# Climate change at Arctic's edge: monitoring early impact data for climate change assessment

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## Background

There is strong evidence that climate change is affecting the physical environment in the Arctic – the sea ice extent is shrinking, glaciers are retreating, and winter snowpack is becoming less extensive and melting earlier in the year. Additionally, plant community types are shifting and other ecosystem characteristics are changing, with potentially negative implications for species at the limits of their distribution.

Further evidence that changes are afoot is found in the degradation of the permafrost. Defined as the condition where ground temperature remains below 0°C for the entire year, permafrost covers 24% of Earth's land mass including 50% of Russia and Canada, 20% of China and 83% of Alaska. In an area of the Mackenzie Mountains in Canada, where the permafrost is close to 0°C, many permafrost landforms have disappeared entirely over the past 65 years and all have shrunk in size. In the Churchill area where the permafrost is colder, landforms appear stable but over the past 30 years it has warmed by 0.5°C to 0.4°C.

Most of the world's peatlands occur at high latitudes and most are in permafrost, which prevents decomposition of the organics they contain – thus locking up almost 90% of the 1,670Pg (one petagram = one billion metric tonnes) of the world's terrestrial carbon. Upon thawing, decomposition of these organics will begin, the by-products of which include carbon dioxide ($CO_2$) and methane ($CH_4$), the two most potent greenhouse gasses emitted by human activities. As permafrost in the northern hemisphere is subjected to warming, permafrost zones are predicted to retreat polewards, resulting in the

