Computational & Information Systems Laboratory

CISL

(Statistical methods for connecting)

Health, heat stress, and vulnerability in urban populations

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Integrated Models for Heat-Health Decision-Making, Toronto, CA, 10/24/2013

NCAR

NSF

Supported by NSF and NASA.

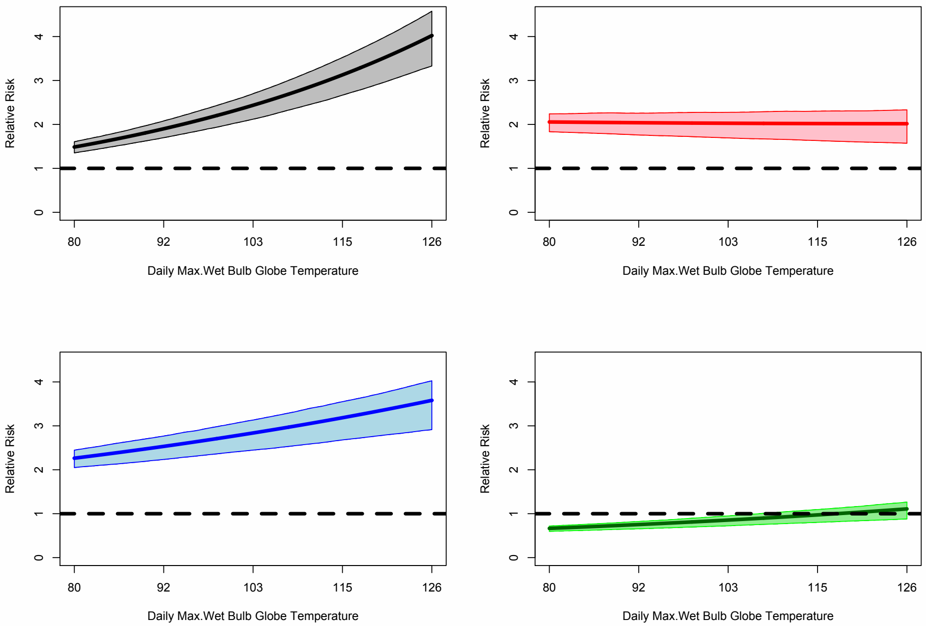
- Disclaimer: This talk is about statistical methods and analysis.
- Motivation: Vulnerability – exposure, sensitivity, and adaptive capacity.
- Challenge: Health impacts are distributed unevenly.
  ★ Differentiated vulnerability.

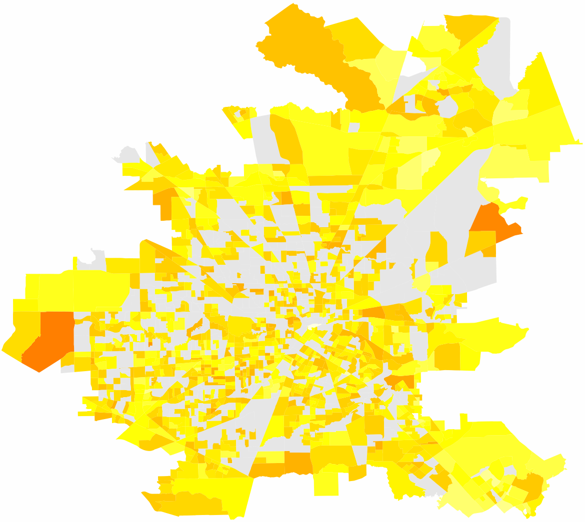
— ephtracking.cdc.gov

- Goal: Incorporate high-resolution numerical model output, satellite data, parcel data, census data, survey data into a statistical model for public-health endpoints (heat-related mortality, hospitalizations, 911 calls, and heat-related attitudes).
- Postscript: Dealing with uncertainty...

The foundation of the statistical approach comes from two ideas:

Each block group has its own heat-related risk curve (differentiated vulnerability).





The spatial variation in these curves can be explained via covariates (e.g., census, parcel, etc.) and spatial random effects.

A hierarchical model for connecting mortality to heat/demographics/etc.

Stage 1: $Y_{tb} \sim \mathcal{P}\left(E_b \exp\{\mu_{tb}\}\right)$

Links mortality to risk

Stage 2: $\mu_{tb} = \beta_0 + (demo_b)'\boldsymbol{\beta} + (heat_{tb})\eta_b + \phi_b + \delta_t$

Links risk to demographics & heat stress

Stage 3: $\eta_b = \gamma_0 + (demo_b^{\star})'\gamma + \nu_b + \zeta_b$

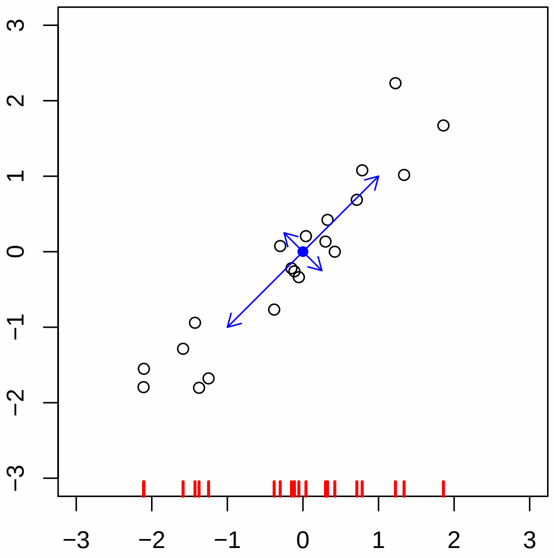
Links heat response to demographics

- Breaks a complicated problem into smaller, more manageable pieces
  - Buy a house with a paperclip? (`oneredpaperclip.blogspot.com`)

A hierarchical model

After some careful consideration (and some math), the hierarchical model boils down to a Bayesian Poisson GLM.

