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Trends and Disparities of Dangerous Humid Heat Exposure Among Incarcerated People in the United States

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Abstract

Incarcerated people in the United States (US) are at high risk for heat-related mortality and morbidity. They are physically confined, socially isolated, and have high rates of chronic illness. Despite this, a critical knowledge gap remains in assessing dangerous heat conditions at US carceral facilities. Here, we evaluate recent exposure to and trends of dangerous humid heat – defined as number of days per year the maximum wet bulb globe temperature exceed 28°C – during 1982 - 2020 at 4,078 continental US carceral facilities that hold 2 million incarcerated people. We assess exposure differences and trends by facility type, state, and population. We estimate that during 2016 – 2020, on average annually, there were 41.25 million person-days of exposure at US carceral facilities, with the greatest contribution from state prisons (61%). Comparing locations with and without carceral facilities, we observed a consistent disparity during 1982 - 2020, with carceral facilities exposed to an average of 5.5 more dangerous humid heat days annually. An estimated 915,627 people (45% of total) are incarcerated in 1,739 facilities that experienced an annual increase in the number of dangerous humid heat days during 1982 – 2020. Southern US facilities exhibited the most rapid warming, with facilities in Florida warming the most among all continental states. Our findings highlight the urgent need for enhanced infrastructure, health system interventions, and reform in the treatment of incarcerated people, particularly as climate change intensifies dangerous heat exposure. Advancing environmental and climate justice necessitates mitigating health risks faced by marginalized communities, especially incarcerated populations.

Main Text

Incarcerated people in the United States are at high risk for heat-related morbidity and mortality (1–3) due to their physical confinement, social isolation, and high rates of chronic mental and physical illnesses (4). Unlike the vast majority of the United States population, who have access to air conditioning (5) – the most effective individual-level intervention to mitigate extreme heat exposure (1) – many of the 2 million incarcerated people (6) are in the 44 states that do not provide universal air conditioning in carceral facilities (7, 8).

Identifying where incarcerated people are exposed to dangerous heat conditions is fundamental to advancing environmental justice for one of the most marginalized and disempowered communities in the United States (3). Yet researchers and policymakers have largely ignored how dangerous heat impacts incarcerated people (3, 9, 10), in part due to perceptions that their physical suffering is justified (3). Concerningly, as climate change accelerates, the United States will experience more frequent, intense, and longer heat waves (11) that may disproportionately affect incarcerated people.

While previous work has assessed how heat impacts incarcerated people in the United States (2), there is a critical need to quantify dangerous heat conditions at carceral facilities (9, 10). Without this knowledge, the effect of more frequent heat waves (11) on incarcerated people cannot be contextualized nor framed against future climate projections. Identifying where incarcerated people may face disproportionately high exposure is essential to guide targeted interventions to reduce harm to incarcerated peoples' health (5). Furthermore, mapping the spatial and temporal pattern of extreme heat trajectories among incarcerated communities – as well as disparities in exposure – can inform policy discussions to reduce harm at the local, state, and federal levels (3, 9, 10).

Here, we evaluate recent exposure to and the trends of dangerous humid heat conditions during 1982 - 2020 for all 4,078 operational and populated carceral facilities (referring to prisons, jails, and other carceral facilities) in the continental United States (Materials and Methods, Supporting Information). We define dangerous humid heat as the number of days per year where the maximum wet bulb globe temperature ($WBGT_{max}$) exceeded 28°C , the threshold defined by the US National Institute for Occupational Safety and Health (NIOSH) for acclimated populations to limit humid heat exposure under moderate workloads (234–349 W) (12). Exposure is defined as the number of days per year that $WBGT_{max}$ exceeded 28°C multiplied by the total estimated incarcerated population exposed (person-days per year).

Our objectives are to (1) characterize dangerous humid heat at each carceral facility location and by facility type and state; (2) measure how exposure to dangerous humid heat at carceral facility locations compares with the rest of the population nationally and by state; and (3) calculate how the trends over of dangerous humid heat at carceral facilities has changed over time. For objectives (1) and (2), we focus on recent years (2016 – 2020) because we are interested in the current dangerous humid heat exposures. For objective (3), we focus on the entire 1982 -2020 period because we are interested in long term trends. We make the underlying, carceral facility-level daily $WBGT_{max}$ records during 1982 - 2020 and the derived data used in our analysis are publicly available (Data, Materials, and Software Availability).

