Four Twenty Seven Climate Solutions

August, 2015

Heat & Social Inequity in the United States

This technical paper explains some key concepts and methods for evaluating heat vulnerability. It includes a discussion of methodological limitations and an exhaustive list of both quantitative and qualitative sources used to assess and extract determinants of heat vulnerability at the county-level.

I. Definitions & Methods

Tab 2:

Heat & Humidity

The Heat and Humidity Stroke Index (HHSI) is a standardized method for measuring the human impact of combined heat and humidity through an indicator known as Wet Bulb Global Temperature (WBGT). Ranges of WBGT are divided into four categories of severity --I: "Uncomfortable"; II: "Dangerous"; III: "Extremely dangerous"; IV: "Extraordinarily dangerous."[1] With the understanding that heat-related morbidity is positively associated with heat and humidity thresholds, we measured the average number of days in a five year interval where WBGT is equal to or greater than "Category II Dangerous."

Climatic variables are derived from the CLIVAR and the Joint Scientific Committee for the World Climate Research Program Coupled Model Intercomparison Project Phase 5 (CMIP5) models. We then evaluated the future climate using the representative concentration pathway (RCP) 8.5 emission scenario (as defined by the IPCC's Special Report on Emission Scenarios (SRES)). We then used a sample of CMIP5 models and fitted outputs to the relevant spatial scales (county) and future time period (2020-2060) at five-year intervals.

The variables for computing wet-bulb temperature through global climate models include daily maximum near-surface air temperature, surface air pressure, and surface daily relative humidity

Tab 3:

Social Vulnerability

Demographics are a key factor when identifying and quantifying the degree of population exposure to climate change. Illnesses from heat are strongly tied to age, social isolation, pre-existing medical conditions, poverty, job type, and other factors.[2] In the U.S., positive associations have been identified between a number of individual factors and heat-related illnesses.

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[1] Rhodium Group. (2014). American Climate Prospectus: Economic Risks in the Unites States. Trevor Houser, Robert Kopp, Solomon Hsiang, Michael Delgado, Amir Jina, Kate Larsen, Michael Mastrandrea, Shashank Mohan, Robert Muir-Wood, DJ Rasmussen, James Rising, and Paul Wilson.

[2] Reid C, ONeill M, Gronlund C, Brines S, Brown D, et al. (2009) Mapping community determinants of heat vulnerability. Environ Health Perspect 117: 1730-1736

The elderly are particularly vulnerable, representing the largest demographic group to experience the ill effects of a heat wave.[3] Social isolation, whether amongst elderly populations or not, holds strong associations to heat mortality in many cases.[4][5] Individuals living alone may not be checked on or be able to request the assistance of an in-home partner or family member during an emergency. Following the 1995 Chicago heat wave, a number of victims were found deceased and alone in their homes.[6]

Poverty may also serve as a proxy for heat exposure, and positive associations between income and heat morbidity have been identified throughout the U.S.[7] Strong positive associations have also been observed among individuals with no high school diploma.[8][9] When examining hospital visits following high ambient temperatures and heat waves in Chicago, the prevalence of diabetes was also shown to have a strong association with heat morbidity.[10][11] Direct and prolonged exposure to also affect a large demographic of outdoor laborers. These "effects tend to occur during outdoor labor as a result of accumulated heat load over a longer time period with little opportunity for rest" as was stated by Mengmeng et al. (2014) in a meta-analysis of thirty-three studies of heat-related morbidity.[12] Please refer to Item 7 in the references tab for how this indicator was calculated.

Tab 4:

Medical Access

As climate change makes extreme weather events more common, demand for medical access will change accordingly. A recent White House publication, the Healthcare Resilience Guide Toolkit (HRCT), describes how an "increase risk of death and hospitalization from heat stress and exacerbation of underlying diseases," causing a surge in demand for health care services during and following an extreme heat event.

