Future Population Exposure to U.S. Heat Extremes

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Mutademo: The Impacts and Challenges of Demographic Change
Paris, France
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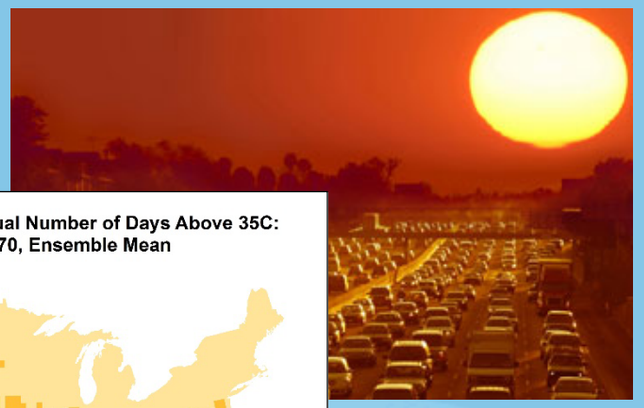
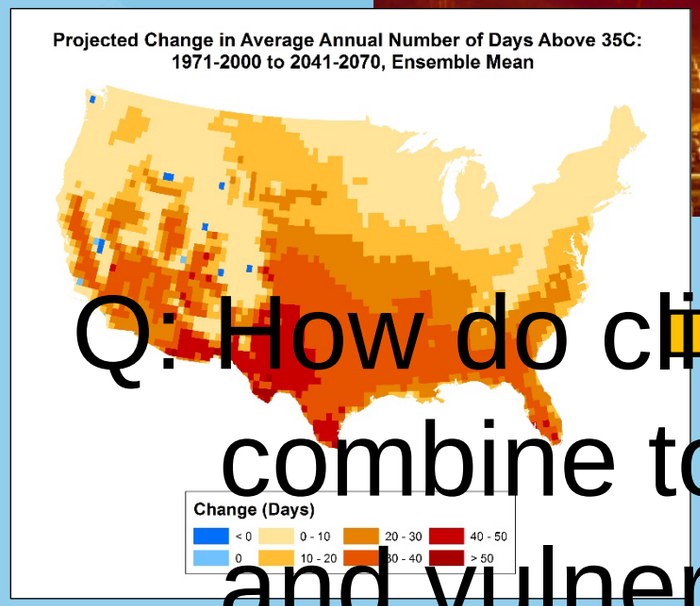
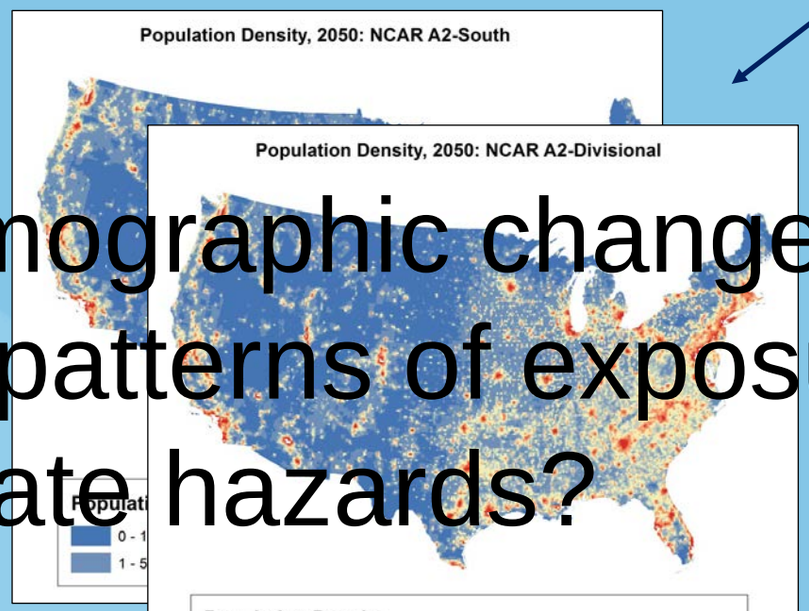
Developing New Models to Understand Human Vulnerability to Climate-Related Hazards at Multiple Scales

Climate Scenarios

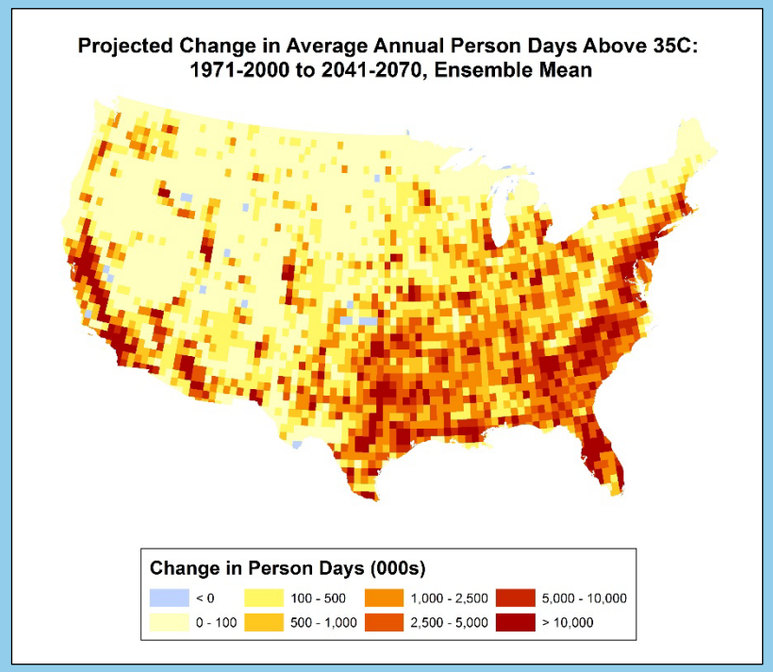




Demographic **Geographic** **Economic**



Q: How do climate and demographic change combine to drive future patterns of exposure and vulnerability to climate hazards?



Vulnerability/Exposure

Spatial Population Scenarios

1. Identify the multi-level drivers of spatial population change.
2. Construct a theoretically consistent modeling framework for producing spatial population scenarios.
3. Assess exposure and vulnerability to climate-related hazards under alternative scenarios.

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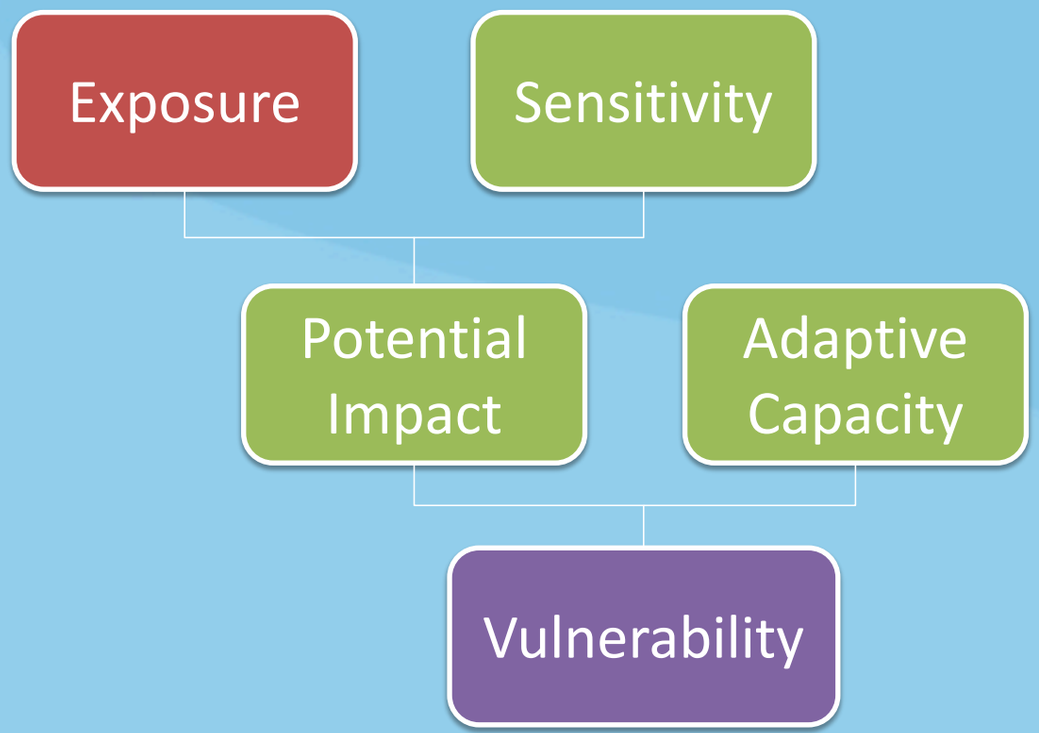
Exposure to Heat Extremes in the United States



