The Canadian National Report on Systematic Observations for Climate

National Activities with Respect to the Global Climate Observing System (GCOS) Implementation Plan

Prepared for Submission to the United Nations Framework Convention on Climate Change (UNFCC)

Compiled by the Meteorological Service of Canada – Environment Canada

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Executive Summary

In 2005 the UN Framework Convention on Climate Change (UNFCCC) Subsidiary Body for Scientific and Technological Advice (SBSTA) issued a request to the Global Climate Observing System (GCOS) Secretariat to provide, for consideration by the SBSTA at its thirtieth session (June 2009), a comprehensive report on progress with the GCOS Implementation Plan. Parties to the Convention were invited by SBSTA to submit to the GCOS Secretariat additional information on their national activities with respect to the implementation plan. This information is intended to help prepare the comprehensive GCOS report that will (1) confirm ongoing requirements and report on progress against the GCOS Implementation Plan and its Satellite Supplement; and, (2) focus on new actions and drivers such as the impacts, adaptation and vulnerability agenda, as well as regional climate needs.

This Canadian report on national activities with respect to the GCOS implementation plan was preceded by the first national report on systematic observations for climate completed in 2002. This was followed by an update on systematic observations included in Canada's 2006 Fourth National Report on Climate Change.

The report follows the revised UNFCCC reporting guidelines on GCOS. Chapter 1 addresses the common issues of national coordination, data policies, the integrity of long-term climate data and monitoring program sustainability. Other topics include support to international data centres for Essential Climate Variables (ECVs), supporting international capacity building and the acquisition and synthesis of paleoclimatic data. Chapters 2, 3 and 4 describe national contributions to the international community pertaining to atmospheric, oceanic and terrestrial ECVs.

While Canada is a significant contributor to the international programs of GCOS, the Global Ocean Observing System (GOOS) and the Global Terrestrial Observing System (GTOS), there tends to be, with the exception of specific initiatives, little national coordination between the atmosphere, oceans and terrestrial systematic monitoring programs. At present there is no national GCOS coordinating committee or up to date national GCOS implementation plan. However, concerns have been raised about the full sustainability of several long-term systematic atmospheric, oceanic and terrestrial surface-based/in-situ monitoring programs if their continuity depends on short-term research projects and action plans.

The Canadian government's full and open access to data policy recognizes Canada's commitment to the international exchange of atmospheric, oceanic and terrestrial ECVs through arrangements established and coordinated by world bodies. RADARSAT-1 and RADARSAT-2 data policies present exceptions from the fully accessible and free of charge approach due to data rights and exclusivities owned by the private sector.

Canada plays an important role in supporting ECV designated international data centres. Examples include operating the World Ozone and UV Radiation Data Centre; as a Responsible National Oceanographic Data Centre assisting the World Data Centre for processing and archiving data from drifting buoys, globally; hosting the Global Terrestrial Network for Permafrost website; developing carbon and oxygen isotope calibration methodologies and protocols, and contributing to the formulation of draft standards for land cover, biomass and fire disturbance ECVs. In terms of capacity building in developing countries, Canada has through engagement with land cover and fire implementation teams, contributed to strengthening the

capacity of eight regional networks in Africa, Asia and South America to collect, exchange and use ECV observations.

Environment Canada's national ground-based weather, climate, upper air and meteorological marine observation networks are well established and follow well-defined operating standards and procedures. Regardless of their primary role, in support of weather or climate programs, the networks, with rare exception, adhere to GCOS climate monitoring principles. Network spatial densities and station distributions are relatively stable with the networks less dense in northern regions. The networks are highly automated and undergoing modernization. The surface weather network is fully automated and the GCOS Surface Network (GSN) is predominantly automated. About 20% of the Reference Climate Station network (of which the GSN is a subset) depends on human-based observations. Approximately 35 to 40 % of the surface weather stations and the Reference Climate Stations (RCS) are modernized to standardized sensor and equipment suites, including processing and reporting algorithms. The pace of modernization has fallen in recent years due to resource constraints. The Canadian contribution to the Voluntary Observing Ship Climate Project (VOSClim) consists of Automated Volunteer Observing Ships (AVOS). Plans call for additional installations to focus on vessels plying data sparse waters, such as in the Canadian Arctic.

Long term, homogenized temperature, precipitation, pressure and wind datasets have been prepared for many locations for the analysis of climate trends in Canada. This includes most GSN stations. With the exception of temperature and precipitation, Environment Canada's digital archive contains data only from 1953 for most meteorological variables. Data rescue, i.e., digitization, of major holdings of historical data, still archived on microfilm and paper, has been limited due to resource constraints.

The Canadian Greenhouse Gases and Aerosols programs continue to evolve to meet Global Atmospheric Watch (GAW) data specifications. The aerosols program, in particular, is in transition from being research project based to a long term systematic program.

Ocean monitoring programs have been developed for both the Atlantic and Pacific coastal and ocean regions and to a lesser but increasing extent for the Arctic. Fisheries and Oceans Canada (DFO) operates both systematic, long-term observation networks and measurement programs dependent on funding from research programs and projects. An example of the former is the sea level measurements routinely made by a network of gauges on both the east and west coasts of Canada and in the Arctic. Another is the network of sub-surface drifters (Argo floats) that Canada contributes to the global Argo array. DFO also processes, quality controls and archives the wave data reported from the coastal moored buoy networks operated by Environment Canada.

Monitoring programs dependent on research-based funding include the temperature and salinity profiles collected through Ship of Opportunity Programmes (SOOP). The arctic moorings monitoring program (profiles of temperature, salinity, currents and ice thickness) is operated and maintained by DFO through funded research and international collaborations. The Atlantic Zone Monitoring Program (AZMP) is Canada's most mature coastal oceanographic and ecosystem observation program. The Pacific program is more ad-hoc with uncertain funding. An Arctic program, similar to the AZMP, is being established under the auspices of the Canadian International Polar Year (IPY).

DFO has the responsibility for managing the Government's oceanographic data holdings. This is carried out through a distributed system of online accessible archives under the functional direction of the Integrated Science Data Management Branch.

Environment Canada's Canadian Ice Service (CIS) weekly ice concentration and type charts for Canada's Arctic, Hudson Bay, East Coast, and Great Lakes are based primarily on RADARSAT and ENVISAT satellite data supplemented by air reconnaissance and ice specialists onboard Coast Guard ships for ground truth and coverage of strategic areas with finer detail. Charts are available from CIS' online archive. An agreement between the Government of Canada and the private sector operator of RADARSAT will allow for the sharing of polar RADARSAT-1 image products archived by CIS as part of a larger set of images processed by the Canadian Space Agency as a contribution to the IPY. CIS made the operational transition to RADARSAT-2 in late 2008.

Canada's terrestrial contribution to GCOS covers a broad spectrum of ECVs, both observed and derived, from observational measurement programs ranging from long-term, systematic to recent programs still in the developmental stage. The make-up of some of these ECVs (for example land cover), and the paucity and fragmented state of some of the ground-based monitoring programs, reinforces the importance and need to develop or refine satellite data both as stand-alone or integrated derived products. Equally important is the need to have sufficient ground-based monitoring systems in place for satellite data and model validation.

Environment Canada operates a fully digital national hydrometric network with two thirds of the stations reporting in real-time. Similar to the ground-based national meteorological networks, the hydrometric program is well established, with defined standards and operating procedures. The data are published annually and made available in an online archive database. The adequacy of the network to describe hydrologic characteristics decreases significantly to the north. Modernization of the monitoring system is ongoing. In support of the Global Terrestrial Network – Rivers (GTN-R), Canada provides data from discharge stations located at or near the mouth of large rivers.

Canada's national snow on ground (snow depth) in situ measurement program is derived from a composite of automatic and staffed stations that are part of Environment Canada's RCS, surface weather and volunteer climate networks and through contractual arrangements with aviation service providers. While the total number of reporting sites has decreased significantly largely due to reductions in the volunteer program, the number of stations reporting in real-time to near-real-time is on the increase due to electronic reporting for the volunteer program. Considerable effort is underway to improve measurement of snow depth and derivation of snowfall from autostations.EC's Canadian Meteorological Centre produces a daily global snow depth analysis based on real-time observations from synoptic and hourly meteorological reports and has plans to refine the resolution in the near future. A project has been started to assimilate satellite derived information on snow cover fraction and water equivalent (SWE) with the Canadian Land Data Assimilation System. EC has made considerable progress in developing passive microwave derived SWE information over the sub-Arctic
of North America. One of the current focuses of the Canadian IPY is the integration of modelling and remote sensing approaches for SWE retrieval in mountainous areas. Natural Resource Canada's (NRCan) Canadian Centre for Remote Sensing (CCRS) has produced daily snow cover derived from NOAA AVHRR observations from 1982 to present as a contribution to the IPY.

Canada's Glacier-Climate Observing System is led by NRCan's Geological Survey of Canada (GSC) and is based on in situ measurements of a reference network of glaciers in the Western and Northern Cordillera and the Arctic Archipelago of Canada. Both aircraft and satellite-based remote sensing are applied to generate regional perspectives of land ice and its responses to climate variations. Change in length and mass balance data and supporting metadata are submitted to designated world data centres.

The Canadian Permafrost Monitoring Network includes two key variables – permafrost thermal state and active layer thickness. The GSC coordinates the submission of Global Terrestrial Network – Permafrost (GTN-P) site data and metadata to the designated world data centres. Recently, there have been enhancements to address key regional and thematic gaps through government baseline studies and IPY funding.

There is no national network to monitor groundwater quality and quantity in Canada. The number of active wells is relatively few and the length of groundwater records is relatively short and often contains continuity breaks due to program changes. However, NRCan has established a National Groundwater database that serves as a repository for their digital records and a catalogue for information held by other agencies. NRCan is engaged in a project to assess several regional key aquifers to add to the national inventory of studied aquifer systems. It also has a project to map temporal variability of groundwater resources in major water basins across Canada.

Similarly, there is no national in situ soil moisture monitoring network. Routine soil moisture monitoring is ad-hoc and lacking coordination between agencies. It has been recommended that the Canadian Group on Earth Observations (CGEO) spearhead the development of a proposal for a national soil moisture monitoring system that would include in situ and remote-sensed observations and measurements, modelling approaches and data assimilation.

The Canadian Forest Service (CFS), in partnership with the Canadian Space Agency, is using space-based earth observation technologies to create products of landscape level detail for forest inventory, forest carbon accounting and sustainable development purposes. Using Landsat data, Agriculture and Agri-food Canada (AAFC) is developing land cover monitoring information for a broad range of needs that include land use management, climate change monitoring and Greenhouse Gas (GHG) accounting and verification. A new 30 metre land cover map of Canada is being assembled that combines the Earth Observation for Sustainable Development of Forests 30 metre product with the 30 metre land cover map of agricultural regions and the CCRS 30 metre map of the arctic region. Once this first integrated land cover map of Canada is completed, future work will turn to the development of a land cover monitoring strategy for Canada.

Canadian efforts to estimate or determine forest biomass, Leaf Area Index (LAI), fraction of Absorbed Photosynthetically Active Radiation (fAPAR), albedo are in various stages of development under the leadership of NRCan. For example, efforts to estimate forest biomass from models, inventory and remote sensing data are being developed and evaluated at several pilot regions by the CFS. For albedo and surface reflectance estimation, CCRS is developing a new generation Canadian Advanced Very High Resolution Radiometer (AVHRR) processing system which is being used to re-process the entire 1 km AVHRR archive assembled over Canada's land mass. The CCRS fAPAR product is an integrated product from satellite observations and model simulations. This product is currently being validated with in situ measurements. CCRS is actively involved in the development and assessment of GCOS compliant LAI products. Activities include instrumentation and protocols for in situ LAI

monitoring, algorithms for LAI retrieval based on satellite measurements, production of LAI datasets and assessment of Canadian and global LAI products.

The currently evolving national space plan includes the development of a Polar Communications and Weather (PCW) two satellite system that will provide valuable observations for meteorological forecasting and mapping ECVs over Canada and the Arctic circumpolar area. The PCW system is planned for 2016 and will enhance capabilities for Arctic meteorology (winds, sea-ice charting) and the mapping of terrestrial ECVs such as albedo, snow cover, fAPAR, LAI and radiation budgets from space.

Canada is firmly committed to the Group on Earth Observations (GEO) coordination efforts to build a Global Earth Observation System of Systems (GEOSS). Canadian GEO, established in 2005, has identified several specific national priorities including soil moisture monitoring, modelling and forecasts; integrated planning of monitoring networks and environmental data /products access; sustained arctic monitoring programs. Canada is also a participant in the international Sustaining Arctic Observing Networks initiative. GCOS contributes the climate component to the GEOSS. Environment Canada's Meteorological Service of Canada (MSC) is responsible for national coordination of GCOS. Experiences gained during the compilation of this national GCOS report affirm the need to re-establish a national coordinating mechanism among participating federal departments and agencies for GCOS related national planning purposes.

Chapter 1: Common Issues

1.1 Coordination

Canada is a significant contributor to the Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS), and Global Terrestrial Observing System (GTOS). Contributions include systematic observations, measurements, derived products and data management related to essential Climate Variables (ECVs), technical and scientific expertise, and to a lesser extent, financial support. The key federal science departments participating in these programs include Environment Canada (EC), Fisheries and Oceans Canada (DFO), Natural Resources Canada (NRCan), Agriculture and Agri-food Canada (AAFC).The Canadian Space Agency (CSA) supports these federal science departments in a wide variety of space-related activities and applications development, including coordination of all aspects of the Canadian Space Program.

The scope of the terrestrial sector in Canada is broad involving a disparate number of ground-based and satellite-based monitoring programs but there are some programs and specific planning initiatives that have provided or have the potential to provide some aspects of national coordination. Within NRCan, work in the area of satellite-derived terrestrial ECVs is conducted primarily within two programs: *Enhancing Resilience in a Changing Climate* and *Understanding Canada from Space*. The CSA provides substantial financial support to these activities through the Government Related Initiative Program. NRCan's Canadian Forest Service (CFS) in cooperation with AAFC has established the Canadian Land Cover Community of Practice (LCCoP) with membership from 8 federal departments with an interest in land cover mapping.

Internationally, Canada participates in both the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), a formal body of the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC). Canada contributes to the Data Buoy Cooperation Panel (DBCP) of the Ship Observations Team (SOT). The DBCP is charged with coordinating at the international level, the drifting and moored buoy programs. Within the Canadian framework, DFO has developed ocean monitoring programs for both the Atlantic and Pacific coastal and ocean regions and to a lesser but increasing extent for the Arctic, but acknowledges that on a national level, integration of monitoring programs and coordination between federal departments involved in marine meteorology and oceanography could be improved.

Except for specific initiatives and despite the substantial Canadian involvement in the international GCOS, GOOS and GTOS activities, there is insufficient national coordination between the atmospheric, oceans and terrestrial systematic monitoring programs. EC's Meteorological Service of Canada is responsible for national coordination of GCOS. In early 2008, EC and the CSA co-sponsored a meeting to gather information pertaining to Canada's role in producing ECV data products from earth observation satellite data. However, at present, there is no national coordinating committee within GCOS that draws from the collective atmospheric, oceanic and terrestrial sectors for ground-based, in situ and satellite observation programs, nor is there a currently relevant national GCOS Implementation Plan. Experiences gained during the compilation of Canada's national report on systematic observations for climate re-affirm the utility of having both re-established. For example, the past national GCOS plan (1999) accelerated the planning process for acquiring climate-related government funding resulting in implementation of significant observational program enhancements.

1.2 Data Policies

It is the policy of the Government of Canada that environmental information is accessible and responsive to the needs of Canadians. Government science-based departments such as EC, DFO, NRCan and AAFC are responsible for the life-cycle management of their respective scientific data and information from observation, processing, quality control, archiving through to dissemination. Subject to copyright limitations, data and information must be available to the general public in a timely manner with full and open access. Data policies also recognize the Canadian government's commitment to the international exchange of meteorological, oceanographic and terrestrial data through arrangements established and coordinated by world bodies such as the WMO and IOC. As a general rule, there are no policy-level barriers to the international exchange of climate data and their provision to international data centres.

There are some provisos such as:

- Access to research datasets may remain under control of the principle investigator for a period of time not to exceed two years beyond completion of the data measurement program.
- Access to data may be subject to certain conditions where specified by agreements with partner organizations.

RADARSAT-1 and RADARSAT-2 data policies present some exceptions from the fully accessible and free of charge approach. The private sector company, MDA Geospatial Services Inc. (MDA GSI), has the exclusive right to distribute the data, data products and value-added products, containing recognizable RADARSAT-1 imagery, to third parties. None of these data or products can be provided to Third Parties in a manner which will compete with commercial sales of data without the permission of the CSA. Subject to conditions, science teams, through research announcements, may be established to conduct research using RADARSAT-1 data. In the case of RADARSAT-2, MDA has all data rights (copyright) as well as intellectual property rights for the processing algorithms. MDA GSI is the sole worldwide owner and distributor. The only data allocation is to the Government of Canada for its own purposes, for example, ice services, although with volume limitations. RADARSAT-2 data from this allocation may be supplied to outside organizations for Government of Canada supported research and applications development provided the use of such data is limited to the defined purpose. In brief, for scientists to access (free, or at a reduced rate) RADARSAT-1 or RADARSAT-2 archived data , a formal program must be in place, approved by MDA GSI, with proposals and an evaluation committee, and strict rules as to the use of the data, project reporting and publication.

References:
http://www.asc-csa.gc.ca/eng/industry/default.asp

http://www.asc-csa.gc.ca/eng/satellites/radarsat2/default.asp

Federal government organizations are attempting to maximize access to their scientific datasets through interactive use of web-based portals. In some cases, new streams and ever-increasing volumes of data and information and user demands have proven to be barriers to unrestricted data access. Data management systems are evolving to meet these challenges. In the interim, some existing interactive web-based portals may be somewhat restrictive in efficient processing of large volume, customized data requests, thereby triggering the application of cost recovery charges for handling the request on behalf of the client.

1.3 Integrity of Long-term Climate Data and Sustainability of Programs

EC's Meteorological Service of Canada has formal processes and structures in place for ensuring the orderly management of change to meteorological, climatological and hydrometric monitoring programs such as the transition from human-based to automated observational systems. The scope includes all systems, instruments, algorithms, procedures, processes and related documentation that influence the collection, processing, quality assurance, reporting and archiving of observations from MSC networks. Using a phased approach, MSC also registered to the ISO 9001 standard in 2007 and continues to expand the scope of its quality management system to include nearly all monitoring, science and service activities. Environmental monitoring was deemed a priority for this undertaking and its core activities were included in the initial registration. This initiative has yielded early benefits, including more disciplined document management and record keeping, structured problem tracking, and better defined internal linkages and roles. Systematic monitoring with its inherent reliance on rigorous compliance to process and established standards will particularly benefit.

All federal departments operating and maintaining systematic, ongoing ECV-related monitoring programs including their data management have quality assurance and quality control processes in place, closely following relevant international standards that have been established. Detailed metadata pertaining to these monitoring programs is maintained. DFO is collaborating internationally in the adoption of marine community metadata profile of ISO 19115 to support the documentation and discovery of marine datasets. Efforts are ongoing across the federal departments to improve the depth of and accessibility to their metadata.

