Heat Stress Induced by Irrigation over the US Great Plains and Related Uncertainties

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Abstract

Irrigation plays a crucial role in agricultural production across the U.S. Great Plains. Meanwhile, it is a key driver of local and regional climate due to its influence on energy and water exchange between land surface and atmosphere. Despite the irrigation-induced evaporative cooling on temperature alone, how irrigation affects summer heat stress – a combination of temperature and humidity can become a concern to public health concern – is not well understood. This study examines the potential impacts of irrigation practices on summer temperature and heat extremes in the Great Plains using a set of sensitivity experiments conducted with the Weather Research & Forecasting (WRF) model for 10 growing seasons. Results show that intensive irrigation lowers the atmospheric temperature, but the increased humidity from enhanced evapotranspiration, especially during the extreme hot and dry summers, can possibly elevate the risks of heat stress in the heavily irrigated area and its surroundings. The response of humid heat extremes to irrigation depends on the heat metrics used in the assessment. For variables like wet-bulb temperature, wet-bulb globe temperature, and equivalent temperature, irrigation leads to significantly intensified humid heat extremes by up to 5°C and increased heatwave frequency by 3 events year^{-1}. In contrast, metrics like the heat index and environmental stress index suggest that irrigation mitigates heat intensity by decreasing the temperature metrics by up to 1°C. Given the importance of irrigation in Great Plains agriculture in a changing climate, these uncertainties underscore the urgent need to connect heat metrics with health outcomes to better address heat mitigation in rural communities.

1. Introductions

As one of the most agriculturally productive regions in the world, the U.S. Great Plains has witnessed severe droughts with considerable economic consequences in the past decade (Basara et al. 2013; Hoerling et al. 2014; Hoell et al. 2020). Irrigation plays a critical role in enhancing agricultural productivity, particularly in semi-arid regions of the Central Plains where rainfall is insufficient for crop growth. This practice involves the artificial application of water to the soil, supplementing natural rainfall to maintain optimal conditions for crop development. For instance, irrigation from the High Plains aquifer has increased total biomass yield by an average of 51% during the period 1960–2007, contributing to an estimated gross annual value of $3 billion as of 2007 (Suarez et al., 2019).

Besides its agricultural benefits, irrigation is often proposed as a climate mitigation strategy due to its cooling effect (Seneviratne et al. 2018). The added water to the soil can stimulate the evapotranspiration processes, such as canopy evaporation, soil evaporation, and canopy transpiration, which reduce surface temperature through evaporative cooling, especially during hot days (Chen and Dirmeyer 2019; Thiery et al. 2020). However, enhanced evapotranspiration also leads to increased humidity over the irrigated region (Mahmood and Hubbard 2002; Mahmood et al. 2008; Zhang et al. 2019; Rappin et al. 2021; Lachenmeier et al. 2024). When considering the combined effect of heat and humidity, irrigation may not always alleviate heat stress or humid heat extremes (Krakauer et al. 2020; McDermid et al. 2021). As global climate change continues to increase the severity of heatwaves and droughts (Cook et al. 2020; Vecellio et al. 2023) and future variability of precipitation highlights the importance of irrigation in drought mitigation for sustainable agriculture in this region, it is urgently needed to address the challenges in understanding the role of irrigation in heat stress over agricultural land and surroundings.

Previous studies in Asia suggest that intensive irrigation can cool surface temperature but raise the moist heat stress (Im et al. 2017; Mishra et al. 2020; Guo et al. 2022; Sun et al. 2024). However, it remains unclear how irrigation may affect heat stress in the Great Plains, potentially adversely impacting its rural communities. Although global-scale studies reveal that irrigation may elevate heat stress and increase the frequency or intensity of heat extremes in the central US (such as Krakauer et al. 2020; Yao et al. 2025), the coarse spatial resolution of global climate models may not well represent the hydroclimatic dynamics at the regional scale. Meanwhile, there are many heat metrics used in environmental health studies (Anderson et al. 2013; Spangler et al. 2022), including wet-bulb temperature, heat index, equivalent temperature, and more. Our previous study suggests that the contribution of humidity to heat stress varies depending on the heat metrics used (Gurung and Chen 2024), therefore the impacts of irrigation on heat stress can also be metric-dependent (Chakraborty 2025; Yao et al. 2025). This highlights the need to examine uncertainties in heat assessment associated with different temperature variables.

To address the knowledge gaps discussed above, this study conducts sensitivity experiments using a high-resolution regional climate model for 10 selected years and analyzes irrigation-induced changes in multiple heat metrics, as well as the intensity, frequency, and duration of heatwaves. We aim to answer two research questions: 1) How does extensive irrigation affect summer heat metrics and extremes over the Great Plains? 2) How different are the impacts among different heat metrics? The rest of the paper is organized as follows: Section 2 describes the model, experiment design, and metrics used to investigate the impacts of irrigation. Results are presented in Section 3, and discussions and conclusions are given in Section 4.

2. Data and Methodology

2.1 Model description

In this study, we use the Weather Research and Forecasting (WRF) model coupled with the Noah-MP land surface model to conduct two sets of experiments assessing the impacts of irrigation on regional temperature and heat extremes. WRF is a non-hydrostatic mesoscale model designed for both research and operational applications. The Noah-MP LSM features multi-parameterization options for dynamic leaf, canopy stomatal resistance, soil moisture factor for stomatal resistance, runoff, and groundwater, and provides multiple options for key land-atmosphere coupling processes (Niu et al. 2011). The coupled WRF–Noah-MP simulations have been widely applied in recent studies on land-atmosphere interactions (e.g., Chen et al. 2018; Zhang et al. 2017) and irrigation impact (Hu et al. 2024; Yang et al. 2019).

