Ontario's Climate in the 21st Century

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While we tend to think of climate as being constant, in fact it is always changing. Some changes follow patterns with extremely long time scales, such as the 21,000 year cycle of the precession of the earth's axis about the pole. Weather, in comparison, is by definition variable, and is the short-term (hours to months) variation of the atmosphere. Climate is the weather at some location averaged over a specified time period (typically 30 years) plus information on the variability and weather extremes. Climate, and its associated weather, influence the natural environment directly, through elements such as temperature and precipitation, and indirectly, through its influence on disturbance and permafrost. Any change in variability in climate could be critical because many of the ecological impacts of climate are the result of extremes. At the local scale, climate is influenced by variations in solar radiation due to latitude, distribution of continents and oceans, atmospheric pressure and wind systems, ocean currents, major terrain features, proximity to water bodies, and local features, such as exposure, local topography, and urbanization (see Trewartha and Horn 1980).

The "greenhouse effect" is the influence of gases such as carbon dioxide, water vapour and methane on the earth's radiation budget. The greenhouse gases in our atmosphere allow the shorter wavelength radiation (incoming solar) to reach the earth's surface while absorbing the longer wavelengths (outgoing terrestrial), which, in part, is re-radiated back to the earth. Human activities have increased carbon dioxide, methane and other natural greenhouse gases, in the atmosphere, as well as added human-made gases such as chlorofluorocarbons (CFCs) and hydroflurocarbons (HFCs). Increases in greenhouse gas concentrations are responsible for enhancing the natural greenhouse effect. Global mean surface air temperature has increased by 0.3° to 0.6°C since the late 19th century (Intergovernmental Panel on Climate Change (IPCC) 1996). For Ontario, surface air temperatures have risen by 0.5° to 0.7°C since 1895 (Gullett and Skinner 1992). The IPCC (1996) states that "the balance of evidence suggests a discernible human influence on global climate" and that the climate is expected to continue to change in the future. Incontrovertible attribution of the long-term cause of current climate change is difficult due to the natural short-term variability in the earth's climate. Future predictions are difficult because of the complex interactions in the climate system.

General Circulation Models (GCMs), sophisticated computer models, are the primary tool used to estimate what the future climate will be. Numerous GCMs are used (Lau et al. 1996), including a Canadian GCM (Boer et al. 1992, McFarlane et al. 1992). Most GCMs have outputs for $1xCO_2$ and $2xCO_2$ scenarios, which roughly correspond to atmospheric CO_2 conditions in the mid-20th century and the second half of the 21st century, respectively. GCMs suggest that the average global surface air temperature will increase by 1 to 3.5°C by 2100 (IPCC 1996). However, more pronounced changes should occur at high latitudes and be greatest in winter. The spatial resolution of these models is often around 400 km. Regional Climate Models are now being developed to provide climate estimates at finer spatial resolution (~40 km). These will be more suitable for predicting regional effects of climate change in Ontario (Caya et al. 1995).

The present climate of Ontario is best described as continental, with cold winters and warm to cool summers. The climate around the Great Lakes tends to be warmer and wetter in winter because of the heat and moisture available from the large bodies of water. Conditions range from warm and moist in the south to cold and dry in the northwest (Table 2.1). A more detailed discussion of the recent climate of Ontario can be found in Hare and Thomas (1974).

Projected global warming of 1 to 3.5°C over the next century means that the climate would warm at a rate faster than at any time in the past. These increased temperatures could make the next century the warmest so far during this interglacial period. Ontario is a large and diverse geographical region with great variation in climate. Figure 2.1 shows the predicted increase in surface air temperature during the 1 May - 31 August period derived from the Canadian GCM, comparing a doubled (i.e., $2xCO_2$) to present (i.e., $1xCO_2$) CO_2 concentration. According to this scenerio, temperature increases of 3°C to over 5°C are expected across Ontario. The largest increases are expected over southwestern sections of northwestern Ontario, while the smallest increases are anticipated over the extreme northwestern region of Ontario along Hudson's Bay. If these predictions are realized, the summer temperature regime in Sudbury at the end of the next century would be similar to the current summer temperature regime in Windsor (Table 2.1).