Several of Canada's core GCOS monitoring programs, especially in Canada's data sparse north, benefited greatly in the early 2000s from the federal government's Action Plan 2000 climate change related funding. A significant number of spatial data gaps and associated data management issues were addressed and some programs that were in decline were stabilized and re-vitalized. Additional program enhancements have been realized through Canadian IPY project funding and environmental baseline studies related to northern hydrocarbon development.

However, concerns have been expressed about some long-term monitoring programs regarding varying degrees of dependence on research-based, short-term projects and plans rather than adequate levels of sustained program funding. Shortages of trained technical specialists have slowed the rate of modernization taking place within surface-based climatological and hydrometric organizations as levels of recruitment have not kept pace with retirements. As a specific issue, the necessary evolution of EC's data management system has resulted in competing demands with operational monitoring requirements for information technology (IT) resources. Also, the incremental cost of installing and maintaining observational systems in the north where there is little or no human presence tends to be a limiting factor. Further, a significant number of MSC's surface weather, reference climate and GSN stations are dependent on continued long-term cooperative partnership arrangements with other agencies and organizations.

The Canadian Group on Earth Observations (CGEO) has included in its priorities "Sustained Canadian Arctic Monitoring Programs". Canada is also participating in Sustaining Arctic Observing Networks (SAON) which was initiated during the IPY. The SAON Initiating Group has included in its draft recommendations intended for the eight arctic states and the Arctic Council expression of commitment to sustain their current level of observing activities and related data

and information management services and increase the scope of these activities in the future; commitment to make data and information freely, openly and easily accessible in a timely fashion at minimal cost; and, creation of an inter-agency/department group for coordination and integration of their Arctic observing activities, and data and information management services.

1.4 Support to International Data Centres

DFO's Integrated Science Data Management Branch (ISDM) is the Responsible National Oceanographic Data Centre assisting the designated World Data Centre for drifting buoys, globally. As part of its role, ISDM acquires, processes, quality controls, and archives real-time drifting buoy messages reporting over the Global Telecommunications System (GTS) as well as delayed mode data acquired from other sources.

Several Canadian Forest Service (CFS) specialists working with the GTOS Panel for Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) have contributed to the formulation of draft standards for the land cover, biomass and fire disturbance ECVs. These draft standards form the basis for ECV discussions currently taking place. GTOS intends to make printed copies of these draft versions available at the UNFCCC Conference of the Parties 14 (COP).

Canada, through NRCan's Geological Survey of Canada (GSC), hosts the Global Terrestrial Network for Permafrost (GTN-P) website.

Environment Canada continues to operate the World Ozone and UV Radiation Data Centre (WOUDC). Also associated with the WOUDC is the Brewer Data Management System which is a primary data repository serving the Brewer Spectrophotometer community. In addition, EC operates the WMO World Calibration Centre Brewer reference triad, which provides the calibration reference for Brewer instruments in the global ozone observing network.

EC is also playing a lead role in developing carbon and oxygen isotope calibration methodologies and protocols so that the isotope data can be eventually reported to the designated world data centre.

1.5 Capacity Building

The CFS provides financial, technical and secretariat support to the GTOS Panel for GOFC-GOLD, which has a focus on the terrestrial ECVs of land cover, biomass and fire disturbance. GOFC-GOLD works with eight regional networks in Africa, Asia and South America, representing approximately 30 developing countries. Through engagement with the GOFC-GOLD land cover and fire implementation teams, capacity of the networks is strengthened to collect, exchange and use ECV observations. With Canadian support, the GOFC-GOLD networks are designing reference sites to provide the observations required for the calibration and validation of satellite data for land cover and fire disturbance. The CFS is working with the Canadian Space Agency to make imagery available from the RADARSAT-1 archive for land and forest cover mapping in tropical regions where significant cloud cover limits the use of optical imagery. The processed archive will be made available to users through the above referenced GOFC-GOLD regional networks.

EC scientists conduct biennial workshops and tutorial sessions to provide support for the operators of Brewer ozone Spectrophotometers in the WMO global ozone and UV observing systems.

1.6 Proposed Implementation of a Global Cryosphere Watch (GCW)

At the 15th WMO Congress in May 2007 the delegation of Canada proposed the creation of a Global Cryosphere Watch, to promote a sustained polar/cryosphere observing system and authoritative information on past, present and future changes of our global snow and ice resources. Congress requested the Inter-commission Task Group (ITG) on IPY to establish an ad-hoc expert group to explore the feasibility of creating a Global Cryosphere System and prepare recommendations for its development. The ITG established the ad-hoc group and tasked it with preparing a scoping document to define the feasibility of developing and implementing a GCW that will involve widespread consultations across all WMO Programmes and Technical Commissions, organizations and agencies involved in cryospheric data and information collection and dissemination, and the cryospheric scientific community. Environment Canada scientists are members of this group including assuming the chair role. A draft scoping document is required by the ITG in early 2009 with a final feasibility study expected for April 2009.

1.7 Paleoclimate Data

Considerable paleo-environmental and paleoclimatic research takes place in Canada, carried out by both the university community and government science organizations focusing on dendrochronologies, snow and ice cores, and sediments. The Earth Sciences Sector of NRCan has established a program on Enhancing Resilience in a Changing Climate, designed to assist Canadians in understanding, preparing for, and adapting to the effects of changing climate. This program includes a paleo-environmental perspectives project with goals to (1) produce national-scale quality databases of paleo-environmental and paleo-climatic scenarios that can be used to assess landscape sensitivities to future climate change;(2) develop paleo-based scenarios and assessments of potential climate change impacts to guide adaptation strategies; and (3) ensure that decision-making bodies are informed and aware of the availability and relevance of these resources. Goals are addressed through thematic activities, some of which consist of data compilation and synthesis efforts while others focus on specific geographical regions of Canada. Some activity examples include: using snow and ice cores to improve understanding of Pacific Northwest climate variability; reconstructing the history of Arctic sea ice cover; analyzing lake sediment cores to investigate extreme changes in the Great Lakes paleo-levels in the early Holocene; and, reconstructing, over the last 200 years, hydroclimatic variables required for hydrologic forecast models using dendroisotopic analysis in the James Bay region of Canada.

The National Tree Ring Database (NTRD) at NRCan's Canadian Forest Service (CFS) is a set of tree ring width data collected from several Canadian forest research projects and spans over 8,000 trees across Canada as of the end of 2008. It has been assembled in a coherent dataset to allow for the analysis of historical forest growth responses to environmental and climatic changes on a large landscape scale. The NTRD is a repository for existing tree and new tree ring collections from across Canada and is based at the CFS Northern Forest Centre. The NTRD web-based interface is designed to allow for selection of records by multiple criteria including geography, terrestrial ecozone, and species; and to output those records in formats suitable for further analysis using existing research tools and programs. Access to the database will eventually be fully open to the public through a web-based interface. The data is primarily

living trees. Data location is accurate to ± 2 km. The NTRD allows for the analysis of historical tree growth responses to environmental and climatic changes on a large landscape scale. It is currently being used for peer-reviewed scientific studies.

There are also a considerable number of Canadian entries in the holdings of the World Data Center for Paleoclimatology that are not contributed systematically but rather through academic networking.

Chapter 2: Atmospheric Essential Climate Variables

Environment Canada is the primary federal department responsible for the operation of the national surface weather, climate, meteorological marine, upper air and atmospheric composition networks from which Canada's atmospheric ECV contribution to GCOS is derived. Several of the systematic meteorological networks have weather service origins. However, established national operating procedures and standards, life cycle management, coordinated modernization of sensors and equipment, and formalized change management processes and quality management systems promote adherence to the GCOS climate monitoring principles.

The atmospheric composition measurement programs operated by Environment Canada tend to be research-based but those contributing ECVs to the GCOS via WMO's Global Atmospheric Watch have made or are making the transition from project-based to long-term systematic measurement programs.

2.1 GCOS Surface Network (GSN)

Canada contributes 87 stations to the GSN, an increase of 15 from those identified in Canada's 2002 GCOS report. The increase addressed data gaps primarily in Canada's north. Federal government climate change program funding supported the network expansion and also addressed upgrading some existing stations to a network standard. The Canadian GSN consists predominantly of automatic stations, with standardized sensor suites, measurement, processing and reporting algorithms, inspection and maintenance standards and procedures. In addition to the Essential Climate Variables (ECVs) identified in Table 1a, the GSN stations also measure and report atmospheric pressure, wind speed and direction, humidity, and snow on ground on hourly and synoptic reporting frequencies. Some data coverage gaps remain in the Canadian GSN, specifically in extremely remote northern regions where it is expensive to install and maintain autostations with little or no human presence.

The Canadian GSN is a sub-set of the Meteorological Service of Canada's (MSC) Reference Climate Station (RCS) network consisting of 305 stations. The RCS network is primarily intended for determining climate trends on regional and national scales. It was initially established in the early 1990s by identifying and designating stations with continuous high quality observations of thirty plus years in duration. The resulting network was a mixture of automated stations, human-based aviation weather observing sites, daily temperature and precipitation climatological stations operated by volunteers and co-operating agencies. Since about 2000, MSC has been converting about 10% of these stations per year to a standardized autostation configuration. However, in recent years this rate of modernization has fallen due to resource limitations. Approximately 60 ordinary climatological stations remain to be modernized.

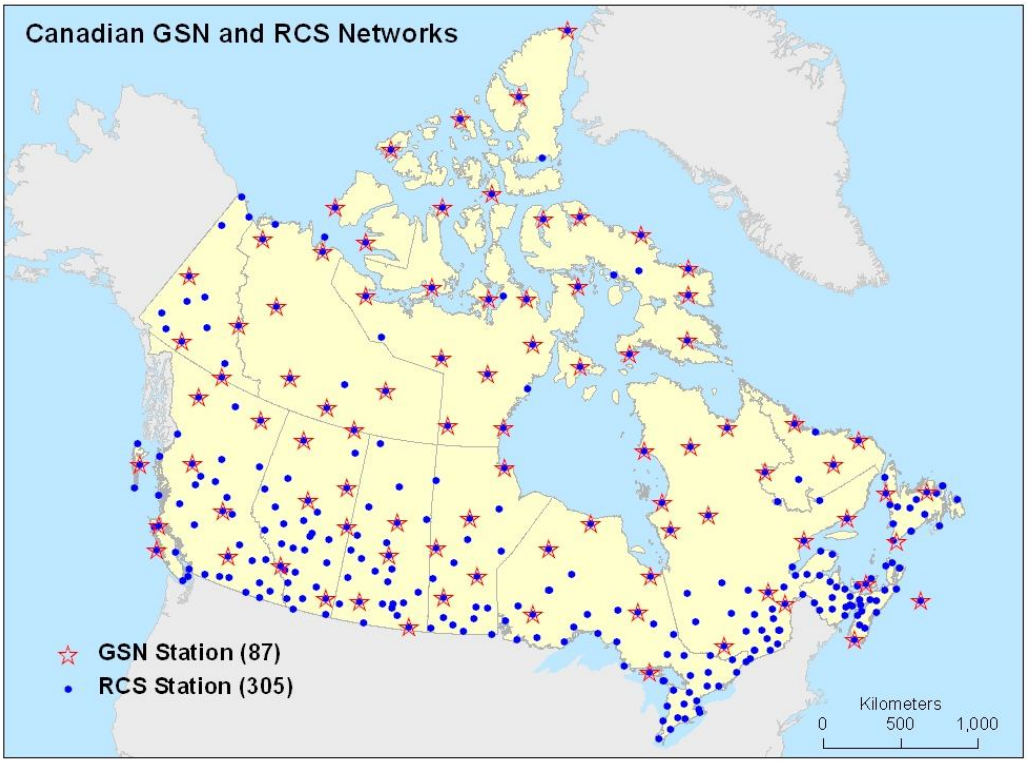

Figure 1 – Canadian GSN and Reference Climate Station Networks
(Source Environment Canada)

Under the auspices of an MOU between Environment Canada and the US NOAA, MSC and the US National Climatic Data Center (NCDC) have entered into a bilateral agreement to coordinate standards, procedures, equipment and measurement programs between the Canadian RCS and the US Climate Reference Network (CRN) with the objective of establishing and maintaining a North American climate reference network. An example is the cooperative effort towards developing an operational snowfall measurement algorithm at the autostations where total precipitation weighing gauges are employed.

2.2 World Weather Watch/Global Observing System (WWW/GOS) Surface Network

The Canadian WWW/GOS synoptic network of 812 stations consists of a composite of automated RCS stations, the MSC surface weather network which is fully automated and an ensemble of both staffed and automated aviation weather reporting stations that also produce synoptic messages. All synoptic stations report the full suite of ECVs noted in Table 1A. Some selected stations, primarily RCS, also report solar radiation and soil temperature. The MSC surface weather network and the aviation weather observation network (operated by NAV CANADA) are also undergoing modernization. For example, the MSC surface weather network is replacing older generation precipitation weighing gauges and installing snow depth sensors where required, the pace of modernization also determined by resource constraints. NAV CANADA is also turning to newer generation automatic weather stations.

The Canadian hourly surface weather network consists of these synoptic stations plus those aviation stations that produce Meteorological Aviation Reports (METARs) only. METARs are distributed internationally via the GTS. The MSC hourlies are distributed within Canada and to NOAA.

Canada also contributes 149 Regional Basic Climatological Stations (RBCN) and 306 Regional Basic Synoptic Stations (RBSN) as defined through WMO's Regional Association IV. It is noted that the RBSN list is significantly larger than that posted on the WMO website. Although an updated station list was provided in 2005, the update was apparently never formalized. Canada will take steps to ensure that the changes are formalized with WMO.

2.3 Baseline Surface Radiation Network (BSRN)

The Canadian BSRN consists of three stations, Bratt's Lake in western Canada and two recent additions in the Canadian Arctic, Alert and Eureka on Ellesmere Island. The Eureka program was established with support from the Canadian International Polar Year Program and Alert was supported by the US NOAA. In addition to maintaining its own BSRN database, Canada will be providing data to the world BSRN archive being transitioned to the Alfred Wegener Institute, Germany. Canada also operates BSRN caliber stations at Environment Canada's Centre for Atmospheric Research north of Toronto, Ontario and in collaboration with NRCan at Varennes, Quebec. EC also plans to establish a BSRN grade station at Iqaluit, Baffin Island in 2009.

2.4 Solar Radiation Network

Of the 41 solar radiation (RF1) stations operated by MSC, 17 have been upgraded with new equipment. The modernized stations are primarily located at RCS and upper air station locations where a human presence is available to carry out routine maintenance such as cleaning of the sensor. The network will consist of 56 stations when the modernization activities are completed. At present, data are not routinely provided to the World Radiation Data Centre due to resource constraints for completing actions to upgrade the MSC's data management system. MSC no longer supports the continuing operation of the hours of bright sunshine national network.

2.5 GCOS and Full WWW/GOS Upper Air Networks

Of the approximately 900 upper air radiosonde stations operating under the WWW/GOS program, 31 are contributed by Canada. Of the approximately 165 stations from the full WWW/GOS upper air network designated as GCOS Upper Air Network stations (GUAN), 5 are Canadian stations. These are: Alert, Goose Bay, Moosonee, Fort Smith and Cambridge Bay, the latter formally designated as a GUAN site shortly after the release of the 2002 Canadian GCOS report.

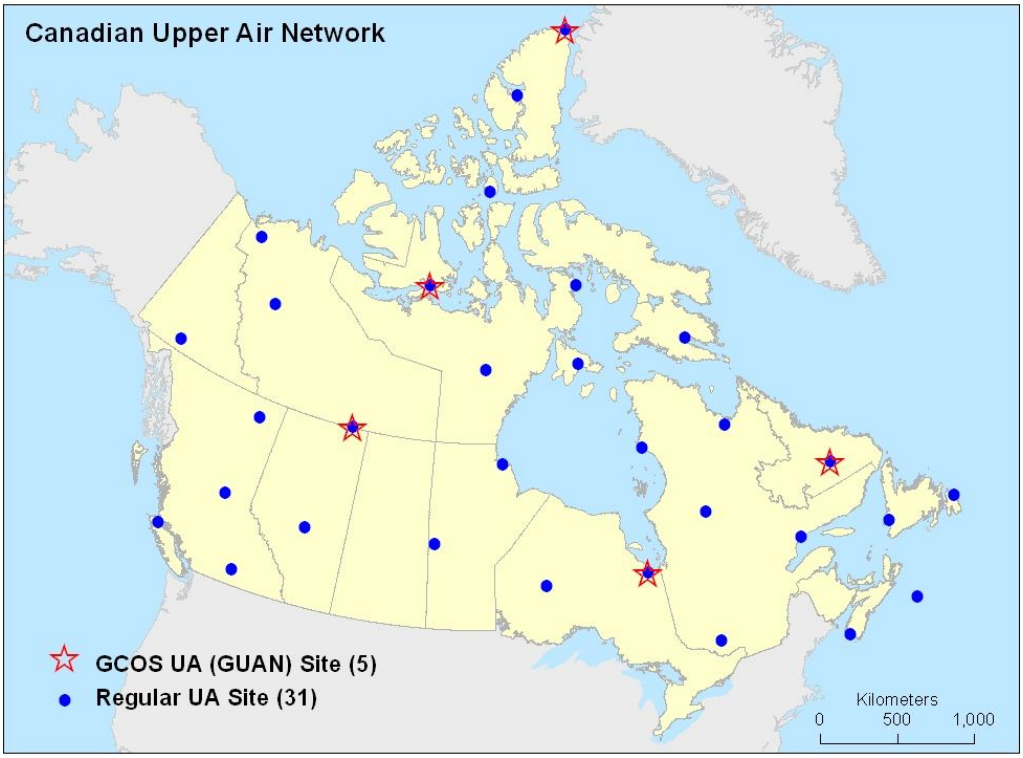

Figure 2 – Canadian Upper Air Network
(Source Environment Canada)

Balloon borne Vaisala RS-92 radiosondes are released twice daily at 0000 UTC and 1200 UTC. The radiosondes measure and simultaneously transmit data including temperature, humidity and pressure to automated ground systems (Vaisala DigiCora II MW15 and Vaisala DigiCora III MW31). Wind direction and speed are determined by using Loran-C and GPS technology to track the radio signal transmitted by the radiosonde. The MSC is currently in the process of upgrading the upper air network to Vaisala DigiCora III MW31 systems. It is expected that all stations will be converted to MW31s by January 2009.

Efforts continue to augment the relatively low density upper air radiosonde network through initiatives such as the Canadian AMDAR (Aircraft Meteorological Data Relay) program. About 35,000 observations of wind and temperature are generated daily by a fleet of about 100 aircraft operated by Air Canada Jazz. These observations translate into roughly 5,000 soundings per week from 54 Canadian airports from coast to coast mostly located south of 55 ^{0}N and from 14 USA airports. The quality of the data is monitored in near-real-time by the Canadian Meteorological Centre before the data are used in CMC's national data assimilation system and distributed internationally. The Canadian AMDAR data are distributed free of charge on the GTS as WMO code FM94 BUFR messages under the headers IUAA01 CWAO and IUAB01 CWAO. Deploying an AMDAR capacity on regional airlines operating in northern Canada would be highly beneficial, however, due to technical difficulties; attempts to date have not been successful.

