Canada's Regional Hydroclimate Project for GEWEX: Transitioning from the Global Water Futures Programme to the Global Water Futures Observatories Facility

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History

Canada has a long history of involvement and contributions to GEWEX dating back to the early 1990s, when regional hydroclimate projects (RHPs) were formed around coordinated research activities in major cold regions river basins of western Canada. The Mackenzie GEWEX Study (MAGS; *https://gwfnet.net/sites/mags/*) was an early Canadian contribution to GEWEX that focused on the 1.8 million km^2 Mackenzie River Basin and had the objectives to 1) understand and model the high-latitude water and energy cycles that play roles in the climate system, and 2) improve our ability to assess the changes to Canada's water resources that arise from climate variability and anthropogenic climate change (Stewart et al., 1998; Woo et al., 2008). The study was carried out between 1994 and 2005 and produced the first comprehensive large-scale assessment and synthesis of cold region atmospheric and hydrologic processes in northern Canada.

The Saskatchewan River Basin (SaskRB) RHP commenced in 2012 and was expanded in 2014 to include the Mackenzie River Basin as part of the Changing Cold Regions Network (CCRN; *https://ccrnetwork.ca/*) research programme. This broader RHP for western Canada had the overall aims to integrate existing and new sources of data with improved predictive and observational tools to understand, diagnose, and predict interactions amongst the cryospheric, ecological, hydrological, and climatic components of the changing Earth system at multiple scales, with a geographic focus on western Canada's rapidly changing cold interior (see DeBeer et al., 2021, and the *HESS* special issue, *https://hess.copernicus.org/articles/special_issue919.html*).

CCRN ended in early 2018, but at that time the new Global Water Futures (GWF; *www.globalwaterfutures.ca*) programme provided an opportunity to expand this RHP geographically across Canada and as a more broadly-based and interdisciplinary initiative. The GWF Canadian RHP commenced that year with its coast-to-coast-to-coast domain covering the Yukon, Mackenzie, Fraser, Columbia, Saskatchewan–Nelson, Great Lakes–St. Lawrence, and Saint John River Basins, including transboundary portions of these basins in the United States. This encompassed a vast range of physiographic and climatological regions, from the Sub-Arctic Taiga, Tundra, and southern Arctic, through the western Cordillera, the vast Boreal Forest, the northern Prairie region, the Great Lakes, the St. Lawrence lowlands, and the Maritime region in the east.

