surface level easterly wind anomalies and increased dry bulb temperature and specific humidity, conditions sometimes associated with monsoon breaks. Further, humid heat is rapidly intensifying and increasing in frequency more dramatically than dry heat in this region (Rogers et al., 2021; van Oldenborgh et al., 2018). However, a dedicated analysis concerning the effect of monsoon precipitation variability on humid heat throughout South Asia has not yet been produced.

Here we explore humid heat variability in South Asia with respect to the timing and intensity of summer monsoon-associated precipitation. To do so, we investigate the conditions coinciding with local Tw extremes and compare the evolution of Tw surrounding monsoon onset with that during wet and dry spells. We describe the data and methods used in Section 2 and discuss the results of our analyses in the context of published literature in Section 3. In Section 4, we describe the implications of our results for understanding the interactions between extreme humid heat and precipitation.

2. Data and Methods

2.1. Data

Daily total precipitation data is retrieved from the Climate Hazards Group InfraRed Precipitation with Station data version 2 (CHIRPS 2.0) at a 0.25° spatial resolution (Funk et al., 2015). All other meteorological variables are retrieved from the fifth major global reanalysis of the European Centre for Medium-Range Weather Forecasts (ERA5) (Hersbach et al., 2020), including 2-m dry bulb temperature, 2-m dewpoint temperature, surface pressure, and surface geopotential height. We further validate these results in Supporting Information S1 using precipitation data from ERA5, the Climate Prediction Center (CPC), the Indian Meteorological Department (IMD), and the Asia Precipitation–Highly Resolved Observational Data Integration Toward Evaluation of Water Resources (APHRODITE) (Xie et al., 2007; Chen et al., 2008; Pai et al., 2014; Hamada et al., 2012).

We select wet bulb temperature as our heat stress metric. Tw is a widely used thermodynamic variable in atmospheric science, and is strongly linked to heat stress due to its direct relationship to evaporative cooling (Bohren & Albrecht, 1998; Sherwood & Huber, 2010). We use Tdry, dewpoint temperature, and surface pressure to calculate a global, gridded hourly scale Tw dataset using the Davies-Jones method (Davies-Jones, 2008), and then convert to daily maximum values. The Davies-Jones method calculates the adiabatic Tw, and we expect conclusions to be consistent when using isobaric Tw (Li et al., 2020) given the magnitudes of these metrics are very similar over typical temperature and humidity ranges in the study domain (Figure S1 in Supporting Information S1). We note that patterns identified through this analysis are somewhat sensitive to the humid heat metric of choice, particularly because Tw is highly sensitive to fluctuations in specific humidity compared to other humid heat variables (e.g., Matthews et al., 2022). Analyses are repeated using a metric which is relatively more sensitive to temperature fluctuations, Humidex, in Figure S2 in Supporting Information S1 for comparison. Overall spatial patterns in the intensity of humid heat and the co-occurring meteorological conditions are similar between extreme Humidex and Tw days, though the timing of these events is slightly different in some areas of the study region.

2.2. Methods

We composite the Tw, Tdry, and specific humidity concurrent with, before, and after three periods of the monsoon season: monsoon onset, dry spells, and wet spells. We calculate the local monsoon season as the days between annual monsoon onset and retreat, following methods from Mondal et al. (2015). Monsoon onset is defined as the first wet day (>1 mm) of the first 5-day wet spell (total wet spell precipitation ≥ 5*mean seasonal precipitation) that is not followed by a 10-day dry spell (<10 mm); monsoon retreat is defined as the last wet day of the last 5-day wet spell which is not immediately preceded by a 10-day dry spell. Here the seasonal mean is defined as the daily mean precipitation across the observational record during May-October. This monsoon season definition is selected based on its original development to measure on-ground impacts of precipitation variability for agriculture, an important outdoor labor sector influenced by extreme humid heat (Orlov et al., 2023;

Parsons et al., 2022). We identify dry and wet spells following methods outlined by Singh et al. (2014) as three or more consecutive days with one standard deviation below or above the seasonal mean precipitation, respectively.