- Barnett et al. (2010) find that the strong correlation between temperature measures lead to similar predictive ability.
- Gasparrini et al. (2012) find that excess mortality related to extreme heat events can be effectively described as the independent effect of individual days' temperature rather than as a function of multi-day heat waves.

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NARCCAP

North American Regional Climate Change Assessment Program

PROGRAM
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RESOURCES
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RESULTS
- Output Data Catalog
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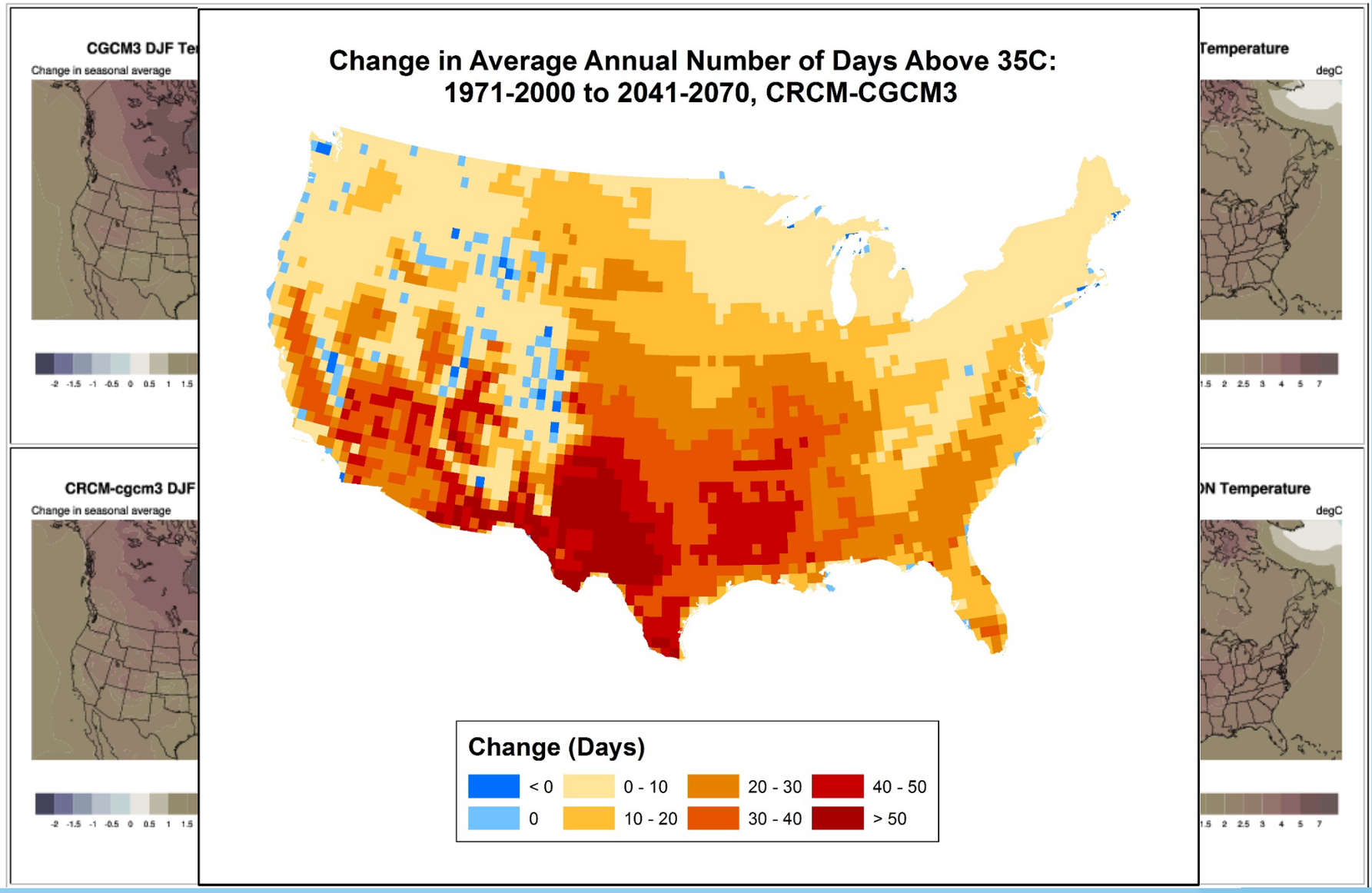
- Climate Change Results
  - CRCM+CCSM
  - CRCM+CGCM3
  - ECP2+GFDL
  - HRM3+GFDL
  - HRM3+HadCM3
  - MM5I+CCSM
  - MM5I+HadCM3 NEW!
  - RCM3+CGCM3
  - RCM3+GFDL
  - WRFG+CCSM
  - WRFG+CGCM3

SPONSORS

CRCM+CGCM3 - Seasonal Climate Change

These figures show seasonal average climate change for the periods 2041-2070 minus 1971-2000 for the CGCM3 driving AOGCM and for the CRCM regional model driven with CGCM3 boundary conditions.

Click for full-sized plots.



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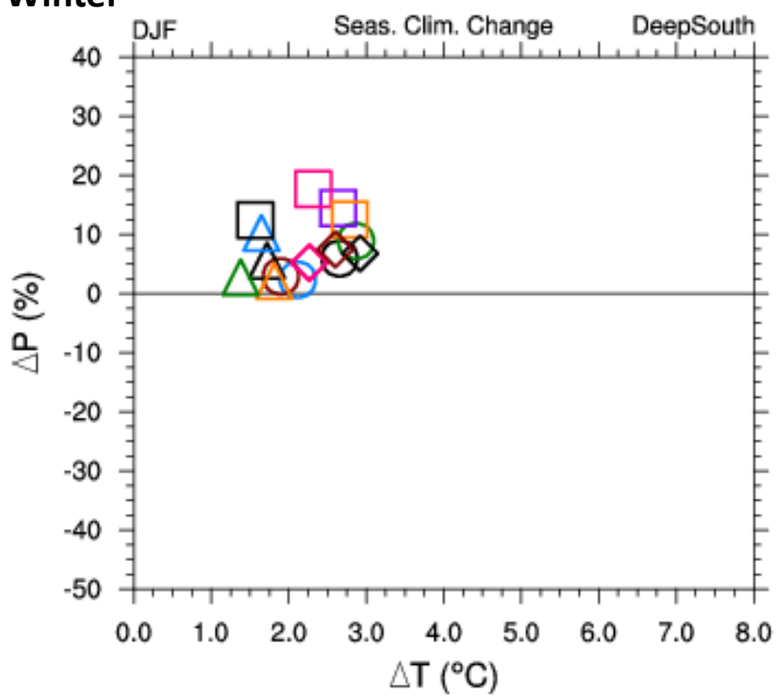
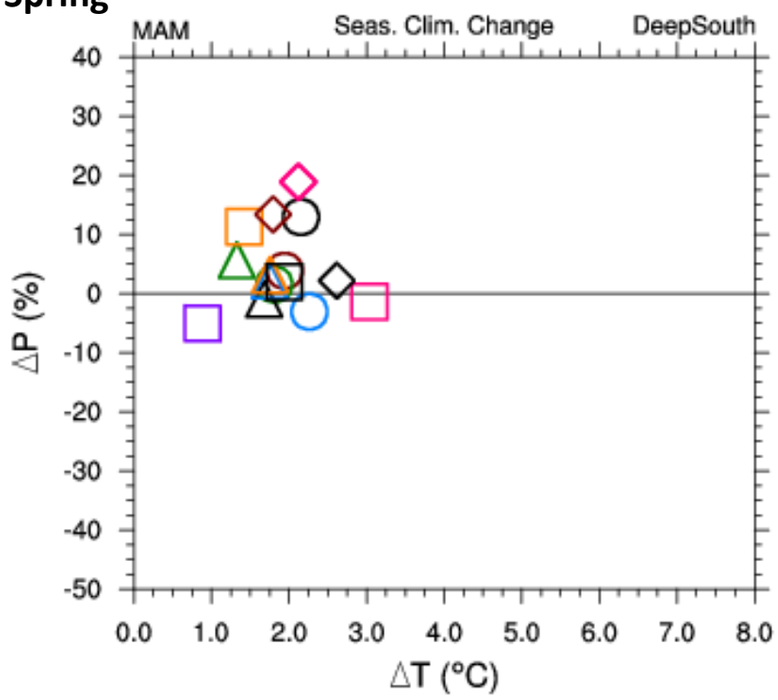
NARCCAP: Temp & Precipitation Anomalies