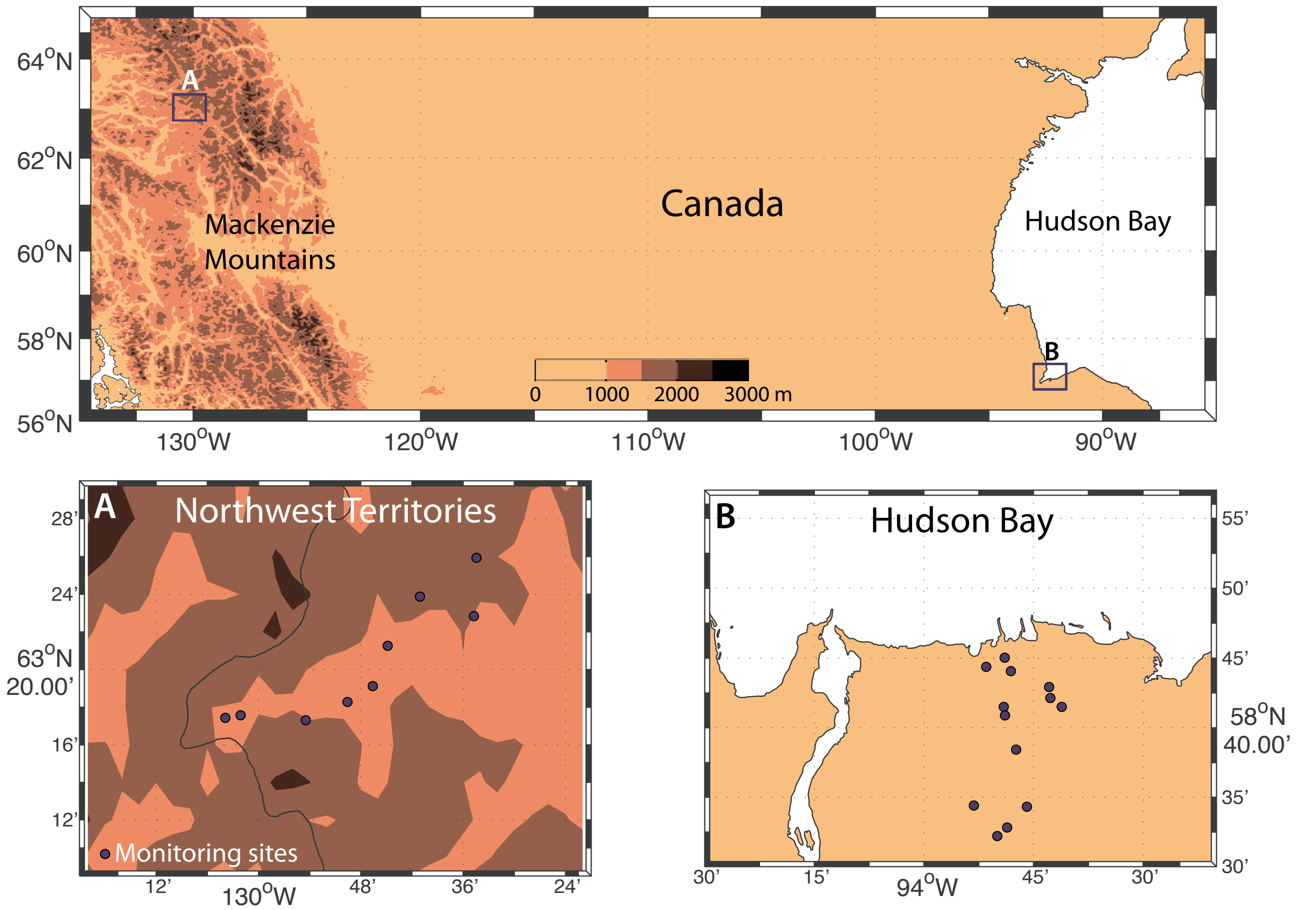



Figure 1. Project research locations in Canada. Mackenzie Mountains on the Yukon-Northwest Territories boundary in the far west, and Churchill, Manitoba, on the shore of the Hudson Bay, east coast of Canada.

Data collection occurs year-round in all seasons and all weathers.

thawing of vast carbon stores which will then begin to decompose. This will further enhance atmospheric concentration of greenhouses gasses, amplifying the warming effect in a positive feedback loop.

The largest peatlands in the North American continent are found within the Hudson Bay Lowlands in Canada. At present, permafrost affects much of this peatland to a depth of 30 to 60m. This includes peat deposits that can be >5m thick, that accumulated since the land emerged from the ocean after de-glaciation 9,000 years ago. However, climate change models predict significant temperature rises for the area, with estimates for warming levels at high latitudes ranging up to 6°C. At Churchill, there has already been ~2°C warming since records began in the 1880s.

The town of Churchill is located on the coast of Hudson Bay, at the mouth of the Churchill River, set in a unique environmental context. Here, the biotic elements of two of the most pristine ecosystems on Earth - the Arctic tundra and the boreal forest - merge together and the environment changes abruptly from treeless to forest over just a few kilometres. Dynamic ecological interactions are driven by the abiotic factors of climate, permafrost and geomorphic history. Churchill has a complex mix of western, eastern, northern and southern fauna, making the region highly biodiverse.

In western Canada, forming part of the Yukon-Northwest Territories boundary, is the Mackenzie Mountain range. The Mackenzie Mountain Barrens lie within an alpine landscape 1,700m above sea level. The landscape is dominated by tundra that falls into an extensive shrub zone interrupted by patches of spruce and accentuated by alpine slopes and snow-capped peaks. The world's largest herd of mountain caribou (*Rangifer tarandus*) lives here, along with other large mammals and more than 130 bird species.

## Project overview

The Earthwatch project began in 2000, and builds on an existing long-term research project which lead scientist Dr Peter Kershaw has been working on since the early 1970s. The primary goal of this research is to quantify the impacts of climate change on ecosystems at the Arctic's edge. This entails gaining an understanding of the current processes and relationships driving these ecosystems and the compilation of a detailed data archive as a benchmark for future reference.

Research takes place at two sites in Canada (Figure 1): Churchill, Manitoba, at the northern edge of the forest-tundra where there is continuous permafrost and the trees reach their latitudinal limit, and the Mackenzie Mountains, in the Northwest Territories, lying within the discontinuous permafrost zone where trees are at their altitudinal limit. This makes it possible to compare responses to global warming at both alpine and

Dr Kershaw prepares volunteers at the Mackenzie Mountains research site before commencing surveys.

arctic treelines where ecosystems are especially sensitive to change.

At Churchill, the Mackenzie Mountains and Wapusk National Park (an area 45km from Churchill, managed by the federal department - Parks Canada) a network of 32 Long-Term Environmental Monitoring Sites (LTEMS) has been established, including natural forest, modified forest and disturbance reclamation test sites. Additional sites were also set up for the 2007/8 International Polar Year, as part of a circumpolar network of research locations for assessing the status of the treeline. As a result, the goal to monitor changes in representative ecosystems can now be achieved as all the dominant ones are covered. The archive of data on key ecosystem components is growing and, with recent inclusion of an abandoned site originally established by government scientists in the mid-70s, it is possible to compare current conditions (including deep permafrost) with those of 35 years ago. At the end of 2009 a ten-year record had been collected for the Churchill LTEMS, while in the Mackenzie Mountains it will be 20 years in 2010 (five years of which have involved Earthwatch volunteers).

