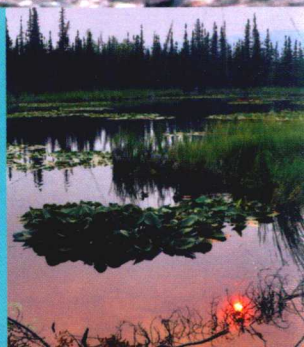
Editors HUGH FRENCH | OLAV SLAYMAKER

Changing Cold Environments

A Canadian Perspective



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Changing Cold Environments

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Preface

Eighteen years ago we edited a volume called *Canada's Cold Environments*. It was a type of regional physical geography of northern Canada and its mountains. In its preface we set the tone by noting that 'coldness is a pervasive Canadian characteristic, part of the nation's culture and history'. In spite of many indications that Canada has become a warmer place since 1993, coldness remains a pervasive and distinct Canadian characteristic. There is, however, sufficient change in the hydroclimate, and indeed in the 'oekumene' of Canada as a whole (those parts of Canada that are inhabited by permanent residents), to warrant a fresh look at Canada's changing physical environment. Moreover, the Canadian experience is a useful barometer against which similar changes in the other regions of the northern Polar World can be compared.

Whether or not the globe as a whole is experiencing a long term warming trend fuelled by increasing greenhouse-gas concentrations in the atmosphere or a cyclic and short term warming trend caused by geophysical drivers such as solar emission or changing Sun–Earth relations is a mega-problem upon which we are not willing or competent to comment. What we do know is that Canada's cold regions, and especially its arctic regions, are experiencing rates of warming that are unprecedented in the past millennium. We also know that human demands on the natural resources of Canada's cold regions are growing apace.

The most obvious changes relate to shrinking glaciers, reductions in annual sea ice extent, and longer duration of ice-free periods on rivers and lakes. These are physical realities that can be readily observed and measured. Others are more subtle. But these changes coincide with a period of increasing global demographic pressure and intensifying resource demand at a time when it is becoming clear that globalization is upon us. In addition, the sovereignty of Canada's Arctic may soon be questioned as the possibility of an ice-free sea route between Europe and the emerging economies of Southeast Asia becomes increasingly a reality. The net effect of these accelerating processes is to focus new and urgent attention on Canada's cold environments.

We have assembled 14 experts, in contrast with just nine in our earlier book. All have extensive Canadian experience. The new topics which now require separate chapter treatment are sea ice, river and lake ice, remotely sensed imagery and the ways in which the northern indigenous peoples (in this case the Inuit) interact with this rapidly changing environment. We have also given more space to ecological changes and provide deeper understanding of the glacial and postglacial histories of our cold

environments. In this way we hope to counteract some of the more emotional responses to contemporary environmental change. It is our conviction that environments have always changed and continue to evolve. In fact, as a society, we can even be grateful for the rapid environmental changes of the last 2.5 million years (the Quaternary); many would argue that such changes have been partially responsible for stimulating the evolution of *Homo sapiens*. Thus, our emphasis upon current and future change indicates our own belief in our continued evolution.

In this volume we, and our contributors, have attempted to provide an authoritative, yet readable scientific statement about the nature of Canada's changing cold environments. We have not attempted a comprehensive geographic coverage. Instead, we have focused on the distinctive attributes of Canada's changing cold environments. Their temporal and spatial variability is central, as is the interaction of northern peoples with those environments. As in our earlier volume, the constraints and opportunities created by coldness for human activity are also considered.

We have both seen a progressive evolution of Canada as a pre-eminent cold-climate nation over the last 40 years. Thus, our objectives in undertaking an assessment of this change have been threefold. The first has been to provide insight into the ways in which biophysical processes are influenced by coldness at a range of scales. The second has been to provide a biophysical context for understanding the human geography of Canada. The third has been to examine current rates of environmental change and, if projected into the future, how those rates of change will affect Canada's cold environments.

