The Health Burden of Climate Change in US: Evidence from Influenza-Like-Illness

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1. Introduction

- Climate change threatens to undermine the last half decade of advances in global health
  - Affecting many social and environmental determinants of health
- As the climate gets warmer, flu outbreaks will get worse
- Each year approximately 5 - 20% of US residents get the flu
  - More than 200,000 people are hospitalized
  - Between 2008 – 2010 flu related medical costs - $10 billion
- Effect of climatic variables on influenza mortality remains disputed

1. Introduction

- Non-parametric analysis
  - Weekly data at the city level in the US
  - 122 cities; over a span of 40 years
- Impact of temperature and humidity on influenza mortality
- Projections using RCP 4.5 and 8.5

2. Climatic Variables and Influenza Interaction

- Low temperatures and/or extreme humidity increases mortality risk
- Affects cardiovascular and respiratory systems
- Low temperatures
  - Reduce blood flow and inhalation of cold air which may increase susceptibility
  - Limits exposure to vitamin D and increases indoor crowding which in-turn increases infections

2. Climatic Variables and Influenza Interaction

- Low humidity
  - Leads to dehydration and increases spread of influenza by increased viral shedding
  - Increases survival times of viral aerosols
  - It may also be connected through changes in the virus stability and transmission
- High humidity
  - Impairs body's ability to sweat and cool itself

- Despite these hypothesized mechanisms, impact of climatic variables on influenza mortality are not well established
  - Especially on human population
  - Little robust empirical evidence

3. Gaps in the Literature

- Assuming that patients are contagious for months
  - Usually contagious for 1-2 weeks
- Understanding is limited to *a priori* assumptions of the pre-determined knots of the influenza distribution
- Existing literature uses simplistic linear models
- Papers using more complex methodologies have focused on specific cities/regions
- Use of relative humidity
  - Strong positive correlation with temperature
  - Common issue!

4. Data

- Large dataset at the city-by-week level
  - 122 cities between 1970 – 2010
- Global Land Data Assimilation System (GLDAS 2)
  - NASA-NOAH Model
  - Utilizes ground and satellite measurements
  - Models global terrestrial geophysical parameters
  - 0.25°by 0.25°spatial and 3-hourly temporal resolution
  - Surface air temperature (K) and specific humidity (g/kg)
- Influenza data from Morbidity and Mortality Weekly Reports
  - Epidemiological report for US by the CDC
- To obtain weekly data - averaged the pixels and aggregated the 3-hourly data into daily averages and finally
  - Computed weekly maximum, minimum, and mean

5. Generalized Additive Model

- No *a priori* reason for choosing a particular response function
- Allows response functions to be generated from the data
- Uses a link function to establish a relationship between the mean of the response variable and a smoothed function of the explanatory variables
- The general form:

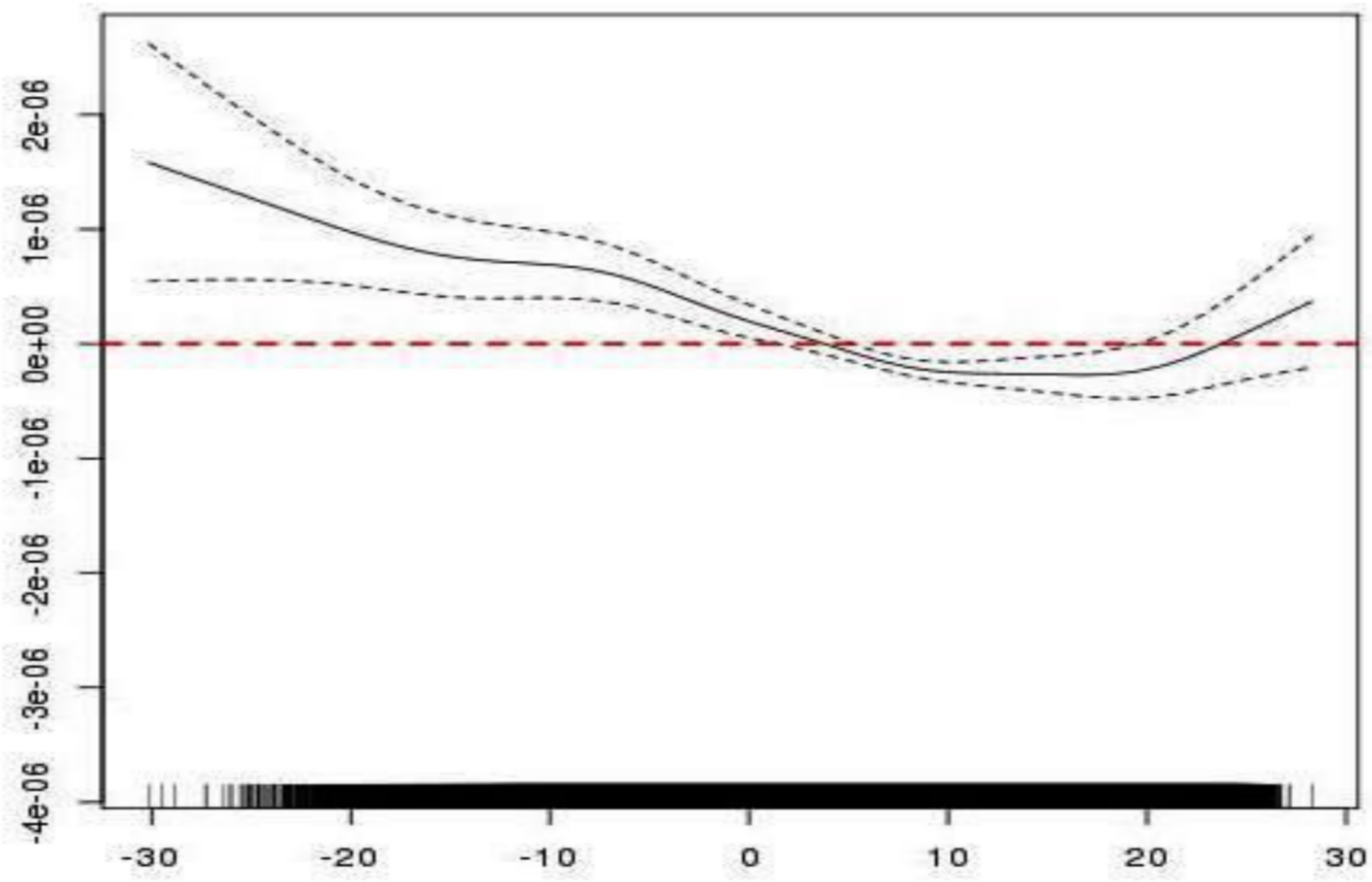
$$y_{iwy} = \alpha_i + \emptyset_{wy} + \sum_{i=1}^{n} f_{iwy}(X_{iwy})$$

- Usual linear function of a covariate, $\beta_i . X_i$, is replaced with f_i - an unspecified smooth function
- Assumption of a rigid form of dependence of mortality on the predictors is not required

5. Generalized Additive Model

- Maximum Likelihood (ML) estimation method
  - Covariance structure is most stable
- Location (city) and time (year and week) fixed effects
  - To control for unobserved heterogeneity
  - Measuring the excess mortality above the all-city long-run average rate for each week
- All the variables are stationary
- All the smooth terms are statistically significant
- Control for per capita income of cities