Winter



Spring



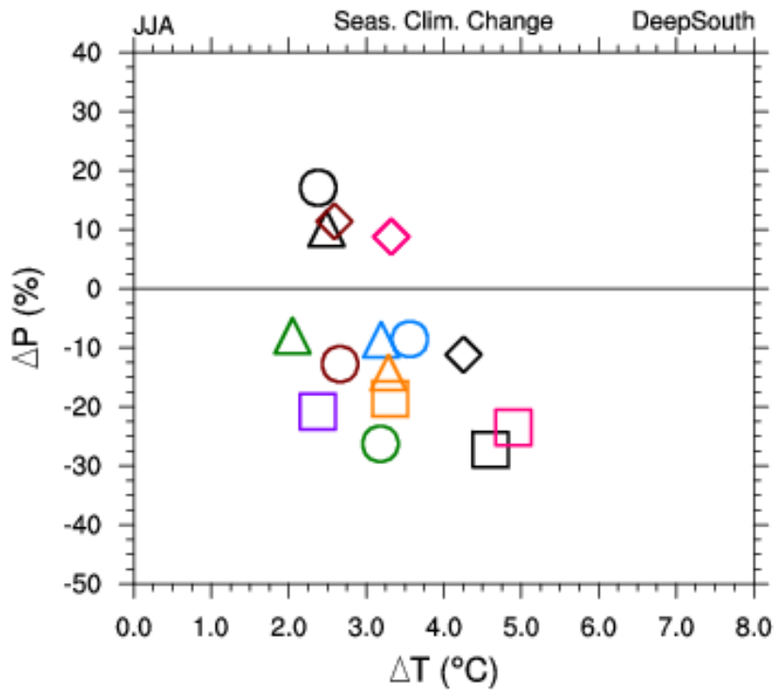
○ CCSM △ CGCM3

□ GFDL ◇ HADCM3

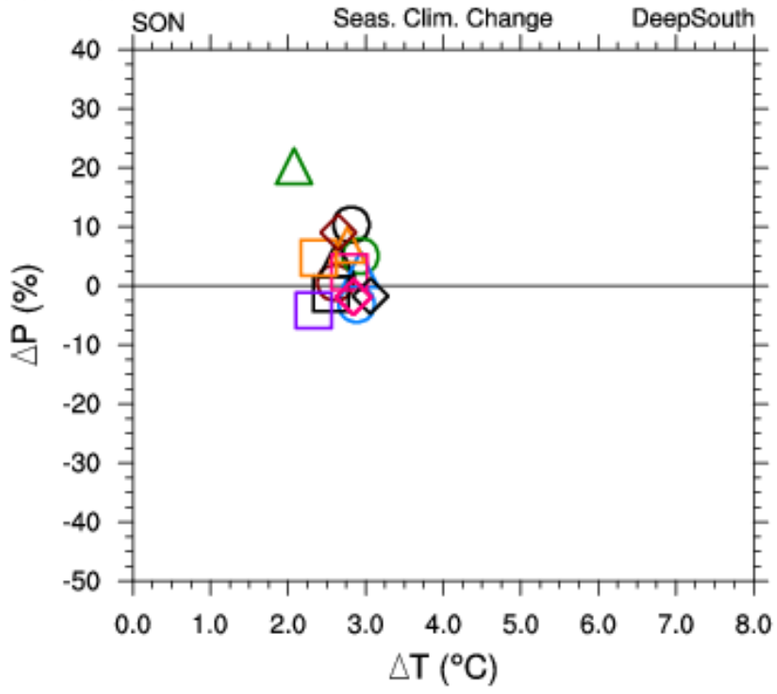
CRCM ECP2 HRM3

MM5I RCM3 WRFG

Summer



Autumn



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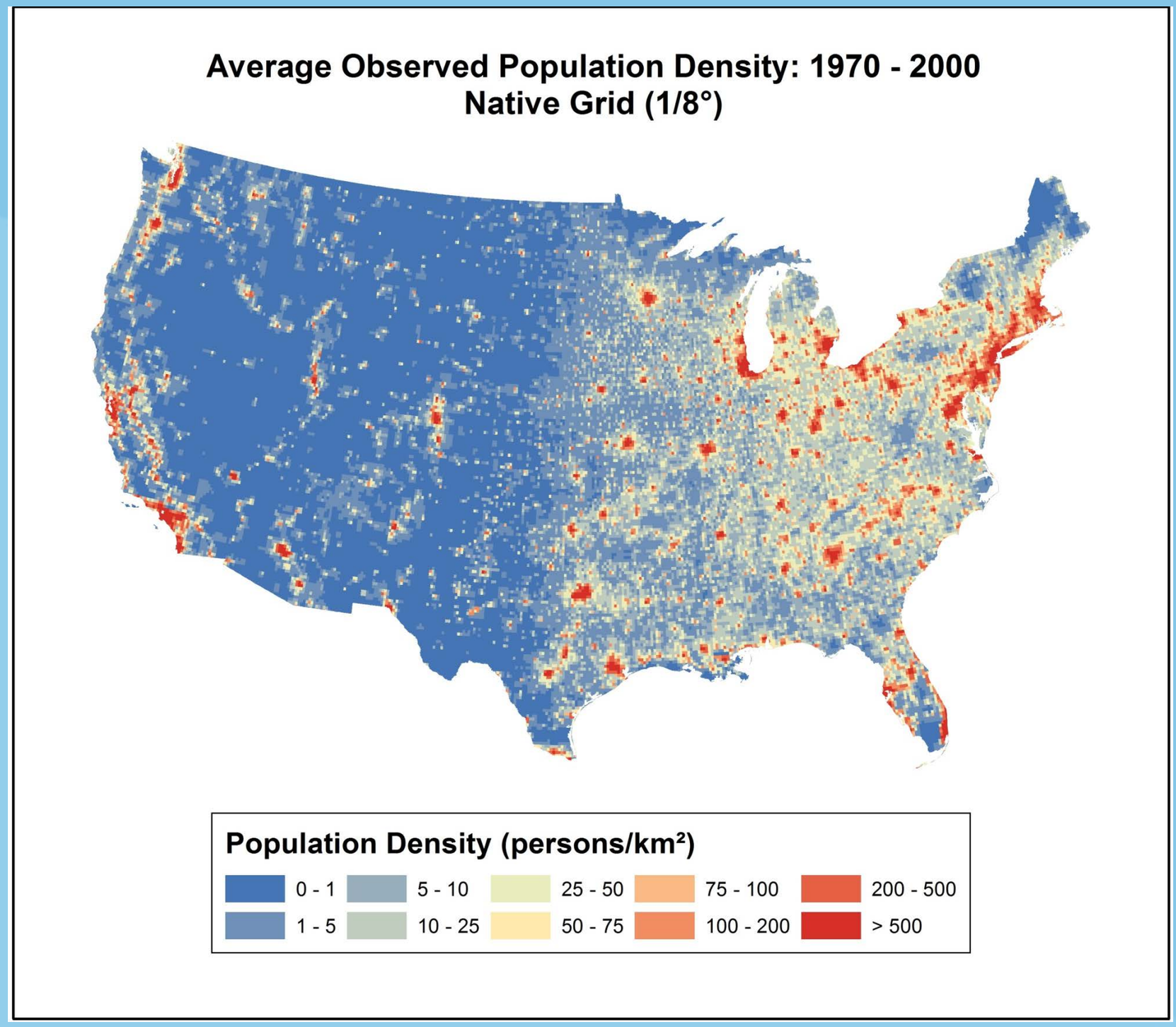
Population Scenario