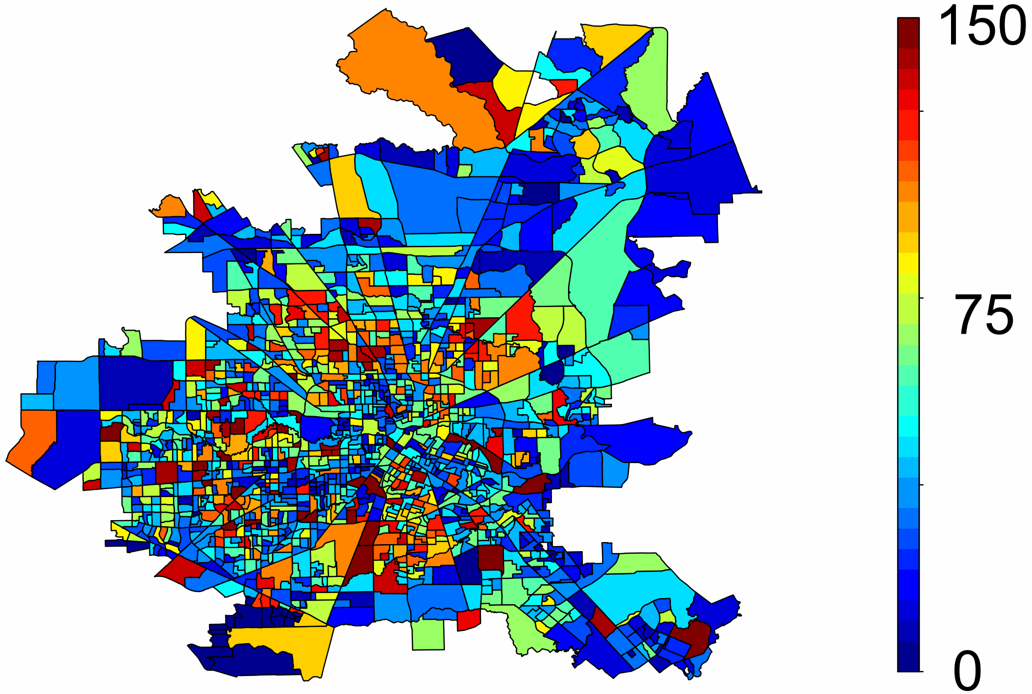
- Covariates enter the model in a way to minimize collinearity.
- Spatial random effects enter through a collection of basis functions that depend on the spatial structure but minimize collinearity with covariates.
- Model includes main effects (demographics, heat, space) and interactions.



With this in mind, we are moving forward to generalize this statistical approach for data exploration, different spatial lattices, and additional locations.

A hierarchical model

Stage 1: $Y_{tb} \sim \mathcal{P}\left(E_b \exp\{\mu_{tb}\}\right)$

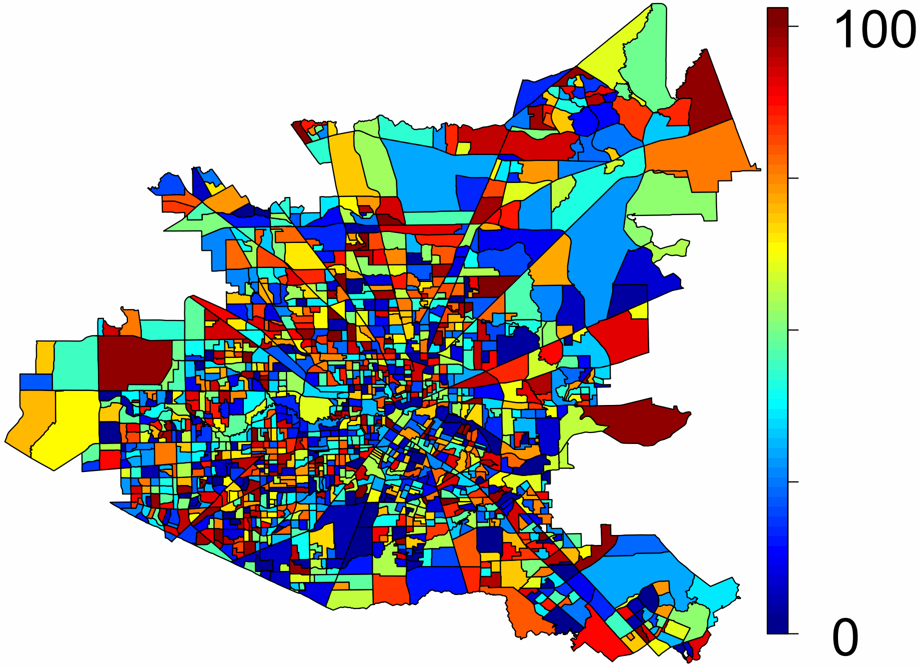


Daily mortality counts, 1999-2006.

- Mortality data from the Texas Department of State Health Services and listing ICD9 codes for cardiovascular, genitourinary, respiratory, nervous system, or hyperthermia as a contributing cause of death.
- Aggregate counts $\{Y_{tb}\}$ to census block groups; focus only on (M)JJA(S).
- Expected counts $\{E_b\}$ computed assuming constant mortality rate.
- $\{\exp\{\mu_{tb}\}\}$ are relative risk of heat-related mortality over space and time.