Composites are generated for these three periods of the monsoon season at the grid cell and regional scale. Regional scale analyses are calculated using area averaged precipitation based on seven subregions, including Bangladesh, Pakistan, and five of the Homogeneous Rainfall Zones (HRZ) of India as defined by the India Meteorological Department (as in Lakshmi Kumar et al., 2014). We do not include the "Hilly Regions" HRZ, as this zone contains two physically distant areas which would likely experience distinct monsoon onset, dry spell, and wet spell dates. Additionally, humid heat is highly sensitive to elevation and these regions have not historically reached high Tw values (Im et al., 2017; Raymond et al., 2020). Visualization of the climatological monsoon season in each region is shown in Figure S3 in Supporting Information S1. Historical average monsoon onset dates range from May 9th in Northeastern India to June 23rd in Pakistan, while retreat dates range from August 17th in Pakistan to September 18th in Bangladesh.

3. Results and Discussion

3.1. Meteorological Conditions During Extreme Tw Events

We find that most of South Asia experiences at least 70% of extreme Tw events during their respective monsoon seasons (Figure 1a; see Figure 2a for analysis boundaries). This includes six of the most populous cities in the region: Ahmedabad, Bangalore, Dhaka, Kolkata, Lahore, and New Delhi. Extreme Tw events take place at especially high rates during the monsoon season in areas which have historically experienced impactful magnitudes of Tw, such as Bangladesh and western Pakistan, where 99th percentile Tw events exceed 28°C (Figure 1b). These two regions have previously been identified as extreme humid heat hotspots, with published literature highlighting influences from Bangladesh's proximity to the warm sea surface temperatures of the Bay of Bengal (Im et al., 2017; Ivanovich et al., 2022) and widespread irrigation in Pakistan's Indus River Valley (Krakauer et al., 2020; Mishra et al., 2020). Regions that experience a higher fraction of extreme Tw events during the pre-monsoon season are the Western Ghats and the eastern coast of India (Figure 1a). In these areas, the timing of Tw extremes is more consistent with that of Tdry extremes, which have received more attention in previous literature. We also note that the strong relationship between Tw intensity and elevation, where the magnitude of mean 99th percentile Tw events declines steeply across the region's mountain ranges (Figure 1b), is consistent with previous results identifying Tw's dependence on elevation in the United States (Raymond et al., 2022).

We examine precipitation during extreme Tw events relative to other days by plotting both the total magnitude of precipitation on these days and the standardized precipitation anomaly compared to the calendar date of these extreme Tw events. The association between precipitation and extreme Tw is heterogeneous across the region. Extreme Tw events tend to occur during rainy days throughout South Asia, with the highest absolute precipitation magnitudes in central India, Bangladesh, and along the southern edge of the Himalayas (Figure 1e). Further, when compared to the climatological mean precipitation on the calendar date of each extreme Tw event, areas in the western edge of the subcontinent tend to experience much more precipitation than usual on high Tw days (Figure 1f). In contrast, Bangladesh, eastern India, the base of the Himalayas, and northern and central Pakistan tend to experience neutral or even slightly negative precipitation anomalies on extreme Tw days compared to the historical mean precipitation on the associated calendar dates. The spatial heterogeneity in the precipitation anomalies during local extreme Tw events indicates that there may be different physical mechanisms driving the relationship between precipitation and Tw in different locations throughout South Asia.

3.2. Evolution of Tw Anomalies Surrounding Precipitation Variability

To further explore these mechanisms, we investigate regional responses to rainfall variability in seven subregions of South Asia, outlined in Figure 2a. Coherent patterns emerge in the local response of Tw to precipitation variability for regions with different background surface moisture availability. The seven subregions' moisture availability can be categorized using a variety of metrics; here we use specific humidity during May-September as an illustrative example of the surface moisture during and surrounding the regional monsoon season. Specific humidity across the region varies from 12 g/kg in the rainshadow region of peninsular India to 24 g/kg across the Indo-Gangetic plains. To examine differences across regions with different humidity levels, we classify these seven regions into two regimes: those with relatively high specific humidity ("high humidity" regime, with more than 25% of land area showing a seasonal mean specific humidity above 20 g/kg) and those with lower specific

