Comparing the Relationships Between Heat Stress Indices and Mortality in North Carolina

Jordan Clark
PhD Student
CISA Research Assistant
Department of Geography
UNC-Chapel Hill
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Overview

- Background on measures of heat stress:
  - Heat index and Wet Bulb Globe Temperature (WBGT)

- Relationships between measures of heat stress and mortality:
  1. Wet Bulb Globe Temperature (WBGT)
  2. Air Temperature
  3. Heat Index

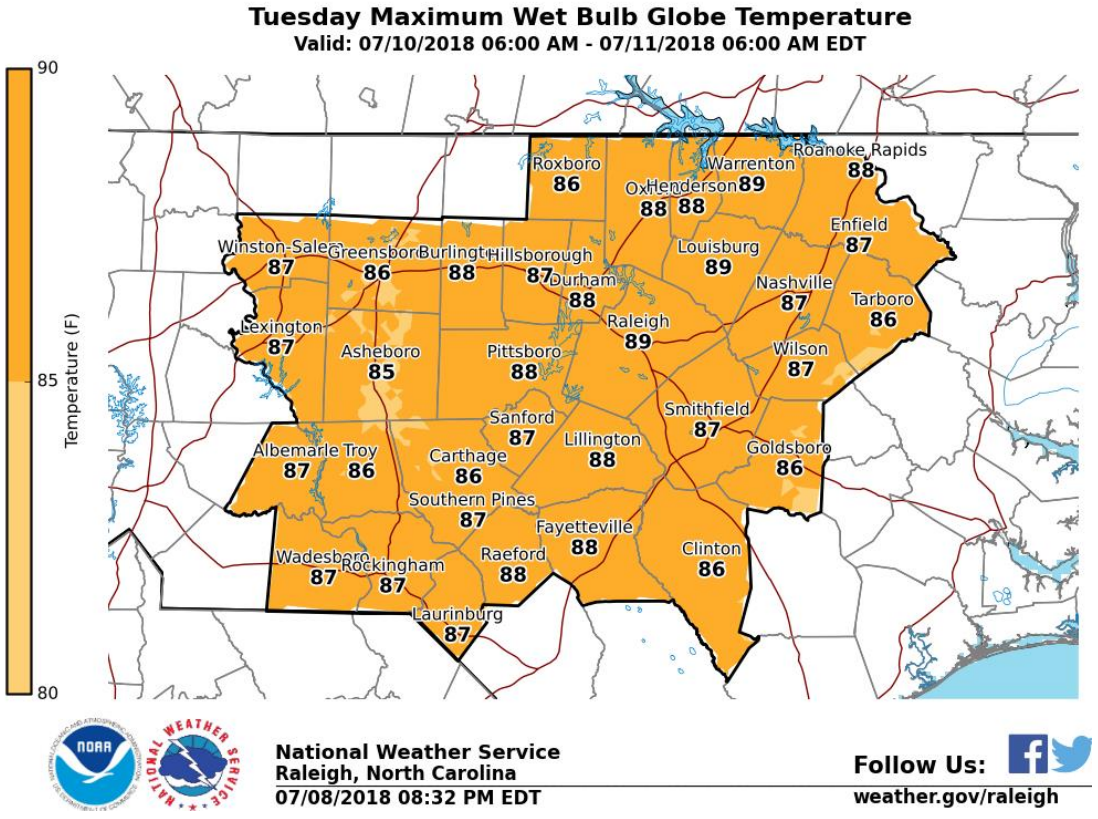
Research Questions

How do the relationships between Mortality and WBGT compare to those between Air Temperature and Heat Index?

Are there regional differences in these relationships across North Carolina?

Background

- Heat is leading cause of weather-related death
- Ability of WBGT to predict health outcomes at a population-level relative to other indices limited in understanding
- Various National Weather Service (NWS) Offices are producing experimental WBGT forecast products
- WBGT increasingly utilized for athletic safety in NC and other states



Source: NWS Raleigh

Heat Stress

- Exposure to environmental conditions:
  1. Air temperature
  2. Relative humidity

  Heat Index

Heat Stress

- Exposure to environmental conditions:
  1. Air temperature
  2. Relative humidity
  3. **Wind speed**
  4. **Solar Radiation**
  5. **Water vapor pressure**

Heat Index

Wet-Bulb Globe Temperature

www.skcinc.com

Heat Stress: Wet-Bulb Globe Temperature

- Created for military training safety (1950s)

