3B.2 EXPLORING UNCERTAINTIES IN CLIMATE CHANGE HEALTH IMPACTS

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1. INTRODUCTION

Statistical studies have demonstrated strong positive relationships between indicators of heat stress and human mortality (Hajat *et al.* 2002, Rainham 2000, Smoyer *et al.* 2000a, 2000b; Kalkstein 1993; Kalkstein and Davis 1989; Chestnut *et al.* 1998). Anthropogenic climate change is generally expected to increase the frequency, duration and severity of heat stress conditions in many regions (Chiotti *et al.* 2002, McCarthy *et al.* 2001, Zwiers and Kharin 2000, Delworth *et al.* 1999, Kalkstein and Green 1997). The magnitude of change is subject to considerable uncertainty as these results are based on a limited number of case studies using different methods and climate change scenarios or models—not to mention the difficulties associated with understanding potential human adjustments, socio-economic or policy responses over the course of the next century. Accordingly, the IPCC (McCarthy *et al.* 2001) and many researchers (e.g., Katz 2002) are emphasizing the improved treatment of uncertainties when estimating the potential impacts of climate change.

This paper examines the implications of using different techniques and methodological assumptions to develop climate change scenarios for one indicator relevant to human health—heat stress days (HSD) as defined by thresholds of daily minimum and maximum temperature. The choice of emission scenario or experiment, climate model, base climate period, base climate station(s), and use of downscaling procedures are compared in terms of projected HSDs for Toronto, Canada.

2. DATA AND ANALYSIS PROCEDURES

2.1 Heat Stress Indicators

Several indices have been developed to assess the combined effects of high temperature and humidity on people. Humidex (Masterton and Richardson 1979), apparent temperature or heat index (Steadman 1979) and synoptic classifications (Kalkstein *et al.* 1998) are among those frequently used in epidemiological research and as a basis for issuing heat-related weather advisories in Canada and the United States.

The objective of this study is not to debate the merits of particular indices but rather to take a simple indicator and examine issues related to its application in studies of anthropogenic climate change. Smoyer *et al.* (2000b) examined the effects of heat stress in five southern Ontario cities, including Toronto, over the period 1986-96 and observed significant statistical relationships between elderly (>64 years) daily mortality and HSDs, defined as a day with a peak hourly apparent temperature greater than 32°C. The Toronto data suggest that a reasonable proxy for this threshold is a daily maximum dry bulb temperature greater than or equal to 30°C and a corresponding daily minimum temperature of at least 20°C. This indicator will be referred to as HSD throughout the remainder of the paper.

2.2. Climate Data and Scenarios

Daily temperature data were obtained for three Greater Toronto Area (GTA) observing stations: Toronto (located downtown), Toronto Island Airport (located on a Lake Ontario island just a few km from downtown) and Lester B. Pearson International Airport (located just northwest of the City of Toronto).

Coupled general circulation models of the atmosphere and ocean (AOGCMs) are the only credible tools presently available to quantitatively estimate the transient global climate response to scenarios of future greenhouse gases, sulphate aerosols and other elements that affect climate forcing (IPCC-TGCIA 1999). The Canadian Climate Impact Scenarios Project provided AOGCM output averaged over an approximate 6° latitude by 8° longitude window centred on the Toronto area for several models and experiments. The data consisted of monthly temperature change factors corresponding to three future timeframes (2010-2039, 2040-2069, 2070-2099) relative to a 1961-90 base period.

These monthly change factors were applied to the daily time series, either directly or using the LARS-WG weather generator parameterized to one of the three observing stations (see Semenov *et al.* 1998). Stochastic weather generators such as LARS-WG are inexpensive computational tools that produce site-specific multiple-year climate change scenarios at the daily time scale, which incorporate changes in mean climate and climate variability as projected by coarse scale AOGCMs (Semenov and Barrow 1997).

Annual HSD counts were calculated for several scenarios and observing stations. These results, reported as 30-year or period-of-record statistics are described in the next section.

