Abstract

The cryosphere - sea ice, lake ice, snow cover, frozen ground, and glaciers - plays a significant role in the Earth's climate system. Canada occupies a unique geographic position on the globe: almost half of the planet's northern cryosphere falls within Canada's territorial boundaries. Under the current conditions of rapid climate change over northern high latitudes, Canada has an obligation to measure, model, and understand the complex relationships between the cryosphere and the Earth's climate system in order to provide accurate and timely information on cryospheric variability and change to the public and decision makers.

Access to timely, comprehensive, and quality cryospheric data is an obstacle to improved knowledge and understanding of the cryosphere in Canada. Important data sets reside in various government or university labs, where they remain largely unknown or where access restrictions prevent effective use. The Canadian Cryospheric Information Network (CCIN) was designed to address this problem by improving the availability and access to cryospheric data sets. In this paper we describe the functionality of the CCIN and its benefits for both the Canadian cryospheric research community and the public at large.

Background

In Canada, the cryosphere (consisting of sea ice, lake ice, glaciers and ice caps, snow cover, permafrost and frozen ground) is one of the most important features of the physical and biological environment:

- most regions of Canada experience at least three months of snow cover each winter,
- nearly all Canadian navigable waters (with the exception of the west coast) are affected by an ice cover for some period during the winter,
- more than half of the country is underlain by continuous or discontinuous permafrost, and
- Canadian terrestrial ice masses constitute the most extensive permanent ice cover in the Northern Hemisphere outside of Greenland.

The Intergovernmental Panel on Climate Change (IPCC) expects that projected global climate change will lead to pronounced reductions in seasonal snow cover, permafrost, glacier and periglacial belts of the world (IPCC, 1996). Because the cryosphere is so closely intertwined in the natural and economic fabric of Canada, these changes can be expected to have widespread and significant impacts particularly in the central regions of the continent and in the Arctic.

In 1988 Canada’s leadership role in northern studies was strengthened by the formation of the CRYSYS research project (Cryosphere System in Canada). CRYSYS is a network of scientists from government, universities and the private sector who are working to develop capabilities to monitor and better understand variations in major components of the cryosphere (sea ice, lake ice, snow cover, glaciers, ice caps and frozen ground/permafrost). Current CRYSYS partners include: the Meteorological Service of Canada (MSC), the Canadian Ice Service (CIS), Geological Survey of Canada (GSC), Canadian Space Agency (CSA), the U.S. National Aeronautics and Space Administration (NASA), and fourteen (14) Canadian universities.

It was recognized early on in the CRYSYS project, and in response to an independent assessment of Canada’s capability to contribute to global needs for monitoring the cryosphere (Barry, 1995), that there was a pressing need to improve access to Canadian cryospheric data sets. A series of consultations were held with a wide cross-section of Canadians (education, research, government, industry) and it was concluded that the best mechanism to achieve both better access to data, and greater information flow to the public and decision makers, was to establish a non-government virtual information node, the Canadian Cryospheric Information Network (CCIN).

The CCIN is a collaborative effort involving the university research community, federal and provincial government agencies, and the private sector to integrate remotely-sensed, in-situ and model information to determine variability and trends in snow, sea ice, glaciers and permafrost. The CCIN is also a focal point for the application of remotely-sensed technologies and techniques being developed in Canada for monitoring the state of the cryosphere. It facilitates the integration of remotely-sensed, in-situ and model information to determine variability and trends in snow, sea ice, glaciers and permafrost.

Objectives

The CCIN, situated at the University of Waterloo, has been created primarily to be a data and information portal among Canadian scientists and with international colleagues (Figure 1). Specifically, it has been designed to:

• improve awareness of data sources (inventory);
• improve data access (request, order, retrieval); and
• provide cryospheric information to public and decision makers (website, outreach).

Data Discovery and Access

An important aspect of the Network is the dissemination of significant cryospheric information to the general public through the State of the Canadian Cryosphere website (http://www.socc.uwaterloo.ca). The website provides information on the current state, past variability and future response of the various components of the cryosphere in Canada.

