PERMAFROST AND GLACIERS/ICECAPS MONITORING NETWORKS WORKSHOP

GEOLOGICAL SURVEY OF CANADA, 601 BOOTH ST
OTTAWA, JANUARY 28-29, 2000

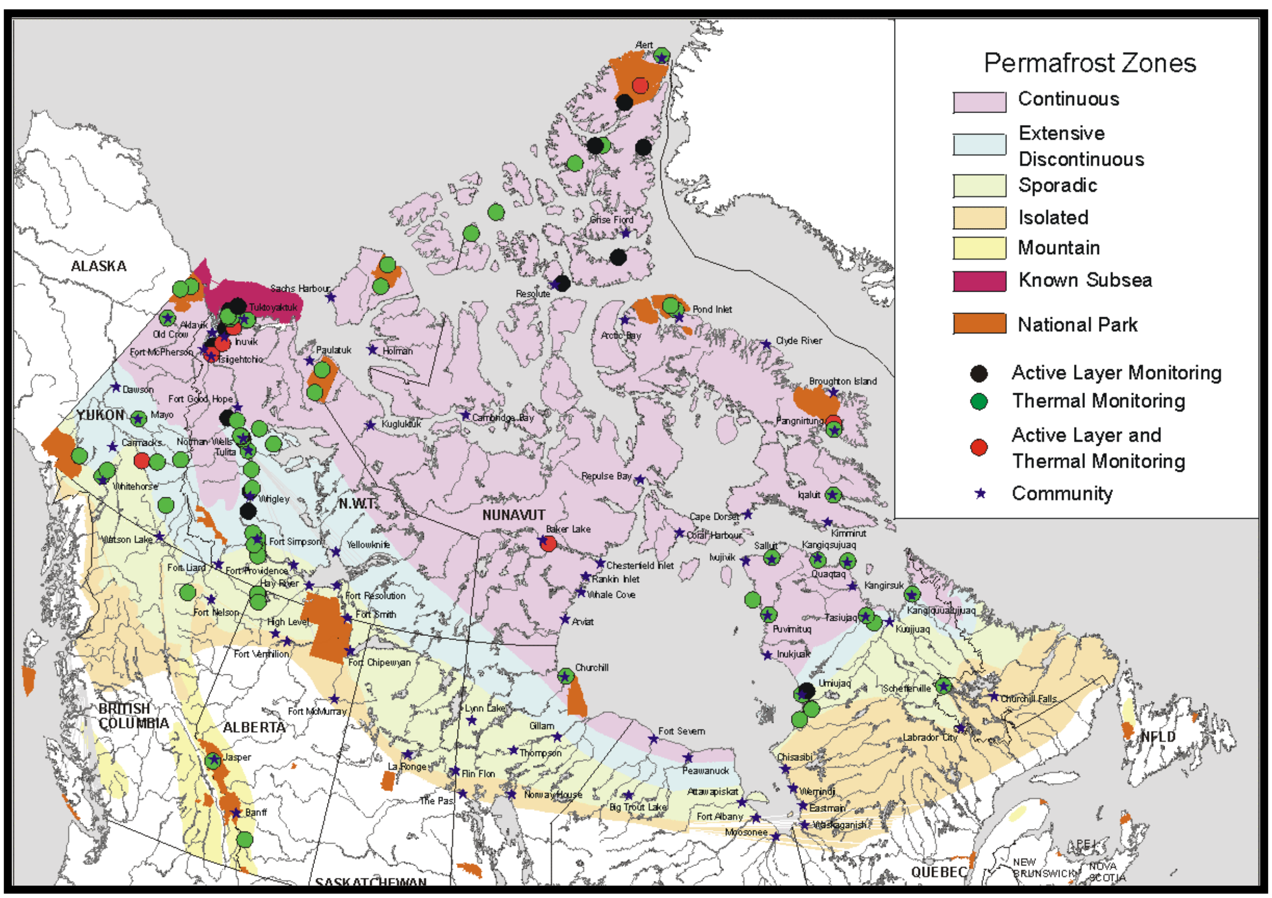
Report on the Permafrost Sessions

Prepared by M.M. Burgess[1], D.W. Riseborough[2] and S. L. Smith[1]

1 – Terrain Sciences Division, Geological Survey of Canada

2 – Department of Geography and Environmenta1 Studies, Carleton University, Ottawa.

A contribution to the development of the
Canadian GCOS- Global Climate Observing System- Cryosphere Plan



FOREWORD

Margo Burgess and Sharon Smith
Geological Survey of Canada
Natural Resources Canada
August, 2000

Climate warming is expected to be greatest over high latitudes and permafrost areas will be among the regions most heavily affected. Over half the Canadian land mass is underlain by permafrost, much of it at temperatures a few degrees from the melting point. Environment Canada's First Generation Coupled General Circulation Model predicts increases in mean annual air temperature of up to several degrees in northern latitudes in response to a doubling of CO_2. Variations in permafrost conditions can be a sensitive indicator of climate change and climate variability. Moreover, warming and thawing of perennially frozen ground has important implications for many landscape processes and hazards (such as increased terrain, slope and coastal instability). These changes as well as associated alterations to surface hydrology, ground water regimes, and surface vegetation have consequent socio-economic impacts (for ecosystems, infrastructure, development). Climate warming in permafrost regions will also affect the carbon cycle through changes in greenhouse gas sources and sinks associated with degradation of frozen peatlands. In addition, large amounts of methane are presently stored in the permafrost region as gas hydrates and their decomposition in response to climate warming may have large potential positive feedbacks.

Canada has committed to the development of a national plan to contribute to global observations of the climate system, including observations of the atmosphere, oceans, hydrosphere, cryosphere and terrestrial system. Permafrost is a key component of the cryosphere. One third of the permafrost regions of the Northern Hemisphere lie within Canada, and thus the international community looks to Canada for leadership in climate related observations of permafrost. Canada is indeed taking an active and proactive role at both the national and international level. Through the Geological Survey of Canada (GSC), Canada is involved in the International Permafrost Association's (IPA) development and implementation of an international permafrost monitoring network, the Global Terrestrial Network for Permafrost (GTN-P). An effective national and international monitoring strategy will provide long-term field observations essential for the detection of the terrestrial climate signal and for the assessment of its impact on permafrost, as well as indications of the spatial variability across the Arctic. This permafrost monitoring information is also critical for the improvement of predictive models and the reliability of impact assessments.

In the spring of 1999 with support from the federal government's Climate Change Action Fund (CCAF), Canada produced a draft national plan for its contribution to the World Meteorological Organization's (WMO) Global Climate Observation System (GCOS). Scoping documents for Canadian cryospheric monitoring networks (permafrost, glaciers and ice caps, sea ice, snow, and lake and river ice) were prepared. The national permafrost monitoring network will focus on initial observations of two key parameters: active layer (thickness, temperature) and permafrost thermal state. In January 2000, a joint national permafrost and glaciers/ice caps monitoring networks workshop was held at the GSC in Ottawa, and also sponsored by the CCAF, to further define the structure and requirements of these networks. The workshop involved a series joint and parallel sessions as outlined in the Agenda reproduced in Appendix A. A list of participants and acronyms are included in Appendices B and C.

This report summarizes the presentations and results of the permafrost components of the workshop.

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Apologia

This workshop report has been assembled in part from the speakers' presentation notes and overheads, editors' notes, and taped transcripts. As a result, there are a variety of formats for the individual reports. The formats chosen represent the editors' best attempt to give a written account of oral and visual presentations. Because of the change in form, it sometimes was necessary to change phrasing and the order in which points were made. Every effort was made to retain the sense of the original presentations. If any of these proceedings are unclear or inaccurate, the responsibility lies with the editors.

EXECUTIVE SUMMARY

In Ottawa, January 28-29, 2000, over 50 participants attended a Canadian Permafrost and Glaciers/Ice Caps Monitoring Network Workshop organized and hosted by the Geological Survey of Canada (GSC). The Workshop, sponsored by the federal government's Climate Change Action Fund (CCAF), was held to review the status of current monitoring activities and to formulate a plan of action and recommendations for the development of a national monitoring network in support of Canada's contribution to the Global Climate Observing System (GCOS).

More than half of the Workshop participants were involved in permafrost monitoring activities. A series of joint and parallel sessions addressed: national and international GCOS programs, current monitoring activities, gaps and weaknesses, techniques and instrumentation, modelling, network requirements and related issues. The deliberations and recommendations of the permafrost sessions are summarized in this report.

To date, there has not been a central agency with a clear mandate to organize and coordinate a national permafrost monitoring network. The Canadian permafrost community (government, universities, industry and other partners) have invested considerable efforts and financial resources in the last two decades for regional and local research and monitoring projects. These activities have been supported through a variety of short-term research programs. They form an impressive, albeit incomplete and currently ad hoc, infrastructure upon which a coordinated and comprehensive national program can be built.

GCOS, Can-GCOS and the GTN-P

The Global Climate Observing System (GCOS) program was established in 1992 by the WMO and other international agencies to address the requirements for global observations of climate change. Since the establishment of GCOS, the importance of systematic observations of the climate system has been given additional emphasis in the UN Framework Convention on Climate Change and by the Kyoto Conference. The five main goals of GCOS are: 1) to characterize the current climate, 2) to detect climate change, determine the rate of change and assist in attributing the causes of change, 3) to determine climate forcing resulting from changing concentrations of greenhouse gases and other anthropogenic causes, 4) to validate models and assist in prediction of the future climate, and 5) to understand and quantify impacts of climate change on human activities and natural systems.

GCOS focuses on implementing global networks for atmospheric, ocean and terrestrial observations, built on existing observing and data management systems and relying on national programs.

A Canadian ad hoc GCOS committee was established in 1992. Five component plans are being developed for the Canadian GCOS program, each by a federal or multi-agency lead: oceans, atmosphere, terrestrial, hydrosphere and cryosphere. The cryosphere plan is also being developed by an ad hoc working group, coordinated through the CRYSYS project (Cryospheric System in Canada), and includes five components: glaciers, permafrost, sea ice, lake ice and snow. With recent support from CCAF, background scoping documents were prepared for the

February 1999 Victoria Can GCOS Workshop and priority action items identified. The goal is to submit a Canadian Cryospheric IOS plan and cost estimates to the Canadian GCOS committee by March 31, 2001.

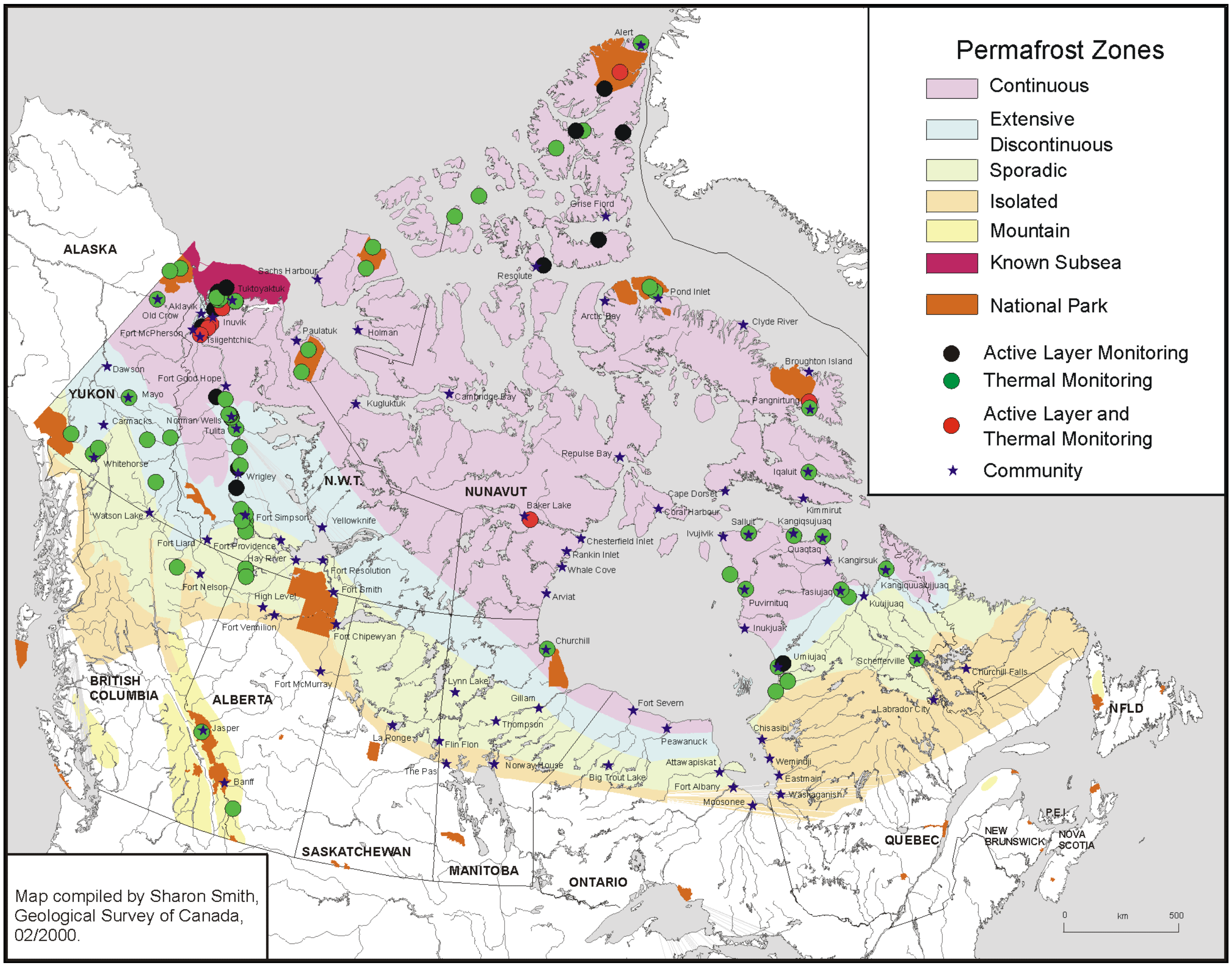
In 1999, the Global Terrestrial Network for Permafrost (GTN-P) was established under GCOS by the International Permafrost Association (IPA) to organize and manage a global network of permafrost observatories, most importantly to monitor changes of permafrost temperature and active layer. The GSC is a member of the GTN-P organizing committee tasked with establishing site selection criteria, protocols for data collection and submission, data dissemination and archiving.

The GTN-P includes the Circumpolar Active Layer Monitoring (CALM) program, established by the IPA in 1991 to obtain long-term active layer measurements. Canada contributes 20 of the more than 80 CALM sites. The current efforts of the GTN-P committee are thus focused on establishing the borehole temperature monitoring component. Most of these boreholes were drilled for either research, geotechnical or resource exploration purposes in the last two-three decades, and they range from single sites, to transects, to regional networks. Canada has proposed over 60 of the 200 candidate borehole sites.

The Geological Survey of Canada (GSC) is providing the national coordination and the international data management for the GTN-P. A GTN-P web site has been established as part of the GSC Permafrost Web site (http://sts.gsc.nrcan.gc.ca/permafrost/). Metadata for network sites will ultimately be accessible as well as regularly submitted summary data. GTN-P data would be subsequently archived through the National Snow and Ice Data Centre, Boulder, Colorado, as part of the IPA's Global Geocryological database and the WCD_A for Glaciology.

Current Canadian Permafrost Monitoring Activities

A pre-workshop survey and the workshop presentations allowed a compilation of monitoring site metadata and summary information. Presentations on active layer, thermal and process monitoring were made by government, universities, and private sector researchers. Each presenter addressed the "who, what, when, where and why" of their monitoring program, as well as provided their insights, lessons learnt, and recommendations for the establishment of a national network.
Example metadata and survey forms are given in Appendix E, while a summary table of monitoring sites, including responsible agency and partners, is given in Appendix F. Over 17 researchers or agencies are leading permafrost monitoring activities. Including partners, the total number of agencies involved is 13. The map above shows the location of existing active layer and thermal monitoring sites. The map below shows the location of permafrost process monitoring sites.