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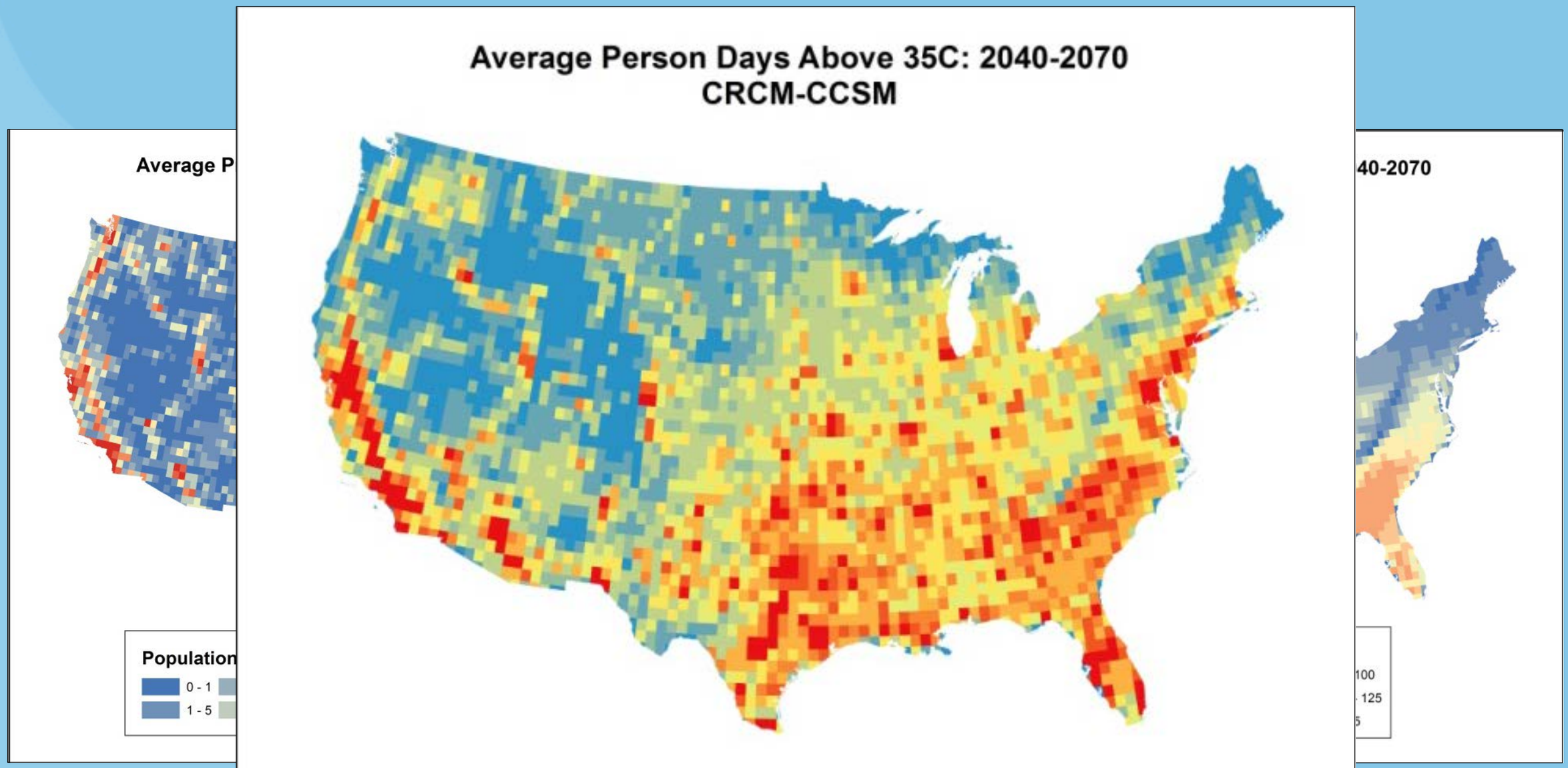
Calculating Exposure



