How does climate change affect heat-related mortality in British Columbia?

Chin Yang Shapland, Eunice Lo, Nick Leach, Éric Lavigne, Kate Tilling and Dann Mitchell

MRC Integrative Epidemiology Unit, University of Bristol, Oakfield House, Bristol, BS8 2BN

Introduction

The exposure to heatwave have been shown to be associated with adverse human health. Due to anthropogenic climate change, extreme heat events are becoming more frequent. To note, between 28th and 30th of June 2021, Pacific Northwest (PNW) have experienced a record-breaking temperature of 49.6 °C. British Columbia Coroners Service has estimated 619 deaths attributed to this single heatwave event and significant increase in number of visits to emergency department.

The temperatures observed in the PNW heatwave 2021 have not been realized and deemed "impossible" from conventional statistical models in attribution, however weather forecast models were able to predict this extreme heatwave event. This reason motivated Leach *et al*. (2024) to propose a forecast-based approach to extreme event attribution, in which they were able to successfully predict the PNW heatwave event.

Quantifying the health impact attributable to anthropogenic greenhouse gas emissions have played an essential role towards lower income countries seeking financial compensation towards loss and damages from climate change and in climate litigation.

Our aim is to provide a reliable estimate of heat-related deaths under "pre-industrial", "current" and "future" scenario, derived from novel approach to extreme event attribution.

Method

Mortality data: To model the exposure-response relationship, we used daily death counts and daily mean temperature between 1981 and 2015, for British Columbia (BC), Canada.

Heatwave attribution data: We used data simulated via forecast-based approach. By perturbing the boundary and initial conditions to forecast scenarios; "pre-industrial" (without anthropogenic influence), "current" and "future". We extracted the three, seven- and 11-days lead times from, ending in the heatwave peak period of 2021 (28th to 30th of June). 11 days lead-time has 251 ensemble members, the other lead-times had 51.

Modelling exposure-response relationship: Distributed lag nonlinear models (DLNM) was used to model the delayed and nonlinear relationship between daily mean temperature and all-cause mortality;

$$\log[\mathrm{E}(Y_t)] = \alpha + \mathrm{f}(x_t;\boldsymbol{\theta}) + \sum_{k=1}^{2} \gamma_k u_{tk}. \qquad (1)$$

Our outcome Y_t will be death counts at day t, x_t is mean temperature and z_t is days of the week at day t. Function $\mathrm{f}(x_t;\boldsymbol{\theta})$ specifies the association with x_t, i.e. mean temperature x at day t and accounting for three days of lagged-response.

The model includes confounders, u_{tk}, days of the week, long term trends and seasonal effects.

Attributable deaths from heatwave: Calculated attributable deaths, D_{HW}, with average temperature extracted from heatwave attribution data;

$$D_{HW} = D_E\left(1 - e^{-(f^*(T_{fore};\theta^*) - s^*(T_{MM};\theta^*))}\right),$$

where D_E is the expected daily deaths counts (averaging daily mortality across 1981 to 2015), T_{fore} and T_{MM} is the daily mean temperature from the heatwave attribution data and minimum mortality temperature, respectively. f^*, s^* and θ^* is derived from Equation (1).

Heatwave attribution

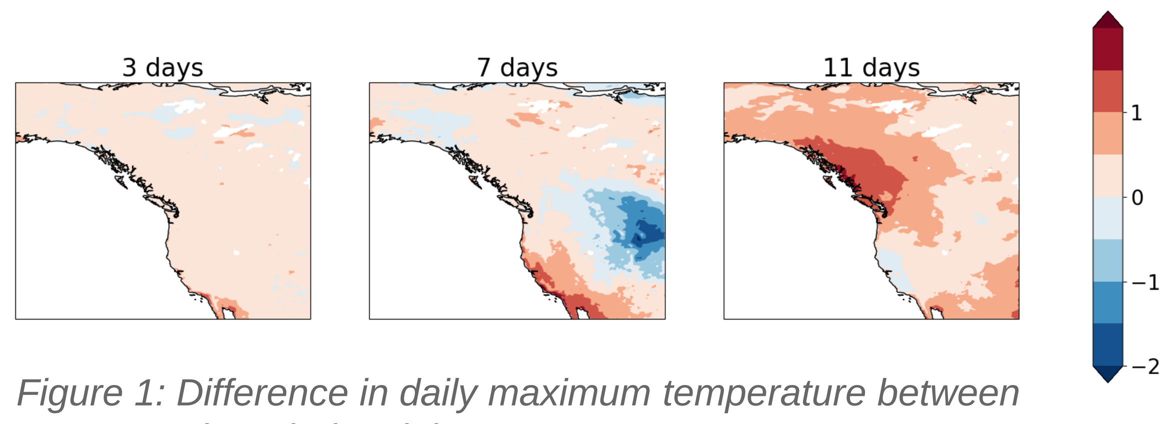


Figure 1: Difference in daily maximum temperature between current and pre-industrial.