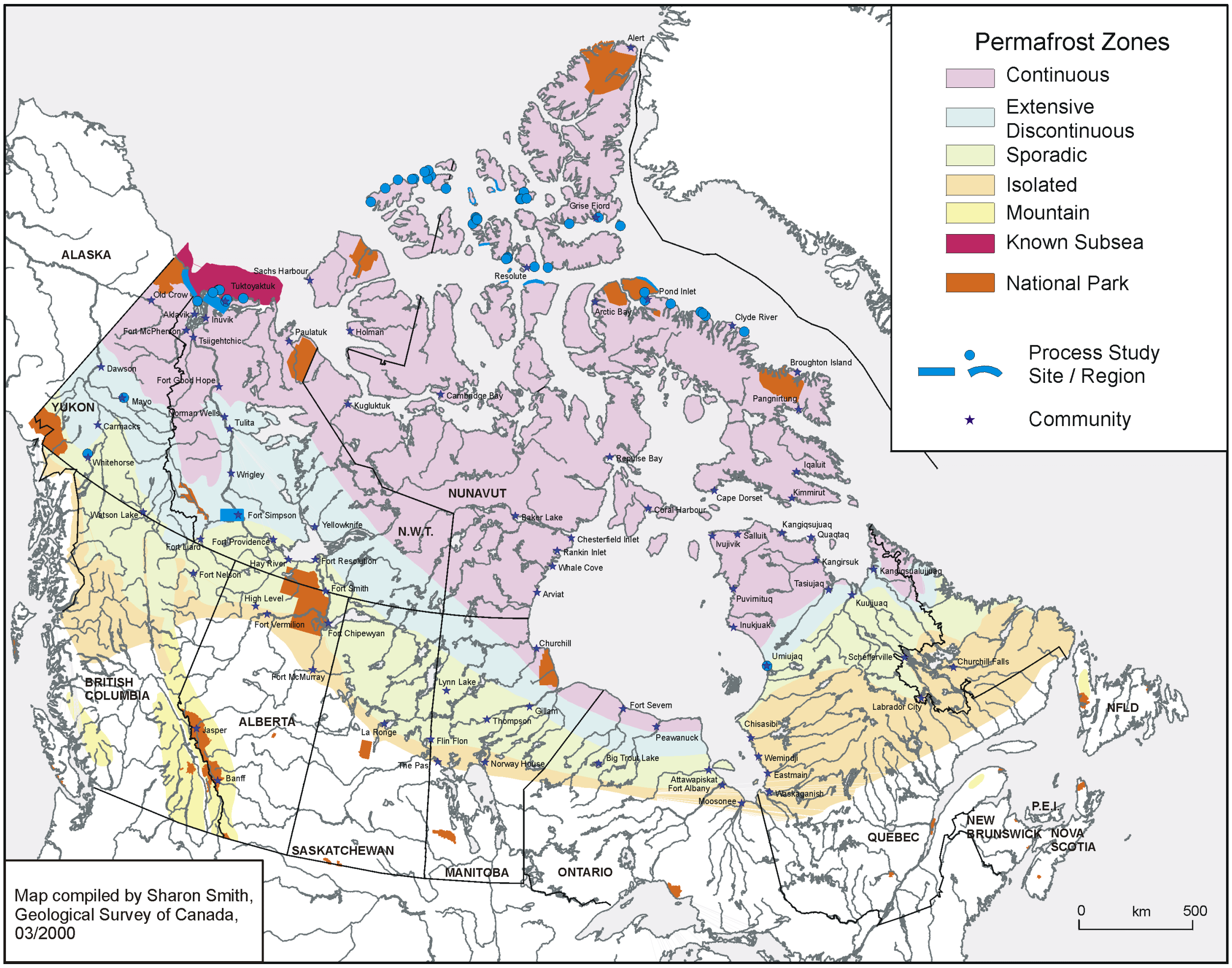


Existing Active Layer and Permafrost Thermal Monitoring Sites

Existing Canadian permafrost monitoring is largely ad-hoc, woven into short-term research projects. Traditionally "monitoring" projects have not been looked upon favourably, and hence not funded, by agencies or programs granting university or government research funds.

Monitoring has been (mostly indirectly) funded from some 9 sources; e.g. several universities, NSERC, PERD, Natural Resources Canada (GSC), Environment Canada, Agriculture Canada, and Parks Canada.

Permafrost Process Study Sites



Permafrost Zones
Continuous
Extensive Discontinuous
Sporadic
Isolated
Mountain
Known Subsea
National Park
Process Study Site / Region
Community
Map compiled by Sharon Smith, Geological Survey of Canada, 03/2000
0 km 500
ALASKA
YUKON
N.W.T.
NUNAVUT
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NFLD
NEW BRUNSWICK
NOVA SCOTIA
P.E.I.

Permafrost Network Requirements

The network requirement group discussions addressed several topics: management and coordination, membership and site selection criteria, data quality control, data reporting and submission, data access and web availability, data archiving, expertise and capacity, priorities and needs, funding requirements. The related key points and recommendations arising from these workshop discussions and the presentations are summarized in point form below. While these relate to an IOS of permafrost thermal and active layer monitoring, process monitoring was identified as being an important component of a comprehensive national network, because of its direct ties to impacts and links to user requirements. Modelling was also seen as part of this network , and important to site selection as well as impact assessment.

Management and Coordination

- need national lead agency for coordination and data management; federal agency buy-in and funding (GSC identified as natural lead)
- move from personal (ad-hoc) to institutional commitment (i.e.mandate)
- the monitoring community will need to lobby CCAF and Government bodies to include monitoring activities as part of the management plan for Arctic science. It is important to change policy, which means speaking directly to policy-makers.
- partnerships critical to maintain existing sites and to network expansion; communities, industry could be further drawn in, build on existing programs
- steering committee or board of directors to oversee operation

Membership Criteria, Site Selection

- representative of eco-regions, terrain and permafrost conditions
- assess and capture regional variability
- sites with long term data and meteorological data
- accessible sites, close to communities or where partnerships can support or reduce logistics
- many regional gaps; sites in discontinuous zone should be given a priority as should sites in the high Arctic (sentinel)
- commitment to submit data

Measurement Protocols

- Canadian network will follow protocols of CALM, GTN-P
- different measurement protocols for different depth ranges in boreholes
- monitoring infrastructure: standards, protocols, perhaps a bank of equipment meeting the standards, maintenance and capital replacement to be factored in

Quality Control

- range of accuracy and precision for existing sites; expected for new sites
- filter for obvious technical problems to be performed by researchers initially, but also checks at submission level
- classify sites according to quality of data

Data Reporting / Submission / Access

- annual or less frequent (depending on parameter, depth) summary data, based on a calendar year; web accessible
- any material or financial support contingent on data submission
- acknowledge individuals and organizations contributions in the archive
- no interagency charge for data

Archiving

- maintenance of database / archive should be integral part of monitoring infrastructure; serious long term issue; unsure of quantity of data
- link to "A State of the Cryosphere in Canada" meeting every few 3-5 years

Expertise / Capacity

- impressive infrastructure of existing sites already exists; lots of resources invested (need to assess the total real value); provides the foundation and framework for packaging and proposing a national plan
- success to date due largely to long term personal commitment of researchers; need shift to stable long term national institutional commitment
- collaboration is essential, involvement of communities (requires sustained effort)
- logistics support of NRCan's PCSP (Polar Continental Shelf Project) is critical to maintain and expand monitoring in the Arctic.

Funding requirements

- consensus that initial national network cost proposals for low level observation were an order of magnitude too low (was estimated at <$1M/yr); post-workshop follow-up survey will be undertaken to solicit estimated cost of existing activities, both real and in-kind support, in order to more accurately prepare network cost estimates
- first priority for new funding for the national network is to set-up coordination and management aspects (personnel and financial resources)
- long term requirements of monitoring network at odds with current "short term" program funding mode
- Kyoto has opened a window of opportunity to lobby for funding for monitoring, since the government has committed itself to do something.

Steps in the establishment of a Canadian Permafrost Network

In summary the key steps for the successful establishment and operation of a National Permafrost Monitoring Network contributing to the Global Climate Observing System are, in order of priority:

1. Secure long-term federal institutional commitment and funding for coordination and operation of a national network. The GSC, a branch of Natural Resources Canada, has been identified as the likely lead agency to undertake the coordination and management.

2. Provide this national coordination with the necessary human and financial resources to: i) establish the national data compilation and distribution centre (web based), ii) support existing government, university and other agency observatories of active layer and permafrost thermal state (where support includes site selection, equipment, personnel and logistics)

3. Support Canadian involvement in international GCOS programs: develop and maintain the GTN-P web site, maintain international metadata and annual summary observations.

4. Restore key inactive Canadian sites where possible.

5. Augment the network by establishing sites to fill critical thematic and regional gaps (e.g. regional gaps in south-eastern N.W.T., Nunavut west of Hudson Bay, and much of the discontinuous permafrost zone), working in partnership with communities, national parks and industry.

6. Support complementary monitoring of active geomorphic processes (eg. slope and coastal stability) to assess and detect long-term climate change.

7. Support research into development and implementation of remote sensing techniques to extend point source permafrost monitoring to broader spatial domain.

INTRODUCTORY REMARKS

Jean-Serge Vincent
Associate Director General
Geological Survey of Canada
Natural Resources Canada

On behalf of the department of Natural Resources NRCan and the Geological Survey of Canada I would like to welcome you to the workshop on permafrost, glaciers and ice caps monitoring networks. I would like to thank the organizers for inviting me to say a few words. I must say I am pleased to see so many people here: many of them are old colleagues and friends. Again, Welcome all. Bienvenue a tous.

The objectives for this workshop are fourfold:

a) Gain understanding of what we are doing in Canada as far as monitoring of permafrost, glaciers and ice-caps
b) Analyze if the current monitoring programs are well targeted. Is what we are now doing as far as monitoring ok or is refocusing required? Are we doing enough as far as interpreting/using the data? Are we doing a proper job of disseminating and archiving the data in appropriate National or International repositories? These are all key questions.
c) Identify exactly what needs further to be done and establish priorities
d) Discuss how best Canadian efforts can be coordinated and managed

In a nutshell, this workshop is about getting our act together, making plans together to ensure that monitoring and associated needs of Canada are met. The results of this workshop are intimately linked to Canada's contribution to an international effort to detect and assess the impacts of climate change. We have international commitments under the International Hydrological Program and the UN Framework Convention on Climate Change (Buenos Aires) to do this.

I cannot overemphasize the importance of this workshop:

- Availability of monitoring data is essential if as a nation we are to be in a position of knowledge to answer critical questions: particularly those dealing with the impacts of climate change on the country
- It is only with monitoring data that we will be in position to detect change, measure the magnitude of the change, evaluate the impact of the change
- It is only by having this data that we will be in a position to propose adaptation strategies to deal with the impacts of the change. This **is** a new but vital role we as scientists will need and be expected to play in coming years.

Here at the GSC we see the acquisition, integration, interpretation and dissemination of monitoring data as one of the key endeavors we must be involved in as a federal science agency. There is a need for having continuity in the provision of such data and we can provide this continuity.

At NRCan we have been collecting data on Arctic glaciers since the 50s, monitoring ground temperatures in permafrost since the 70s, active layer changes since the late 80s and various permafrost related processes such as creep also since the 80s. We take this role very seriously as do our colleagues in Environment Canada who have collected data on Cordilleran glaciers since the 60s or researchers at the Centre d'Etudes Nordiques who have been collecting data on the permafrost of northern Quebec since the 80s. The new NRCan-EC National Glaciology Program has brought the Arctic and Cordilleran interests together. This is an example of effective collaboration between agencies, which can serve as a model to all of us.

Notwithstanding these efforts much more needs to be done and it must be done in a coordinated and integrated way across Canada. Plans must be developed. This is the key challenge that awaits you over the next two days. With the ever-growing recognition that climate change is for real and that it will have serious impacts on our economy, society and environment, the time is ripe to come up with well-laid plans to ensure he availability of monitoring data.

I would like to invite you to not shy away from thinking big at this workshop. My sincere hope for the success of this workshop is that you will come up with a series of clear recommendations on exactly what needs to be done as far as monitoring is concerned and on how to achieve this as community of interested scientists. I believe that the plans you will come up with are extremely important if we are to take advantage of new funding opportunities that are likely to come up in the near future.. some of these may be linked to the availability of a larger CCAF or to other sources, particularly some made available through international co-operation.

Again I wish to stress that we need to hear about what you see as needs, priorities and implementation strategies. We need to hear the detailed requirements for establishing, operating and maintaining the national permafrost and glacier/ice-caps monitoring networks. Short well articulated recommendations are also appropriate. For example: "Over a five year period a series of some 30 boreholes need to be drilled and instrumented across Canada in order to monitor ground temperature changes." or "Long term funding must be secured to continue operation of existing sites/programs as well as to establish new ones in areas of critical gaps"

If we clearly articulate the need and agree amongst ourselves on that need, I think we will be in a strong position to react to opportunities when these come about. I hope you will take me up on this challenge and I wish you all the best in your deliberations today and tomorrow. I am looking very much forward to hearing about the outcome of the workshop. Bonne Chance!

One last word: *My colleague Paul Egginton had hoped to be here with you through-out this workshop but he has been diverted on some other issues, he sends his apologies.*

1. NATIONAL AND INTERNATIONAL GCOS PROGRAMS

1.1 Global Climate Observing System: GCOS

Ross Brown
Meteorological Service of Canada
Environment Canada

GCOS Initiation

- IPCC (1990) highlighted the vital importance of systematic long-term observations
- 2nd World Climate Conference (1990) recommended developing a system of observations of the various components of the climate system
- GCOS established in 1992 by four agencies: WMO, IOC, UNEP and ICSU
- GCOS took on coordinating role for existing global observing systems: e.g. GTOS (terrestrial) and GOOS (oceans)

GCOS Goals

- Characterize the current climate - natural variability, extreme events
- Earliest possible detection of climate trends and climate change due to human activities
- Provide observations to determine climate forcing from anthropogenic activities
- Provide observations to validate climate models (reduction of uncertainties)
- Improved information to understand and quantify impacts of climate change

Organization and Planning

- Joint Scientific and Technical Committee (JSTC) and a Joint Planning Office (JPO) established to oversee development.
- Five standing panels established to elaborate component plans:
  - **<u>Atmosphere:</u>** GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC)

Terrestrial: GCOS/GTOS Terrestrial Observation Panel for Climate (TOPC) **(includes the cryosphere).**

Oceans: GCOS/GOOS/WCRP Ocean Observation Panel for Climate (OOPC)

Data and Information: GCOS/GOOS/GTOS Joint Data and Information Management Panel (JDIMP)

Space Systems: Global Observing Systems Space Panel (GOSSP)

GCOS **Implementation**

- Three-phase approach:

  1. Design an effective operational system

  2. Establish an initial Observational System (IOS) composed of existing components (plus enhancements) that are immediately feasible

  3. Promote emerging technologies to respond to future requirements e.g. remote sensing

- As an operating principle, GCOS is being built on existing observing and data management systems, and is relying on national programs.

GCOS OBSERVING NETWORKS

- ATMOSPHERIC OBSERVATIONS (AOPC, in cooperation with WMO):
  - GCOS Surface Network (GSN)
  - GCOS Upper-Air Network (GUAN)
  - Global Atmosphere Watch (GAW)

- OCEAN OBSERVATIONS (OOPC, in cooperation with GOOS, JCOMM):
  Climate components of:
  - Ships of Opportunity Programme (SOOPIXBT)
  - Global Sea-Level Observing System (GLOSS)
  - Tropical Atmosphere-Ocean (TAO) Array
  - PIRATA
  - Drifting Buoys (DBCP)
  - Argo

- TERRESTRIAL OBSERVATIONS (TOPC, in cooperation with GTOS):
  - Permafrost (GTN-P)
  - Glaciers (GTNet-G)
  - Carbon flux (FLUXnet)

- Hydrology (GTN-H) (proposed)

Canadian GCOS Program

- Canadian *ad hoc* GCOS committee established in 1992
- NO formal structure for Canadian GCOS program
- Using guidelines from Victoria Workshop (Feb. 1999) and CCAF support to promote agenda
- **Objectives:** Assess capacity to meet GCOS (and Canadian) requirements, and propose cost-effective options to meet them
- **Deliverable:** Canada to report on progress in contributing to GCOS at next Framework Convention on Climate Change (Spring 2001).