2.6 Moored Buoys

The MSC currently operates 46 moored buoys of which 16 are located off Canada's west coast and 10 off Canada's east coast. The remaining 20 are seasonally operated in the Great Lakes and other large freshwater lakes. The buoys range from 6 metre NOMADs used in deep water moorings (down to a 4000 metre depth) to 1.7 metre WatchKeeper buoys used in small inland waterways. Buoys measure the following elements: air and sea surface temperature, wind speed and direction, atmospheric pressure and wave spectra. The buoys utilize a data logger system which integrates the sensors with communications and power systems allowing for autonomous operation for many months at a time. All buoys use GOES satellite with NESDIS processing as the primary data delivery system. Pacific buoys use system ARGOS for backup communications as well as buoy position monitoring (alarm triggered if buoy leaves expected radius area). Atlantic buoys only use ARGOS for buoy position monitoring. Data availability is very high, generally exceeding 90%. Currently, there are no plans to increase the size of this network.

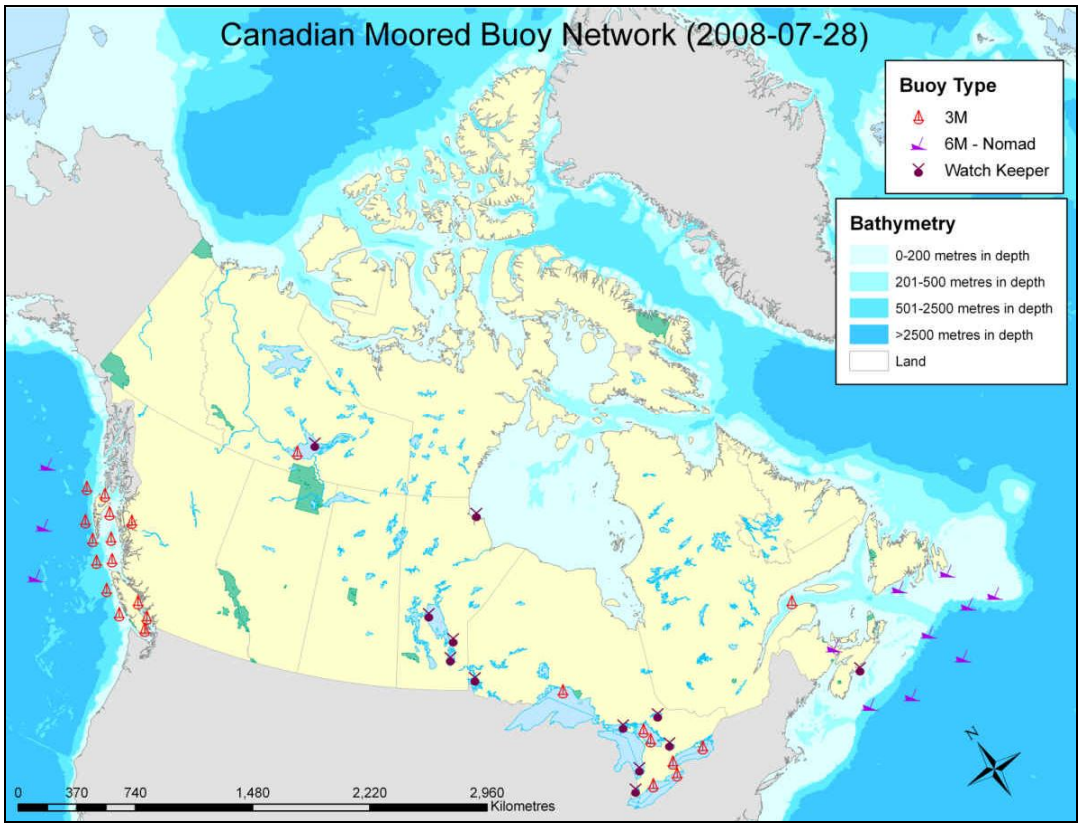

Figure 3 – Canadian Moored Buoy Network
(Source Environment Canada)

2.7 Drifting Buoys

The MSC continues to deploy approximately 8 drifting buoys per year in the Northeast Pacific with the goal of maintaining at least 16 buoys operational upstream of Canada's Pacific Coast. An additional 4 to 6 are deployed annually in the Northwest Atlantic. As of August 2008, 26 drifting buoys are reporting in the Northeast Pacific and 5 are reporting in the Northwest Atlantic. All buoys measure air and sea surface temperature, currents and atmospheric pressure. Some also measure wind speed and direction. The drifting buoys use ARGOS satellite communications with commercial data processing. MSC is participating in the JCOMM Iridium Pilot Project and will deploy 5 buoys equipped with Iridium transmitters. In the future, MSC will have to rely solely on ships of opportunity to deploy drifting buoys in the Northeast Pacific rather than air deployment. Deployments will likely be concentrated in shipping lanes limiting MSC's ability to maintain the buoy array in grid formation.

Normally, two to three buoys/beacons are deployed annually via air drop on ice in the arctic basin for operational meteorological purposes as part of the International Arctic Buoy Programme (IABP). In recent years incremental funding in support of the IPY has resulted in 12 MSC-funded ICEX buoys reporting surface air temperature and pressure and position as of August, 2008. Issues affecting longevity of the buoys operations include battery failure and decay, melting or break up of the underlying ice. The data is processed by service ARGOS and distributed via the GTS. Data are archived in Canada at DFO's ISDM and the designated world data centre (See section 3.1).

2.8 Voluntary Observing Ship Climate Project (VOSClim)

Currently, the Canadian contribution to VOSClim consists of 45 Automated Volunteer Observing Ships (AVOS). Nearly 50 percent of these platforms are installed on Canadian Coast Guard (CCG) vessels. Plans call for 75 AVOS with additional installations to focus on vessels plying data sparse waters such as the Canadian Arctic. AVOS is based on the same system used on the moored buoys, with a similar suite of sensors. In addition to the automated program, a touch-screen "Bridge PC" allows the ship crew to augment the automated observations with manual reports of sea state, visibility, ice conditions and other meteorological phenomena.

AVOS uses INMARSAT transmitters to relay data in real-time to MSC and the GTS. MSC has an agreement with NOAA to assist with the processing of the raw INMARSAT data. AVOS reports at the following time intervals depending on their location:

- In Canadian waters north of 51 °N – hourly
- In Canadian waters south of 51 °N – every 3 hours
- In International waters – every 6 hours (0000 UTC etc.)

Future challenges include consideration of Iridium communications to get a higher percentage of observations in the far north where INMARSAT does not perform well. There is an additional challenge related to the dissemination of AVOS data. An international effort is underway to work with VOS fleets to limit the release of call sign and position data. This is primarily due to security concerns and piracy increases in certain parts of the world. As an interim measure, MSC is working with NOAA and the Japanese Meteorological Agency to utilize the "SHIP" call sign mask scheme, which MSC hopes to implement for CCG ships this fall. The Ship Observations Team of WMO is working on a longer term solution that will utilize encryption of the FM13 data messages. However, this will not be implemented until at least 2013.

2.9 National Climate Data and Information Archive

The National Climate Data and Information Archive operated and maintained by Environment Canada, contain the official climate and weather observations for Canada. Datasets include elemental storage of surface weather, climate, marine, and upper air observations. Radar volume scans are also archived. With the automation of many of the contributing national observing networks and the automatic weather station's capability to provide data at increased observing and reporting frequencies, additional elements have been added to the archive. For example, the archive database now includes (without quality control) 15 minute precipitation amounts from the precipitation weighing gauges and snow depth amounts (snow on ground) at 15 minute intervals. Increased digital data entry systems such as COOLTAP/IVR (internet and touchtone telephone-based) are providing near-real-time data from the volunteer climate observer program as compared to the previous paper-based monthly summary approach.

A digitization lab has been recently established to handle scanning of the paper-based data still being sent by volunteer program observers although this is dwindling as COOLTAP/IVR takes over. The lab will, subject to availability of resources, address the digitization of major holdings of historical data still archived on microfilm and paper, media at risk to decay and deterioration, fire and water damage, etc.

The MSC is gradually implementing a new Data Management System (DMS) intended to improve life cycle management of its operational weather, climate and hydrometric observations. Features will include improved quality assurance and quality control, a consistent approach to the handling of data and metadata, histories of any and all data transformations retained, interoperability of datasets, and, extensibility to new data types and streams, for example, AMDAR data. The end result will be a single system of systems, from the user perspective, to access needed datasets.

The transition to the new DMS has had some impact on current observed data handling due to its pressures on the availability of IT human resources for operations. For example, work on ingesting other new data elements into the National Climate Archive has been put on hold while DMS develops the necessary data message decoders. Data from a modernized solar radiation program integrated into the RCS/GSN network is not transmitted globally or archived as it awaits new data management protocols and decoders.

Direct access by the public to weather and climate information in the archive is available free of charge at Climate Data Online - http://www.climate.weatheroffice.ec.gc.ca. Bulk data can be downloaded although there are volume limits on each individual query. Alternatively, for large datasets, an order for a customized request can be placed through an MSC climate services office but a cost recovery service charge will apply. As the new DMS matures and more bandwidth is available, the trend will be to enhanced interactive bulk access – more data elements, larger volumes, more formats and more metadata.

2.10 Specialized Metadata, Climate Data Adjustment and Rescue

A realistic and reliable assessment of historical climate depends on a long-term, homogeneous time series of climate data. Climate data homogenization eliminates, to the extent possible, artificial shifts in the time series caused by changes in exposure and location, observing practices and equipment, etc. Environment Canada developed a special metadata database by

extracting from Station Inspection Reports (SIR) the change-related metadata and organizing it electronically in an Access database from which users can extract information via queries related to their specific needs. Currently, the metadata for 376 long-term stations across Canada includes most of the Canadian GSN stations. This database is being expanded to include precipitation related metadata for over 4000 climate stations. The extraction of this metadata has been limited to the paper archive of SIRs which covers the period up to the mid-1990s.

2.10.1 Homogenized and Adjusted Climate Data

Long-term and homogenized temperature datasets have been prepared at 210 locations (including 76 of the 87 GSN stations) for the analysis of climate trends in Canada. Almost all of the 210 stations are included in the RCS network. A second generation of homogeneity work is under development resulting in an expansion of the database to 336 locations to provide better spatial coverage. Many RCS/GSN stations have been automated since the 1990s. Overlapping records between the previous human-based programs and autostations are now used to develop transfer functions or compute biases between both sets of observations to allow joining of the old and new data records.

Adjusted historical precipitation data has been prepared for 495 Canadian locations including 79 GSN stations. Similar to the temperature time series, datasets extend back as far as 1895 although most of the Canadian Arctic data availability is limited to the mid-1940s to present. For each rain gauge type, corrections to account for wind under catch, evaporation and gauge specific wetting loss were implemented. For snowfall, density corrections based upon coincident snow ruler and Nipher measurements were applied to all ruler measurements.

A homogenized database of hourly station and sea-level pressures has been prepared for 761 stations in Canada including all GSN stations. The database covers the period from 1953 to 2002 and will soon be updated to include observations in recent years.

Homogenized surface wind speed data have been prepared for 117 long-term stations for the period 1953-2006. Hourly wind speeds are adjusted for non-standard anemometer heights using the logarithmic wind profile. Monthly mean surface wind speeds are derived from the anemometer-height-adjusted hourly wind speeds and subjected to a homogenization procedure in which a series of geostrophic wind speeds calculated from homogenized hourly sea level pressure data is used as a reference series.

All adjusted/homogenized data are freely available to researchers and can be accessed through www.cccma.bc.ec.gc.ca/hccd/

2.10.2 Data Rescue

With the exception of temperature and precipitation, Environment Canada's digital archive contains data only from 1953 for most meteorological variables. Data rescue has focused on digitizing pre-1953 surface pressure data in paper and microfilm media in the EC's national archive from about the 1920s. Other sources include daily meteorological logs archived in the National Library of Canada.

In addition some Hudson's Bay Company ships logs containing observations of weather conditions, wind force and direction have been scanned to digital images. They are borrowed from Hudson's Bay Company Archives for 72 HBC ships for the period from 1750 to 1900.

2.11 Spatial Modelling of Climate Data

NRCan's Canadian Forest Service (CFS) with significant collaboration from EC has put considerable effort into high resolution spatial modelling of various climate and historical weather data. The models cover daily time steps of temperature and precipitation from 1961 through to historical monthly time steps from 1901 and longer-term averages for different time periods. Much of that work is available through an internet mapping system at a resolution of approximately 10 km; however, customized data requests are freely available which may include point estimates at specific locations or different resolution spatial models.

Reference: http://cfs.nrcan.gc.ca/subsite/glfc-climate

2.12 World Meteorological Organization/Global Atmospheric Watch (WMO/GAW) Greenhouse Gases and Aerosols Observations

The Canadian GHG and aerosols programs continue to evolve to meet GAW/IGACO data specifications. All sites are located in remote continental/regionally representative locations. 2008 will see full implementation of continuous in-situ GHG measurements at all sites. EC's GAW Observatory at Alert, Nunavut is one of three WMO Global GHG inter-comparison sites. C and O isotope measurements are well established. EC is playing a lead role in developing the isotopes calibration methodologies and protocols.

The aerosols observations program is in transition from being research project based to a long term program building on the observations initiated at Alert thirty years ago. Substantial progress is being made in establishing the suite of aerosol chemistry and physical properties measurements at four sites: Alert; Whistler, British Columbia; East Trout Lake, Saskatchewan; and, Egbert (EC Centre for Atmospheric Research), Ontario.

GHG data is reported to the WMO world data centres, with the exception of C and O isotopes data for which sampling protocols do not yet exist. Aerosols data is reported for the Alert GAW site only thus far. Ground level ozone data is a product of the Canadian Air and Precipitation Monitoring Network (CAPMoN), a non-urban network where the measurement sites are selected to be regionally representative. Data analysis/interpretation studies coordinated with development and evaluation of climate chemistry models (for C,N and S cycles) are emerging as data records that now span sufficient years to provide representative records for all seasons and atmospheric transport regimes. Parallel research pertaining to C sources and sinks, aerosol processes, ice core aerosol characterization and forest fire impacts are underway to improve historical and current quantification of natural and anthropogenic emissions.

The EC climate chemistry program uses the GCOS Implementation Plan (2004), along with WMO, IGACO, WCRP and other programs to guide ongoing observations and modifications to the surface measurements for atmospheric composition ECVs.

Environment Canada's long term GHG and aerosols observations and science program is somewhat at risk due to decreasing resources over the past three years; however, it is anticipated that despite this challenge observations will continue at key sites. Clear acknowledgement by data users in science articles/reports and policy communities would assist in ensuring the long term stable support and recognized value of these observations.

EC also operates one station (Bratt's Lake, Saskatchewan) measuring aerosol optical depth as part of the WMO/GAW precision filter radiometer network. In addition, EC in collaboration with the university community operates AEROCAN, a network of 20 sites across Canada, 10 which operate in the real-time. AEROCAN is a sunphotometer and sky-scanning radiometer network which is part of the federated AERONET network. AEROCAN's mission is to acquire sufficient spatial-temporal data to validate the development of a Canadian climatology for aerosol optical properties such as optical depth, size distribution and mass. The climatology is targeted towards atmospheric correction applications in remote sensing. Provision of data is through the NASA AERONET website.

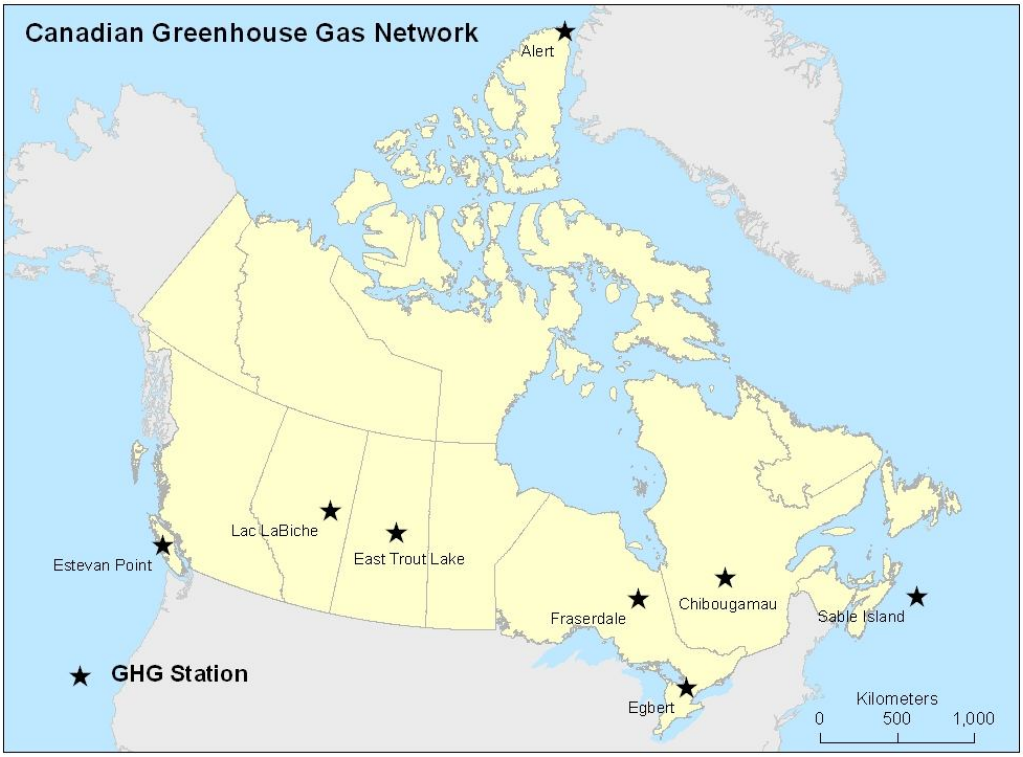

Figure 4 – Canadian Greenhouse Gas Network
(Source Environment Canada)

2.13 WMO/GAW Ozone and Ultraviolet Observations

Environment Canada launches ozonesondes from 10 locations across Canada on a weekly basis. These sites are co-located with MSC upper air radiosonde stations. The majority of ozonesondes are also paired with Brewer Ozone Spectrophotometers. The ozonesonde program is somewhat dependent on year-to-year funding. EC operates 11 Brewer spectrophotometer stations at 9 Canadian locations including two at Eureka, Ellesmere Island and two in the Toronto area. The automated Brewers are used to measure column ozone, and solar spectral UV irradiance on a daily basis. In addition, one station is maintained at Mauna Loa, Hawaii for calibration of the world ozone reference triad of Brewers.