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3. RESULTS

3.1 Assumptions About Emissions

A major source of uncertainty with respect to modelled estimates of climate change relates to assumptions about future emissions. The climate scenarios used in this project were derived from experiments designed to test the impact of changing emissions and atmospheric concentrations of greenhouse gases (GHG) and sulphate aerosols. IPCC (2000) recently released an expanded set of 40 emission scenarios grouped into four families (A1,A2,B1,B2) having similar demographic, societal, political, economic and technological assumptions. A subset of these experiments (A2,B2), along with the previous IS92a standard experiment, were available from the Canadian Climate Impacts Scenarios Project (CCIS 2002) and incorporated into this analysis.

Climate change factors from these different emission scenarios, derived from output from the Canadian coupled climate model (CGCM2), were applied to LARS-WG generated time series for the Toronto (downtown) observing station. Resulting mean annual HSD frequencies and 95 percent confidence intervals (CI) for the base period and 30-year future time slices are presented in Figure 1. The different assumptions about GHG emissions begin to show by the 2050s. Towards the end of the century, HSDs under the A21 scenario are about twice as frequent as under the B2x scenario.

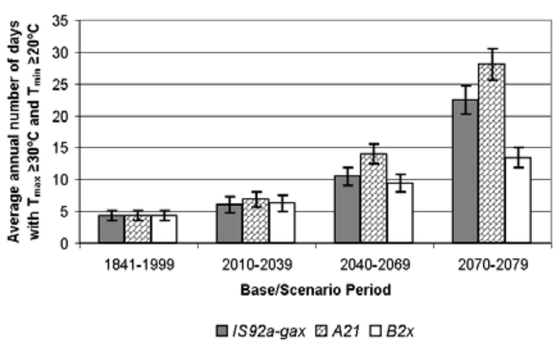

FIGURE 1 HSD comparison for three emission scenarios (CGCM2 model, Toronto time series)

3.2 Different Climate Models

Another source of uncertainty is related to the choice of AOGCM used to develop future climate scenarios. Each model is somewhat unique—for example with respect to parameterizations of climate processes, resolution, energy and moisture flux corrections, and translation of emissions into radiative forcing (for more information see Coupled Model Intercomparison Project 2002). Figure 2 illustrates the effects of these differences on HSD frequencies derived from CGCM2 and an Australian climate model (CSIROmk2b) for the A21 emission experiment. As with the emission comparison, changes are not substantial until the 2080s period when the CSIRO-based results exceed those for the CGCM2 by 17 days (61 percent).

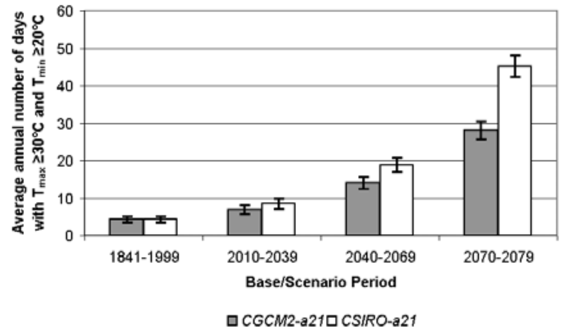

FIGURE 2 HSD comparison for scenarios derived from CGCM2 and CSIROmk2b climate models (A21 emission scenario, Toronto time series)

3.3 LARS-WG Parameterization Period Length

Downscaled climate projections for the Toronto station were generated by LARS-WG using two different parameterization periods—the full period of record (1841-1999) and a shorter period (1961-90) consistent with the 30-year AOGCM baseline. HSD comparisons are presented in Figure 3. Although the relative ratio of mean HSDs remains similar through each future scenario period, the absolute difference increases from about 4 during the 2020s to 12 by the 2080s.