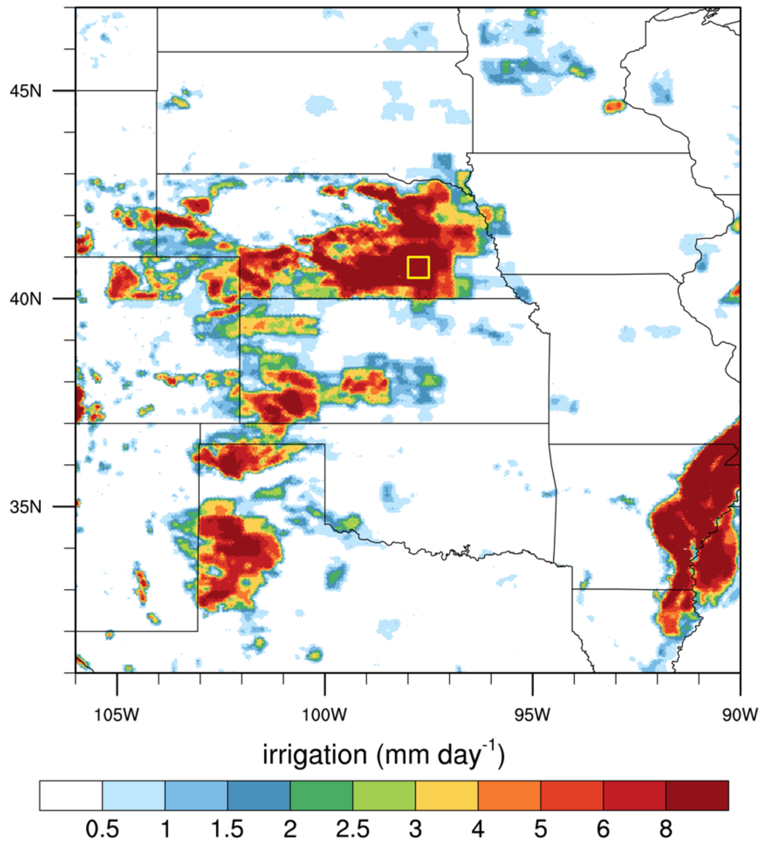

Figure 1. *Simulated irrigation amount over the central US in the inner domain of WRF irrigation simulations. The yellow box over southeastern Nebraska shows the selected irrigated area used for time series analysis. This area is chosen because of its intensive irrigation and significant temperature responses.*

There are two domains in the WRF setup: the outer domain has 210×180 horizontal grid points with a 20-km resolution covering the contiguous US, and the inner domain has 601×521 grid points with a 4-km resolution covering the Great Plains (Figure 1). The 4-km resolution is used to explicitly represent convective precipitation processes while the cumulus scheme is turned off. A similar setup has been used in previous studies focusing on the Great Plains (Hu et al. 2024; Stoy 2024). The selection of other physical parameterizations is the same as Hu et al. (2024).

The boundary and initial conditions are obtained from 6-hourly North American Regional Reanalysis (NARR, Mesinger et al. 2006) at a horizontal resolution of ~32 km. Land use/land cover conditions are derived from the MODIS-based International Geosphere-Biosphere Programme (IGBP) classification. For the simulations that include irrigation, irrigated areas are defined based on the percentage of areas equipped for irrigation in each grid cell developed by Siebert et al. (2015). In Noah-MP, there are multiple irrigation methods, including channel, drip, and sprinkler. For the Great Plains, we choose the sprinkler method, in which the irrigated water is treated directly as "rainfall" in the model (He et al. 2023). Over the grids with irrigation fraction greater than zero, sprinkler irrigation is turned on every three days, applying a total of 24 mm water to irrigate for two hours from 9 AM to 11 PM. This configuration replicates the common irrigation practice in Nebraska, where center pivot irrigation typically applies 1 inch of water every three days to maintain optimal crop yields (Alter et al. 2015). The three-day cycle is chosen because of a full rotation for center-pivot irrigation, which is a commonly used irrigation system in the Great Plains. Similar frequency of applications was also used in California Central Valley (Snyder 1992) and other modeling studies (e. g., Gibson et al. 2017; Kala et al. 2023). The irrigation rate of 1 inch per 3 days is based on the research conducted by the authors of the current study (Hu et al. 2024); the average crop water use rate across Nebraska (Kranz et al. 2008); and the most common diversion rate for irrigation (0.34 inches/day) approved by the Nebraska Department of Natural Resources for surface water appropriations (NDNR 2017).

2.2 Experimental design

To comprehensively understand the impacts of irrigation on temperature extremes, we consider two different climate regimes over the central Great Plains based on summer (June-August) precipitation conditions. Based on seasonal total precipitation during the period 1981-2020, we identify five dry years (1983, 1984, 1988, 2011, and 2012) and five wet years (1993, 2004, 2008, 2016, and 2017).

There are two reasons for considering the dry years and wet years separately in our experiments. First, temperature and precipitation are mostly negatively correlated over the land during summer. In other words, dry years are typically associated with relatively high temperatures, while wet years tend to have lower temperatures. Considering the dry/hot years and wet/cool years separately allows us to examine the temperature effects of irrigation under different climate conditions, offering insights into how irrigation activities may affect heat extremes in a changing climate. Second, land-atmosphere coupling strength is strongly influenced by moisture availability. For instance, evapotranspiration rates become more sensitive to soil moisture variability within a moisture-limited regime, while they become less sensitive in an energy-limited regime. Therefore, from a land-atmosphere-coupling perspective, the impacts of irrigation are expected to be different between the wet years and dry years.