Results

During 2016 - 2020 there were, on average, an estimated 41.25 million person-days of dangerous humid heat annually at carceral facility in the United States. State prisons accounted for 61% (24.48 million person-days) of total exposure (Figure 1a), followed by county prisons (11.09 million person-days; 27%). The estimated 145,240 people in Texas and 98,941 in Florida housed in state-run carceral facilities in 2018, 12% of all incarcerated people in the United States, accounted for 52% of total exposure (28% in Texas, 24% in Florida) (Figure 1a). An estimated 118 carceral facilities, largely in southern California, Arizona,

Texas, and inland Florida, experienced on average 75 days or more per year of dangerous humid heat (Figure 1b). Across all carceral facilities in the US, the Starr County Jail, a county facility in Rio Grande, TX that incarcerated an estimated 249 people in 2018, experienced the largest number of dangerous humid heat days on average during 2016 – 2020 (126.2 days per year).

During 1982 - 2020, carceral facility locations were, on average, exposed to 5.5 more dangerous humid heat days annually compared to locations without carceral facilities (Figure 2a). However, there was a considerable amount of variance from year to year, with a maximal disparity of 9.8 more days at carceral facilities than locations without carceral facilities in 1998 and a minimal disparity of 3.5 days in 1994. Arizona, California, and Nevada ranked as the top three states with the greatest exposure disparities (Figure 2a). Carceral facilities in Arizona experienced 13.1 more days per year than the rest of the state and 40.9 more days compared to the entire continental United States during 1982 - 2020 on average.

An estimated 915,627 people in the United States, 45% of the estimated total incarcerated population, were housed in 1,739 carceral facilities with an annual increase in the number of days per year WBGT_{max} exceeded 28°C during 1982 – 2020 (Figure 2b). These facilities are primarily located in the Southern United States, which faced the greatest the number of dangerous humid heat days per year since 1982 (Figure 2b). At the state level, carceral facilities in Florida experienced on-average 22.1 more days in 2020 compared to 1982, the greatest increase in dangerous humid heat days for all continental states.

Discussion

The majority of carceral facilities in the Southern United States have experienced an increase in dangerous hot humid days and are located in states that do not have mandatory indoor temperature requirements for state-run institutions (7, 8). This geographic disparity reflects state-level criminal justice policies, as Southern states have the highest incarceration rates in the United States (17), and the inherent differential effects of climate change. Throughout the country, including in the Northeast and Midwest, many locations with carceral facilities also experienced an increasing number of dangerous humid heat days compared to locations without them.

Incarcerated people have few options to reduce the impact of heat waves (3, 10, 9) and these marginalized communities are often disproportionately susceptible to the effect of dangerous humid heat given preexisting health conditions. In fact, 43% of the state prison population has a previous mental health diagnosis (18) and people on psychotropic medications are at increased risk for heat illness (10). Exposure to dangerous humid heat can also cause both acute health effects, such as heat stroke or mortality, and long-term damage. For example, chronic dehydration strains kidney function and those with chronic heat exposure have been shown to have higher rates of kidney disease (13).

From a climatic perspective, we find that 1998 and 2010 were the worst two years, respectively, for heat disparities between incarcerated and non-incarcerated populations in the United States. These two years were also strong El Niño events (14). While El Niño affected other years during 1982 - 2020, our findings suggest that El Niño may be an important precursor to elevated exposure disparities and seasonal forecasts could help facilities prepare for summer humid heat waves to reduce the impacts of dangerous conditions for incarcerated communities.

Our work highlights how incarcerated populations in the United States are systematically exposed to dangerous humid heat with the greatest exposure and rates of increase concentrated in state-run institutions. Federal, state, and local laws mandating safe temperature ranges, enhanced social and physical infrastructure, and health system interventions could mitigate the effect of dangerous heat on this underserved and overburdened group. Underlying this is the need for a fundamental overhaul to the

perception and treatment of incarcerated people in environmental public health policy and regulatory action. Doing so is critical to environmental justice, particularly for incarcerated people with limited social and political agency.

Materials and Methods

We assigned daily WBGT_{max} estimates to 4,078 carceral facility locations for the United States during 1982 - 2020. WBGT_{max} is constructed from high-resolution (4 km) daily maximum 2m air temperatures (T_{\max}) and maximum vapor pressure deficit (VPD_{max}) from the PRISM dataset (15). T_{\max} and VPD_{max} are used to construct daily maximum heat index (HI_{max}) following the US National Weather Service's procedure (16), which is converted to shaded or indoor WBGT_{max} using a quadratic transform that assumes fixed wind speeds and no radiated heat (Supporting Information). Facility location and population data is from Homeland Infrastructure Foundation-Level Data (HIFLD), produced by the Department of Homeland Security (6).

We then define dangerous humid heat frequency as the number of days per year where the maximum wet bulb globe temperature (WBGT_{max}) exceeded 28°C, the threshold used by the US National Institute for Occupational Safety and Health (NIOSH) for acclimated populations to limit humid heat exposure under moderate workloads (234–349 W) (12). Exposure during 2016 - 2020 is measured by multiplying the number of incarcerated people housed at each carceral facility in 2018 by the average number of days WBGT_{max} exceeded 28°C during 2016 - 2020. Annual disparity between incarcerated and locations without carceral facilities is measured by taking the population-weighted difference between the number of days WBGT_{max} exceeded 28°C at the location of a facility and the rest of the state. To measure the annual rate of change in dangerous humid heat days per year, we fit linear regressions to the count of days WBGT_{max} exceeded 28°C per year for each facility. For a more detailed explanation of methods, see the Supporting Information.

