Annual Progress Report – Project Year-1

1 December, 2013

Executive Summary

The Changing Cold Regions Network (CCRN) formally commenced on 1 February, 2013, and was officially announced on 17 May, 2013. CCRN has made significant progress to date in developing the science programme, as outlined in the main report, and has been functioning well as an integrated network. Strategic appointments have been made to our Board of Directors and International Advisory Panel, our network secretariat positions have been filled, and our management and theme leadership structure is in place and functioning effectively. Two full network meetings have taken place along with many theme and sub-theme meetings. A major focus has been the development of short- and long-term work plans, which are documented in detail in a draft network inception report. Collaboration and joint activities among the network and various government, international, and other partners have been developed. In addition, we have planned two major cross-cut initiatives: a Coordinated Enhanced Observation Period (CEOP) involving the Water, Ecosystem, Cryosphere, and Climate (WECC) observatories across the network's geographic domain during 2014–15, and a focused analysis of the extreme weather and flooding events in western Canada during June 2013. We have been active in developing our outreach and engagement (O&E) framework and looking at how to support and build upon existing relationships among stakeholders and network researchers, and to reach out to new stakeholder groups. A public face to the network has been provided through our website (*www.ccrnetwork.ca*), which also serves as a key hub of information for network activities and accomplishments, and we have been active in media engagement. We have recruited students and post-doctoral fellows and have begun providing them exceptional research and network opportunities within CCRN. Finally, we have carefully considered and begun to implement a strategic framework for the data management in this network and its legacy after the end of the 5-year programme.

Introduction

CCRN's overall aims are to integrate existing and new experimental data with modelling and remote sensing products to understand, diagnose, and predict changing land, ecosystems, water, and climate, and their interactions and feedbacks over western Canada's cold interior. We use a network of 14 world class WECC observatories to study these detailed processes and connections in the permafrost regions of the Sub-Arctic, the Boreal Forest, the Western Cordillera, and the Prairies, and we are working to better understand the changing regional climate and its effects on large-scale Earth system change and the region's major river basins: the Saskatchewan and Mackenzie.

The programme and its objectives are divided into five major thematic components. *Theme A, Observed Earth System Change in Cold Regions – Inventory and Statistical Evaluation*, documents and evaluates observed change, including hydrological, ecological, cryospheric, and atmospheric components, in the cold regions of interior northwestern Canada over a range of scales. *Theme B, Improved Understanding and Diagnosis of Local-Scale Change*, improves our knowledge of local-scale change by developing new

and integrative knowledge of Earth system processes, incorporating these processes into a suite of process-based integrative models, and using the models to better understand Earth system change. *Theme C, Upscaling for Improved Atmospheric Modelling and River Basin-Scale Prediction*, improves large-scale atmospheric and hydrological models for weather, climate, and river basin-scale modelling and prediction of the changing Earth system and its feedbacks. *Theme D, Analysis and Prediction of Regional and Large-Scale Variability and Change*, focusses on the driving factors for the observed trends and variability in large-scale aspects of the Earth system and their representation in current models, and the projections of regional-scale effects of Earth system change on climate, ecology, land, and water resources. *Theme E, Outreach and Engagement*, builds a community of partners and users, including local stakeholder groups, provincial and federal policy/decision makers, national and international research organizations, and other relevant groups, and disseminates the improved knowledge and tools within this extended community.

Programme Management

The network's management structure has been implemented as proposed, based on an internal structure of theme and sub-theme leads, together with cross-cut activities. External scrutiny and advice is provided by a Board of Directors (BoD) and an International Advisory Panel (IAP). Terms of reference for both of these groups have been developed and their membership is now complete and active (see *www.ccrnetwork.ca* for details).

The BoD includes senior staff from many of our federal and provincial partner institutions, and other prominent members of the scientific community. As such, it ensures oversight and accountability while facilitating important outreach linkages between the CCRN and these partner institutions, and with other stakeholder groups. The BoD has met twice at network meetings so far (see next section). Our IAP consists of distinguished senior scientists who are also members of various international initiatives and organizations that are strongly linked to the interests of CCRN. The IAP provides scientific advice to the network, keeps us informed of relevant international activities, and directly facilitates liaison between CCRN and these organizations, including leveraging opportunities for common data collection, model development and testing, and other strategic activities. The IAP has been closely involved with the CCRN at its launch workshop and Annual General Meeting (AGM), and will have important roles in future planned workshops.

Workshops and Meetings

In year-1 of the project, the CCRN has held several major workshops and meetings to advance different thematic aspects of the research programme and to plan future network activities. These are briefly described below and more detailed information is provided on the CCRN website. In addition, there have been 25 teleconference meetings among various groups within the CCRN.