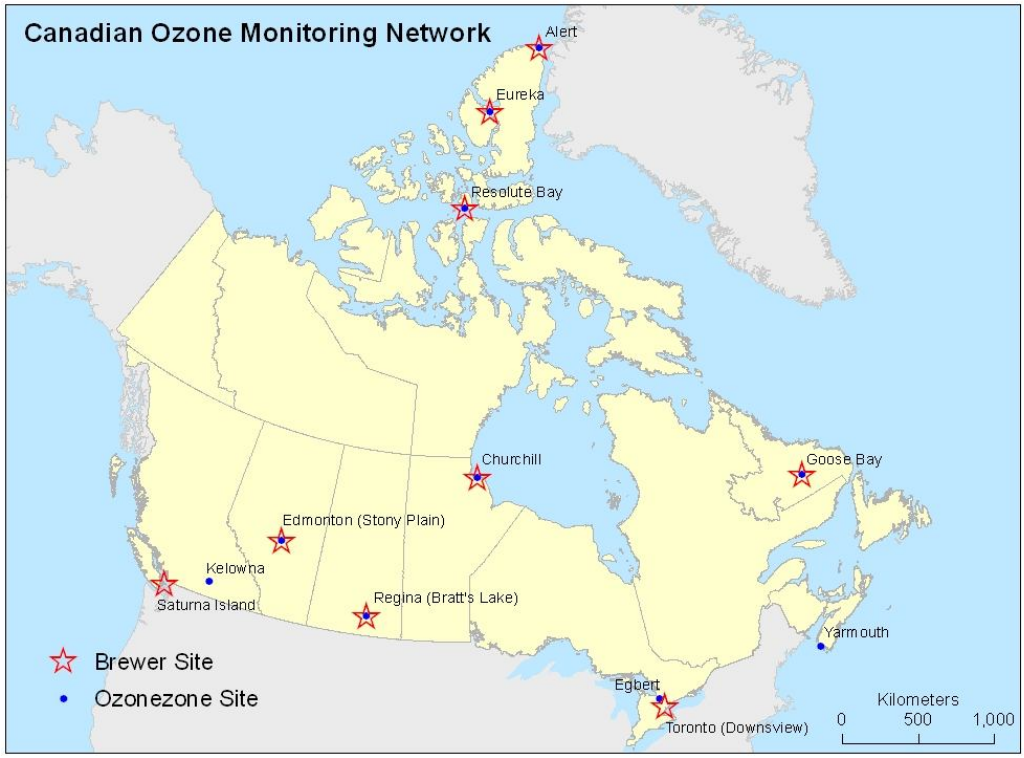

Figure 5 – Canadian Ozone Monitoring Network
(Source Environment Canada)

EC is engaged in a program to map ozone daily over Canada, the hemispheres and the globe. Depending on the map product, analyses are based on ground-based measurements and on an integration of ground-based measurements with satellite observations. Maps are available from:

www.woudc.org/data/OzoneMaps_e.html.

2.13.1 World Ozone and UV Radiation Data Centre (WOUDC)

The WOUDC has been operated by Environment Canada since 1961 and serves a broad community of ozone and UV scientists, data assimilators and modellers. The data are routinely used for large studies such as the quadrennial UNEP Scientific Assessments of Ozone Depletion. The archive is comprised of ozone, including total column and altitude profiles, and UV data files and value added products such as time series plots and daily ozone maps. The primary roles and responsibilities are outlined in the WMO-GAW Strategic Plan (2007-2015) and the IGACO initiative. WOUDC reports to three main WMO-GAW working groups: the Science Advisory Groups (SAGs) for Ozone and UV and the Expert Team on the World Data Centres.

The core of the WOUDC archive is the data files themselves and the associated metadata which are tracked and updated regularly. Data are received daily (for ozone maps) and the general archive processes the inbound data weekly.

Also associated with the WOUDC are the Brewer Data Management System which is a level 0 (primary) data repository, serving the Brewer community, and the WMO World Calibration Centre for Brewer instruments in the global ozone observing network.

The data centre has both a website (www.woudc.org) and ftp (ftp.tor.ec.gc.ca) for information and data access. The ozone data archive is published each year under the title "Ozone Data for the World" in DVD format. Special data requests are also processed on an individual basis. The data are publicly accessible and are available free of charge, but a data disclaimer fronts the archive, specifying that the use of the data is for scientific or educational purposes and that each data originator or their agencies should be acknowledged when their data are used. Funding for the WOUDC remains stable and sustainable.

2.13.2 SCISAT

The Canadian Space Agency's SCISAT was launched in August 2003 and continues to provide valuable information on the depletion of the ozone layer and the distribution and concentration of a large number of greenhouse gases that contribute to climate change. The primary scientific goals of the SCISAT-ACE (Atmospheric Chemistry Experiment) mission were to understand the chemical and dynamical processes that control the distribution of ozone in the stratosphere and upper troposphere, particularly in the Arctic; explore the relationship between atmospheric chemistry and climate change; study the effects of biomass burning in the free troposphere; and measure aerosols and clouds to reduce the uncertainties in their effects on the global energy balance.

The SCISAT-ACE project has provided evidence that the Montreal Protocol is yielding good results. It is also the only current satellite capable of monitoring the gases regulated by the Montreal Protocol in a three dimensional sense. Consequently it has proven useful in assisting Canadian and international policy makers. Detailed information on SCISAT-ACE including access to datasets is available at:

http://www.asc-csa.gc.ca/eng/satellites/scisat/default.asp

2.14 Future Satellite System Plans

The current evolving national space plan includes the development of a Polar Communications and Weather (PCW) satellite system that will provide valuable observations for meteorological forecast applications and for mapping ECVs over Canada and the Arctic circumpolar area. The PCW is envisaged as a two satellite system in a highly elliptical Molniya[1]-type orbit. This configuration allows continuous 24/7 observation of the entire circumpolar region with a targeted refresh rate of 15 to 30 minutes. Each PCW satellite is expected to carry an imaging spectroradiometer with up to 20 spectral bands covering the entire solar and thermal spectral domains with a spatial resolution from 0.5 km to 2 km. In addition to the imager, each PCW satellite may carry a broadband radiometer for earth radiation budget observations. The PCW system is planned to start operations in 2016 and will significantly enhance capabilities for Arctic meteorology (examples, nowcasting, polar winds, sea-ice charting) and the mapping of

[1] A Molniya orbit is a type of highly elliptical orbit with an inclination of 63.4 degrees and an orbital period of about 12 hours. Molniya orbits are named after a series of Russian communications satellites. A satellite placed in a Molniya orbit spends most of its time over a designated area of the earth as a result of "apogee dwell". *Source:* Wikipedia

terrestrial ECVs such as albedo, snow, fAPAR, LAI and radiation budgets over the Arctic region from space.

Table 1 - National contributions to the surface-based atmospheric essential climate variables

Contributing networks specified in the GCOS Implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of Stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
GCOS Surface Network (GSN)	Air Temperature	87	87	87	87	87
	Precipitation	87	87	87	87	87
Full World Weather Watch/Global Observing System (WWW/GOS) Surface Networks	Air Temperature, Air Pressure, Wind Speed and Direction, Water Vapour	812	812	812	812	812
	Precipitation	812	812	812	812	812
Baseline Surface Radiation Network (BSRN)	Surface Radiation	3	3	3	3	3
Solar radiation and radiation balance data	Surface Radiation	41	17	56	0	0
Ocean drifting buoys	Air Temperature, Air Pressure	43	43	36	43	43
Moored buoys	Air Temperature, Air Pressure	45	45	46	45	45
Voluntary Observing Ship Climate Project (VOSClim)	Air Temperature, Air Pressure, Wind Speed and Direction, Water Vapour	45	45	60	45	45
Ocean Reference Mooring Network and sites on small isolated islands	Air Temperature, Wind Speed and Direction, Air Pressure	0	0	0	0	0
	Precipitation	0	0	0	0	0

Table 2 - National contributions to the upper air essential climate variable

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
GCOS Upper Air Network (GUAN)	Upper-air Temperature, Upper-air Wind Speed and Direction, Upper-air Water Vapour	5	5	5	5	5
Full WWW/GOS Upper Air Network	Upper-air Temperature, Upper-air Wins Speed and Direction, Upper-air Water Vapour	31	31	31	31	31

Table 3 – National contributions to the atmospheric composition essential climate variables

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
World Meteorological Organization/ Global Atmosphere Watch (WMO/GAW) Global Atmospheric CO_2 & CH_4 Monitoring Network	Carbon Dioxide	8	8	5	5	5
	Methane	8	8	5	5	5
	Other greenhouse gases					
	CO	8	8	5	5	5
	N2O, SF6	8	8	5	0	0
	13C, 18O	5	4	4	0	0
	CFC-11 CFC-12	1	1	1	0	0
	Ozone	17	17	17	0	0
WMO/GAW Ozone sonde Network	Ozone	10	10	10	10	10
WMO/GAW Column Ozone Network	Ozone	9	9	9	9	9
WMO/GAW Aerosol Network	Aerosol Optical Depth	1	1	1	1	1
	Other Aerosol Properties					
	OC and EC/BC on Filters	6	6	1 - 2	0	0
	BC, TSP	1	1	1	1	1
	Light Absorption, 3λ, 1 & 10 µm	1	1	4	0	0
	Light absorption 1λ, 2.5 µm	3	3	0	0	0
	Light scattering, 3λ, 1 & 10 µm	1	1	4	0	0
	Light scattering 1λ, 2.5 µm	3	3	0	0	0
	Particle number concentrations	2	2	4	0	0
	Aerosol Ion Chemistry, TSP	1	1	1	1	1
	Aerosol Ion Chemistry, 2.5 µm	3	3	3	0	0
	Particle size distribution	2	2	4	0	0

EC – Elemental Carbon BC – Black Carbon OC – Organic Carbon TSP – Total Suspended Particulates

Chapter 3: Oceanic Essential Climate Variables

In Canada, the responsibility for the planning and implementation of ocean observing systems rests primarily with Fisheries and Oceans Canada (DFO). Collaborations are established with other government departments and agencies to include oceanographic activities for which the responsibility falls outside DFO. Within the Canadian framework, ocean monitoring programs have been developed for both the Atlantic and Pacific coastal and ocean regions and to a lesser but increasing extent for the Arctic.

Canada's Ocean's Action Plan (OAP) articulates a vision for Canadians to ensure the sustainable development and safe use of Canadian waters. The Plan confirms a mission to deliver to Canadians: Safe and Accessible Waterways, Healthy and Productive Aquatic Ecosystems, and Sustainable Fisheries and Aquaculture.

The OAP identified four pillars: International Leadership, Sovereignty and Security; Integrated Oceans Management; Health of the Oceans and advancements in Oceans Science and Technology. Within these pillars are activities of ocean monitoring that are crucial to achieve the goals of sustainable development for Canada's three oceans. A copy of Canada's OAP is available at:

http://www.dfo-mpo.gc.ca/oceans-habitat/oceans/oap-pao/pdf/oap_e.pdf

In the 2002 GCOS report, Canada indicated that it had undertaken a national review of the nation's aquatic observing networks to identify shortcomings and systematically consolidate and enhance their long-term effectiveness. The resulting report ensuing from that effort is available at:

http://www.dfo-mpo.gc.ca/csas/Csas/Proceedings/2006/PRO2006_003_E.pdf

Canada recognizes that a key factor in medium and long term weather forecasts, climate change prediction and climate change detection is quality oceanic observations on a global basis and that acquiring adequate observations, at a reasonable resolution, on such a scale requires international cooperation. Hence Canada is an active participant in both GCOS and GOOS and a number of Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) committees to help achieve an integrated sustainable global ocean observing system.

3.1 Surface Drifting Buoys

DFO's Integrated Science Data Management Branch (ISDM) acquires, processes, archives and disseminates all real-time surface drifter data that are distributed on the Global Telecommunications System as well as delayed mode data acquired from other sources. The reports are processed to remove duplicates and quality control routines are applied to the reported measurements. As a designated Responsible National Oceanographic Data Centre (RNODC), DFO partners with the Atlantic Oceanographic and Meteorological Laboratory in the U.S. to provide long term archive facilities for the Global Drifter Center data. ECVs included are surface and subsurface water temperatures, air pressure and pressure tendency, surface and subsurface salinity, surface currents. Public access to this data is available at:

http://www.meds-sdmm.dfo-mpo.gc.ca/meds/Prog_Int/RNODC/RNODC_e.htm

3.2 Sea Level Network

Sea level measurements are made routinely by a suite of gauges on both east and west coasts and in the Arctic. Figures 6 and 7 depict the east and west coast sea level networks. Most of the gauges sample at 3 or 1 minute intervals with a few older gauges sampling at 15 minute intervals. The DFO's ISDM system receives data from the east coast daily while data from the west coast and Gulf of St. Lawrence arrive monthly. The processed data are added to archives. Five of the gauges constitute Canada's contribution to the core Global Sea Level Observing System (GLOSS). These gauges are located at Nain on the Labrador coast; St. John's, Newfoundland; Halifax, Nova Scotia; Tofino and Prince Rupert in British Columbia. The core station data is reported on a 3 monthly basis to the sea level centre in Hawaii. A number of the gauges are co-located with full 3-D GPS and in particular the 5 Arctic gauges are so equipped. Canada also monitors water levels in the Gulf of St. Lawrence, along the St. Lawrence Seaway, in the Great Lakes and Hudson Bay. Canada is also re-establishing key Arctic sea level gauges, and several ice thickness moorings. Maps of all the water level networks are available at:

http://www.meds-sdmm.dfo-mpo.gc.ca/MEDS/Databases/TWL/TWL_e.htm

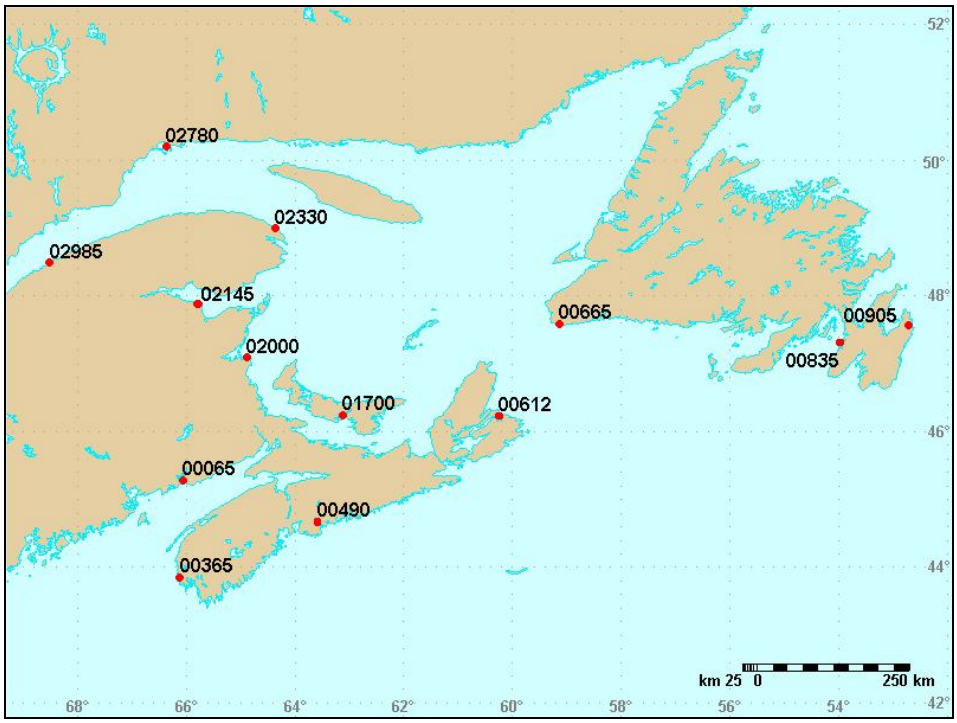

Figure 6 – Canadian East Coast Sea Level Network
(Source Fisheries and Oceans Canada)

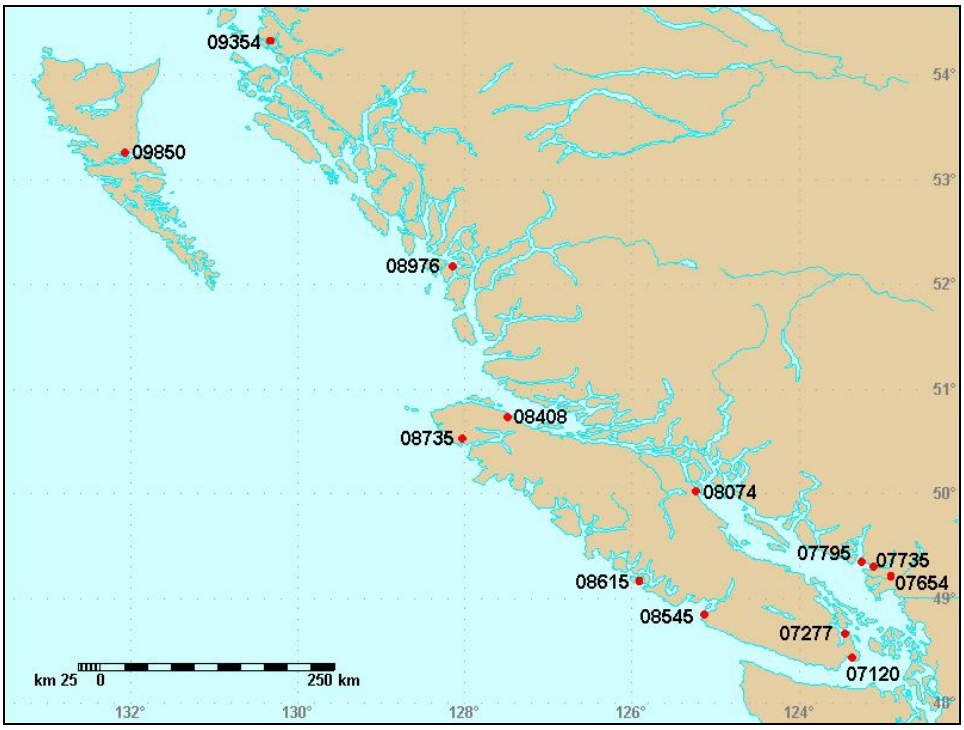

Figure 7 – Canadian West Coast Sea Level Network
(Source Fisheries and Oceans Canada)

Infrastructure is currently being implemented that will provide daily transfers of tide gauge data to the fast delivery sea level data centre at the University of Hawaii.

It should be noted that most Canadian sea level gauges are not corrected for sea level pressure. However, for a subset of gauges, the air pressure measurements of adjacent Environment Canada stations are jointly available with the tide gauge observations.

3.3 Ship of Opportunity Programme (SOOP)

Most temperature and salinity profiles collected by DFO are funded under Canadian research programs and usually are not part of an operational international program. Because of this, the ocean areas sampled and the measurements made are project dependent rather than systematic. However, within this envelope, a number of standard sections and stations are sampled routinely including Ocean Weather Station (OWS) P and Line P in the Northeast Pacific, OWS B and a number of sections (mostly extending to the shelf break) in the Northwest Atlantic. All of these are normally done four times per year, and other stations may be sampled more frequently, sometimes as frequently as every two weeks.

Some subsurface temperature and salinity observations from DFO vessels and all unclassified observations from Canadian naval vessels are reported, checked for quality and uploaded to EC for distribution on the GTS in real-time.