Data, Materials, and Software Availability

Daily 4-km PRISM data from 1982 to 2020 and HIFLD data are freely available at <https://prism.oregonstate.edu/recent/> and <https://hifld-geoplatom.opendata.arcgis.com>, respectively. National Center for Health Statistics (NCHS) bridged-race dataset (Vintage 2020) is available from during 1990 to 2020 https://www.cdc.gov/nchs/nvss/bridged_race.htm and from the US Census Bureau before 1990 <https://www.census.gov/data/tables/time-series/demo/popest/1980s-county.html>. All code to reproduce this work, as well as underlying daily WBGT_{max} for each carceral facility during 1982 - 2020 and analytical products used here, are freely available at [Github link provided upon publication].

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Figures

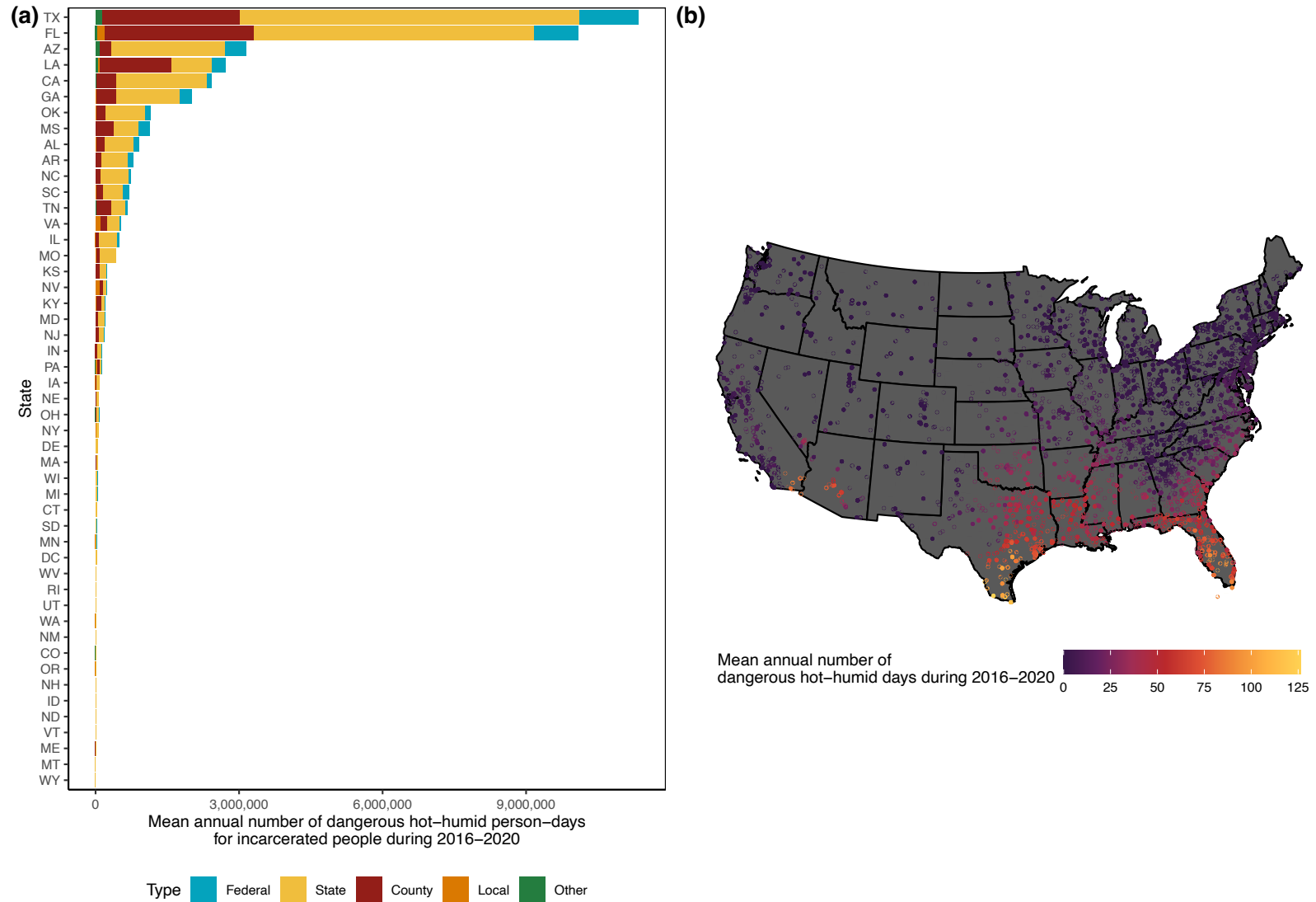


Figure 1. Mean annual exposure during 2016 - 2020 to dangerous humid heat in carceral facilities within the continental United States (N=4,078), measured by: (a) the number of person-days $WBGT_{max}$ exceeded 28°C for incarcerated people by state and carceral facility type; and (b) the number of days $WBGT_{max}$ exceeded 28°C for each carceral facility.