Current short-term objectives working towards the primary goal include:

- Building a regional chronology of past climate for the research areas using tree rings
- Quantifying the different microclimates and compiling a continuous database
- Assessing the past and current status of permafrost in order to extend the existing database and evaluate the impact of anticipated global warming
- Test reclamation treatments for assisting natural afforestation processes in borrow pits and gravel pads
- Quantifying the different snow packs and compiling an annual database
- Quantifying the amount and characteristics of organic carbon stores
- Assessing the past and current status of treeline/shrubline
- Carrying out twig and leaf collections to assess water availability and tissue desiccation related to wind direction and proximity of the snowpack

Earthwatch volunteers make it possible for the research team to collect otherwise impossibly large numbers of samples, particularly in the short time period of the summer thaw season. Research activities include soil sampling, permafrost coring, frost probing and vegetation sampling. At the start and end of the summer thaw season, a ground-penetrating radar survey is completed at each site, including a simple topographic survey. Cover values for shrubs and trees are estimated, the depth of thaw is probed and standard soil characteristics including organic matter, moisture content and pH are determined.

## Outcomes and actions

Through establishing such a long-term environmental monitoring network, enabling quantification of the ecological impacts of climate change, the research team has found substantial evidence that permafrost is warming at both study areas (Figure 2, Mackenzie Mountains). In the Mackenzie Mountains, landforms with a permafrost core continue to shrink – circumstances which appear to be driven by warmer air temperatures, as recorded by the scientists at six permanent monitoring sites since 1990. The scientists have confirmed that warming has been occurring at an increasing rate up to the present day by using an instrumental record of climatic conditions upheld since the late 1800s, and a proxy record that provides data from as far back as the mid-1600s. Climate proxies are indirect methods for deducing climate patterns of the past, by measuring a record that has been laid down over a long period of time. For example, tree ring width and other characteristics infer variations in temperature over time. The Mackenzie Mountains record from the last 20 years confirms permafrost warming of ~1.25°C. Tree ring chronologies are the proxy being used by the scientists and have revealed periods of enhanced and suppressed tree growth back to *circa* 1650. During the early part of the record, good correlations were found between growth characteristics and recruitment (origin date of tree) but these relationships were not found in the most recent portion of the record for the late 1900s onwards. This suggests a decoupling of climate and tree growth in the warmest part of the record, which needs further study to determine why this has happened and what the implications are. In terms of seedling ages, there is good evidence of recent recruitment which can only occur

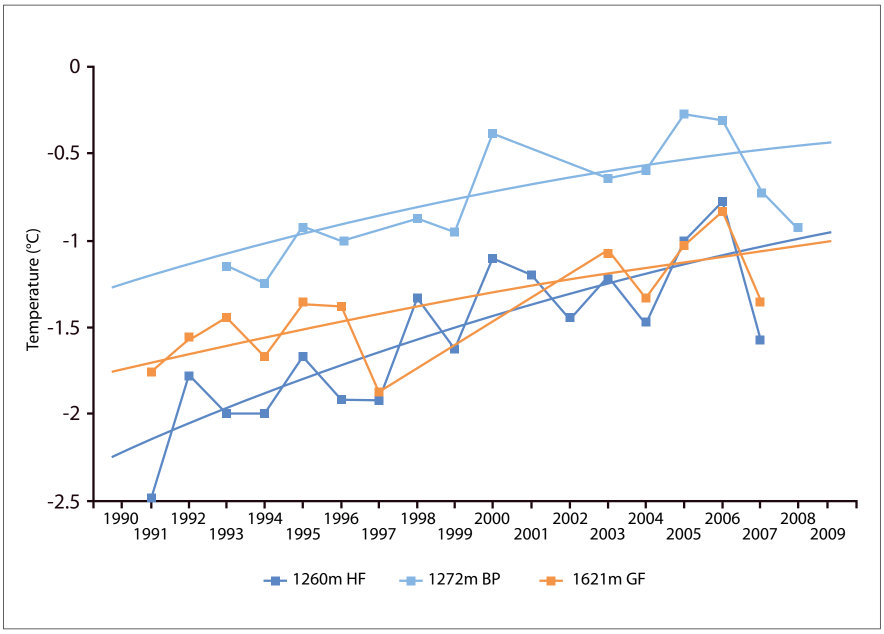



Figure 2. Permafrost temperature from the three most continuous stations in the Mackenzie Mountain research area, Canada. The trend clearly indicates warming over the record period. HF=Hare Foot; BP=Beaver Pond; GF=Goose Flats; m=height above sea level.

with successful seed production and germination. Arctic treeline ecosystems exist right on the edge of their tolerance limits and are particularly susceptible to extreme weather events (often infrequent and ephemeral), which can significantly affect their ecological function and status.