As a partner in the Global Temperature and Salinity Profile Project (GTSPP), DFO also receives, processes, archives and disseminates all of the ocean profile data reported in real-time on the GTS. These data are collected by a variety of platforms and instruments, ranging

from ships, moored or autonomous platforms, and instrumented animals. Processing requires resolution of duplicate and near-duplicate messages, and quality control of the reported measurements. Observations are forwarded to the U.S. NODC 3 times per week where real-time data is combined with delayed mode to produce a high quality archive of subsurface water temperatures, salinities and currents.

DFO is also a partner in the Global Ocean Surface Underway Data (GOSUD) project by providing the processing of the real-time data reported on the GTS in TRACKOB code form. The surface water temperatures and salinities data are passed to the project Data Assembly Centre in France daily.

3.4 Sub-Surface Drifters (Argo)

Argo is an international collaboration that collects temperature and salinity profiles from the upper 2000 metres of the ice-free global ocean and currents from intermediate depths. Each of the profiling floats is programmed to dive to a pre-determined depth, drift for a pre-determined period and take measurements on ascent or descent. Once it reaches the surface, it transmits the data via satellite. By August 2008, Canada had 112 operational floats contributing to the Argo array and plans to maintain its contribution in this range. Most of the floats are deployed on Canada's east and west coasts, but in an effort to encourage international cooperation, Canada has partnered with Chile, Russia, Japan and India in deploying or donating floats and data management services to assist these nations initiate their participation in the Argo program.

Most Canadian floats report through the ARGOS satellite communication system to the DFO's ISDM system in Ottawa. Canada has one float that uses the Iridium communications system. Data is received every 6 hours, processed automatically and subjected to automated data quality control and duplication checks. They are then transmitted to the GTS and Argo Servers within 24 hours. The data are readily available to support science investigations through a request mechanism and are also posted to the ISDM website for general use. Data received in delayed mode from science programs are also checked for duplication, quality controlled and archived in the ISDM Argo database.

Canada is one of a number of countries that have installed dissolved oxygen sensors on Argo profilers. These data are reported routinely with the temperature and salinity data.

3.5 Moored Buoys

Optical sensors have been added to some of the coastal buoys described in Section 2.6 to measure insolation, water colour, salinity and fluorescence. Additional capacity is also available to monitor further parameters when required.

The wave data from these buoys are acquired daily and processed by ISDM. A subjective quality inspection of each observed wave spectra is performed prior to update into the database. Flags are assigned to the observed and derived parameters reflecting data quality. Quality control is performed by examining the energy distribution of the power spectrum and comparing relative values of significant wave height and peak period between neighboring buoys. The ISDM historical wave spectral density (meters squared per Hertz) data was obtained by Fast Fourier Transform of the original 20-minute surface elevation time series record. There are approximately 60 estimates of spectral density supplied at equal intervals of frequency between 0.05 and 0.5 Hz.

In 2008, 45 arctic moorings were operated and maintained by DFO through funded research and collaborations with USA and Japanese oceanographic institutions and universities. DFO operated 33 coastal moorings while the collaborative operated 12 in the open-ocean. Of these, 34 sites have been operated for 5 years or more while 8 have operated for 10 years or more. Measurements include temperature, salinity and currents at various depths as well as ice thickness and pressure. Only Beaufort Sea and North Water Polynya data are currently online with considerable lag before data are posted.

Reference: http://members.shaw.ca/oceans/

3.6 Hindcast and Extreme Wave Data

Long-term hind-cast databases of winds and waves have been developed by Environment Canada for the east coast of Canada and the Beaufort Sea by the application of well known procedures to so-called “hindcasting” of these fields using all available observations, output from global re-analysis projects and wave models. The data are available on a 0.5 ° coarse mesh grid and a 0.1 ° fine mesh grid south of 50 °N and west of 40 °W and a 28 km grid for the Beaufort Sea. The North Atlantic database covers the period 1954-2005; the Beaufort Sea covers the period 1985-2005.

Canada is a joint leader in the establishment of an extreme wave event data archive through the JCOMM Marine Climatology Expert Team and Waves and Storm Surge Expert Team. The objective of this archive is to assemble in one place the measurements of large wave events to facilitate easier data access to improve modelling efforts for waves.

3.7 Coastal Observations

There are four oceanographic observation programs in the Atlantic region that are relevant. They include the Atlantic Zone Monitoring Program (AZMP), the Labrador Sea Monitoring program, the Bedford Basin Monitoring program and the St Andrews Phytoplankton - Harmful Algal Blooms (HAB) Monitoring program. Each has a specific set of goals and each generates a specific suite of products but collectively, they have been designed to address a number of societal issues such as the detection and prediction of the effects of global climate change on coastal ecosystems; the reduction of public health risks; the protection and restoration of healthy ecosystems; and restoration and sustainability of living marine resources.

The AZMP consists of a set of seven fixed time series stations sampled bi-weekly; a network of shallow coastal stations collecting temperature; a two line continuous plankton recorder (CPR) program; annual ecosystem trawl survey to observe numbers and distributions of various fish species in relation to bathymetry, temperature, salinity and lower trophic levels; and an annual fall survey of temperature, salinity, nutrients and plankton across the entire zone. All AZMP data are validated, archived and accessible to the public at the following website:

http://www.meds-sdmm.dfo-mpo.gc.ca/zmp/main_zmp_e.html

In the Pacific, there are a number of *ad hoc* monitoring activities, but sustained funding is uncertain and the program does not have official status. These observations are currently maintained through short term opportunity funding. Therefore, even the top priority contributions (Station Papa – Line Papa) are in jeopardy. Data is available at:

http://www-sci.pac.dfo-mpo.gc.ca/osap/data/linep/linepselectdata_e.htm

In the Arctic, an ocean observing program, similar to the Atlantic is currently being established under the auspices of the International Polar Year (IPY). One major Arctic component is the Line-A in the Beaufort Sea. Line A is a series of stations along a section that extends from the Beaufort Shelf to the Canada Basin interior and traverses shelf, slope and basin waters and includes the boundary current region. This line was first sampled from 1980 to 1986 when Conductivity, Temperature and Depth (CTD) and limited geochemical data were collected. In addition, sustained observations in the Arctic Archipelago are equally relevant to both Canadian and international interests.

Observations are also being made as part of the Three Oceans program, a component of Canada's IPY. The goal of Canada's Three Oceans is to observe North Pacific, Arctic, and North Atlantic waters and establish a scientific basis for sustainable, long-term monitoring. To achieve this goal, scientists used two Canadian Coast Guard icebreakers as research platforms along this track to measure ocean temperature, salinity, oxygen, nutrients, tracers, biota and wildlife in 2007 and 2008.

3.8 Other Ocean Programs

On the Pacific coast there is a well established network of stations measuring daily temperature and salinity that has provided data for close to a century. All data were originally gathered by lighthouse keepers and their families. These stations are gradually being automated as are the lighthouses. Locations of these stations are shown in Figure 8.

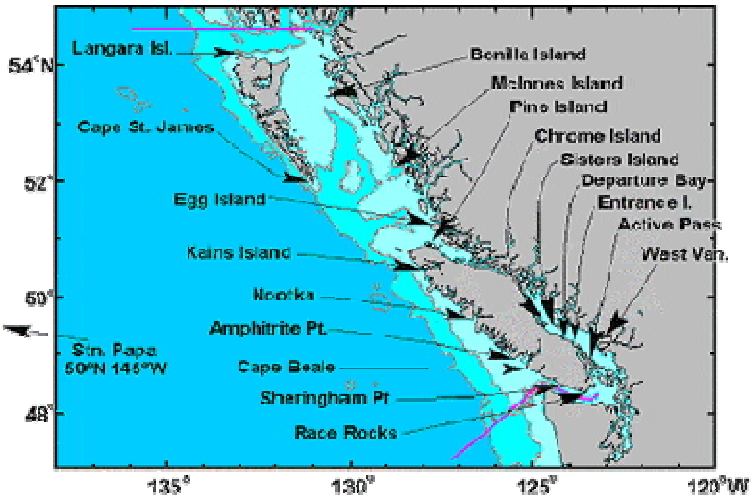

Figure 8 – West Coast Temperature and Salinity Network
(Source Fisheries and Oceans Canada)

On the Atlantic coast there is a long- term temperature monitoring network that has been beneficial to the aquaculture and lobster fishery. This network is depicted in Figure 9.

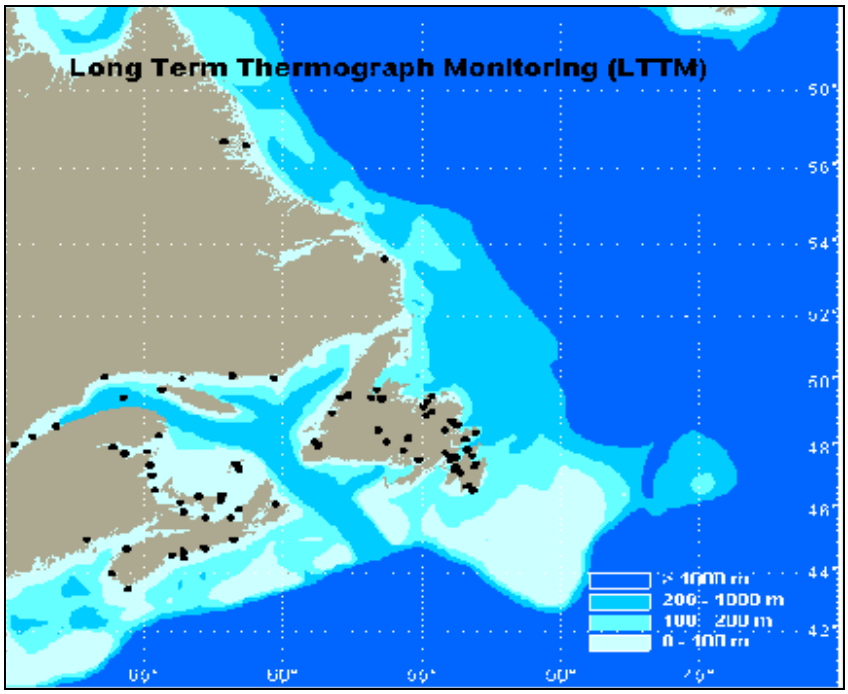

Figure 9 – East Coast Long Term Thermograph Network
(Source Fisheries and Oceans Canada)

Canada has a limited harmful algae bloom observation program and harmful algal events are input annually to the Intergovernmental Oceanographic Commission Harmful Algae Event Database. Nutrient, carbon and tracer data arrive in delayed mode at national archives. There they undergo checks of quality and it is ensured that sufficient metadata are present to allow proper interpretation of the measurements into the future.
Plankton data, which in the past was held in diverse archives, through a new DFO initiative, are now populating a national archive which already contains more than 1.5 millions observations. These data have not yet been sent to the world data centre.

There is no routine collection and archiving of surface temperatures and salinities taken from DFO science vessel cruises, apart from those that are generated by subsurface observations. While such data are often collected using a ThermoSalinoGraph (TSG), the data are used while on board but do not reach managed archives. Some near surface temperature and salinity data are collected using a TSG on a commercial vessel operating mostly in the Gulf of St. Lawrence. These data reach a managed archive within DFO, though do not yet pass through to the Global Ocean Surface Underway Data (GOSUD) Project. Actions are underway to implement a process to accomplish this.

Partial Carbon Dioxide (pCO_2) measurements are made in all three oceans by DFO staff. These are delivered in delayed mode and also contributed to the International Ocean Carbon Coordination Project (IOCCP).

DFO has supported a number of data rescue projects in the last 3 years. These include pCO_2 observations from the Pacific Ocean, plankton data from both the Atlantic and Pacific Oceans, and a number of Arctic data collections including under ice ecosystem studies, nutrients and

tracer data. These data are being added to DFO archives and contributed through the usual channels to the international archives.

3.9 Ocean Data Management

Fisheries and Oceans Canada has the responsibility for managing the Government's oceanographic data holdings. It accomplishes this through the Integrated Science Data Management (ISDM) Branch, formerly Marine Environmental Data Services (MEDS), which was established in 1968 to coordinate the processing and archival of physical oceanographic data. Data management, archival and dissemination of physical oceanographic data and data products on national and international scales are still key components of the ISDM mandate; however, responsibilities have been broadened to include chemical and biological oceanography.

The Canadian primary area of interest is 35 to 90 °N latitude and 40 to 180 °W longitude but for some specialized data types and programs the area of interest is global. Real-time, near-real-time or historical data are made available as appropriate. Physical, chemical and biological data collected by the Department of Fisheries and Oceans are today managed by a distributed system of archive centres within DFO. Policy, standards, and responsibilities are developed by a National Science Data Management Committee (NSDMC) chaired by ISDM with members from all DFO regions that collect the data. NSDMC was also mandated to coordinate and standardize processing, archival, and access procedures and policies for these data. ISDM and the regional centres thus provide coordinated data, data products and services to the marine community. Metadata such as the information about data collection methods, instruments, etc. are also archived for use by the oceanographic community and the public.

DFO plays major roles in supporting international data centres and data management activities. In cooperation with Environment Canada (EC), DFO receives all of the oceanographic data distributed on the Global Telecommunications (GTS) in international accepted formats (BATHY, TESAC, TRACKOB etc). Data is subjected to quality control procedures, archived and distributed, in accordance with established procedures, to international partners

Delayed mode ECV data are also received, quality controlled and archived. The time delay between observation and delivery to the archive depends on the type of variable with the physical variables arriving sooner than the biogeochemical ones.

3.10 Oceans Satellite Imagery

Satellite data images are captured by DFO at receiving stations at the Bedford Institute of Oceanography (BIO) – Atlantic Region, the Institute of Ocean Sciences (IOS) - Pacific Coast and at Resolute Bay, Nunavut. Sea-surface temperatures images are derived from AVHRR on the NOAA series of polar orbiting weather satellites. Both the Pacific Coast and the Resolute Bay datasets are transmitted to l'Institue Maurice Lamontagne for analysis. Chlorophyll concentration images are produced from SeaWifs data collected on the ORBView-2 satellites. Primary Production images are derived from the semi-monthly composites of chlorophyll concentration and temperature. On-line archives of imagery are available from BIO and IOS.

3.11 Sea Ice

Environment Canada's Canadian Ice Service (CIS) produces weekly ice analysis regional charts for Canada's navigable waters in the Western and Eastern Arctic, Hudson Bay, Canada's east Coast and Great Lakes. Ice concentration and ice type are reported using WMO standards. The ice charts are based on all available satellite data, primarily RADARSAT and ENVISAT, within 3 days of the valid date. CIS made the transition from RADARSAT-1 to RADARSAT-2 in late 2008. Satellite information is supplemented by air reconnaissance and Ice Service Specialists onboard ships for ground truth and coverage of strategic areas with finer detail. These charts are available from the CIS on-line archive:

http://ice-glaces.ec.gc.ca/WsvPageDsp.cfm?Lang=eng&lnid=7&ScndLvl=no&ID=11712

Paper charts from 1968 to 1998 were digitized in ArcGIS format. From 1998 to present the Ice Analysis charts have been produced in ArcGIS format and are available in real-time. Ice data is provided to the designated world data center at the US National Snow and Ice Data Center (NSIDC).

CIS also maintains an archive of data from ice thickness stations going back as far as 1947. By the beginning of 2002 the ice thickness program stopped due to station closures and other resource constraints. Renewed funding restored nine stations (Alert (2), Eureka, Resolute, Cambridge Bay, Coral Harbour, Baker Lake, Hall Beach and Yellowknife) in the Canadian Arctic beginning the fall of 2002. In addition, CIS deploys about 6 buoys per year on ice floes in the Canadian arctic primarily to track ice movement.

CIS has archived RADARSAT 1 data from 1997 to October 2006 as 2X2 block-averaged Level 1 ScanSAR image products in the Committee on Earth Observation Satellites (CEOS) format. All data are on CD and disk storage. An agreement has been reached between the Canadian government and the private sector operator of RADARSAT to allow the sharing of polar RADARSAT-1 data for research purposes only as a Canadian contribution to IPY. The CIS dataset will be part of a larger set of images processed by the Canadian Space Agency (CSA) for this purpose. CSA is preparing contracts to make it available shortly. Users will be required to register, accept the end user licensing agreement, describe the project purpose and report on results.

The Science and Technology Branch of Environment Canada has developed a new sea ice algorithm (ECICE) which is an improvement over the NASA Team2 (NT2) and is more general in that it can use sea ice information from several satellite sensors. It combines different satellite information using statistical optimization procedures. The additional information from several satellites allows the algorithm to estimate the concentration of more sea ice types than is currently allowed in the NT2 algorithm with better overall performance.

EC used spatially enhanced Advanced Microwave Scanning Radiometer for EOS (AMSR-E) data to calculate sea ice motion and ice area fluxes estimates for the main channels of the Canadian Archipelago and Baffin Bay for the period of the AMSR-E record (2002 to 2007). Results indicate that the Archipelago is a region of net sea ice production over the winter. This work will lead to the capability to estimate sea ice fluxes between the Archipelago, the Arctic Ocean and Baffin Bay and within Baffin Bay and Davis Strait on an ongoing basis. A sea ice motion database for the Arctic Archipelago and Baffin Bay is available through the Canadian Cryosphere Information Network at http://www.ccin.ca/.

3.12 RADARSAT-2

The RADARSAT-2 program assures data continuity for RADARSAT-1 users. Along with additional beam modes, RADARSAT-2 is designed with RADARSAT-1 compatible beam modes and will follow the same orbit, repeat cycle, and ground track as RADARSAT-1.

Other key features of RADARSAT-2 include the ability to select all beam nodes in both left- and right-looking modes allowing more frequent re-visits of targets, higher downlink power resulting in a lower cost of entry for new ground stations, secure data and telemetry transfers, solid-state recorders, on-board GPS receiver for real-time position knowledge, and the use of a high-precision attitude control system.

RADARSAT-2 contains numerous technical enhancements that will enhance data availability and improve product quality over RADARSAT-1.