For the 10 selected years, we carry out two experiments to isolate the impacts of irrigation: (1) control run without irrigation; and (2) irrigation run with sprinkler irrigation. It should be noted that the irrigation rate remains constant across both dry and wet years to ensure a fair comparison of the irrigation effects between the two climate regimes. This setup also reflects the actual irrigation practice before groundwater use regulations were implemented. This idealized approach can also avoid the uncertainties associated with irrigation rates and scheduling in different years. As the main goal of this study is to examine the irrigation impacts in different climate conditions, the consistent setting of irrigation practice allows us to focus on the atmospheric response to irrigation in different years, and avoid the complexity involved by irrigation difference. For each year, the simulation starts on April 1st and ends on September 30th, and results during the summer are used in our analysis.

2.3 *Impact analysis*

Besides 2-m air temperature (T_a), this study also examines the impacts of irrigation on heat stress, which considers both temperature and humidity conditions. To assess the uncertainties related to the choice of heat stress variables, we use five commonly used temperature variables to quantify heat stress.

The wet-bulb temperature (T_W) is defined as the temperature an air parcel would reach if cooled adiabatically to saturation at constant pressure by evaporation of water into it. The calculation of

T_W is based on 6-hourly WRF output of 2-m temperature (T, °C) and relative humidity (RH, %), shown in Eq. 1 (Stull, 2011).

$$T_W = T_a\left[0.152\,(RH + 8.314)^{1/2}\right] + (T_a + RH) - (RH - 1.676) + 0.004RH^{3/2} * (0.023\,RH) - 4.686 \quad \text{(Eq. 1)}$$

Wet bulb globe temperature (T_{WBG}) is a measure of the heat stress in direct sunlight, which considers temperature, humidity, wind speed, sun angle, and solar radiation. For simplicity, here we adopt a simplified T_{WBG} calculation, which is an approximate form requiring only temperature and humidity, and explicitly assuming fixed moderately high solar radiation and low wind speeds, as shown in Eq. 2 (Willett and Sherwood 2011), in which e_a represents vapor pressure.

$$T_G = 0.567\,T_a + 0.393\,e_a + 3.94 \quad \text{(Eq. 2)}$$

Environmental stress index (ESI) is an alternative to the wet bulb globe temperature. The ESI calculation is based on 2-m air temperature (T_a), relative humidity (RH), and incoming solar radiation (SW), as shown in Eq. 3 (Moran et al. 2001).

$$ESI = 0.63Ta - 0.03RH + 0.002SW + 0.0054(Ta \cdot RH) - 0.073(0.1 + SW)^{-1} \quad \text{(Eq. 3)}$$

Equivalent temperature (T_E) represents the temperature that a moist air parcel would reach if all its water vapor condensed out under constant pressure and adiabatic conditions. By definition, T_E accounts for both dry and moist heat of the atmosphere and provides total atmospheric heat content (Pielke et al. 2004, Matthews et al. 2022; Lachenmeier et al. 2024; Zhang et al. 2019). The calculation of T_E is based on 2-m air temperature (T_a) and specific humidity (Q), shown in Eq. 4 (Schoof et al. 2017), in which where L_v is the latent heat of vaporization and Cp is the specific heat of air at constant pressure.

$$T_E = T_a + \frac{L_v q}{C_p} \quad \text{(Eq. 4)}$$

Lastly, heat index (HI) is a measure of how hot weather "feels" to the body, developed by National Weather Service (Rothfusz 1990). It is an empirical method of using temperature and humidity to produce an "apparent temperature”.

Similar to the temperature extreme index TXx (Karl et al. 1999), which is defined as the maximum value of daily maximum temperature within a year or month, we calculate TXx using all the temperature variables to quantify the intensity of extreme heat. Meanwhile, we use three metrics to characterize the frequency and longevity of extreme heat. Hot-day frequency is defined as the number of days with temperatures exceeding the 90th percentile, which is calculated based on the 10-year daily maximum temperature from the control simulations. Heatwave frequency is defined as the number of unique heatwave events that consist of at least three consecutive hot days, while heatwave duration is the average length of heatwave events. The difference in temperature or heatwave metrics between the WRF simulations with and without irrigation is considered as the effects of irrigation. A Student's *t*-test is used to assess the statistical significance of the difference between the two simulations.

3. Results

Figure 2 shows the impacts of irrigation on seasonal average temperature over the Great Plains. Overall, irrigation leads to a strong cooling effect on 2-m air temperature during the summers of the wet and dry years (Figure 2a-c). In areas with intense irrigation, such as central Nebraska, air temperature decreases by more than 3°C. Such a cooling effect is attributed to the enhanced evapotranspiration over the cropland following continuous irrigation (Figure 3). Even with the same irrigation amount, the cooling effect is slightly stronger during the dry years than in the wet years. This is mainly because evapotranspiration (ET) increases more significantly after irrigation in dry climate regimes when there is stronger atmospheric demand (Figure 3c), leading to stronger evaporative cooling.