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[3] Gronlund, C.J.; Zanobetti, A.; Schwartz, J.D.; Wellenius, G.A.; O'Neill, M.S. Heat, heat waves, and hospital admissions among the elderly in the United States, 1992–2006. Environ. Health Perspect. 2014, 122, 1187–1192.
[4] Semenza JC, McCullough JE, Flanders D, McGeehin MA, Lumpkin JR. (1996) Excess hospital admissions during the July 1995 heat wave in Chicago. Am J Prev Med. 1999;16(4):269–277
[5] Naughton MP, Henderson A, Mirabelli MC, Kaiser R, Wilhelm JL, Kieszak SM, et al.(2002) Heat-related mortality during a 1999 heat wave in Chicago. Am J Prev Med. 2002;22(4):221–227
[6] Klinenberg E. (2003). Review of heat wave: a social autopsy of disaster in Chicago. N Engl J Med.2003;348(7):666–667
[7] Curriero FC, Heiner KS, Samet JM, Zeger SL, Strug L, Patz JA. (2002). Temperature and mortality in 11 cities of the eastern United States. Am J Epidemiol. 2002;155(1):80–87
[8] Medina-Ramon M, Zanobetti A, Cavanagh DP, Schwartz J. (2006). Extreme temperatures and mortality: assessing effect modification by personal characteristics and specific cause of death in a multi-city case-only analysis. Environ Health Perspect. 2006;114:1331–1336
[9] O'Neill MS, Zanobetti A, Schwartz J. (2003). Modifiers of the temperature and mortality association in seven US cities. Am J Epidemiol. 2003;157(12):1074–108
[10] Schwartz J. (2005). Who is sensitive to extremes of temperature? A case-only analysis. Epidemiology.2005;16(1):67–72
[11] Semenza et al. (1996)
[12] Mengmeng Li, Shaohua Gu, Peng Bi, Jun Yang, Qiyong Liu. (2014). Int J Environ Res Public Health. 2015 May; 12(5): 5256–5283. Published online 2015 May 18. doi: 10.3390/ijerph120505256 PMCID: PMC4454966

To evaluate a county's ability to handle this surge of patients in need of concurrent medical attention, we evaluated two indicators that measure access to medical services: “physician access” measures the number of physicians per 100,000 people using databases from the Health Resources and Services Administration; while “hospital access,” produced by the ESRI Health and Human Climate Geo Platform, examines the number of people per facility within a county. Please note that travel times were not considered.

Tab 5:

Physical Environment

Green space and shelter, including housing, parks, and vegetation are critical to health. The potential thermal comfort of housing during heat waves has direct linkages to excess risk during heat waves. [13][14][15] Similarly, the cooling properties of tree canopy can also help mitigate against urban heat island effects.[16] Also, increased access to well-vegetated parks can help improve air quality,[17] temper urban thunderstorms and precipitation anomalies,[18] and provide a refuge from heat in urban and peri-urban communities.[19]

Tab 6:

Heat Vulnerability

The scores we have calculated reflect a county’s degree of vulnerability to future heat and humidity conditions based on existing levels of population exposure. Equal weighting was assigned to the average number of days between 2020 and 2060 that are equal to or exceed HHSI Category II; and the average of the social vulnerability, medical access, and physical environment county scores. Zero represents low vulnerability and 100 indicates high vulnerability to heat. Scores are unitless for purposes of comparability and relative to all U.S counties.

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[13] Evans G. W., Wells N. M., Moch A. Housing and mental health: a review of the evidence and a methodological and conceptual critique. Journal of Social Issues2003;59:475-500.

[14] Howden-Chapman P. Housing standards: a glossary of housing and health.Journal of Epidemiology Community Health 2004;58:162-168

[15] Lawrence R. J. Housing and health: from interdisciplinary principles to transdisciplinary research and practice. Futures 2004;36:487-502

[16] Christopher P. Loughner, Dale J. Allen, Da-Lin Zhang, Kenneth E. Pickering, Russell R. Dickerson, and Laura Landry. (2012). Roles of Urban Tree Canopy and Buildings in Urban Heat Island Effects: Parameterization and Preliminary Results. *J. Appl. Meteor. Climatol.*, 51, 1775–1793. doi: http://dx.doi.org/10.1175/JAMC-D-11-0228.1

[17] Nowak, David J. 1995. *The effects of urban trees on air quality.* Washington, D.C.: U.S. Department of Agriculture Forest Service. www.fs.fed.us/ne/syracuse/gif/trees.pdf.