RADARSAT-2

Innovation	What this means for users
3-metre ultra-fine resolution	• Improves object detection and recognition
Fully polarimetric imaging modes	• Enhance capabilities for various applications
Left- and right-looking capability	• Faster revisit time • Routine Antarctic mapping available
GPS receivers onboard	• ±60-metre real-time position information
10 ms delay between imaging modes	• Faster mode changes
Yaw-steering for zero-doppler shift at beam centre	• Decreased image processing time • Improved image quality
Star-trackers onboard	• Easier to maintain satellite stability
Higher power data downlink	• 3-metre minimum size antenna on ground allowing station portability • Lower “cost of entry” for new ground stations
Solid-state recorders for onboard image storage	• Higher reliability, faster image access, simultaneous recording and downlink

Table 4 – National contributions of oceanic essential climate variables – surface

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
Global surface drifting buoy array on 5x5 degree resolution	Sea surface temperature, sea level pressure, position-change-based current	31	31	30	31	31
GLOSS Core Sea-level Network	Sea level	5	5	5	5	5
Voluntary observing ships (VOS)	All feasible surface ECVs	0	0	0	0	0
Ship of Opportunity Programme	All feasible surface ECVs	12	12	12	12	12

Table 5 – National contributions of oceanic essential climate variables – water column

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
Global reference mooring network	All feasible surface ECVs	0	0	0	0	0
Global tropical moored buoy network	All feasible surface ECVs	0	0	0	0	0
Argo network	Temperature, salinity, current	112	112	112	112	112
Carbon inventory survey lines	Temperature, salinity, ocean tracers, biogeochemistry variables	2 lines, ~30 stations and 26 stations each	2 lines, ~30 stations and 26 stations each	2 lines, ~30 stations and 26 stations each	2 lines, ~30 stations and 26 stations each	2 lines, ~30 stations and 26 stations each

Chapter 4: Terrestrial Essential Climate Variables

This chapter addresses Canadian contributions to the observation of the 13 terrestrial ECVs identified in the GCOS implementation plan as feasible for global implementation and are important in terms of UNFCCC requirements. Key federal departments are NRCan, EC and AAFC, supported by the Canadian Space Agency. National measurement programs associated with the terrestrial ECVs range from long-term, systematic programs such as Environment Canada's hydrometric network to those that are recent and under development, for example, NRCan-led efforts to derive LAI and fAPAR products. Some in situ programs are in decline or inadequate in terms of spatial coverage, specifically the number of surface stations measuring snow depth, soil moisture and groundwater monitoring; others are somewhat dependent on research-based and short term funding rather than sustained operational budgets, for example glaciers and permafrost. The importance of the terrestrial ECVs and the ever increasing role of earth observation satellites have led to product development that includes integration of satellite data, in-situ measurements, and modelling for many of these variables. The Global Terrestrial Observing System and its Panels are currently assessing the status of the development of international standards and methodologies for each of the terrestrial ECVs[2]. GTOS is also collaborating with the CEOS Working Group on Calibration and Validation to establish terrestrial ECV validation protocols and benchmarks.

4.1 River Discharge and Water Levels

Environment Canada is the national agency responsible for the collection, interpretation and dissemination of standardized water level and river discharge data and information in Canada. In partnership with Canada's provinces and territories, Environment Canada operates over 2,400 hydrometric stations, and publishes the data annually in the national HYDAT archive database. Historical data for an additional 5,500 discontinued stations are also stored in HYDAT. Station metadata are stored in the national HYDEX database. The present network is now fully digital and over 1,600 stations transmit data in near-real-time. Both near-real-time data and historical data are accessible via the web at http://www.wsc.ec.gc.ca.

Most of the hydrometric stations are located in the southern half of the country where the population and economic activities are the greatest. As a result, the adequacy of the hydrometric network to describe hydrologic characteristics, both spatially and temporally, decreases significantly to the north. Furthermore, 20% of the network in the north is supported by short-term project-based funding which, if terminated, may lead to station closures in the Mackenzie Basin in the next few years.

Modernization of the hydrometric monitoring system is ongoing. All stations are equipped with digital data loggers and the goal of 100% near-real-time reporting is gradually being achieved. In addition, hydro-acoustic technologies have been introduced to facilitate the measurement of velocity profiles. In the next few years, the data acquisition and production components will be modernized with the development of the hydrometric workstation.

[2] See GTOS 52: Terrestrial Essential Climate Variables for Climate Change Assessment, Mitigation and Adaptation. FAO (2008). http://www.fao.org/gtos/doc/pub52.pdf.

Probably the biggest challenge today for the hydrometric program is associated with human resource needs. Recruitment of young technologists and engineers is not keeping pace with retirements, and this is putting a strain on operations.

Canadian hydrometric data have been provided to the Global Runoff Data Centre (GRDC) electronically (CD-ROM) since 1991. In recent years, a web-based dissemination system for both near-real-time and archived data was developed which meets many of the GRDC's needs for regular and timely data (see above referenced website). Work continues to improve real-time data management and delivery systems to meet current and emerging international standards for data exchange, including metadata and web services.

In participating in the Global Terrestrial Network – Rivers (GTN-R), Canada is providing data for 44 discharge stations located at or near the mouths of large rivers to assess the freshwater flux into oceans. At this time, Canada is unable to fulfill GRDC's request to provide discharge data in near-real-time in a fully automated fashion. However, work is underway to develop this capability within the 2010 timeframe indicated by the GRDC.

At the request of the GRDC, Canada recently identified 229 active river discharge stations that meet the criteria for another GCOS reference network well suited for climate trend analysis. Known in Canada as the Reference Hydrometric Basin Network (RHBN), these river basins are generally much smaller than those of the GTN-R, and they are characterized by either pristine or stable hydrological conditions, with 20 or more years of good quality record.

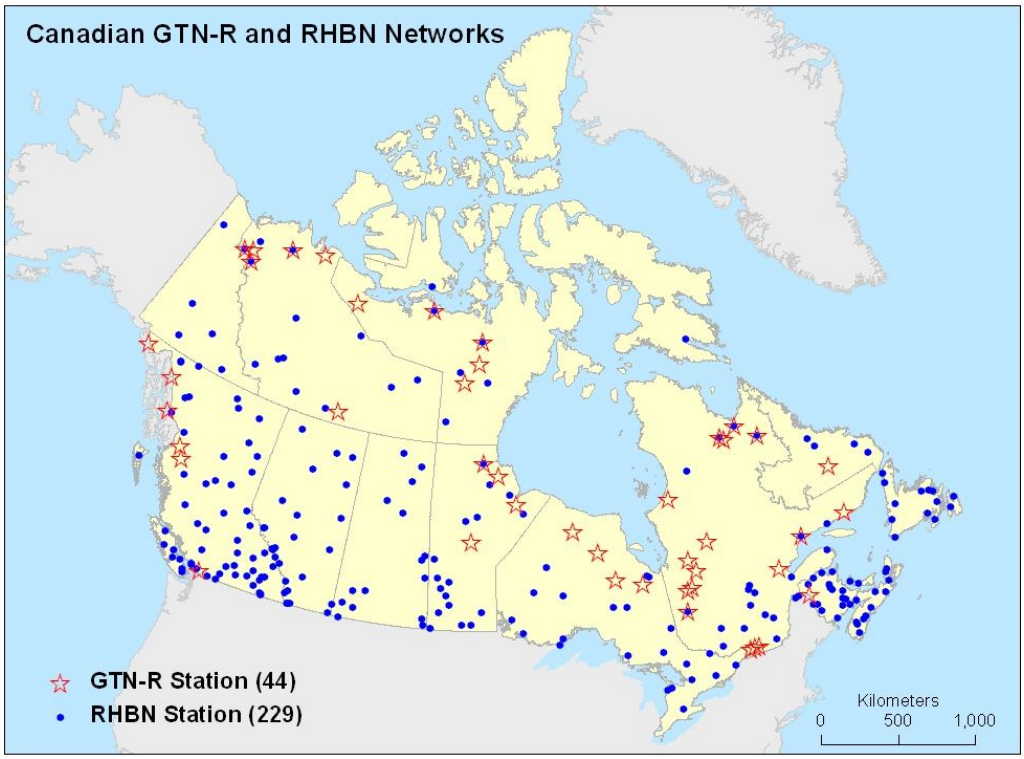

Figure 10 – Canadian GTN-R and RHBN Networks
(Source Environment Canada)

GCOS/GTOS has reportedly identified about 150 of the world's largest lakes as part of the developing GTN-Lakes reference network. Canada has not yet been formally asked to identify its contribution to the GTN-L but is ready to participate. Canada's national hydrometric network includes over 500 stations that monitor the level of Canada's lakes and reservoirs.

4.2 Snow Cover

4.2.1 Snow Depth and Snowfall Observations

Via WWW/GOS synoptic reporting, Canada contributes 322 snow depth observations in real-time on the GTS at 1200 UTC daily. Approximately 200 of these observations are from MSC surface weather and Reference Climate Station (RCS) autostations that include acoustic sensors for measuring snow depth. The remainder is provided by staffed aviation weather sites. Another 496 snow depth observations are provided in near-real-time from volunteer and cooperative agency climate observers reporting via the internet or telephone touch pads. Snow depth data from an additional 61 volunteer stations, designated as RCS sites but still recording climate summaries on paper, is also processed. Snow depth data from all 879 stations can be accessed from MSC's Climate Data Online. The total number of stations measuring and reporting snow depth has declined significantly since the early 1980s.

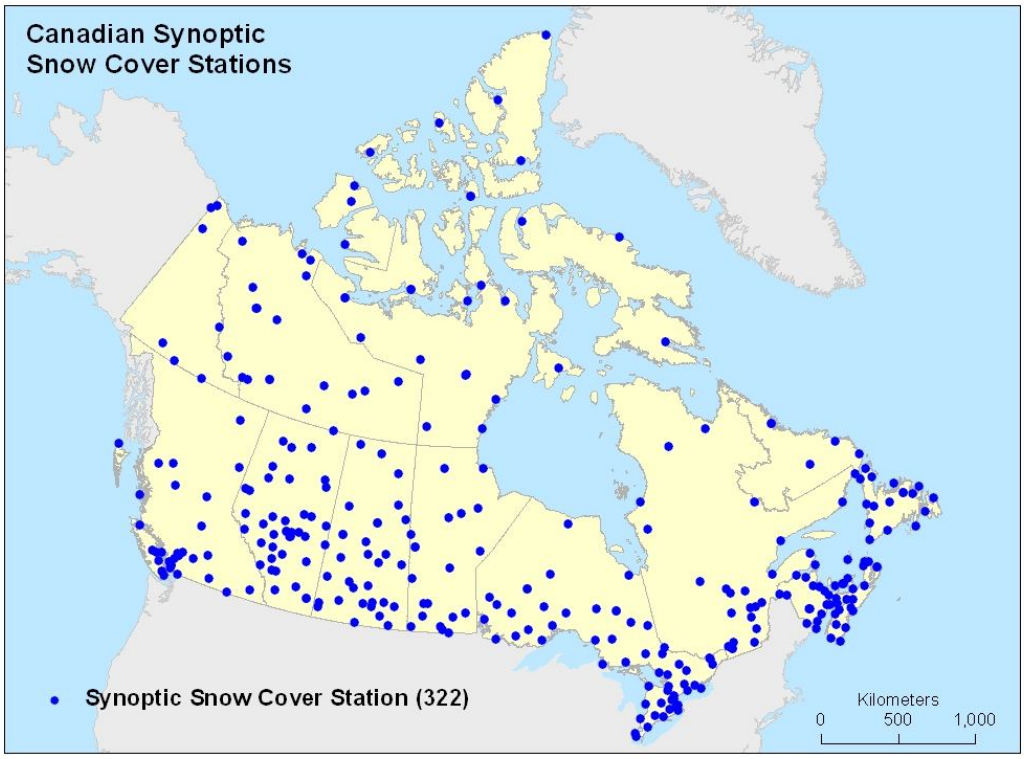

Figure 11 – Canadian Synoptic Snow Cover Network
(Source Environment Canada)

Similarly, MSC reports internationally, via the GTS, snowfall from 312 synoptic stations. The number of snowfall observations from volunteer and cooperative climate stations is the same as for snow depth and they too can be accessed via the climate archive on-line.

Several initiatives are underway within MSC's surface weather, RCS, volunteer and cooperative agency climate observing programs aimed at improving the availability and quality of snow measurements in the real to near-real-time. First, MSC has a goal to have all surface weather stations and RCS network operating with the same base autostation configuration including a standardized suite of sensors such as acoustic snow depth instrumentation. Currently, the modernization of these networks is about 40 % complete. By 2010, another 25 stations will be automated to the "modernized" configuration. Secondly, by 2010, approximately 650 volunteer/cooperative agencies will be providing daily climate data by internet and touchtone telephone-based reporting and processing systems which includes basic quality control of ingested climate reports.

Finally, considerable effort is underway to improve measurement of snow depth and derivation of snowfall from autostations. This includes, via an MOU between Environment Canada and NOAA, cooperation on development of algorithms to derive snowfall data, testing snow targets for acoustic snow depth sensors, evaluating various wind shields, for example, double alter, on all weather precipitation weighing gauges, etc.

A national compilation of quality controlled daily snow depth and snow course data released in 2000 by MSC was updated to 2002/03 for snow depth and 2003/04 for snow courses. These data are available online through the Canadian Cryospheric Information Network www.ccin.ca. The updating of these data is only done on an *ad hoc* basis due to resource limitations.

4.2.2 Snow Products

MSC's Canadian Meteorological Centre (CMC) has been producing since 1998 a daily global snow depth analysis at 0.3 ° resolution based on optimal interpolation of real-time observations from synoptic and hourly meteorological reports. These data are in the process of being documented and provided to NSIDC. There are plans to increase the resolution of the snow analysis to 10 km by 2010 and 5 km by 2014. North American snow analysis will be performed on a 2 km grid by 2010 and on a 1 km grid by 2014. Production issues include some countries not regularly reporting their snow depth data over the GTS; and, ongoing validation of the snow depth analysis at CMC is precluded by resource constraints.

A Canadian Space Agency (CSA) supported project was initiated in 2008 to advance the capability of CMC to assimilate satellite derived information on snow cover parameters (snow cover fraction, snow water equivalent (SWE)) with the Canadian Land Data Assimilation System (CaLDAS) currently under development by MSC. This system is scheduled for operational implementation in the 2011-2012 timeframe. This project will involve the development of quantitative uncertainty estimates for MODIS and passive microwave derived snow cover and Snow Water Equivalent (SWE), and an assessment of the impact of satellite snow cover observations in the assimilation process from independent satellite and ground measurements

Environment Canada has made considerable progress in developing passive microwave derived SWE information over sub-Arctic regions of North America where pre-existing algorithms were unable to account for the influence of lake ice and forest cover. Previous uncertainties in retrieving SWE across the boreal forest have been resolved with the combination of 18.7 and 10.7 GHz measurements from the AMSR-E (2002-present). A primary

challenge in developing tundra specific SWE retrievals from microwave measurements is resolving the influence of lakes. Satellite measurements coupled with model simulations have illustrated frequency dependent, seasonally evolving relationships between brightness temperature and lake fraction. A potential solution based on the temporal evolution of 37 GHz AMSR-E measurements shows some promise as this was found to be significantly correlated with field measurements of tundra SWE and to be relatively insensitive to lake fraction. The mountains remain a region of undeveloped SWE retrieval capability as regions of complex topography cannot be resolved with current satellite passive microwave technology. One of the current focuses of IPY supported activities in Canada is the integration of modelling and remote sensing approaches for SWE retrieval in mountainous areas. This system will build on the operational National Snow Analysis snow cover monitoring system of the US National Operational Hydrologic Remote sensing Center and use information from a range of satellites (such as MODIS and AMSR-E) to generate an optimal SWE analysis.

NRCan's Canada Center for Remote Sensing (CCRS) has been working with NOAA in the production and assessment of consistent near-real-time Snow Cover Extent (SCE) satellite products over North America. CCRS is also working on the production of historical circumpolar daily SCE products from historical NOAA AVHRR datasets. The near-real-time snow cover product corresponds to a blending of MODIS 500 metre clear sky land SCE and lake ice cover and 4 km NOAA Automated Monitoring System land SCE in near-real-time followed by a revision using 1 km resolution historical SCE over land. The dataset has been validated over Canadian in-situ snow courses and found to be close to the 10% error rate specified by CEOS. CCRS has also produced 1 km (over Canada) and 5 km (circumpolar Arctic) daily SCE from 1982 to present, as part of their contribution to the IPY. The products derived from available NOAA AVHRR observations have similar accuracy to MODIS products at the same resolution but provide almost continuous (>95%) retrieval rates in contrast to infrequent (<30%) rates from MODIS. The CCRS products do not show degradation in performance during melt conditions. The products are now undergoing further inter-comparison at NOAA and EC. There are insufficient Fundamental Climate Data Records (FCDRs) to meet both the GCOS resolution requirements (100 metre spatial, daily temporal) over complex terrain while current near-real-time products do not meet the 1km resolution specification for other terrain conditions. In addition, all SCE products tend to show larger errors during snow onset conditions when cloud free sampling by Visible and Near Infrared (VNIR) sensors is sometimes insufficient. There is also no dedicated CEOS Land Parameter Validation Sub-group to characterize the performance of products and make recommendations to CEOS regarding FCDRs. This is reflected in the absence of protocols for in-situ SCE mapping as well as scaling these estimates to allow optimal assessment of coarser resolution SCE products.

Dataset availability is as follows:

Near-real-time: http://www.socc.ca/examples/socc/snow_images/daily_images.jsp

Historical 5 km SCE (1 km data to be posted November, 2008) (will also be posted at www.socc.ca November 2008); ftp://ftp.ccrs.nrcan.gc.ca/ad/IPY/snowapp/.

4.3 GCOS Glacier Monitoring Network (GTN-G)

Canada's Glacier-Climate Observing System is delivered through the multi-lateral initiative "State and Evolution of Canada's Glaciers" led by the NRCan - Geological Survey of Canada (GSC) in partnership with other federal departments and agencies, and universities. Glacier – climate observations are derived from the in situ measurements of a network of reference glaciers in the Western and Northern Cordillera and the Arctic Archipelago of Canada. Both aircraft and satellite-based remote sensing are applied in a multi-scale/multi-mode fashion to generate regional perspectives of land ice and its responses to climate variations.

Change in length information for some Canadian glaciers extends back to the late 19th century. Mass balance measurements were initiated for some glaciers and ice caps in Canada during the late 1950s and early 1960s. Data and supporting metadata on Canada's reference glacier measurements are submitted to the World Glacier Monitoring Service (WGMS). Digital data are stored in the World Glacier Inventory and are also accessible through a website located at the USA National Snow and Ice Data Center. All told, there are 28 mass balance programs records archived internationally at the NSIDC and 24 at the WGMS. These records are also maintained at the GSC.

Canada contributes 16 locations to the GCOS GTN-G network. It is expected that will increase to 21 by 2010 with programs under development in the Lloyd George, St. Elias, Penny Ice Cap, Bylot Island and Grise Fjord regions.