CCRN Launch Workshop: The CCRN came together for its first physical meeting on 30/31 May, 2013 at Environment Canada's (EC) National Hydrology Research Centre in Saskatoon, SK. This workshop, attended by NSERC, included descriptions of individual research plans, and was a first opportunity to refine the network research programme and themes as a collective group, to further develop the integrated activities and workplans, and to address early identified gaps in personnel, resources, and commitments. The workshop also included an informal meeting of the BoD.

Targeted Process Studies Workshop: This workshop, held at McMaster University, Hamilton, ON, on 12/13 September 2013, focused on Theme B deliverables, and in particular sub-Theme B1 – Targeted Process Studies. Outcomes included preliminary plans for both a Coordinated Enhanced Observation Period (CEOP) in 2014-15 and a focused analysis of the June 2013 extreme weather and flooding events in western and northern Canada (see *Planning of Special Network Activities*), as well as plans for the first network publications on process dynamics and sensitivity over the cold regions of western and northern Canada.

Uncertainty Estimation for Environmental Modelling Workshop: This workshop was held at the University of Saskatchewan on 4 October, 2013 and led by Professor K. Beven of Lancaster University, UK and H. Wheater, CCRN Principal Investigator (PI). The workshop provided an important training opportunity for professionals and graduate students interested in environmental modeling, addressing concepts and approaches to uncertainty estimation, with a particular focus on hydrological models. It included a clinic based on CCRN case study presentations.

CCRN First Annual General Meeting (AGM): The CCRN held its first AGM in Saskatoon on 21-23 October, 2013, which also included the first formal BoD meeting and attendance of several international collaborators and members of the IAP. The main objectives of the meeting were to refine the draft version of the CCRN inception report and solidify short-term theme plans, define a data plan (see *Data Management Activities*), identify needs for network cross-cut activities, identify gaps and opportunities to fill them, and continue to build the CCRN community. The meeting was organized around the five themes of the CCRN programme, with overview presentations on progress and developments, and the integration of individual co-investigator's and collaborator's research plans.

2014 Workshop Plans: A workshop organized by EC staff in the Climate Research Division and the Meteorological Service of Canada will take place in January 2014 in Montréal, QC. This will focus on land surface modelling and data assimilation aspects of relevance to CCRN Theme C. On 11/12 February, a cross-cut workshop in Canmore, AB will focus on assessment and diagnosis of the extreme weather and flooding that occurred in northern and western Canada during June 2013, along with a review of lessons learned and insight into the future occurrence and risk of similar events. This event will include significant outreach components, with attendance of key stakeholder group representatives and an evening public talk and panel discussion in the town of Canmore. In September 2014, a workshop is tentatively planned in Saskatoon that will bring in some of our international collaborators, to focus on change detection modelling methodology. This workshop will advance aspects of the CCRN programme under sub-Theme B3 – Diagnosis of Local Past Change. The second CCRN AGM will be held in October 2014 at Wilfrid Laurier University.

Theme Activities and Inception Report

Considerable effort in year-1 has focussed on production of a network inception report, which describes on-going and planned CCRN activities and deliverables from the broad theme level down to the more detailed individual activities. The report is intended as a guidance document to move from our network proposal to a set of firm short-term plans and broader long-term plans, including contributions by specific individuals and groups, realistic timelines and deliverables, and anticipated difficulties or gaps that need further consideration. It is a living document with the current version to be finalized by the end of this calendar year. Draft sections are available on our website under the section on our first AGM. A brief review of CCRN theme activities and areas of progress is provided below.

Theme A: Work planned and underway includes the analysis of federal and provincial monitoring network data sets and remotely sensed imagery (e.g., MODIS), including aspects of snow, climate, streamflow, and vegetation. Shorter observational records from the WECC observatories will be used to exemplify the regional patterns of change and place them within a conceptual framework. Such models of change within the WECC observatories have been developed for each major biome and were presented at the AGM. Existing data sets from the observatories are being catalogued and entered into the data management system, while new datasets have been collected, including seasonal mass balances at glacier sites and tree cores at many northern and boreal sites. Code has been developed and applied to analyze monitoring data across the CCRN domain. Instrumentation at WECC observatories has been strengthened along with an increased focus on ecological data in advance of the CEOP, and further stations have been established to regionalize WECC data. In addition, Theme A is undertaking a comprehensive literature review, led by our network manager Dr. C. DeBeer, to synthesize previous research on change in the study domain.

