The Influence of Spatial Resolution of Temperature Estimates on Predicting Personal Exposure and Adverse Health Outcomes Associated with Heat Waves

Connor Y.H. Wu[1,2], Anna A Scott[3], Molly B. Richardson[1], Pranavi Ghugare[3], Samarth Swarup[1], Benjamin F. Zaitchik[3], Julia M. Gohlke[1]

[1]Department of Population Health Sciences, Virginia Tech, Blacksburg, VA; [2]Department of Geospatial Informatics, Troy University, Troy, AL, [3]Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD

Introduction

- ❖ Neighborhood-level microclimates and climate-controlled indoor environments influence temperature exposure.
- ❖ Exposure misclassification could lead to bias in epidemiological studies linking health effects to ambient temperatures measured at a nearby weather station.
- ❖ Use of spatially resolved remotely sensed datasets and measurements from thermometers co-located with people can be used to address this gap in knowledge.

We hypothesized:

1. Increasing spatial resolution of exposure metrics using remotely sensed data will reduce error in associations between heat waves and mortality or adverse birth outcomes in Alabama.
2. Nearest weather station temperatures are less predictive of personally experienced temperatures when compared to neighborhood-level temperatures, particularly in an urban setting.

Methods

Study 1: Heat wave – health associations

- ❖ A total of 534,792 live births and 262,510 deaths between 1990-2010 for the warm months (May-September) were obtained from the Alabama Department of Public Health.
- ❖ Air temperature data from Phase 2 of North American Land Data Assimilation System (NLDAS) were downscaled using 1 km resolution land surface temperature (LST) from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on the Terra satellite.
- ❖ Heat waves were defined using relative and absolute metrics. A case-crossover design was used to determine associations between heat waves and preterm birth (PTB) and non-accidental death (NAD).

Study 2: Personally experienced temperature

- ❖ Participants were recruited to wear thermometers clipped to their shoe for 7 days in July 2017. Inclusion: Women, aged 19-66 years old, availability to participate in a week-long study. Exclusion: Inability to spend time outdoors.
- ❖ Data from iButtons worn by participants were matched to nearest community iButton deployed and nearest weather station (WS) using participant's residential address (Figure 3). After removal of outliers a total of 25,415 (=25,707-292) person-hours were considered in a linear mixed effects regression model.

Study 1: Urban heat islands are evident when using downscaled data and absolute heat wave metrics.