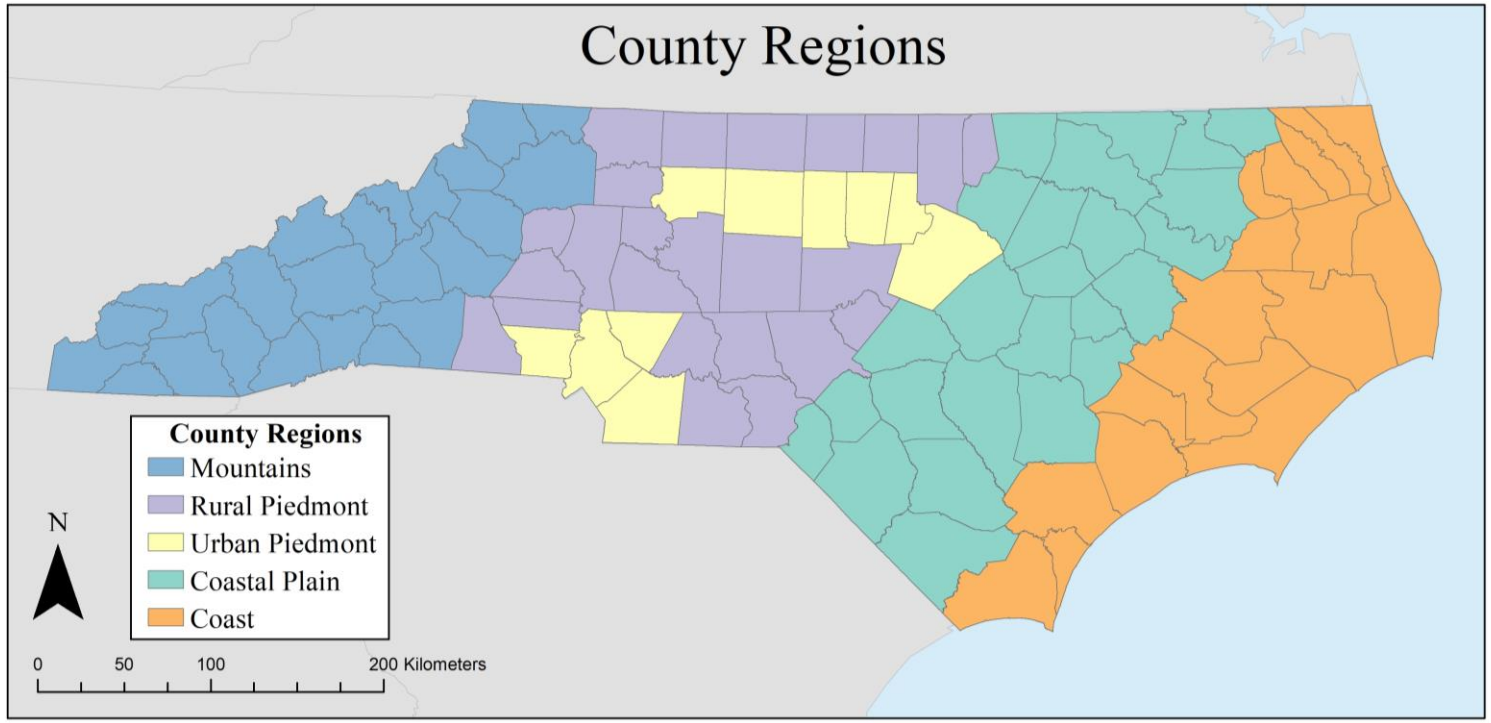
- Three components

1		2		3		
Dry-Bulb Temperature	+	*Natural* Wet-Bulb Temperature	+	Globe Temperature	=	WBGT

$$WBGT = 0.7NWB + 0.2GT + 0.1DB$$

Methods: Mortality Data and Regionalization

- Death records for NC
  - Heat Season (May 1 - Sept.30) for 2005 – 2015
- Counties were grouped into 5 regions
- Two Piedmont Regions
  - Urban and rural



Methods: Cause-Specific Mortality

All-Cause mortality in addition to:

1. Cardiovascular disease
   - *(ICD10 I00-I99)*
2. Renal Disease
   - *(ICD10 N00-N39)*
3. Respiratory Disease
   - *(ICD10 J00-J99)*

Region	Total
Mountains	47,579
Rural Piedmont	65,181
Urban Piedmont	127,269
Coastal Plain	64,410
Coast	32,834

Cause	Statewide Count
All-Cause	133848
Cardiovascular Disease	110776
Renal Disease	9363
Respiratory Disease	84460

Methods: WBGT Estimation

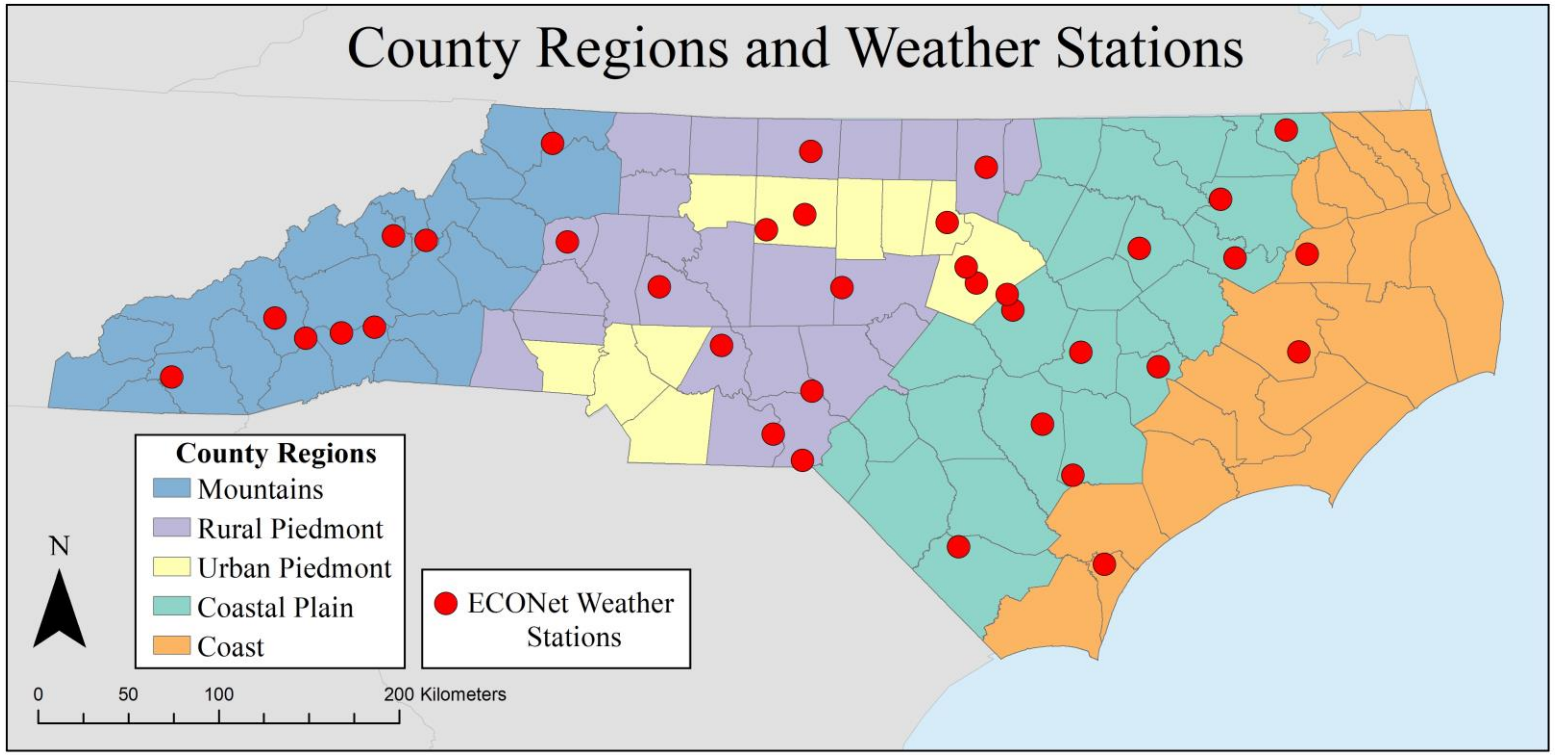
- Since WBGT is not routinely measured, it was estimated using:
  - Hourly Observations from 36 ECONet stations:
    1. Air Temperature
    2. Dew point temperature
    3. Relative humidity
    4. Pressure
    5. Wind speed
    6. Solar radiation
    7. Zenith angle (half past the hour)