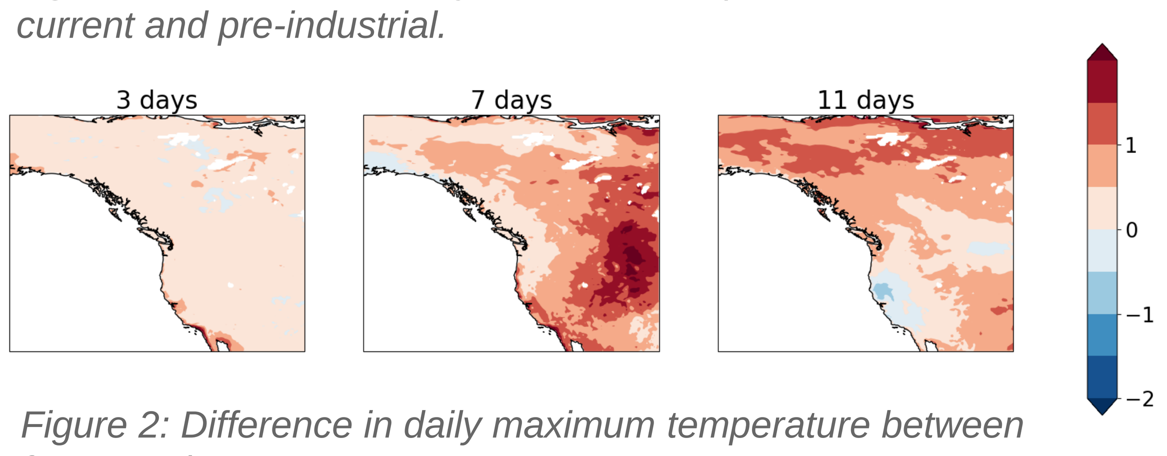


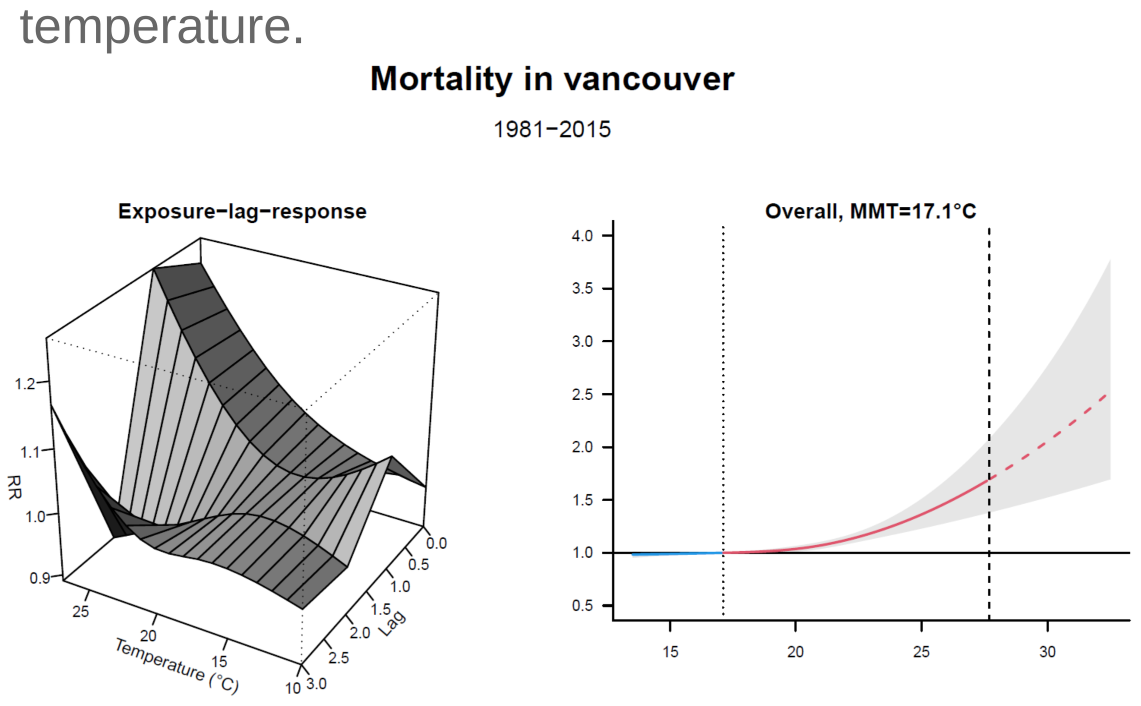
Figure 2: Difference in daily maximum temperature between future and current.

Figure 1 shows forecasting with current climate conditions is hotter than forecasting with pre-industrial conditions. Figure 2 shows air temperatures are hotter with future climate conditions than with current climate conditions.

The further away from the actual predicted date (26th -30th of June 2021), the more extreme the difference between current and pre-industrial, and between future and current.

