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

**Supplementary Information**

Cascade Tuholske1,2\*, Victoria D. Lynch3, Raenita Spriggs3, Yoonjung Ahn4 Colin Raymond5, Anne E. Nigra3, Robbie M. Parks3\*

1Department of Earth Sciences, Montana State University, Bozeman, Montana, 59717, USA.

2GeoSpatial Core Facility, Montana State University, Bozeman, Montana, 59717, USA.

3Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York, New York, 10032, USA.

4Department of Geography and Atmospheric Science, University of Kansas, Lawrence, KS, 66045, USA.

5Joint Institute for Regional Earth System Science and Engineering, University of California, Los Angeles, Los Angeles, California, 90095, USA.

\* Correspondence to: [robbie.parks@columbia.edu](mailto:robbie.parks@columbia.edu) and [cascade.tuholske1@montana.edu](mailto:cascade.tuholske1@montana.edu)

**Incarceration Data**

We use carceral facility (referring to prisons, jails, and other carceral facilities) locational boundaries (polygon latitudinal and latitudinal coordinates) and population data from the Homeland Infrastructure Foundation-Level Data (HIFLD), produced by the United States Department of Homeland Security.1 We included 4,078 operational and populated prisons, jails, and carceral facilities including ICE detention centers, juvenile or geriatric facilities, and halfway houses in the continental United States in our analysis. Of these, there were 232 federal, 1,606 state, 2,142 county, and 73 local facilities. Twenty-five (0.6% of total) carceral facilities did not fall into these categories and were classed as ‘other’. Texas had the single most prisons and jails (411 or 10.1% of total). In total, in 2018, there were 2,032,647 incarcerated people in included prisons and jails, of which 187,847 were in federal, 1,202,930 in state, 604,699 in county, 25,267 in local, and 11,904 in other. Texas was also the state with the single most incarcerated people (233,601 or 11.5% of total). The single largest prison by population was Cook County Jails, IL, with 8,216 incarcerated people.

**Climate data**

The Parameter-elevation Relationships on Independent Slopes Model (PRISM) dataset from Oregon State University provides high-resolution (4 km grids) daily Tmax and maximum vapor pressure deficit (VPDmax) from 1981 - to near present.2 As described in,3-5 mean fields are produced by interpolating data from a dense network of weather stations with a spatial-weight regression model that uses landscape features like elevation and aspect to predict daily meteorological conditions across the continental United States (CONUS). PRISM data has been well-validated and shown to be well-suited for heat-related epidemiological research in the United States.5 The 4-km dataset is freely available.

**Daily WBGTmax Estimates**

Tmax and VPDmax mean fields were converted to approximated indoor or shaded WBGTmax following the procedure described in full elsewhere.6,7 First, VPDmax are converted to daily minimum relative humidity fields described in full elsewhere.5 Next, we combine Tmax and RHmin to create daily maximum heat index (HImax) mean fields following the U.S. National Weather Service’s procedure.8 The full heat index equation is provided in our code (Data, Materials, and Software Availability). To calculate HImax for each day, we use Tmax and RHmin to best align relatively humidity at the time the daily maximum temperature occurs during a given diurnal cycle.5

We then use the quadratic relationship identified in previous work9 between HImax and WBGTin to convert HImax values to an approximated WBGTmax (eq. 1).

WBGT (°C) = -0.0034HI2 + 0.96HI - 34 (°F) (eq. 1)

Outdoor wet bulb globe temperature (WBGTout) is a linear combination of wet bulb temperature (Tw), black globe temperature (Tg) and dry bulb temperature (Td) (eq 2), whereas indoor wet bulb globe temperature (WBGTin) combines only Tw and Tg (eq 3). Both require in-situ field instruments to correctly measure, though several methods exist to approximate WBGTout from meteorological data.10

WBGTout = 0.7Tw + 0.2Tg + 0.1Ta (eq. 2)

WBGTin = 0.7Tw + 0.3Tg (eq. 3)

We recognize that our WBGTmax approximation assumes fixed wind speeds (0.5 m s-1) and neglects radiated heat of WBGTout. But given that incarcerated Americans spend the preponderance of their time indoors and that most carceral facilities lack AC, WBGTin is appropriate to measure how humid heat exposure and changed across carceral facilities in the continental United States. Further, WBGT thresholds are used by multiple organizations, including ISO and the US National Institute for Occupational Safety & Health (NIOSH), to identify occupational risks related to heat stress.