A hierarchical model

Stage 2: $\mu_{tb} = \beta_0 + (demo_b)'\boldsymbol{\beta} + (heat_{tb})\eta_b + \phi_b + \delta_t$



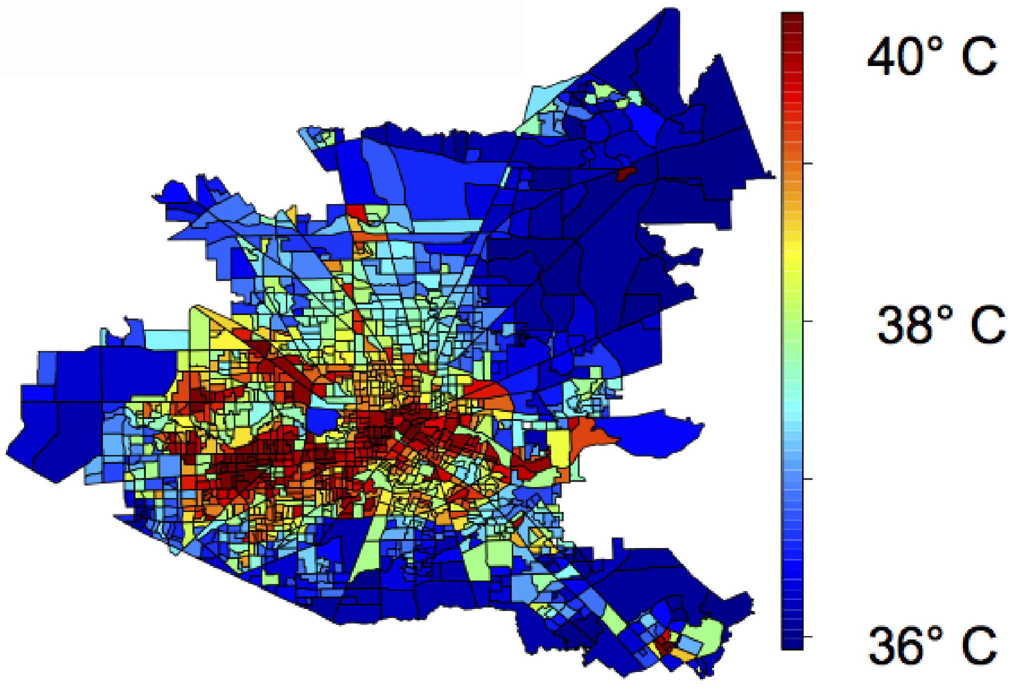
% in Poverty, 2000 Census.

Demographic variables:

- Census: race, age, living alone, public transportation, poverty, education, etc.
- Parcel: air conditioning, age of residential buildings, pools, building quality, etc.

A hierarchical model

Stage 2: $\mu_{tb} = \beta_0 + (demo_b)'\boldsymbol{\beta} + (heat_{tb})\eta_b + \phi_b + \delta_t$



HRLDAS, 1999-2006.

- High Resolution Land Data Assimilation System (HRLDAS) coupled with an Urban Canopy Model (UCM) to better represent the physical processes involved in the exchange of heat, momentum, and water vapor in the urban environment.
- Heat stress measured through various heat indices: discomfort index, NWS heat index, humidex, apparent temperature, wet bulb globe temperature, daily max/min temp.

Variable selection for heat stress:

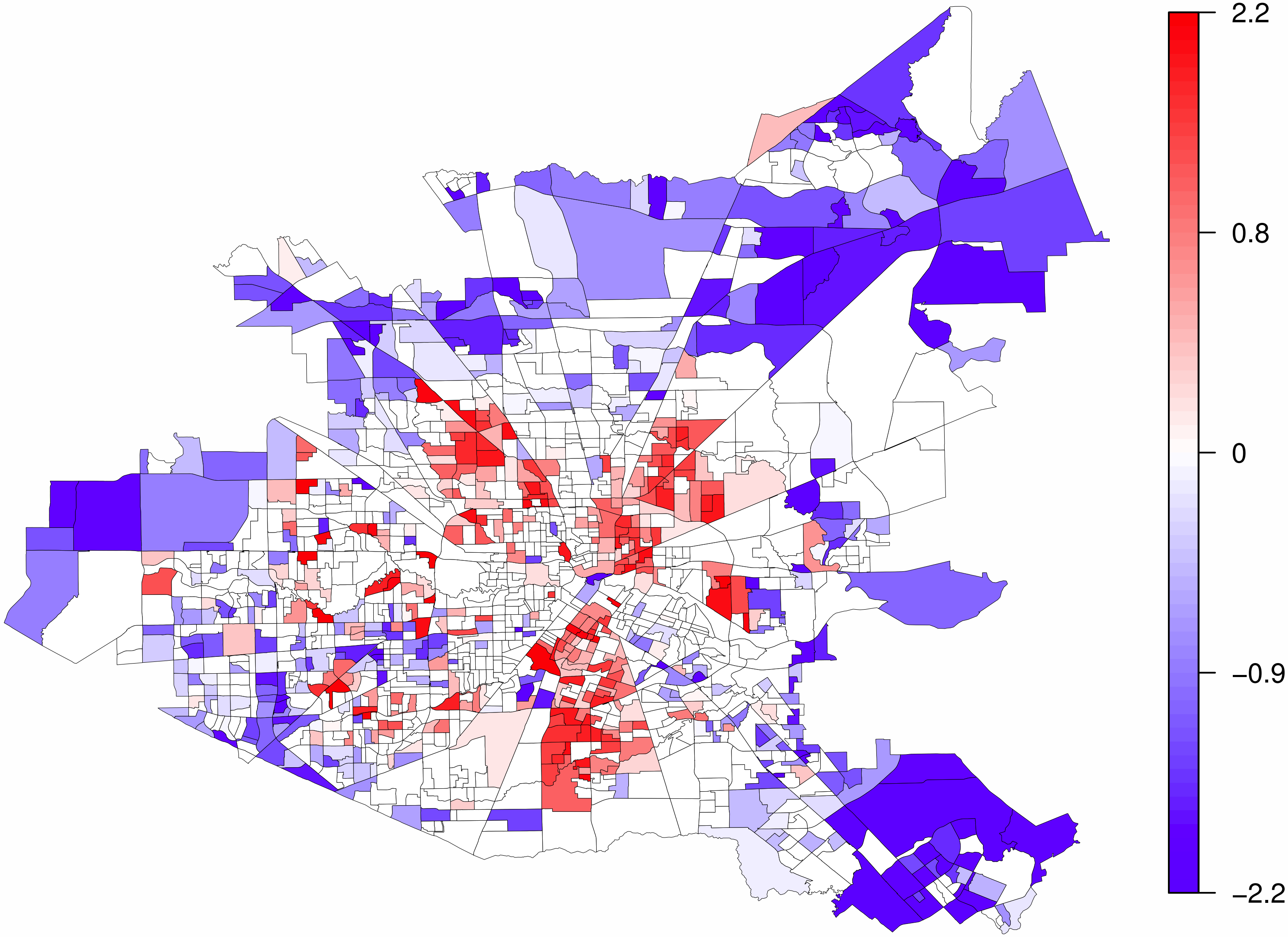
Rank	Likelihood	# Positive CIs	Total
1	TMP:MIN	TMP:MIN	TMP:MIN
2	HI:MIN	HU:MAX	DI:MIN
3	DI:MIN	DI:MIN	WBGT:MIN
4	WBGT:MIN	AT:MAX	DI:MAX
⋮	⋮	⋮	⋮

