The Effects of Climate Change on Temperature-Related Mortality in New York City

ABSTRACT

Heatwaves cause significant increases in the average daily mortality of a region and thus pose a serious and growing public health risk, particularly in the context of anthropogenic climate change (Kalkstein & Greene, 1997; Kovats & Hajat, 2008; Meehl & Tebaldi, 2004). Although net winter mortality currently exceeds that of summer, rising global average temperatures may cause increases in heat-related mortality that will not be offset by declines in cold-related mortality. This study uses temperature, dew point, and mortality data from 1987 to 2000 in New York City to develop a model projecting daily temperature-related mortality anomalies and predict how climate change may affect daily mortality in the 21st century. The resulting model was run on seven general circulation models from the years 2020-2080; an analysis of the developed model's projections shows a significant overall increase in annual temperature-related mortality, suggesting a need to address the rising risk of extreme heat caused by climate change.

BACKGROUND

Climate Change, Heat Waves, and Mortality

- By 2100 alone, a net increase of up to 12 ° F in the U.S. is expected[2].
- **High temperatures are the primary weather-related cause of human death**. Notably, the European heatwave of 2003 caused 70,000 heat-related mortalities[3]
- Although the number of winter deaths exceed that of summer, **current climate projections suggest a higher frequency of longer and more severe heat waves in the future, with a lower frequency of extreme-cold events**[4].
- Despite the danger posed by heat waves, "best practice guidelines had not been developed…until recently,"[5] **suggesting the need for additional investigation on the potential impact of future heat waves**.

How Do Humidity and Heat Cause Death? High humidity inhibits the evaporation of the body's sweat, impairing the regulation of body temperatures[5] and potentially inducing lethal hyperthermia[6]. High temperatures place a strain on other systems in the body, leading to seemingly unrelated causes of death[7].

General Circulation Models (GCM): GCMs are used to project changes in our climate; they numerically simulate our climate system by numerically describing atmospheric, oceanic, and land surface processes.

QUESTION AND HYPOTHESIS

Question: How will climate change affect temperature-related mortality in a climate with high temperature and humidity in the summer, but cold temperatures in the winter over the 21st century?

Hypothesis: Given projected changes to our climate (namely a higher frequency of severe heat waves), **it is suspected that that rising average global temperatures may result in decreases in extreme cold events and cold-related mortality, yet this effect will be unable to compensate for corresponding increases in heat-related mortality.**

METHODS

Observational Data Sources:

- Dew point, temperature, and mortality data were used from a period of 1987 to 2000 in New York City. Observational mortality data was from the Health Effects Institute Research Report. Dew points and temperatures were from a National Oceanic and Atmospheric Administration (NOAA) station at LaGuardia Airport.

Adjustments to Observational Mortality and Climate Data:

- A moving average of the daily mean temperatures was calculated with a lag of 5 to account for the effect of multi-day heatwaves, rather than singular hot days.
- In order to identify mortality anomalies (mortalities above the norm), it was necessary to account for the seasonal cycles in mortality and the significant decrease in mortality from 1996 and onwards (Figure 1).
- **Mortality anomalies were defined as the observed mortality subtracted by the smoothed mortality (with a lag of 30).**

METHODS (CONT.)

Model:

- Multiple ordinary least squares (OLS) linear regression **was used to create two models for the climate-mortality relationship—one for summer (Jun, Jul, Aug) and one for winter (Dec, Feb, Jan).**
- Observational mortality/climate data for the summer and winter was split into a training and testing set, with an **80:20 ratio**.

GCM Data Source: Seven GCMs were used for climate projections from the years of 1987to 2000 and 2020 to 2080. The temperature and dew point projections were adjusted using the same methods as specified for the observational data.