Theme B: Major advancements in Theme B progress have resulted from the recent workshops. Planning for the CEOP is well underway (see *Planning of Special Network Activities*), as is progress towards two joint-authored papers: 1) Examination of multi-scale hydrological, cryospheric, ecological and atmospheric process dynamics leading to an inter-comparison of current dynamics across the CCRN domain, and 2) Examination of the sensitivity of process dynamics and response to atmospheric and/or system change leading to an intercomparison of process responses across the CCRN domain. Ongoing work on various process parameterization methods (e.g. frozen soil, permafrost, precipitation phase) has been carried out by individual co-investigators. The application of the CRHM model to assess hydrological sensitivity to climate has been undertaken at some WECC sites. Several notable modelling activities to diagnose local change (sub-Theme B3) have been conducted and a planned 2014 workshop will further advance sub-Theme B3 and integrate its activities within the network (see *Workshops and Meetings*).

Theme C: Network activities under Theme C have progressed well during year-1, with key linkages between CCRN and EC being defined and strong international collaborations being forged. EC models such as CLASS (Canadian Land Surface Scheme) and CTEM (Canadian Terrestrial Ecosystem Model) are being configured for baseline simulations at the WECC observatories, and a distributed version of standalone CLASS has been configured for regional simulations over the CCRN domain. Setup of the EC MESH modelling system is underway for the entire Saskatchewan River Basin (SRB), and there has been a focus on individual MESH setups and preliminary intercomparison runs for some of the headwater basins. Planning of future developments and testing of the models at WECC observatories is underway, and the scope of joint EC–CCRN activities is moving forward under a framework document developed by EC staff. Collaborative activities with key international researchers have also focused on model development and testing of the Joint UK Land Environment Simulator (JULES), and discussions are underway with major international initiatives (Global Energy and Water Exchanges Project (GEWEX), and Integrated Land Ecosystem – Atmosphere Process Study (ILEAPS)) for a joint inter-comparison project based on CCRN sites.

Theme D: Although many of the deliverables associated with this theme are scheduled for later in the programme, important developments and progress have occurred in year-1. A collaborative CCRN and EC study of the string of extreme events (floods, fires, drought) affecting the CCRN region from 2009–11, is nearing completion. Significant progress is being made on other joint projects with EC, including studies on winter precipitation extremes and on precipitation measurement in the Rocky Mountain Front Ranges. The latter has involved compilation of synoptic precipitation, including local radar coverage, and temperature information covering the June 2013 flooding events, and will form a key component of the planned network focal analysis of the events. To facilitate the interaction between Themes C and D, a summary model activity table has been developed to clarify details such as what models are to be used,

who will be running them and providing access to the source code and data, and over what temporal and spatial domains. In addition, reanalysis data products are being identified and assembled for future use in the network.

Theme E: Several important activities have taken place in outreach and engagement (O&E) during year-1. We have completed an inventory of the existing O&E linkages within the network and among our team of co-investigators and collaborators. This has allowed us to identify not only where our strengths lie in terms of existing contacts with key stakeholders and outside groups, but also what future connections are perceived by the network to be important and where we should focus further attention. We have produced a draft framework for our O&E activities, which outlines our strategy and describes the multi-tiered engagement plans at the grassroots, provincial/territorial, federal, and international levels. Immediate plans include the involvement of various federal and provincial agencies, and other key stakeholders, especially in our focal analysis of the June 2013 events and workshop. We have conducted numerous media interviews in relation to the June 2013 events and produced many editorial pieces within local media outlets. Our O&E activities will be further supported with external funding to leverage CCRN funds: our network outreach coordinator, Dr. G. Strickert, has been awarded two SSHRC grants for stakeholder engagement in the SRB, while Dr. W. Quinton, Theme E leader, has been awarded a Canadian Water Network grant for engagement activities in the Northwest Territories. BoD and IAP members are actively involved in O&E activities within their agencies and contacts.

Collaborations and Interactions with CCRN Partners

As noted, we have taken considerable effort to identify the existing individual and network-level relationships among researchers and relevant partners, and to define the framework for continued collaborations. The draft inception report includes details of existing and potential relationships, as well as the strategy and implementation plan for the O&E activities. We have identified existing involvement with 106 different partners, including 11 First Nations groups, 11 Canadian and U.S. federal departments, 2 regional water boards, 24 provincial and territorial agencies, 4 urban municipalities, 7 non-governmental organizations, 19 water and environmental stewardship societies, 26 industrial companies, 6 research and education centres, and 2 consultancies. Continued involvement with these partners will be fostered at the network level to the extent possible. Below, we briefly review recent collaborative activities and plans with key partners, with further information available in the draft Theme E framework document.