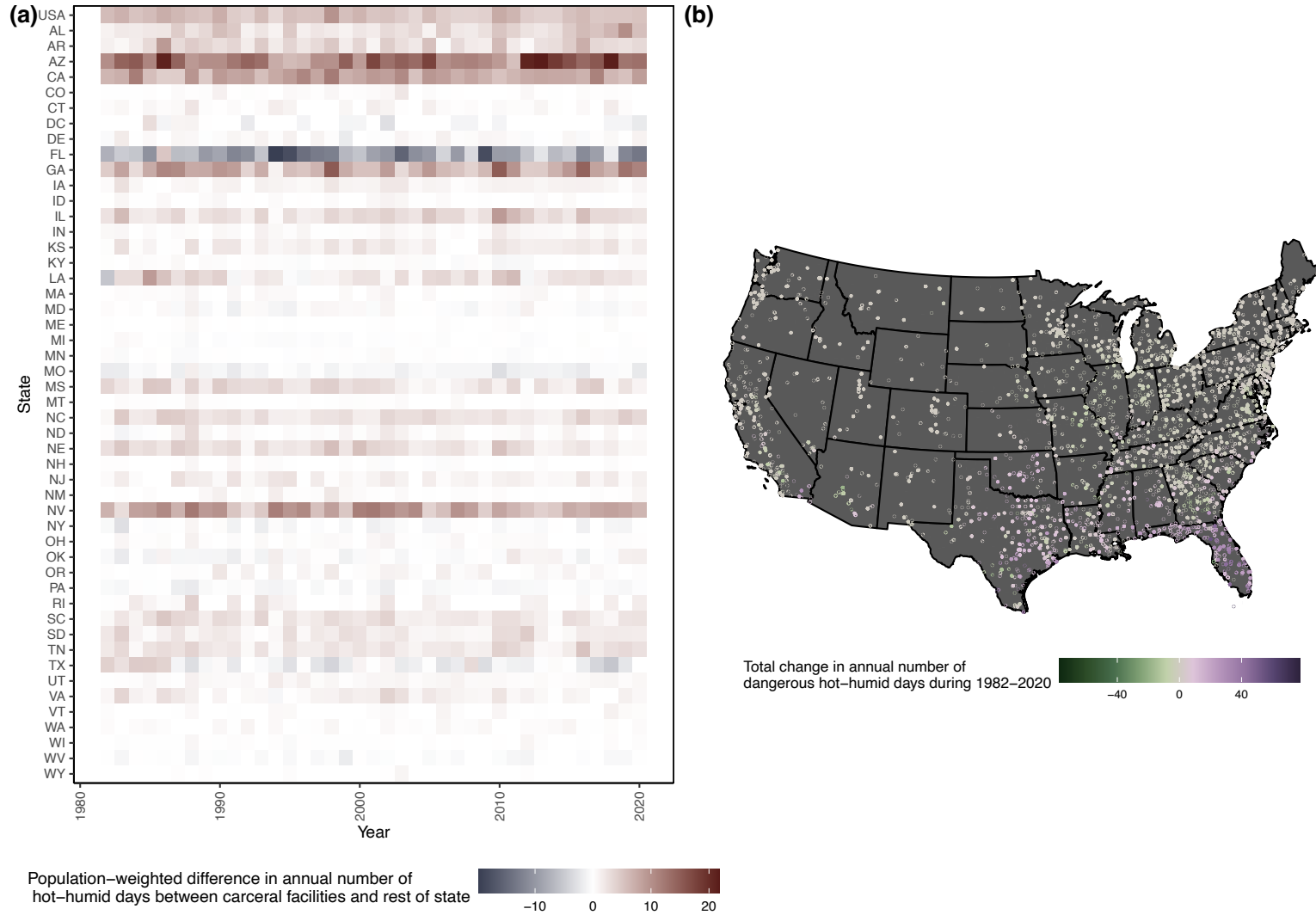


Figure 2. (a) Population-weighted difference between the annual number of dangerous hot-humid days (defined as WBGT_{max} exceeding 28°C) at the location of carceral facilities versus all other locations in the continental US from 1982 – 2020, overall and stratified by state, and (b) the total change in the number of dangerous hot-humid days per year WBGT_{max} exceeded 28°C for each carceral facility in the continental United States from 1982 - 2020.