6. Results: Minimum Temperature



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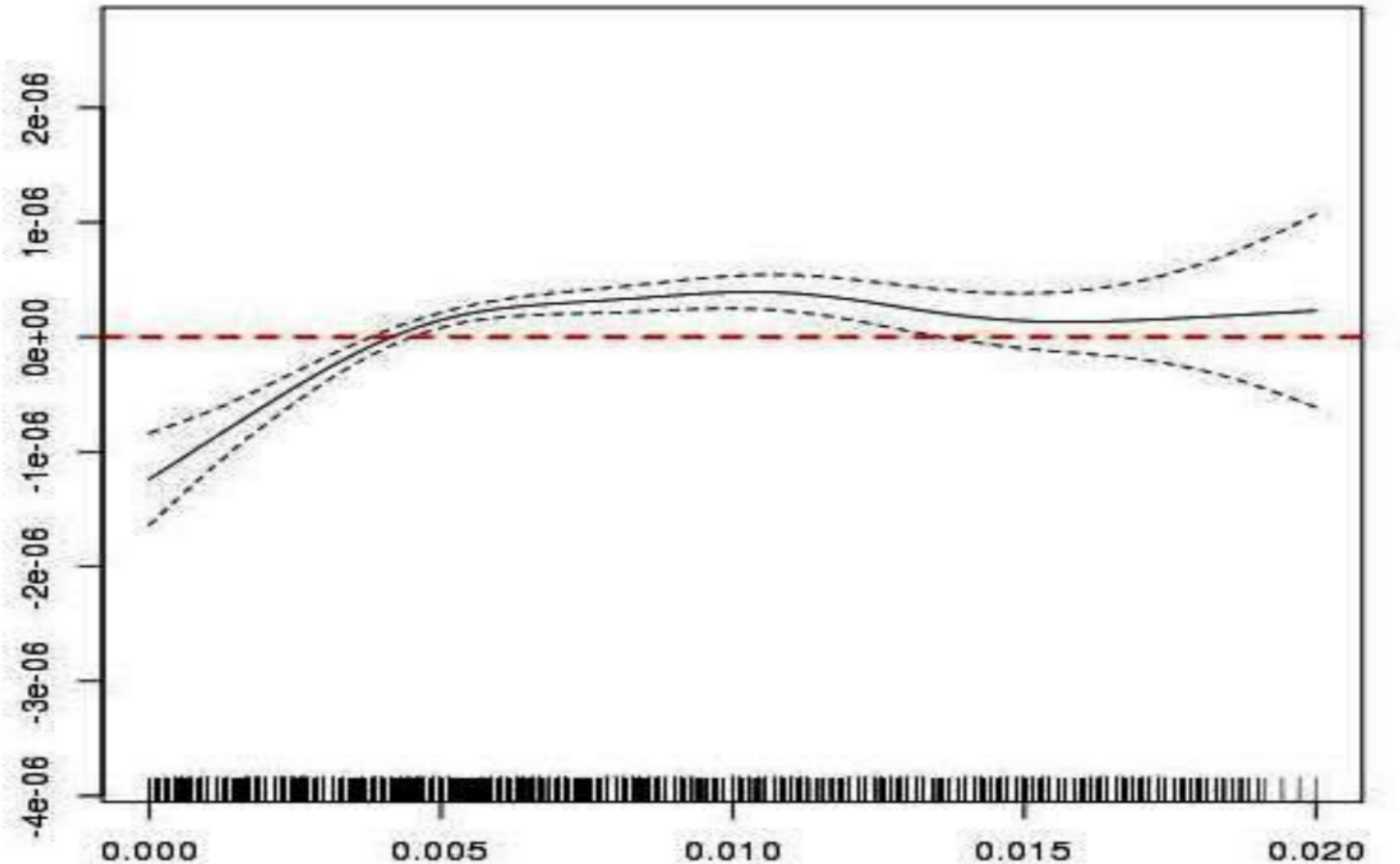
6. Results: Minimum Temperature

- Risk of influenza mortality is highest between minimum temperatures of −30°C and 5°C
- Risk is negative between 5°C and 25°C
- U-pattern – risk becomes positive again beyond 25°C
- Under laboratory conditions, Lowen et al. (2007 and 2008) demonstrated that viral shedding in animals increases at 5°C

6. Results: Minimum Specific Humidity



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6. Results: Minimum Specific Humidity

- Effect of humidity is negative below 4 g/kg
  - But increasing
- At minimum specific humidity levels between 4 g/kg and 14 g/kg - influenza mortality is likely to increase
- Risk of mortality is highest at 12 g/kg
- Laboratory experiments show that the efficiency of influenza viruses is highest between RH of 20% and 35%
  - Equivalent to specific humidity between 3.5 g/kg and 6 g/kg

7. Projections

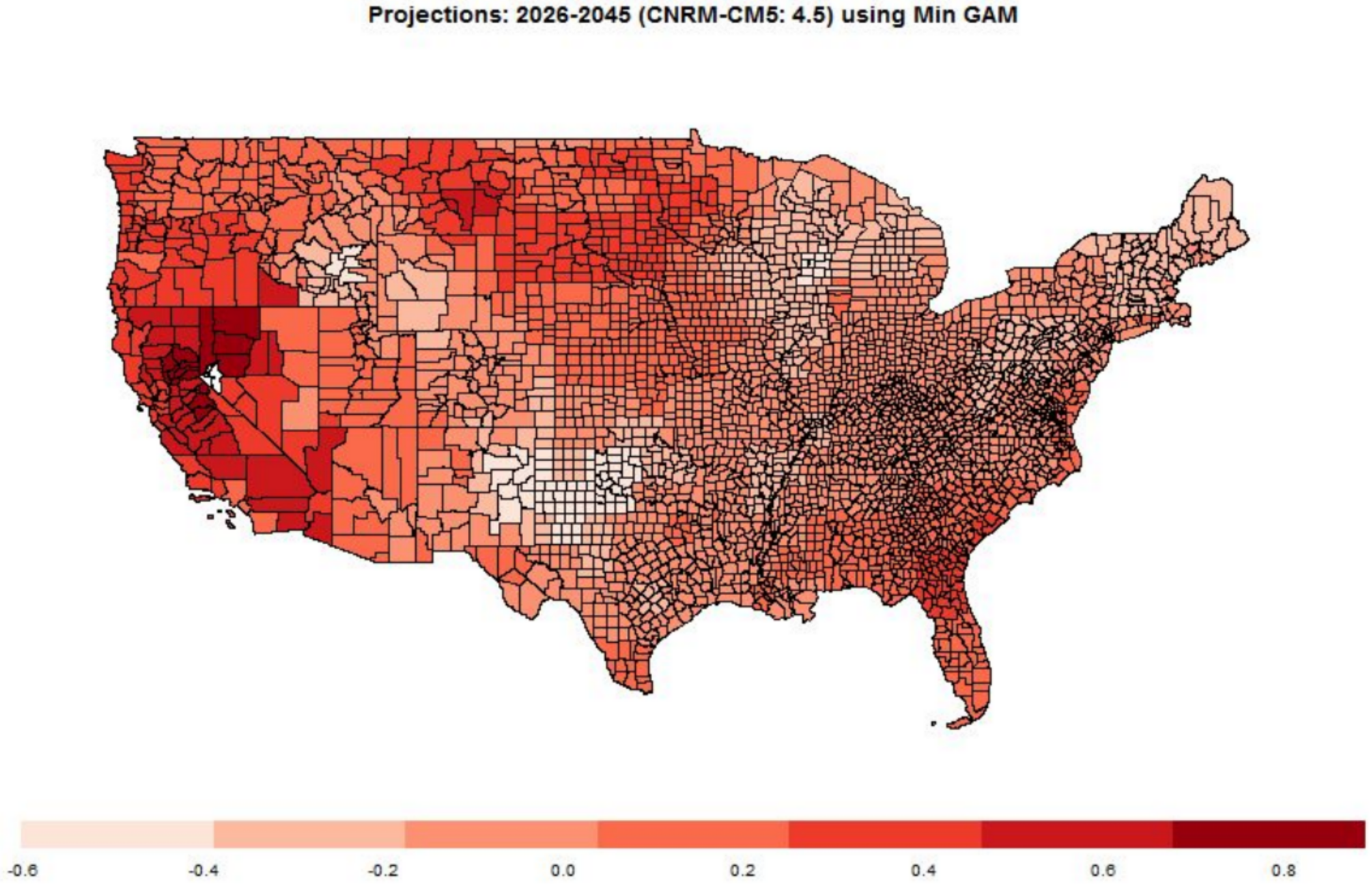
- Bias corrected methodology
  - GCMs do not correctly simulate weather at high frequency
  - Over a long period they get the average right
  - Juxtaposing GCMs' projections of the future with that of the past provides unbiased comparisons