**Calculating humid heat exposure and trajectories of change metrics**

For each carceral facility, we calculated the number of days in each year during 1982-2020 that were greater than 28°C WBGTmax (n\_daysyear). We first assigned the average number of days per year WBGTmax exceeded 28°C from 2016 - 2020. Then, we measured exposure during 2016 - 2020 by multiplying the number of incarcerated people housed at each carceral facility in 2018 by the average number of days WBGTmax exceeded 28°C from 2016 - 2020.

To calculate the disparities between carceral facilities with the rest of the state, we calculated state-level estimates for n\_daysyear by aggregating across counties in each state in each year using county-level population weights derived from the NCHS Vintage 2020 bridged-race dataset during 1990 - 201911 and from the US Census Bureau prior to 1990.12 We then made a population-weighted estimate of the state-level carceral facility value for n\_daysyear and subtracted the estimate calculated for the entire state to obtain the annual estimated disparity in exposure to humid heat days in each year of study in each state.

To estimate trajectories of change in dangerous humid heat, we performed a linear regression of n\_daysyear ~ year to estimate the change in n\_daysyear per year from 1982 - 2020. Using this fitted linear regression for each carceral facility, we then used the estimated parameter (β) multiplied by the number of years between 1982 - 2020 (37 years) to estimate the fitted change in number of humid heat days.

**References**

1. U.S. Department of Homeland Security, HIFLD Open Data, https://hifld-geoplatform.opendata.arcgis.com, Accessed July 10, 2023.
2. PRISM Climate Group, Oregon State University, https://prism.oregonstate.edu, data created 4 Feb 4, 2014, accessed Jul 10, 2023.
3. C. Daly, J. I. Smith, K. V. Olson, Mapping Atmospheric Moisture Climatologies across the Conterminous United States. *PLOS ONE* 10, e0141140 (2015).
4. Daly, C., Halbleib, M., Smith, J. I., Gibson, W. P., Doggett, M. K., Taylor, G. H., ... & Pasteris, P. P. (2008). Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. International Journal of Climatology: a Journal of the Royal Meteorological Society, 28(15), 2031-2064.
5. Spangler, K. R., Weinberger, K. R., & Wellenius, G. A. (2019). Suitability of gridded climate datasets for use in environmental epidemiology. Journal of exposure science & environmental epidemiology, 29(6), 777-789.
6. Tuholske, C., Caylor, K., Funk, C., Verdin, A., Sweeney, S., Grace, K., ... & Evans, T. (2021). Global urban population exposure to extreme heat. Proceedings of the National Academy of Sciences, 118(41), e2024792118.
7. Bernard, T. E., & Iheanacho, I. (2015). Heat index and adjusted temperature as surrogates for wet bulb globe temperature to screen for occupational heat stress. Journal of Occupational and Environmental Hygiene, 12(5), 323-333.
8. National Weather Service, Heat Index Equation, https://www.wpc.ncep.noaa.gov/html/heatindex\_equation.shtml Accesssed July 10, 2023).
9. Bernard, T. E., & Iheanacho, I. (2015). Heat index and adjusted temperature as surrogates for wet bulb globe temperature to screen for occupational heat stress. Journal of Occupational and Environmental Hygiene, 12(5), 323-333.
10. Q. Kong, M. Huber, Explicit Calculations of Wet-Bulb Globe Temperature Compared With Approximations and Why It Matters for Labor Productivity. *Earths Future* 10, e2021EF002334 (2022).
11. U.S. Census Bureau, U.S. Census Populations With Bridged Race Categories (2022), Accessed, https://www.cdc.gov/nchs/nvss/bridged\_race.htm Accessed July 17, 2023.
12. U.S. Census Bureau, U.S. Bureau, County Intercensal Tables 1980-1990. https://www.census.gov/data/tables/time-series/demo/popest/1980s-county.htmlAccessed July 17, 2023).