We wish to thank the authors of the individual chapters for their willingness to join us in this venture and to share their experience and wisdom. Needless to say, not all of them provided material in a timely and efficient manner. But they have all achieved, in our opinion, the desired mix of authoritative information and accessible style. Our cartographers, Ole Heggen and Eric Leinberger, deserve special recognition for the quality of the figures and images.

Any lack of coherence and errors of fact or interpretation are our responsibility and we request your indulgence.

Hugh French
Olav Slaymaker
June 2011

Glossary

Active layer The layer of ground above permafrost that freezes and thaws each year.

Albedo The reflectivity of an entity. An albedo of 0 (1) indicates that all solar energy is absorbed (reflected).

Alp A shoulder high on the side of a glacial trough.

Arctic (1) Geographic definition: the area north of the Arctic Circle (latitude 66° 33′N); (2) Climatic definition: the region where the warmest monthly mean air temperature does not exceed 10 °C and the coldest is below 0 °C.

AVHRR (Airborne Very High Resolution Radiometer). A sensor system deployed on NOAA satellites that returns 1.1 km resolution images of the Earth.

Bubnov A unit for quantifying rates of slope retreat or ground loss.

Co-management A co-management agreement is a management plan that specifies the objectives, partners to the agreement, and rights and responsibilities of the partners.

Community-based research A participatory approach to research in resource and environmental management.

Comprehensive land claims Aboriginal title to land.

Cryosphere Ice sheets, glaciers, sea ice, river and lake ice, snow, and both seasonally and perennially frozen ground.

Debris flow A form of mass movement of a mixture of water, rocks, fine sediments and/or organic debris.

Degree days (1) *Growing degree-days* (GDD) are usually measured from a threshold value of 5.5 °C and defined as $\Sigma(Ta - 5.5)$ °C where Ta is mean air temperature for the day and Σ indicates that successive daily values are summed. (2) *Freezing degree-days* (FDD) are the summation of the daily temperatures that are below 0 °C.

Disjunc (as used in ecology) An organism that is found in two locations that is separated by more than the usual dispersal distance.

ELA (Equilibrium Line Altitude) A notional altitudinal line on a glacier where ablation balances accumulation.

First year sea ice Sea ice that has not yet survived a winter, with thicknesses ranging from 30 cm at the beginning of the season to 2 m near the end of the season.

Flaw lead A linear crack in sea ice created by divergent winds and/or shear zones.

Frazil ice Small spicules of ice that nucleate in river flow under a slight amount of supercooling.

Freshet The rise in spring river flow, typically due to snowmelt.

Geopolitics An area of geographical enquiry which considers space to be important in understanding the constitution of international relations.

Governance (1) the nature of organizations and (2) the nature of the relations between organizations.

Ground ice Ice formed in freezing and frozen ground. Ground ice may constitute between 40–60% by volume of the upper 10 m of permafrost.

Ground temperature envelope The graphical representation of the annual range in ground temperature with depth.

Ice jam An accumulation of fragmented ice floes that constricts the flow of water.

Jokulhlaup Catastrophic drainage of a subglacial or ice-dammed lake.

Krummholz The shrub form of trees, such as spruce, which are typically found in stressed environments.

Latent heat of fusion The heat given off or taken in by a material during a change of phase between liquid and solid states.

Milankovitch effects Periodicities in the Earth's orbit due to changes in eccentricity (~100 000 y), axial tilt (~41 000 y) and precession of the spring equinox (~23 000 y).

MYI (Multi-year sea ice) Ice that has survived a summer melt season, with thicknesses ranging from 2–4 m as ice grows beneath the ice sheet.

Natural hazard The coincidence in space or time of extreme geophysical events and human use systems.

Neoglaciation A local scale glacial advance that occurred during the Holocene Epoch.

Nival regime streamflow The discharge pattern of a stream that results from the melt of seasonal snow and ice.