Canadian GCOS Implementation

- Five component plans being developed:
  - **Oceans** (DFO lead)
  - **Atmosphere** (EC/MSC lead)
  - **Terrestrial** (NRCan/CCRS lead)
  - **Hydrosphere** (EC/MSC lead)
  - **Cryosphere** (multi-agency collaboration coordination through CRYSYS project)
- Scoping documents prepared for Victoria Workshop (Feb 1999) (existing networks, problems, priorities, action items)
- Funding from CCAF to support some of the identified priority action items

Canadian GCOS Component Plan Guidelines

- GCOS Initial Observing System requirements (GCOS-32) Canadian requirements beyond GCOS
- Assessment of existing observing networks/systems to meet requirements
- Recommended Canadian contributions to GCOS IOS
- Coordination of observing networks/systems
- Implications for remote sensing (e.g. Canadian Space Plan)
- Implications for Data Management

- Implications for Agencies

- Recommended Actions (and estimated costs) 2001-2009 time-frame

Cryosphere IOS for Canada

- Development being led by ***ad hoc*** working group coordinated through CRYSYS project, with extensive consultation and involvement of research community

Chair.- B. Goodison (CRYSYS PI)
Coordinator.- R. Brown (CRYSYS Secretariat)
Consultant: D. O'Neill (DONMEC Consulting)

Glaciers: R. Koerner and M. Demuth (GSC)
Permafrost: M. Burgess (GSC)
Lake Ice: C. Duguay (U. Laval)
Sea Ice: B. Ramsay (MSC/CIS) and H. Melling (DFO)
Snow: A. Walker (MSC/CRB)

- **Background documents** prepared for Victoria workshop (Feb 1999) (existing networks, problems, action items)

- **Network Definition Workshops** planned for 2000

- (Glacier/Permafrost - GSC; Snow/Lake ice/Sea ice - MSC)

- **Goal:** Submit Canadian Cryosphere IOS Plan and cost estimates to Canadian GCOS Committee by March 31, 2001.

Priority Assessment for Canadian Climate Monitoring and for Overall Canadian Needs.

Cryospheric Variable	GCOS Priority and Feasibility	CDN Climate Monitoring Priority	CDN Cost	CDN Needs Priority
Firn temperatures	P2 Fl	M	L	M
Glaciers and ice cap mass balance	Pl Fl	H	M	H
Lake and river freeze-up and break-up	P2 F2	M	M	M
Permafrost - active layer, thermal state	Pl Fl	H	M	H
Sea ice concentration/extent	Pl Fl	M	M	H
Sea ice motion	P2 F2	M	M	M
Sea ice thickness	Pl F2	H	H	H
Snow cover extent	Pl Fl	H	L	M
Snow depth	Pl F2	H	M	H
Snow water equivalent	Pl F2	H	M	H
Snowfall, Solid	Pl F2	H	H	H

Recommended Priority Areas for Canadian Cryosphere Contribution to *GCOS*

1. **Snow Cover** (depth and SWE) - surface observations .for GSN; regional mapping of SWE from passive m/w

2. **Glacier Mass Balance** as part of planned GTOS Global Terrestrial Network for Glaciers program (GTN-G)

3. **Permafrost Active Layer and Thermal State** as part of newly formed GTOS Global Terrestrial Network for Permafrost program (GTN-P)

4. **Sea Ice Thickness** from ULS at key locations in the Arctic

5. **Snowfall and Solid Precii2itat** on - measure at GSN stations; provide corrected precipitation values to Global Precipitation Climatology Centre.

Key Steps to Developing an Effective Canadian Cryospheric Monitoring System

- Network Optimization for Climate Monitoring (this workshop!)
- Include Climate Monitoring in Institutional Mandates
- Effective Use of Remote Sensing Technology
- Facilitate Access and Exchange of Climate Monitoring Data e.g. U. Waterloo CCIN initiative
- Deliver Timely, Relevant Information
- Maintain an Integrated View of the Cryosphere!

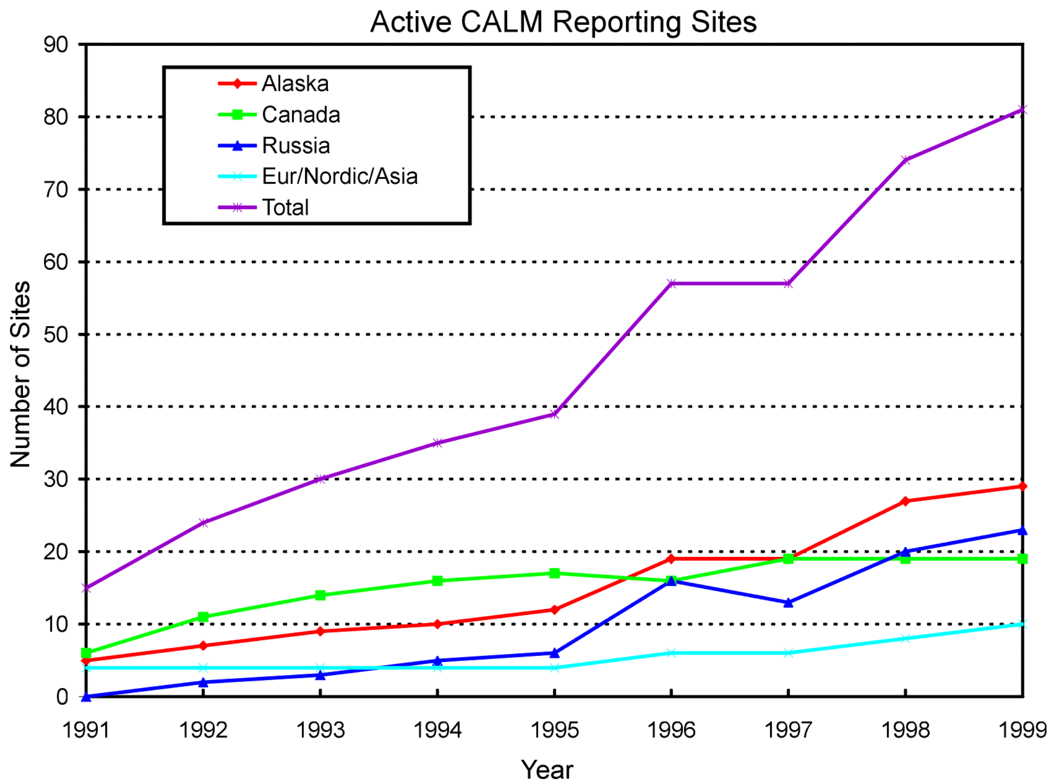
1.2 International Networks: Global Terrestrial Network for Permafrost GTN-P[1]

Jerry Brown
International Permafrost Association

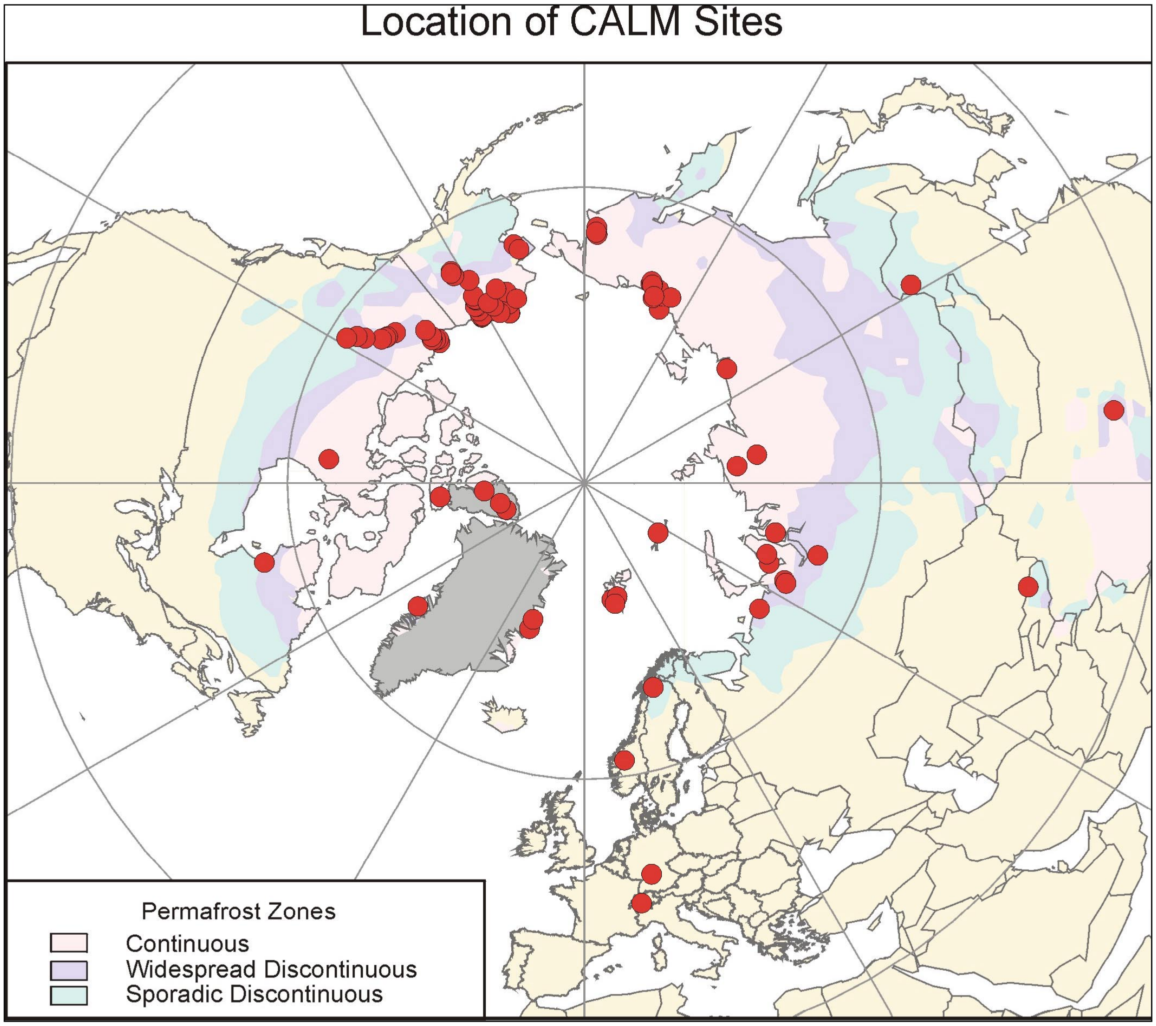
It's a pleasure to be here and to provide a status report[2] on our current activities associated with the international active layer and permafrost borehole networks, and to take into account the on-going and future activities here in Canada. The preceding report by Ross Brown provides background on the WMO program under Global Climate Observing System (GCOS) and related start up activities in Canada. I thank Sharon Smith for preparing many of the overheads used in this presentation.

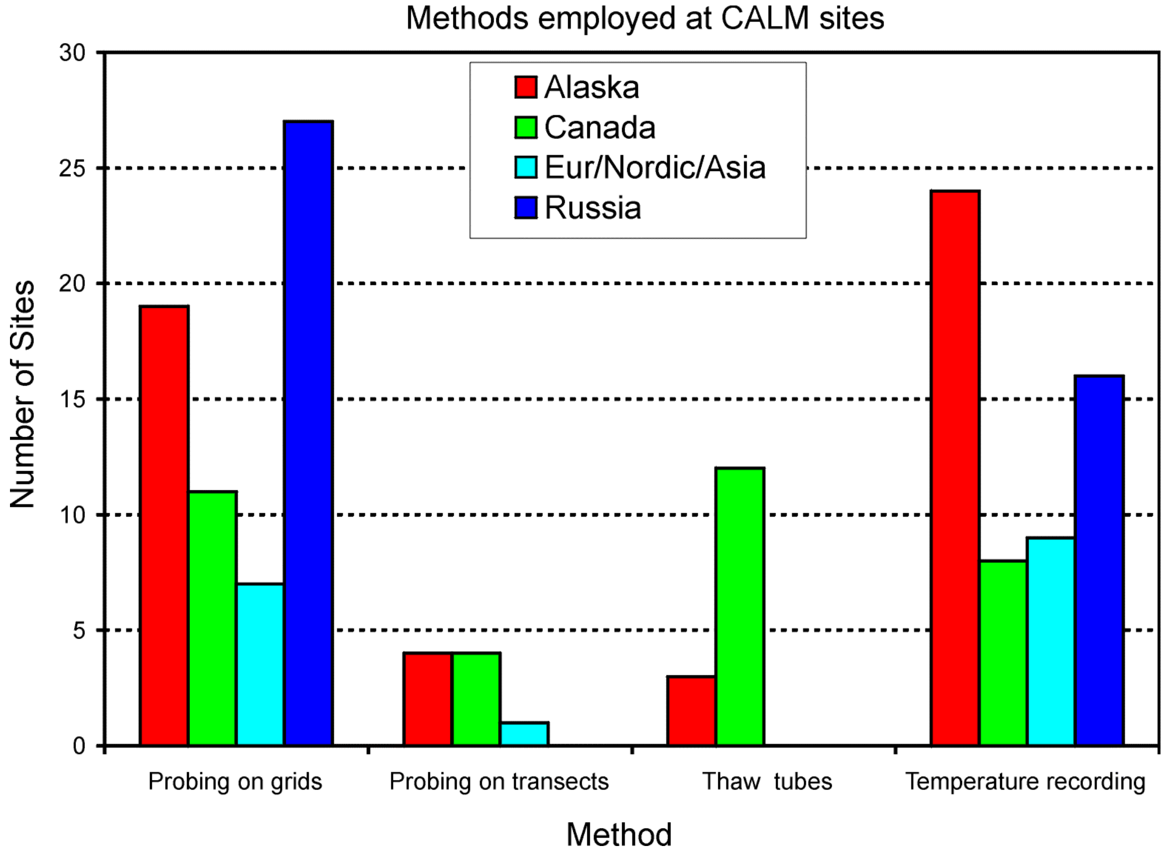
Active layer and permafrost thermal state were identified as key cryospheric variables for monitoring through the World Meteorological Organization's Global Climate Observing System (GCOS) (WMO 1997a). Wilfried Haeberli from Zurich was instrumental in formulating the two monitoring parameters for GCOS and for recommending the establishment of a permafrost network similar to the glacier network we just heard about. An international network, the Global Terrestrial Network for Permafrost (GTN-P), has been approved under GCOS and is being planned and coordinated by the International Permafrost Association (IPA). The active layer component, the Circumpolar Active Layer Monitoring (CALM) program, is already in place for much of the Northern Hemisphere. The GTN-P organizational efforts are thus focussed on the development of the permafrost temperature monitoring program. Although several regional permafrost borehole temperature networks exist, a globally comprehensive network for ground temperature measurements is required to provide long-term field observations essential for the detection of the climate change signal, for the assessment of its impact on permafrost, and for indications of spatial variability across the permafrost regions.

[1] In some documents the acronym used may be GTNet-P.
[2] Subsequent to the January Permafrost Monitoring Workshop, a report on the status of the GTN-P was published in the Geological Survey of Canada's Current Research series, see Burgess et al. 2000.



The Circumpolar Active Layer Monitoring Program (CALM) was established under the auspices of the International Permafrost Association in 1991 to obtain long-term active layer measurements. As we all know, the active layer is the uppermost layer of the ground, which freezes and thaws seasonally and overlies permafrost. Important observations in the active layer include the maximum thickness of the seasonal thaw at the end of summer, and, when possible, a record of ground temperatures and soil moisture. The network has grown from an initial 15 sites to more than 80 sites located throughout the permafrost regions of the Northern Hemisphere. Methods employed at CALM sites to determine active layer thickness include probing, thaw tubes and temperature measurements. Maximum annual active layer thickness, and the method of its determination, are reported annually and posted on the CALM web site (http://www.geography.uc.edu~kenhinke/CALM/index.html). The metadata, measurement protocols, site submission information, product descriptions from commercial vendors, etc. are also available on the web site. Metadata for most sites are also available on the Circumpolar Active-Layer Permafrost System (CAPS) CD (IPA, 1998). The U.S. National Science Foundation, in a five-year grant to Ken Hinkel at the University of Cincinnati, is providing partial logistic expenses for the development of more than 20 Russian sites and the maintenance of the CALM web site.


Location of CALM Sites
Permafrost Zones
Continuous
Widespread Discontinuous
Sporadic Discontinuous



Since the formal establishment of the GTN-P in early 1999, the IPA organizing committee has focussed its efforts on establishing the permafrost temperature monitoring program. This program consists of a globally comprehensive network of boreholes for ground temperature measurements. In permafrost, temperature-depth profiles are required, with the desired frequency of observations decreasing with depth (Riseborough and Burgess, 1996). For example, measurements are desirable several times throughout the year in the upper 5 to 15 m, where ground temperatures experience an annual temperature cycle (lagged and attenuated from the annual air temperature wave). At depths below the penetration of the annual wave (known as the depth of zero annual amplitude), and up to 50 m, annual observations are sufficient. Biennial or less frequent observations (5 to 10 year intervals) are acceptable at the greater depths (up to several hundred metres) where temperature changes very slowly. These temperature measurements are obtained in boreholes, using one of several types of thermistor sensor and measurement systems, e.g. through repeated logging of boreholes by lowering a single sensor probe or by installation of a multisensor cable read manually or read by a data logger.

