CMOS Council decided in September 2006 to ask the CMOS Scientific Committee to elaborate a comprehensive CMOS Statement of Position on the science of climate change. After extensive work by the members of the committee and review by the Executive, it was approved by the CMOS Council in December, subject to the insertion of comments on the emerging issue of ocean acidification. This revised version was approved for publication by the Executive and Council in March 2007.

# Canadian Meteorological and Oceanographic Society

## Comprehensive Position Statement on Climate Change

The Canadian Meteorological and Oceanographic Society (CMOS) is the national society of individuals and organisations dedicated to advancing atmospheric and oceanic sciences and related environmental disciplines in Canada. CMOS has more than 800 members from Canada's major research centres, universities, private corporations and government institutes.
CMOS is uniquely positioned to provide expert advice to Canadians on the science of climate change. Many of its members are internationally recognized scientific experts who are extensively involved in comprehensive assessments of the current state of knowledge with respect to this complex issue. Such assessments require atmospheric and ocean scientists working together with scientists in related environmental, social and economic disciplines.

As an input into the current public and political debate on this important issue, the following statement is issued on the state of the science of climate change and the need for immediate action:

### The state of the science

#### Canada's climate is changing dramatically

- On a global scale, average surface temperatures have increased by about 0.7C during the past century. The nine warmest years of this period have all occurred within the past decade.
- While there remain significant uncertainties about trends in global temperatures prior to the past century, there is convincing evidence that the past 50 years have been warmer than at any time during the past 1300 years.
- Average surface temperatures across Canada are now about 1C warmer than they were when systematic nation-wide weather observations began in 1948.
- Many other aspects of Canada's climate, including glacier size, snow cover, lake and river ice cover, Arctic sea ice thickness, extent and permafrost depth and sea levels show trends that are consistent with a warmer Canada.
- The changes in climate are affecting Canadian ecosystems and wildlife. Some impacts, such as the increased length and warmth of growing seasons, are beneficial. Others, such as the increased loss of forest biomass to insects and wildfire and the stress on animal species such as the polar bear and Arctic ungulates, are harmful.
- There is significant evidence that some extreme climate events, particularly heat waves and intense precipitation events, are increasing on a global scale. In recent decades, the intensity of energy dissipated by intense tropical storms appears to have increased.
- Arguments by a few individuals that recent temperature trends may not be unprecedented within the past thousand years and can therefore be fully explained by natural variability and causes for change (often referred to as the 'hockey stick debate') are based on limited assessments and are seriously flawed. While some uncertainty is an inherent aspect of all science, related international research studies continue consistently to refute such conclusions.

#### There is strong evidence that changes in climate during the past 50 years are human-induced

- The most comprehensive projections of future climate rely on numerical models of the climate system. These models are based on fundamental physical principles. After decades of intensive research by scientists within Canada and abroad, models are now able to replicate current and past climates with increasing confidence.
- Simulations with these models, together with observational evidence, demonstrate that there is a natural greenhouse effect that is an essential aspect of the global climate system, and that increases and decreases in the concentration of greenhouse gases over time cause the intensity of this effect to be enhanced or diminished, respectively.
- There is clear evidence, based on direct observational data and indirect indicators from proxy sources such as polar ice cores, that current concentrations of major greenhouse gases, particularly carbon dioxide and methane, are now higher than at any time during the last 650,000 years.
- The increase in atmospheric carbon dioxide concentration since the late 1800s is mostly as the result of fossil fuel burning, and partly from clearing of forest vegetation.
- A broad range of simulations of past climate using climate models consistently indicate that changes in temperatures at global and continental scales during the past 50 years are fully consistent with forcings related to human emissions of greenhouse gases and aerosols.
- The changes in temperatures cannot be adequately explained by either natural variability or natural causes of change such as solar variability or volcanic eruptions. Hence, researchers involved in these studies conclude with 95% confidence that recent changes in climate at global and continental scales are caused by human emissions.
- Similar conclusions cannot as yet be made for most sub-continental scale changes. One exception is the major 2003 heat wave over Europe, which can be attributed with confidence to rising global temperatures.
- Canadian trends in climate are fully consistent with those expected due to human-induced changes in climate.

**Projections for future increases in greenhouse gas concentrations and related climate change are of concern to scientists in CMOS**

- Given the already significant atmospheric load of greenhouse gases since the industrial revolution, as well as the huge inertia and long delays characterizing the atmosphere-ocean-biosphere system's response to greenhouse gas climate forcing, further changes in the climate over the coming decades are inevitable.
- Nearly half of all the carbon dioxide that humans have emitted since the start of the nineteenth century has been absorbed by the ocean, resulting in an increase of the partial pressure of carbon dioxide ($pCO_2$) of surface waters. The change in $pCO_2$ is certain to reduce the capacity of the ocean to buffer further increases in atmospheric $CO_2$.
- Possibly as much as 20% of anthropogenic $CO_2$ emissions will continue to contribute to warming and sea level rise for thousands of years, because of the long time scales required for buffering by the ocean, including dissolution of $CaCO_3$ sediments.
- Further increases in greenhouse gas are virtually certain to produce further increases in temperature.
- Considering the uncertainties in both the future increases of greenhouse gas concentrations and in the climate system response to such increases, experts now project that, by 2100, average surface temperatures will rise by at least another $2^oC$ and possibly by as much as $7^oC$.
- Observations over the 20$^{th}$ century indicate that the warming was disproportionately larger over Canada, particularly over the Arctic region, where temperature trends exceeded North Hemispheric trends by 50%. Projected trends show an even stronger signal for the 21$^{st}$ century, with a temperature increase for the Arctic of at least $4^oC$.
- Clean-air legislation, although essential to human health, will curb the emissions of aerosols and the precursor gases that form aerosols following atmospheric chemical reactions. Some aerosols in the atmosphere act to cool the planet, and their reduction

would diminish their role as counterweight to greenhouse gases and lead to a short term increase in the rate of global warming.