- Wind speed uncertainty
  - Minimum threshold of 1 m/s based on sensitivity of anemometers at ECONet weather stations

Credit: NC State Climate Office

Weather Station Data: County-Level

- Assigned each county one station based on closest station via Euclidean distance
  - If station's daily measure was missing or failed QC, data from second closest station was used



Methods: Statistical Analysis

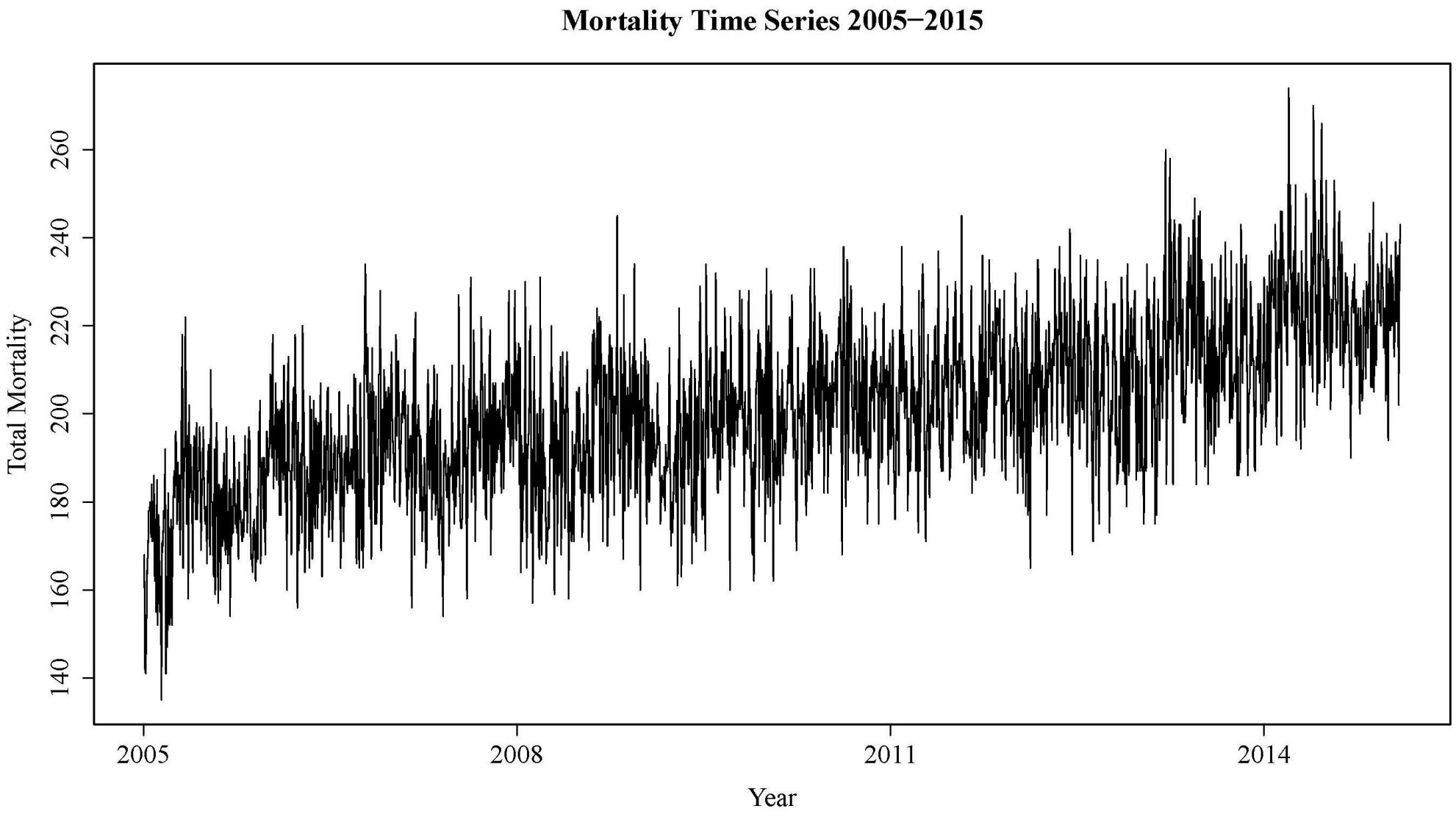
- Distributed lag non-linear model (0-3 day lags)