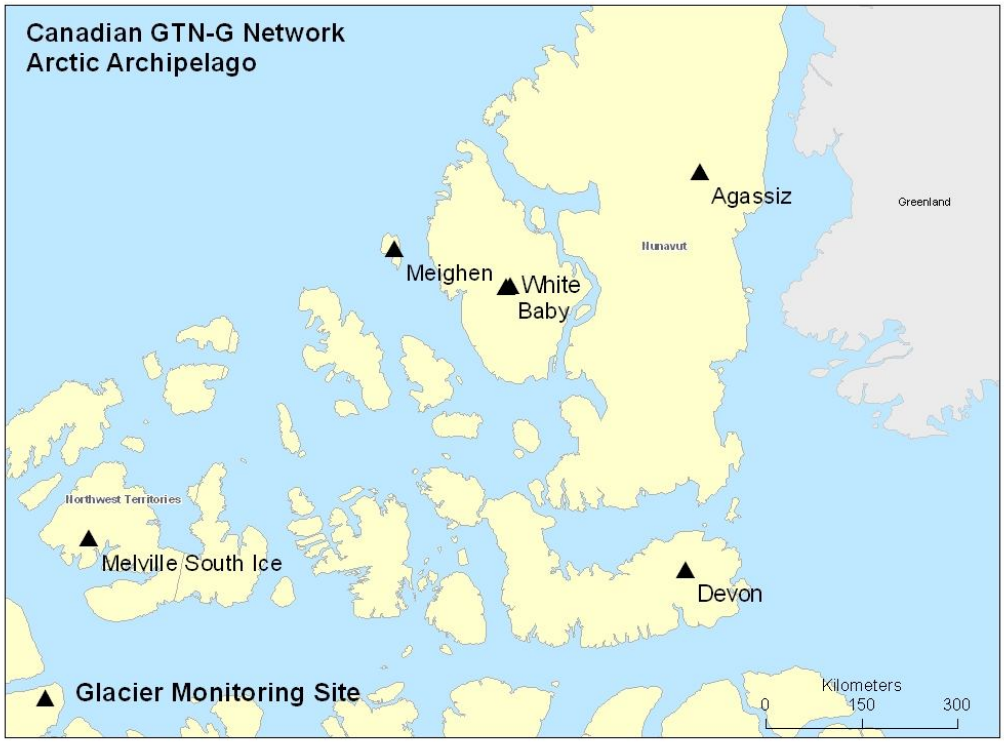

Figure 12 – Canadian GTN-G Network - Arctic Archipelago
(Source Natural Resources Canada)

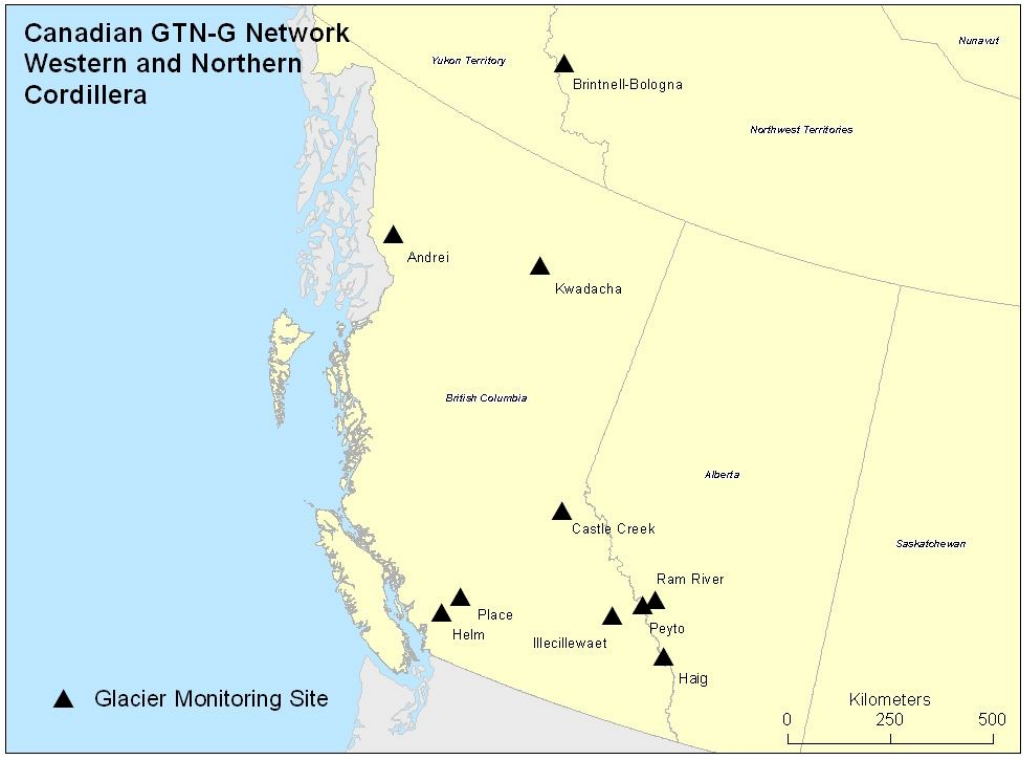

Figure 13 – Canadian GTN-G Network - Western and Northern Cordillera
(Source Natural Resources Canada)

Canada's participation in the Global Land Ice Measurements from Space (GLIMS) project and related initiatives has provided recent regional products documenting glacier area and length-wise change and inferred volume changes. The nature of these methods is such that the interval between data epochs can be large. However, the Canadian Glacier-Climate Observing System and its partners are utilizing airborne laser altimeter mapping missions to conduct assessments of regional changes over shorter intervals of 2 to 5 years, in addition to the seasonal/annual measurements of mass balance conducted for its in-situ reference network. The importance of maintaining a network of reference sites where seasonal mass balance measurements are conducted cannot be overstated since glaciers are responding to changes in both seasonal phases of the mass balance year. GLIMS data pertinent to Canada are housed domestically at two regional data centres, University of British Columbia and University of Alberta, as well as internationally at the NSIDC.

Internationally, as it concerns GCOS-Implementation Plan action item T-13: *maintaining sites for observing glaciers in Africa, the Himalayas, New Zealand and South America,* discussions have been initiated between the Centro de Estudios Cientifico (Valdivia Chile), the University of Ottawa and the Geological Survey of Canada and guided by the Chile-Canada Partnership Framework towards scientific exchanges that would foster observations and assessments of glacier fluctuations in Chile and Canada.

Required funding for sustaining long-term observation series of mass balance is unclear at this time. Notably, several observation series that were initiated or re-established as part of Canada's GCOS Implementation Plan for the Cryosphere, and with resources from Canada's Action Plan 2000, are at risk of being discontinued. At the same time there are increasing requirements for such information as it relates to coastal communities/infrastructure being impacted by sea level rise, Arctic marine navigation, and significant water resources that are in need of better definition. It is anticipated that recommendations from the SAON (Sustaining Arctic Observing Networks) community of practice will provide some impetus for member states of the Arctic Council to continue support for long-term mass balance measurements.

For more information on the State and Evolution of Canada's Glacier Program see:

http://pathways.geosemantica.net/WSHome.aspx?ws=NGP_SECG&locale=en-CA

4.4 GCOS Permafrost Monitoring Network (GTN-P)

The Canadian Permafrost Monitoring Network monitors two key variables identified by the WMO under the GCOS, permafrost state and active layer thickness. The network consists of over 100 thermal and active layer monitoring sites maintained by government and universities sometimes in partnerships with industry and northern communities.

The network currently consists of 70 long-term thermal monitoring sites which contribute to the GTN-P. Most of these have been in operation for one to two decades and measure ground temperatures in the upper 20 metres with a few deeper boreholes. Over the past three years there has been considerable enhancement to the monitoring network to address key regional and thematic gaps including those in Nunavut and under-represented areas in the Western Arctic. A number of drivers have contributed to these recent efforts. In the Mackenzie corridor, proposals for hydrocarbon development have led to increased efforts to improve baseline permafrost knowledge within the region. Funding acquired by Canadian government departments under the Northern Energy Development Memorandum to Cabinet has (between 2005 and 2007) supported the drilling and instrumentation of 74 boreholes which now contribute to the monitoring network. Funding acquired by government and academia through the federal government's IPY program and other sources as well as through a number of partnerships has facilitated the establishment of 15 new monitoring sites in other regions including the Yukon Territory, northern Manitoba and communities in the Baffin region of Nunavut. A total of 89 new boreholes have been added resulting in a thermal monitoring network of 159 sites. In addition, there are plans to establish 4 to 8 sites over the next one to two years including additional sites in communities in Nunavut.

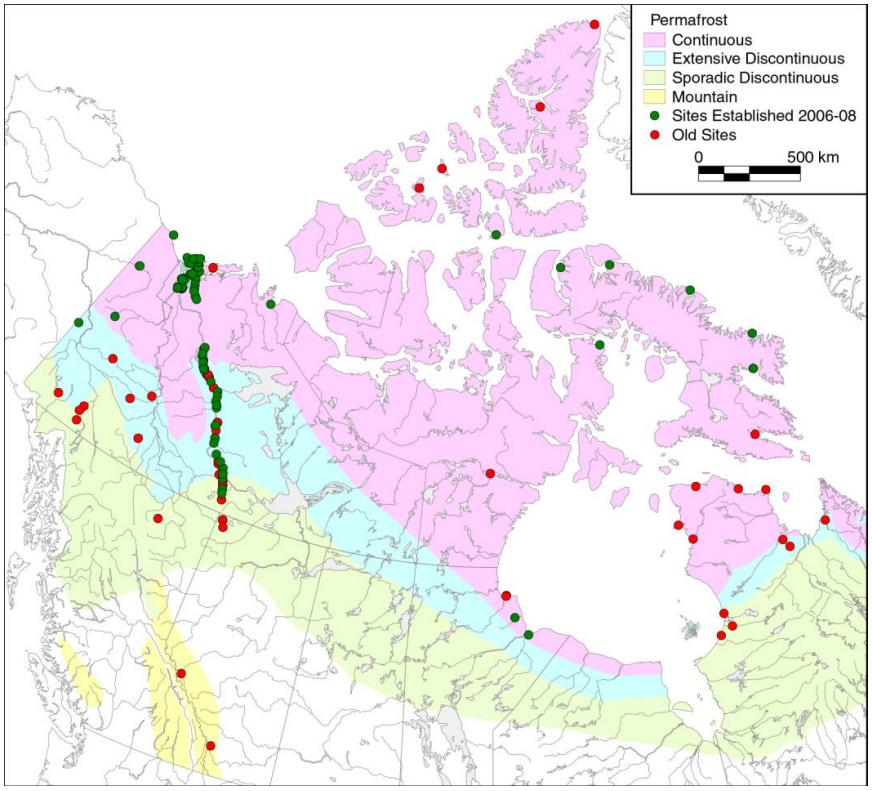

Figure 14 – Canadian GTN-P Borehole-Temperature Network
(Source Natural Resources Canada)

At the present time, Canada maintains 20 active layer monitoring sites which contribute to the Circumpolar Active Layer Monitoring Program (CALM) within the GTN-P. Four of these are also thermal monitoring sites. There are no plans at present to increase the number of dedicated active layer monitoring sites. However, since thaw depths may be determined from shallow ground temperature data collected at thermal monitoring sites, there is the possibility that additional sites could contribute to CALM in the future.

Data from active layer sites are submitted on an annual basis to the CALM program and posted along with site metadata on the website hosted by the University of Delaware. The GSC coordinates the submission and dissemination of thermal monitoring data and also hosts the GTN-P and Canadian Permafrost Monitoring Network websites. Current summary time series datasets are posted for 18 thermal monitoring sites. There are plans, as part of the IPY, to post summary data for the 70 long-term monitoring sites as well as initial data for sites established over the past three years. Archiving of historical data from all sites will be made available through the World Data Centre and the US National Snow and Ice Data Center. Site metadata (site descriptions) are available for most of the 70 thermal monitoring sites and posted on the GTN-P website. Metadata are currently being compiled for recently established thermal monitoring sites and will be made available.

Additional monitoring sites may be added in the Mackenzie Valley that may contribute to the GTN-P. For example, field sites established by the Canadian Forest Service under an IPY initiative to assess recent changes in carbon source-sink relationships along the Mackenzie Valley include baseline measurements of ground temperature and active-layer thickness which could possibly be maintained and contribute to the long-term monitoring network.

Operation of the GTN-P network has relied on a number of short-term funding sources and there is no long-term dedicated funding for permafrost monitoring. A number of sites are tied to funding acquired by universities for specific research projects. The same is true for sites operated by government which may also be in response to government priorities as is the case in the Mackenzie corridor where recent efforts were driven by the need to address baseline knowledge and science gaps associated with hydrocarbon development.

References to National Permafrost Monitoring Networks and Databases:

http://gsc.nrcan.gc.ca/permafrost/database_e.php

http://www.gtnp.org/canpfnet/network_e.html

4.5 Groundwater and Aquifer Monitoring

With the exception of inter-jurisdictional and transboundary matters, the management of water resources (groundwater and surface water) in Canada is a provincial and territorial government responsibility. There is no national network to monitor groundwater quantity and quality. There are about 1600 active wells in Canada, operated by the provinces and territories. The GSC, in partnership with agencies from individual provinces, has conducted assessments of several regional aquifers, and as a consequence, established small incremental monitoring networks that have been transferred to the provincial and territorial partners for continued operation. With respect to the study of impacts of climate variability and change on groundwater supplies, the length of groundwater records is relatively short and often contains continuity breaks due to program changes. No long-term records are available for large parts of Canada. In recent years there has been some increase in groundwater monitoring for reasons such as addressing regional/local contamination issues.

NRCan has established a National Groundwater Database (NGWD) with the goal of providing relevant information on groundwater for decision making and sustainable development. It serves as a repository for NRCan's digital groundwater information and a catalogue for digital groundwater information held by other agencies at the provincial, territorial and municipal levels. The NGWD is publicly available and operates as a backbone to the Groundwater Information Network (GIN). The GIN is a collaboration between NRCan and several provinces to make water well databases available on the web, using open geospatial standards and technologies. A central portal will enable access, via common standards, to water well databases held in different geographic locations and agencies. Users will be able to search for well data, view it, analyze it using custom tools and download it in a standard format, without having to know the data is coming from different multiple sources. The system will be operational by April, 2009 and will be available to anyone with web access (see http://gin-ries.nrcan-rncan.gc.ca/). Depending on results and interest, the network could be expanded in the future to include other agencies and provinces/territories.

NRCan is currently engaged in a project to assess several regional key aquifers and add to the national inventory of studied aquifer systems in Canada. This effort will produce groundwater quantity and quality maps and contribute to the NGWD. NRCan is also undertaking a project to map temporal variability of groundwater resources in major water basins across Canada using the GRACE gravity mission launched in 2002. Plans include the production of a series of maps showing surface water storage changes in these basins over the GRACE observation period (2002 to 2009).

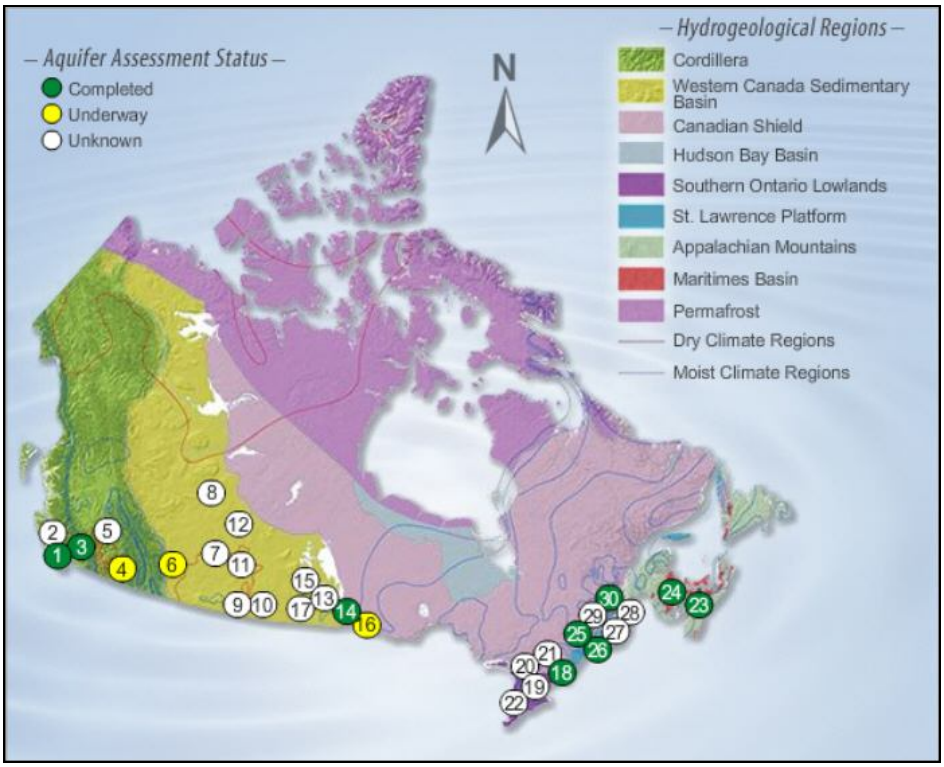

Figure 15 – Key Aquifer and Hydrogeological Regions of Canada
(Source Natural Resources Canada)

4.6 Soil Moisture

There is no national in situ soil moisture monitoring network in Canada although some provincial and federal government agencies and research bodies carry out localized or regional in-situ monitoring. However, a Soil Moisture Working Committee established by the Canadian Group on Earth Observations (CGEO) in recognition of the importance of soil moisture to environmental monitoring and to sectors such as agriculture, forestry, water management and public health, recognizes that routine monitoring of soil moisture is ad-hoc and lacking coordination between agencies addressing the issue. The Committee has recommended that the CGEO identify a federal government steering committee structure mandated to develop a vision, plan and funding proposal by 2010 for a Canadian soil moisture monitoring system that would include observations and measurements (in situ and remote-sensing), modelling approaches and the assimilation of data into a Canadian Land Data Assimilation System (CaLDAS).

4.7 Albedo and Surface Reflectance

Historically, satellite observations of Canada's landmass were obtained from the AVHRR High Resolution Picture Transmission (HRPT) data at 1 km spatial resolution. Presently a fifth generation Canadian AVHRR processing system (CAPS) is being developed. CAPS uses a MODIS 250 metre resolution imagery database as a reference and 250 metre resolution Digital Elevation Model (DEM) to improve the accuracy of pixel geolocation to the level required by

GCOS and GEOS specifications. CAPS is being used to re-process the entire AVHRR 1km archive assembled over Canada.

To refine the radiometric calibration of historical AVHRR data, CCRS is working with NOAA and NASA through the CEOS Working Group on Calibration and Validation on CEOS task CL-06-02-01 "Improving measurement consistency for 1-5 km sensors" and CEOS actions T3 and T4[3].

Another source of satellite data used at CCRS for mapping terrestrial ECVs at 1 km resolution since 1998 is the SPOT VEGETATION data distributed as clear sky composites by VITO (http://www.vgt.vito.be).

With support from the CSA and the Canadian IPY Program, CCRS has begun mapping Canada and the circumpolar Arctic region with MODIS/TERRA data at seven spectral bands (B1 to B7) at 250 metre resolution. The MODIS bands B3 to B7 originally observed at 500 metre resolution are downscaled to 250 metre for consistency with bands B1 and B2. This attempt is undertaken to meet GCOS 250 metre resolution requirements.

Clear sky compositing, atmospheric correction, bi-directional reflectance distribution function (BRDF) fitting and albedo derivations from MODIS and AVHRR data are carried out as independent technology developed at CCRS. The BRDF and albedo production steps are still in research mode as parameterization for scenes with snow and ice presence requires further work. The challenge is to build adequate BRDF models for snow and ice and mixed scenes to describe surface roughness, scene heterogeneity and snow crystal effects at the same time. Snow/ice free scenes are processed with a BRDF approach based on Polarization and Directionality of the Earth's Reflectances (POLDER) models.