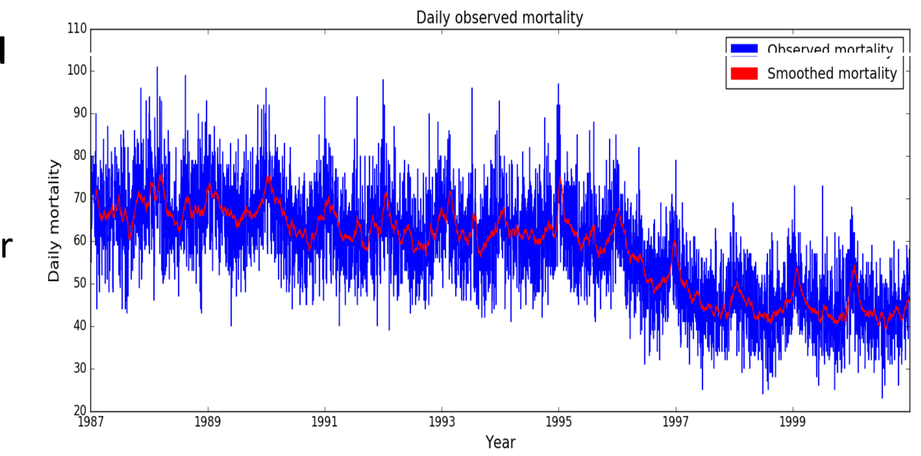

Figure 1. Daily observed mortality over time

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Simply put:

- **Explanatory (Independent) Variables: Temperature and Dew Point**
- **Dependent Variable: Mortality**

RESULTS

Results of Preliminary Analysis:

- Applying simple linear regression to climate data shows that **seasonal minimum winter temperatures are increasing faster than daily or seasonal mean or maximum temperatures.**
- **Mortality anomalies increase at both hot/cold extreme temperatures, regardless of the length of the temperature event. Extreme hot temperatures result in larger mortality anomalies than cold temperatures**. See Figure 3: each day in a cold/hot event has a mean temperature that is either above or below thresholds ranging from the 5th to 100th temperature percentiles.

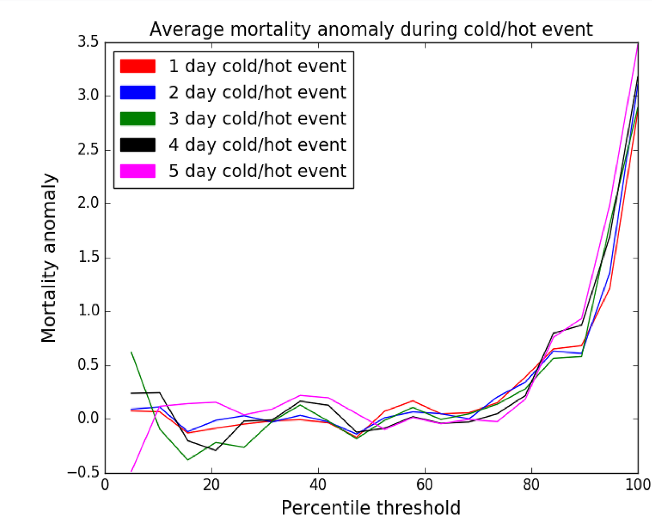

Figure 2. For percentiles of 50% or above, thresholds are a minimum temperature. For percentiles below 50%, thresholds are a maximum temperature.

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Model Development and Projections:

- **Summer Model:** Summer model was trained with mortality and climate data from summer days for which the mean temperature was above the 95th percentile of observational temperatures. **Training the model with both temperature and dew point data greatly improves the variability of projected mortality values (Figure 3).**
- **Winter Model:** All winter climate and mortality anomaly data was used. Data selection below a specific percentile was found to be infeasible, as temperatures rose too quickly in GCM projections for 2020-2080 for there to be sufficient data points under a reasonable temperature threshold.

- Changing which portion of data was selected for the training set significantly altered the model's projections for mortality anomalies.
- A positive relationship for summer and a negative relationship for winter between temperature/dew point and mortality, was found to be statistically significant. ($p < 0.003$ and $p < 0.04$, respectively).
- The resulting summer and winter models were run on each of the seven GCMs' climate projections, over the intervals 1987-2000 and 2020-2080. Total mortality anomalies of the season were summed for each year (Figure 4).
- The relative difference between summer and winter mortality anomalies was calculated by subtracting projected winter mortality anomalies from projected summer mortality anomalies (See Figure 4 for example with *one* GCM).