Variable selection for Stage 2: $\mu_{tb} = \beta_0 + (demo_b)'\boldsymbol{\beta} + (heat_{tb})\eta_b + \phi_b + \delta_t$

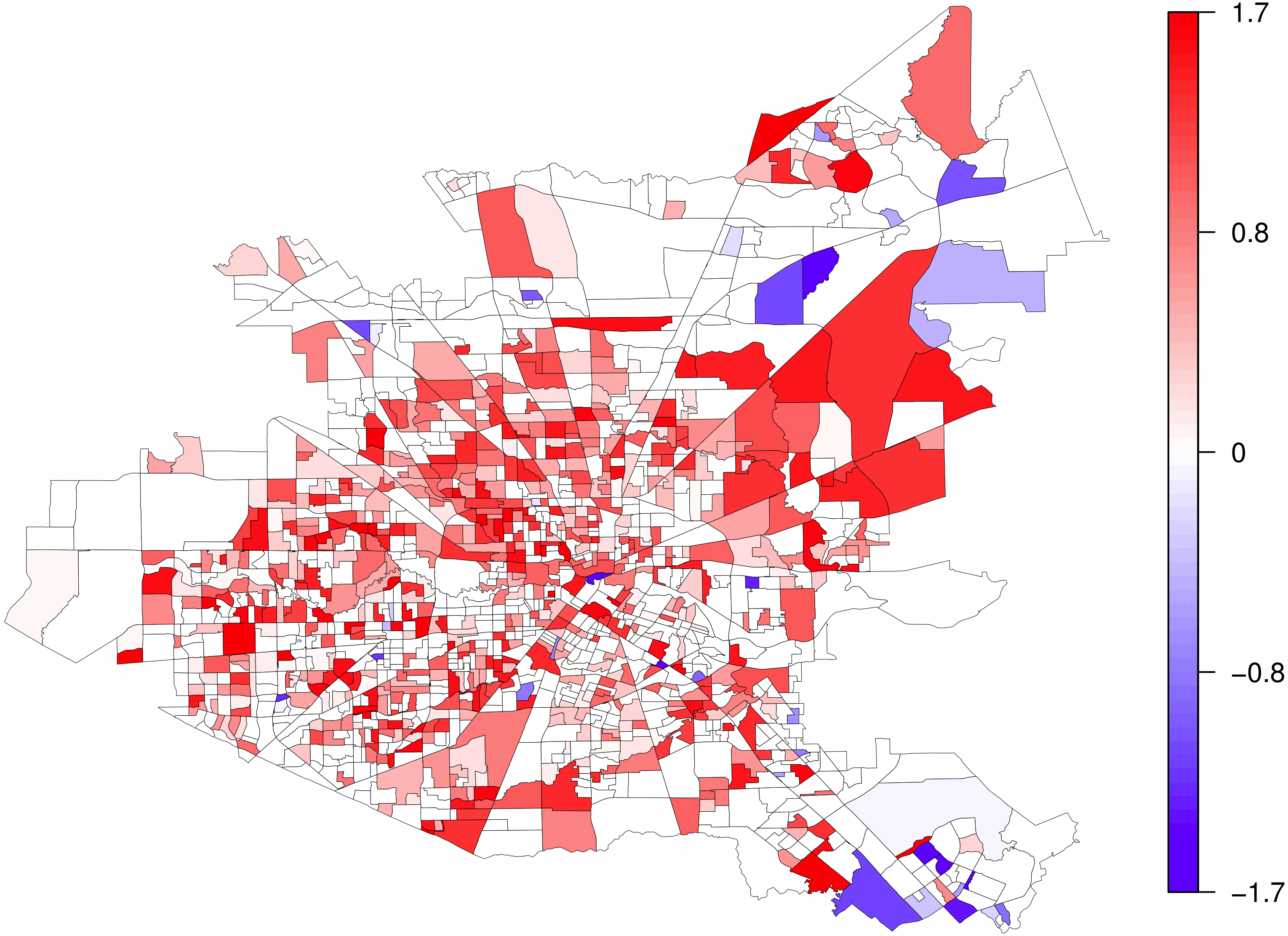
Variable	Post. Mean	95% CI
% older than 65 years	5.66	(5.49, 5.80)
% with no air conditioning	0.48	(0.37, 0.61)
% living alone	0.95	(0.80, 1.21)
% African American	0.55	(0.35, 0.81)
% in poverty	0.49	(0.36, 0.65)
% under 5 years	-1.93	(-2.06, -1.76)