- Remedy is to compare each GCM's projections of the future against its own simulation of the historical period (1980 – 2005)
  - Resulting comparison should be bias free

7. Projections

- Three GCMs: CNRM-CM5, GISS-ER-2 , and NorESM1-M
- RCP 4.5 and RCP 8.5
  - 2026 – 2045
    - RCP 4.5 → 1.4°C (0.9°C to 2.0°C)
    - RCP 8.5 → 2°C (1.4°C to 2.6°C)
  - 2081 – 2100
    - RCP 4.5 → 1.8°C (1.1°C to 2.6°C)
    - RCP 8.5 → 3.7°C (2.6°C to 4..8°C)
- Differences between the historical and future periods provide
  - Change in per capita influenza mortality

7. Projections: CNRM-CM5 (4.5 Mid-century)



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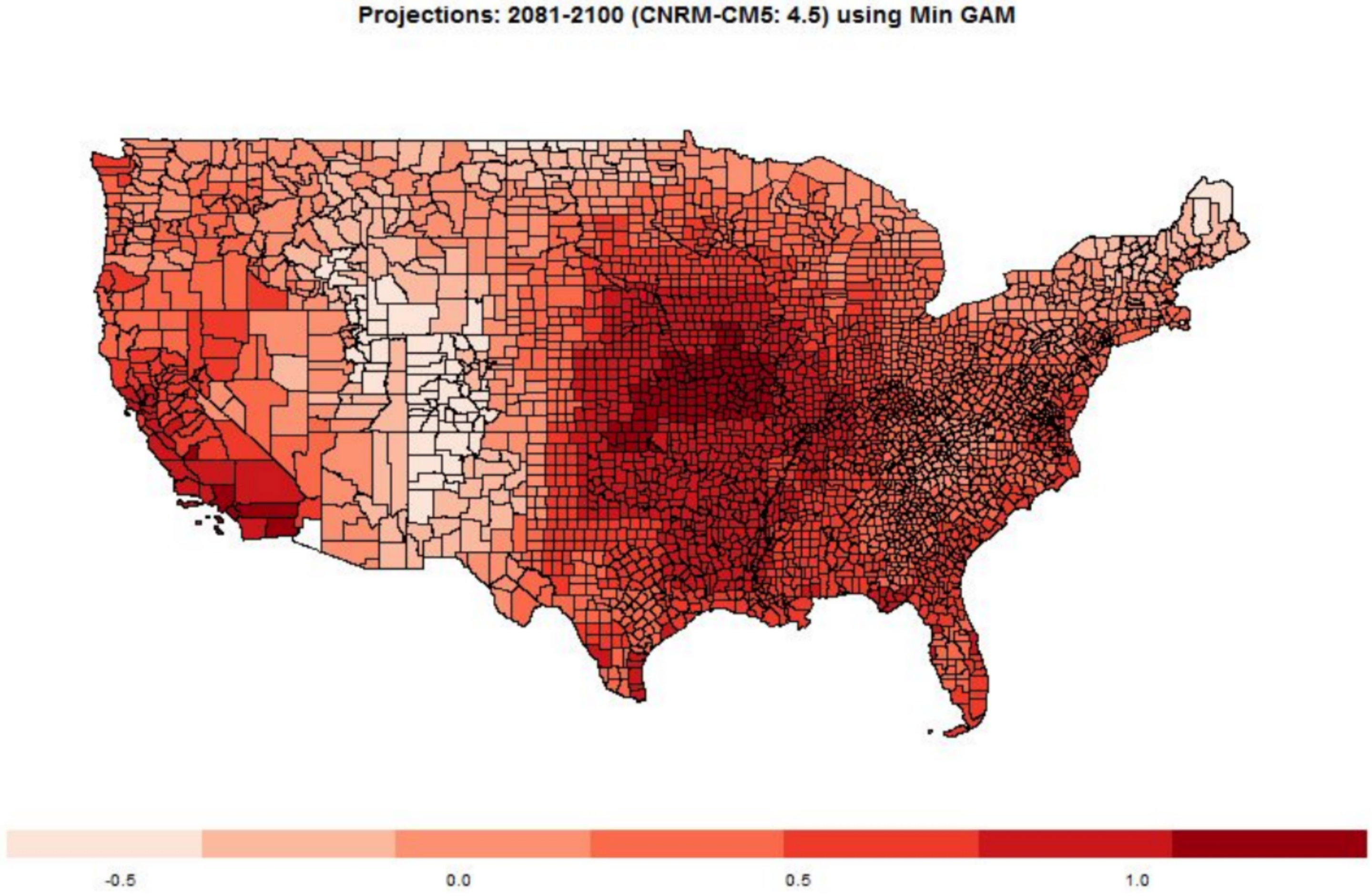

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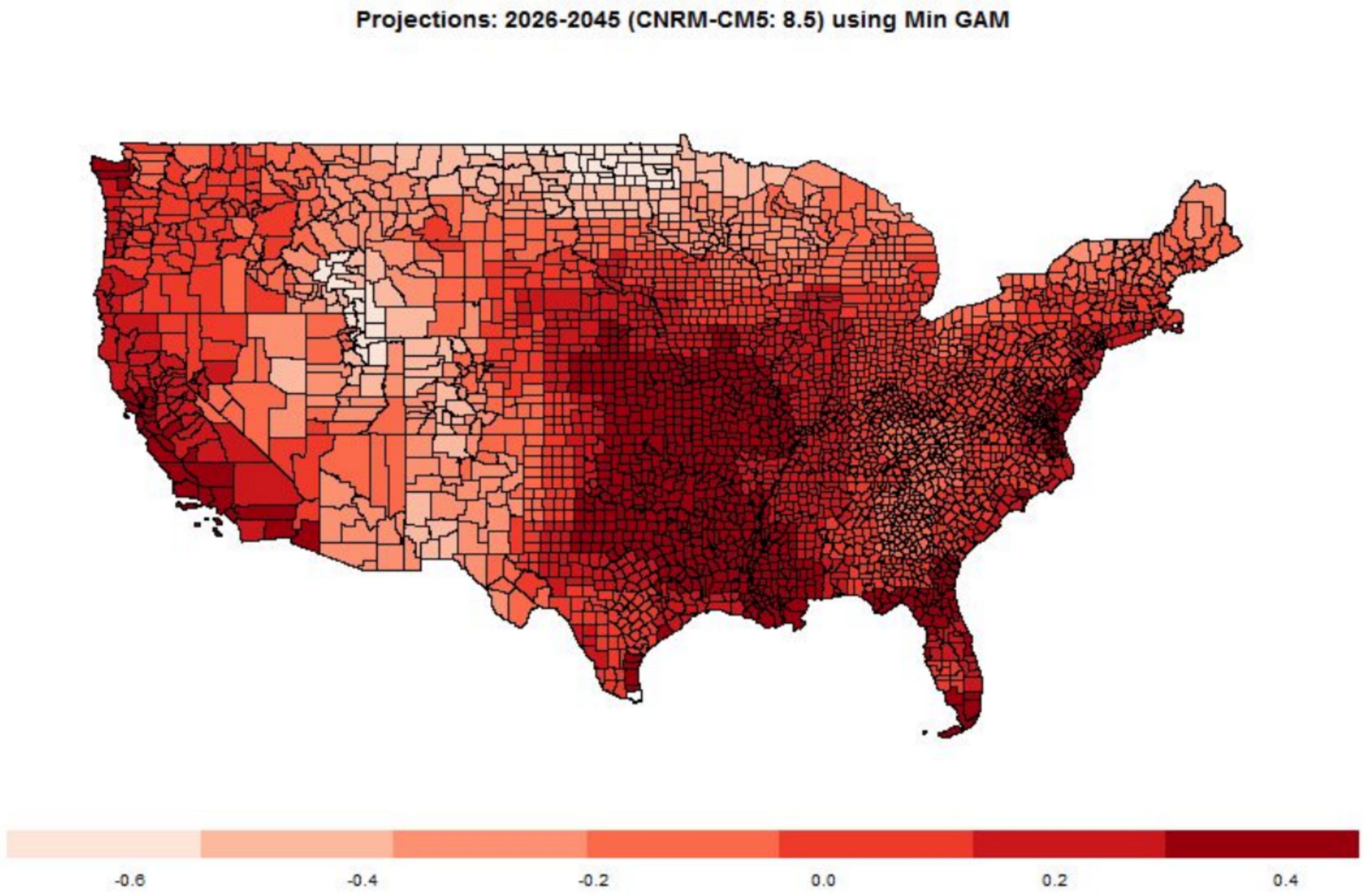
7. Projections: CNRM-CM5 (8.5 Mid-century)



