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Extreme cold weather alerts in Toronto, Ontario, Canada and the impact of a changing climate

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The extreme cold weather alerts (ECWAs) were examined for Toronto, Canada for the winters of 2004–05 to 2011–12. ECWAs are triggered by extreme cold temperature, wind chill and intense winter precipitation. Just over 40% of the ECWAs occurred when the temperature fell below a −15 °C threshold. All but two of the alerts had a wind chill below −15 °C. The use of a −10 °C threshold captured well the frequency of wind chill events with half the −10 °C or lower events meeting the wind chill threshold. The modified −10 °C threshold and the −15 °C threshold were subsequently used to first assess how well climate models reproduced contemporary climate conditions, as well as three projection periods (2020s, 2050s, 2080s) to assess the impacts of a changing climate. The climate models reproduced current conditions well. In all projection cases the frequency of occurrence of events below the two thresholds decreases throughout the projection period but do not completely disappear. Interannual variability of projected events indicates a range of frequencies with some years similar to the contemporary climate. This suggests that thermal and wind driven ECWAs will continue for Toronto under climate change scenarios, although with gradual decreasing frequency.

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1. Introduction

Climate change has been communicated often in the first instance as a global mean temperature change. Such a representation, while simple to present, is less simple to understand in terms of lived experience which is closely tethered to local spatial and temporal scales (Gough, 2008). The projected warming of 1.5–4 °C (Trenberth et al., 2007) for example is the type of variation that is experienced and often exceeded diurnally, seasonally and annually. Thus, the implications of such apparently small changes needs further unpacking. One way is to examine extreme events and their frequency of occurrence. This type of analysis has become increasingly the focus of both climate change detection and climate change projection (Easterling et al., 2000; Bonsal et al., 2001; Frich et al., 2002; Vincent et al., 2005; Vincent and Mekis, 2006; Brown et al., 2008; Griffiths and Bradley, 2007; Huang et al., 2010; Mohsin and Gough, 2014; Allen et al., 2014), as an increase in the frequency and intensity of climate extremes can have significant implications for a variety of societal applications, including public health, infrastructure and biophysical systems (Parmesan et al., 2000; Haines et al., 2006; WMO, 2009). Cold events, for example, have significant impacts on human health. Mortality rates have been found to significantly increase with extreme cold events (Huynen et al., 2001; Medina-Ramón and Schwartz, 2007).

Various studies have focused on occurrences of extreme events and consistently reported fewer extreme cold events on global and regional scales (Alexander et al., 2006; Griffiths and Bradley, 2007). Understanding the nature and trajectory of such climate events is critical for urban governments to implement effective public health response systems. In this work, we examined extreme cold events for Toronto, Ontario, Canada, through the analysis of the Extreme Cold Weather Alert (ECWA) system, which has been in operation in Toronto since 2004.

Climate extremes, often defined as associated with the tail of a probability distribution, are typically measured through a given threshold and the number of times this threshold is exceeded (WMO, 2009). Cold weather extremes, in particular, may be measured through various climatic indices, including threshold exceedances, frost days (number of days Tmin < 0 °C), icing days (number of days Tmax < 0 °C), and cold spell duration index (e.g., six consecutive days of Tmax < 10th percentile) (City of Toronto, 2012a; ETCCDI/CRD, 2012). At times, specific thresholds are altered, depending on the purpose of the study. Medina-Ramón and Schwartz (2007) defined extreme cold events as days where Tmax is less than or equal to the 1st percentile. Other studies have examined cold extremes through cold waves, where the Tmin of six consecutive days have negative deviations of at least 5 °C from the normal value of each calendar day (Sanchez et al., 2004).

For public warning systems, cold alerts are typically based on threshold exceedances of a specific temperature value rather than percentiles. England, for example, has implemented a four-level cold alert system based on a threshold of Tmean less than 2 °C for 48 h or longer; and the occurrence of significant snowfall/ice. In 2011, several states (e.g., South Dakota, North Dakota, and Minnesota) in the USA implemented the extreme cold alert system based on whether temperatures were less than −34.44 °C (−30 °F) (NOAA, 2011). However, the alert systems in these states reverted back to the previous warning system in 2012, which is based on a wind chill threshold of −31.67 °C (−25 °F) (NOAA, 2012). In Toronto, an ECWA is invoked when minimum temperatures (normally occurring at night) are forecast to be −15 °C or lower without wind chill; when a wind chill warning of −15 °C or below is issued; and when extreme weather events (e.g., blizzard, ice storm or sudden drops in temperature) are forecasted (City of Toronto, 2012a). The declaration of an ECWA enables resources to be made available largely to assist the city's homeless population in finding shelter; reducing health risks to extreme cold. Toronto's public health response includes opening up additional shelter spaces, relaxing shelter restrictions, and providing transportation to shelters (City of Toronto, 2012a). In 2009, the homeless population for Toronto was estimated to be over 5000 people, 400 of whom were sleeping outdoors (City of Toronto, 2012b). It is this latter group that is targeted by the ECWA emergency response, as they are significantly more vulnerable to cold events (Hwang, 2001).