4.8 Land Cover

In 2005, the Inter-Agency Committee on Geomatics (IACG) established a land use community, with Agriculture and Agri-Food Canada (AAFC) as the land use community coordinator. The first community initiative was the establishment of the Canadian Land Cover Community of Practice (LCCoP) which includes 25 members representing 8 federal departments with an interest in land cover mapping. AAFC currently chairs the LCCoP and CFS provides the secretariat. Recent achievements include completion of a users need assessment study for land cover across Canada; facilitation of a new national land cover layer which includes a harmonized legend derived from land cover maps in forest, agriculture and northern regions. The new land cover layer has been adopted by GeoBase, which is a federal, provincial and territorial government initiative. The new 30 metre land cover map of Canada being assembled combines the Earth Observation for Sustainable Development of Forests (EOSD) 30 metre product with the CCRS 30 metre map of the arctic region and the 30 metre land cover map of agricultural regions. Through its portal, GeoBase ensures the provision of, and access to, a common, up-to-date and maintained base of quality geospatial data for all of Canada. Now that the first integrated land cover map of Canada is nearing completion, it is expected the future work of the LCCoP will turn to the development of a land cover monitoring strategy for Canada.

Reference: http://www.geobase.ca/geobase/en/index.html.

[3] The Committee on Earth Observations (CEOS) Response to the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (October 2006) http://www.ceos.org/CEOS%20Response%20to%20the%20GCOS%20IP.pdf

Canada requires a next generation forest measuring and monitoring system that responds to key policy drivers related to climate change and to report upon sustainable development of Canada's forests. The CFS, in partnership with the CSA, is using space-based earth observation technologies to create products of landscape level detail for forest inventory, forest carbon accounting, monitoring sustainable development, and landscape management. The EOSD initiative works in partnership with the Provinces and Territories to develop land cover maps of the forested area of Canada. Land cover has been mapped based on Landsat-7 Enhanced Thematic Mapper Plus (ETM+) data acquired by the NRCan Centre for Topographic Information and other sources. The first map, now complete and freely available on-line, is based on circa 2000 data, classified in conjunction with the provinces, territories, universities and industry.

Research programs to develop techniques for change monitoring, biomass estimates and automated processing to aid in production are also a component of EOSD. Inputs from EOSD are an important data source at landscape level detail for the National Forest Carbon Accounting Framework and to enhance Canada's new plot-based National Forest Inventory. Initially, EOSD has worked with other levels of government, universities and industry to develop a national map of the forested land cover of Canada with the long term goal of producing not only land cover maps, but maps of forest composition, temporal change, and biomass.

EOSD land cover products are available for download on a 1:250,000 NTS map sheet basis. Each map sheet represents an area of 14,850 km². EOSD land cover and data products are freely available to the public and accessible through the National Forest Information System (NFIS); and, System of Agents for Forest Observational Research with Automation Hierarchies (SAFORAH).

Reference: http://cfs.nrcan.gc.ca/subsite/eosd

AAFC is developing medium-resolution land cover monitoring information for agricultural regions of Canada (30 metre-resolution Landsat data). The AAFC land cover has been developed in coordination with the CFS and provincial land cover initiatives. AAFC has developed a legend and classification methodology which is specific to the needs of the agriculture sector. However, the AAFC legend has been mapped to the Land Cover Classification System (FAO) and the CFS land cover legend.

The AAFC land cover monitoring has been developed to support a broad range of agri-environmental information and application needs, which may include decision support for land use and management; production insurance; development of agri-environmental performance indicators; climate change monitoring plus carbon and GHG accounting and verification; biodiversity monitoring; environmental farm planning and incentive programs for the adoption of beneficial management practices. The land cover monitoring work currently includes a circa 2000 baseline inventory which will be completed in March 2009.

Five year interval land cover products for the period of 1985-2005 have been generated at CCRS using moderate resolution (1 km) satellite data from AVHRR and SPOT VEGETATION. The Land Cover Map of North America at 1 km spatial resolution was developed with the United States Geological Survey (USGS) to contribute to the Global Land Cover 2000 led by the Joint Research Centre of the European Commission. Presently, CCRS is involved in the validation phase of European Space Agency (ESA) GLOBCOVER initiative aimed to produce the global land cover map at 200 metre spatial resolution for 2005 from the MERIS sensor onboard ENVISAT.

CCRS is collaborating with the USGS and INEGI (Mexico) on R&D of a land cover change monitoring system for North America using satellite observations of various spatial scales from MODIS (250 metre), MERIS (300 metre), and Landsat (30 metre).

Land cover data and metadata are available for public access from:

(a) Multi-Temporal Land Cover Maps of Canada using NOAA AVHRR 1 km data from 1985-2005: ftp://ftp.ccrs.nrcan.gc.ca/ad/NLCCLandCover/LandcoverCanada1985_2005_1KM/
(b) Land Cover Map of North and Central America – Global Land Cover 2000: ftp://ftp.ccrs.nrcan.gc.ca/ad/EMS/Landcover2000/
(c) Land Cover Map of Canada 2005 at 250 metres: ftp://ftp.ccrs.nrcan.gc.ca/ad/NLCCLandCover/LandcoverCanada2005_250m/
(d) Circa-2000 Northern Land Cover of Canada at 30 metres: http://geogratis.cgdi.gc.ca/frames.html
(e) EOSD Land Cover of the Forested Area of Canada from 30 metres Landsat data: http://www4.saforah.org/eosdlcp/nts_prov.html

4.9 Fraction of Absorbed Photosynthetically Active Radiation (fAPAR)

fAPAR is defined as the fraction of photosynthetically active radiation absorbed by a vegetation canopy[4]. Spatially-detailed descriptions of fAPAR provide information about the strength and location of terrestrial carbon sinks, and can be of value in verifying the effectiveness of the Kyoto Protocol's flexible implementation mechanisms. fAPAR is not directly retrievable from satellite observations, but is inferred from models describing the transfer of solar radiation in plant canopies, using remote sensing observations as constraints. The CCRS fAPAR product is an integrated product from satellite observations and Ecological Assimilation of Land and Climate Observations (EALCO) model simulations.

Improvement of fAPAR products has been achieved by enhancing data quality control of satellite observations and by the EALCO model radiation transfer scheme. The EALCO model employs gap probability-based successive orders of scattering approach for canopy radiation transfer simulations. It includes the heterogeneities of stands and crown elements and the multiple scattering of radiation. EALCO includes multi-canopy layers and spectral intervals for direct and diffuse shortwave calculations. The model also simulates vegetation indices and surface radiation variables that can be employed for assimilation of and comparison with satellite observations.

The CCRS fAPAR product is being produced at 1 km from AVHRR observations since 1985 and at 250 metre spatial resolution since 2000 based on MODIS observations. Further validation of this product using in situ measurements is currently being conducted. CCRS is collaborating with the Chinese Academy of Sciences in experience sharing and personnel training in the use of the EALCO land surface scheme for EO-based observations.

[4] See GTOS 52: Terrestrial Essential Climate Variables for Climate Change Assessment, Mitigation and Adaptation. FAO (2008). http://www.fao.org/gtos/doc/pub52.pdf.

4.10 Leaf Area Index (LAI)

Canada is actively involved in the development and assessment of GCOS compliant LAI products. Activities include instrumentation and protocols for in situ LAI monitoring, algorithms for LAI retrieval, production of LAI datasets, and assessment of Canadian and global LAI products and their underlying algorithms.

CCRS has developed new approaches for non-destructive in situ monitoring of LAI through the use of digital hemispheric cameras as well as a hand-held radiometer. CCRS has worked with CEOS and Fluxnet Canada to specify protocols for up-scaling plot based LAI estimates to match the spatial footprint of typical 250 metre or coarser spatial resolution. In situ datasets are now provided to the CEOS Land Parameter Validation Sub-group Databases held in the Oak Ridge National Laboratory (ORNL) Mercury system. They are intensively used for validation of global LAI products.

Conventionally, LAI retrievals based on visible and near infrared satellite measurements are limited to low (<4) LAI levels due to saturation of the top-of-canopy signal. Work at CCRS has shown that saturation is not present over both broadleaf and needle leaf forests when using short wave infrared satellite observations. It has also been demonstrated that the variability in LAI retrievals due to species is also substantially minimized with these wavelengths. These findings have led to new algorithms for LAI retrieval with these wavelengths that have been successfully applied to SPOT-VEGETATION imagery to produce 1 km resolution 10-day products over Canada. More recent work has also produced 250 metre resolution prototype products from MODIS.

CCRS has contributed to defining the CEOS global LAI validation framework and the identification of global inter-comparison sites, “BELMANIP”, as well as supplying LAI data. These datasets have demonstrated that the CCRS Canada-wide LAI products have total errors (accuracy + stability) of less than 20% or 1 LAI unit. No current global LAI product consistently meets this level of performance over Canada. These reference datasets have limited temporal and spatial sampling and must be augmented to meet the CEOS sampling strategy. This work has highlighted the priority to implement long term in situ LAI monitoring to satisfy the “BELMANIP” sampling plan and to allow for refinement of LAI algorithms.

CCRS is also producing regional LAI products at medium (<100 metre) resolution over all major Canadian aquifers (see 4.5). CCRS has also committed to working jointly with Mexico and the USA to produce consistent North American land surface characterization including LAI. CCRS and the CSA have a joint activity for near-real-time production of GCOS compliant 250 metre resolution LAI products from MODIS and MERIS sensors. Data assimilation strategies will likely be required to meet the current daily temporal resolution specified by GCOS for LAI.

Available LAI Datasets and Metadata:

Canada-wide LAI at 1 km resolution
http://gcmd.nasa.gov/records/CANADA-CGDI_Canada_GeoGratis_SPOTVEGETATION.html

CEOS LPVG Reference LAI Products for Canada: http://lpvs.gsfc.nasa.gov/lai_intercomp.php
http://daac.ornl.gov/LAND_VAL/guides/Fernandes_LAI_Valeri.html

LAI Products over Canadian Groundwater Aquifers
http://ess.nrcan.gc.ca/2002_2006/gwp/p2/index_e.php

Fluxnet Canada LAI Datasets:
http://fluxnet.ccrp.ec.gc.ca/e_DataAccess.htm

Protocols and Tools for In Situ LAI Retrieval
ftp://ftp.ccrs.nrcan.gc.ca/ad/EMS/LEBLANC/

4.11 Biomass

Forest biomass is the mass of the above ground portion of the live tree per unit area. It is a basic forest property linked to productivity and forest ecosystem processes, and is an important indicator of carbon stocks that help determine the contribution of Canada's forests to the global carbon cycle. Methods to estimate forest biomass from models, inventory and remote sensing data are being developed, evaluated and demonstrated at several pilot regions across Canada.

EOSD maps provide spatially-explicit information on forest biomass within a national framework of satellite land cover maps of the forested areas of Canada. Mapping outputs contribute to Canada's new National Forest Inventory (NFI) and provide data to the National Carbon Accounting Framework.

In addition to biomass mapping, forest biomass can also be derived from Canada's existing national forest inventory (CanFI) which is compiled approximately every five years by aggregating provincial and territorial forest management inventories and reconnaissance level information. Stand-level data provided by the provincial and territorial government agencies are converted to a national classification scheme, and then aggregated to the map sheet, provincial and national levels for storage, analysis and reporting. The most recent version, CanFI2001, is derived from 57 source inventories.

NFI takes information from systematically located permanent forest plots across Canada. The NFI's plot system was established in 2006; the first national inventory report was produced in 2007.

References:
http://cfs.nrcan.gc.ca/subsite/eosd
http://cfs.nrcan.gc.ca/subsite/canfi

4.12 Fire Disturbance

The Canadian Wildland Fire Information System (CWFIS) is a computer-based fire management information system that monitors fire danger conditions across Canada. Daily weather conditions are collected from across Canada and used to produce fire weather and fire behavior maps. In addition, satellites are used to detect fires. The CWFIS also provides fire emissions data to the National Carbon Accounting Framework.

National maps of fire weather and fire behavior show current and archived forest fire conditions. Fire M3 Hotspots[5] show fires detected by remote sensing, featuring near-real-time imagery. Regional satellite images display large historical fires. The National Forest Fire Situation Report is a weekly summary of fire activity across Canada.

The Historical Analysis provides the fire danger climatology for Canada. Fire Weather Normals and Fire Behavior Normals display the mean values of fire weather indices and fire behavior indices over a 30-year period (1971-2000). The Large Fires Database is a summary of fires larger than 200 ha from 1959 to 1999.

Reference: http://cwfis.cfs.nrcan.gc.ca/en/index_e.php

Canada, through the Canadian Space Agency (CSA) is also a partner in the development of a novel thermal infrared radiometer that is planned to be launched in 2010 as part of the NASA/CONAE Aquarius/SAC-D mission. This New InfraRed Sensor Technology (NIRST) uses a microbolometer developed by CSA. The microbolometer technology allows a detector package that is uncooled and hence has a smaller mass than previous space-borne thermal IR instruments. NIRST comprises mainly two cameras, one operating at 3.4-4.2 µm and the other at 10.4-11.3 µm and 11.4-12.3 µm. It is optimized for retrieving forest fire and sea surface high temperature events in an early evening orbit. NIRST will have a spatial resolution of 350 m and, to shorten revisit times, a steerable swath of 180 km over a 500 km accessibility swath on either side of nadir.

[5] A hotspot is a satellite image pixel with infrared intensities typical of burning vegetation. The Fire Monitoring, Mapping and Modelling System (Fire M3) is an initiative of the Canadian Centre for Remote Sensing (CCRS) and the Canadian Forest Service (CFS). The Fire M3 hotspots are obtained from 3 sources: AVHRR imagery, Moderate Resolution Imaging spectrometer (MODIS) imagery and Along Track Scanning Radiometer (ATSR) World Fire Atlas.

Table 6 – National contributions to the terrestrial domain essential climate variables

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
GCOS baseline river discharge network (GTN-R)	River discharge	44	44	44	40 reporting in near-real-time	44
GCOS baseline Lake Level/Area /Temperature Network (GTN-L)	Lake level/area /temperature	N/A	N/A	N/A	N/A	N/A
WWW/GOS synoptic network	Snow cover	322	322	347	322	322
GCOS glacier monitoring network (GTN-G)	Glaciers mass balance and length, also ice sheet mass balance	16	14	21	9	9
GCOS permafrost monitoring network (GTN-P)	Permafrost borehole-temperatures	159 (70 long-term, 89 recently established	159	~165	Data from 18 sites currently on GTN-P website. At end of IPY all 159 will be reporting	At end of IPY historical record from 70 existing long-term sites to be available.
	Active-layer thickness	20 (4 are also thermal monitoring sites)	20	20	20	20

Appendix: Acronyms

AAFC	Agriculture and Agri-Food Canada
ADCP	Acoustic Doppler Current Profilers
AERONET	Aerosol Robotic Network
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AOPC	Atmospheric Observational Panel for Climate
Argo	Global Array of Profiling Floats
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AVOS	Automated Voluntary Observing Ship
AZMP	Atlantic Zone Monitoring Program
BATHY	Bathythermal Observation Code
BELMANIP	Benchmark Land Multi-site Analysis and Inter-comparison of Products
BIO	Bedford Institute of Oceanography
BSRN	Baseline Surface Radiation Network
CaLDAS	Canadian Land Data Assimilation System
CALM	Circumpolar Active Layer Monitoring Program
CAS	Commission for Atmospheric Sciences
CCRS	Canada Centre for Remote Sensing
CEOS	Committee on Earth Observation Satellites
CFS	Canadian Forest Service
CGEO	Canadian Group on Earth Observations
CIS	Canadian Ice Service
CMC	Canadian Meteorological Centre
COP	Conference of the Parties (UNFCCC)
CPR	Continuous Plankton Recorder
CRN	Climate Reference Network (US)
CSA	Canadian Space Agency
CTD	Conductivity, Temperature and Depth
DBCP	Data Buoy Cooperation Panel
DND	Department of National Defence
DFO	Fisheries and Oceans Canada
EC	Environment Canada
ECVs	Essential Climate Variables
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agriculture Organization (UN)
fAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FCDR	Fundamental Climate Data Record
GAW	Global Atmospheric Watch
GCMPs	GCOS Climate Monitoring Principles
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GHG	Greenhouse Gas
GLOSS	Global Sea Level Observing System
GLIMS	Global Land Ice Measurements from Space
GOES	Geostationary Operational Environmental Satellite
GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
GOOS	Global Ocean Observing System

GOS	Global Observing System of the World Weather Watch
GOSUD	Global Ocean Surface Underway Data
GRACE	Gravity Recovery and Climate Experiment
GRDC	Global Runoff Data Centre
GSC	Geological Survey of Canada
GSN	GCOS Surface Network
GTN-G	Global Terrestrial Network - Glaciers
GTN-P	Global Terrestrial Network - Permafrost
GTN-R	Global Terrestrial Network - Rivers
GTS	Global Telecommunications System
GTSPP	Global Temperature and Salinity Profile Project
GTOS	Global Terrestrial Observing System
GUAN	GCOS Upper Air Network
HAB	Harmful Algal Blooms
HRPT	High Resolution Picture Transmission
HYDAT	Hydrometric Data (Water Survey of Canada)
HYDEX	Hydrometric Index (Metadata – Water Survey of Canada)
IABP	International Arctic Buoy Programme
IGACO	International Global Atmospheric Chemistry Observations
IOC	Intergovernmental Oceanographic Commission
IOCCP	International Ocean Carbon Coordination Project
IOS	Institute of Ocean Sciences
IPY	International Polar Year
ISDM	Integrated Science Data Management Branch of DFO
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
LAI	Leaf Area Index
MERIS	Medium Resolution Imaging Spectrometer
METAR	Meteorological Aviation Report
MODIS	Moderate Resolution Imaging Spectroradiometer
MSC	Meteorological Service of Canada
NOAA	National Oceanic and Atmospheric Administration (US)
NCDC	National Climatic Data Center (US)
NESDIS	National Environmental Satellite, Data and Information Service (US)
NGWD	National Groundwater Database
NRCan	Natural Resources Canada
NSIDC	National Snow and Ice Data Center (US)
OAP	Ocean Action Plan
pCO_2	Partial Carbon Dioxide
POLDER	Polarization and Directionality of the Earth's Reflectances
RBCN	Regional Basic Climatological Network
RBSN	Regional Basic Synoptic Network
RCS	Reference Climate Station
RHBN	Reference Hydrometric Basin Network
RNODC	Responsible National Oceanographic Data Centre
SAON	Sustaining Arctic Observing Networks
SCE	Snow Cover Extent
SOOP	Ship of Opportunity Programme
SOT	Ship Observations Team
SST	Sea Surface Temperature
SWE	Snow Water Equivalent
TRACKOB	Along Track Ship Observation Code

UNEP	United Nations Environment Programme
USGS	United States Geological Survey
UV	Ultraviolet
VNIR	Visible and Near Infrared
VOS	Voluntary Observing Ship
VOSClim	Voluntary Observing Ship Climate Project
WCRP	World Climate Research Programme
WGMS	World Glacier Monitoring Service
WMO	World Meteorological Organization
WOUDC	World Ozone and Ultraviolet Radiation Data Centre
WRDC	World Radiation Data Centre
WWW	World Weather Watch of the WMO
XBT	Expendable Bathythermograph
XCTD	Expendable Conductivity, Temperature and Depth System