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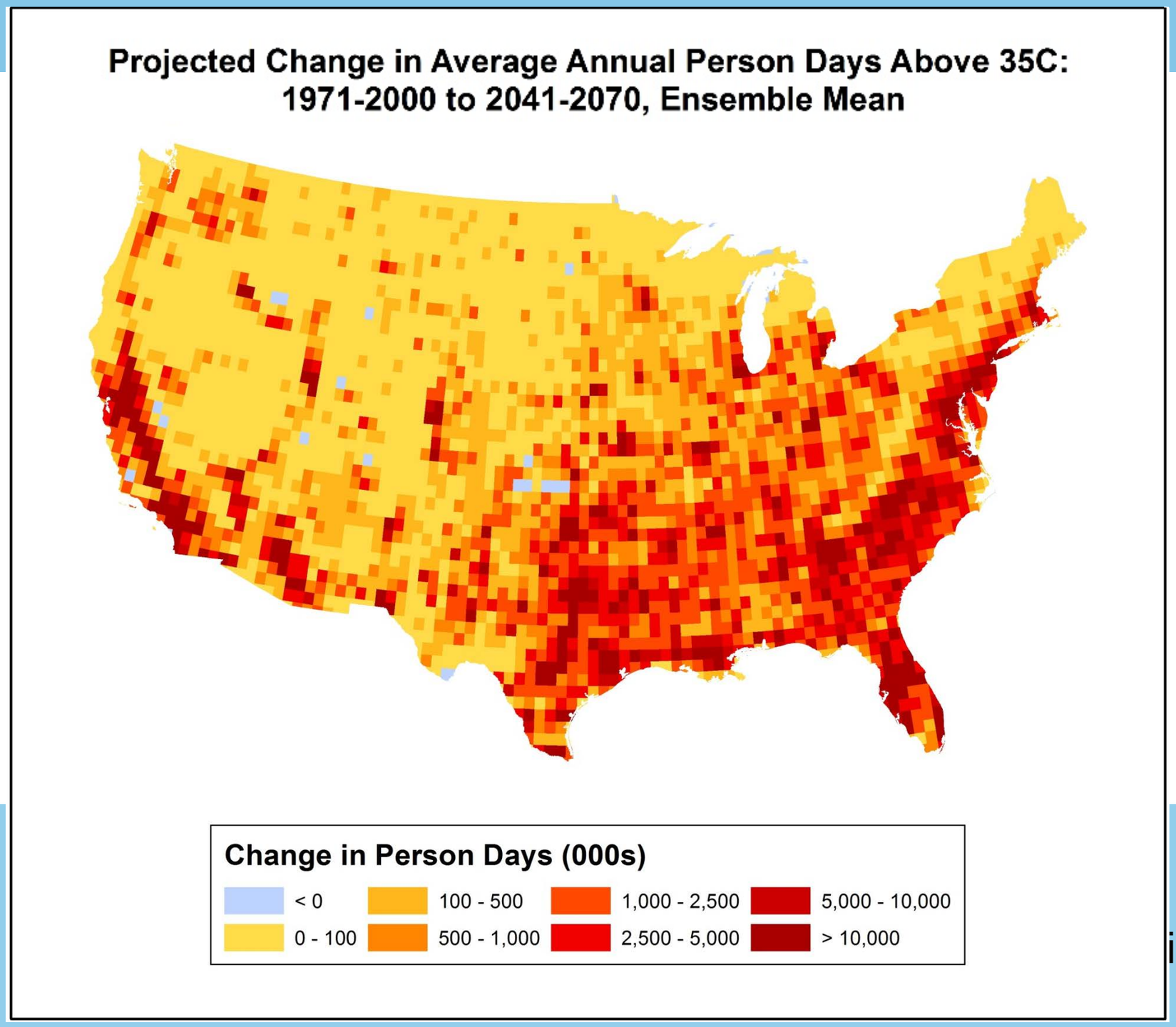
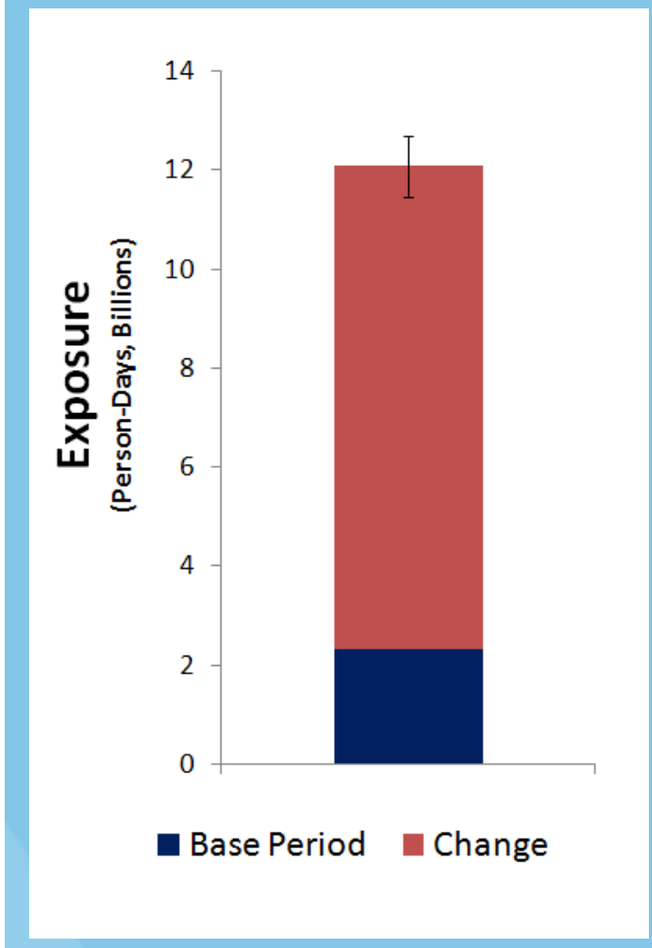
Projected Change in Exposure

Exposure





2.8 billion person days

imes observed levels

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Decomposing Change in Exposure

Additional model runs:

1) Constant population (Climate Effect)

2) Constant climate (Population Effect)

3) Constant climate, constant spatial distribution (National)

4) Constant climate, constant spatial distribution (Divisional)

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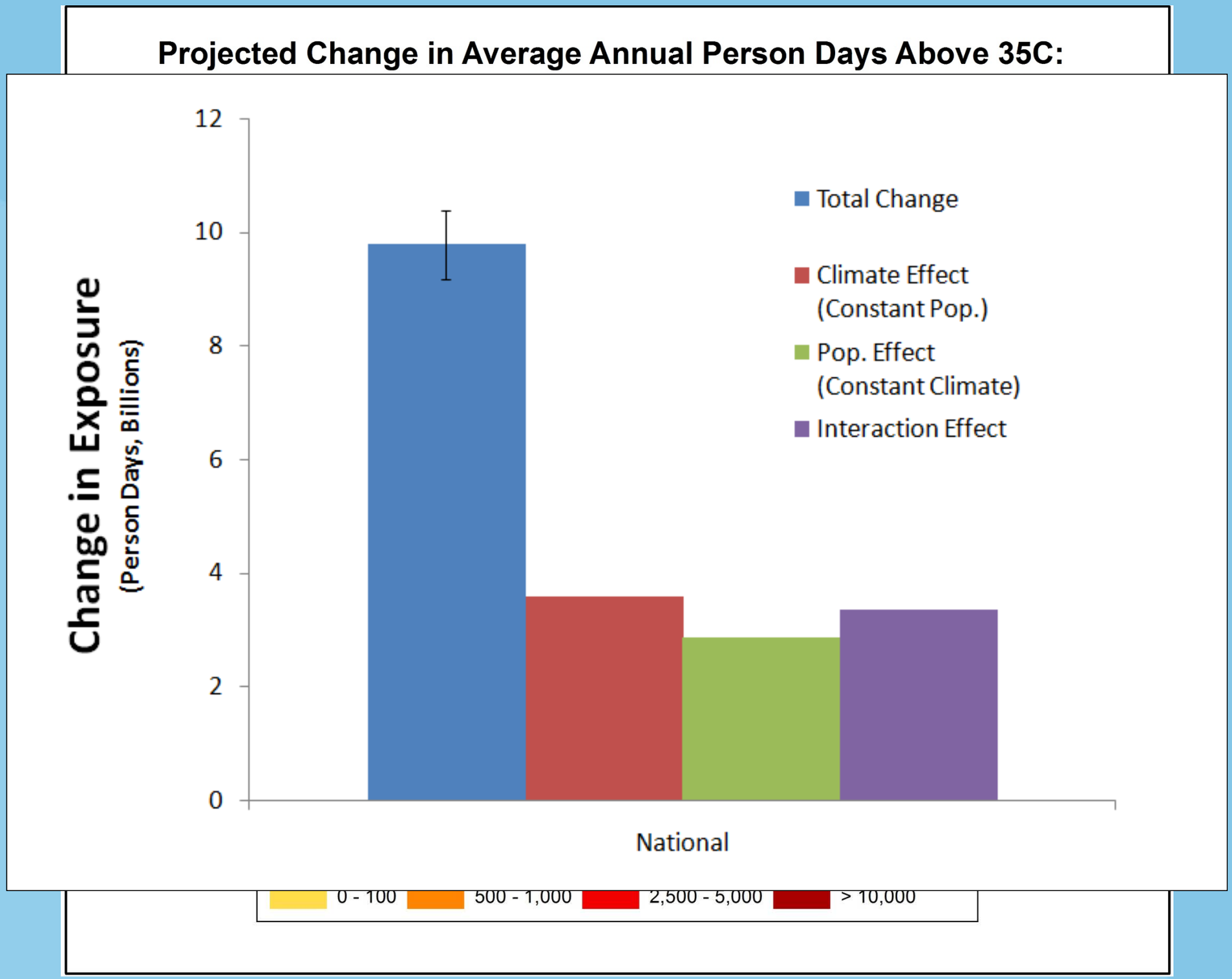
National-level Decomposition