Variable selection for Stage 3: $\eta_b = \gamma_0 + (demo_b^\star)'\boldsymbol{\gamma} + \nu_b$

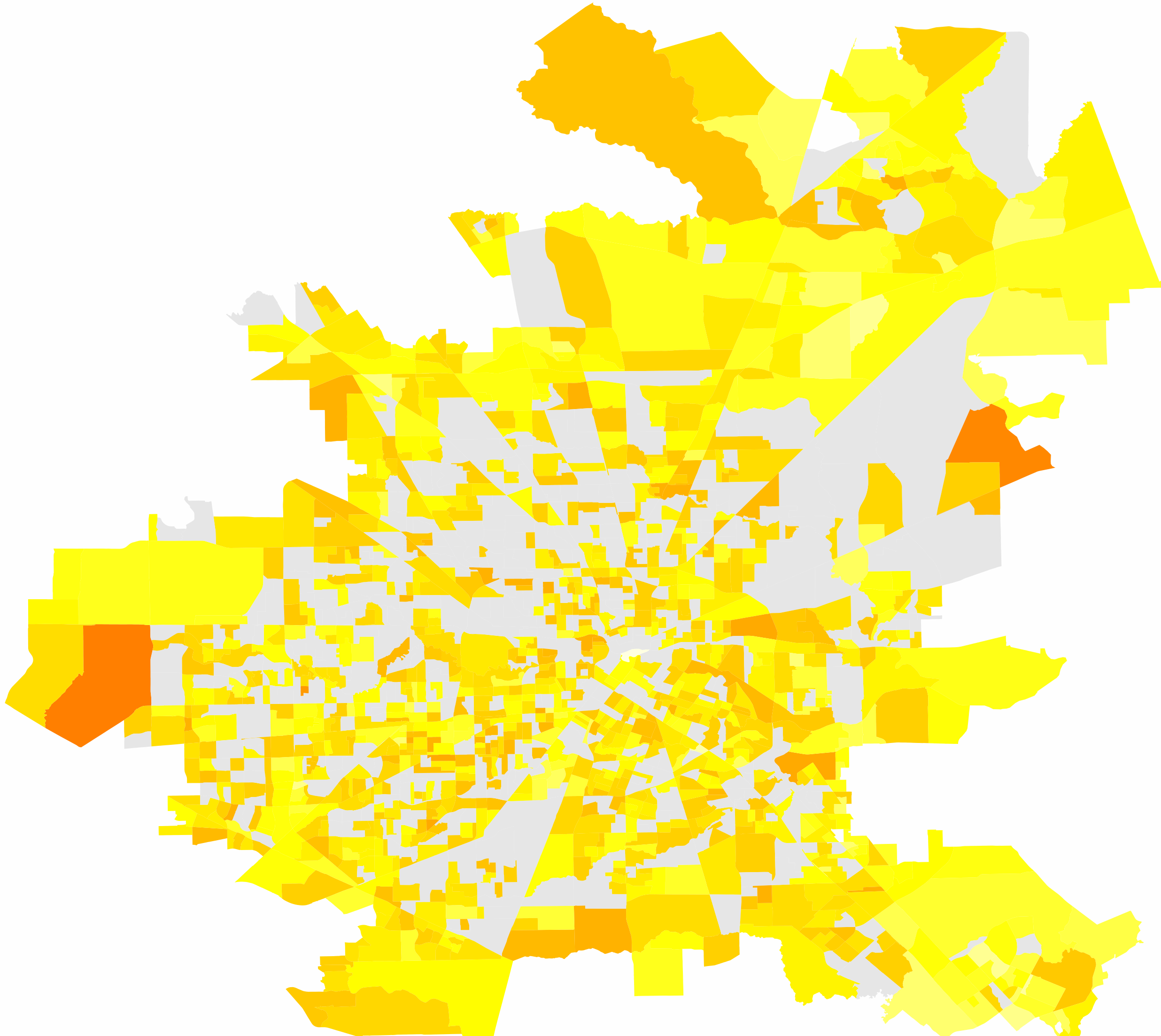
Variable	Post. Mean	95% CI
% older than 65 years	1.80	(1.39, 2.22)
% Caucasian, older than 65, Living Alone	0.60	(0.38, 0.83)