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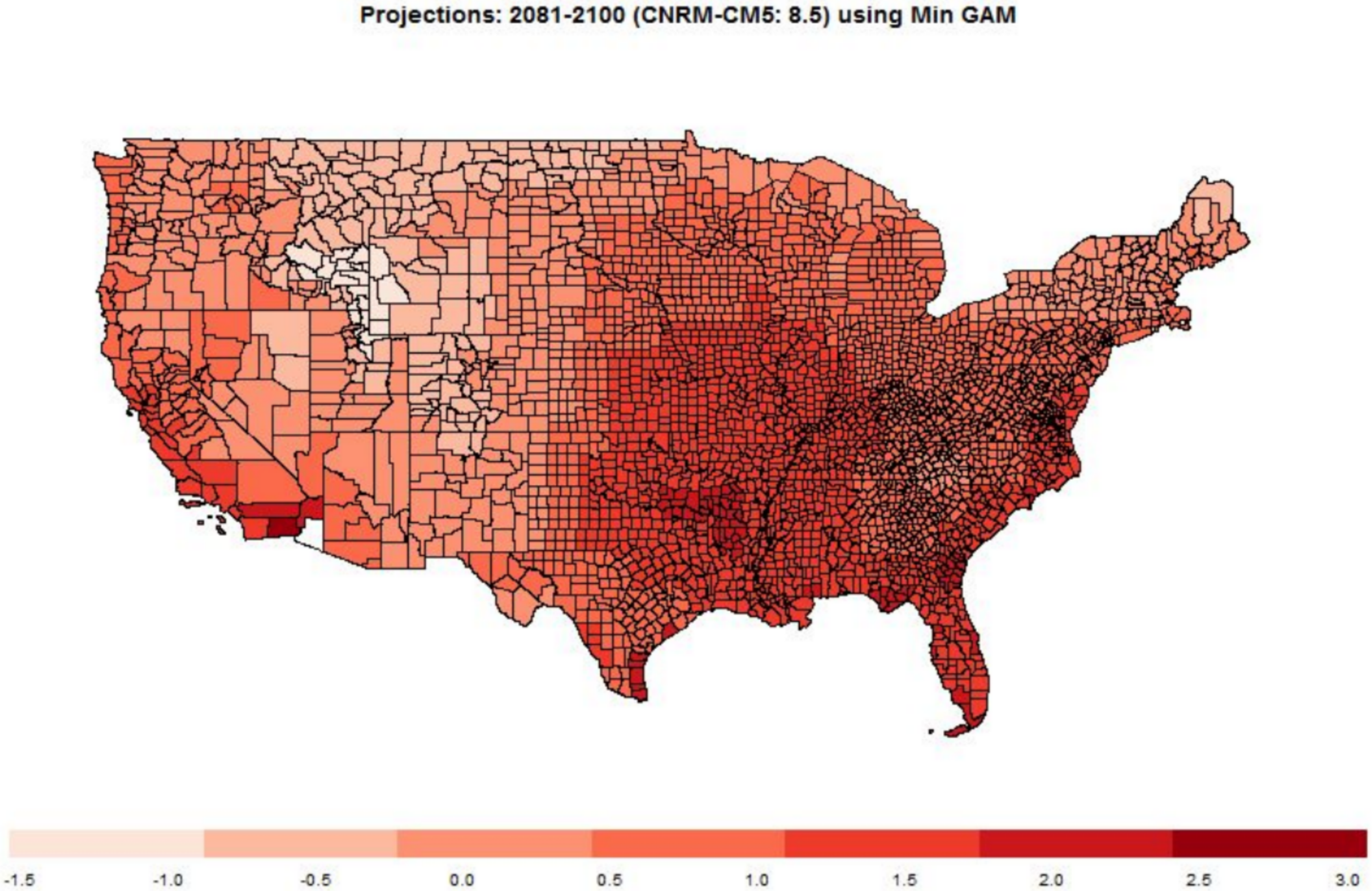
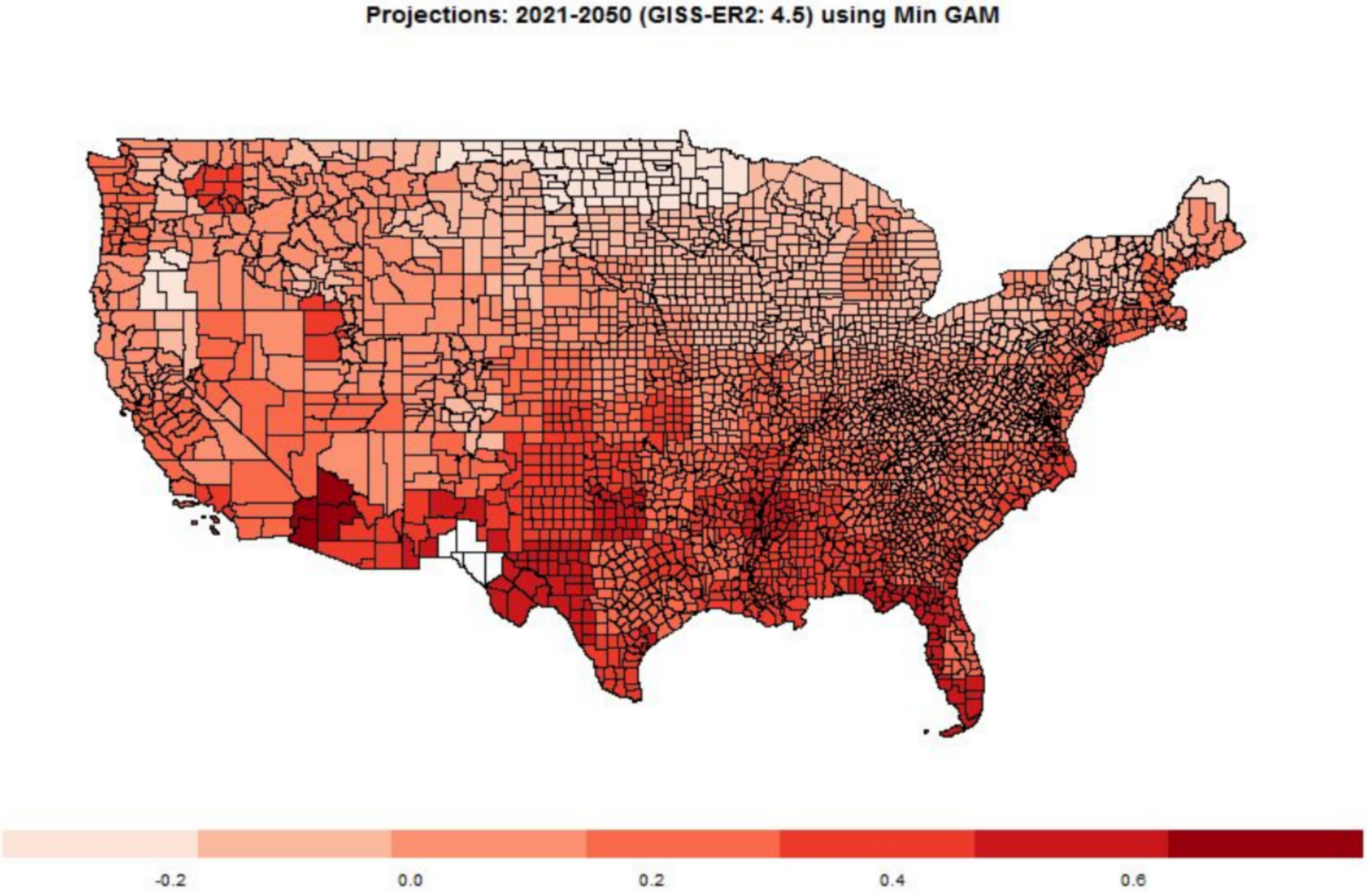