- Controls for underlying seasonality in mortality:
  - Day of year (short-term trends)
  - Year (long term trends)
  - Holidays

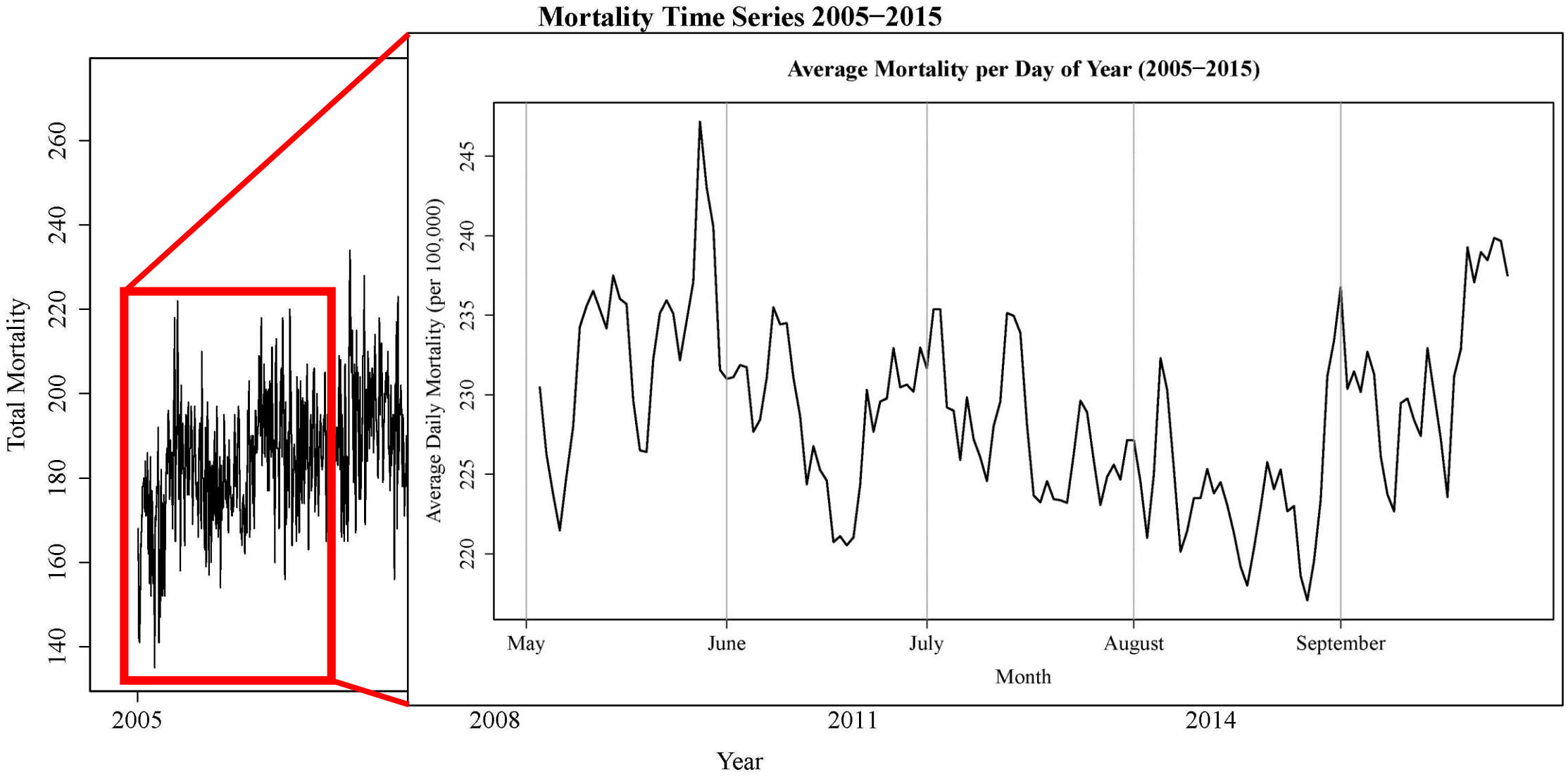
- Natural cubic splines of WBGT, heat index, and air temperature with 5 degrees of freedom

$$\text{Log}(\mu) = \beta_0 + \beta_1(Temp,\ df = 5) + \beta_2(DOY,\ Year,\ df = c(4,\ 5)) + \beta_4\text{Holiday}$$