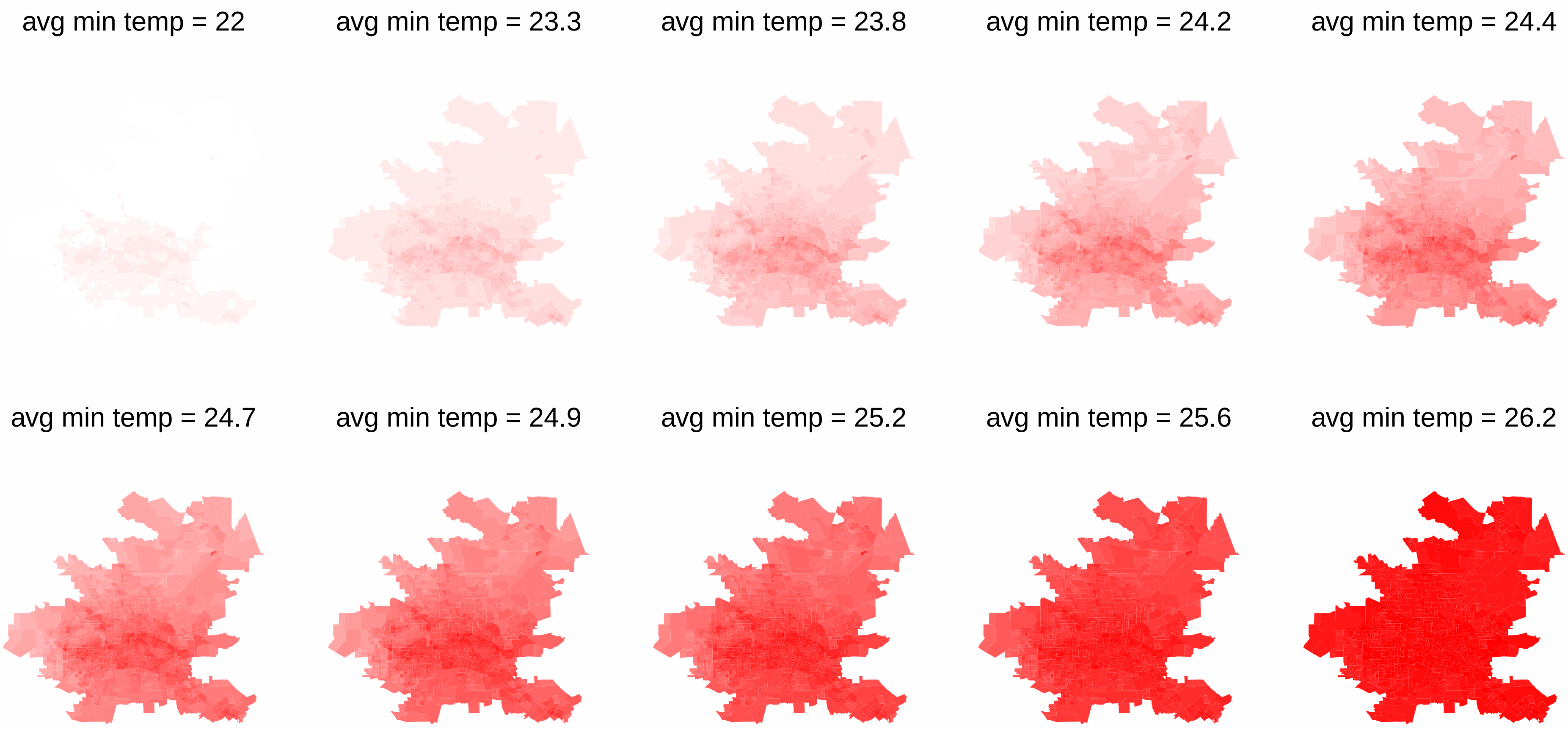
Posterior mean of (time averaged) mortality risk
$(8 \times 92)^{-1} \sum_{y,t} \exp\{\mu_{ytb}\}$



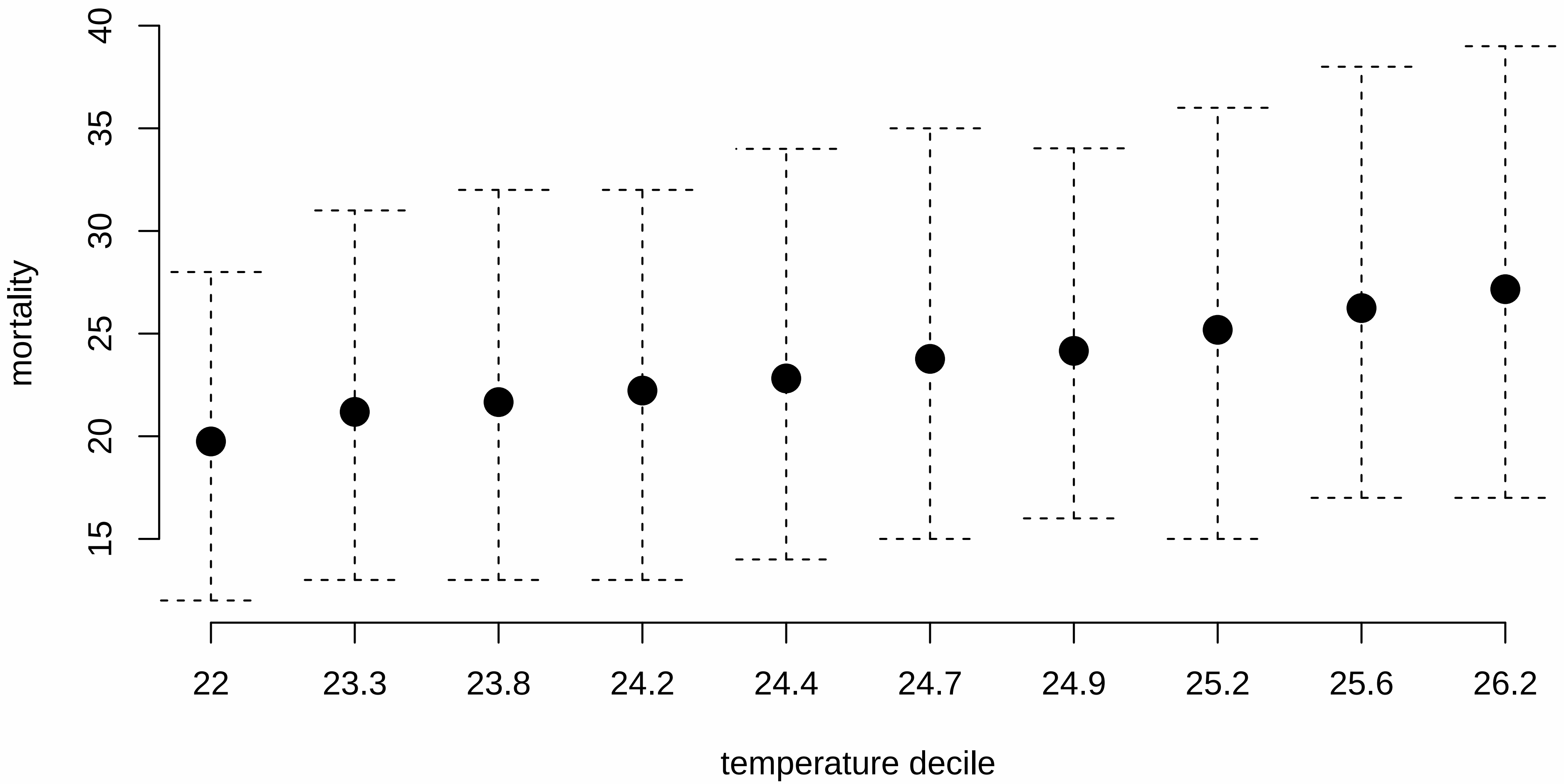
Posterior mean of heat exposure mortality risk
$(8 \times 92)^{-1} \sum_{y,t} (\text{heat}_{ytb}) \eta_b$