[18] Lin, Q., and R. Bornstein. 2000."Urban heat island and summertime convective thunderstorms in Atlanta." *Atmospheric Environment*.Vol. 34, 507-516

[19] Spronken-Smith,R.A.,and T.R.Oke.1999."Scale modeling of nocturnal cooling in urban parks." *Boundary-Layer Meteorology*. Vol. 93, No. 2: 287-312

Scoring:

To create a score for each of the components, we standardized all variables to make them comparable using an observed min-max scaling method.[20] Normalized indicators were scaled to a range of 0 to 1 where zero represents the lowest (or worst) score for a specific indicator and one corresponds to the highest (or best) score. Distributions were then tested for skewness and refitted accordingly. Each indicator was weighted equally, averaged within its components (social vulnerability, medical access, physical infrastructure; and HHSI), and finally scaled to give a value 0 to 100. For any indicators that were considered to add resilience (e.g., tree canopy coverage), the inverse of the observation was then rescaled. *Higher scores represent higher potential risk based on concurrent and related levels of climate drivers and population exposure.*

II. Limitations:

1) Business-as-Usual Assumption

Some historical associations and thresholds of heat and human health may not hold under future climate scenarios as some adaptation measures continue to improve or demographic shifts and exposure levels change over time.

2) Climate Data

Due to data source limitations, the scale of projected WBGT is not currently available at a resolution finer than that provided by global circulation models.

3) Hospital Focus

This study focuses on hospital visits for the selected conditions, but not ambulatory visits and thus might underestimate the impact of elevated climate stressors on health outcomes that are more likely to be addressed in an ambulatory care setting.

4) Baseline Considerations

Data used to determine the weighted exposure of populations (via public data) may not be representative of average conditions, and vulnerability types may not be indicative of future vulnerabilities.

III. References

Tab 3:

Social Vulnerability

1) 65+: Percent of residents 65 years and over (US Census, 2010)

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[20] Similar method used in Cutter, Susan L.; Burton, Christopher G.; and Emrich, Christopher T. (2010) "Disaster Resilience Indicators for Benchmarking Baseline Conditions," Journal of Homeland Security and Emergency Management: Vol. 7: Iss. 1, Article 51.

2) 65+ living alone: Percent of households - one-person, 65 years and over (US Census, 2010)
3) Living alone: Percent of households with only one-person (US Census, 2010)
4) Below Poverty Line: Percent of people of all ages in poverty (US Census, 2010)
5) No High School Diploma: Percent 25 years and over without finishing high school (US Census, 2010)
6) Diabetes: Diagnosed diabetes prevalence (CDC, 2012)
7) Outdoor workers: Percent of private-sector jobs in heat-sensitive industries
    a) Note: Four Twenty Seven cross-referenced employment figures by county (QCEW – Quarterly Census of Employment and Wages, 2014) with industries where work is considered high exposure (NIOSH, 1986) and primarily performed outdoors – construction (NAICS 23); agriculture, forestry, fishing, and hunting (NAICS 11); mining (NAICS 21); waste management (NAICS 562); automotive repair and maintenance manufacturing (NAICS 8111); and manufacturing (NAICS 31-33), which may include facilities are typically not climate controlled and the production process often generates considerable heat.

Tab 4:

Medical Access

8) Physician Access: Rate of access to a physician for every 100,000 people (Health Resources and Services Administration via Area Health Resources File, 2004)
    a) Note: Anomalies in original dataset substituted with county health department data
9) Hospital Access: People per facility: county's population divided by the number of health care facilities (hospitals, medical centers, federally qualified health centers, and home health services). Travel time is not considered (Esri Health and Human Climate Geo Platform via U.S. Department of Health & Human Services, US Census Bureau, 2012.)

Tab 5:

Physical Environment

10) Access to parks: Percentage of population living within half a mile of a park (CDC National Environmental Public Health Tracking Network (EPHTN, 2010)
11) Tree canopy coverage: indicator for percent forest canopy by county. The most recent data is 2001 and excludes AK and HI (EPHTN, 2001)
12) Housing stress: Percentage of households with at least 1 of 4 housing problems: overcrowding, high housing costs, or lack of kitchen or plumbing facilities (County Health Rankings & Roadmaps (CHR), 2007-2011)

Risk Framework Literature:

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