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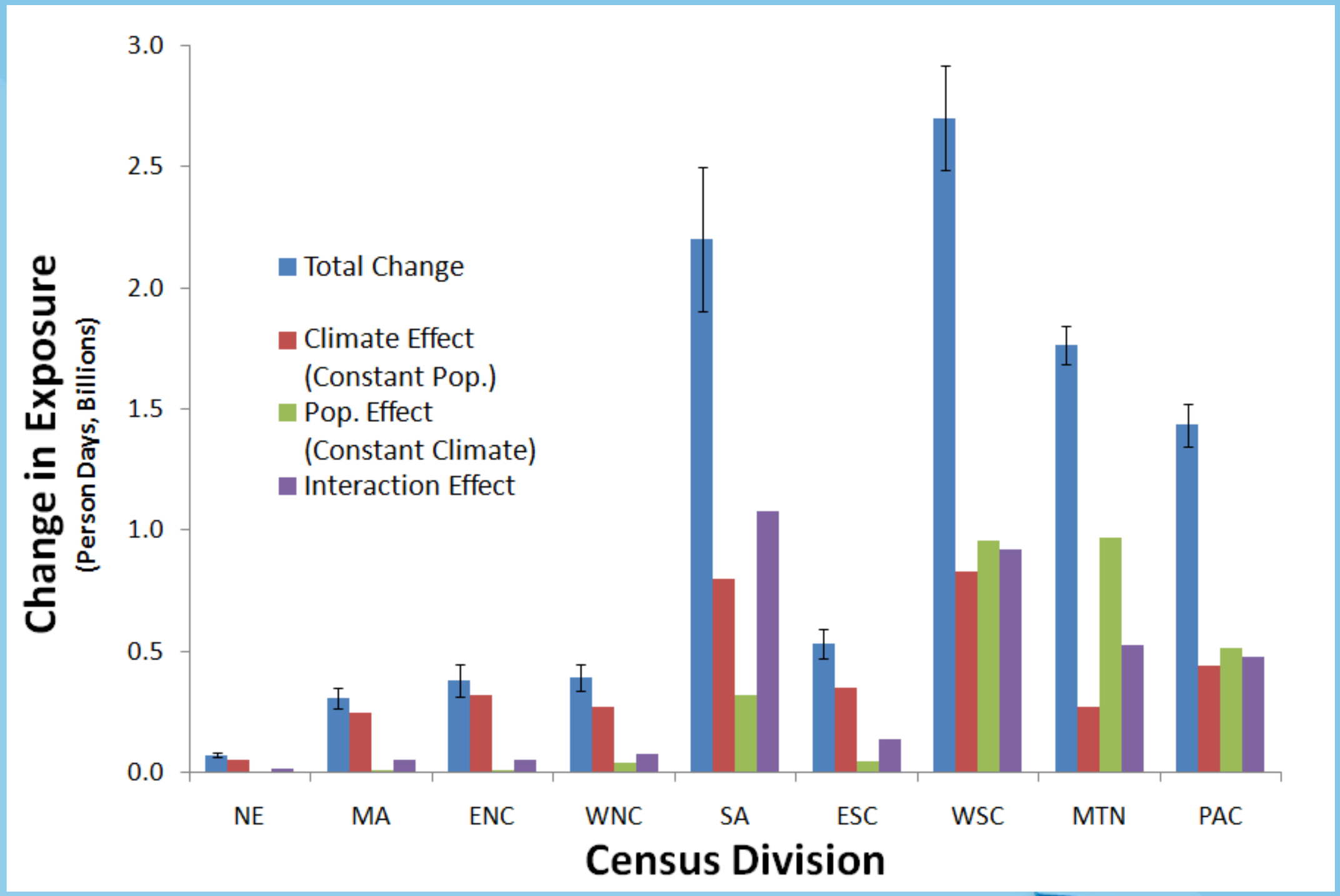
Divisional-level Decomposition



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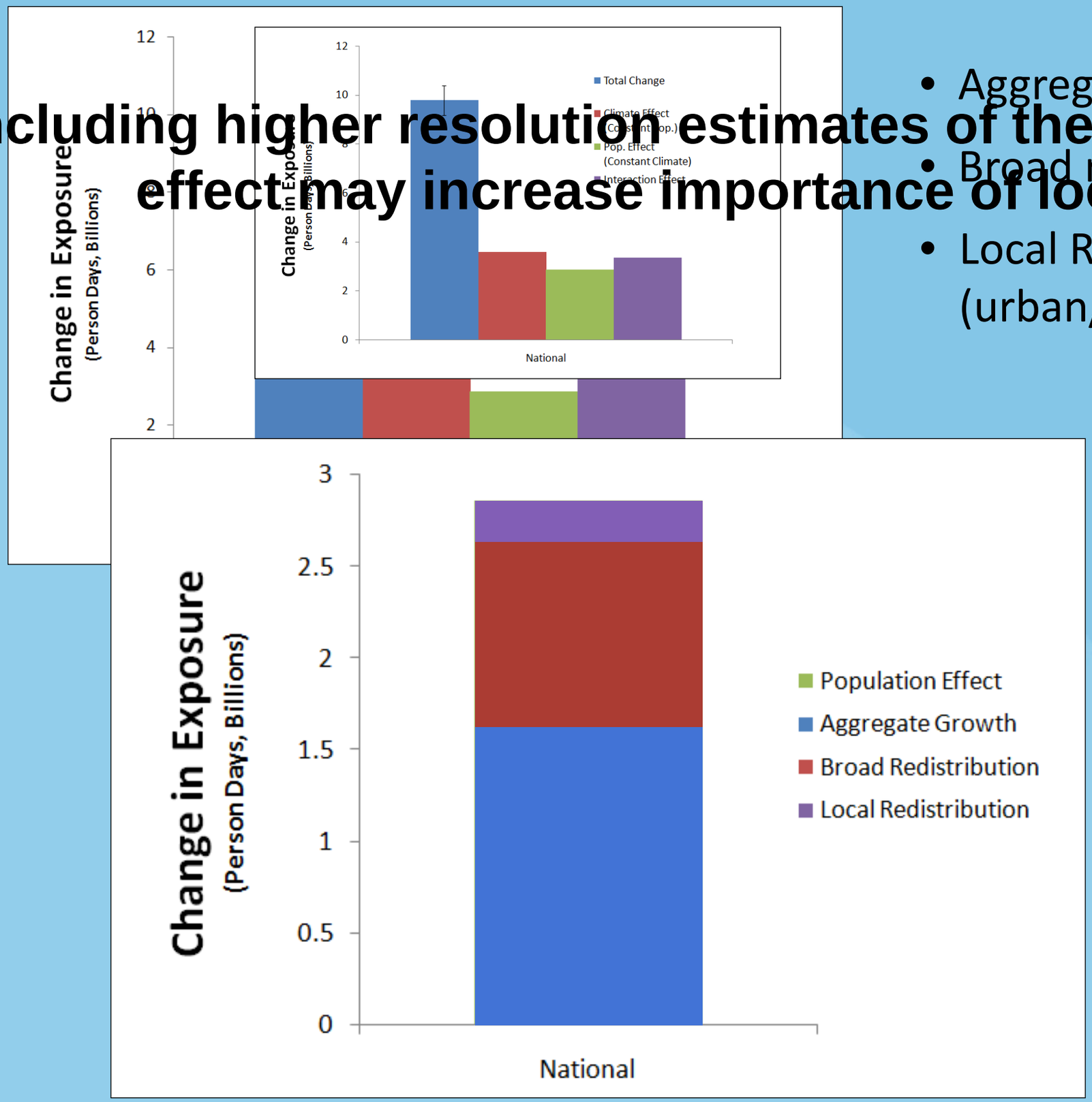
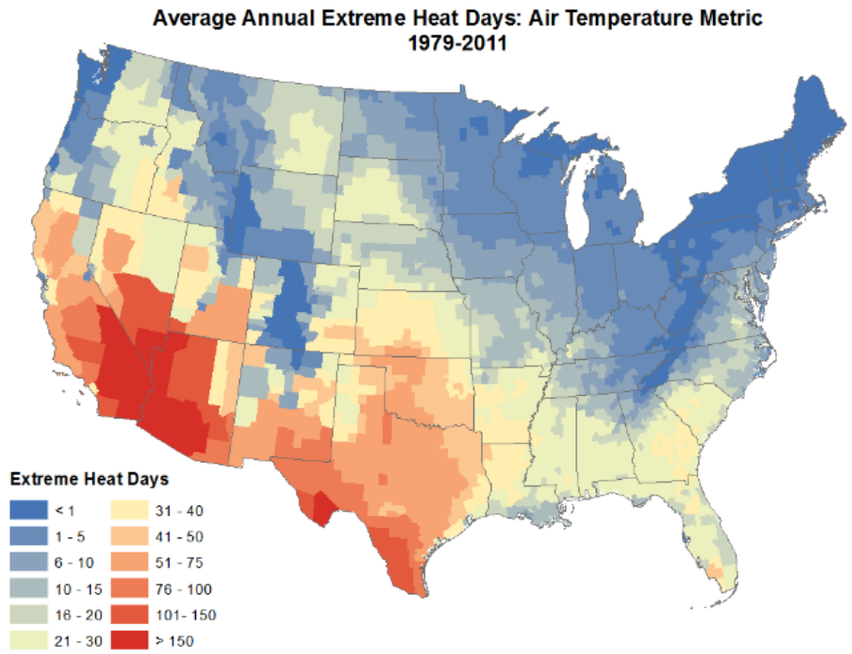
Decomposing the Population Effect