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Data Discovery and Access

The CCIN has a unified geographical user interface to facilitate data exploration and data mining exercises. The Network provides integrated access to a variety of historically disparate climate-related data sets of relevance to cryospheric research. For example, users are able to interactively identify a search location on a map and be provided with a listing of all relevant data sets available for that region. The CCIN then negotiates with all selected data providers on behalf of the user to fill data requests in near real-time.
Figure 1: CCIN Information Connectivity

Figure 2: Data Portal Process Flow
Figure 2 is a flow diagram showing how a user interacts with the system. Conceptually, the user interaction is divided into five procedures: Login, Query, Review, Order, and Delivery.

Login
Access to the CCIN system is by username and password entry. In addition to helping track system usage, user identification is necessary for determining data access privileges. At present, there are three data access levels: Level 1 data are accessible to the general public; access to Level 2 data is limited to the CRYSYS research community; and Level 3 data are restricted to members of specific CRYSYS projects.

Level 3 Data
One of the functions of the CCIN is to act as a working data repository for on-going CRYSYS research projects. As project team members collect data, they can forward them to the CCIN for secure storage and cataloging. Since it may take several months after data collection to properly verify many raw data sets, access is restricted to team members who understand their use and limitations. After they have been properly validated and documented, however, Level 3 data sets are moved up to Level 2 or 1, depending on intellectual property agreements.

Level 2 Data
The CRYSYS community has negotiated extended access to the proprietary climate and sea ice archives of the MSC and CIS, respectively. While components of both of these archives are accessible to the general public, data ordering for verified CRYSYS members can be made directly through the CCIN. The Network automatically processes and tracks these types of data retrievals for auditing purposes.

Level 1 Data
The CCIN has the capacity to provide unrestricted access to many data sets. These data may be derived from internal CRYSYS research (i.e., the data have been promoted from Level 1 or 2) or are publicly accessible from other sites (e.g., a U.S. public data archive). It should be noted, however, that not all public data are available without charge. Part of the user login procedure allows proper billing mechanisms to be established, if appropriate.

The user login procedure is designed to maintain control of specific sensitive data sets, not to inhibit access to the CCIN. New users are able to create login accounts interactively and guest access privileges are available.

Query
Primary data selection is by theme, time period, and geographic region (e.g., Figure 3). The user is instructed to select a theme(s) of interest from a drop-down list of available data and cross-referencing keywords. They can then narrow their search temporally by indicating a specific date or date range. Date ranges can be linear (e.g., all dates from January 1, 1996 through March 31, 2001) or seasonally (e.g., all January, February, and March dates from 1996 through 2001). The geographic area of interest can be specified through interactive definition on a displayed map graphic, selection of a pre-defined region from a pull-down list, or by manual coordinate entry.

Review
The initial response to the user's query is a collections listing. A collection is a higher-level grouping of data. For example, all data from the Seasonal Sea Ice Monitoring and Modelling Site (SIMMS) field experiment in could be grouped in a collection. Collections and associated metadata descriptions are listed in table format from which the user selects the collections they are interested in.

The system responds with a products listing. Products are the individual data types within a collection: ice concentration or surface salinity could be data products in the SIMMS example. Just as in collections, products and their metadata descriptions are listed in table format. Also included in product listings is a graphical representation of the spatial extent ("footprint") of the data in the file and, for image products, a thumbnail view of the data. The user makes their final data selections from the product list.
Note that only those collections and products which the user has authority to access are presented.

Order
A tabular listing of the selected products from the review page is presented. For each product, the user selects a data format for delivery, a delivery mechanism, and completes the billing information (where applicable).

Delivery
Possible delivery options include:
- individual data file download from a web page;
- compressed data files are staged on an ftp site within 24 hours for user access; and/or
- DVD/CD copies of the data are mailed to the user.
**System Architecture**

The CCIN system is fully scaleable and is currently composed of a Silicon Graphics server with the full suite of Compusult's software for data warehousing and mapping services. In addition, a SGI workstation is available for rescuing hardcopy datasets into digital form and to perform analysis on data. CCIN will be a Z-client and Z-server giving it the capability to perform distributed searches to remote Z-servers as well as searched from peer systems. Additional peripherals include a DVD-Writer and a DVD jukebox with a terabyte of on-line storage.

