The Impact of Heat Waves on Mortality in Belgium

Aksoy Bariş, Becerra Contreras Mario, Ismail Hameed Mohammed Saif,
Martínez Rea David, Tsibart Anna, Zdravković Aleksandra

1 Introduction

Over the past decades, a number of studies have been focused on the heatwaves, defined as prolonged periods of high temperature. The topic has received considerable research attention because of adverse effect on the human health and reported excessive mortality rates. These effects were reported for different locations and climates. Moreover, in future the negative effects of heat waves are expected to increase due to climate change and growing urban population, which is more exposed to the heat waves effects.

Belgium has one of the highest level of population density and urbanization among European countries, which makes it prone to a high mortality during the heat wave episodes. Moreover, Belgium has a high spatial variation in elevation levels from coastal flat area in the east to the hilly Ardennes region in the south, which potentially could result in uneven heat wave spatial distribution and different effect on mortality rates.

Therefore, the objective of this project is to analyze the temporal and spatial trends in heat waves and to identify the heat wave effect on the mortality rates in Belgium.

2 Data collection and wrangling

The main datasets used in this work were first cleaned and processed as follows:

- Population data: We obtained yearly population data which was then transformed into weekly and daily population data using a linear interpolation per arrondissement. The data were obtained from the Statbel website (`https://statbel.fgov.be/`).
- Mortality Data: This dataset was kindly created by the people at Statbel. They created an ad-hoc table with our requirements. They could only share weekly data per arrondissement due to privacy. Hence, we had a time series of weekly mortality counts for the period 2000-2019 in the 43 administrative arrondissements in Belgium, separated by natural or other type of death. This data was merged with the interpolated weekly population data.
- Coordinates and shapefiles for arrondissement: This data was acquired from the Digital Atlas of Belgium (`atlas-belgique.be`)
- Temperature Data: Daily temperature data (minimum, maximum, and average) was retrieved from the Agri4Cast resource Portal (`agri4cast.jrc.ec.europa.eu`) for the period of 1980-2020. The JRC MARS Meteorological Database contains meteorological observations from weather stations interpolated on a 25×25 km grid. The coordinates of the centroid of each arrondissement were taken and the temperature of the closest point of the grid was assigned to this centroid.

After preprocessing, the three datasets were joined by using Python's library `pandas`. The join was performed by arrondissement, year, and week and by using the function merge of `pandas`. For reading and processing the spatial data `geopandas` package was applied.

3 Modeling

The modeling is based on Gasparrini and Armstrong (2011) and on Gasparrini, Armstrong, and Kenward (2012). Particularly, the latter paper sought to come up with a two-stage statistical analysis of temperature data and mortality in 20 cities of the USA over 13 years. We followed the same approach for the 20 year data in all 43 arrondissements in Belgium.

In the first stage of the modeling, a spline-based quasi-Poisson model for over dispersed data is applied to each of the 43 arrondissements, using the number of deaths as response variable. This first stage of the model intends to find an association between the number of deaths and a variable of exposure (temperature) while controlling for confounding variables (seasonal and long-term trends, as well as day of the week). This association is done through a generic function $s(\cdot)$, which in this case is a B-spline in order to derive non-linear association between mortality and climatological and time covariates. This first stage of modeling also estimated a variance-covariance matrix S_i for each $i \in \{1, ..., 43\}$ corresponding to each arrondissement.

The first stage of the modeling returns a vector of parameter estimates, denoted by $\hat{\theta}_i$ for each $i \in \{1, ..., 43\}$, which are then used as outcome in the second stage of the process. Particularly, the estimates are combined using multivariate meta-analysis within the context of a multivariate normal linear mixed model. As in conventional meta-analysis, the goal is to obtain a set of regression coefficients that define an average exposure–response association across the cities.

4 Results and discussion

4.1. Trends in heatwaves

A clear increasing trend in terms of both heat frequency and heat intensity was observed in Belgium. In 1980-s the average annual number of heatwave episodes varied from 0.5-1.5 and in 2010-s it reached 1.5-2.5 depending on the geographic location. Average intensity, which was defined as the average temperature above the local threshold during the heatwaves (°C) changed from 0.5-1°C till 1.5-2°C withing four decades. These findings are in line with the global trends reporting the acceleration of trends in heatwave frequency, duration and cumulative heat have.

In the period of 1980s-2000s no consistent trends in the spatial variation of heat waves was detected. However, during the last decade of 2010s we observed the highest heat stress in the inland areas in the eastern part of the country. This part of the country is furthest from the coastal line and experienced the lack of cooling effect. Despite the proximity to a coastal, the northern flat areas in the last decade also had high intensity of heatwaves. The possible explanation was the abundance of sandy soils in these areas. They are prone to soil moisture depletion which increases the air temperature through land-atmosphere interaction.

The comparison of the Brussels arrondissements and surrounding area (arrondissement Leuven), did not result in identification of the urban heat island. Therefore, the resolution of available data was too coarse to represent the evolution of temperatures in cities.

4.2. Mortality and heat waves

The first-stage generalized linear model described in Section 3 was fitted to the data from each arrondissement. The vectors $\hat{\theta}_i$ and variance-covariance matrices S_i are then pooled across cities in a multivariate meta-analysis. All the models are fitted through maximum-likelihood estimation. The model indicates an increase in risk for non-accidental mortality for both low and high temperatures, with a steep increase at high temperatures. Additionally, the model can be used to obtain city-specific estimates. We find that the arrondissements of Virton, Phillipeville, Dinant, Tielt, Maaseik, and Aalst seem to have a more-than-average increase in mortality with higher temperatures than the rest of the arrondissements.

5 Application

Findings from the Section 3 and 4 are visualized in an app made using Python packages `plotly` and `dash`.

Conclusions

- The heat waves frequency and intensity increased over 4 decades in Belgium.
- The inland regions (south, south-east of Belgium) are more prone to the heat waves.
- The model shows that there is an increase in the relative risk of death with an increasing temperature. This increase seems to be stronger in certain arrondissements like Virton, Phillipeville, Dinant, Tielt, Maaseik, and Aalst.

References

Gasparrini, A., & Armstrong, B. (2011). The impact of heat waves on mortality. *Epidemiology (Cambridge, Mass.)*, *22*(1), 68.

Gasparrini, A., Armstrong, B., & Kenward, M. G. (2012). Multivariate meta-analysis for non-linear and other multi-parameter associations. *Statistics in Medicine*, *31*(29), 3821-3839. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1002/sim.5471 DOI: https://doi.org/10.1002/sim.5471