Natural Disasters and Their Impact in Canada

Melissa Van Bussel, Ankai Liu, Carlone Scott and Mark Weygang

Department of Mathematics and Department of Advanced Modelling and Quantitative Methods
Faculty Advisor: Wesley S. Burr

Abstract

A wide variety of natural disasters have occurred throughout the history of Canada, costing over 20 billion dollars and claiming over 55000 lives between the years of 1900-2014 alone. The frequency of these events has been increasing with time, and what was once rare may now be considered common.

This case study was conducted to determine how natural disasters have been changing over time in Canada, how they have been affecting diverse regions and groups of Canada differently, and whether or not any predictions can be made about future natural disasters and their effects on both Canadians and Canada itself.

The statistical language R was used to examine the dataset, to perform calculations, and to plot the data. In doing so, the packages `readr`, `ggplot2`, `lubridate` and `ggmap` were used. Population information were obtained from Statistics Canada and used for standardization of counts. All examinations discussed on this poster were completed graphically using exploratory data analysis, with the exception of a simple log-linear model which was fit to the normalized cost-per-person of historical Canadian disasters.

We exhibit patterns in the disasters showing large growth rates in both the occurrences and severity of events over time, in particular from the mid-point of the 20th century to the present. Both events which require evacuations and total evacuation numbers have increased dramatically, while fatalities have fallen steadily over time, a finding we attribute to increased funding and preparedness of emergency services.

Evolution of Disasters over Time

It is clear from a graphical examination of event frequency and severity over time that the impact of disasters is not stationary. From Figure 1 (Top Left), we see that incidence rates of disasters of multiple types increase rapidly from the midpoint of the 20th century. Figure 2 shows that the same increasing pattern appears for disaster subtypes wildfires, floods, and storms, but not droughts.

It is interesting that the three most rapidly increasing disaster types occur naturally. This dataset is restricted to disasters with significant human impact, so it is not possible to distinguish between increasing numbers due to changes in climate conditions and increasing numbers due to changes in human population density and habitation patterns.

From Figure 1 (Bottom two panels), we see that population-normalized fatalities are decreasing with time, while population-normalized evacuations are increasing. The same effect is seen in the raw counts (not shown). The population-normalization was done by start year of disaster event, using aggregate Canadian population.

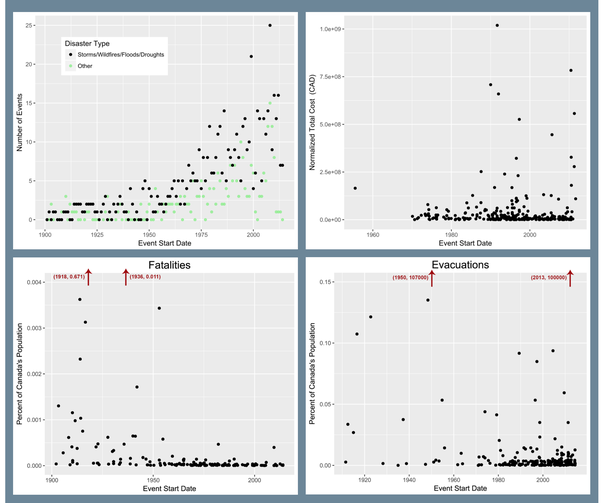

Figure 1: (Top Left) Total number of disasters for all of Canada, by year, split into two categories: wildfires/droughts/floods/all storms; and others. (Top Right) Total normalized cost, by event, for events with data available. (Bottom Left) Normalized (by time-dependent Canadian population) fatality rate by event. Note that two extreme disasters are not visible: 1918 Spanish flu (50,000 fatalities), 1936 heat wave (1180 fatalities). (Bottom Right) Normalized (again by time-dependent Canadian population) evacuation rate by event. Note that two extreme evacuations are not visible: 1950 Manitoba flood (107,000 evacuations), 2013 Alberta flood (100,000 evacuations).