7. Projections: GISS-ER2 (4.5 Mid-century)



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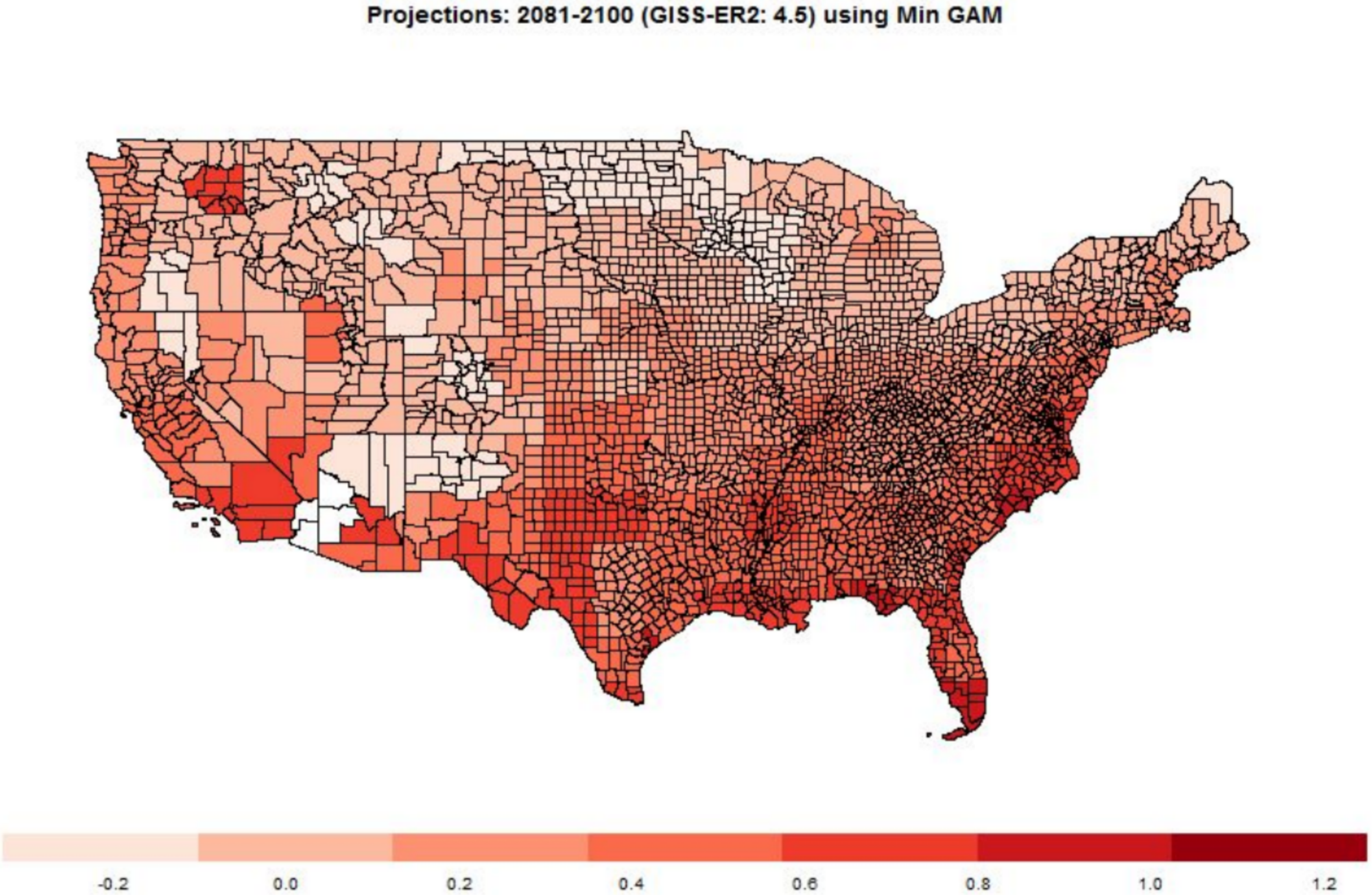

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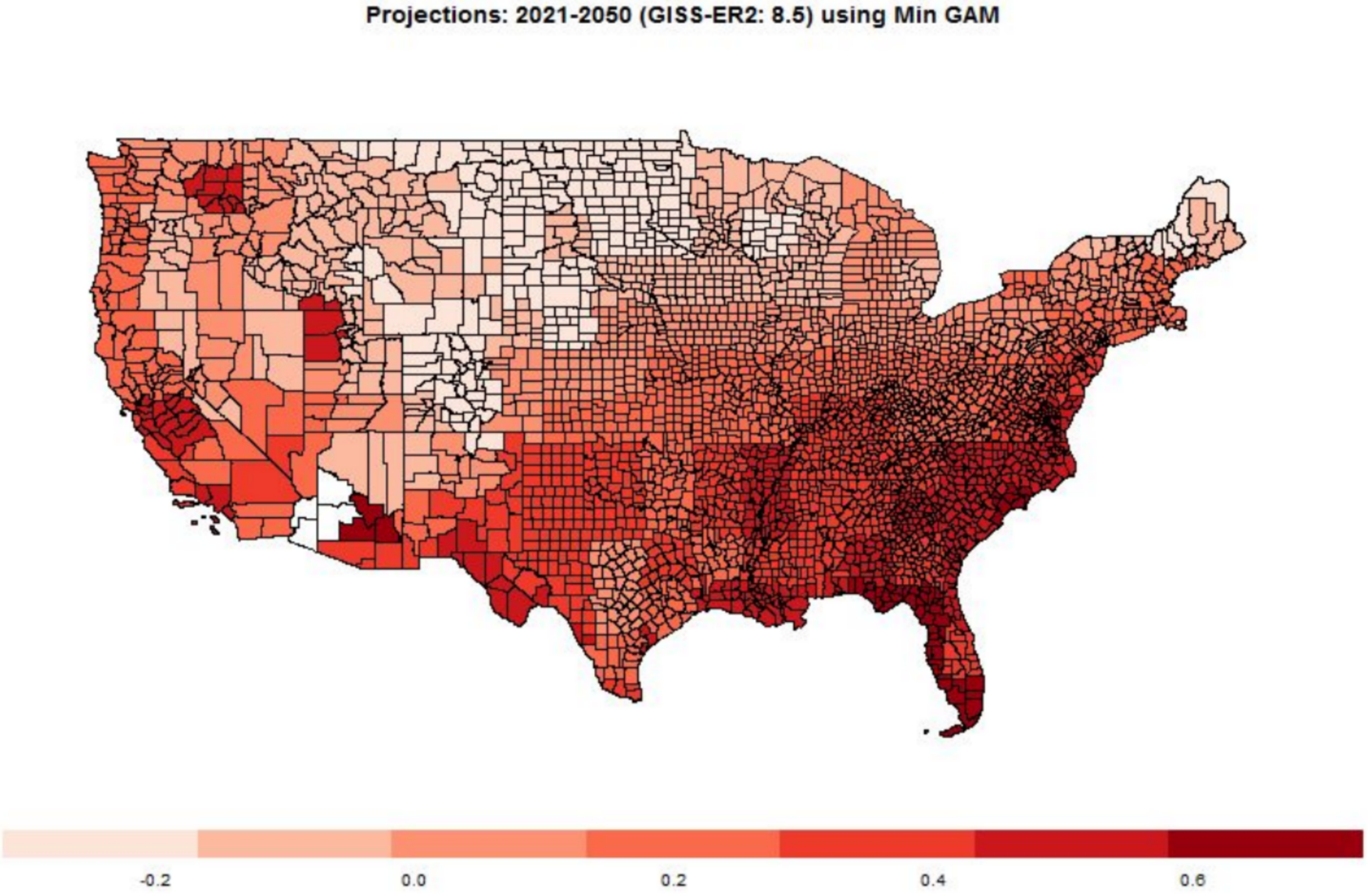