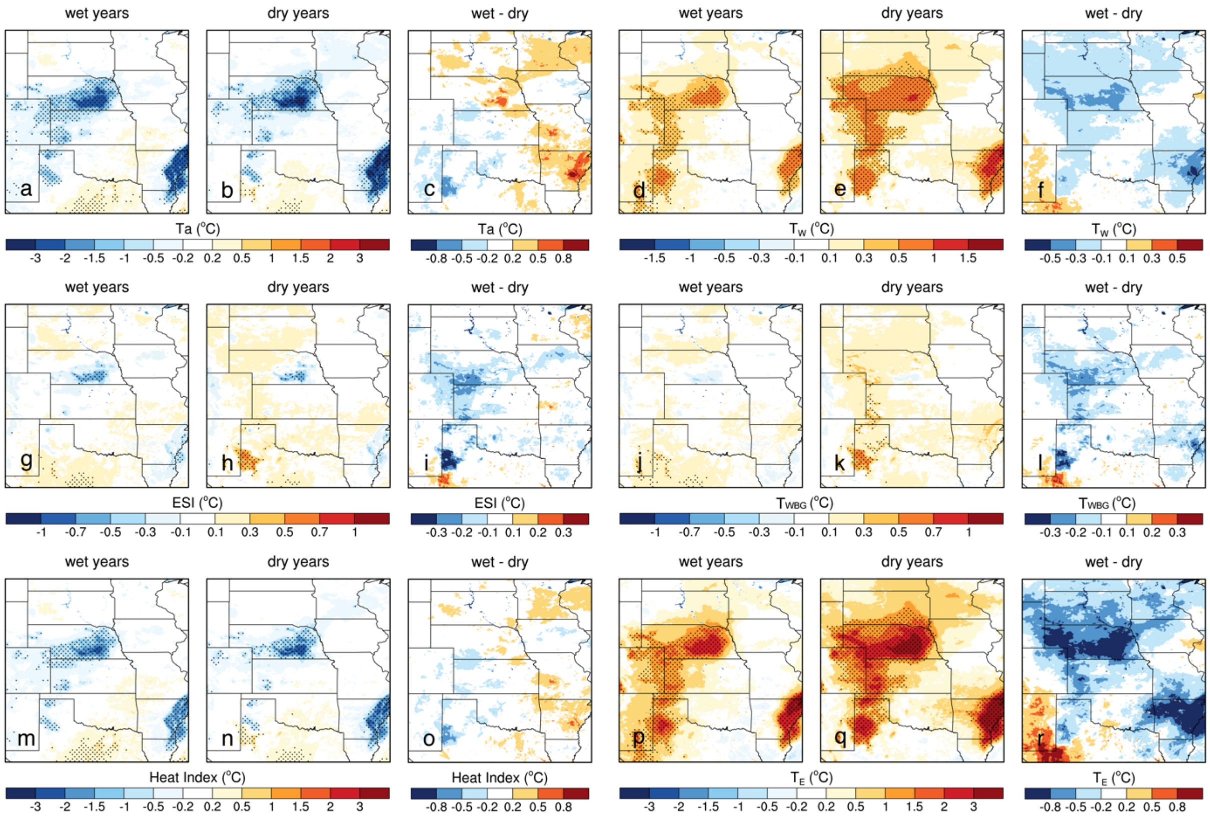

Figure 2. *Impacts of irrigation on JJA average temperature based on six temperature variables (a-c: air temperature; d-f: wet-bulb temperature, g-i: environmental stress index; j-l: wet-bulb globe temperature; m-o: heat index; and p-r: equivalent temperature) during the wet years and dry years, and the difference in impacts between wet years and dry years. Stippling indicates the irrigation effect is statistically significant.*

With humidity incorporated into the temperature variables T_W, T_{WBG}, and T_E, irrigation exerts opposite effects. Although irrigation lowers air temperature alone, it considerably increases T_W, T_{WBG}, and T_E due to the elevated atmospheric humidity (Figure 3d-e). It should be noted that near-surface humidity shows a stronger increase over a broader area during dry years (Figure 3f), suggesting that irrigation-atmosphere feedback influences moisture transport to neighboring and remote regions beyond the irrigated cropland. During the dry years, the seasonal average wet-bulb temperature T_W can increase by more than 1°C in the intensively irrigated areas, such as Nebraska and the Lower Mississippi River Basin. Similarly, stronger impacts of irrigation are found during the dry years than in the wet years. Because equivalent temperature T_E takes into account the heat required to vaporize liquid water, humidity plays a dominant role in T_E

variations (Gurung and Chen 2024), and the irrigation-induced increase in T_E is even more pronounced (Figure 2p,q). During the dry years, the warming can exceed 3°C in regions like Nebraska and northern Texas.

The changes in wet-bulb globe temperature T_{WBG} are less pronounced than in T_W and T_E. Over central Nebraska in the dry years, the warming in T_{WBG} becomes much weaker than T_W, mainly because the strong cooling in T_a offsets the effect of increased humidity from irrigation. Instead, relatively strong T_{WBG} warming is found over the drier western plains, including western Nebraska, Kansas, and northern Texas, where the humidity increase is substantial (Figure 3d) and not substantially offset by the temperature decrease. During the wet years, irrigation has minimal impact on T_{WBG}.

