

1 **Hazardous heat exposure among incarcerated people in the United States**
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Deleted: Trends and disparities of hazardous heat exposure among incarcerated people in the United States

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Climate change is predicted to increase the frequency of potentially hazardous heat-conditions across the United States, putting the incarcerated population of 2 million at risk for heat-related health conditions. We thus evaluate the exposure to potentially hazardous heat for 4,078 continental US carceral facilities during 2016-2020. Results show that the number of hot days per year increased during 1982-2020 for 1,739 carceral facilities, primarily located in the Southern US. State-run carceral facilities in Texas and Florida account for 52% of total exposure, despite holding 12% of all incarcerated people. This highlights the urgency for enhanced infrastructure, health system interventions, and treatment of incarcerated people, especially under climate change.

Incarcerated people in the United States (US) are at high risk for heat-related morbidity and mortality due to their physical confinement, social isolation, and high rates of chronic mental and physical illnesses.¹⁻³ Unlike the large majority of the US population, who have access to air conditioning (central and any air conditioning equipment)⁴ – the most effective individual-level intervention to mitigate heat exposure¹ – many of the 2 million incarcerated people⁵ are in the 44 states that do not universally provide air conditioning in carceral facilities.^{6,7}

Identifying where incarcerated people are exposed to hazardous heat conditions is fundamental to advancing environmental justice for one of the most marginalized and disempowered communities in the US.³ Yet researchers and policymakers have largely overlooked how heat impacts incarcerated people,^{3,8,9} in part due to perceptions that their physical suffering is justified.³ As climate change accelerates, the US will experience more frequent, intense, and longer heat waves that may disproportionately affect incarcerated people.⁸

Deleted: The ~2 million incarcerated people in the United States face growing heat-related health risks. We evaluated exposure to potentially hazardous heat for 4,078 continental US carceral facilities during 2016-2020. We found that state-run carceral facilities in Texas and Florida accounted for 52% of total exposure, despite holding 12% of all incarcerated people. Further, the number of hot days per year increased during 1982-2020 for 1,739 carceral facilities, primarily located in the Southern US. We highlight the urgency for enhanced infrastructure, health system interventions, and treatment of incarcerated people, especially under climate change. ¶

62 Here, we evaluate recent exposure to and the trends of potentially hazardous heat conditions
63 during 1982-2020 for all 4,078 operational and populated carceral facilities (referring to
64 prisons, jails, immigration detention facilities, and other carceral facilities) in the continental
65 US (Methods). We define potentially hazardous heat as the number of days per year where the
66 indoor maximum wet bulb globe temperature (WBGT_{max}) exceeds 28°C, the threshold defined
67 by the US National Institute for Occupational Safety and Health (NIOSH) for acclimated
68 populations to limit humid heat exposure under moderate workloads (234–349 W).¹⁰

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70 During 2016-2020, there were, on average, 41.3 million person-days of heat exposure annually
71 at carceral facilities in the US. State prisons accounted for 61% (24.5 million person-days) of
72 total exposure (Figure 1a), followed by county jails (11.1 million person-days; 27%). The
73 estimated 145,240 people in Texas and 98,941 in Florida housed in state-run carceral facilities
74 in 2018 – 12% of all incarcerated people in the US, – accounted for 52% of total exposure
75 (Figure 1a). At 118 carceral facilities, largely in southern California, Arizona, Texas, and
76 inland Florida, experienced on average, 75 days or more per year where WBGT_{max} exceeded
77 28°C (Figure 1b). Air conditioning in carceral facilities in these states is spotty or relies on a
78 less effective cooling system like evaporative cooling¹¹ where air conditioning even exists.^{6,7}
79 Across all US carceral facilities, the Starr County Jail, a county facility in Rio Grande, TX, that
80 held 249 people in 2018, experienced the largest number of day per year WBGT_{max} exceeded
81 28°C on average during 2016-2020 (126.2 days per year). We include additional analyses by
82 further carceral facility types in Supplementary Figures 1–2.

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84 During 1982-2020, carceral facility locations were, on average, exposed to 5.5 more days per
85 year where WBGT_{max} exceeded 28°C annually compared to locations without carceral facilities
86 (Figure 2a). However, there was a considerable amount of variation by year, with a maximal

91 disparity of 9.8 more days at carceral facilities than locations without carceral facilities in 1998
92 and a minimal disparity of 3.5 days in 1994. Arizona, California, and Nevada ranked as the top
93 three states with the greatest exposure disparities (Figure 2a). Carceral facilities in Arizona
94 experienced 13.1 more days per year than the rest of the state and 40.9 more days compared to
95 the entire continental United States during 1982-2020 on average. Statistics comparing the
96 characteristics of incarcerated and non-incarcerated people are found in Supplementary Tables
97 1 and 2.