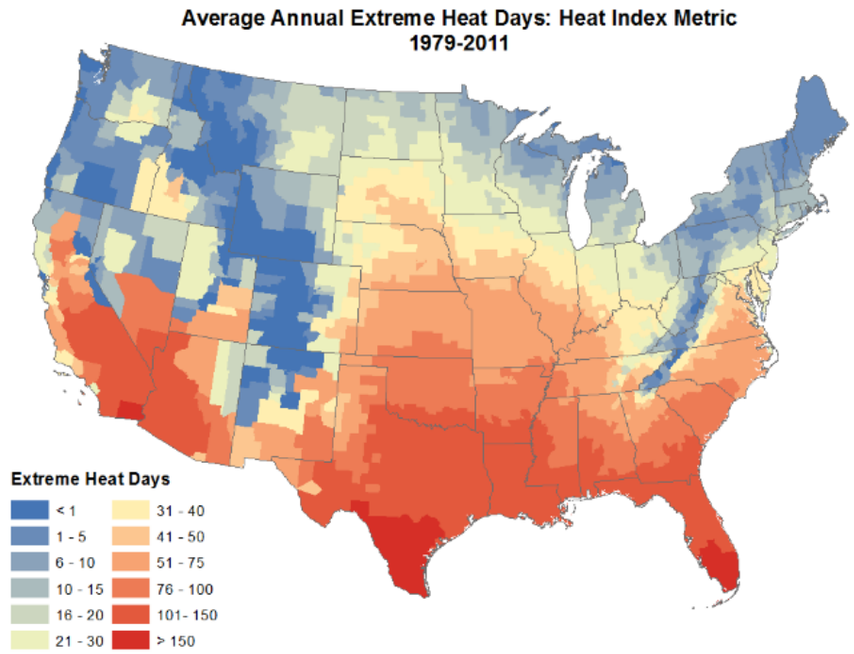
Including higher resolution estimates of the urban heat island effect may increase importance of local change.

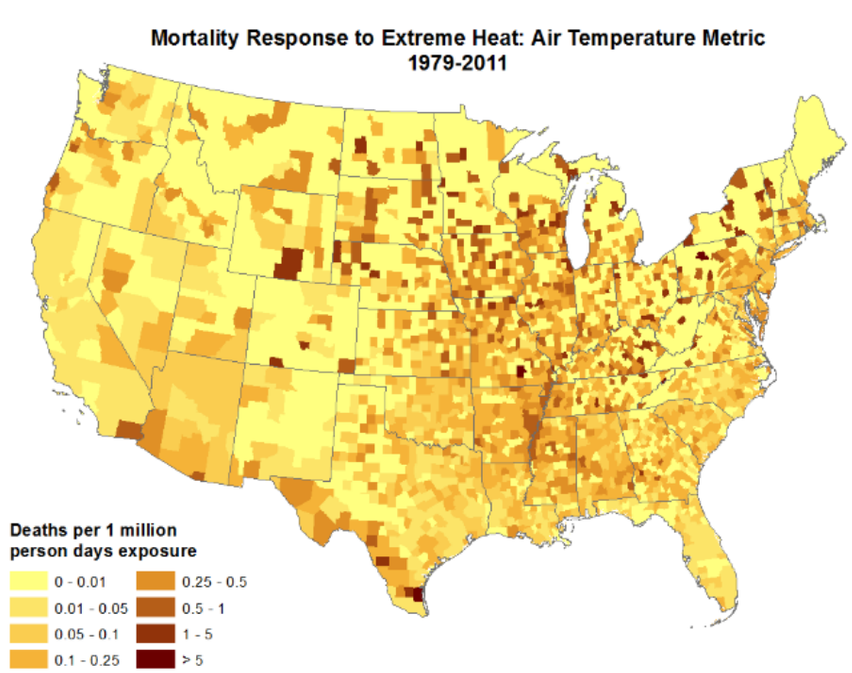
- Aggregate growth
- Broad redistribution (migration)
- Local Redistribution (urban/spatial structure)