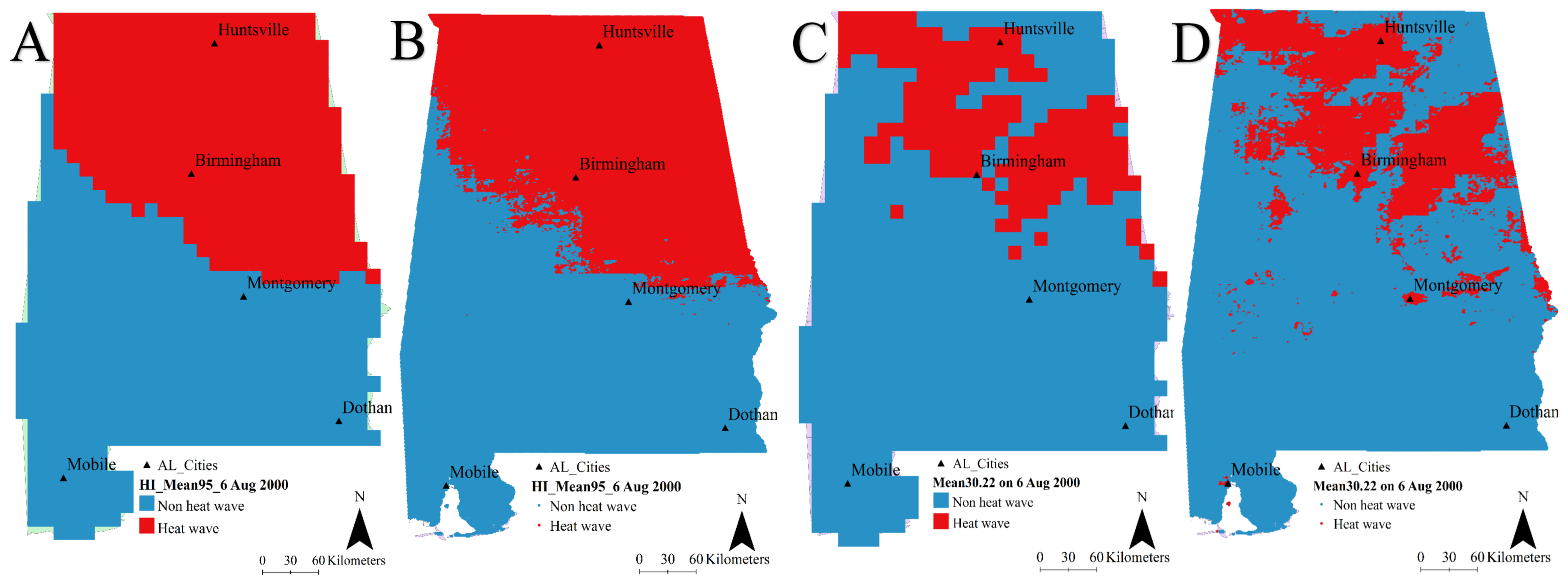

Figure 1. Heat wave grids in Alabama on 6 August 2000 at the NLDAS 12.5 km grid level (A and C) and downscaled 1 km grid level (B and D) in relative HIs defined as Mean95th (A and B) and absolute HIs Mean30.22 (C and D)

Study 1: The association between heat waves and PTB or NAD was significant and positive. ZIP code-, 12.5 km, and 1 km exposure metrics produced similar effect estimates.

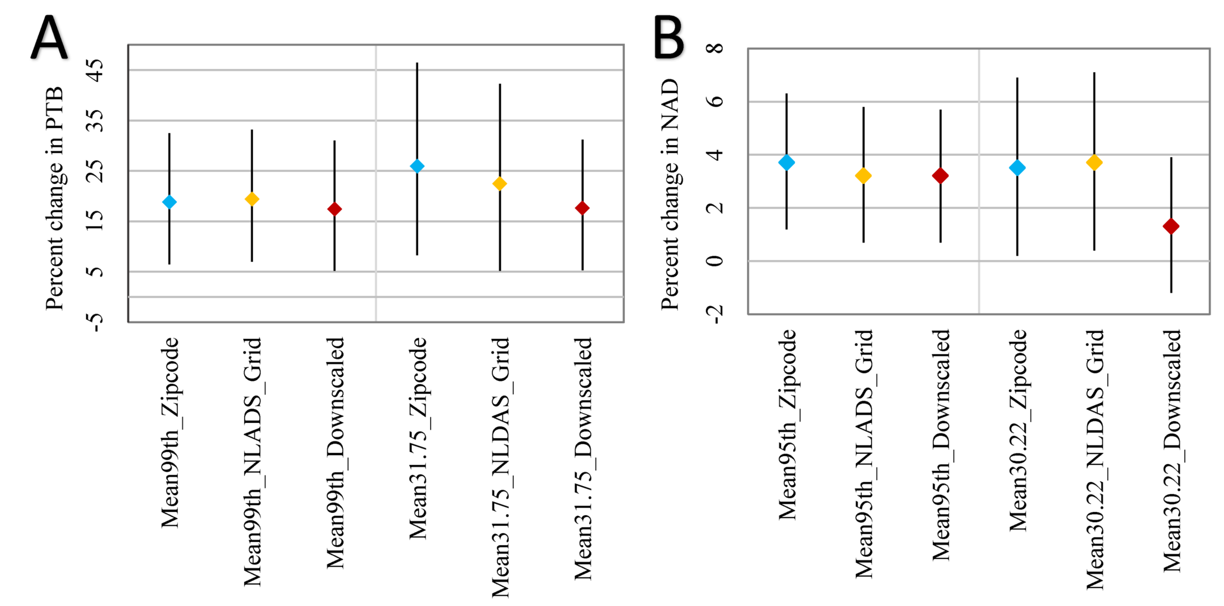

Figure 2. Percent difference [=(OR-1)*100], 95% CI, in PTB (A) or NAD (B) on a heat wave day, compared with corresponding non-heat wave days at ZIP code-level (blue), NLDAS grid level (yellow), and downscaled-level (red), defined in selected HIs.

Study 2: Demographic and geographic information on personal temperature monitoring

Table 1. Demographic characteristics of urban (Bham) and rural (Wilcox) participants

	Wilcox	Bham	*P* value	Total
N	90	90		180
Age – median (range)	54 (19-67)	42 (20-69)	**0.017**	50 (19-69)
Income (>$ 20K) N (%)	30 (34.5)	60 (67.4)	**<0.001**	90 (51.1)
Education (> high school) N (%)	48 (54.5)	44 (48.9)	0.45	92 (51.7)
Distance (km) to nearest community iButton - Mean (SD)	3.89 (7.29)	4.40 (5.81)	0.600	4.14 (6.58)
Distance (km) to nearest WS- Mean (SD)	38.04 (7.85)	11.88 (4.79)	**<0.001**	24.96 (14.6)

