Metrics for the Air Health Indicator Project

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Background: What is the AHI?

- Health Canada has recently developed the Air Health Indicator (AHI) to assess the effects of short-term exposure to outdoor air pollution on population health risk
- The AHI is part of the Canadian Environmental Sustainability Indicators (CESI) program

Why is the AHI important?

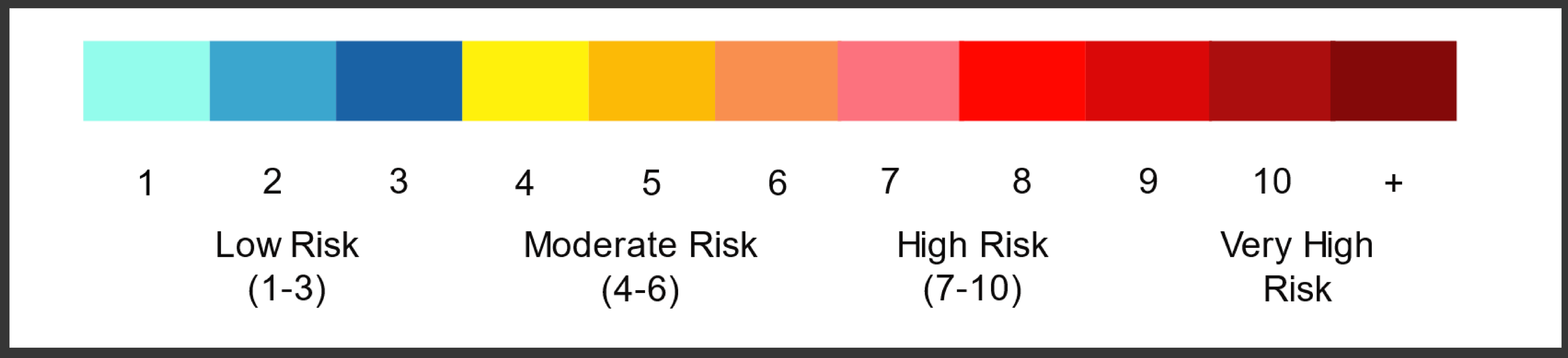
- Canadians are exposed to outdoor air pollution sources, such as transportation and industrial activities, on a daily basis. These sources can contribute to the onset or worsening of many medical issues, such as difficulty breathing, lung diseases, or even heart attacks and strokes
- The onset or worsening of these medical issues affects all Canadians: this leads to increased volume in doctors' offices and emergency rooms, and increased mortality rates. The AHI is important for minimizing these risks, and for increasing our understanding of how air pollutants affect human health
- The AHI can be used in policy creation, to ensure that Canadians' exposures to harmful pollutants are minimized
- Additionally, the AHI is an important tool for analyzing current policies, as it can be used to assess the impacts of air quality regulation policies in Canada

Objectives

- Previous AHI models have estimated health risks for individual air pollutants, so the aim of this study was to develop an advanced model to estimate the population health risk of multiple pollutants at the same time