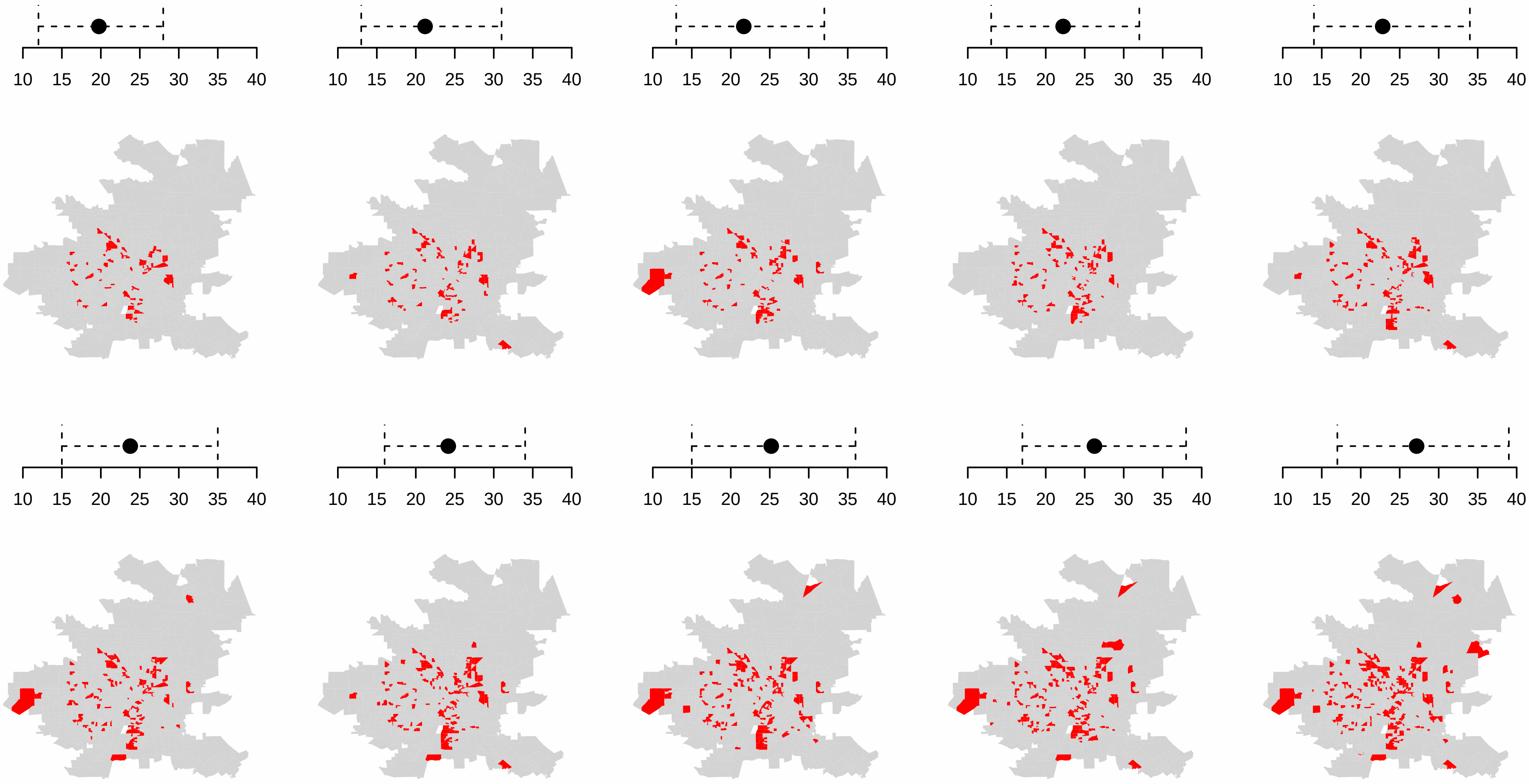
Posterior mean of η_b (sensitivity), given η_b is credibly greater than zero.



Heat maps (exposure).