Progress is continuing on establishing the amount of carbon within specific organic stores in the region, such as peatlands, with an archive of soil carbon values created for the Churchill LTEMS. Soil pits are being excavated, described and sampled, and organic matter depth measurements taken. In areas of thick peat, permafrost coring has been conducted to measure carbon content with depth. Similar studies in the Mackenzie Mountains are providing data for comparisons between mountainous and lowland environments. At Churchill, the soil carbon pool varies from ~300g to 900kg. The lowest value was found after a forest fire while the highest was in peat plateaus or fens.

Nationally, the data on permafrost status and environmental conditions across the country are providing a more accurate picture of the current situation and trends so that predictions of future change can inform decisions on park management. Wapusk National Park has been indicated to be entirely underlain by permafrost. Also, polar bear, classified as Vulnerable (IUCN Red List), are common in the park during the ice-free season and pregnant females den in the area until mid-winter. The permafrost provides perfect thermally-regulated conditions for dens constructed within it.

## Scientist profiles

**Dr Peter Kershaw** is Associate Professor at the University of Alberta, Canada. He has worked and taught in Churchill for more than 15 years and has been conducting research in the area since the early 1970s.

**Dr Lee Ann Fishback** has been Scientific Coordinator at Churchill Northern Studies Centre, Canada, for the last eight years. In addition, she is Adjunct Professor at the University of Winnipeg, Canada. She received her PhD from the University of Western Ontario in London, Ontario, Canada.

**Dr Ben Cash** has worked in Churchill for seven years. Ben began his training through a BSc at Piedmont College in Georgia, USA, then obtained his MSc from Georgia Southern University. At the University of Mississippi, USA, Ben received a PhD for research on behavioural and physiological aspects of the biology of slider turtles.

## Collaborative organisations

- Canadian Circumpolar Institute, University of Alberta, Canada
- Department of Earth and Atmospheric Sciences, University of Alberta, Canada
- Churchill Northern Studies Centre, Canada
- Government of Canada - International Polar Year
- Parks Canada
- Natural Sciences & Engineering Research Council of Canada

## Project websites

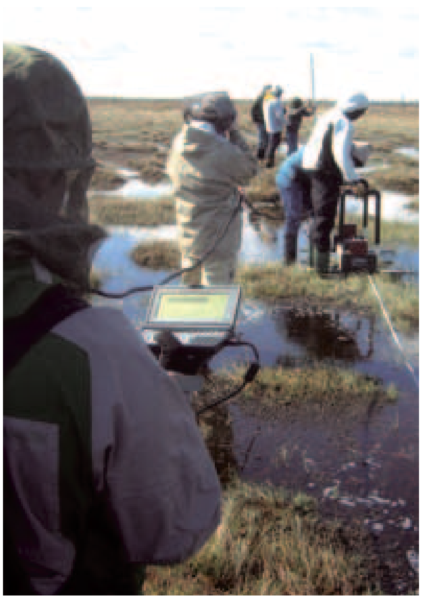
www.earthwatch.org/europe/exped/kershaw_Churchill.html

www.earthwatch.org/europe/exped/kershaw_mackenzie.html

## Key publications

Kershaw, G.P., Mamet, S.D. & Suter, J.A. (2009) *Climatological, snowpack, and dendroclimatological investigations, Wapusk National Park*. Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton.

Kershaw, G.P. (2008) Snow and temperature relationships on polygonal peat plateaus, Churchill, Manitoba, Canada. In: Kane, D.L. & Hinkel, K.M. (Eds.) *Proceedings of the Ninth International Conference on Permafrost*. Institute of Northern Engineering, University of Alaska, Fairbanks, Alaska.



Volunteers conduct ground-penetrating radar surveys along transects to measure permafrost thickness.