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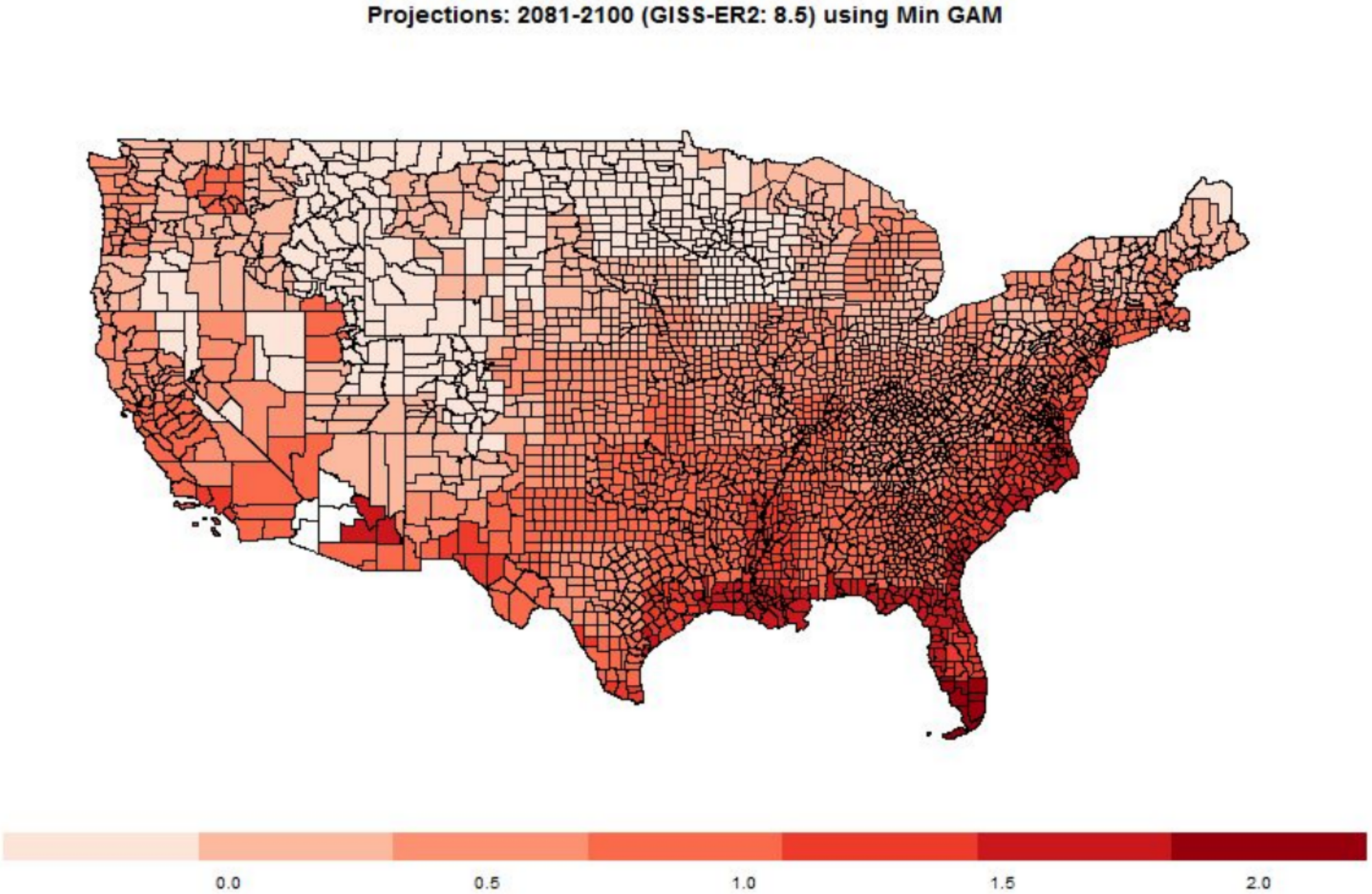

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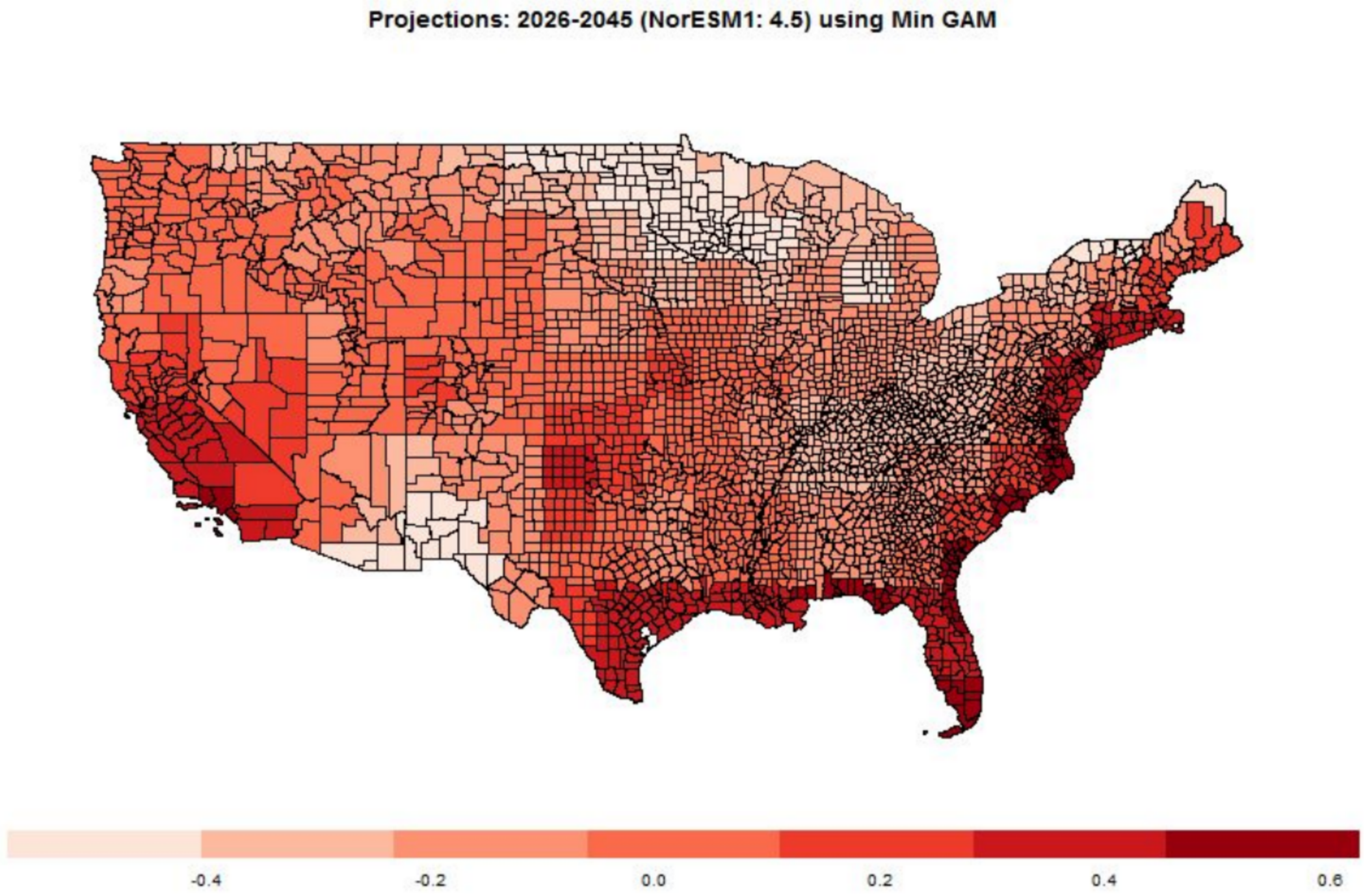
7. Projections: NorESM1-M (4.5 Mid-century)