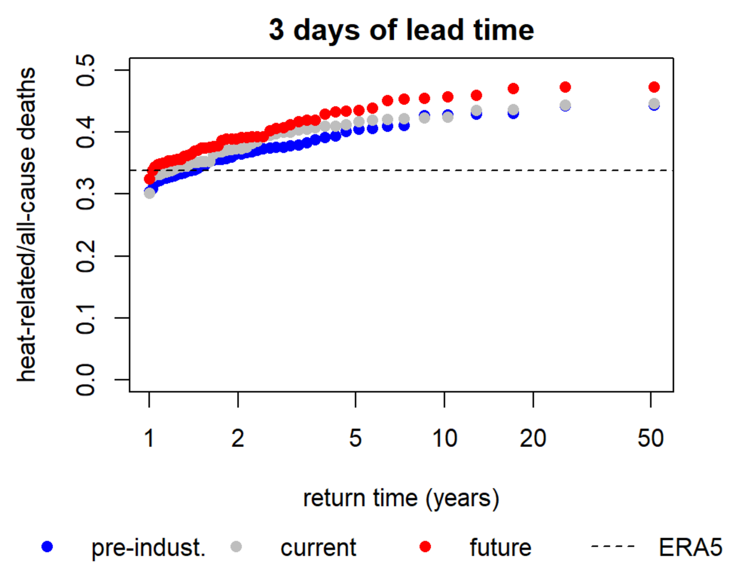
Exposure response

In Vancouver, demonstrates increased in mortality as daily average temperature rises (Figure below). The minimum mortality temperature is at 17.1°C (dotted vertical line), the relative risk exponentially increases to 1.60 (95% CI:1.34-1.91) when daily average temperature is risen to 27°C. Curve beyond the dashed vertical line is the exploration of maximum observed temperature.

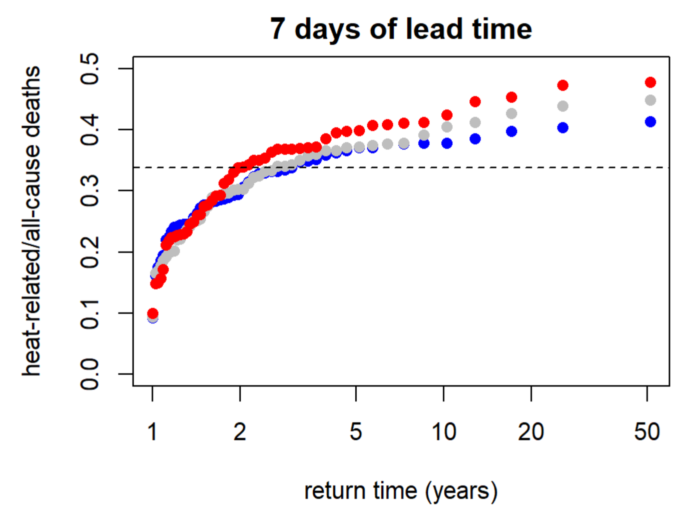


Abbotsford has also shown an increase in mortality with rising temperature. There is no evidence of an effect of temperature on mortality in Lytton or Victoria.

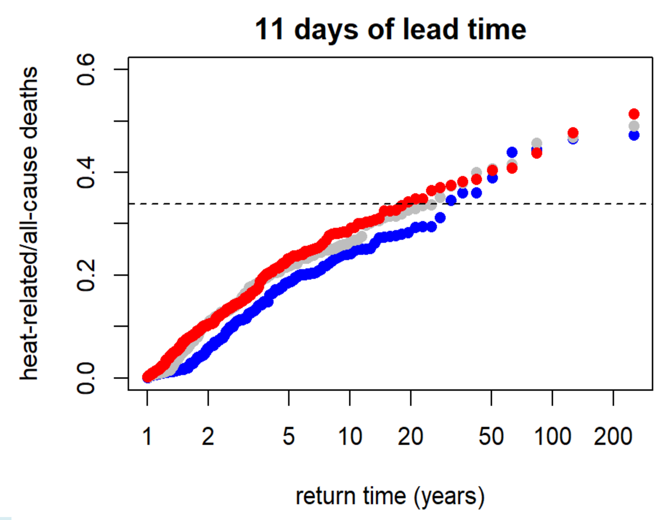
Health attribution



Most of the ensemble members have correctly predicted the observed (dotted horizontal line) proportion of heat-related mortality in the expected all-cause mortality (3 days lead time). 1 in 5 chance that 41% of mortality is caused by heat in pre-industrial, 42% and 44% for current and future climate, respectively.



For seven days of lead time, 1 in 5 chance that 37%, 37% and 40% of mortality is heat-related for pre-industrial, current and future climate.



For 11 days of lead time, 1 in 5 chance that 19%, 22% and 23% of mortality is heat-related for pre-industrial, current and future climate.

Key messages

- Evidence for rising temperature causing increasing in number of deaths in BC.
- Lower mortality is estimated without anthropogenic climate change ("pre-industrial") in comparison to "current" climate condition and higher heat-related mortality in "future" climate without mitigation.
- Evidence of a relationship between temperature and mortality in Vancouver and Abbotsford but not for Lytton or Victoria, could be due to limited mortality data, or genuine difference between cities (e.g. city heat-dome effects).
- We have demonstrated how to use climate attribution data to predict heat-related deaths attributable to anthropogenic climate change.
- This work can provide evidence financial claims for loss and damages from climate change and in climate litigation.

Acknowledgements

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