Canadian Federal Government Partnerships: CCRN is actively engaged with several Canadian federal government agencies, and senior staff are included on our BoD.

EC staff have been closely involved with the development and management of the CCRN. Interaction with EC is facilitated by the appointment of Dr. M. Jean to the BoD and the appointment of Drs. A. Pietroniro, M. MacKay and P. Marsh (EC adjunct, now at Wilfrid Laurier) to the CCRN Science Committee and as thematic leaders, as well as Dr. C. Spence as leader for sub-Theme A1. A total of 15 EC staff are named participants of the network. In addition to collaboration on field-based research and process modelling, an important collaboration is in land surface modelling for weather and climate models and large-scale hydrological modelling. EC modellers have developed a comprehensive land surface modelling strategy that facilitates collaboration with CCRN, and specific work plans are being finalized.

Collaboration with Agriculture and Agri-Food Canada (AAFC) is facilitated through the appointment of Dr. D. Petitclerc to the BoD and the appointment of Dr. A. Howard to the Science Committee and Theme E leadership. It includes integration of the AAFC soil moisture monitoring sites in the Brightwater Creek

study area in the CCRN study to sites run by EC and the Universities of Saskatchewan and Guelph to form a core site for the National Aeronautics and Space Administration (NASA) calibration and validation study associated with their SMAP (Soil Moisture Active Passive) mission planned for launch in February 2014.

CCRN interaction with the Parks Canada Agency (PCA) is in the early phase of development, and future directions for collaborative activities are being facilitated by Dr. W. Wu, who is a named collaborator of the network. Specific activities include developing protocols for PCA's ecological integrity monitoring programs and public education. A letter of support from PCA was included within the original proposal listing forms of support; in particular, several of the WECC observatories are located within the National Parks and PCA assistance can help support activities there.

Linkages with Natural Resources Canada (NRCan) have been developed through the operation and scientific contributions at several of the WECC observatories, and at the network management level through the appointment of Dr. D. Kirkwood to the BoD. Dr. M. Demuth, a network collaborator, operates the glacier/icefield observatories through NRCan funding. In addition, NRCan involvement includes collaboration on the use and analysis of remotely sensed Gravity Recovery and Climate Experiment (GRACE) gravitational field data together with the CCRN PI.

Provincial and Territorial Partnerships: CCRN is involved with many provincial and territorial agencies and has been actively developing collaborative relationships during year-1 of the project. The network is engaged with agencies responsible for the management of water and other natural resources, including Saskatchewan Water Security Agency (WSA), Alberta Environment and Sustainable Resource Development (AESRD), Yukon Environment, and Northwest Territories Environment and Natural Resources. The linkage to Saskatchewan WSA and AESRD have been formally established through the appointment of Dr. W. Dybvig and Dr. K. Greenway to our BoD. Connections with Yukon Environment are facilitated through R. Janowicz, who is a named collaborator of CCRN. In the Northwest Territories, the appointment of D. Livingstone to our Board of Directors, and of Dr. W. Quinton to our Science Committee and Theme E leadership, has facilitated a direct linkage between CCRN and the Government of Northwest Territories (GNWT) and Wilfrid Laurier Partnership. This partnership is a key O&E mechanism in the north and is seen as highly important for the provision of scientific advice and water management and climate change decision support to the GNWT.

International Collaborations: As a network, we have actively involved many international researchers and organizations. The IAP is comprised of key researchers who represent an important bridge to GEWEX, the US National Oceanic and Atmospheric Administration (NOAA), the World Climate Research Programme's Climate and Cryosphere Project (CliC), and NASA's Arctic-Boreal Vulnerability Experiment (ABoVE) (see *www.ccrnetwork.ca*). Several of the IAP members were present and spoke at our launch workshop and AGM on the envisioned collaborative activities between CCRN and their organizations. Our network also includes 14 key international collaborators who have been involved in various ways during year-1 and are being included in plans for future activities in the programme. Some of these collaborators, including Drs. R. Essery, D. Lettenmaier, and T. Link, attended our AGM and discussed their involvement with CCRN. Further, plans have emerged to include the Reynolds Creek Experimental Watershed in Idaho, U.S.A. as a WECC observatory in CCRN, which represents an important extension of the WECC observational network into more temperate mountainous regions. Several of the planned workshops in 2014 and beyond will engage more of our international colleagues.