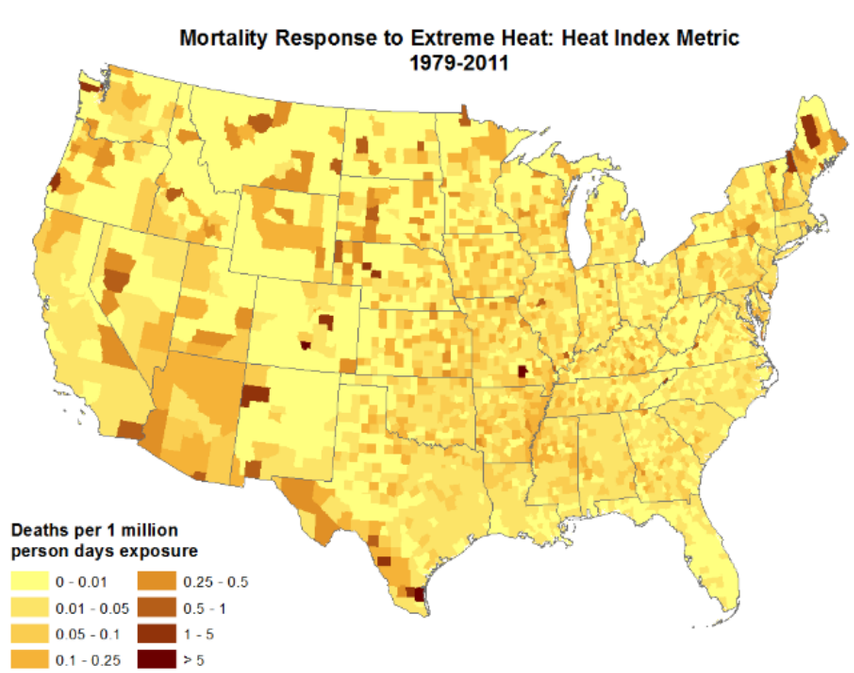


Ongoing Work: Alternative Heat Extremes and Mortality









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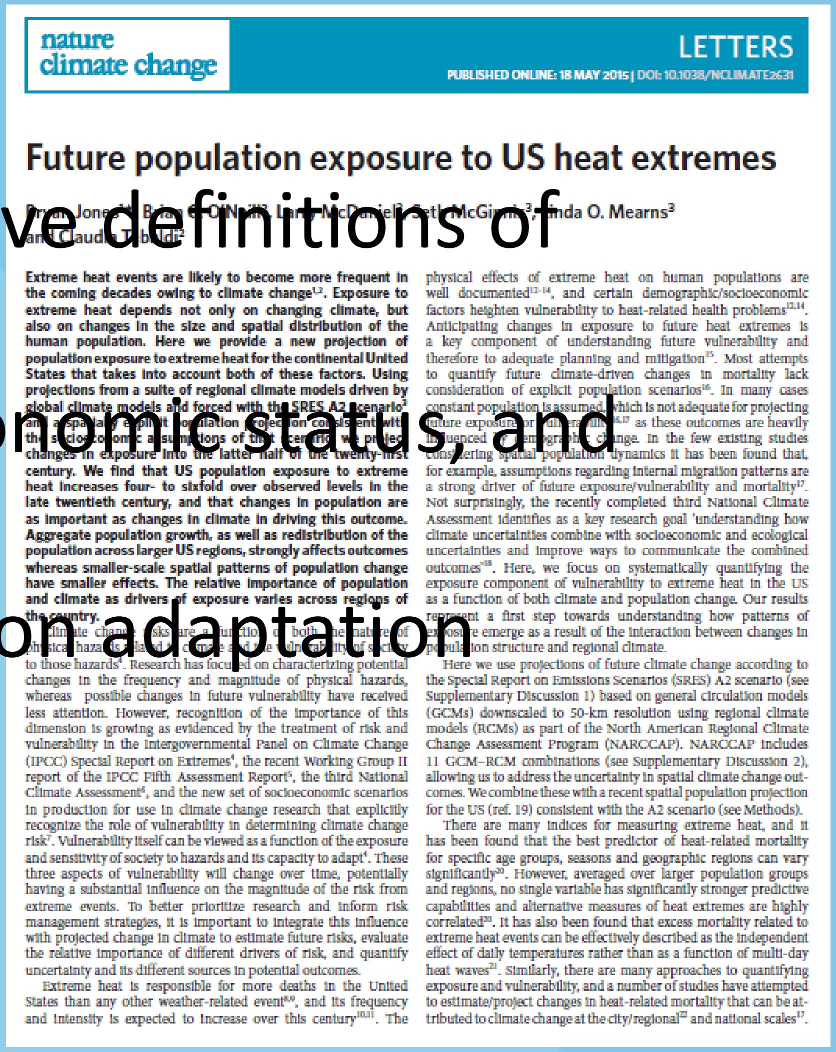
Conclusions and Ongoing Work

- A four to sixfold increase in exposure to temperatures above 35°C is projected over the next 40 years.
- Population and climate change both contribute significantly.
- There is significant regional variation in both exposure and its drivers.
- Aggregate population growth and broad population redistribution drive the population effect.

- Global exposure
  - Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) combinations
  - CESM climate projections (29-member ensemble)
  - SSP-based spatial population scenarios
- Extreme-heat mortality
  - Mortality response to exposure (alternative definitions of extreme heat)
  - Impact of population structure, socio-economic status, and mitigation strategy
  - Probabilistic mortality projections based on adaptation assumptions


nature climate change
LETTERS
PUBLISHED ONLINE: 18 MAY 2015 | DOI: 10.1038/NCLIMATE2631

Future population exposure to US heat extremes

[illegible] Linda O. Mearns[3] and Claudia [illegible][2]

Extreme heat events are likely to become more frequent in the coming decades owing to climate change[1,2]. Exposure to extreme heat depends not only on changing climate, but also on changes in the size and spatial distribution of the human population. Here we provide a new projection of population exposure to extreme heat for the continental United States that takes into account both of these factors. Using projections from a suite of regional climate models driven by global climate models and forced with the SRES A2 scenario[3] and a spatially explicit population projection consistent with the socioeconomic assumptions of that scenario, we project changes in exposure into the latter half of the twenty-first century. We find that US population exposure to extreme heat increases four- to sixfold over observed levels in the late twentieth century, and that changes in population are as important as changes in climate in driving this outcome. Aggregate population growth, as well as redistribution of the population across larger US regions, strongly affects outcomes whereas smaller-scale spatial patterns of population change have smaller effects. The relative importance of population and climate as drivers of exposure varies across regions of the country.

[illegible] to those hazards[4]. Research has focused on characterizing potential changes in the frequency and magnitude of physical hazards, whereas possible changes in future vulnerability have received less attention. However, recognition of the importance of this dimension is growing as evidenced by the treatment of risk and vulnerability in the Intergovernmental Panel on Climate Change (IPCC) Special Report on Extremes[4], the recent Working Group II report of the IPCC Fifth Assessment Report[5], the third National Climate Assessment[6], and the new set of socioeconomic scenarios in production for use in climate change research that explicitly recognize the role of vulnerability in determining climate change risk[7]. Vulnerability itself can be viewed as a function of the exposure and sensitivity of society to hazards and its capacity to adapt[4]. These three aspects of vulnerability will change over time, potentially having a substantial influence on the magnitude of the risk from extreme events. To better prioritize research and inform risk management strategies, it is important to integrate this influence with projected change in climate to estimate future risks, evaluate the relative importance of different drivers of risk, and quantify uncertainty and its different sources in potential outcomes.

Extreme heat is responsible for more deaths in the United States than any other weather-related event[8,9], and its frequency and intensity is expected to increase over this century[10,11]. The physical effects of extreme heat on human populations are well documented[12–14], and certain demographic/socioeconomic factors heighten vulnerability to heat-related health problems[12,14]. Anticipating changes in exposure to future heat extremes is a key component of understanding future vulnerability and therefore to adequate planning and mitigation[15]. Most attempts to quantify future climate-driven changes in mortality lack consideration of explicit population scenarios[16]. In many cases constant population is assumed, which is not adequate for projecting future exposure [illegible] as these outcomes are heavily influenced [illegible] change. In the few existing studies considering spatial population dynamics it has been found that, for example, assumptions regarding internal migration patterns are a strong driver of future exposure/vulnerability and mortality[17]. Not surprisingly, the recently completed third National Climate Assessment identifies as a key research goal 'understanding how climate uncertainties combine with socioeconomic and ecological uncertainties and improve ways to communicate the combined outcomes'[18]. Here, we focus on systematically quantifying the exposure component of vulnerability to extreme heat in the US as a function of both climate and population change. Our results represent a first step towards understanding how patterns of exposure emerge as a result of the interaction between changes in population structure and regional climate.

Here we use projections of future climate change according to the Special Report on Emissions Scenarios (SRES) A2 scenario (see Supplementary Discussion 1) based on general circulation models (GCMs) downscaled to 50-km resolution using regional climate models (RCMs) as part of the North American Regional Climate Change Assessment Program (NARCCAP). NARCCAP includes 11 GCM–RCM combinations (see Supplementary Discussion 2), allowing us to address the uncertainty in spatial climate change outcomes. We combine these with a recent spatial population projection for the US (ref. 19) consistent with the A2 scenario (see Methods).

There are many indices for measuring extreme heat, and it has been found that the best predictor of heat-related mortality for specific age groups, seasons and geographic regions can vary significantly[20]. However, averaged over larger population groups and regions, no single variable has significantly stronger predictive capabilities and alternative measures of heat extremes are highly correlated[20]. It has also been found that excess mortality related to extreme heat events can be effectively described as the independent effect of daily temperatures rather than as a function of multi-day heat waves[21]. Similarly, there are many approaches to quantifying exposure and vulnerability, and a number of studies have attempted to estimate/project changes in heat-related mortality that can be attributed to climate change at the city/regional[22] and national scales[17].

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