Figure 2.2 shows the predicted effect of a doubled CO_2 environment on summer precipitation across Ontario, according to the Canadian GCM. Values over 1.0 indicate increases in precipitation whereas values less than 1.0 indicate decreases in precipitation for the end of the next century. Precipitation ratios range from just under 1.0 for much of northwestern Ontario and most of southern Ontario to over 1.2 for northeastern Ontario. There is increased potential for water stress over regions with decreased precipitation in conjunction with increased temperatures. Precipitation has been increasing since 1910 over the continental United States and most of this increase is due to increased frequency of extremely heavy precipitation events (Karl and Knight 1998). An increase in the number and severity of extreme weather events also is predicted to result from climate change.

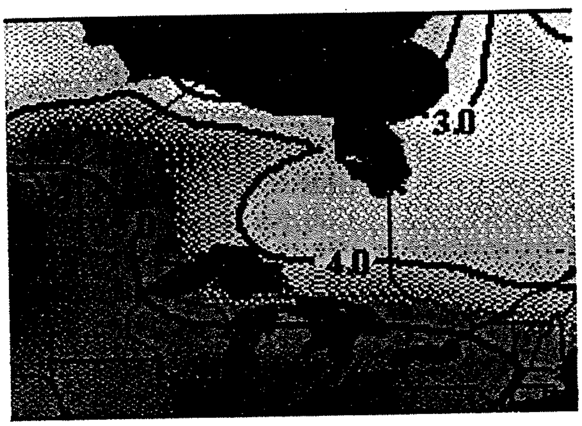

Figure 2.1 Predicted mean increases in summer temperature (°C) (1 May-31 Aug.) for a doubled compared to present atmospheric CO_2 concentration.

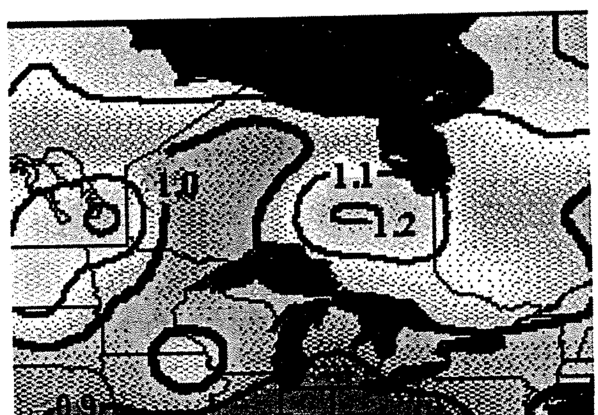

Figure 2.2 Predicted precipitation ratio for a doubled compared to present atmospheric CO_2 concentration. The thick black lines are the 1.0 ratio (no change in precipitation); values greater than 1 indicate increased precipitation, while values less than 1 indicate decreased precipitation.

The impacts of climate change have broad and far reaching implications for Ontario's forests, ranging from disturbances (insects, disease, fire and wind) and biotic responses (physiology, genetics and plant succession) to how we manage our forests within this new environment (Weber and Flannigan 1997). The continued development of regional circulation models with shorter time intervals will be important to predict and respond to the impacts of climate change on Ontario's forests.

Table 2.1. *Selected climate data for selected sites across Ontario from 1961-90 (Environment Canada 1993).*

Station	Latitude (ºN)	Longitude (ºW)	Mean annual temp. (ºC)	Mean annual prec. (mm)	Mean January temp. (ºC)	Mean July temp. (ºC)	Growing degree days (base 5ºC)
Windsor	42	83	9.1	902	-5.0	22.4	2544
Sudbury	47	81	3.5	872	-13.5	19.1	1680
Big Trout Lake	54	90	-2.8	598	-23.9	16.2	1075

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The Impacts of Climate Change on Ontario's Forests

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