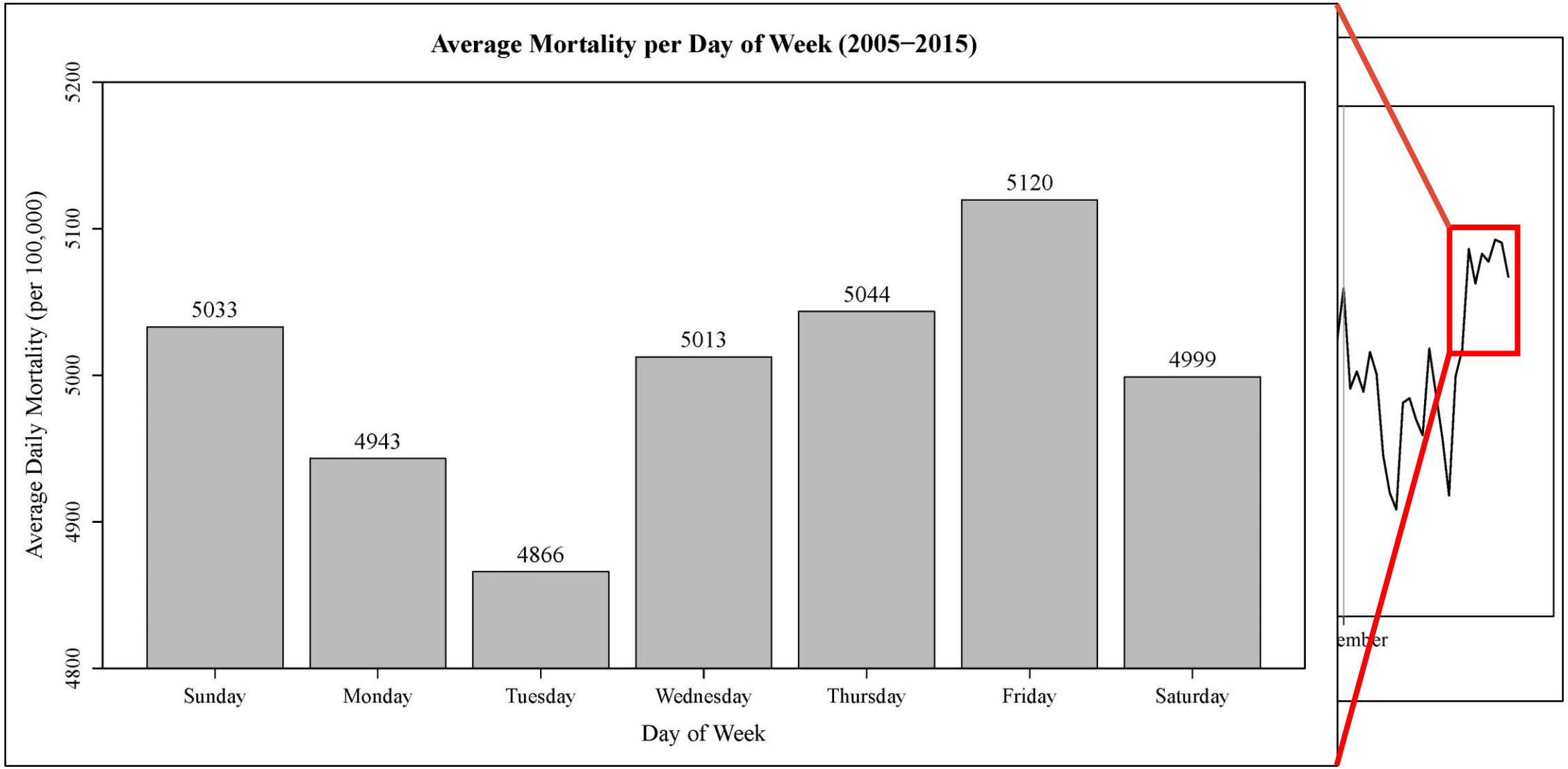
Mortality Seasonality



Seasonal Mortality



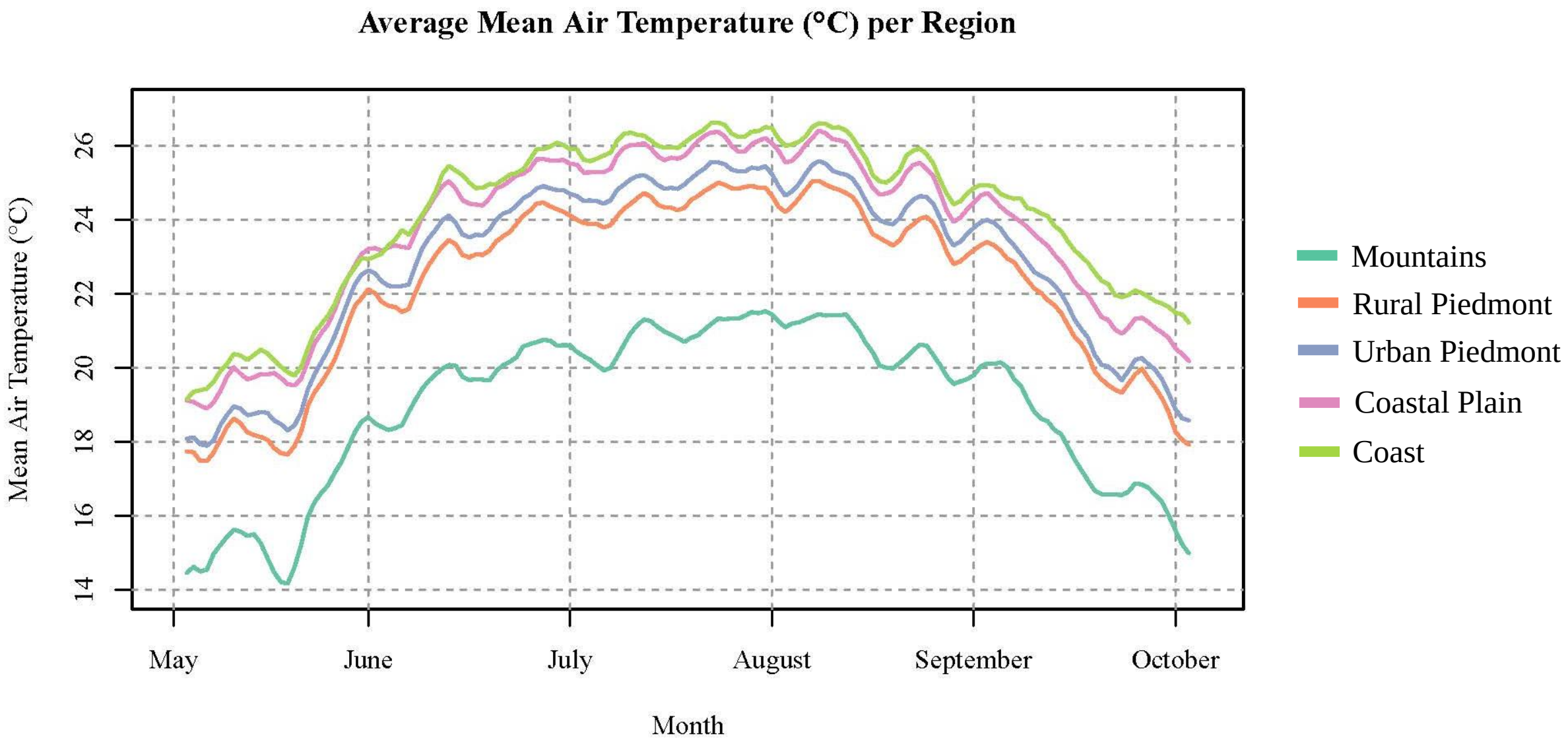
Weekly Mortality



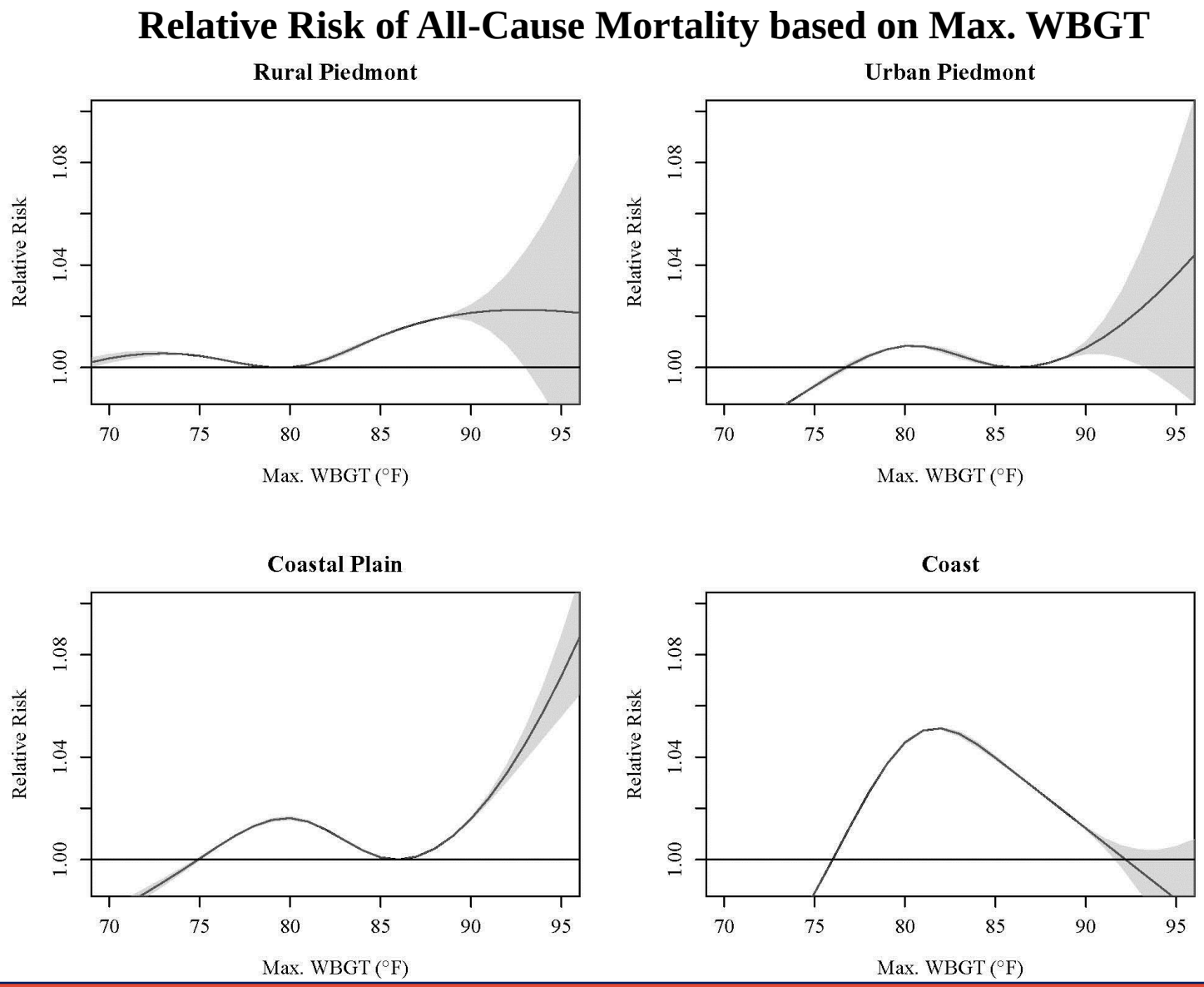
Methods: Threshold Determination

- Temperature thresholds were identified in which the lower 95% confidence interval of the response curve was statistically different from zero
- Results are presented as relative risk of mortality per degree compared to mortality risk at temperature threshold
- Models with air temperature, heat index, and WBGT were compared based on Akaike Information Criterion (AIC)