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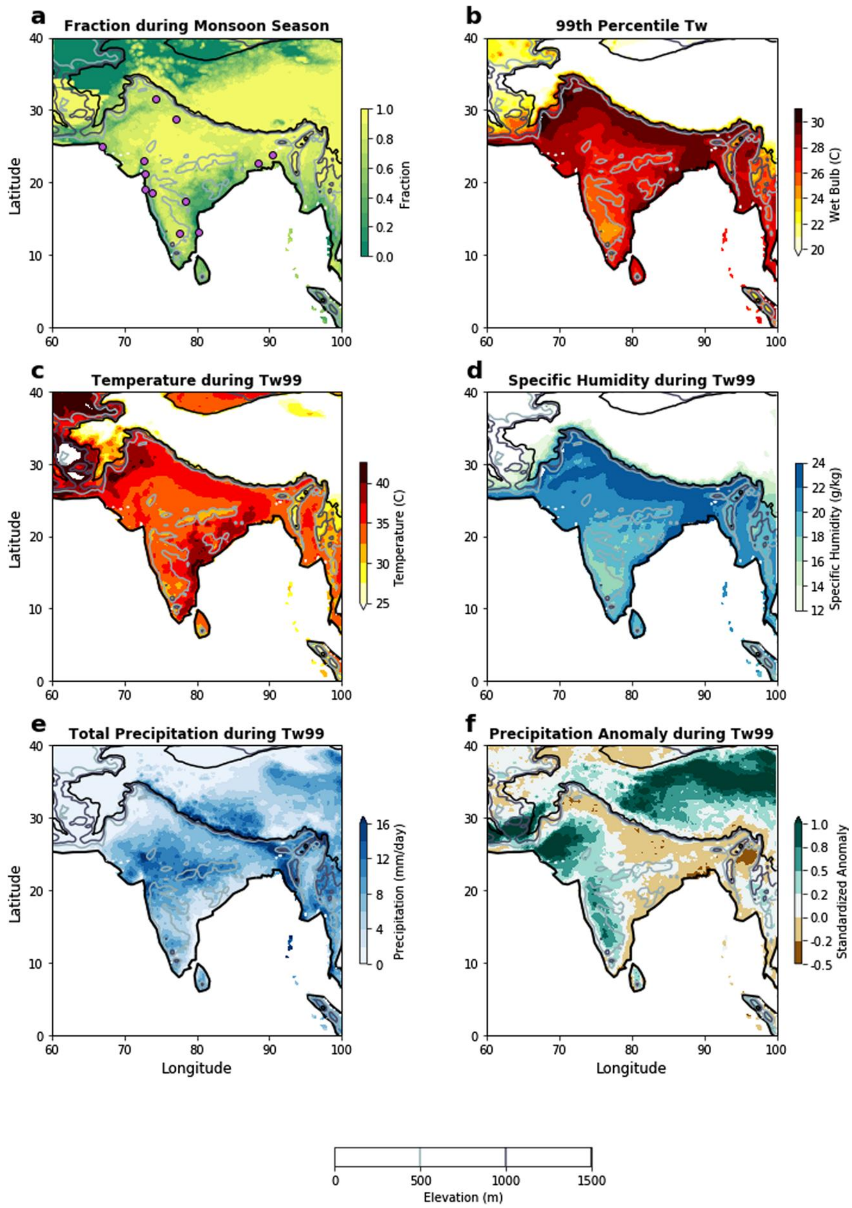

Figure 1. Conditions during local extreme Tw events. (a) Fraction of 99th percentile Tw days occurring during the monsoon season. Purple points indicate the 12 most populous cities in the region, in decreasing order: Mumbai, Karachi, New Delhi, Dhaka, Bengaluru, Hyderabad, Ahmedabad, Lahore, Chennai, Kolkata, Surat, and Pune (United Nations Department of Economic and Social AffairsPopulation Division, 2022). (b) Magnitude of extreme Tw events. (c) Mean daily maximum Tdry during extreme Tw days. (d) Mean specific humidity during extreme Tw days. (e) Total magnitude of precipitation on extreme Tw days. (f) Standardized precipitation anomaly on extreme Tw days, relative to annual precipitation standard deviation on the given calendar date. For each plot, gray contours indicate surface elevation.