Nordicité A concept coined by the Québec geographer Louis-Edmond Hamelin to quantify what is understood by the term 'northern'.

NDVI	(Normalized Difference Vegetation Index) A numerical indicator applied to remote sensing data that compares visible light and near infrared reflectance from the Earth's surface to determine vegetation density and health.
Pancake ice	Circular disks resulting from the accumulation of frazil ice crystals with a range in size from a few centimeters to 3–5 metres in diameter.
Paraglacial	Non-glacial processes conditioned by glaciation.
Passive microwave radiation	Naturally emitted radiation that can be observed by a radiometer.
Periglacial	An environment with permafrost and intense frost activity.
Permafrost	Ground (soil or rock) that remains at or below 0 °C for at least two years.
Phylogeography	The distribution of organisms using molecular data.
Phytogeography	The distribution and abundance of plants.
Polar amplification	Amplified temperature trends over the Arctic Ocean compared with the rest of the hemisphere.
Polynya	A region of open water, where sea ice would normally be expected to occur, established by persistent divergent winds or upwelling of warm water.
Proxy records	Sources such as tree rings, pollen, ice and sediment cores that allow past climatic conditions to be inferred.
Quaternary Period	The last 2.6 million years (approximately) during which time many major glaciations occurred.
Relict	(as used in ecology). A taxon surviving in a region after being eliminated from most of its original distribution.
Sea ice	An entity of frozen water that floats on the surface of the ocean.
Sea ice concentration anomaly	Departures in sea ice concentration from a climatological mean.
Sea ice dynamics	Sea ice motion and circulation that is driven by atmospheric circulation and winds and/or ocean currents.
Sea ice extent	A measurement defined as the area with at least 15% ice concentration that is used to monitor the edge of sea ice.
Seasonally frozen ground	Ground that remains frozen for part of the year.
Sediment cascade	The sequence of sediment production, transport and deposition.
Snow albedo feedback	The effect of changing the land surface from a snow-covered surface (high albedo) to a snow free surface (low albedo).
SCA	(Snowcover area) The extent of snow cover within a given area.
Snow stratigraphy	The configuration of layering in the snow pack and variations in snow properties through the vertical profile.
Snow sublimation	The process by which snow evaporates.

SWE (Snow-water equivalent). The amount of melted water from a column of snow.

Socioecological system A system viewed with the understanding that what matters to humans is the environment as filtered through culture-specific perception and behaviour.

Spectral reflectance A critical property for differentiating surfaces in remote sensing.

Subarctic A climatic and/or ecological term that refers to those areas where the mean monthly air temperatures do not exceed +10 °C for more than four months and where the coldest is below 0 °C.

Thermal offset The difference in mean annual temperature between the ground surface and the top of permafrost.

Thermal conductivity The ability of a material to conduct heat.

Thermal diffusivity The ability of a medium to propagate a temperature disturbance.

Thermokarst The process by which terrain is modified when ice-rich permafrost thaws.

Timberline The upper, altitudinal, limit of continuous closed forest stand. (1) In mountains, the forest may reach its upper limit as a closed stand and cease abruptly as a sharp line against a treeless alpine zone. (2) Alternatively, the forest gradually dissolves from a dense closed stand (timberline) to isolated trees and finally to stunted individuals.

Transient layer The layer at the top of permafrost that thaws from time to time due to climatic variation. The timescale for development of the transient layer is unfortunately undefined precisely, but it may be considered to be on the order of tens to hundreds of years.

Treeline The northern, latitudinal, limit of trees. The northern boundary of the subarctic approximates the treeline.

Vulnerability The ability of an individual or group of people to anticipate, avoid, cope with and resist the impacts of a natural hazard.

Wind chill An index of the degree of atmospheric cooling experienced by a person. It is usually expressed as the temperature in still air that would correspond to the cooling generated by a particular combination of temperature and wind speed.

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