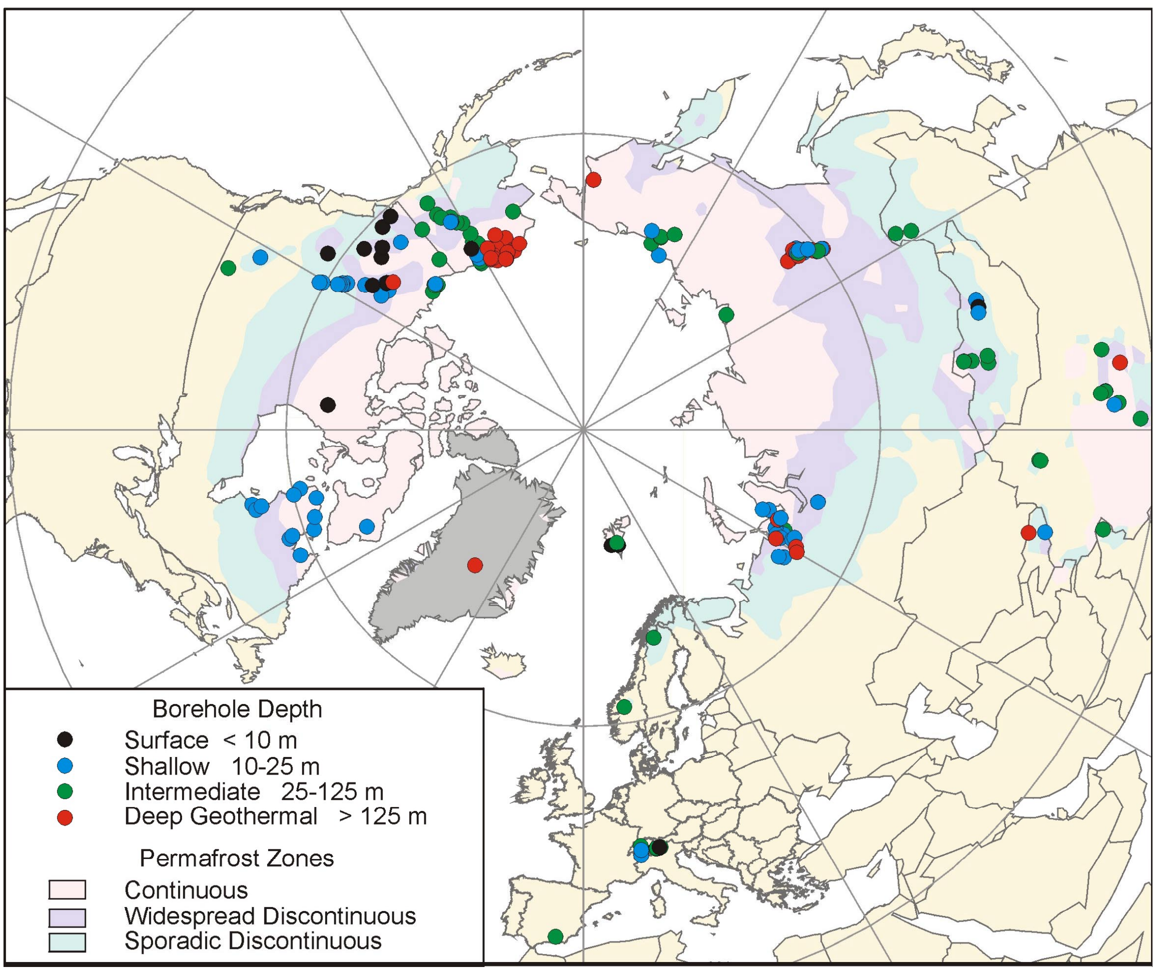
Summary of Active Layer (CALM) and Permafrost Borehole Sites by Country **(March 1999 compilation)**

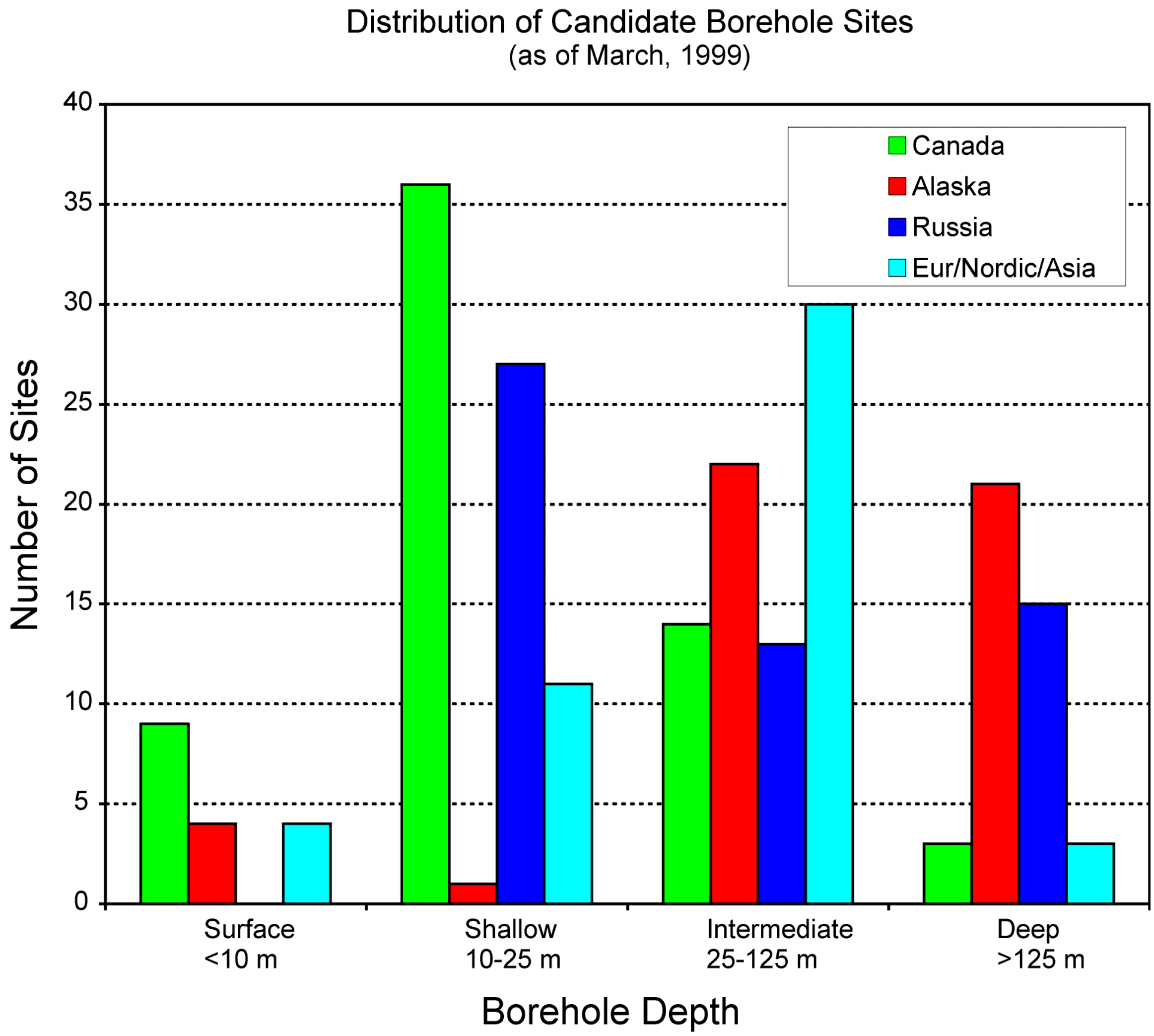
Country	CALM sites	Boreholes			
		Surface 0-10 m	Shallow 10-25 m	Intermediate 25-125 m	Deep >125 m
Austria-Russia	1				
Canada	20	9 (1)	36 (2)	14	3
China	2		3 (1)	12	1
Denmark-Greenland	3				
Germany-Russia	2				
Germany-Switzerland				1P	
Italy	3	1 (1)	1P	1P	
Italy-Antarctica		3			
Japan-Russia			5	2	
Kazakstan	1		3 (1)		1
Mongolia		1	3	6	
Norway				1P	
Norway-Svalbard				1P	
Poland-Svalbard	1				
Russia	21		22 (9)	11	15
Spain				1P	
Sweden	1			1P	
Sweden-Svalbard	1	2 (1)			
Switzerland	1		1P	6 (1) [2P]	
US-Alaska	25	4	1	22 (8)	21 (6)
US-Antarctica			1		1
US-Greenland					1

P=PACE borehole; ( ) number of boreholes associated with CALM sites.

A number of boreholes drilled for research, geotechnical or resource exploration purposes in permafrost regions in the last half of the twentieth century have been maintained as thermal monitoring sites. A survey conducted in early 1999 identified about 200 candidate boreholes in the circumpolar north for future long-term observations of permafrost temperatures and related climatic variables. The boreholes range from single sites, to transects or regional networks, and vary in depth from less than 5 m to over 125 m; a number of them are co-located with CALM sites. Regional networks include those of the Geological Survey of Canada (GSC) in Mackenzie Valley and Delta, the University of Alaska's Alaskan transect, the United States Geological Survey's deep boreholes in Northern Alaska, a series of holes in the Kolyma River Valley and West Siberia, and the European Community's Permafrost and Climate in Europe (PACE) project of mountain boreholes from southern Europe to Svalbard.

Candidate Boreholes for Permafrost Thermal Monitoring
(as of July, 1999)





A borehole metadata form (Appendix E)was developed and distributed internationally in late 1999. As a result approximately 75 additional candidate sites were identified including some in Mongolia, several regions of Russia, the Canadian High Arctic and Antarctica. Additional sites are in the process of being nominated. Protocols for borehole temperature data collection and submission and procedures for data dissemination and accessibility are subjects of a planned international workshop organized by Vladimir Romanovsky for June 2000 at the International Arctic Research Center in Fairbanks.

The GSC currently supports the international data management for the GTN-P borehole temperature monitoring program. A GTN-P web page is under development on the GSC's Permafrost Web Site and the list of candidate boreholes has been posted (http://sts.gsc.nrcan.gc.ca/gtnp). Metadata forms for the submission of new borehole sites are also available. Metadata for network sites will ultimately be accessible as well as regularly submitted data and protocols.

A major problem for retrospective analyses of temperature trends is that the substantial amount of useful historical data is dispersed, generally not in a digital format compatible with current data management systems, and often have not been subjected to quality control procedures. To ensure that valuable records are not lost, these data need to be located, processed and archived in an accessible form. Resources are thus required for data rescue as well as data management. GTN-P data will be subsequently archived through the National Snow and Ice Data Centre, Boulder, Colorado, as part of the IPA's Global Geocryological Database (IPA, 1998) and the WDC-A for Glaciology.

GCOS and thus GTN-P is built upon national programmes. The development of national programmes is critical to ensure the continuation of existing networks as well as the expansion of activities, such as the addition of new sites to fill in regional or thematic gaps, and the establishment of central coordination and database management capability. Most permafrost countries currently lack a central agency with the clear mandate and necessary resources to organize, coordinate and operate a national network. In fact, appropriate ministries in many permafrost countries are unaware of the existence of the GTN-P or of the importance of permafrost data for GCOS's mission. This contributes to a lack of resources for implementation, management and continuing operation of national networks.

Many existing boreholes are in remote and often inaccessible locations; hence, there are logistical and financial difficulties reaching sites on a regular basis. Regional gaps also exist in most mountainous and plateau areas of both hemispheres, the Antarctic, central Arctic and sub-Arctic Canada, and a number of regions of Eurasia. Additional boreholes are required to ensure adequate coverage for a global observation network, but new holes are expensive to drill. At least 20 new holes are required initially in under-represented regions.

To help overcome some of these administrative constraints, WMO Secretary-General Obasi is sending letters to Foreign Ministers of countries with permafrost activities and interests requesting their commitment and continued support for GTN-P (Appendix H). These letters can be used as added justification when requesting funds for permafrost observing projects.

Our next steps in the development of the GTN-P are to formally select specific active sites for the network and assign them to the spatially distributed categories according to the GHOST-Global Hierarchical Observing Strategy (WMO 1997b). This will be done through evaluation of metadata for nominated sites. Following site selection and protocol development, available data will be submitted. Our plan is have the metadata officially released as a GSC Open File. Summary data will also be provided on the GTN-P web site. Data will be submitted annually (less frequently for deeper measurements) and annual summaries will be posted on the web site. The Canadian portion of the database will be linked to the permafrost component of the State of the Cryosphere and CCIN web sites, supported by CRYSYS (use of the Cryospheric System to Monitor Global Change in Canada). Progress towards meeting our GTN-P goals is reviewed at annual meetings of the American Geophysical Union and the Russian permafrost conference in Pushchino. A five-year summary report organised by regional editors is envisaged with the draft to be presented in 2003 at the Eighth International Permafrost Conference in Switzerland.

Before concluding, I would like to mention another permafrost network that is presently under development. An international workshop on Arctic Coastal Dynamics (ACD) was convened in Woods Hole, MA, this past November. We recommended implementation of a circumarctic monitoring network for observing rates and causes of coastal erosion (see Appendix D). The workshop was organized under the auspices of the IPA Erosion Subgroup chaired by Steve Solomon. I would hope the subject of erosion of high-ice, permafrost-dominated shorelines will be considered over the next few days and included as a recommendation for monitoring. A GSC Open File report (Brown and Solomon 2000) and a web site contain the results of the ACD workshop and other information < http://www.awi-potsdam.de/www-pot/geo/acd.html>.

1.3 Can GCOS – Cryosphere: Permafrost

Margo Burgess
Geological Survey of Canada

I would like to present the current status of the permafrost component of Can-GCOS Cryosphere plan. When I became involved in the ad hoc Can-GCOS committee a year ago, I indicated that my permafrost contributions had not resulted from a broad consultation with the Canadian permafrost community (due to lack of time and resources) and that I certainly could not be considered to be speaking on behalf of the whole community. The permafrost community is perhaps a bit larger than the glacier community, and perhaps a bit younger too. At the international level, the glacier community have had their "monitoring act" together for over 100 years, while the IPA's CALM has only been around for 10 years. Because of the greater numbers in the permafrost community, it is not as easy to know what is going on across the country. The permafrost scoping documents and contributions to the Victoria Can-GCOS Workshop in February 1999 were my attempt to represent the Canadian permafrost community. This Ottawa workshop is intended to improve on that effort and obtain wider input.

In the last year, I have also been involved with Jerry Brown and the IPA on the GTN-P ad hoc committee, trying to establish the network, inventory and pick candidate borehole sites for this international thermal monitoring program. As a result of this involvement, I was able to relay to the Canadian GCOS committee, the international status of permafrost monitoring programs on active layer and ground temperature monitoring - the two initial parameters that GCOS has identified for permafrost monitoring. A map compiled of monitoring sites in Canada, compiled with available information a year ago, showed a concentration of sites in the Mackenzie Valley (largely GSC research), in Northern Quebec (Universite Laval), a scattering of additional sites and large areas of the country, particularly Nunavut, where there was very little monitoring. Through the monitoring survey forms (Appendix E) completed by workshop participants, we have now have a much improved location map and knowledge of Canadian permafrost monitoring activities (see Appendix F and location maps in Executive Summary).

There are a few additional tasks on the Workshop agenda. We want to go beyond active layer and ground temperature monitoring, to look at processes as well and discuss what kinds of process monitoring should be included in our Canadian monitoring network, eg.s creep, ice-wedges, coastal, etc. In addition, we had hoped to discuss the role of remote sensing in permafrost monitoring. Unfortunately, our presenter on remote sensing was unable at the last minute to attend.

Individual commitment, rather than institutional commitment, has largely accounted for the permafrost monitoring that has been accomplished to date. These individuals have succeeded through creative use of , or piggybacking on, NSERC or other funding sources for targeted short term research. Just as with the glacier community, there has been no identified commitment to support national or regional networks for the long term. We are fortunate to have had observations for 10 to 20 years, thanks to these many dedicated individuals. There is, however, no guarantee that the monitoring work of these individuals will continue should they retire or move to other positions.

Permafrost was identified as one of the priorities for cryosphere monitoring by GCOS/GTOS. While it is important to detect and monitor the climate signal is in permafrost, assessing the impacts of climate change on permafrost are also important for the landscape and ecosystems, and for northern communities and development.