humidity ("low humidity" regime, with more than 25% of land area showing a seasonal mean specific humidity below 16 g/kg). We present results in the main text for one representative region of each regime, namely Bangladesh ("BGD") and Northwestern India ("NW") for the high and low humidity regimes, respectively. These two regions are also featured because they have historically experienced exceptional Tw values above 28°C (Figure 1b). At the same time, these regions experience markedly different monsoon seasons. The monsoon season in Bangladesh begins earlier and lasts longer than in Northwestern India (with regional climatological onset and retreat dates calculated here as May 14 to September 18 and June 23 to September 5, respectively), and is associated with higher precipitation intensity and variability throughout the wet season (Figure S3 in

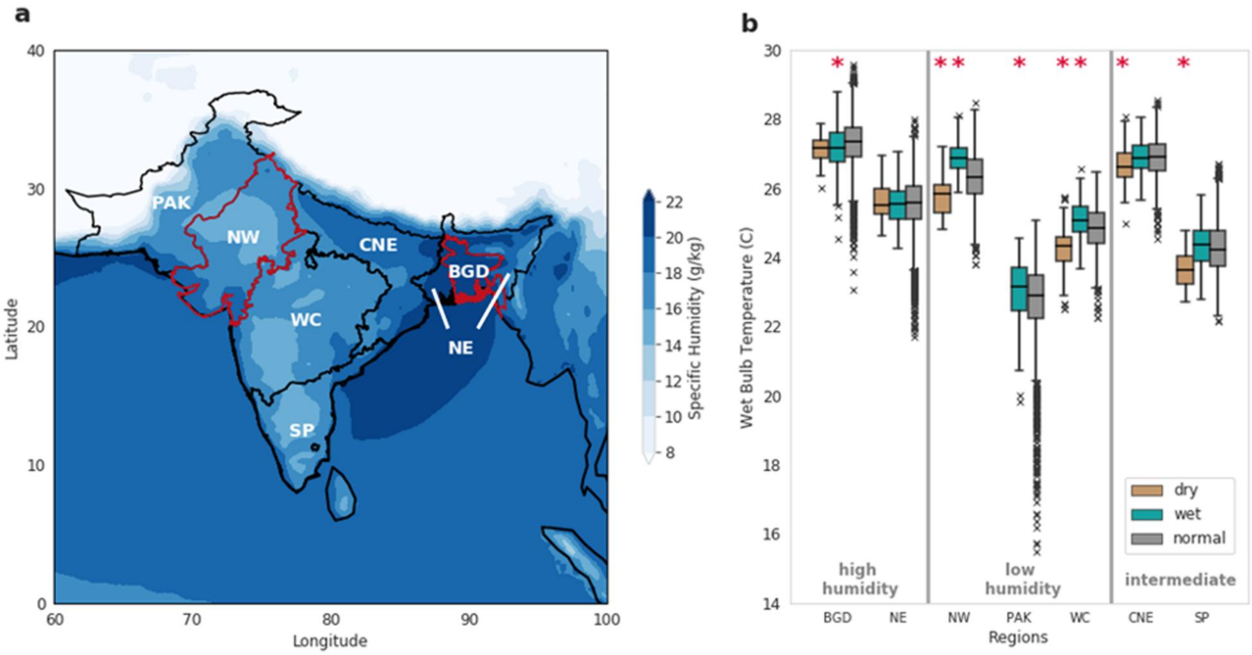

Figure 2. Seven subregions of analysis. (a) Subregional boundaries shaded with mean surface specific humidity during May-September. The two example regions discussed in the main text, Bangladesh and Northwestern India, are outlined in red. (b) Boxplots of Tw during the monsoon season in each subregion. Conditions are binned by days categorized as typical monsoon days, dry spells, or wet spells. Plot sections indicate subregions which are categorized as high humidity regimes (BGD and NE), low humidity regimes (NW, PAK, and WC), and intermediate regimes (CNE and SP). Red asterisks indicate wet or dry spell days in each region with mean Tw statistically different from normal monsoon days using a non-parametric permutation test (see Supporting Information S1). Note that there are no dry spells as defined in the methods that occur in the historical record for Pakistan.

Supporting Information S1). Additional results for the other five subregions are included in Supporting Information S1 (Figures S4–S13).