98
99 In 2018, 915,627 people in the United States, 45% of the estimated total incarcerated
100 population, were housed in 1,739 carceral facilities with an annual increase in the number of
101 days per year WBGT_{max} exceeded 28°C during 1982-2020 (Figure 2b). These facilities are
102 primarily located in the Southern US, which faced the greatest number of potentially hazardous
103 heat days per year since 1982 (Figure 2b). Carceral facilities in Florida experienced on-average
104 22.1 more days in 2020 compared to 1982, the greatest increase in humid heat days for all
105 continental states, consistent with previous work finding that the largest relative increases in
106 heat stress are expected at latitudes closer to the equator.¹² The greatest overall increase relative
107 to the state was for Webb County Jail, TX, with 58.7 more days than the rest of Texas in 2020
108 compared with 1982 (Figure 2c). We also present results from Figures 1 and 2 with alternative
109 thresholds of 26°C and 30°C (Supplementary Figures 3-6).

110
111 The majority of carceral facilities in the Southern US have experienced a rapid increase in
112 potentially hazardous heat exposure since the 1980s and are located in states that do not have
113 mandatory conditioning access for state-run institutions.^{6,7} While physically this rapid increase
114 in heat exposure is a result of anthropogenic climate change, land-cover and land-use change,
115 including an urban heat island effect caused by the materials used to construct carceral

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118 facilities,³ this geographic disparity reflects state-level criminal justice policies, as Southern
119 states have the highest imprisonment rates in the US (though not necessarily highest jailing
120 rates)¹³ and the inherent differential effects of climate change. Throughout the country,
121 including in the Northeast and Midwest, many locations with carceral facilities also
122 experienced an increasing number of days WBGT exceeded 28°C compared to other locations.
123 This continuing intensification limits the effectiveness of heat-mitigation plans (if they exist at
124 all) at non-air-conditioned facilities.¹¹

125
126 That we found carceral facilities are systematically exposed to an increasing number of
127 potentially hazardous heat days compared to other areas of the US is plausible for several
128 reasons. First, carceral facilities are often built where there is availability of low-cost land and
129 limited resistance of local communities.¹⁴ In many states, areas that meet these criteria are in
130 sparsely populated desert or swampy environments.⁵ Zoning laws in urban environments and
131 security issues also favor construction in isolated, desert-like areas.¹⁴ The lack of disparity we
132 identify in Florida is an exception likely due to the north-south climate gradient, with a relative
133 dearth of carceral facilities in the most hot-humid, but economically wealthy and densely
134 populated southern tip. We found that the top-four most exposed states to potentially hazardous
135 heat days per year were Texas, Florida, Arizona, and Louisiana, all of which do not provide
136 universal air conditioning to all their prisons,⁷ potentially creating a double burden of increased
137 exposure and vulnerability.

138
139 Incarcerated people have few options to reduce the impact of hazardous heat^{3,7,9} and these
140 marginalized communities are often disproportionately susceptible to the effect of heat
141 exposure given preexisting health conditions. An estimated 43% of the state prison population
142 has a previous mental health diagnosis¹⁵ and people on psychotropic medications are at

143 increased risk for heat illness.¹⁶ Exposure to elevated heat can also cause both acute health
144 effects, such as heat stroke or mortality, and long-term damage. For example, chronic
145 dehydration strains kidney function and those with chronic heat exposure have been shown to
146 have higher rates of kidney disease.¹⁷ Such vulnerabilities are especially relevant given
147 restrictive prison policies with respect to drinking water and other potential heat-adaptation
148 tools.³

149
150 Though there have been recent declines, the incarcerated population of the US has increased
151 by 500% over the past four decades.¹⁸ People of color are overrepresented in carceral facilities
152 and compose an estimated two-thirds of the total incarcerated population. The prison
153 population is also aging, with 1 in 7 serving life in prison,¹⁹ potentially resulting in potentially
154 greater heat vulnerability to those incarcerated. Structural racism manifests in persistently
155 higher proportions and rates of incarcerated people being people of color.²⁰ Acknowledging
156 and accounting for the role structural racism plays in incarceration is critical to understand both
157 key vulnerabilities to heat as well as contextualizing solutions to exposure to heat. Appropriate
158 preparation for periods of elevated heat is also critical. For example, seasonal forecasts could
159 help facilities prepare for summer heat waves to reduce the impacts of hazardous conditions
160 for incarcerated communities.

