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# Daytime heat stress is reduced by agricultural irrigation in North American cities

This study examines the influence of agricultural irrigation on heat stress and contrasts it against local impacts of urbanization in North American cities using regional climate model simulations. The results indicate that irrigation decreases air temperature and increases relative humidity, with daytime urban moist heat stress reduced according to most indices.

## The question

Irrigation is a widespread land management practice crucial for human food supply. It also strongly influences regional climate, with potential effects on heat stress (the harmful effects of overheating). There has been considerable debate on the impact of agricultural irrigation on moist (accounting for the impact of humidity) heat stress[1]. In parallel, cities, where most people now live, also modify heat stress locally[2]. Studies on agricultural irrigation's impacts on moist heat generally ignore urban areas. Similarly, although studies have looked at the impacts of urban-scale irrigation on heat hazard, how large-scale agricultural irrigation changes moist heat stress in cities is unknown. We used regional climate model simulations that took into account convection and had sufficient resolution for urban-scale analysis to address this gap and investigate how irrigation and urbanization modulate urban moist heat stress.

## The discovery

We ran the Weather Research and Forecasting model to simulate summer climate dynamics covering most of North America under three distinct model configurations. The simulations incorporated an explicit irrigation scheme and an urban canopy module and enabled us to isolate the effects of irrigation and urbanization on multiple variables, including temperature, humidity, wind speed, various moist heat stress indices, and components of the surface energy budget (the balance of the energy received and dissipated by the Earth's surface).

We find that irrigation substantially impacts regional climate in the simulations, with, for instance, changes in almost all components of the surface energy budget. Overall, there is a decrease in temperature and an increase in relative humidity during daytime, with a reduction in moist heat stress over most of the area covered by the model. The irrigation-induced moist heat stress reduction also extends to most of the >1,600 urban clusters in the study area, where we also see urbanization-induced local changes in moist heat. We consider several heat stress indices, including wet bulb globe temperature, which considers the effects of radiation and wind speed on human heat loading and can assess heat hazard in both indoor and outdoor conditions. We also look at wet-bulb temperature, a component of wet bulb globe temperature that is often directly used as a proxy for moist heat stress in the geosciences[3]. We show that the sign of wet-bulb temperature change is opposite to the sign of wet bulb globe temperature change due to irrigation – that is, irrigation reduces wet bulb globe temperature but increases wet-bulb temperature (Fig. 1). By contrast, urbanization decreases both indices during daytime, whereas it increases both at night.

## The implications

An important implication of these findings is on the use of wet-bulb temperature as a primary heat stress index in the geosciences, and how it limits our understanding of real-world physiological impacts of climate perturbations. Wet-bulb temperature is rarely used in the epidemiological literature and does not perform well at explaining variability of thermal strain on a continuous scale[4]. The assumptions used to link this variable to human adaptability limits are quite idealized[3], with possible overestimations or underestimations of impacts, as demonstrated through our wet bulb globe temperature component attribution and descriptions of real-world exposure scenarios. Realistic assessments of heat risks using climate or weather models are hindered by both methodological limitations and simplistic assumptions. The variables simulated by these models provide measures of outdoor hazard at somewhat coarse scales. Although coarse urbanization-induced heat stress signals are interesting from a climatological perspective, there are crucial spatial variabilities in heat stress[5] within cities that are barely resolved by most models. Moreover, how these variables relate to population-level heat risk is increasingly being discussed in the geoscience literature, and it depends strongly on both exposure (when and where humans navigate outdoor and indoor environments) and vulnerability (affected by many factors, including building insulation and access to space cooling).

Although all simulations (across all the years included in the model) showed irrigation-induced reductions in urban heat stress, we should treat magnitudes of change from models with caution. Models make structural and parametric simplifications in both urban and irrigation schemes. An exciting future research topic is on the impact of seasonal patterns of irrigation on heat stress. Studying this impact requires high-resolution seasonal irrigation water use estimates that are not constrained by physical water demand, like the estimates used here.

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## EXPERT OPINION

The authors utilize high-resolution regional climate simulations to investigate how irrigation influences heat stress in over 1,600 urban clusters across North America during summer. The study examines the discrepancies between different heat stress metrics and explores the combined effects of urbanization and irrigation on urban heat stress, underscoring the complexities of these interactions. The findings indicate that irrigation generally alleviates heat stress during the summer, particularly in arid urban clusters near heavily irrigated fields — an intriguing topic. **Yadu Pokhrel, Michigan State University, East Lansing, MI, USA.**

## FIGURE

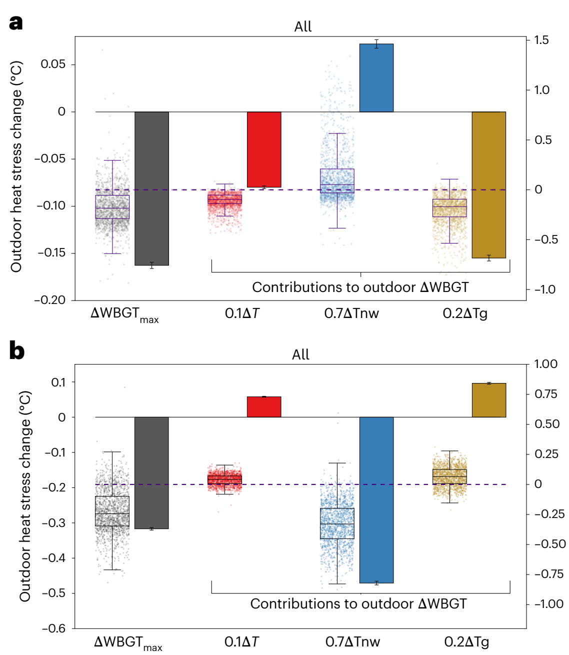


**Fig. 1 | Irrigation and urbanization impacts on urban heat stress.** **a**,**b**, Changes in average maximum outdoor wet bulb globe temperature ($\Delta WBGT_{max}$) and its components – air temperature (ΔT), natural wet-bulb temperature (ΔTnw), and black-globe temperature (ΔTg, which is normally measured with a thermometer inside a black globe and indicates the heat felt in direct sunlight) – in urban clusters as a result of agricultural irrigation (**a**) and urbanization (**b**). Bars represent area weighted means; error bars show area weighted standard errors. The distributions of the cluster-level data and the associated box and whisker plots correspond to the right-hand *y* axis range. © 2025, Chakraborty, TC et al.

## BEHIND THE PAPER

In 2022, we published a study in which we examined how urban moist heat stress varied across scales, and how it compared to urban climate signals from satellite-derived land surface temperature data[2]. Because we calculated several moist heat stress indices, we were able to compare the sensitivities of the different indices to humidity. They were all over the place, which sometimes led to conflicting results about whether urbanization was increasing or decreasing daytime moist heat stress.

A year later, another study demonstrated that the choice of heat stress index can determine the key results related to impacts of irrigation on heat stress[1]. Irrigation studies are usually not done with urban-resolving models. However, we had convection-permitting and urban-resolving model simulations that were performed as part of an ongoing project. We took advantage of these simulations to more comprehensively answer how regional-scale irrigation would impact urban heat stress. **T.C.**

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## FROM THE EDITOR

As global temperatures continue to rise, heat stress is becoming an increasingly important issue. This work stood out to me because the authors use high-resolution modelling capable of resolving atmospheric convection and urban environments. This approach enables them to explore the influence of irrigation on heat stress in highly populated urban clusters and provide valuable insights that might contribute towards strategies to mitigate extreme urban heat. **Tom Richardson, Senior Editor, *Nature Geoscience*.**