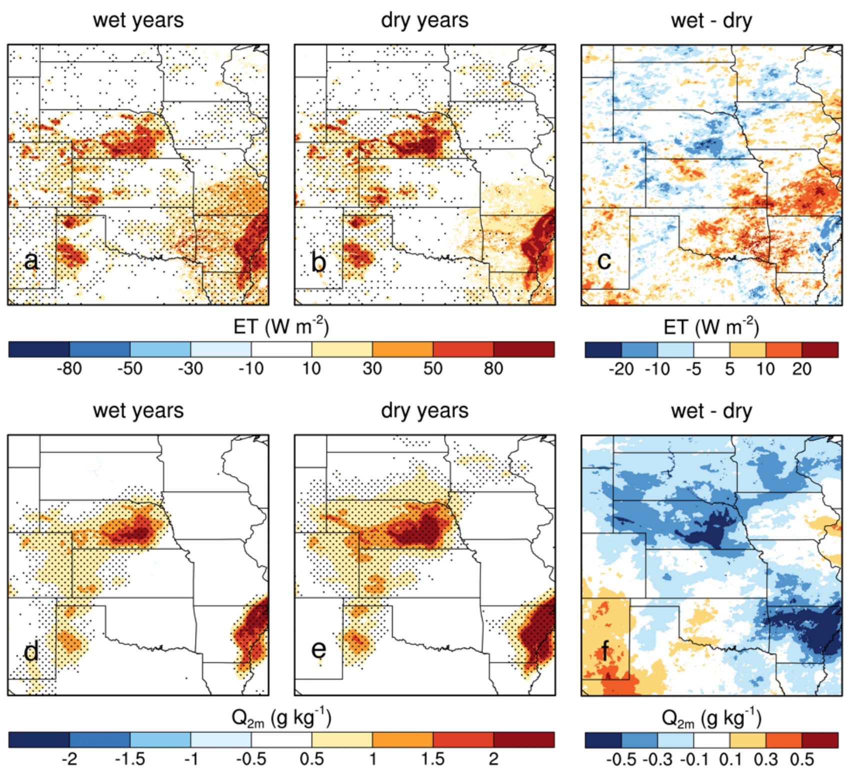

***Figure 3**. Impacts of irrigation on JJA average evapotranspiration (a-c) and specific humidity (d-f) during the wet years and dry years, and the difference in impacts between wet years and dry years. Stippling indicates the irrigation effect is statistically significant.*

However, not all the humidity-considered temperature variables exhibit a warming effect from irrigation. Changes in heat index (HI) closely follow the pattern of 2-m air temperature, showing a notable decrease over extensively irrigated regions and stronger cooling during dry years (Figure 2m,n). The magnitude of the decrease in "*feel-like*" temperature is comparable to the reduction in T_a. This suggests that, in contrast to equivalent temperature T_E, heat index is more dominantly influenced by temperature than humidity. Irrigation also reduces environmental stress index (ESI) in the central plains. However, similar to T_{WBG}, ESI increases over the western Plains, particularly in northern Texas, highlighting its potential as a practical alternative to T_{WBG} (Moran et al. 2001).

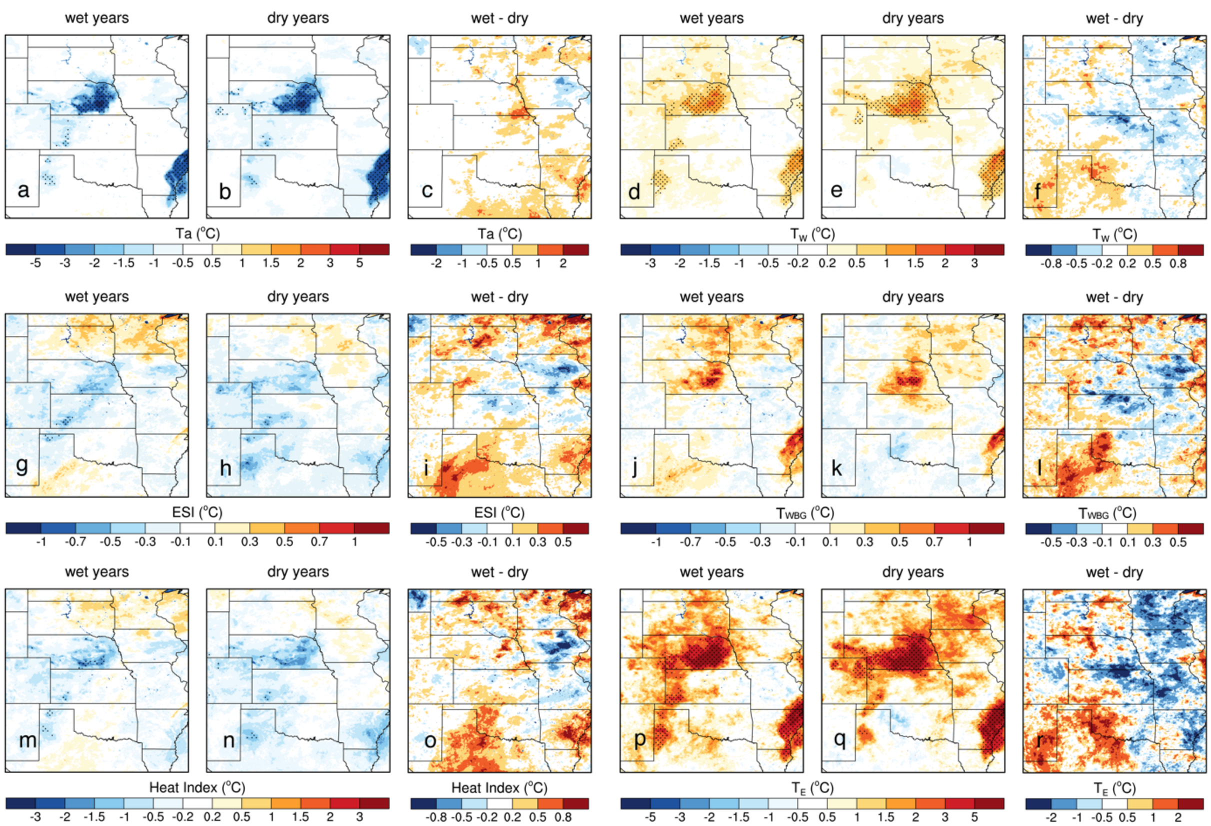

Figure 4. *Impacts of irrigation on TXx based on six temperature variables (a-c: air temperature; d-f: wet-bulb temperature, g-i: environmental stress index; j-l: wet-bulb globe temperature; m-o: heat index; and p-r: equivalent temperature) during the wet years and dry years, and the difference between wet years and dry years. Stippling indicates the irrigation effect is statistically significant.*