To recap,

- One of the priorities identified after the February 1999 Victoria Can-GCOS workshop was to hold a permafrost workshop to bring the interested parties together, to build on the initial permafrost network scoping document and draft plan. Thanks to the CCAF, we are holding this workshop today. We hope that at the end of this workshop we will have further developed that plan.
- One important goal of the workshop is to find a way to enshrine the mandate for monitoring. Jean-Serge Vincent gave us some very encouraging words of support. Climate change now figures prominently in the strategic plan for the next 5 years for the Earth Science Sector of Natural Resources Canada. One of the goals articulated in the strategic plan is: "To understand the earth science aspects of the impacts of climate change". Implementation strategies to achieve that goal now include the word "monitor". "Monitor" used to be something of a four-letter word in the earth sciences research community, to the extent that it was necessary to avoid using the word. It now appears that it is gaining greater credibility and acceptance.
- To quote from a presentation, given by a modeller from the U.S's National Centre for Atmospheric Research (NCAR) at the December 1999 American Geophysical Union (AGU) conference in San Francisco: "One golden observation is worth a thousand simulations."

2. CURRENT PERMAFROST MONITORING ACTIVITIES

Researchers from government, universities, and industry were invited to give a series of short presentations covering geographic and thematic aspects of:

- Active Layer and Thermal Monitoring
- Processes/Landscape/Impact Monitoring
- Carbon Cycle (sources/sinks)

Most speakers dealt with at least two of these sub topics in their presentations. Nearly all of the thermal monitoring activities presented were undertaken with specific research objectives in mind, rather than for monitoring per se. The temperature of permafrost and the thickness of the active layer are crucial to many processes (hydrology, slope stability, carbon sequestration, etc.).

University-based speakers discussed their individual projects, some of which were carried out at long-established (and sometimes currently abandoned) field stations.

Don Hayley was the only presenter speaking from the point of view of industry. His primary point was that opportunities exist for access to boreholes and data that have been obtained for engineering purposes.

Observations of active layer thickness and permafrost temperatures over the last two decades in North America show significant regional and temporal variation.

Over the last decade, the GSC has been monitoring the depth of seasonal thaw penetration in the Mackenzie Valley and Delta. Observations show that thaw depths have increased with the greatest thaw penetration occurring during the summer of 1998. Since 1991 thaw settlement has also occurred with the maximum amount occurring in 1998 (Wolfe et al., 2000).

Ground temperatures at a depth of 20 m in Alaska recorded by University of Alaska, Fairbanks, indicate a cooling trend between 1983 and 1986 (Osterkamp and Romanovsky, 1999). Since 1986, ground temperatures have generally increased. Observations also indicate significant inter annual variability. In the Whitehorse area of the Yukon Territory, the warmer signal noted in western Alaska is however, not observed.

In northern Quebec, air temperatures cooled throughout the 1980s. This cooling trend lasted until 1993. Observations of ground temperatures by Université Laval also show a cooling trend and at depths of about 10 m it was observed to last until the mid 1990s (Allard et al., 1995). In the last few years a warming trend has been noted.

Stuart Harris of the University of Calgary did not attend the workshop, but has written a report on his monitoring-related activities in the Cordilleran Region. His report is included as part of this section.

The presentations summarized in this section are:

Recent Warming Impacts in Western Arctic Canada: Evidence from Air Temperatures, Active Layers, and Ice Wedges.
Stephen Wolfe
Terrain Sciences Division
Geological Survey of Canada

Active Layer Monitoring: Geological Survey of Canada
Mark Nixon
Geological Survey of Canada

Soil Climate Monitoring
Charles Tarnocai
Agriculture and Agri-Food Canada

Permafrost temperature monitoring, Yukon and Western Arctic Canada
C.R. Burn
Carleton University

Activities of the Centre D'Etudes Nordiques
Michel Allard
Centre D'Etudes Nordiques, Université Laval

McGill University Field Stations
Wayne Pollard (presented by Dale Anderson)
Department of Geography
McGill University

Arctic Climate/Permafrost Stations
Joe Eley (presented by Paul Louie)
Climate Research Branch/MSC

Permafrost Research at University of Calgary
Brian Moorman
University of Calgary

Cordilleran Air and Ground Temperature Monitoring.
S. A. Harris
Department of Geography
University of Calgary

Climate Reconstruction from Borehole Temperatures

Alan Taylor
Consultant

Frost Table Pattern And Development In Patchy High Arctic Wetlands

Kathy L. Young
Geography Department,
York University,

CALM Project at Baker Lake, Nunavut.

Orin Durey,
Baker Lake,
Nunavut

Josef Svoboda,
Department of Botany,
University of Toronto

Margo Burgess,
Geological Survey of Canada,
Ottawa

Joe Eley,
Environment Canada,
Saskatoon, Saskatchewan

Permafrost Monitoring System in Alaska: Structure and Results

V. E. Romanovsky and T.E. Osterkamp
Geophysical Institute
University of Alaska at Fairbanks

Arctic Marine and Coastal Monitoring at the GSCA

Steven Solomon
Atlantic Geoscience Center
Geological Survey of Canada

Slope Stability

Larry Dyke
Terrain Sciences Division
Geological Survey of Canada

Monitoring Peatland Carbon Sources and Sinks in Permafrost Areas

Stephen Robinson
Geological Survey of Canada/ McGill University

Deep Ground Temperatures, Ekati Mine, NWT

Don Hayley
EBA Engineering

Slope Instability and Gas Hydrates

Scott Dallimore
Terrain Sciences Division
Geological Survey of Canada

Permafrost Databases

Sharon Smith
Terrain Sciences Division
Geological Survey of Canada

The Norman Wells Pipeline Thermal Monitoring Program

Margo Burgess
Geological Survey of Canada

3. CLIMATE AND PROCESS MODELLING NEEDS

The interaction between monitoring and modelling was discussed in this session. Monitoring data are often a trigger to modelling efforts. Data are what first makes us aware of unanticipated changes in the environment (such as decreasing stratospheric ozone levels, or increasing CO_2 concentrations). Models are a test of our understanding of the processes that underlie the data collected. Once the modelling-monitoring dialogue is engaged, there are opportunities for refinement in both what is monitored and what is modelled.

Walter Skinner presented the new Gridded Canadian Normal Temperature and Precipitation dataset, a project just completed for MSC and which Climate Research Branch are willing to share with researchers and modellers. The grid covers Canada with a 50 km resolution, and is based on carefully corrected and homogenized climate data.
.

Al Taylor discussed the potential for using deep ground temperature logs to reconstruct past climate histories. As such, the model results can fill data gaps in space and time. Given projected changes in surface temperature, numerical ground temperature simulation models can be used to predict the consequences of changing climatic and environmental conditions.

Mike Smith discussed a simple analytical model that describes the relationship between climate and permafrost temperature, using parameters that describe atmospheric conditions (air temperature and snowcover), surface microclimatic effects (n-factors), and subsurface properties. The model indicates that changes in atmospheric temperature do not translate directly to changes in permafrost temperature. By demonstrating the importance of snowcover and soil moisture conditions to the climate-permafrost relationship, it suggests the need to monitor these parameters in order to understand the results of permafrost temperature monitoring.

Fred Wright identified important differences between modelling at national and regional scales. The differences arise due to the different questions that are local scales, and to significant differences in the amount and type of data that are available at these scales.

- The use of data at shorter time scales
- Accounting for the effects of increased spatial variability
- Use of relatively scarce climatic information
- A general lack of ground temperature data

While Diane Verseghy was unable to attend the workshop, Ross Brown conveyed her main points on Permafrost Data Needs for GCMs to the assembled group via an overhead slide:

- The current resolution of GCMs is too coarse to simulate the ground temperature regime in any detail.

- Deeper soil layers (> 5.0 m) will be required to maintain permafrost (current maximum depth in CLASS is -4.0 m)

- Higher resolution regional climate models (RCMs) have potential to simulate the ground thermal regime.

- Soil temperature data and maps of permafrost distribution will be required to validate current climate simulations.

- Information on soil moisture and ice content of soil will be required for model initialization.

Issues to consider in the use of models include
- Balancing the precision of input data and parameterisations with the accuracy of model output;
- Capturing the spatial variation of results;
- Accounting for the time delay between permafrost surface temperature conditions and the realisation of "equilibrium" permafrost temperature profiles.

The presentations summarized in this section are:

Rehabilitated Gridded Canadian Historical Air Temperature & Precipitation Database
Walter Skinner
Environment Canada

Ground Temperature Modelling: Backward and Forward
Alan Taylor
Consultant

Monitoring and Modelling: Permafrost Temperature
M.W. Smith
Carleton University

Regional Scale Modelling
Fred Wright
Terrain Sciences Division
Geological Survey of Canada

4. PERMAFROST MONITORING TECHNOLOGY AND TECHNIQUES, PRESENT AND FUTURE

Active layer and ground temperature monitoring were covered in depth. The most recent thaw tube design, installation, and measurement techniques were presented by Mark Nixon, followed by a series of presentations dealing with temperature measurement technology: Use of micro-loggers (such as HOBO and Vemco loggers) for air temperature and near surface ground temperature measurements; multi-thermistor temperature cables; single probe borehole logging; the relationship between frequency of measurement, depth of measurement, and accuracy in ground temperature reconstruction from infrequent measurements.

Geophysical methods were discussed as a means of enhancing monitoring efforts and extending point source data in two or three dimensions. Periodic geophysical surveys at monitoring sites can reveal the interaction of temperature change with thermally dependent processes and states.

The presentations summarized in this section are:

Near Surface Instrumentation
Mark Nixon
Terrain Sciences Division
Geological Survey of Canada

Single Probe Borehole Logging
Vlad Romanovsky
University of Alaska

Ground Temperature Measurement Frequency
D. W. Riseborough
Department of Geography
Carleton University

Geophysical Methods For Characterization Of Permafrost Monitoring Sites
(Presented by Stephen Robinson) By Members of the Terrain Geophysics Section,
Geological Survey of Canada

Geophysics - Current And Potential Uses, Surface And Borehole Surveys
Richard Fortier
Centre D'Etudes Nordiques, Université Laval

5. PERMAFROST NETWORK REQUIREMENTS

Group Discussion

Following the sessions on monitoring activity, modelling, and technical issues, workshop attendees participated in a semi-structured discussion of the founding and structure of the proposed network. The agenda included:

- Membership criteria, site selection
- Measurement Protocols
- Data quality control
- Data reporting/submission, web availability
- Data access and exchange
- Data archiving
- Expertise and Capacity
- Priorities/Needs - thematic, geographic, research, analysis, technology development
- Funding Requirements - low, moderate, high programs; implementation and operation
- Co-ordination/Management -Federal government role/mandate?

The material presented in this section is a summary of the comments made during the discussion sessions. Persons making comments are not identified. Comments have been taken out of chronological sequence and arranged according to the agenda above.

Membership criteria, site selection

How many sites are required? What criteria should be used to choose between candidate sites? Who are the users of monitoring site data? What are the users data requirements?

- Filling gaps in network should be an early priority, with accessible sites close to communities as most desirable.

- Most monitoring sites are concentrated in Northern Quebec and the Mackenzie Valley.

- Major communities (Yellowknife, Iqaluit, Churchill) are not represented in the current monitoring network (as mapped- some activities are ongoing in these communities but are subject to verification before inclusion), and are obvious places to establish monitoring stations. Collaboration might also be sought with BOREAS (Thompson Site)

- When filling gaps in a ground temperature monitoring network, preference should be given to sites with existing long-term meteorological data, such as North Warning System sites.

- Many potential monitoring sites are not near any settlements (For example: there are no communities between Fort Reliance and Baker Lake. Collaboration with Parks Canada, Mining or other extractive operations (e.g. Ikadi mine) can support monitoring by allowing access to boreholes, and field support.

- MSC weather stations are analogous to monitoring sites.
- Sites could be selected to be representative of eco-regions, or of terrain conditions.

Measurement Protocols

Can we establish monitoring Protocols?

- One of the difficulties in establishing a monitoring network is that it intended to answer questions that we do not know we need to ask.
- GCOS requires long term systematic monitoring. The purposes of monitoring are not only to answer immediate questions of concern to Canada. Monitoring data will be used to answer questions posed in the future. Canada's contribution to GCOS will also be used to contribute to answers to global questions.
- The CALM protocol exists for active layer measurements, and can be used for GTOS.
- It is clear that the necessary frequency with which measurements should be taken depends on particular thermal regimes, depths, etc., so no concrete guideline can be established.
- The monitoring protocol for the Alaska Pipeline may have been based on a single paper written by Tom Osterkamp ?

Data quality control

Who will be responsible for quality control?

- Existing data have a range of accuracy and precision. The same can be expected with new data.
- Data should be filtered for obvious technical problems: Should this be done by the archiving body, or by those submitting data?
- One model would be for a central agency to invest in data acquisition equipment acquisition and maintenance. (Analogous to TFSS?) Researchers, communities, government agencies, etc. who are interested in contributing to the network could apply to the monitoring co-ordinator for access to the datalogger bank. This would help to establish some consistency between sites in terms of equipment maintenance, standardisation of meteorological measurements and equipment, etc. A standard agreement on site longevity, use of data, use of dataloggers, etc. would need to be established. Anyone who becomes part of the monitoring network should commit to submitting data.

- Sites could be classified as to the quality of the data they produce. At least in the initial stage, there is no reasonable way for the monitoring agency to exert quality control.

Data reporting/submission, web availability

- Data should be submitted annually (less frequently for deep temperature sites), with a reporting period based on the calendar year. Any material of financial support to contributors should be contingent on data submission. Since monitoring will not be the main activity for most contributors, contributors should submit only data relevant to monitoring. The contributions made by individuals and organizations should be acknowledged in an archive, and a request for notification of use of data should be included in archive metadata.

Data access and exchange

- Interagency charges for data should be eliminated.

Data archiving

- Maintenance of the Archive/Database should be the core of the monitoring infrastructure.

- We need to establish protocols and set data standards for archiving and metadata.

- One way to initiate the archive that would give it a profile in scientific and broader circles would be to produce a national assessment, with network contributors presenting to a "State Of The Cryosphere" meeting, and the production of a joint publication.

Expertise and Capacity

- The long-term existence of the current monitoring efforts has been attributed to the long-term commitment of individual researchers. A stable long-term national monitoring program will require a shift to (or an added) commitment on the part of institutions.

- Monitoring sites, equipment, and archives should be considered as a component of the national infrastructure. Existing sites are infrastructure already in place.

- The current value of existing sites should be determined, including the cost of drilling and equipment. What is the total value?

- Collaboration with local communities is essential. Communities will be directly affected by changes in permafrost conditions, and therefore will have a direct interest in monitoring results. Collaboration with schools would be mutually beneficial: schools (or community organisations) in smaller communities can be involved directly in monitoring activities. Arctic Colleges can collaborate in data collection and analysis. While communities cannot be expected to supply funding for monitoring, they can be valuable allies when seeking funding.

- Maintaining community involvement once established requires sustained effort. Ongoing reporting of results is essential, and communities should not be expected to supply unpaid work.

Priorities/Needs - thematic, geographic, research, analysis, technology development

- As Mike Smith pointed out in his presentation, in 1990 the IPCC asked some simple overarching questions about permafrost and Climate. Some of the answers lie in deep borehole temperature logs, but others need data from shallower holes for which more intensive/frequent monitoring is required.

- Monitoring should include process studies and monitoring of non-thermal processes. Process studies are needed in order to understand feedback between permafrost temperature, physical properties, hydrology, human infrastructure and the biotic environment.

- Snow cover and soil moisture are also important parameters to monitor in association with permafrost temperature, since these are critical to the link between atmospheric conditions and ground temperatures.

- Monitoring activities in discontinuous permafrost region will be most useful in identifying impacts of climate change; Monitoring in cold/continuous permafrost will be most useful in providing direct evidence of a climate change signal.

- An inventory of Northern buildings would be useful, since it would could be used in conjunction with monitoring data or climate-permafrost change scenarios to estimate the magnitude of impacts on communities. (MMB: An inventory of buildings exists for Norman Wells)

- Climatic normals are no longer applicable in long term engineering design: We need to know how much to add?

Funding Requirements - low, moderate, high programs; implementation and operation

- The consensus is that proposed permafrost monitoring budgets (550k low; 750k med 850k high) are low by perhaps an order of magnitude.

- The network now operating in Northern Quebec has been created from sites originally established for individual projects. The cost per site is approximately $10.000 per year, including equipment maintenance, site visits, and data analysis. This is estimated to be the full cost for acquiring and archiving data. Equipment was "donated" to monitoring by the individual researchers to help create a group-supported network, supported by provincial research funding in a creative way. Where monitoring activity can be piggybacked on other fieldwork, the incremental cost could be much less. It would be a useful exercise to prepare a detailed breakdown of the cost of the current nation-wide monitoring network.

- The best way to ensure the maximum leverage for monitoring funds would be to give a high priority within the monitoring agency to co-ordination of monitoring initiatives.

- Some portion of the budget for monitoring will require commitments for database personnel, equipment, the physical archive, and the maintenance of an archive web site.