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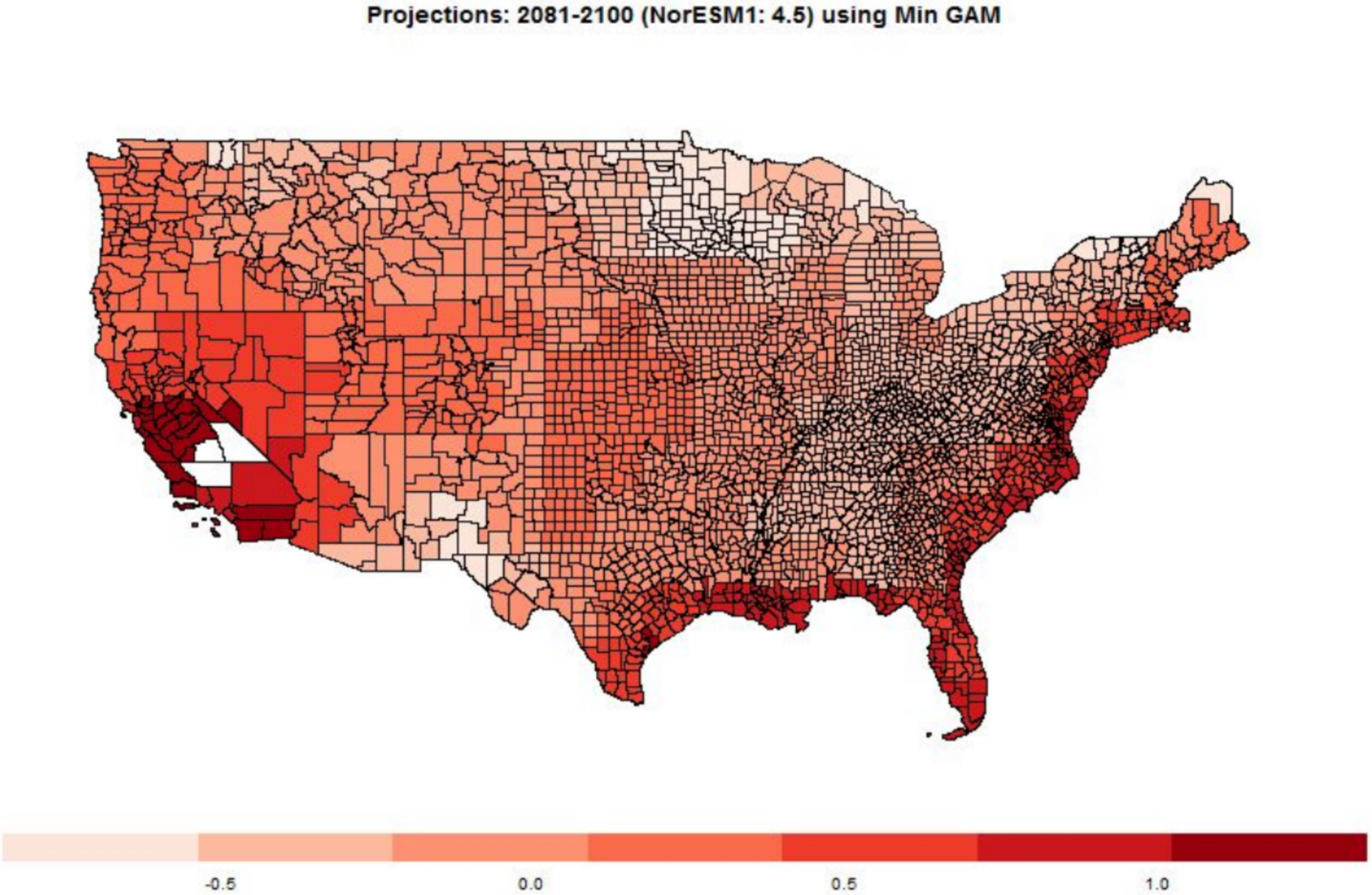