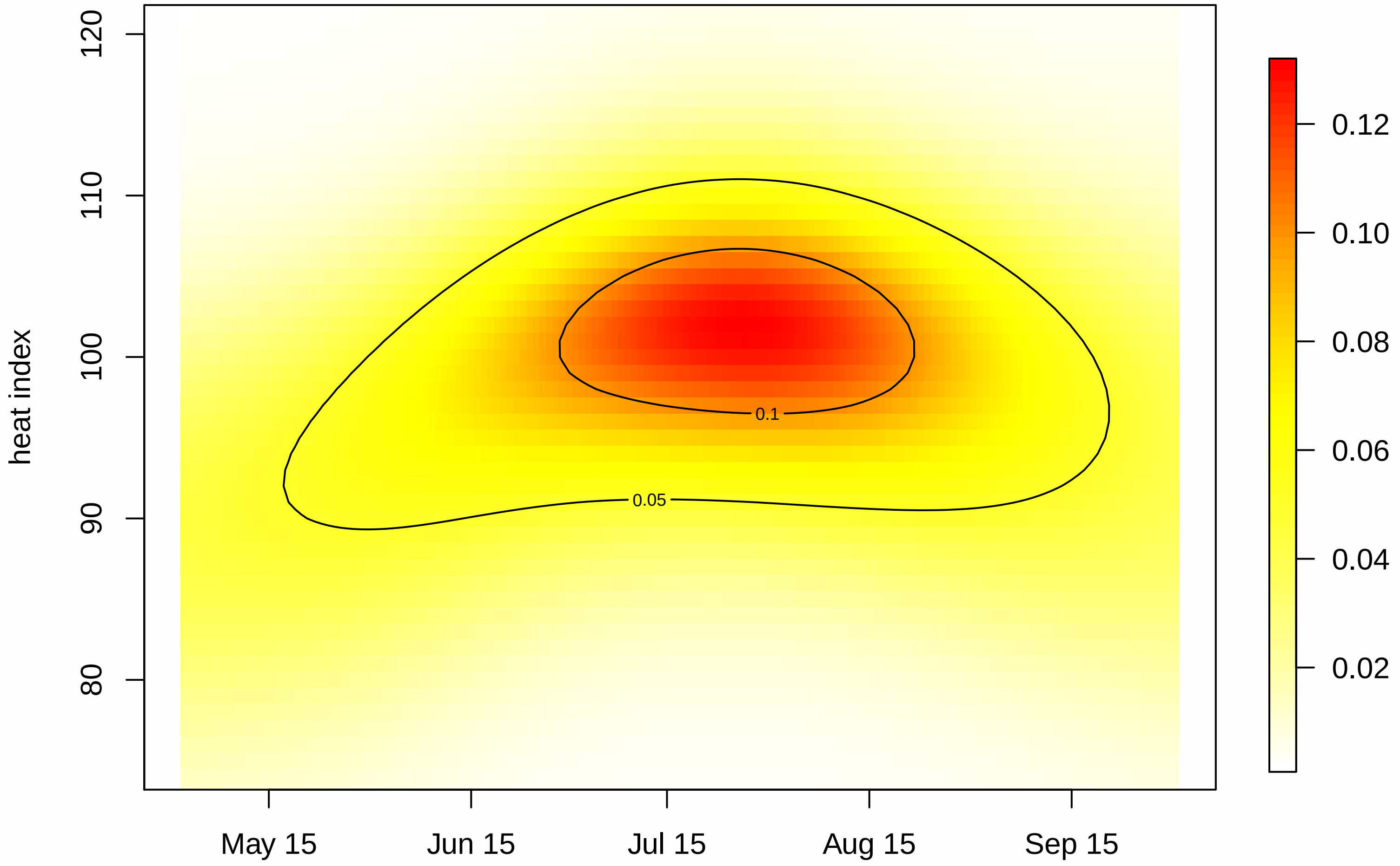


Total mortality w/ prediction intervals.



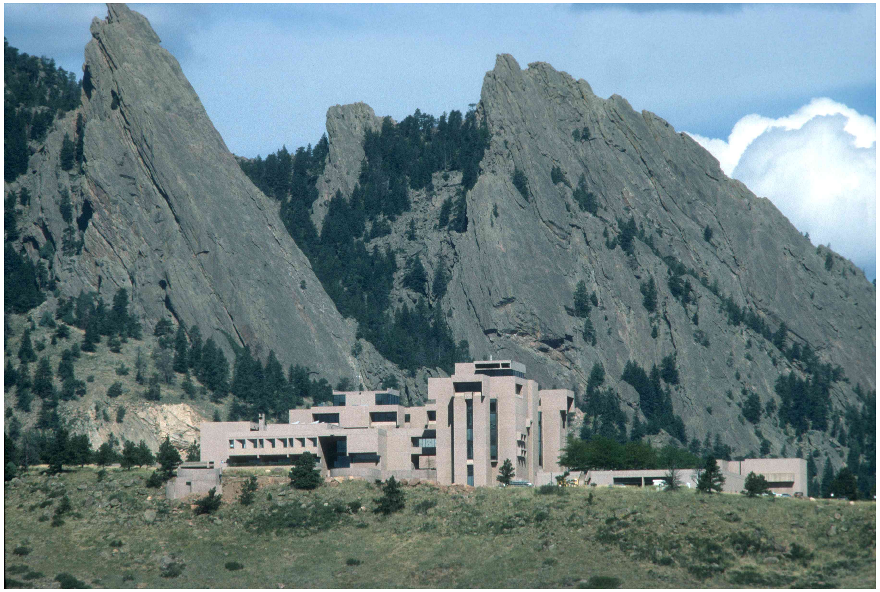
Total mortality and block groups with high (>2.5 deaths/100K people) average mortality rates (exposure+sensitivity).

911 Calls



Probability of at least one 911 call from an analysis of $n = 2054$ heat-related 911 calls from 2006-2010 via a marked point pattern.

Questions?



ssain@ucar.edu
http://www.image.ucar.edu/∼ssain

Thank You!

- Heaton et al. (2013), "Characterizing urban vulnerability to heat stress using a spatially varying coefficient model," submitted.
- Heaton et al. (2013), "An analysis of an incomplete marked point pattern of heat-related 911 calls," submitted.