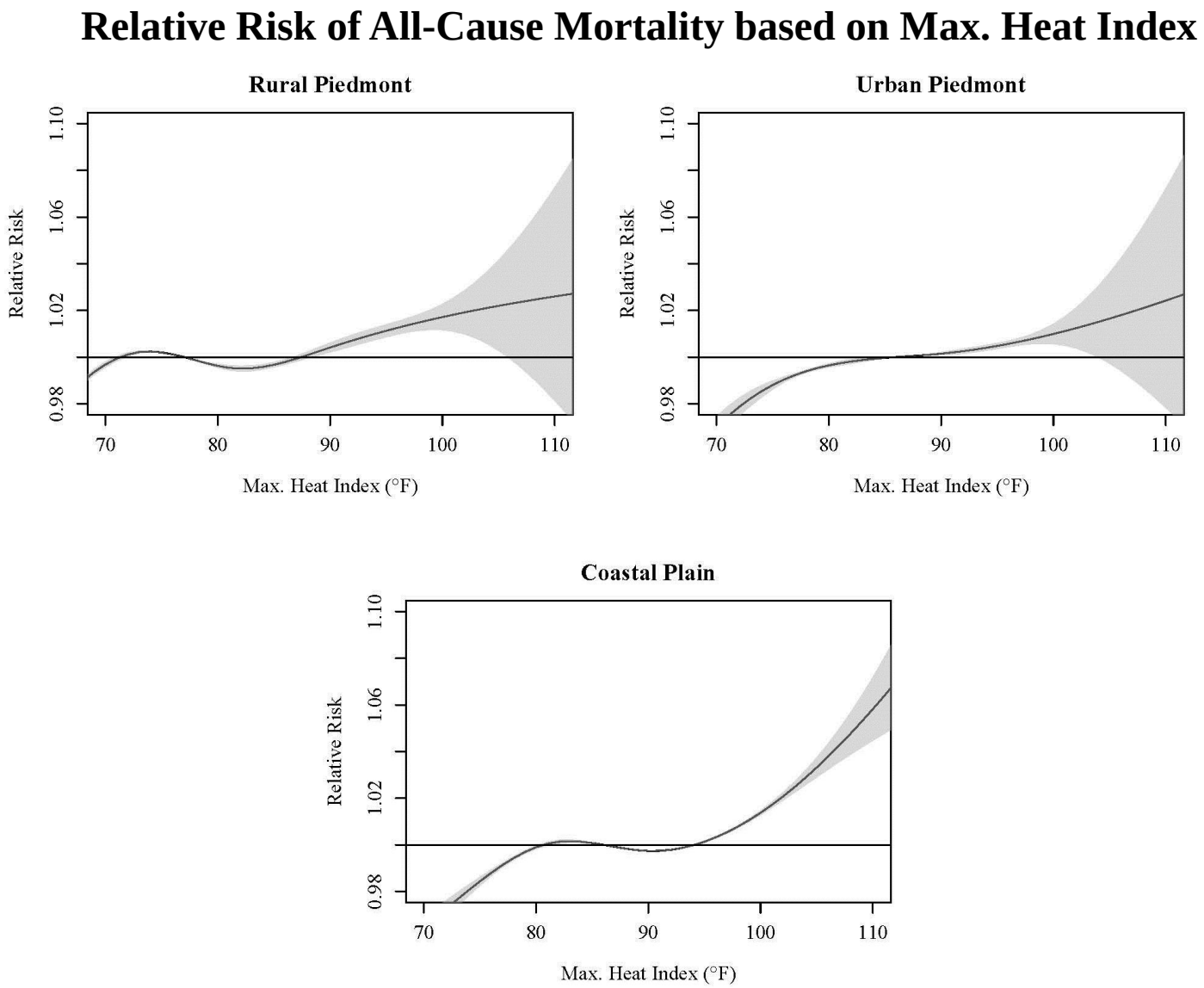
Regional Climate Differences



All-Cause Mortality: WBGT

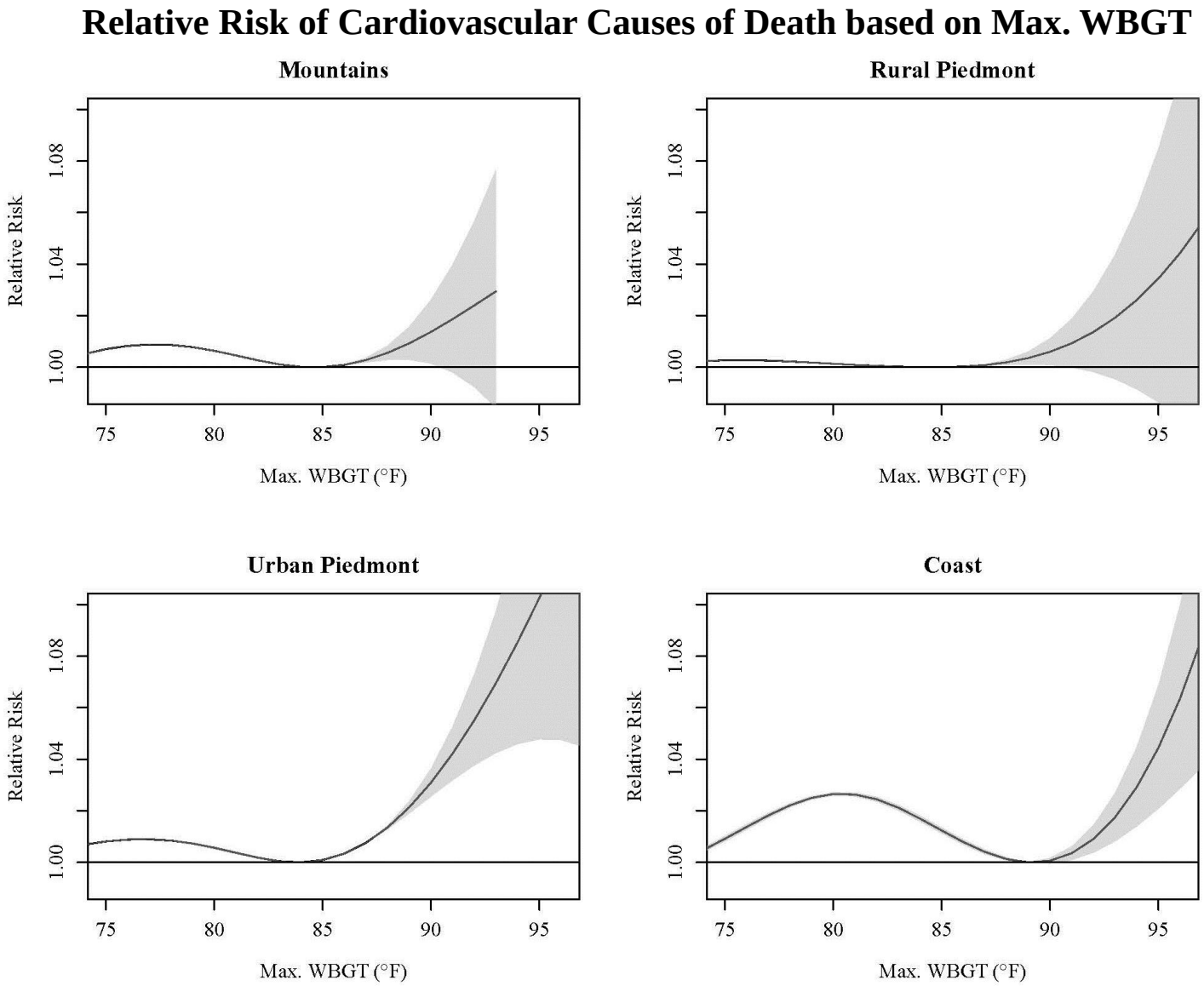


All-Cause Mortality: Heat Index



Cardiovascular-Related Mortality

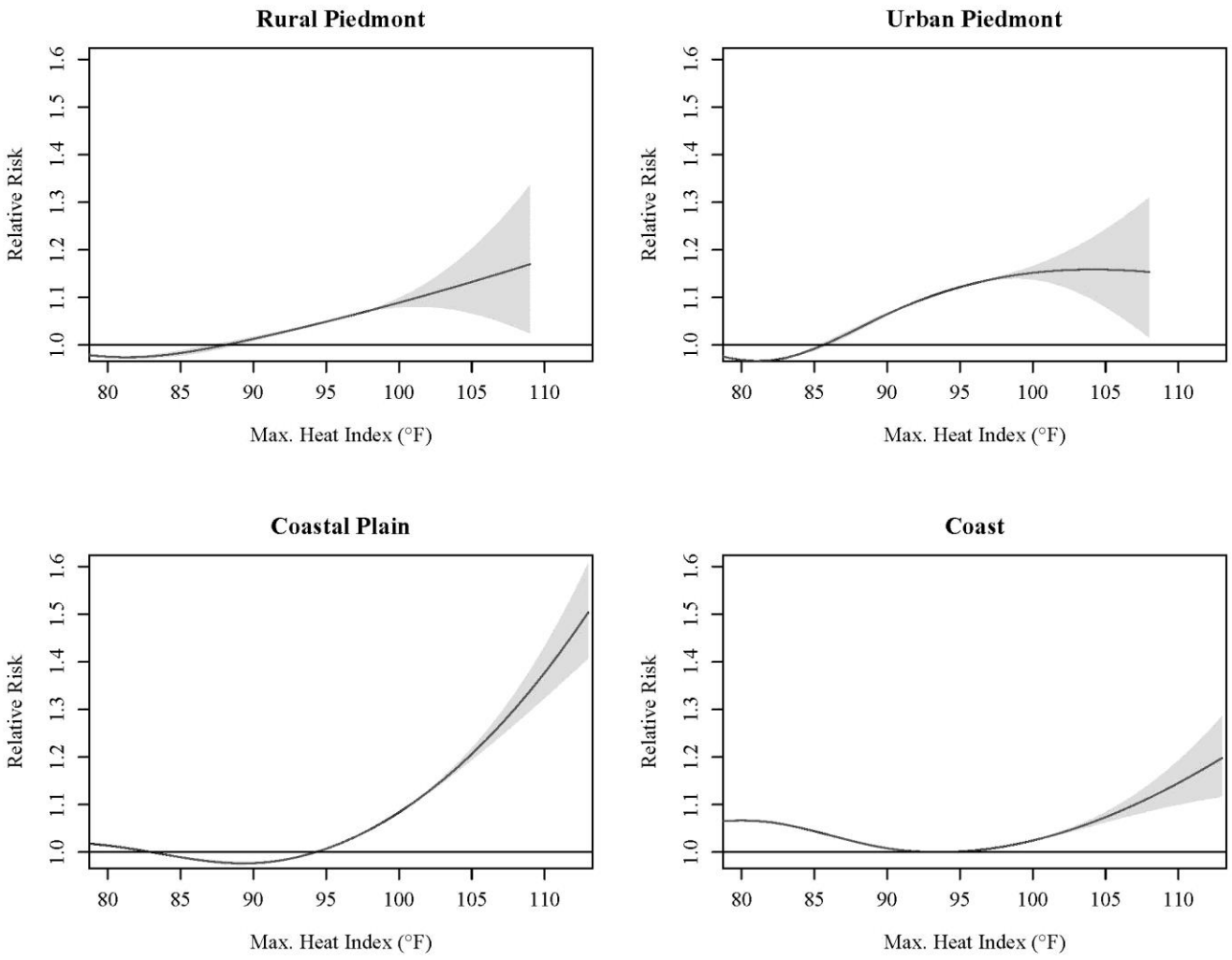
- WBGT models strongest for cardiovascular causes of death
  - No significant relationship in Coastal Plain region
  - Strongest relationship in the Urban Piedmont and Coast region.



Renal Disease Mortality

- Heat Index most statistically robust for causes of death related to renal disease and renal failure
  - Strong relationships in all regions except Mountains

Relative Risk of Mortality due to Renal Disease and Renal Failure based on Max. Heat Index



Conclusions

- WBGT outperformed heat index and air temperature overall
  - However, relationships in the Mountains were poor, with air temperature serving as the best index
- Both WBGT and Heat Index identified highest risk of death due to heat for cardiovascular-related mortality and renal disease
- This study demonstrated the overall utility of using WBGT to establish relationship between heat and mortality compared to commonly used metrics