Planning of Special Network Activities

Based on network discussions, plans are taking shape for two major network-wide focal activities: 1) a Coordinated Enhanced Observation Period (CEOP) to occur between October 2014 and September 2015 across the entire network of WECC observatories, and 2) a detailed analysis of the events surrounding the extreme weather and flooding disasters that occurred in northern and western Canada during late June 2013. Both of these activities will cut across themes and involve a range of participants, with the analysis of the June 2013 events involving numerous stakeholders who are looking for improved tools to better predict similar future events and mitigate associated risks. In the case of this focal June 2013 analysis, this was seen as a proactive opportunity for the network to address a significant high-profile event.

Initial planning for the CEOP has focused on 2014–15 implementation in order to provide the necessary time to plan and prepare logistics, and to maximize the synergies with other planned initiatives in these years (e.g., initial SMAP work, ABoVE initiatives and linkages, EC polarizing radar and precipitation experiments). Previous CEOP programs in the Mackenzie GEWEX program are still yielding scientific dividends over 10 years later, and we believe that the CEOP activities and data will be a lasting legacy of CCRN. During this CEOP, we will deploy additional instrumentation at the WECC observatories and other sites, ensure that existing instrumentation is operational and well-maintained, collect other special data sets (e.g., remotely sensed data, field-based observations, isotope and geochemical tracers, etc.), and work with our federal partners for rapid collection and processing of meteorological and hydrometric network data. Coordination of the CEOP will be overseen by Dr. W. Helgason with support from several other researchers in the network, and will involve the participation of all WECC observatory leaders.

Analysis of the June 2013 events will include a multi-faceted investigation focusing on synoptic- and continental-scale meteorological conditions associated with the events, the hydrological behavior and response of watersheds arising in the Rocky Mountains and elsewhere, the performance of various models in simulating these events based on conditions and observations at the time, the management and decision-making approach during the events, the statistical characterization of these events in the context of a changing climate and the likelihood of future similar events, related extreme events at other times and in other geographic regions, and the lessons learned and improvements for management that can be drawn from this experience. The starting point for this activity will be the February workshop, and, in future, we plan to produce a comprehensive report or special issue journal publication to summarize and document this important initiative.

Recruitment and Training of Highly Qualified Personnel

One of the most important aspects of the network is the training of the next generation of scientists, and CCRN has been committed to ensuring that this activity is well-supported. At the present time the network includes 19 MSc students, 19 PhD students, and 20 PDFs working on CCRN projects. Although some of these personnel had been in place prior to the network commencing, 7 MSc students, 5 PhD students, and 3 PDFs have been recruited to fill specific positions advertised under CCRN since the spring of 2013. In most instances, the salary and support funding for the students and PDFs has been leveraged by other sources. We note that there have been delays in the recruitment of some HQP due to the mismatch between the CCRN project/fiscal year and the academic year, delays in position advertising under the network and funds transfers, and lack of qualified or suitable candidates applying for some positions. However, recruitment will increase over the coming months with more students and PDFs coming on. At the network level, and among individual co-investigators, we have developed a revised fiscal plan that

includes our projections to the end of fiscal year-1 as well as beyond into future years of the project (see *Expenditures to Date and Future Budget Projections*).

Data Management Activities

As a network, we are committed to produce, document, and archive our results in an integrated, long-term repository, and we have been actively focused on developing a data management strategy to achieve this. One of the first actions taken was the drafting of a data access policy by the Science Committee, based largely on the policies and best practices from previous successful Canadian hydrometeorological research networks, including the Mackenzie GEWEX Study (MAGS), the Drought Research Initiative (DRI), and the Improved Processes and Parameterization for Prediction in Cold Regions (IP3) Network. It was understood that a first step towards many of our planned research activities was to catalogue and inventory the existing datasets across the WECC observatories and begin to work towards centralizing some of this data and processing it in a standardized way. We have recently completed a meta-data catalogue and work is underway to bring various data into a central repository that is maintained by the Global Institute for Water Security (GIWS) at the University of Saskatchewan. The platform on which GIWS currently operates is the Water Information System Kisters (WISKI), which supports features to import, analyze, and visualize large quantities of data with the option to use Kisters' or external modelling and scripting tools for further data processing. In addition to data sets collected at WECC observatories, CCRN is bringing together data from a variety of other sources including remote sensing products, atmospheric reanalysis data, regional data from EC weather and hydrometric sites, and other pertinent baseline information. Collation and management of this data will be an ongoing network activity requiring considerable resources.

Recognizing the importance of the data management aspect of the network and the attention that it requires, a team of network co-investigators and collaborators was formed to help guide and direct these activities. A draft guidance document has been produced on developing a data management framework for CCRN to be part of our inception report. The strategy will be based on the key values of simplicity, clarity and efficiency. The policy will facilitate data sharing, establish clear and simple protocols for data cataloging and storage, support modeling activities, and ensure a long-term quality data archive as a network legacy.