We find that the effect of subseasonal precipitation variability on local Tw varies strongly in association with background specific humidity. These patterns are summarized for all subregions in Figure 2b by categorizing all historical monsoon season days in each region as those satisfying the definition of either a dry spell, a wet spell, or neither. These results indicate that in low humidity regimes such as Northwestern India, mean Tw during wet spells is significantly higher than mean Tw during normal days, while dry spells are associated with significantly lower mean Tw. In contrast, mean Tw is significantly lower during wet spells in Bangladesh relative to normal days, but there is no significant difference during dry spells.

During dry spells, Tdry anomalies are positive in both Bangladesh and Northwestern India (Figures 3a and 3b). This is likely driven by the decreased cloudiness, increased sensible heating, and decreased evaporative cooling during dry spells in each region, but the anomalies are larger in magnitude in Northwestern India than in Bangladesh. Concurrently, negative specific humidity anomalies compensate for this effect in Northwestern India, leading to net negative Tw anomalies for the duration of the dry spell. In Bangladesh, dry spells do not strongly influence specific humidity anomalies, and Tw anomalies follow the pattern of Tdry to build throughout the duration of the dry spell, elevated by almost 0.5°C by the final day of the dry spell.

The opposite patterns are observed for wet spells (Figures 3c and 3d). While both regions experience sharp declines in Tdry anomalies during these periods of increased precipitation intensity, specific humidity increases in Northwestern India while it is not strongly influenced in Bangladesh. Together, this results in an increase of almost 1°C in Tw anomalies in Northwestern India and a more moderate decrease in Tw anomalies in Bangladesh during wet spells. We note that in these composite analyses which average across regions and over many events, Tw anomalies of even a fraction of a degree may trigger extreme humid heat events and strongly impact heat stress, as regional baseline Tw is high and a small increase over climatological values may be associated with a relatively large increase in the number of days above a high risk threshold dangerous to human health (Cheng et al., 2019; Vecellio et al., 2022).