Figure 4 shows the impacts of irrigation on the intensity of heat extremes (TXx) based on different temperature variables. Consistent with the changes in seasonal average temperature, irrigation significantly reduces T_a-based extremes and HI, while notably increasing T_E-, T_W-, and T_{WBG}-based extremes. ESI and HI show minimal change, suggesting a slightly cooling (up to 1 °C) or no significant effect on its extremes. The cooling or warming in most of the extremes (except for ESI and HI) shows a greater magnitude than the changes in their seasonal averages. Over central Nebraska, the intensity of T_W and T_{WBG}-based extremes can be elevated by more than 2°C, and T_E-based extremes can be intensified by up to 5°C. However, unlike the contrast in seasonal average T_a between wet and dry years, differences in the intensity of heat extremes are less pronounced across both temperature-only and humidity-inclusive metrics. This suggests that heat extremes are more strongly influenced by synoptic processes on shorter temporal scales.

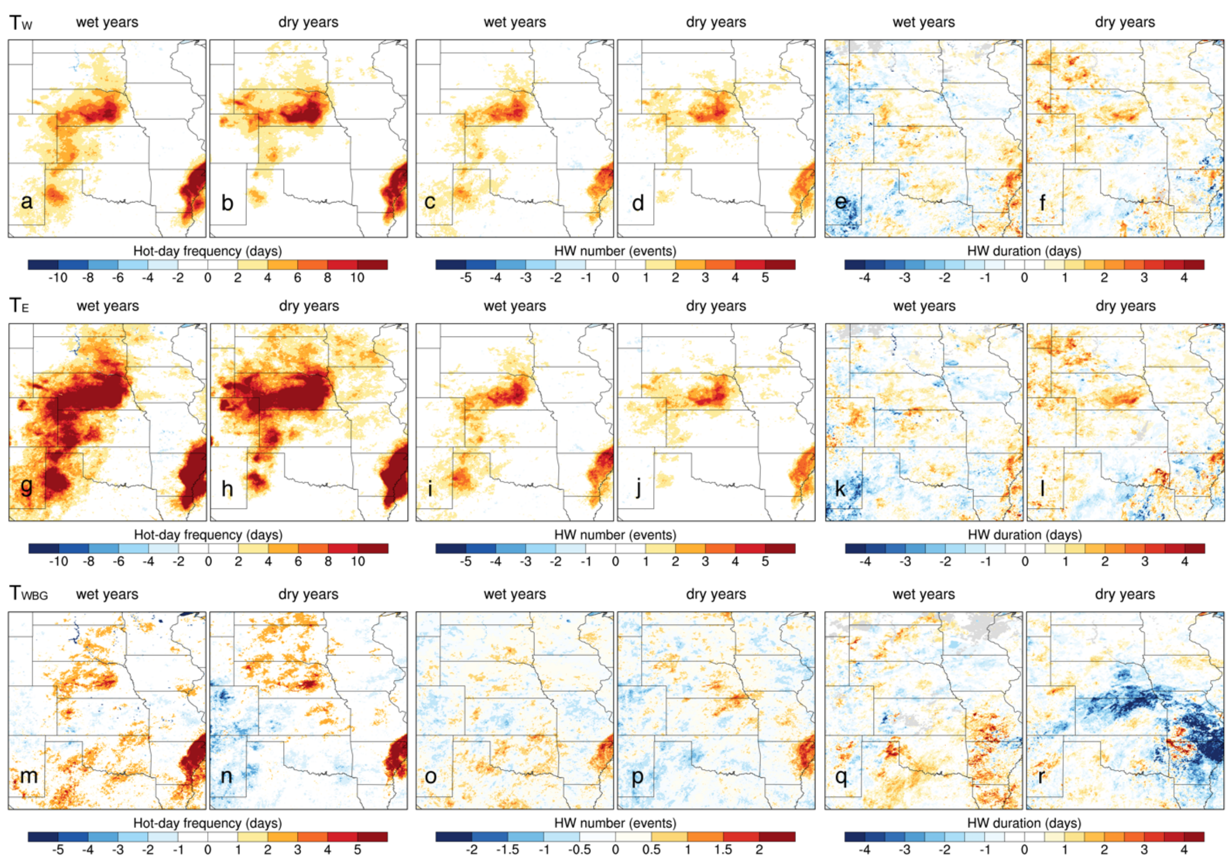

Figure 5. *Impacts of irrigation on three heatwave metrics: hot-day frequency (left), number of heatwave events (middle), and heatwave duration (right), derived from three humidity-considered temperature metrics (a-f: wet-bulb temperature, g-l: equivalent temperature; m-r: wet-bulb globe temperature) during the wet years and dry years.*

To further examine the impacts of irrigation on heat extremes, we use three metrics to quantify the frequency and duration of humid heatwaves derived from different temperature variables (Figure 5). According to T_W and T_E, irrigation leads to a substantial increase in the number of hot days and heatwave events. During the summer, irrigation can add more than 10 days on average with T_W and T_E surpassing the 90th percentile threshold over intensively irrigated areas. Similarly, within selected five wet years or dry years, more than three humid heatwave events per year are associated with irrigation activities. The magnitudes of the increased frequency are comparable between dry and wet years. On the other hand, the duration of humid heatwaves is not significantly affected by irrigation. When using T_{WBG} to quantify the humid heatwaves, irrigation still increases the number of hot days by about 5 days in some regions, but it does not significantly affect the number of heatwave events or their duration.