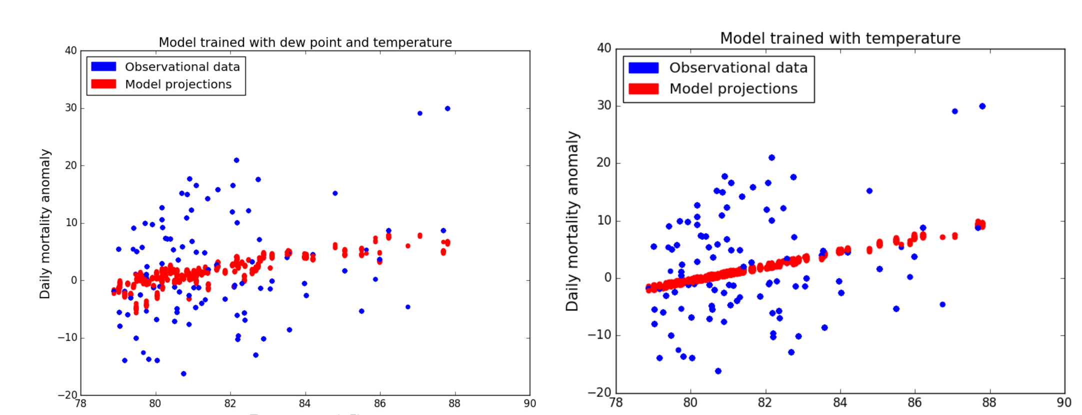

Figure 3. Result of running model on testing set. Blue indicates observational data and red indicates model's projections using the same (blue) observational climate temperature data.

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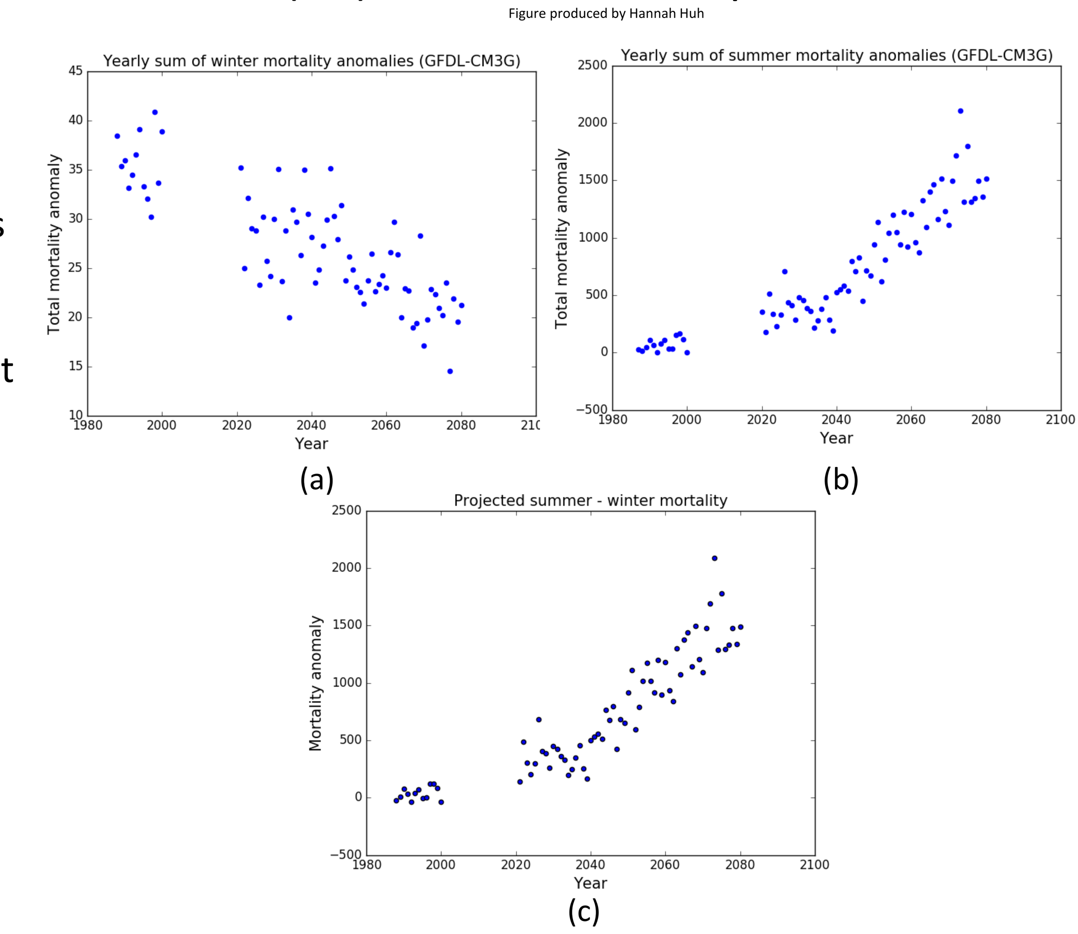

Figure 4. Using climate projections from a GCM (the GFDL-CM3G model) yearly sum of cold-related (a.) mortality and heat-related (b.) mortality. (c.) shows total winter temperature-related mortalities subtracted from total summer temperature-related mortalities.