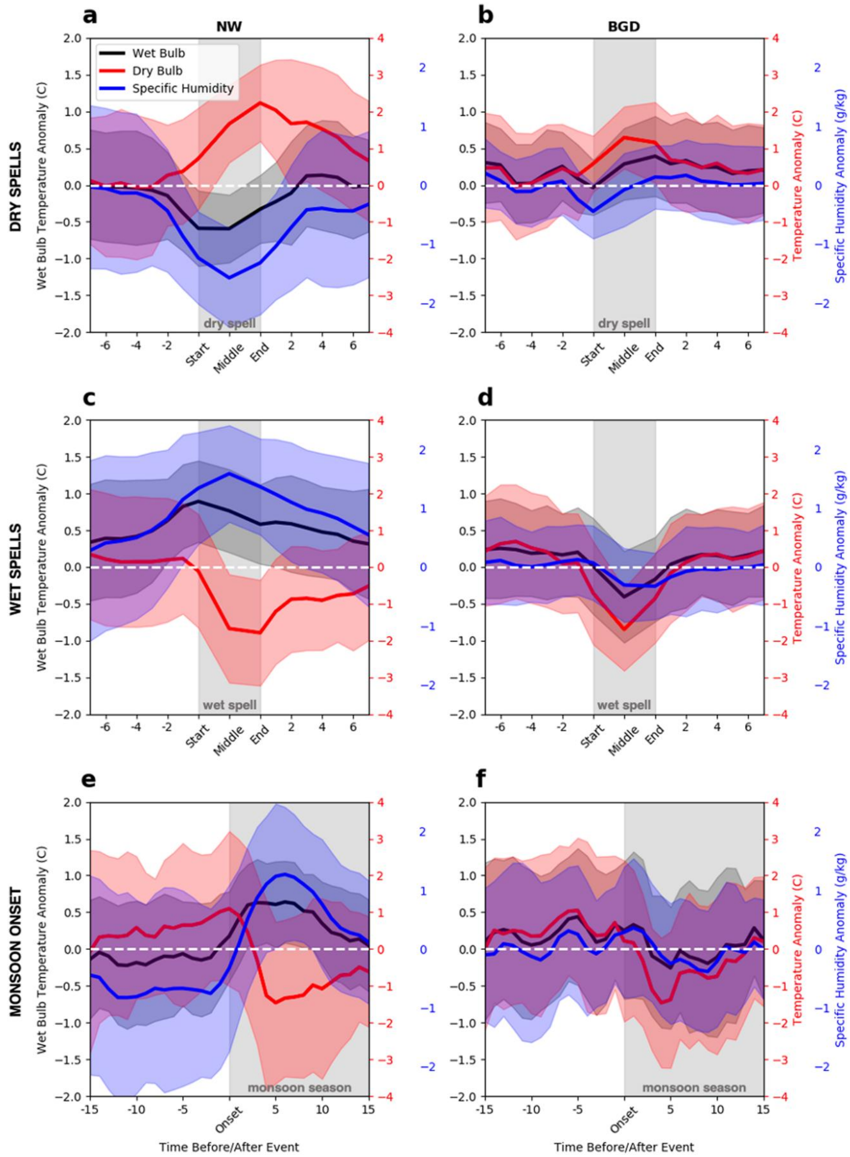

Figure 3. Conditions surrounding dry spells, wet spells, and monsoon onset in left) Northwestern India and right) Bangladesh. Anomalies compared to day-of-year historical mean values for Tw (black), Tdry (red), and specific humidity (blue) are shown. Solid lines indicate mean over all events in each region. Colored shading shows ± 1 standard deviation. Light gray shading shows normalized dry/wet spell duration or monsoon season.

In addition, we analyze the influence of monsoon onset on humid heat by examining the evolution of Tw in the weeks before and after annual monsoon onset in each region. In Northwestern India, monsoon onset is also accompanied by a strong increase in surface specific humidity that compensates for decreased Tdry, leading to a net positive increase in Tw anomalies that can be sustained for up to a week after onset (Figure 3e). In contrast, specific humidity is not strongly affected by monsoon onset in already-moist Bangladesh, resulting in total anomalies of Tw that are close to zero in the weeks before and after onset (Figure 3f).

We also find different effects of the timing of monsoon onset during the calendar year on local Tw anomalies between the two regimes. In Northwestern India, climatological Tw continues to increase throughout the start of the monsoon season, as increasing specific humidity is able to counteract the sharp decline in Tdry that begins slightly before the historical mean monsoon onset (Figure 4a). However, Tw anomalies with respect to a daily climatology are negatively correlated with monsoon onset date, indicating that the effect of delayed onset in this