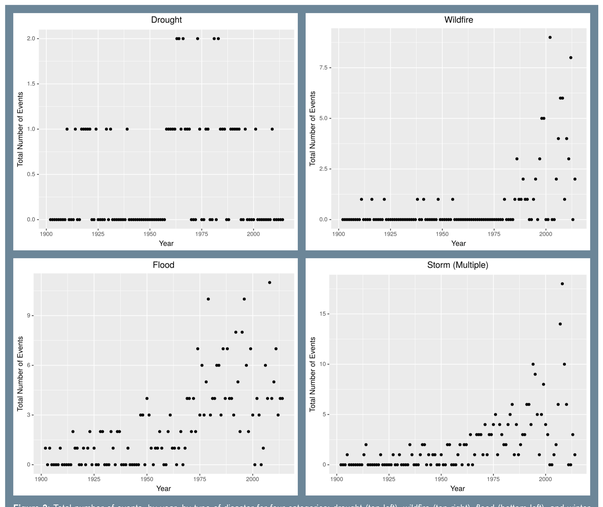

Figure 2: Total number of events, by year, by type of disaster for four categories: drought (top left), wildfire (top right), flood (bottom left), and winter storms/severe thunderstorms/hurricanes/other (bottom right).

If we examine the occurrence of floods and wildfires with at least one death or evacuation, by month, we see (Figure 3) that wildfires with this characteristic occur largely in the summer months, and almost entirely after 1970. In addition, deaths due to wildfires in the database are largely before 1970. This may indicate the benefits of modern detection and firefighting techniques at controlling the spread and speed of wildfires. The top facet of Figure 3 shows floods in a similar way, with floods occurring more often in the spring, and a different pattern to evacuations and fatalities, presumably because swimming is easier than walking through fire. In addition, while there may be more flood events happening recently, there is not the same (obvious) pattern of increasing evacuations.

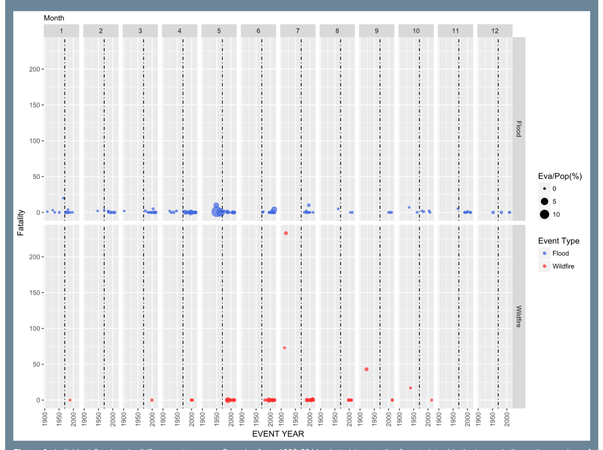

Figure 3: Individual flood and wildfire events across Canada, from 1902-2014, plotted by month of start date. Vertical axes indicate the number of fatalities associated with the individual events, while the size of the points represent the population-normalized evacuations of the same. In this case, the population-normalization is done by province/region of the event's occurrence. For each month sequence, the vertical dot-dashed line indicates 1970, a convenient break-point in the time evolution, as seen in Figures 1 and 2.

Impact Across Regions

To consider fatalities by province, we must consider that populations have changed dramatically from 1902-2014. We obtained provincial and territorial population information from CANSIM, as well as population information for the Dominion of Newfoundland prior to 1949.

To compare the deaths representatively, we normalized fatality counts to population-standardized rates, by year of the start date of the disaster, using the population of the province or territory that the event occurred in.

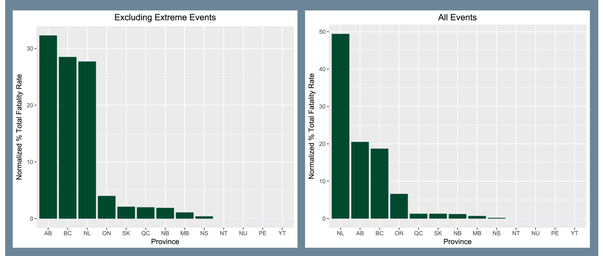

Figure 4: Two presentations of the aggregate total normalized fatality rate, across the data set. Each event is normalized using the population of the province the event occurred in for the year of the start date. The rates are then aggregated by province, and standardized as percentages of the whole. (Left) The normalization applied to all events in which a fatality occurred, excluding events which had more than 100 fatalities. (Right) The normalization applied to all events in which a fatality occurred.