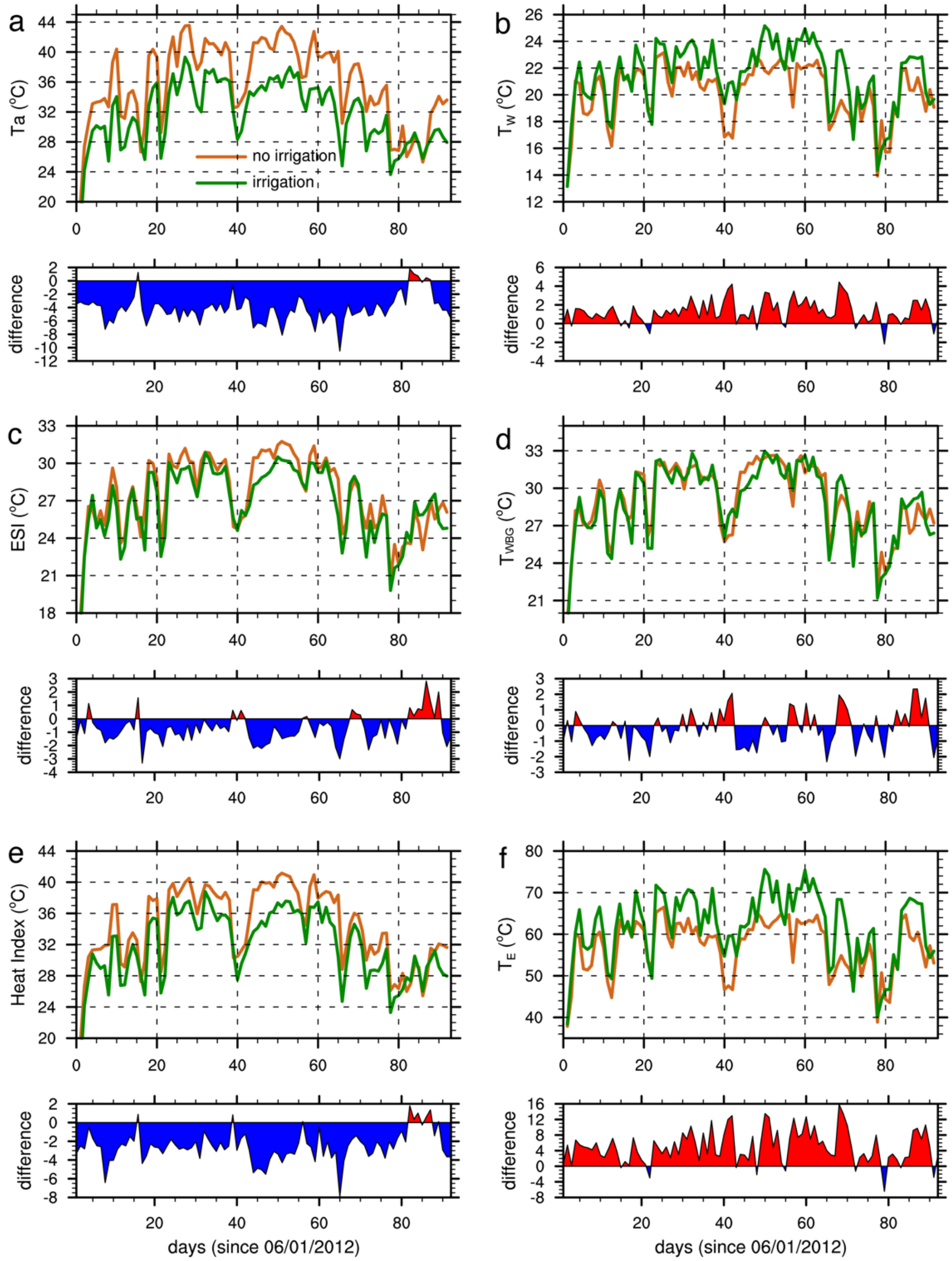

Figure 6. *Time series of daily maximum temperature in summer 2012 averaged over an irrigated area in Nebraska (40.5 – 41°N, 97.5 – 98°W) based on six temperature variables (a: air temperature; b: wet-bulb temperature, c: environmental stress index; d: wet-bulb globe temperature; e: heat index; and f: equivalent temperature) from the simulations with (green lines) and without (orange lines) irrigation, and their difference (shaded line graphs at the*

bottom, in which the blue shading indicates an irrigation-induced cooling effect and the red shading indicates a warming effect).