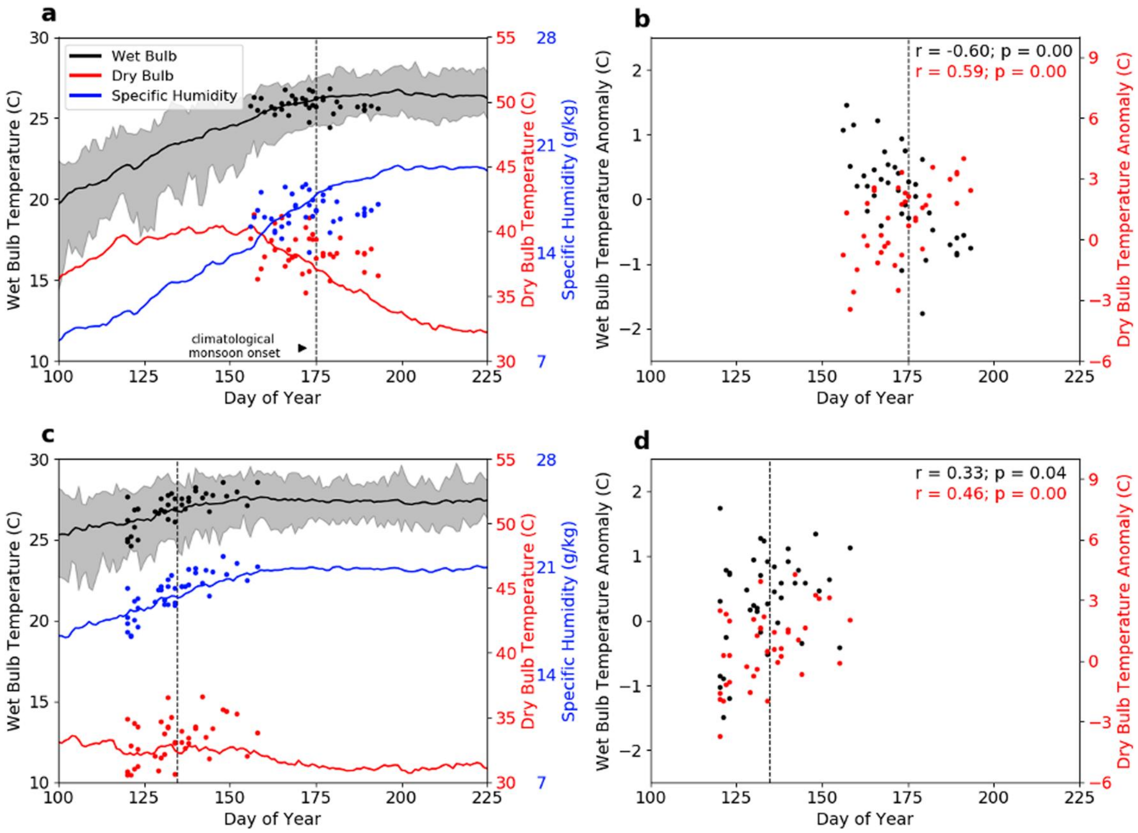

Figure 4. Effect of monsoon onset timing on Tw intensity for Northwestern India (top) and Bangladesh (bottom). Left column: Tw (black), Tdry (red), and specific humidity (blue) mean climatologies plotted alongside a scatter plot of each variable the day before monsoon onset each year in the historical record. Vertical dashed line indicates climatological monsoon onset date for the region. Gray shading indicates historical minimum and maximum Tw. Right column: Correlation between annual monsoon onset date and Tw and Tdry anomalies the day before monsoon onset. Anomalies calculated relative to calendar date historical mean values.

region is to suppress local Tw (Figure 4b). In contrast, in Bangladesh, Tdry is relatively stable as the monsoon season develops, with a decline throughout the monsoon period, while specific humidity continues to increase and then stabilizes in the weeks following monsoon onset (Figure 4c). This leads to a slight increase in climatological Tw around monsoon onset, and then a plateau in early June. Tw on the day before monsoon onset each year in this region increases alongside the Tw seasonal climatology, and Tw anomalies are positively correlated with monsoon onset date even when the background climatology is removed (Figure 4d). This suggests that a delay in monsoon onset itself can intensify Tw in this region.

Overall, these patterns indicate that the physical processes governing the relationship between precipitation and Tw in each subregion may be distinct. In Northwestern India, surface specific humidity is relatively low in comparison to South Asia as a whole. The increase of precipitation associated with earlier onset of the summer monsoon and during wet spells suppresses local Tdry in this region, but provides additional moisture to the surface and increases local specific humidity. This may be due to moisture advection associated with precipitation or to evaporation that takes place following the moistening of the land surface (Kong & Huber, 2023). In either case, the additional humidity dominates the Tw signal in the region, driving increased Tw during periods of enhanced precipitation. On the other hand, surface specific humidity is already very high in Bangladesh. If mean conditions support abundant moisture transport to the lower atmosphere from saturated soils, thick vegetation, and the nearby warm Bay of Bengal, surface specific humidity may be largely controlled by air temperature as prescribed by the Clausius Clapeyron relationship. In such regions, decreases in cloud cover and increases in temperature during dry periods may offer the pathway to higher specific humidity and higher Tw. Because Tdry decreases during enhanced precipitation and intensifies during suppressed precipitation, anomalies of Tdry, specific humidity, and Tw tend to change in tandem in Bangladesh and Tw anomalies are most strongly positive during delayed monsoon onset and wet spells.

4. Conclusions

In this analysis, we show that extreme Tw events throughout South Asia often occur during the monsoon season. However, the influence of precipitation variability on Tw, whether due to monsoon onset or subseasonal variability within the monsoon, differs depending on the local surface moisture climatology. Regions with relatively high background specific humidity experience greater Tw values during suppressed precipitation, associated with delayed onset and dry spells. Those with relatively low background specific humidity, in contrast, tend to experience Tw intensification during periods of enhanced precipitation, such as early onset and wet spells. Because low humidity regimes are associated with larger fluctuations in Tw, precipitation variability in these regions can exert a stronger overall influence on Tw than in high humidity regimes.