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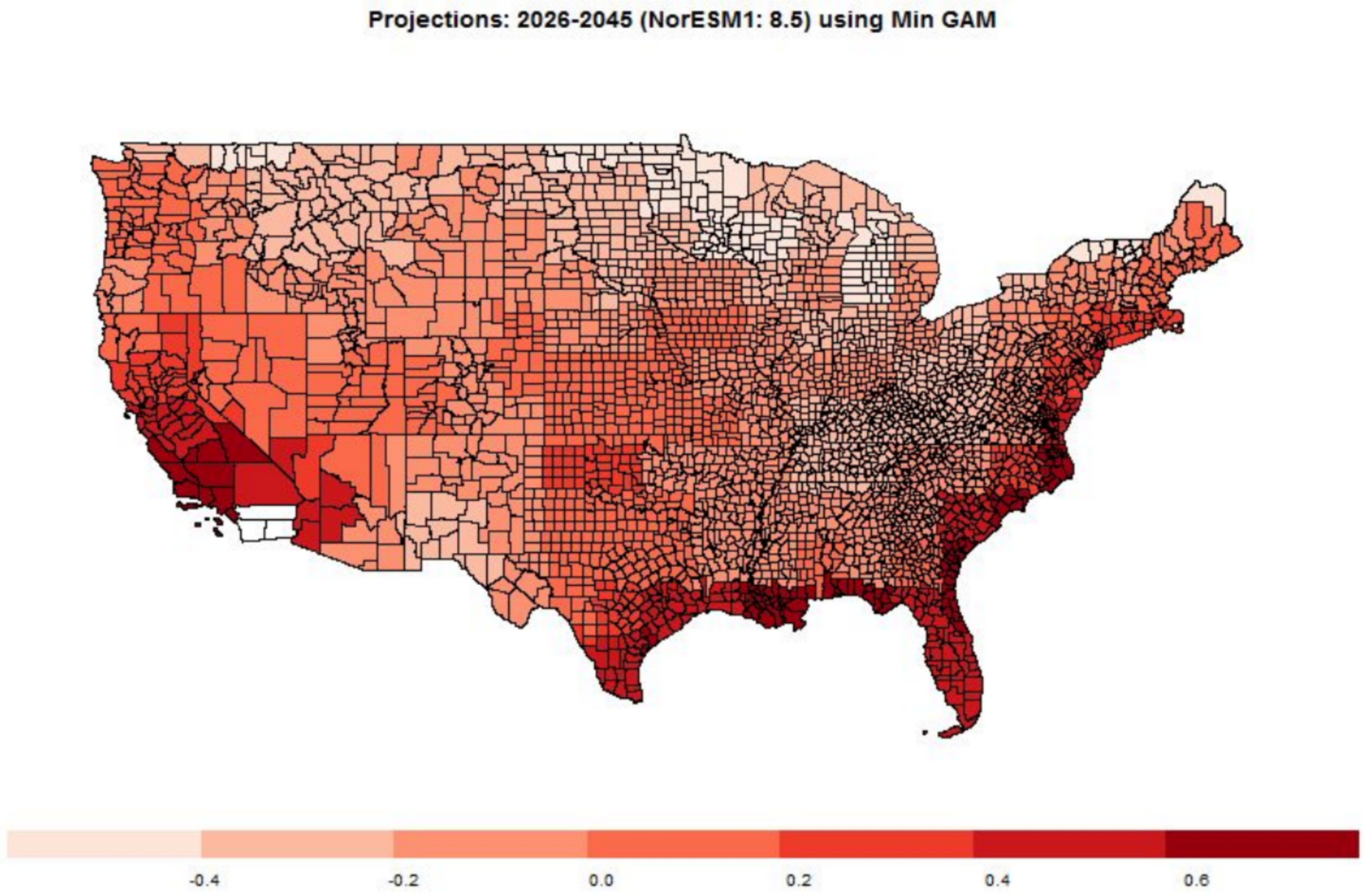

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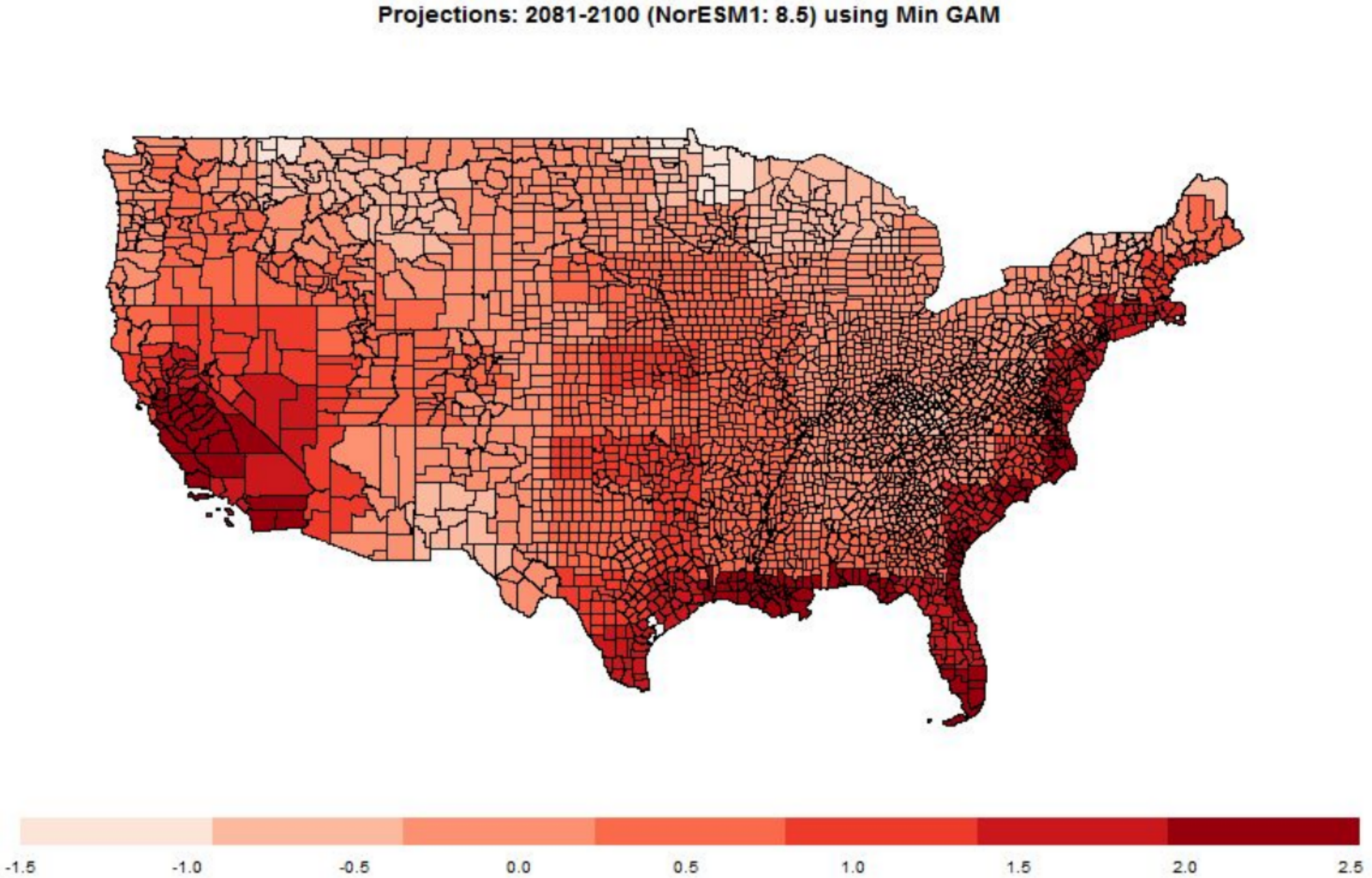

7. Discussion: Projections - RCP 4.5

Mid-century **(2026 – 2045)**

- Parts of West and Southwest US likely to experience increases
  - Change in per capita influenza mortality between 0.6% and 1%
  - Extreme temperatures over summer and winter
  - Low levels of humidity
  - Arizona and New Mexico
- Northwest and Midwest US are likely to face declines
  - Between −0.20% and −0.40%

End-century **(2081 – 2100)**

- Increases in Midwest, Southeast, and Northeastern US
- Change in per capita mortality between 0.5% and 1.5%
  - Midwestern states have humidity levels around 10 g/kg
  - Parts of the Southeastern US (Georgia and Florida) often experience temperatures above 25°C

7. Discussion: Projections - RCP 8.5

Mid-century **(2026 – 2045)**

- Increases in Southwest, Midwest, and Southeastern parts of US
  - Change in per capita influenza mortality between 0.2% and 0.6%
  - Humidity and temperature interaction likely drivers

End-century **(2081 – 2100)**

- Relatively large increases of up to 3% in some areas
- Southeast – North and South Carolina, Georgia, and Florida
- Midwest - Nebraska, Illinois, and Kansas
- Parts of the Eastern US - Massachusetts and Rhode Island
- 8 – 10 deaths per million by the end of the 21st century

8. Conclusion

- Robust evidence of non-linear impact
- Risk of influenza mortality is highest at lowest temperatures
  - Specific humidity levels between 4 g/kg and 14 g/kg
- West, Midwest, and Southeastern US are at high risk of increase in per capita influenza mortality due to climate change
  - Up to 3% by the end of the 21st century
- Spatial shift of influenza mortality risk
  - From the West and Southwestern US to the Midwest, South and Southeastern regions during the 21st century
- Findings can be used to target locations at high influenza risk
  - Focused vaccination drives

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