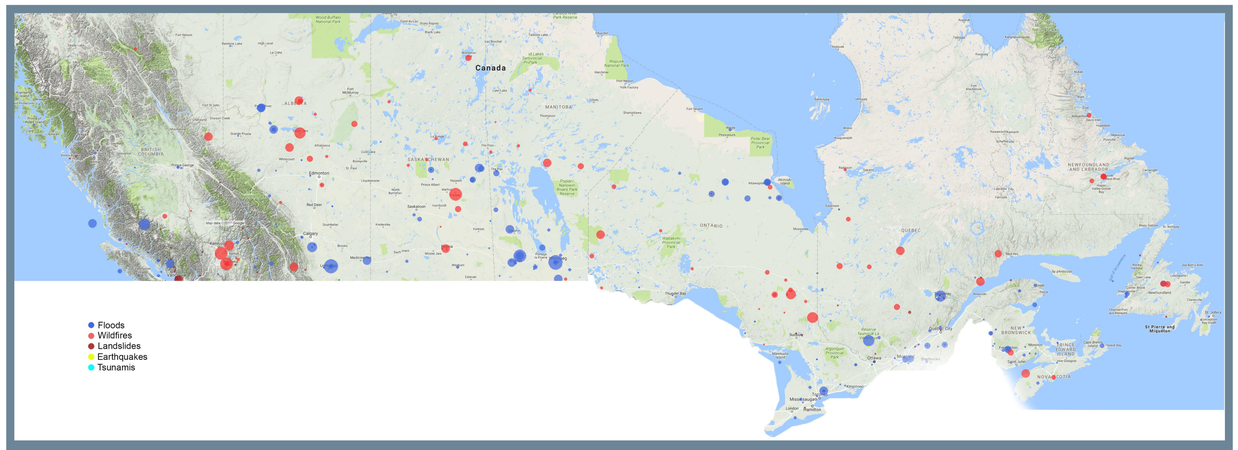

Figure 5: All natural disaster events for which there were evacuations that occurred in the southern provinces of Canada from 1900-2014. Each point on the map represents an individual disaster, and is placed on the approximate location of where the event took place. The size of each point corresponds to the number of evacuations for the individual event. Note: while all event type categories are plotted on the map, only those which had many evacuations (floods, wildfires, landslides, earthquakes, and tsunamis) are visible due to the relationship between the size of points and their associated number of evacuations.

Figure 5 shows the distribution of all events requiring evacuation across the provinces of Canada. The results are as expected: the majority of floods have occurred near waterways and lakes, and the majority of wildfires have occurred in areas of forest. Figure 5 also demonstrates that the event types which are most likely to require large evacuations of the population are floods and wildfires, followed by landslides, earthquakes, and tsunamis. It can also be seen that most of the natural disaster events throughout Canada's history (1900-2014) which have required substantial evacuations have happened in the lower parts of Canada.

It Is important to note that large numbers of evacuees does not necessarily imply that an event was severe. As was seen in Figure 1, the number of evacuations for an individual event has been increasing over time; likely due to increased preventative measures.

The results are shown in Figure 4, for all such events (Right) and excluding extremes (Left). What these results show is that, historically, certain regions of Canada have been disproportionately affected with respect to the number of fatalities from natural disasters.

The difference in the two facets of Figure 4 is largely dominated by the fact that three of the six extreme loss-of-life single-province disasters in Canadian history (1902-2014) occurred as storms in Newfoundland.