The core software technology used by CCIN is Compusult's Percipio data warehousing software, Map Manager for serving maps on the Web, and Metamanager that supports Z39.50 query and review. This is Canada's premiere geospatial data warehousing software currently deployed at CEONet, EROS Data Centre, and Space Imaging.

Remote Z-servers will use Noetix's Data Access and Distribution (DAD) software, which integrates Compusult's Metamanager for query and review with Z-clients. This software is currently deployed at the Canadian Ice Services and used to disseminate their ice charts to the public.

**Linkages**

The CCIN is linked to CRYSYS scientists and data sources via the high-speed communication channels (Figure 4). The intra- and inter-university networks are important components as the specific function of the CCIN is to provide one-shop computer linkages via the internet and local storage to:

- climate data from the Meteorological Service of Canada;
- sea ice image and data archives from the Canadian Ice Service;

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*Figure 4: Data Server Linkages*
off-line cryospheric data rescued from hard copy archives in government, industry and private holdings;
• atmospheric numerical forecast and model output from a variety of international sources;
• imagery from the Canada Centre for Remote Sensing;
• cryospheric data holdings at the U.S. National Snow and Ice Data Centre;
• cryospheric image data of the NASA EOS through EOSDIS (EOS Distributed Information System); and
• cryospheric data from other international holdings.

We recognize that many Canadian agencies (e.g., the Canadian Ice Service, the Meteorological Service of Canada) already have efficient data archiving mechanisms. The CCIN has been designed to be less of a data repository and more of a data conduit to provide transparent access to other data providers, instead of storing duplicate data. It provides integrated access to holdings at several different government and non-government agencies.

CCIN – CEONet Link

Noetix Research Inc. is currently developing a peer-to-peer linkage between CCIN and CEONet (Canada's geospatial data clearinghouse) (Figure 5). This project is very timely from the viewpoint that CEONet can play a significant role in the identification of applicable datasets for a given cryospheric theme or application. CCIN will serve as a vortal (vertical applications portal) for cryospheric data and structure queries to CEONet by application/theme and present the results to users within the context of the application/theme. Conversely, CEONet will be able to query CCIN and receive information about unique data and suppliers that are linked to CCIN.

The advantages of this connection include:
• The use of CEONet's existing and future linkages to data suppliers connected to the Canadian Geospatial Data Infrastructure (CGDI) will enable CCIN to achieve its objective to provide a comprehensive source of cryospheric data to the user;
• Dynamic query to CEONet enables most up to date input. As new servers and datasets become available and linked to CEONet, CCIN will have access to this information as soon as they become on-line;
• CEONet will have a connection to datasets that are not listed in its catalogue; and
• Users will have a one window access to information on Canada's cryosphere.

The CCIN and CEONet will be peer systems both with the capability to be Z-server and Z-client. CCIN will be designed to provide a structured user interface covering all themes of the cryosphere. Within the structure, a user will be able to perform application and theme specific queries for relevant data sets and suppliers. CEONet will be the core system containing the catalogue of datasets and suppliers. Results from a peer to peer query will be displayed within the context of the theme/application in the CCIN.

Conclusions

New approaches are required to make data and information available if we are to improve our knowledge of environmental issues, including climate change, and to share environmental information among scientists, decision-makers, and the public. The Canadian Cryosphere Information Network presents an exciting opportunity to bring together data and information from a variety of sources, including in-situ observations, digital remote sensing, temporal analysis of spatial data, climate and hydrological modelling that will allow information to be integrated, shared and provided to those who need it. The cryosphere is an excellent forum for such development as it brings together interests and expertise from different disciplines which are of ever increasing interest to the public and to policy-makers. The consolidation of disparate data sets using state-of-the-art geographic information system interfaces from a Canadian company fosters new opportunities in data mining, archive searching, distributed processing of vast data volumes and new image analysis algorithms. CCIN supports a rapidly growing desire for
information and knowledge of the cryosphere system in Canada, while providing a system for developing needed advances in information management of coordinated data volumes.

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References