- Long-term science in a changing research climate requires ongoing creativity on the part of grant seekers. NSERC does not support monitoring activity.

- Monitoring efforts can be piggybacked on short-term projects and mandated project monitoring such as the Ekati mine, or the Norman Wells Pipeline.

- The NSF LTR (U.S. National Science Foundation Long Term Research) model is one worth investigating as a way of making agencies such as NSERC more favourable to monitoring activity. Research funding is for 5-year renewable terms, and involves research teams with an emphasis on interdisciplinary studies. (Response: The drawback of multidisciplinary teams in the current funding environment is the requirement for multiple sources of funding. Funding bodies tend to give a relatively small grants on the expectation that the researchers will find matching funds.)

- The LTR model is really intended for intensive research projects, and sites have not been chosen with long term monitoring in mind.

- Support of monitoring should include funding for a data archive as well as data rescue.

- Resource developments offer an opportunity for environmental monitoring, which should include terrain and thermal monitoring. Such programs could be partially funded by the resource companies as part of their statutory requirements for performance monitoring. This would constitute “forced collaboration”. Companies would likely not be directly interested in the long-term behaviour of the terrain, except as it has an impact on design performance.

- Funding requests for permafrost monitoring should emphasise the role of permafrost within ecosystems, and its connection to the global climate system (through its role in forest fires, peatlands, and the carbon balance). Changes in permafrost conditions are likely to effect traditional activities on the land.

Co-ordination/Management -Federal government role/mandate?

- Monitoring is vital to the achievement of the goals CCAF and Canada’s commitments under the Kyoto protocol.

- Kyoto has opened a window of opportunity to lobby for funding for monitoring, since the government has committed itself to do something.

- The monitoring community will need to lobby CCAF and Government bodies to include monitoring activities as part of the management plan for Arctic science. It is important to change policy, which means speaking directly to policy-makers.

- Who will be the lead agency: CHS (Canadian Hydrographic Service), MSC (Meteorological Service of Canada), NRCan? Perhaps monitoring should be a collaborative. NRCan would be a natural leader for permafrost monitoring.

- A long-term (permanent) position at GSC dedicated to on-going recovery, archiving, and analysis of permafrost temperatures throughout Canada is suggested. The position should be fully funded for this task, and have an adequate field budget for data collection, upgrading and maintenance of borehole instrumentation (and potential establishment of new boreholes). The position should be protected for 10 years.

6. MEETING SUMMARY

Des O'Neill
Consultant to Meteorological Service of Canada
Environment Canada

Mr O'Neill acted as a rapporteur for the permafrost sessions and provided the overview below at the conclusion of the workshop.

Developing a national permafrost plan, a number of important considerations were noted:

There is a need:

- For sites to be long term, continuing ones.
- To represent various regions and coastal zones
- To archive data and metadata, and to make it accessible
- To monitor more than permafrost/soil temperatures. As much as possible, these should be accompanied by air temperature, vegetation and soil moisture data, and other site information.
- To Link monitoring and modelling efforts for mutual advantage.
- For a national lead agency to coordinate activities.
- For a national lead agency for archival and database maintenance.

In short, an Institutional commitment is needed, probably at the federal level, if a long term national monitoring program is to be maintained for permafrost. This ties ito the requirement for the mandate in NRCAN to be firmed up.

Ms. Burgess presented a first cut at a permafrost plan, which was discussed in general terms. Points made in this discussion included:

- The institutional commitment requirement noted above.
- The need for teamwork or partnership approaches, building on existing skills, programs, and activities across the country.
- The idea that a national permafrost infrastructure is needed to achieve the goals of CCAF, and that big chunks of that already exist in current university, NRCan, and other programs.
- The funding requirements in the draft plan are probably unrealistically low. There may need to be some front-end loading of figures/costs.
- A national program will need to have a set of agreed standards and protocols.
- There is a need to clarify and take advantage of other agencies/programs activities that could complement or facilitate permafrost monitoring.

We also had good discussions on the best approaches to packaging or presenting a permafrost plan to (hopefully) gain funding support, and on how to fill gaps in the network – using for example opportunities at mining sites, North Warning sites,, climate stations, etc.

Points raised included:

- There is a need to articulate the user requirements for monitoring data (for example, engineering design implications in the face of climate change).
- While monitoring will be designed to answer known questions (especially concerning the climate signal in permafrost, and for prediction of foreseen impacts) , it should also position us to answer future unknown and unasked questions.
- Observations are needed in the South, where permafrost may disappear, and in the North, to detect the climate in permafrost, and validate projected scenarios.
- Monitoring should include monitoring of *processes*. Doing this properly will require an infrastructure something like that of the Polar Continental Shelf Project.
- Communities in the affected area should be involved in any long-term monitoring program, following a community-based approach. These communities are the constituency for this work. Community involvement could strengthen the case for program support.

The issues of membership criteria, the number of sites needed, and where sites should be added first were also addressed:

- The program should start with existing sites. New funding can fill gaps with industry and community supported sites.
- It should be relatively easy to add sites at some larger communities (Churchill, Yellowknife, Inuvik) and at national parks.
- The highest priority should be given initially to sites in the discontinuous permafrost zone.
- Criteria for new sites should also include the need to represent the variety of climatic zones and ecoregions in the permafrost zones.

Measurement protocols were discussed briefly:

- Most people follow or will follow the CALM protocols, although there are a number of measurement approaches and instruments used in boreholes.
- Different measurement protocols may need to be developed for different depth ranges.
- The idea of a monitoring infrastructure for Canada should include some standards and protocols, and possibly a bank of equipment meeting the network standards. A national infrastructure should have common standards for a monitoring program.
- Even NSERC would probably support a proposal for an infrastructure if well presented. CFI funds might also be sought or directly from government budget.
- At present, researchers routinely do data quality control as data is collected. For new stations, a scheme may need to be developed.

Data reporting and submission:

- Annual reporting and submission is suggested, although a longer interval would be acceptable for deep borehole sites and sites with data acquisition that are visited infrequently.
- Initially, only selected data from sites would be submitted to the monitoring archive from researchers. Later, perhaps after research results have been published, all available data for sites could be submitted.
- It was suggested that national monitoring results be evaluated and presented approximately every three years, at a workshop intended to evaluate “The State of the Cryosphere”.

Data Archiving:

- This will be a serious long-term issue.
- There is uncertainty regarding how much data there will be.
- Archiving must be an integral part of monitoring infrastructure.
- The Geological Survey is natural home for archiving activity.

GTOS' GHOST hierarchy was not accepted enthusiastically.

The final discussion returned to how to present the total costs of monitoring plans: total, real costs, or eliminate in-kind support from the total.

Initially, funds are needed to set up and coordinate current efforts, and then bring in other partners (territories, private sector).

7. ACKNOWLEDGEMENTS

The joint Permafrost, Glaciers and Ice caps Canadian monitoring networks workshop was supported by the Government of Canada's Climate Change Action Fund. Funding was obtained as part of a series of workshops to define a core Canadian cryospheric network of *in situ* and remotely sensed data for monitoring the Canadian crysophere in support of GCOS (CCAF project # S99-12-08). The Geological Survey of Canada hosted the Workshop, and provided in-kind support for the organization of the workshop and participants' attendance. Janice Naufal (GSC) assisted greatly with the workshop logistics, ensuring a smooth and successful meeting..

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APPENDICES:

A. Workshop Agenda
B. List of Participants
C. List of Acronyms
D. Letter from WMO
E. Recommendations from Coastal Workshop
F. Monitoring Site Meta-Data Forms
G. Monitoring Sites: Summary Table
H. Presentation Transcripts/Summaries

A. Workshop Agenda

Canadian GCOS- Global Climate Observing System- Cryosphere

Glaciers/Icecaps and Permafrost Monitoring Network Workshop

Geological Survey of Canada, 601 Booth St
Ottawa, January 28-29, 2000

DAY 1 "What have we done, where are we and what are our needs ?"

8:30 - 10:00 JOINT SESSION - OPENING REMARKS and OVERVIEWS
(Why are we doing it and who cares)

Introduction - Jean-Serge Vincent, GSC/ESS/NRCan
GCOS Overview - invited
International Networks
- GTN-G - Mike Demuth (on behalf of Haeberli)
- GTN-P - Jerry Brown, IPA

Can GCOS - Cryosphere - overview including CLIC by Ross Brown, EC
- Glaciers/Icecaps by Koerner and Demuth, GSC
- Permafrost by Burgess, GSC

See attached for list of acronyms

10:00-10:20 Refreshment break

BREAKOUT PRESENTATIONS/DISCUSSIONS: (separate Permafrost and Glacier/Ice-caps)

10:20-12:30 Current Permafrost Monitoring Activities -
(*Who, what, where, how, how much)* - series of invited presentations by researchers, ranging from 5-15 minutes each, and covering geographic and thematic aspects of:
Active Layer and Thermal Monitoring
Processes/Landscape/Impact Monitoring
Carbon Cycle (sources/sinks)

12:30 - 13:30 LUNCH - to be provided on site

13:30 - 15:00 Current Permafrost Monitoring Activities (continuation of morning session)

15:00 - 15:15 Refreshment Break

15:15 - 16:15 Gaps and Redundancy - Permafrost; group discussion, no formal presenters

16:15- 17:30 JOINT SESSION - Climate and Process Modelling Needs
(invited presentations and group discussion)
GCMs
Permafrost modelling - backwards and forwards
Glacier/Climate/Process/Hydrology modelling

DAY 2: "Where are we going and how are we going to do it ?"

TASKS FOR A THE DAY - Laying out a network foundation/structure

Breakout Presentations and Discussions Continue

8:30 - 10:15 Permafrost Monitoring Technology and Techniques, Present and Future
invited presentations including discussion of protocols and data frequency requirements

Active Layer - thaw tubes, probing, cables
Temperature - cables
- single probe borehole logging
- data frequency as function of depth
Geophysics - current and potential uses, surface and borehole surveys
Remote Sensing - what does, can it or could it do

10:15- 10:30 Refreshments

10:30 - 12:30 Permafrost Network Requirements - Group Discussion

Membership criteria, site selection
Measurement Protocols
Data quality control
Data reporting/submission , web availability
Data access and exchange
Data archiving
Expertise and Capacity
Priorities/Needs - thematic, geographic, research, analysis, technology development
Funding Requirements - low, moderate, high programs ; implementation and operation
Coordination/Management -Federal government role/mandate?

12:30 - 13:30 LUNCH - to be provided on site

13:30 - 15:00 Permafrost Network Requirements Discussions, continuation of above session

15:15 - 16:45 JOINT SESSION Glaciers/Ice-caps/Permafrost
(Invited presentations and group discussion)

Synergies, logistics, partnerships, commonalities
Data archiving - the WGMS model
Summary of what was achieved in the workshop

16:45 - 17:00 Closing/wrap-up remarks - next steps

B. List of Participants

Permafrost Sessions

Last Name	First Name	Affiliation/Address	City	Phone	Fax	E-mail
Allard	Michel	Centre d'etudes nordiques, Universite Laval, Ste-Foy, PQ, G1K 7P4	Sainte-Foy, PQ	418 656 5416	418 656 3960	michel.allard@cen.ulaval.ca
Andersen	Dale	Dept. of Geography, McGill University	Montreal, PQ			andersen@geog.mcgill.ca
Anions	Doug	Parks Canada, Nunavut	Hull, PQ	819 997 1281	819 994 5131	doug_anions@pch.gc.ca
Brown	Jerry	IPA (International Permafrost Association), PO Box 7, Woods Hole, MA 02543	Woods Hole, MA, USA	508 457 4982	508 457 4982	jerrybrown@igc.apc.org
Burgess	Margo	Geological Survey of Canada, NRCan	Ottawa	613 996 9317	613 992 0190	mburgess@nrcan.gc.ca
Burn	Chris	Carleton University	Ottawa			crburn@ccs.carleton.ca
Couture	Nicole	Geography Dept. McGill University, 805 Sherbrooke W. H3A 2K6	Montreal, PQ	514 276 7572	514 398 7437	ncoutu@hotmail.com
Dallimore	Scott	Geological Survey of Canada	Ottawa	613 992 1658	613 992 0190	sdallimo@nrcan.gc.ca
Durey	Orin	Educator/Operator of ground temp monitoring site, PO Box 38, X0C 0A0	Baker Lake, NU	867 793 2389	867 793 2125	do440@ncf.ca
Duchesne	Caroline	Geological Survey of Canada	Ottawa, Ont	613 992 7141		cadic@cyberbus.ca
Dyke	Larry	Geological Survey of Canada	Ottawa	613 996 1967	613 992 0190	ldyke@nrcan.gc.ca
Fortier	Richard	CEN, Universite Laval	Sainte-Foy, PQ	418 656 2746	418 656 7339	richard.fortier@ggl.ulaval.ca
Hanna	Alan	AGRA Earth & Environmental Ltd.	Calgary, AB	403 569 6534	403 248 2188	ahanna@agraee.com
Hayley	Don	EBA Engineering Consultants Ltd., 7110 Brent Rd. Peachland, BC V0H 1X0	Peachland, BC	250 764 9033	250 767 9083	hayley@eba.com
Hughson	Paula	Parks Canada, Nunavut Field Unit, 25 Eddy St.	Hull, PQ	819 994 3178	819 994 5131	Paula.hughson@pch.gc.ca
Louie	Paul	Environment Canada, MSC, Climate Processes and Earth Observation, 4905 Dufferin, Toronto, Ont. M3H 5T4	Toronto, Ont.	416 739 4351	416 739 5700	Paul.Louie@ec.gc.ca
Moorman	Brian	University of Calgary	Calgary, AB	403 220 8929	403 210 8105	moorman@acs.ucalgary.ca
Nixon	Mark	Geological Survey of Canada	Ottawa, Ont	613 992 2469	613 992 0190	mnixon@nrcan.gc.ca

Last Name	First Name	Affiliation/Address	City	Phone	Fax	E-mail
O'Neill	Des	Consultant to MSC, EC, 110 Johnson Cres. Lower Sackville, NS, B4C 3A5	Lower Sackville, NS	902 865 7208	902 864 2919	oneilld@ns.sympatico.ca
Pollard	Wayne	McGill University	Montreal			pollard@hawk.igs.net
Riseborough	Dan	Dept. of Geography, Carleton University	Ottawa, Ont	613 741 1393	613 520 4301	drisebor@ccs.carleton.ca
Robinson	Stephen	Geological Survey of Canada	Ottawa, Ont	613 992 0612	613 992 0190	srobinso@nrcan.gc.ca
Romanovsky	Vladimir	Geophysical Institute, University of Alaska Fairbanks, 99775	Fairbanks, Alaska, USA	907 474 7459	907 474 7290	ftver@aurora.alaska.edu
Smith	Mike	Dept of Geography, Carleton University	Ottawa, Ont.	613 520 2566	613 520 4301	mike_w_smith@carleton.ca
Smith	Sharon	Geological Survey of Canada	Ottawa	613 947 7066	613 992 0190	ssmith@nrcan.gc.ca
Solomon	Steve	Geological Survey of Canada - Atlantic, PO Box 1006	Dartmouth, NS	902 426 8911	902 426 4104	ssolomon@agc.bio.ns.ca
Svoboda	Josef	Biology Dept, Univeristy of Toronto, Erindale, L5L 1C6	Mississauga	905 828 5368	905 828 3792	jsvoboda@credit.erin.utoronto.ca
Tarnocai	Charles	Agriculture and Agri-Food Canada	Ottawa, Ont	613 759 1857	613 759 1937	tarnocaict@em.agr.ca
Taylor	Alan E.	Consultant, ASL	Sidney, BC	250 656 0690	250 565 2162	altaylor@pinc.com
Vician	Peter	GNWT, Transportation	Yellowknife, NWT	867 920 3461	867 873 0363	peter_vician@gov.nt.ca
Wolfe	Stephen	Geological Survey of Canada	Ottawa, Ont	613 992 7670	613 992 0190	swolfe@gsc.nrcan.gc.ca
Wright	Fred	Geological Survey of Canada	Ottawa	613 996 9324	613 992 0190	fwright@gsc.NRCan.gc.ca
Young	Kathy	Geography Dept., York University, Toronto, M3J 1P3	Toronto, Ont.	416 736 5107	416 736 5988	klyoung@yorku.ca