161
162 Our work highlights how incarcerated populations in the US are systematically exposed to
163 potentially hazardous heat with the greatest exposure and rates of increase concentrated in
164 state-run institutions. Federal, state, and local laws mandating safe temperature ranges,
165 enhanced social and physical infrastructure, and health system interventions could mitigate the
166 effect of hazardous heat. Underlying this is the need for a fundamental overhaul to the
167 perception and treatment of incarcerated people in environmental public health policy and

168 regulatory action. Further work is critical to comprehensively characterize the vulnerability of
169 the United States incarcerated population to heat, as well as how heat impacts health, to build
170 reliable and validated datasets of cooling mechanisms in prisons and jails, to directly measure
171 indoor temperatures in prisons and jails, and to deploy adaptation measures to mitigate the
172 worst impacts of climate-related stressors. Doing so is critical to environmental justice,
173 particularly for incarcerated people with limited social and political agency.

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.²¹ T_{max} and VPD_{max} are used to construct daily maximum heat index (HI_{max}) following the US National Weather Service's procedure,²² which is converted to indoor, or shaded, WBGT_{max} using a quadratic transform that assumes fixed wind speeds (0.5 m s⁻¹) and no radiated heat (Daily WBGT_{max} estimates in Supplementary Information). Facility location and population data is from Homeland Infrastructure Foundation-Level Data (HIFLD), produced by the Department of Homeland Security.⁵ We evaluated PRISM-derived WBGT_{max} against ERA5-, and HadISD-derived WBGT_{max} in Supplementary Figures 7 and 8.

We then define potentially hazardous 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 heat exposure under moderate workloads (234–349 W)¹⁰ and it is used widely in environmental epidemiological research.^{23–24} 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 per year 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. Population weighting fairly reflects the experience of a population to heat stress. To measure the annual rate of change in annual heat exposure, we fit linear regressions to the count of days WBGT_{max} exceeded 28°C per year for

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326 each facility. For a more detailed explanation of methods, see [Calculating humid heat exposure](#)
327 [and trajectories of change metrics in](#) Supplementary Information.

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Data availability

Data used for this analysis are available via https://github.com/sparklabnyc/temperature_prisons_united_states_2024. The data used in this study were created from the following datasets. Daily 4-km PRISM data during 1982-2020 and HIFLD data are freely available at <https://prism.oregonstate.edu/recent/> and <https://hifld-geoplatform.opendata.arcgis.com>, respectively. National Center for Health Statistics (NCHS) bridged-race dataset (Vintage 2020) is available during 1990-2020 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>.

Code availability

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 https://github.com/sparklabnyc/temperature_prisons_united_states_2024.

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504 **Author contributions**

505 C.T. and R.M.P. designed research; C.T., V.D.L., and R.M.P. performed research; C.T. and
506 R.M.P. contributed analytic tools; C.T., V.D.L., Y.A., C.R., and R.M.P analyzed data; and C.T.,
507 V.D.L., R.S., A.E.N. and R.M.P wrote the paper with assistance from Y.A. and C.R.

508

509 **Competing interests statement**

510 The authors have no competing interests to declare.

511 **Figure captions**
512 **Figure 1. Mean annual exposure during 2016-2020 to potentially hazardous heat in**
513 **carceral facilities within the continental United States.** For each carceral facility (N=4,078),
514 metrics of potentially hazardous heat measured by: (a) the number of person-days WBGT_{max}
515 exceeded 28°C for incarcerated people by state and carceral facility type; and (b) the number
516 of days WBGT_{max} exceeded 28°C for each carceral facility.

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518 **Figure 2. Trends in annual exposure during 1982-2020 to potentially hazardous heat in**
519 **carceral facilities within the continental United States.** (a) Population-weighted difference
520 between the annual number of days WBGT_{max} exceeded 28°C at the location of carceral
521 facilities versus all other locations in the continental United States during 1982-2020, overall
522 and stratified by state, ordered by average population-weighted difference, (b) the total change
523 in the number of number of days WBGT_{max} exceeded 28°C per year for each carceral facility
524 in the continental United States during 1982-2020, and (c) the total change in disparity in
525 number of number of days WBGT_{max} exceeded 28°C per year for each carceral facility in the
526 continental United States, compared with the rest of the state the carceral facility is located,
527 during 1982-2020.

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