- Ocean warming and melting land ice are likely to cause a rise in sea level by about 20 to 60 cm over the next century, and much more over subsequent centuries. Sustained warming will likely, over millennia, lead to complete melting of the Greenland ice sheet and a related sea level rise of 6 to 7 meters.
- Other implications for Canada's climate and weather include:
    - Reduced extent and shorter seasons for snow cover over land and ice cover on lakes and rivers;
    - Widespread increases in summer thaw depth over permafrost regions.
    - Shrinkage of Arctic sea ice cover, with possible total disappearance in late-summer by the latter part of this century;
    - A continued increase in the frequency and intensity of hot extremes, heat waves, and heavy precipitation events;
    - A slight poleward movement of storm tracks, with related increases in wind and precipitation events in polar regions;
    - Wetter conditions, on average, across northern regions of Canada, but a potential increase in the frequency of severe droughts in southern Canada.

**Projected changes in climate will have serious implications for global and Canadian ecosystems and socio-economic infrastructure**

- Within Canada, warmer temperatures and changing weather patterns are expected to cause:
    - Significant benefits in terms of reduced winter-season space-heating energy requirements, longer and warmer growing seasons, longer marine navigation seasons, and enhanced ecological productivity; but
    - A dramatic change in Arctic ecological and social systems caused by reduced sea, lake and river ice cover, increased land instability due to permafrost melting and changes in weather;
    - Increased loss of forests to insect infestations and fire;
    - Increased number of summer hot days and heat spells, with associated degradation in air quality, rise in related pulmonary and cardio-vascular health concerns, and an increase in summer energy requirements for space cooling which in turn leads to further air quality degradation;
    - Increase in intense precipitation events with implications for water resource management and flooding;
    - Increased risk of summer drought, particularly in regions where the stream-flow is provided by spring and summer runoff, due to a decrease in snow-pack and melting of Rocky Mountain glaciers;
    - Increased risk of damage by storm surges to coastal regions due to higher sea levels, and more vigorous weather systems;
- Increased threat to endangered animal, bird and fish species where climate changes negatively affects their habitat and food supply. Of particular concerns are species such as the polar bear, Arctic seals and fresh water fish species, including migrating Pacific salmon species. Globally, impacts will be disproportionately adverse for developing nations. Because of prevalent poverty within most of these nations, they have limited adaptive capacity. Furthermore, since most are located in warm and often arid regions at lower latitudes, warmer temperatures increase stress levels for both ecosystems and society, while increased drought risks significantly enhance the risk of starvation.
- Ocean acidification due to carbon dioxide uptake will impact marine ecosystems. These impacts may include a reduction in the ability of seashell creatures and corals to produce the calcium carbonate required for their shells and skeletal structures.
- Well-respected economists, and most recently the Stern Review on the Economics of Climate Change, indicate that, by the latter part of the 21st century, potential annual global economic costs of warmer climates may be trillions of dollars.

**Greenhouse gas emission reductions, and adaptation and mitigation measures are essential to reduce the damage that will result from climate change**

- Once introduced in the atmosphere, carbon dioxide remains for at least a few hundred years, with 15-20% remaining for tens of thousands of years - which virtually guarantees sustained future warming and sea level rise. Hence Canada must inevitably deal with adaptation and even mitigation in the coming decades to reduce the negative consequences and take advantage of the potential opportunities of climate change.
- The most direct human impact on climate change is through emissions of greenhouse gases. Immediate reduction of global greenhouse gas emissions can be part of the approach to mitigate the negative consequences of forthcoming further global change..

**Improved scientific understanding is critical**

- There is strong evidence that climate is changing, and that humans have significantly contributed to this change. However, the atmosphere-ocean-biosphere system is highly complex, and there remain a number of uncertainties that need to be addressed in order to increase confidence in climate projections. Effective adaptation and mitigation policies critically depend on improved scientific understanding, which will provide more accurate forecasts of what changes we will need to adapt to, and how the impacts can be reduced. The need for further scientific research on climate should not, however, justify delays in implementing mitigation actions to reduce greenhouse gas emissions.

**A call to action**

- Climate-change science is a rigorous field of study. Its findings are periodically reviewed and assessed as part of an international effort led by the United Nations and the World Meteorological Organisation (WMO), known as the Intergovernmental Panel on Climate Change (IPCC). The Third IPCC Assessment Report (2001) concluded that the balance of evidence suggests a discernible human influence on global climate. Results published since then in peer reviewed journals have only strengthened this conclusion (The Fourth IPCC Assessment Report will be published in early 2007).
- Given the current and increasing significant load of greenhouse gases in the atmosphere, future warming is inevitable. Because the changes will occur more rapidly than at any time during at least the last 650,000 years, appropriate adaptation policies and programs must be designed to help increase our adaptive capacity. Climate-change protection is needed now.
- The global reduction of greenhouse gas emissions cannot be achieved by any single country, but each country must contribute its share towards accomplishing the global goal.
- The atmosphere-ocean-biosphere constitutes a highly complex system. Our ability to make comprehensive climate projections is hindered by the lack of accurate characterization of important processes and feedbacks. Further process-studies, assessments of paleoclimate evidence, modelling and observations, are needed to understand and to improve predictions of climate change at the global and especially regional scales. Research is essential to our ability to mitigate and adapt to climate change.