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RESULTS (CONT.)

GCMs: Over time, the variability across the seven GCMs' average temperature projections increases. This rising uncertainty is likely due to an amplification of the differences between the GCMs, which can include different climate sensitivities, or responsiveness to greenhouse gas concentrations such as carbon dioxide.

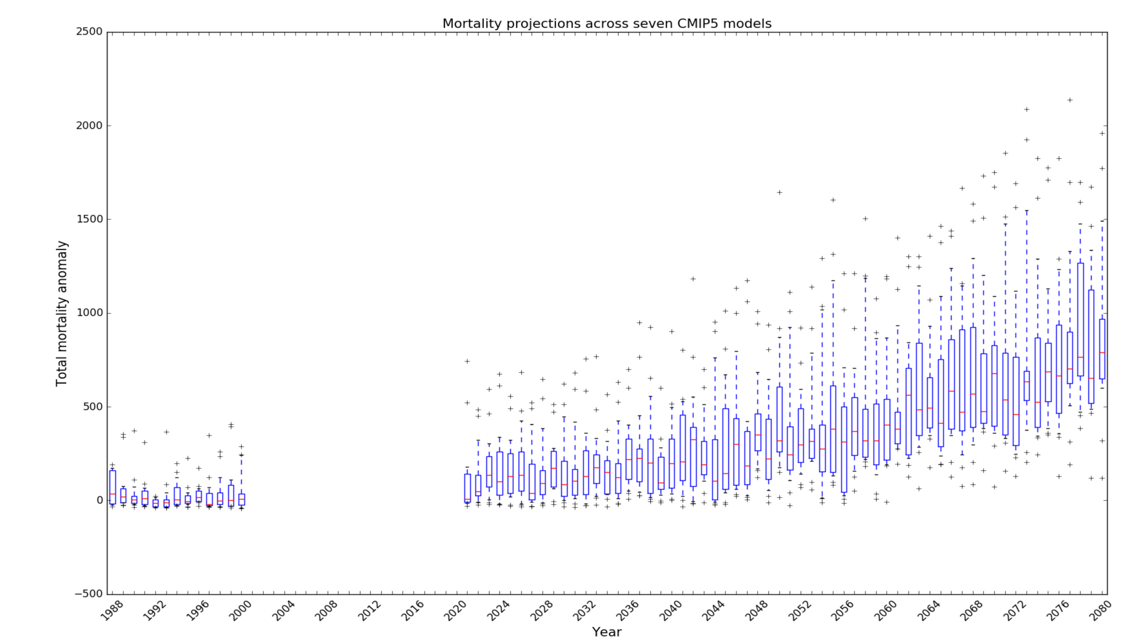

Figure 5. Model's yearly total mortality projections cross all climate models, compiled into boxplots; Whiskers are calculated to the 10th and 90th percentiles

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Mortality Projections: My model's projections show that although decreases in cold-related mortality are significant, they will be unable to compensate for the rise in excess deaths caused by extreme heat. This was found to be true across all projections run on the seven GCM models (Fig 5); note that the variation in mortality projections increases with time, due to the increasing uncertainty across GCMs. **The projected increase in mortality over time demonstrates a significant rise in annual heat-related mortality, indicating our hypothesis is likely true.**

DISCUSSION AND CONCLUSION

Potential factors that may indicate the model's projections are an overestimation are:

1. The CMIP5 models assume a worst-case scenario based on the current trajectory of our climate; future greenhouse gas emissions could potentially decrease.
2. The model's behavior was impacted by the starting and ending points of the intervals of its training set and was limited by the size of the training data set.
3. Populations may adjust to the increasing extreme heat over time, either through their own behavior or physiological acclimatization[6].

A significant limitation to this study was due to the size of the available data set. Mortality data was only available from 1987-2000. Another primary challenge was developing a model that could capture the variability in mortality (Figure 3); the same temperature can result in very different mortality anomalies. Incorporating additional climate data may result in a more robust model. Additionally, given the unpredictability of weather on a small scale and various health-related, environmental, economic, cultural, and geographic factors that will affect mortality, further study of the temperature-mortality relationship is needed.

This research predicts a sharply rising rate of change in heat related mortality during the latter part of the 21st century, indicating that we will encounter an urgent public health hazard in the future and further, highlighting the importance of additional investigation of the climate-mortality relationship.

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