Participants in Joint Sessions and Glacier Workshop						
Brown	Ross	Environment Canada, MSC, 2121 Trans-Canada Highway, Dorval, PQ, H9P 1J3	Dorval,PQ	514 421 4772	514 421 4768	Ross.Brown@ec.gc.ca
Skinner	Walter	Environment Canada, Climate Research Branch and Adaptation Research Group, AES Downsview, 4905 Dufferin	Toronto, Ont.	416 739 4327	416 739 5700	walter.skinner@ec.gc.ca
Vincent	Jean-Serge	Geological Survey of Canada	Ottawa	613 947 2190	613 996 6575	jvincent@nrcan.gc.ca
Alt	Bea		Carlsbad Springs			
Bourgeois	Jocelyne	Geological Survey of Canada	Ottawa			
Cogley	J. Graham	Trent University	Peterborough			
Demuth	Mike	Geological Survey of Canada	Ottawa			
Ecclestone	Miles	Trent University	Peterborough			
Fisher	Dave	Geological Survey of Canada	Ottawa			
Gratton	Denis	U Q Trois-riviere				
Gray	Lawrence	CCRS	Ottawa			
Hamilton	Stuart	MSC, Environment Canada	Vancouver			
Jasper	Jesse	Environment Canada	Yellowknife			
Koerner	Fritz	Geological Survey of Canada	Ottawa			
Loken	Olav	Canadian Committee for Antarctic Research	Ottawa			
MacCulloch	Greg	Environment Canada	Calgary			
Morris	Elizabeth	British Antarctic Survey, Cambridge,	UK			
Moore	Dan	University of British Columbia	Vancouver			
Munro	Scott	University of Toronto	Toronto			
Ostrem	Gunnar		Oslo			
Pietronino	Alain	National Water Research Inst.	Saskatoon			
Ranhoff	Per-Jan		USA			
Sharp	Martin	University of Alberta	Edmonton			
Welch	David	Parks Canada	Ottawa			
Wheate	Roger	UNBC	Prince George			
Young	Gordon	Wilfrid Laurier	Waterloo			
Zdanowicz	Christian	Geological Survey of Canada	Ottawa			
Welch	David	Parks Canada	Ottawa			

C. List of Acronyms

A-base	Core funded activity (Federal Govt.)
AOPC	Atmospheric Observation Panel for Climate (GCOS/WCRP)
CALM	Circumpolar Active Layer Monitoring Network
CCAF	Climate Change Action Fund
CCIN	Canadian Cryospheric Information Network (U. Waterloo)
CFI	Canadian Foundation for Innovation (Federal Govt.)
CIS	Canadian Ice Service (AES)
CLIC	Cryosphere and Climate project of WCRP (in planning)
CRYSYS	Variability and Change in the Cryospheric System in Canada
DFO	Department of Fisheries and Oceans (Canada)
EC	Environment Canada
EOS	Earth Observing System
EMR	Department of Energy, Mines and Resources, (Canada) – Now NRCan
ESS	Earth Science Sector of Natural Resources Canada
GAW	Global Atmosphere Watch (GHG network)
GCOS	Global Climate Observing System
GHOST	Global Hierarchical O ………….
GLIMS	Global Land Ice Mapping from Space (EOS project)
GOOS	Global Ocean Observing System
GOSSP	Global Observing Systems Space Panel (GCOS)
GPCC	Global Precipitation Climatology Centre
GSC	Geological Survey of Canada (Natural Resources Canada)
GSN	GCOS Surface Network
GTN-G	Global Terrestrial Network for Glaciers (planned GCOS network)
GTN-P	Global Terrestrial Network for Permafrost (GCOS network)
GTOS	Global Terrestrial Observing System
GUAN	Global Upper-Air Network
IABP	International Arctic Buoy Program
ICSU	International Council of Scientific Unions
IPA	International Permafrost Association
IOC	International Oceanographic Commission
IOS	Initial Observational System
IPCC	Intergovernmental Panel on Climate Change
JCOMM	Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology
JDIMP	Joint Data and Information Management Panel (GCOS/GOOS/GTOS)
JPO	Joint Planning Office (GCOS/GOOS/GTOS)
JSTC	Joint Scientific and Technical Committee (GCOS)
MSC	Meteorological Service of Canada
NRCan	Natural Resources Canada
OOPC	Ocean Observation Panel for Climate (GCOS/GOOS/WCRP)
PIRATA	Pilot Research Moored Array in the Tropical Atlantic
TOPC	Terrestrial Observation Panel for Climate (GCOS/GTOS)
UN	United Nations
UNEP	United Nations Environment Programme
WCRP	World Climate Research Project
WDC	World Data Centre
WGMS	World Glacier Monitoring Service
WMO	World Meteorological Organization

D. Letter of Invitation from the WMO

7 *bis*, avenue de la Paix
Case postale No. 2300
CH-1211 Genève 2
Téléphone : +(41) (22) 730 81 11
Facsimilé : +(41) (22) 730 81 81
Télégramme : METEOMOND GENEVE
Télex : 41 41 99 OMM CH

World Meteorological Organization
Organisation météorologique mondiale

SECRETARIAT
Genève - Suisse

Our ref.: 10.059/P/GTN-P

GENEVA, 31 August 2000

Annexes: 2 (available in English only)

Sir/Madam,

I have the honour of informing you about the Global Terrestrial Network for Permafrost (GTN-P) and of inviting through you your country to participate in developing this important network of the Global Climate Observing System (GCOS). GCOS was established by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission of UNESCO, the United Nations Environment Programme, and the International Council for Science to ensure that the needs of users (such as the Parties to the United Nations Framework Convention on Climate Change (UNFCCC)) for climate data are met. As you are aware, a number of important decisions on research and systematic observations were taken by the fourth and fifth sessions of the Conference of Parties (COP) to the UNFCCC. Decision 14/CP.4 urged Parties to undertake programmes of systematic observations, including the preparation of specific national plans based on the information developed by GCOS and its partner programmes. Decision 5/CP.5 adopted the GCOS Reporting Guidelines. These Guidelines, which identify an initial set of climate observations (including permafrost observations) important for the detection, attribution, and monitoring of climate change, are to be used by the Parties in reporting on global observing systems for climate.

In early 1999, the GCOS Steering Committee approved the GTN-P, which was jointly developed under the aegis of GCOS and the Global Terrestrial Observing System (GTOS). The permafrost layer is one of the most sensitive indicators of climate change. The permafrost monitoring network will provide the data needed to determine changes in the conditions of the permafrost layer globally and will be used nationally in assessing the impacts of climate change and in designing adaptation and mitigation strategies. If the GTN-P is to fulfil these purposes, it will require the active support and cooperation of national programmes to obtain high-quality permafrost data. Adequate global coverage is required to determine global changes in permafrost that would allow for the interpretation of national data for national applications.

Annex 1 provides a list of the measurements comprising the GTN-P, and Annex 2, included only if your country conducts current permafrost activities, provides the list of permafrost sites in your country (and/or investigated by you in other countries or regions) that contribute to the GTN-P. I am requesting your country's continued backing for the GTN-P activities that you currently support or sponsor and also that you consider improvements to these activities in line with the assessments sponsored by the scientific panels of GCOS and GTOS. I would be most appreciative if your commitment to these activities could be reflected in your country's report on systematic observations to the Conference of Parties to the UNFCCC in November 2001.

To: Ministers of Foreign Affairs of the Members of the International Permafrost Association

Also, could you kindly identify a contact person or organization for permafrost activities in your country who could assist in coordinating permafrost activities internationally. The International Permafrost Association (IPA) has agreed to coordinate the activities of the GTN-P internationally, and each country with permafrost research or monitoring activities is represented in the IPA. Reports on the GTN-P will be issued periodically, and your national contact person would receive a copy of the first report in early 2001, which will be a survey of existing and proposed permafrost measurement sites.

On behalf of WMO and the other sponsors of the Global Climate Observing System, I am most appreciative of your interest and participation in this important climate observing network. I would be pleased to provide you with any further information that you might require with regard to the implementation of the Global Terrestrial Network for Permafrost.

A copy of this notification is being sent to the Permanent Representative of your country with WMO and to selected permafrost experts.

Accept, Sir/Madam, the assurances of my highest consideration.

(G.O.P. Obasi)
Secretary-General

WORLD METEOROLOGICAL ORGANIZATION

ANNEX 1

Global Terrestrial Network for Climate (GTN-P)

The current measurements within the GTN-P include:

(1) Permafrost active layer - the thickness, and if possible, the temperatures of the seasonally freezing and thawing zone overlying permafrost - measurement of the thickness is to be determined at a minimum by soundings in late summer at the time of maximum thaw depth, through the installation of thaw tubes, or through temperature profiling; and

(2) Permafrost thermal state - the temperature profile within perennially frozen ground at frequencies ranging from weekly to monthly in the upper permafrost layer and at annual or lower frequency (for example, up to every 5 years) for greater depths.

These observations are important indicators of climate change, of ecosystem function, and of stability in high latitudes and high mountain areas and plateaus of both hemispheres.

Over 80 active layer and 300 borehole sites have been identified as potential long-term GTN-P observational and research sites in fifteen countries representing both Northern and Southern Hemispheres. Additional sites are required to assure spatial representation according to scientific guidelines developed by the Terrestrial Observation Panel for Climate (TOPC), jointly sponsored by the Global Terrestrial Observing System (GTOS) and Global Climate Observing System (GCOS).

The specifications for these measurements, including "best practices", are:

VARIABLE:	Permafrost active layer
DATA SET:	Active layer depth
DATA ADDRESS:	http://www.geography.uc.edu/CALM
AUTHOR:	37 observers from 15 countries
UNITS:	Depth in cm
SOURCE:	Circumpolar Active Layer Monitoring (CALM) network
RESOLUTION:	Point measurement
COVERAGE:	Approximately 80 reporting sites mostly in Arctic and Sub-Arctic
METADATA :	Adequate
VALIDATION:	Annual by investigator
REVIEW (peer):	Funded National Science Foundation (NSF) peer reviewed grant; various papers published on individual or groups of sites are peer reviewed. Web master and IPA coordinator review annual inputs
USE in refereed papers:	Yes (bibliography being compiled)
APPLICATION:	Trace gas emission, climate index, soil nutrient availability, slope failures
RECOMMENDATION:	Fully accepted

VARIABLE:	Permafrost thermal state
DATA SET:	Temperature profile as measured in a borehole
DATA ADDRESS:	http://sts.gsc.nrcan.gc.ca/permafrost/

ANNEX 1, p. 2

AUTHOR:	35 observers from 14 countries
UNITS:	Degrees C
SOURCE:	Jerry Brown, International Permafrost Association, POB 7, Woods Hole, MA 02543
RESOLUTION:	Point measurement
COVERAGE:	Approximately 300 potential sites in the Arctic, Sub-Arctic, Antarctica, and major mountain ranges and plateaus of both hemispheres
METADATA:	Metadata form circulated in second half of 1999
VALIDATION:	By individual investigators
REVIEW (peer):	Peer reviewed funded proposal in US, Canada, and Europe (Permafrost and Climate Change in Europe (PACE)); various papers published on individual or collective sites are peer reviewed
USE in refereed papers:	Yes (current bibliography to be compiled based on metadata forms)
APPLICATION:	Decadal to secular climate changes, trace gas emission, slope failures
RECOMMENDATION:	GCOS approved February 1999.

GLOBAL
CLIMATE
OBSERVING
SYSTEM

of UNESCO WMO UNEP ICSU

Global Climate Observing System
GCOS Secretariat
c/o World Meteorological Organization
7 *bis*, Avenue de la Paix
P.O. Box No. 2300, CH-1211 Geneva 2, Switzerland
Tel.: +41 (22) 730 8275/8067; Fax: +41 (22) 730 8052; E-mail: gcosjpo@gateway.wmo.ch

Our ref.: 10.070/P/GTN-P
Annex: 1

Geneva, 11 September 2000

Dear Colleague,

Recently, the Global Climate Observing System Steering Committee approved the establishment of the Global Terrestrial Network for Permafrost (GTN-P). This network was established to provide the data needed to determine changes in the conditions of the permafrost layer, one of the more sensitive indicators of climate change. To announce the new network, the WMO Secretary-General, Professor G.O.P. Obasi, recently sent a letter to the Foreign Ministers of those countries that currently undertake permafrost measurements at borehole sites in their own or other countries. Although your country is not currently engaged in this specific activity, and thus your Foreign Minister did not receive a letter, I am apprised that you have a special interest in permafrost research and thus wish to inform you of the action WMO has taken. A copy of the letter to Foreign Ministers and of Annex 1 to the letter is enclosed for your information. I would like to encourage you to support the new Global Terrestrial Network for Permafrost. For additional information on the implementation of the network you may contact Dr Jerry Brown, Secretary of the International Permafrost Association, at P.O. Box 7, Woods Hole, MA 02543, USA. Dr Brown's email address is: jerrybrown@igc.apc.org.

Yours sincerely,

Alan R. Thomas

Alan R. Thomas
Director
GCOS Secretariat

E. Recommendations from Coastal Workshop

Coastal Working Group, International Permafrost Association Woods Hole, Massachusetts November 1999

Workshop participants approved the following:

1. High-latitude coastlines, dominated by cryological processes, are sensitive to climate variations, and therefore, the associated coastal impacts and adaptations should be appropriately recognized in the forthcoming Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and by national and international organizations.
2. A concerted and coordinated international data synthesis and mapping effort is required to properly assess the magnitude of sediment derived and transported from the coast onto the shelf.
3. An international network of representative key and observational sites is required for assessing long-term changes, including threats to local communities, habitat modifications, and carbon and sediment budgets, etc.
4. A local community-based monitoring protocol should be part of an international design with observations conducted by Arctic residents.
5. There is a need to prepare a synthesis of existing data and information concerning fluvial sediment inputs to the Arctic shelves and basins.

Future Activities: International planning, cooperation and funding of national, bilateral and multi-national projects are required to accomplish the following:

6. Develop a circum-Arctic monitoring network of key and observational sites based on a metadata inventory of potential regional sites.
7. Construct databases for web-based delivery.
8. Apply the coastal classification to representative sites.
9. Develop circum-Arctic map products of coastal sediment yields, climate change sensitivity, severity of environmental forcing, etc.
10. Explore and develop international cooperation and projects with other organizations including the International Arctic Science Committee (IASC), Intergovernmental Oceanographic Commission (IOC), International Hydrographic Organization (IHO), IGBP-Land-Ocean Interaction in the Coastal Zone (LOICZ), Arctic Paleo-Discharge (APARD), IGU), and IGU commissions.
11. Convene workshops periodically to assess progress and facilitate the development of specific activities.

Information available: Posters highlighting the workshop's accomplishments were presented at the Laptev Sea conference in St. Petersburg, Russia (November 2628,1999) and at the AGU Fall Meeting in San Francisco (December 13-17,1999). These posters will be presented at other meetings in 2000 to inform individuals and organizations of the present status and future directions of the Arctic Coastal Dynamics initiative. The AGU poster is available on ftp://aac.bio.ns-ca/pub/solomon/AGUposter. A final workshop report is in preparation. For additional information contact the workshop conveners: Jerry Brown jerrybrown@igc.org) or Steve Solomon (ssolomon@agc.bio.ns.ca), on behalf of the International Permafrost Association (IPA) and its Coastal Erosion Subgroup.

E. Monitoring Site Meta-Data Forms

PERMAFROST MONITORING PROJECT INFORMATION - Summary Sketch

(repeat form as necessary for each site and/or activity)

A. Permafrost thermal monitoring or active layer monitoring

Site location (Lat/Long)

Active or inactive

Length of record

Measurement method

Measurement frequency

Borehole depth, if applicable

Other climate data or related observations (eg. Heave or settlement, moisture content)collected

Responsible person and agency

Partners for site operation/analysis

Current funding source and duration

Membership if any in existing programs such as CALM, ITEX, ..

Other comments on your site

B. Process/Impact Study - eg. Coastal processes, slope stability, hydrology, carbon sources and sinks

Type of study/objective (brief description)

Location (lat/long)

Type of data collected

Measurement method and frequency

Duration of study & whether ongoing

Responsible person and agency

Current funding source and duration

Partners for site operation/analysis

GLOBAL TERRESTRIAL NETWORK - PERMAFROST (GTNet-P)
BOREHOLE METADATA FORM (01/2000)

Return by email to:

English Forms	Margo Burgess **mburgess@nrcan.gc.ca** and	
	Sharon Smith **ssmith@nrcan.gc.ca**	
Russian Forms	Vlad Romanovsky **ffver@aurora.alaska.edu**	

BOREHOLE NAME

COUNTRY

LATITUDE AND LONGITUDE (degrees, minutes, seconds if available)

BOREHOLE DEPTH (m) AND MEASUREMENT INTERVAL IF DIFFERENT FROM DEPTH

YEAR DRILLED

METHOD OF DRILLING

DURATION OF DRILLING (hours/days)

TYPE OF AND DISTANCE FROM HEAT SOURCES (surface disturbance, m)
Natural [ ] no disturbance [ ] lake [ ] river [ ] other natural disturbance (describe)
[ ] anthropogenic (describe type of disturbance; pipeline, storage area, reservoir, etc.)