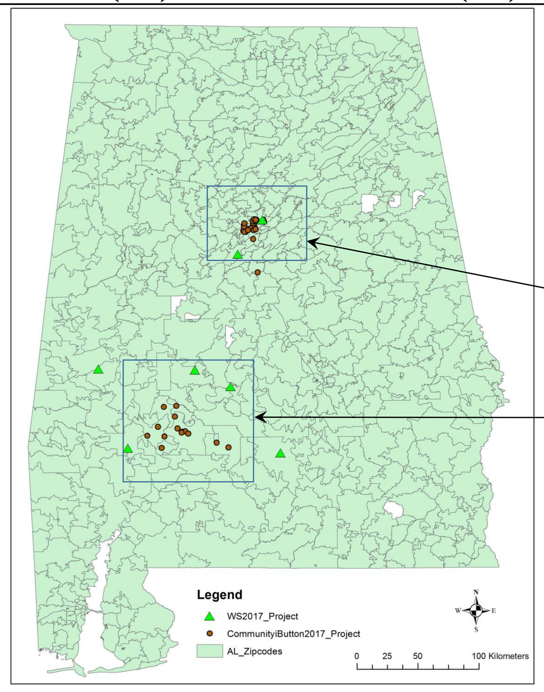

Figure 3. Locations of weather stations and community iButtons in rural and urban study sites

Study 2: Neighborhood-level and nearest weather station temperatures are significant predictors of personal temperature. Temperatures experienced in urban site were lower than in rural site, particularly during the nighttime.

Table 2. Coefficients from linear mixed effects regression (Participant temp (°C) ~ 1 + Community temp + WS temp + Income + Education + Body fat + Age + Groundskeepers + Type 2 Diabetes + Urban +Nearest Community iButton distance+ Nearest WS distance + (1 | Subject_ID)

	Baseline days* β (95% CI)	Intervention days* β (95% CI)	Intervention days (nighttime only) β (95% CI)
Community temp	**0.11 (0.08, 0.14)**	**0.17 (0.15, 0.19)**	**0.04 (0.01, 0.08)**
WS temp	**0.38 (0.35, 0.41)**	**0.32 (0.30, 0.34)**	**0.43 (0.39, 0.48)**
Income > $20K? (reference: <=$20K)	-0.45 (-0.93, 0.04)	-0.18 (-0.68, 0.32)	-0.17 (-0.78, 0.45)
Education > high school (reference <=high school)	-0.28 (-0.73, 0.17)	-0.05 (-0.52, 0.42)	-0.12 (-0.69, 0.46)
Body fat (%)	-0.03 (-0.06, 0.01)	-0.02 (-0.06, 0.02)	-0.01 (-0.05, 0.03)
Age (years)	0.003 (-0.01, 0.02)	0.01 (-0.004, 0.03)	0.01 (-0.01, 0.03)
Groundskeepers? (reference: Non-groundskeepers)	**1.13 (0.48, 1.77)**	0.32 (-0.35, 0.99)	-0.13 (-0.95, 0.68)
Type 2 Diabetes (reference: no)	-0.23 (-0.78, 0.32)	-0.14 (-0.71, 0.43)	-0.06 (-0.76, 0.63)
Urban? (reference: Rural)	**-1.37 (-2.43, -0.31)**	-1.04 (-2.14, 0.06)	**-1.79 (-3.13, -0.44)**
Near community distance (km)	0.004 (-0.03, 0.04)	-0.01 (-0.05, 0.02)	-0.01 (-0.06, 0.03)
Near WS distance (km)	-0.02 (-0.05, 0.02)	-0.02 (-0.05, 0.02)	-0.02 (-0.07, 0.02)
R squared value	0.412	0.411	0.504

*Baseline are first 2 days of participation, Intervention are next 5 days of participation. Participants were asked to increase outdoor time by 30 minutes above baseline during intervention days.

Conclusions, limitations and next steps

Characterization of neighborhood-level and behavioral factors influencing temperature exposures across urban and rural settings can aid in the development of targeted adaptation and mitigation strategies.

- ❖ Highly spatially resolved temperature and protected (address level) health information may not improve health evaluations of effects of heat waves or determination of most appropriate heat wave definition for warning systems; *however* further analysis in a variety of climates and using other health outcomes is required to determine generalizability of these conclusions.
- ❖ Weather stations are predictive of personally experienced temperatures, suggesting microclimates may not add substantial predictive power for characterizing exposure; *however* further analysis of the potential exposure reduction from interventions that reduce urban heat island are needed.
- ❖ Further comparisons of exposures and behaviors that impact exposures in urban versus rural locations are needed to develop targeted adaptation strategies. Current results suggest intervention trials in rural areas targeting adverse health outcomes associated with nighttime heat exposure.

Acknowledgements This project was funded through a grant from the National Institute of Environmental Health Sciences (R01ES023029). The protocols for this research was reviewed and approved by the Institutional Review Board at Virginia Polytechnic Institute and State University (Protocols #15-1145 and #15-761).

Contact: Julia Gohlke (jgohlke@vt.edu) with any questions and visit our project website at www.enactalabama.org