The AHI vs. The AQHI

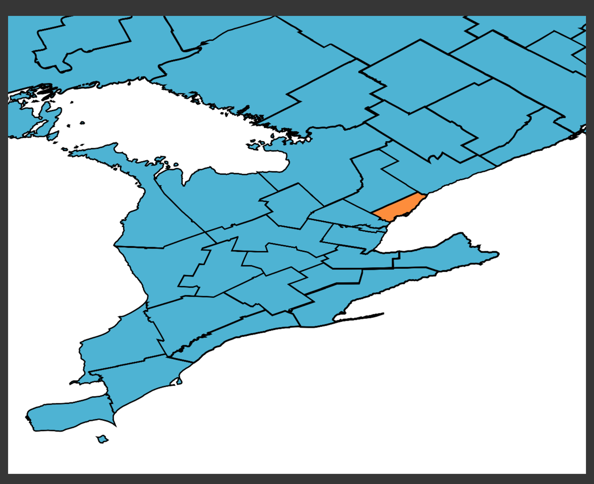
- The Air Quality Health Index (AQHI) measures the air quality on a scale from 1 to 10, where greater values correspond to greater health risks associated with air quality
- The AQHI is a tool designed to help those who are sensitive to air pollution (such as those with cardiopulmonary diseases) limit their short-term exposure to air pollution
- The AQHI is calculated based on Ozone (O_3), Fine Particulate Matter ($PM_{2.5}$, PM_{10}), and Nitrogen Dioxide (NO_2), and is reported for hundreds of regions across Canada on an hourly basis
- The AQHI assigns a category describing the level of health risk associated with the reading of the index, and provides valuable health messages for each category for both the general population and the "at risk" population
- Essentially, the AQHI is a scale aimed at a mass audience, and is designed for Canadians to make informed decisions about their exposure to air pollution, while the AHI is used by Health Canada to monitor the impacts of outdoor air pollutants on the health of Canadians over time



Current Developments: The O_x Method

In 2014, a new approach was published by Williams et al., for modeling multiple pollutants in risk models. The authors compared single-pollutant models for both O_3 and NO_2 to a new metric, "O_x", defined as O_3 + NO_2. They found that in London, England, the 24-hour mean O_x had a stronger association with mortality than either of the single pollutant models

Applying the O_x Method to Toronto, ON



To explore the idea of the O_x metric further, we investigated this metric for Census Division (CD) 3520, which is Toronto, Ontario. CD 3520 is highlighted in orange in the map to the left.

Methodology

- We created a data frame in R containing annual (1984-2012) risk coefficient estimates for each of the two pollutants we were interested in (O_3 and NO_2), along with annual average values for the lag-0 24-hour maximums of each pollutant. The head of the data frame now looked like this:

```
>head(toronto_combined, n = 2)
```

Year	kO3.24hm	kNO2.24hm	kO3.Estimate.quasi	kNO2.Estimate.quasi
1984	15.91407	27.47813	-0.0003258080	-1.556474e-03
1985	15.93018	27.28399	0.0005181281	1.762321e-03

- The next step was to try to create a new risk coefficient, by combining the two estimates (`kO3.Estimate.quasi and kNO2.Estimate.quasi`) in a sensible way
- We decided to take an AQHI-like approach, and create a coefficient that would be scaled from 0 to 10. In order for this to make sense, two negative coefficients should produce a new coefficient close to 0, while two large positive coefficients should produce a new coefficient close to 10
- Many different versions of this new coefficient were tested, but only a few were sensible in the way previously described

Our Three New Estimates

- If β_i represents the annual value of `Estimate.quasi` for the i^{th} pollutant, and x_i represents the annual average lag-0 24-hour maximum concentration of the i^{th} pollutant, then the first two estimates are:

$$\text{Estimate}_1 = \sum_{i=1}^{2} 100(e^{\beta_i x_i} - 1) \qquad \text{Estimate}_2 = \sqrt{\sum_{i=1}^{2} \beta_i^2}$$

- Let φ_i represent the scaled from 0 to 10 value of `Estimate.quasi` for the i^{th} pollutant. Then the third estimate is:

$$\text{Estimate}_3 = \frac{1}{2}\sum_{i=1}^{2} \varphi_i^2$$

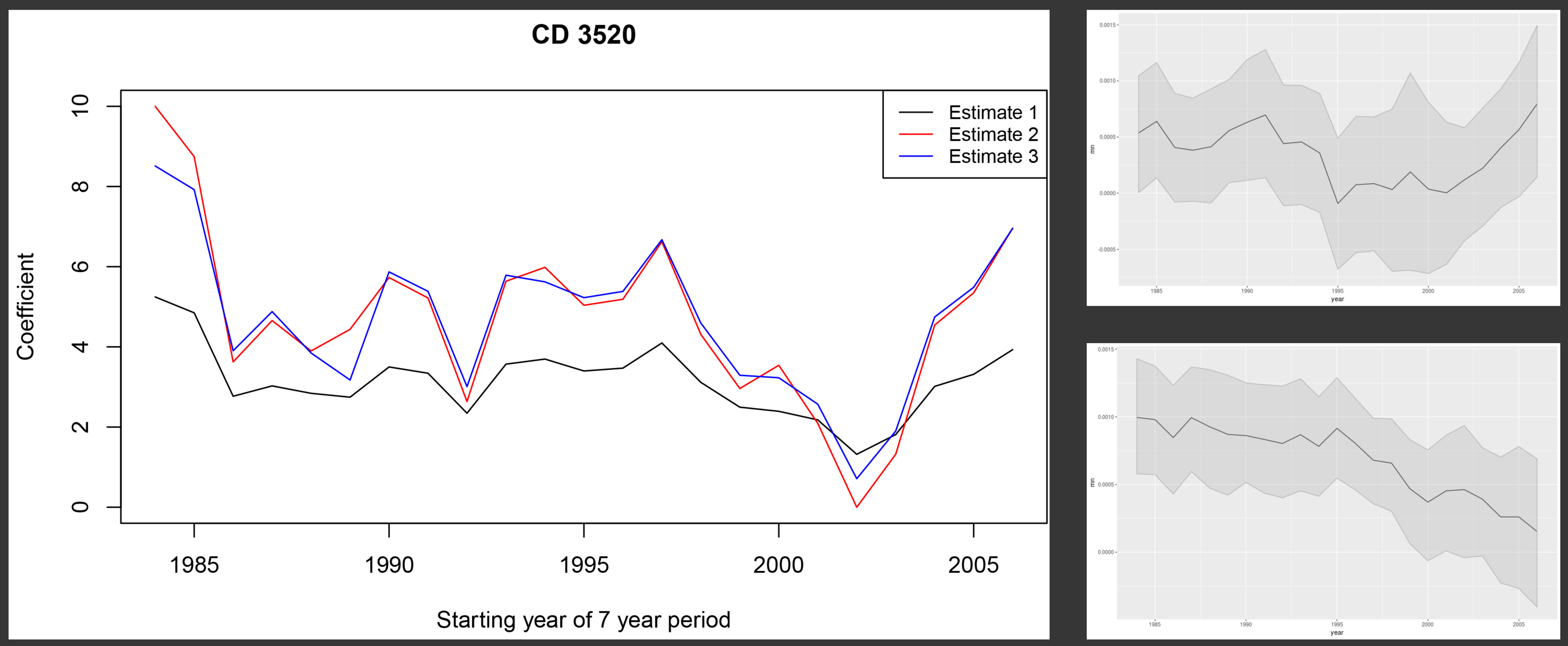


Figure 1: (Left) The three new O_x estimates over time for CD 3520 (Toronto, ON), calculated using 7-year blocks. The years shown in the figure are the starting years of the 7-year periods. (Top Right) Bayesian hierarchical model estimates for national risk due to NO_2 (24-hour mean lag-0) using All-cause All-age mortality. The year shown is the first year of the 7-year block. (Bottom Right) Bayesian hierarchical model estimates for national risk due to O_3 (max 8-hour mean, lag-1) using All-cause All-age mortality. The year shown is the first year of the 7-year block.

Conclusions

Through appeal to the AQHI formulation, we developed an aggregation metric for exposure to multiple air pollutants which allows for an estimate of national risk due to multiple pollutants simultaneously, replacing separate pollutant models which were unable to account for the interaction between the pollutants. Work continues on implications and performance of this new model.

References & Acknowledgments

M.L. Williams, R.W. Atkinson, H.R. Anderson, and F.J. Kelly. Associations between daily mortality in London and combined oxidant capacity, ozone and nitrogen dioxide. Air Qual Atmos Health, 7:407–414, 2014.

https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-health-ozone-fine-particulate-matter.html

https://www.canada.ca/en/environment-climate-change/services/air-quality-health-index/about.html

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