Lastly, we use the daily maximum temperature in the summer of 2012 in an irrigated area (York, Hamilton, Clay, and Fillmore counties) of Nebraska to demonstrate the relationship between irrigation and temperature variability (Figure 6). The year 2012 is chosen because of historic drought and extreme heat over the central US (Rippey 2015). In the simulation without irrigation, T_a can exceed 40 °C for most of the time from late June to late July, while irrigation reduces T_a by more than 5 °C in some days (Figure 6a). The heat index shows a similar response to T_a, and the irrigation-induced cooling is most prominent during late July (Figure 6e). On the other hand, T_W and T_E suggest an overall warming effect. Without irrigation, the previously identified "hot period" from late June to late July does not stand out and exhibits a comparable heat condition to late August when using the humidity-considered temperature metrics. With irrigation, T_W and T_E have been substantially elevated during that hot period. Furthermore, irrigation has limited effects on ESI and T_{WBG}, showing mixed cooling and warming with a smaller magnitude compared to other temperature metrics. Additionally, despite irrigation's warming and cooling effects, the overall temperature variability across the season follows consistent patterns, such as the cool conditions around July 10th and August 17th and the warm conditions in late July. This highlights the primary influence of synoptic processes on regional temperature variability.

4. Discussions and Conclusions

Due to its influence on surface energy/water balance and biogeochemical cycle, irrigation has been incorporated into the current Earth system models as an important anthropogenic forcing to better represent land management and its role in regional and large-scale hydroclimate (McDermid et al. 2023). Although previous studies have suggested that irrigation may enhance moist heat stress extremes via increased humidity (e.g., Im et al. 2017; Kang and Eltahir 2018; Mishra et al. 2020; Krakauer et al. 2020; Wouters et al. 2022), our results highlight the uncertainties in irrigation effects associated with the temperature metrics used in the analysis. Over the Great Plains, irrigation leads to an increase in heat stress when using T_W and T_E, while a cooling effect is found in ESI or heat index. Such a disagreement is also found in recent studies by Simpson et al. (2023), Chakraborty et al. (2025), and Yao et al. (2025). Since the goal of heat extreme assessment is typically to evaluate its impact on the local population, it is important to understand how those heat metrics relate to physiological responses. For instance, which heat variable shows a stronger relationship with body temperature, heart rate, and magnitude of dehydration (Ioannou et al. 2022)? Which heatwave definition is more closely associated with heat-related illness (Puvvula et al. 2022)? Recent studies have highlighted the importance of considering humidity in improving the predictability of heat-related mortality and morbidity (Lu et al. 2023; Guo et al. 2024a), but which heat metric best predicts health consequences may vary by region (Guo et al. 2024b). The diverse responses in heat metrics to irrigation activities may further amplify metric-dependent uncertainties in public health communication and heat-alert systems. Therefore, a more extensive analysis is needed to further address the irrigation-induced heat risk on public health.

Another novel perspective of this study is investigating the irrigation effect during wet years and dry years separately. With the same irrigation amount, there is a difference in seasonal average temperature between the wet and dry years (Figure 2). For instance, the cooling effect on 2-m air temperature and the warming effect on humidity-considered temperature (e.g., T_W, T_{WBG}, and T_E) are stronger during the dry years. This can be associated with more enhanced ET and greater increased humidity during the dry years (Figure 3). Another potential mechanism of the land-atmosphere interactions in the context of irrigation is the feedback to precipitation processes. Our previous study suggests that irrigation during the dry years results in increased rainfall intensity for individual events (Hu et al. 2024), which further reduces temperature and increases humidity. We also find that the differences in extreme heat intensity and heatwave frequency are less evident between the wet and dry years. This implies that the land-surface feedback in heat extremes may not be significantly affected by seasonal or longer-term conditions if the irrigation forcing stays the same. Instead, the synoptic atmospheric processes mainly drive the variability of regional temperature, as shown in Figure 6. Therefore, a process-focused analysis is needed to further investigate specific heatwave events and understand how irrigation may affect regional land-atmosphere interactions that either exacerbate or mitigate the development of heat extremes.

Meanwhile, several limitations should be noted. First, the results are based on sensitivity experiments from a single climate model. Warm and dry biases over the central US have been a long-standing issue in current global or regional climate model (Lin et al. 2017; Liu et al. 2017). Although these biases can partially be attributed to the absence of irrigation effects in the climate models (Qian et al. 2020), our previous study (Hu et al. 2024) shows that the warm and dry biases persist even in simulations that consider irrigation. These biases can potentially influence the strength of land-atmosphere coupling and introduce uncertainties in simulated irrigation impacts in this region. Addressing those uncertainties requires multi-model experiments, such as the Irrigation Model Intercomparison Project (IRRMIP, Yao et al. 2025). Second, a constant irrigation rate is used across different years to reflect traditional irrigation practices in Nebraska. However, this approach may not fully capture real-world irrigation practices, especially when considering water regulations in response to groundwater depletion and the changing climate in this region. With the increased adoption of management practices for water conservation during the past decade (Gonçalves et al. 2020; Steiner et al. 2025), irrigation impacts may be more pronounced during dry years when irrigation demand is higher.

In summary, this study investigates the potential impacts of irrigation activities on summer temperature and heat extremes in the Great Plains using a set of sensitivity experiments. Although intense irrigation lowers the atmospheric temperature, the increased humidity through enhanced evapotranspiration, especially during the extreme hot and dry summers, can possibly elevate the risks of heat stress in the heavily irrigated area and its surroundings. The response in humid heat extremes to irrigation depends on the heat metrics used in the assessment. Given the importance of irrigation in Great Plains agriculture, such uncertainties highlight the urgent need to connect heat metrics with health responses to better address heat mitigation in rural communities.

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Data Availability Statement

The WRF output and processed data are available upon request.

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