The patterns identified above regarding surface humidity regimes are reminiscent of the delineation between moisture-limited and energy-limited evaporative regimes (e.g., Koster et al., 2009; Seneviratne et al., 2010). Previous research has used these evaporative regimes to describe how soil moisture can influence dry and humid heat extremes (Benson & Dirmeyer, 2021; Chiang et al., 2023; Kong & Huber, 2023). Here, high humidity regimes serve as an atmospheric equivalent of energy-limited surface regimes, while low humidity regimes are similar to moisture-limited surface regimes. Tw is closely linked to evaporative efficiency (Bohren & Albrecht, 1998), and thus the controlling mechanisms driving humid heat extremes in each type of region may be similar to those facilitating evapotranspiration. Future research could explicitly test how these mechanisms may interact with other influences on surface moisture, such as advection from the warm Bay of Bengal and irrigated lands over the Indus River Valley, boundary layer depth, and vegetation dynamics, to drive humid heat extremes in South Asia.

Our result that extreme Tw events tend to occur on rainy days during the monsoon season suggests further investigating the role of land-atmosphere feedbacks to understand the dynamic relationship between Tw and surface moisture. Examining these relationships on subdaily or hourly timescales would facilitate evaluation of whether Tw extremes are occurring while it is raining or if the diurnal cycles of Tw and precipitation are out of sync. This is especially important in determining the timing of the highest risk for heat stress, particularly because Tw extremes can be short-lived (Raymond et al., 2020) and heat stress can occur over short exposure periods (Sherwood & Huber, 2010). Determining the hour of day when Tw extremes occur is also relevant to the timing of outdoor agricultural labor activities that are required throughout the monsoon season (Diaz et al., 2023). Future work could also evaluate whether the identified spatiotemporal relationships hold in monsoon regions across globe, such as Australia and the Sahel, which have also experienced dangerous thresholds of extreme humid heat (Raymond et al., 2020; Rogers et al., 2021). Further understanding of how these complex relationships may change with warming as monsoon dynamics and baseline surface moisture shift is important for characterizing potential nonlinear societal impacts in an densely populated region already experiencing high thresholds of heat stress (Li et al., 2020; Zhang et al., 2021).

Potential limitations of this study stem from the sensitivity of the results to the selected humid heat metric. We focus on Tw because of this metric's direct link to evaporative efficiency and associated influence over how well humans can cool themselves down through sweating (Buzan et al., 2015; Sherwood & Huber, 2010). However, because Tw is relatively sensitive to fluctuations in humidity, using a different heat stress metric such as Humidex which weights air temperature more strongly demonstrates distinct responses to changes in temperature and humidity modulated by monsoonal precipitation variability in South Asia (as shown in Figure S2 in Supporting Information S1). Further, humans' experience of heat stress is dependent upon additional variables including solar insolation and wind speed (Budd, 2008; Buzan et al., 2015), and the use of an alternative heat stress metric which captures the effects of these variables' fluctuations such as Wet Bulb Globe Temperature or the Universal Thermal Climate Index could generate different patterns from those presented here using Tw. The overall relationships between heat stress and surrounding meteorological conditions have been shown to depend strongly upon the selected heat stress metric (Baldwin et al., 2023; Sherwood, 2018; Simpson et al., 2023; Vanos et al., 2020), but there is no one-size-fits-all metric which best represents human experience around the world (Grundstein & Vanos, 2021). Directly quantifying the mortality and morbidity impacts of dry versus humid heat extremes in this region could highlight which variables are most representative, but is complicated due to the lack of publicly available and comprehensive health data. Recent work by Justine et al. (2023) has indicated that the best match between the timing of recorded mortality and heat extremes in South Asia occurs on days which maximize an intermediate value between Tdry and Tw. Additional work linking this type of physical atmospheric science analysis with human health or agricultural production data could be particularly beneficial in shedding light on these complex relationships.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

All datasets used in this analysis are publicly accessible via the links in the references list below associated with Funk et al. (2015), Hersbach et al. (2020), Xie et al. (2007), Chen et al. (2008), Pai et al. (2014), and Hamada et al. (2012). All code used in the analysis and to generate figures is available on Github at the following repository: https://github.com/ccivanovich/Monsoon_Humid_Heat/.

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