PERIOD OF PRIOR MEASUREMENTS AND FREQUENCY (starting date; annually, monthly, weekly, or daily etc.)

METHOD OF TEMPERATURE MEASUREMENT (thermistor probe, permanent cable [provide number of sensors and nominal depth], fluid filled hole and its level, diameter and type of casing , depth of casing, etc.)

PERMAFROST ZONE Continuous [ ] Discontinuous [ ] Sporadic [ ]
Isolated [ ] Mountain [ ]

PERMAFROST [ ] PRESENT [ ] ABSENT

PERMAFROST THICKNESS (if known, m)

MEAN ANNUAL GROUND TEMPERATURE AT OR NEAR DEPTH OF ZERO ANNUAL AMPLITUDE (°C) – report value for most recent year or 12 month interval

Depth of zero annual amplitude (or depth of measurement reported above) (m)

Year or 12 month interval for mean reported above

Range (if applicable) of mean annual ground temperature over observation period (°C)

ELEVATION (above sea level , m)

SITE SLOPE (angle, aspect)

SITE TOPOGRAPHY AND LOCAL RELIEF [ ]Valley [ ]Top of hill or ridge [ ]Plain
Local relief (m)

LANDFORM OR GEOMORPHOLOGICAL DESCRIPTION AND HISTORY OF SITE (age)

GEOLOGY (brief description of bedrock, sediments, including types and estimate of ice content volume [high, medium, low])

DOMINANT SITE VEGETATION
[ ] Polar desert [ ]Tundra [ ] Shrub Tundra [ ] Forest Tundra [ ]Coniferous Forest
[ ] Deciduous Forest [ ] Grassland [ ] Other (describe)

AIR TEMPERATURE AND SNOW COVER THICKNESS/DENSITY MEASUREMENTS AT THE BOREHOLE SITE (indicate frequency of observations):
Air temperature: Yes [ ] No [ ] Snow thickness: Yes[ ] No[ ] Density: Yes [ ] No[ ]

ACCESSIBILITY OF THE BOREHOLE
Mode of transportation (helicopter, road, offroad vehicle, river, etc.)

Distance from road access (km)

NAME AND LOCATION OF CLOSEST CLIMATE STATION (latitude, longitude, and distance from borehole, km) – provide (if available) mean monthly air temperature and snow depth of reporting interval for mean annual ground temperature

RESPONSIBLE INDIVIDUAL(S) AND ORGANIZATION FOR DATA COLLECTION (complete mailing address, email and fax addresses)

RELEVANT PUBLICATIONS (complete citation, use additional space)

OTHER COMMENTS: (use additional space)

F. Monitoring Sites: Summary Table

Latitude (°N)	Longitude (°W)	Location	Type of Study	Responsible person	Partners
58.3	69.6	Aupaluk/HT289	Thermal Monitoring	Allard, Laval	
60.8	78.2	Akulivak/HT230	Thermal Monitoring	Allard, Laval	
58.7	66.0	George River	Thermal Monitoring	Allard, Laval	
55.6	77.2	Manitounuk	Thermal Monitoring	Allard, Laval	
55.9	76.2	Petite Riviere/PBA	Thermal Monitoring	Allard, Laval	
60.0	77.3	Povungnituk/HT177	Thermal Monitoring	Allard, Laval	
61.0	69.6	Quaqtaq/HT156	Thermal Monitoring	Allard, Laval	
62.2	75.6	Salluit/HT154	Thermal Monitoring	Allard, Laval	
58.7	69.9	Tasiujaq/HT157	Thermal Monitoring	Allard, Laval	
61.5	71.9	Wakeham/HT159	Thermal Monitoring	Allard, Laval	
56.6	76.1	Sheldrake River	Active Layer	Allard, Laval	
73.0	78.0	Bylot Island	Thermal Monitoring	Allard and Gauthier, Laval	Canadian Wildlife Service
75.6	84.7	Truelove Lowland Devon Is	Active Layer	Bliss	
69.2	122.4	Tuktuk Nogait	Thermal Monitoring	Bucher, Parks Canada	MSC
68.2	122.0	Qavvik Lake	Thermal Monitoring	Bucher, Parks Canada	MSC
82.5	62.4	Alert	Thermal Monitoring	Burgess GSC,Taylor ASL	DND
80.0	84.1	Gemini E-10	Thermal Monitoring	Burgess GSC,Taylor ASL	
77.4	105.5	Pat Bay A-72	Thermal Monitoring	Burgess GSC,Taylor ASL	
76.3	109.0	Marryatt K-71	Thermal Monitoring	Burgess GSC,Taylor ASL	
65.2	126.5	Canyon Creek 2A/HT/84-2A	Thermal Monitoring	Burgess, GSC	
65.2	126.5	Canyon Creek 2A/T4/84-2A	Thermal Monitoring	Burgess, GSC	
65.2	126.5	Canyon Creek North Slope - T4/84-2B	Thermal Monitoring	Burgess, GSC	
65.2	126.5	Canyon Creek South Slope -T4/84-2C	Thermal Monitoring	Burgess, GSC	
65.9	125.6	Great Bear River B - T4/84-3B	Thermal Monitoring	Burgess, GSC	
65.6	123.6	Table Mountain A/HA/85-7A	Thermal Monitoring	Burgess, GSC	
65.6	123.6	Table Mountain A/T4/85-7A	Thermal Monitoring	Burgess, GSC	
63.6	123.6	Table Mountain B/T4/85-7B	Thermal Monitoring	Burgess, GSC	
63.6	123.6	Table Mountain B/T5/85-7B	Thermal Monitoring	Burgess, GSC	
63.6	123.6	Table Mountain C/T4/85-7C	Thermal Monitoring	Burgess, GSC	
63.6	123.6	Table Mountain C/T5/85-7C	Thermal Monitoring	Burgess, GSC	

61.6	121.1	Manner's Creek A/T4/85-8A	Thermal Monitoring	Burgess, GSC	
61.6	121.1	Manner's Creek B/T4/85-8B	Thermal Monitoring	Burgess, GSC	
61.4	120.9	Mackenzie Hwy S/T4/85-10B	Thermal Monitoring	Burgess, GSC	
61.2	120.7	Jean Marie Ck B/T4/85-12B	Thermal Monitoring	Burgess, GSC	
59.8	119.5	Petitot River N. A/T4/84-5A	Thermal Monitoring	Burgess, GSC	
59.8	119.5	Petitot River N. B/T4/84-5B	Thermal Monitoring	Burgess, GSC	
59.5	119.2	Petitot River S/T4/8-6	Thermal Monitoring	Burgess, GSC	
65.3	126.7	Kee Scarp	Thermal Monitoring	Burgess, GSC	
65.8	127.9	Gibson Gap	Thermal Monitoring	Burgess, GSC	
65.3	126.8	KP2 - offrow	Thermal Monitoring	Burgess, GSC	
65.3	126.8	KP5 - offrow	Thermal Monitoring	Burgess, GSC	
64.3	124.5	KP182 - offrow	Thermal Monitoring	Burgess, GSC	
65.3	126.9	Pump Station 1/T4/84-1		Burgess, GSC	
63.6	135.9	Mayo	Thermal Monitoring	Burn, Carleton U	Community of Mayo, MSC
60.9	135.5	Takhini Valley	Thermal Monitoring	Burn, Carleton U	White, Whitehorse
		Mackenzie Delta	Slope stability/deep creep fo buried ground ice	Dallimore&Nixon, GSC	Ladanyi&Foriero, Ecole Polytechnique
58.8	-94.1	Churchill	Thermal Monitoring	Eley, MSC	
63.7	-68.5	Iqaluit	Thermal Monitoring	Eley, MSC	Nunavut Science Centre
56.6	76.6	Umiujaq	Thermal Monitoring Mechanical properties	Fortier, Laval	Allard, Laval
61.2	135.4	Fox Lake	Thermal Monitoring	Harris, U of Calgary	
63.2	130.6	MacMillan Pass	Thermal Monitoring	Harris, U of Calgary	
52.8	118.1	Marmot Basin	Thermal Monitoring	Harris, U of Calgary	
50.3	114.5	Plateau Mountain	Thermal Monitoring	Harris, U of Calgary	
62.6	132.3	Sheldon Lake	Thermal Monitoring	Harris, U of Calgary	
58.6	124.6	Summit Lake A	Thermal Monitoring	Harris, U of Calgary	
61.3	129.6	Tuchitua km 161	Thermal Monitoring	Harris, U of Calgary	

61.0	138.0	Sulphur Lake	Thermal Monitoring	Harris, U of Calgary	
79.5	75.5	Alexandria Fiord	Active Layer	Henry UBC	
66.2	65.8	Pangnirtung Res.	Thermal Monitoring	Hyatt	
69.2	140.2	Ivvavik	Thermal Monitoring	Larsen, Parks Canada	MSC
68.8	140.9	Margaret Lake	Thermal Monitoring	Larsen, Parks Canada	MSC
73.2	119.7	Thomsen	Thermal Monitoring	Lawrence, Parks Canada	MSC
74.1	120.0	Aulavik	Thermal Monitoring	Lawrence, Parks Canada	MSC
81.4	76.7	Tanquary Fiord Ellesmere Is	Active Layer	Lewkowicz, U of Ottawa	
80.0	85.8	Eureka Ellesmere Is	Active Layer	Lewkowicz, U of Ottawa	
55.9	76.2	Quebec	Thermal Monitoring	Michaud, GSC-Que	Centre d'etudes nordiques, Laval
73.0	78.0	Bylot Island	Thermal Monitoring, Glacial hydrology and permafrost interactions	Moorman, U of Calgary	
69.4	135.0	Taglu C4	Active Layer & Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.2	134.3	Lousy Pt C5	Active Layer & Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.7	134.5	North Head C3	Active Layer	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
68.7	134.1	Reindeer Depot C7	Active Layer	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
67.8	134.1	Rengleng C8	Active Layer	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
65.7	128.8	Mountain River C9	Active Layer	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
65.2	126.5	Norman Wells C11	Active Layer	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
63.5	123.7	Ochre River C13	Active Layer	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
62.7	123.1	Willowlake River C14	Active Layer	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
61.9	121.6	Fort Simpson C15	Active Layer	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.5	132.6	Involuted Hill/IH88-1	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.5	132.6	Involuted Hill/IH88-2	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute

69.2	134.4	Lousy 1/91GSC6	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.2	134.3	Lousy 8/91GSC13	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.1	134.4	Swimming Pt1/91GSC1	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.1	134.4	Swimming Pt2/91GSC2	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.1	134.3	Swimming Pt5/91GSC5	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.2	134.3	Lousy 5/91GSC10	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.2	134.3	Lousy 10/91GSC12	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
69.1	134.7	YaYa Lake/90SI1	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
61.8	121.3	Fort Simpson/FS deep	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
61.5	121.4	Liard spruce/97TC4	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
62.0	121.9	Wrigley trans/97TC5	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
61.5	121.4	Liard shrub/97TC3	Thermal Monitoring	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
		55-60 sites Mackenzie Valley/Delta	Active Layer	Nixon, GSC	Inuvik Research Centre, Aurora Research Institute
54.8	-66.8	Shefferville	Active Layer & Thermal Monitoring	Pollard, McGill	NRCan, Environment Canada, EMAN
79.4	-90.5	Expedition Fiord	Active Layer & Thermal Monitoring	Pollard, McGill	NASA, Trent, Waterloo, Wilfrid Laurier, CCRS
61.8	121.4	Fort Simpson	Carbon Storage in Peatlands	Robinson GSC	Moore, McGill U
		Yukon Coast, Tuktoyaktuk Pen. Arctic Island Coasts	Coastal monitoring,erosion studies	Solomon, GSC	
64.2	95.5	Baker Lake	Active Layer & Thermal Monitoring	Svobda, U of T	Burgess GSC, Eley MSC, Durey
69.0	133.6	Parsons Lake	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada

62.3	133.4	Inuvik South 1	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
68.1	133.5	Inuvik South 2	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
68.9	133.5	Inuvik South 3	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
67.5	133.8	Arctic Red R	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
65.3	126.9	Pump Stn	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
65.2	126.5	Canyon Creek	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
64.9	125.6	Great Bear R	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
63.6	123.6	Table Mtn	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
61.6	121.1	Manners Ck	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
59.8	119.5	Petitot R	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
81.8	71.4	Lake Hazen	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
66.4	65.5	Overlord Baffin Is	Active Layer & Thermal Monitoring	Tarnocai, AgCan	GSC, Parks Canada
67.6	139.8	Old Crow		Trimble, EBA	
74.7	93.8	Cornwallis Island	Active Layer	Young, York U	Woo, McMaster U
		Yukon Coast	Coastal Slope Processes	Wolfe, GSC	

G. Presentation Transcripts/Summaries

The presentations summarized in this section are:

Recent Warming Impacts in Western Arctic Canada: Evidence from Air Temperatures, Active Layers, and Ice Wedges.
__Stephen Wolfe,__ Terrain Sciences Division, Geological Survey of Canada

Active Layer Monitoring: Geological Survey of Canada
__Mark Nixon,__ Geological Survey of Canada

Soil Climate Monitoring
__Charles Tarnocai,__ Agriculture and Agri-Food Canada

Permafrost temperature monitoring, Yukon and Western Arctic Canada
__CR Burn,__ Carleton University

Activities of the Centre D'Etudes Nordiques
__Michel Allard,__ Centre D'Etudes Nordiques, Université Laval

McGill University Field Stations
__Wayne Pollard (presented by Dale Anderson),__ Department of Geography McGill University

Arctic Climate/Permafrost Stations
__Joe Eley (presented by Paul Louie),__ Climate Research Branch/MSC

Permafrost Research at University of Calgary
__Brian Moorman,__ University of Calgary

Cordilleran Air and Ground Temperature Monitoring.
__S. A. Harris__ ,Department of Geography,University of Calgary

Climate Reconstruction from Borehole Temperatures
__Alan Taylor,__ Consultant

Frost Table Pattern And Development In Patchy High Arctic Wetlands
__Kathy L. Young,__ Geography Department, York University

CALM Project at Baker Lake, Nunavut.
__Orin Durey,__ Baker Lake, Nunavut
__Josef Svoboda,__ Department of Botany, University of Toronto
__Margo Burgess,__ Geological Survey of Canada, Ottawa
__Joe Eley,__ Environment Canada, Saskatoon, Saskatchewan

Permafrost Monitoring System in Alaska: Structure and Results
__V. E. Romanovsky and T.E. Osterkamp,__ Geophysical Institute, University of Alaska at Fairbanks

Arctic Marine and Coastal Monitoring at the GSCA
Steve Solomon, *Atlantic Geoscience Center, Geological Survey of Canada*

Slope Stability
Larry Dyke, *Terrain Sciences Division, Geological Survey of Canada*

Monitoring Peatland Carbon Sources and Sinks in Permafrost Areas
Stephen Robinson, *Geological Survey of Canada/ McGill University*

Deep Ground Temperatures, Ekati Mine, NWT
Don Hayley, *EBA Engineering*

Slope Instability and Gas Hydrates
Scott Dallimore, *Terrain Sciences Division, Geological Survey of Canada*

Permafrost Databases
Sharon Smith, *Terrain Sciences Division, Geological Survey of Canada*

The Norman Wells Pipeline Thermal Monitoring Program
Margo Burgess, *Geological Survey of Canada*

Monthly Rehabilitated Gridded Canadian Historical Air Temperature and Precipitation Database
Walter Skinner, *Environment Canada*

Ground Temperature Modelling: Backward and Forward
Alan Taylor, *Consultant*

Monitoring and Modelling: Permafrost Temperature
M.W. Smith, *Carleton University*

Regional Scale Modelling
Fred Wright, *Terrain Sciences Division, Geological Survey of Canada*

Near Surface Instrumentation
Mark Nixon, *Terrain Sciences Division, Geological Survey of Canada*

Single Probe Borehole Logging
Vlad Romanovsky, *University of Alaska*

Ground Temperature Measurement Frequency
D. W. Riseborough, *Department of Geography, Carleton University*

Geophysical Methods For Characterization Of Permafrost Monitoring Sites
Members of the Terrain Geophysics Section (Presented by Stephen Robinson)
Geological Survey of Canada

Geophysics - Current And Potential Uses, Surface And Borehole Surveys
Richard Fortier, *Centre D'Etudes Nordiques, Université Laval*