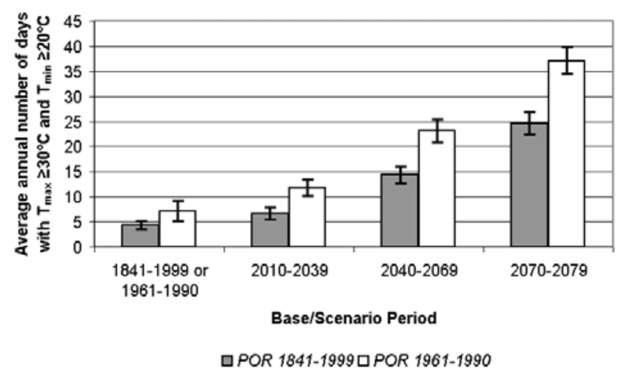

FIGURE 3 HSD comparison for two LARS-WG parameterization period lengths (CGCM2 model, A21 emission scenario, Toronto time series)

3.4 Choice of Base Climate Observing Station

As noted in section 2.1, HSDs were analyzed for three separate base climate observing stations: Toronto, Toronto Island Airport and Lester B. Pearson International Airport. The results demonstrate the importance of location—the impacts of climate change on HSD frequencies are markedly higher for the downtown Toronto station (Figure 4). Undoubtedly, the urban heat island, primarily through higher base minimum temperatures, elevates the Toronto statistics relative to the other locations within the GTA.

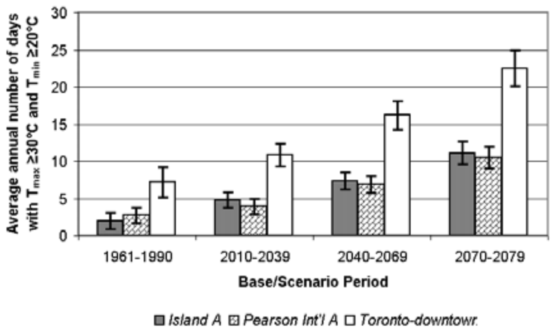

FIGURE 4 HSD comparison for different base climate observing stations (CGCM2 model, A21 emission scenario)

3.5 Simple Adjustment vs. LARS-WG

Many climate change impact studies completed prior to 2000 relied upon a simple technique for adjusting daily time series to generate a climate change scenario. Monthly change factors derived from AOGCM (or GCM) simulations were simply added (temperature) to or multiplied (precipitation) by daily data to produce a single new adjusted data set. Stochastic weather generators allow multiple randomly generated scenarios to be produced using the same change factors and thus permit more formal risk analysis. Although multiple scenarios were not yet available for this paper, it is important to note that estimates made using the simple approach (raw adjustment) adopted in past studies may be different from estimates generated through LARS-WG or similar downscaling tools (Figure 5).

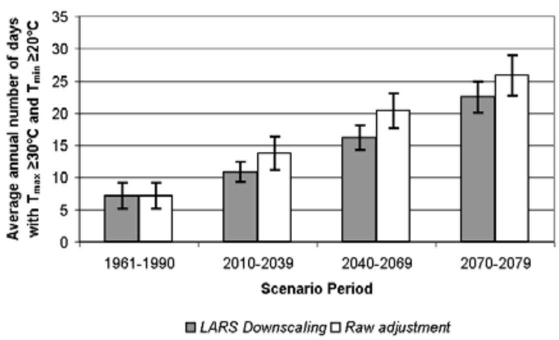

FIGURE 5 HSD comparison using LARS-WG and raw adjustment (CGCM2 model, A21 emission scenario, Toronto time series)

4. CONCLUSION

Uncertainty is a characteristic feature of all climate change impact assessments—in part due to the choices researchers make with regard to method and application of future climate change scenarios derived from AOGCM simulations. This paper demonstrated that the selection of emission scenario, climate model, base climate period, base climate station(s), and use of downscaling procedures significantly influence the estimated impacts of climate change on the occurrence of HSDs for Toronto. It is likely that the same observation may be made about more complex indicators and for other places. That said, all of the scenarios and methods examined support the conclusion that heat stress conditions will become much more frequent under anthropogenic climate change. The limited set of 2080s mean annual HSD estimates noted in this paper ranged from 10.5-45 (relative to a 4.5 baseline)—which could lead to a similarly wide range of human health outcomes.

Other, likely greater sources of uncertainty relate to the long-term interactions between heat stress and an ever-changing, mobile and acclimatizing human population. Future research will examine some of the socio-economic and policy aspects of uncertainty and will develop more quantitative risk estimates using LARS-WG and other downscaling tools.

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