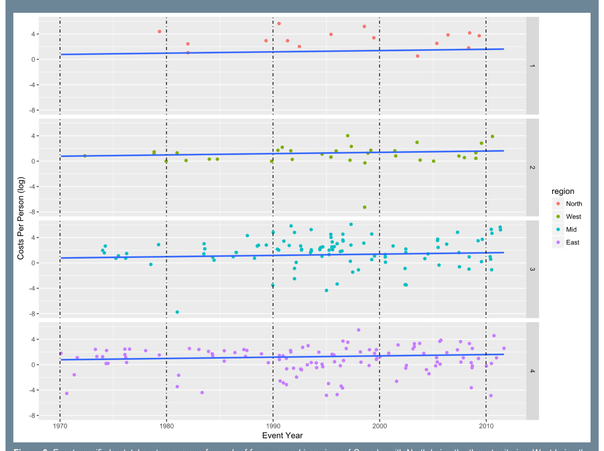

Figure 6: Event-specific log-total-cost-per-person for each of four geographic regions of Canada, with North being the three territories; West being the three prairie provinces and BC; Mid being ON and QC; and East being the Maritimes. The blue line is a log-linear fit to the entire aggregate set of costs per person, by year. The normalization is done by standardizing by the population of the region that each event occurred in.

In Figure 6, we examine the characteristics of disasters restricted to geographic sub-regions of Canada. The blue log-linear fit line was fit to the entire set of log-costs-per-person. Thus, we see that disasters in this database have above average costs for the territories, while both the Mid (ON, QC) and East (Maritimes) provinces exhibit more variability in their normalized costs. Historically, it appears that the 1990s had a large number of above-average costing disasters for the Mid provinces.

In honour of our conference location, we did a closer examination of historical floods and wildfires for the province of Manitoba (Figure 7). We see from this figure that floods occur at the south of the province, at the bottom of a watershed, while wildfires occur to the north, further from the large bodies of water. The majority of the evacuations occur in a single cluster near Winnipeg at the bottom of the watershed running through the Red River.

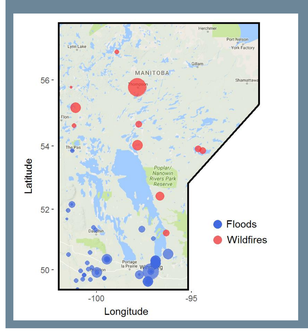

Figure 7: All evacuations due to wildfires and floods for the province of Manitoba, from 1902-2014. Each point represents a single event, with the size of each point representing the number of evacuees.

Impact in the Future

From Figures 1 and 2, we saw that incidence rates of wildfires, floods, and storms have been increasing steadily since the mid 20th century. While the growth rate appears to be exponential, it does not seem reasonable to expect this growth rate to continue, unless we expect weekly wildfires, floods, and storms. It is scientifically accepted that anthropogenic climate change is a reality, and one of the implications of climate warming is increasing *variability* in climate and the accompanying disasters. For example, 100-year floods have been occurring frequently over the last several decades in a number of areas of Canada. However, the Canadian government is aware of this increasing variability and it is common in the news to see announcements of remediation and prevention efforts. Thus, while Figure 6 might suggest that exponentially increasing costs are a reality for the future, preventative efforts may mitigate the worst of these effects. In addition, it is probable that some of the increasing costs are not due to climate change and changes in disaster frequency, but rather due to increased urbanization and population density in areas of Canada vulnerable to these disasters.

One positive finding from this exploration is that fatalities due to natural disasters appear to have been mitigated through the latter half of the 20th century, likely due to increasing preventative measures, early warning systems, and advances in technology. Thus, predicting increased deaths due to natural disasters does not seem reasonable, given the historical trends and the current societal support for funding preventative measures. One exception to this is not shown on this poster: biological natural disasters have occurred more frequently in recent years than for quite some time historically. The advent of H1N-strains of virulent flu may continue to challenge Canada's public health system, as SARS in 2003 and the H1N1 (swine) flu epidemic of 2009 showed.

References & Acknowledgments

Statistics Canada. Table A2-14, Population of Canada, by province, census dates 1851 to 1976. https://goo.gl/PmpkGQ

Statistics Canada. CANSIM: Table 051-0001, Estimates of Population, by age group and sex, for July 1, Canada, Provinces and Territories. https://goo.gl/aQKITE

Melissa Van Bussel is supported by the Trent University *Dr. Alicja and Dr. Gosia Zobel Student Conference Fund* and *NSERC* via the USRA program.