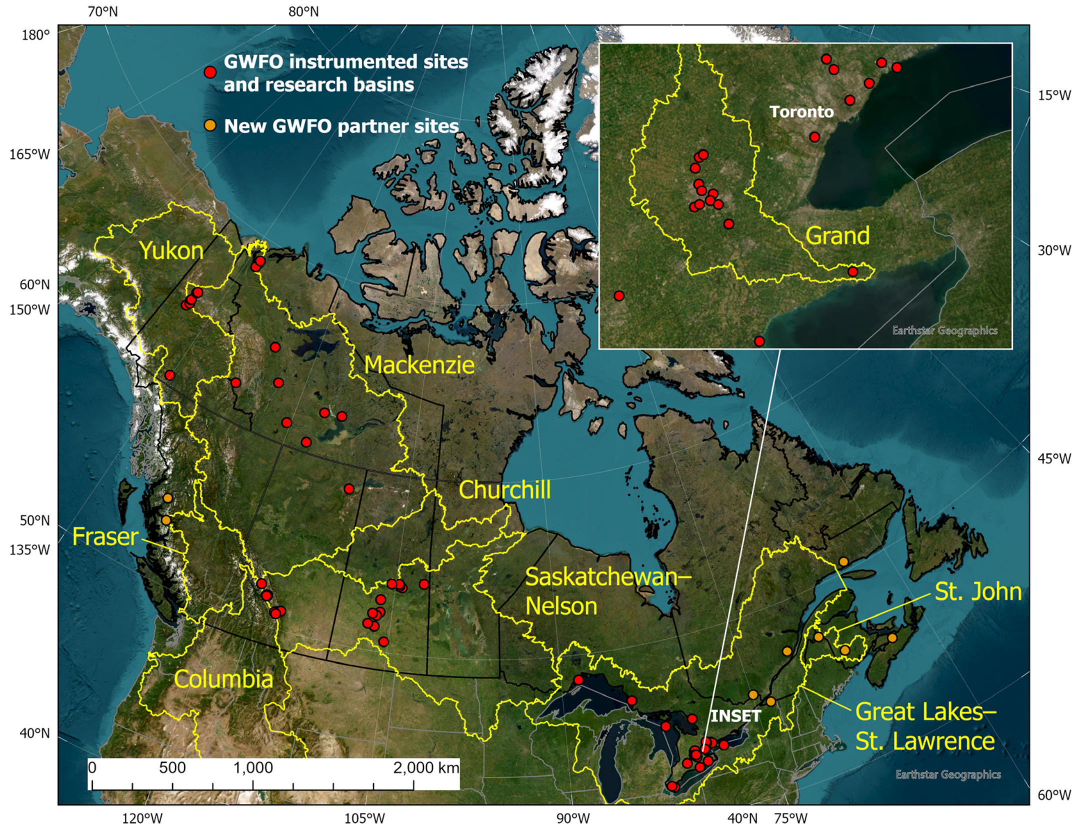
The Global Water Futures Programme

GWF was conceived in 2015 to address a grand challenge for water science in Canada and globally: 'How can we best prepare for and manage water futures in the face of dramatically increasing risks?' With a $78M investment from the Canada First Research Excellence Fund (CFREF) and significant leveraged support from its lead partner institutions [University of Saskatchewan (USask), University of Waterloo, McMaster University, and Wilfrid Laurier University], GWF aimed to position Canada as a global leader in water science for the world's cold regions and to provide strategic tools to manage water futures for Canada and the world. It was a major undertaking to develop and operate this large university-led, transdisciplinary, multi-institutional water research programme, and much of what was done was new and unique. A recent paper describes how GWF did this and shares some of the important lessons learned and reflections (DeBeer et al., 2025).

With end-user needs at the forefront, driving GWF strategy and shaping its science, GWF focused on three main objectives:

1. Deliver new capability for providing disaster warning to governments, communities, and the public, including Canada's first national flood forecasting and seasonal flow forecasting systems, new drought warning capability, and water quality models and monitoring that warn of hazards to health and drinking water supply;
2. Diagnose and predict water futures to deliver improved scenario forecasting of changing climate, landscape, and water for the future, with information outputs tailored to the needs of users; and
3. Develop new models, tools, and approaches to manage water-related risks to multiple sectors, integrating natural sciences, engineering, social, and health sciences to deliver transformative decision-making tools for evidence-based responses to the world's changing cold regions.

GWF sustained the work of 65 research projects and core teams. Its research projects were selected through a competitive peer-reviewed process with the help of an International Science Advisory Committee. Indigenous community projects were co-developed and co-led with the communities and evaluated by an Indigenous Engagement Committee. GWF's core teams provided programme support in communications, data management, and knowledge mobilisation, and led strategic developments such as new computer modelling and collecting observations from over 70 instrumented research sites. GWF's four partner universities hired 40 new freshwater professors, and the funding provided to more than 200 faculty members at 23 universities across Canada led to the hiring and training of over 1700 undergraduate and graduate students, postdoctoral fellows, research scientists, technicians, and visiting scientists in groundbreaking scientific research. The research findings generated by this increased capacity are beginning to change freshwater and climate adaptation policy priorities and management practices across Canada and are providing the foundation for the country's essential climate and water prediction capability.



Canada's RHP in GEWEX and the major river basins comprising it. GWFO supports world-leading cold regions water science and modelling efforts focussed around its network of instrumented sites, deployable systems, and water laboratories, and through its leadership of other global programmes.

GWF studies have investigated diverse aspects of hydrology, water quality, aquatic ecology, wildfires, health and wellbeing, water prediction and monitoring, science-art approaches to communication, the impacts of climate change on water resources, permafrost and glacier dynamics, and the effects of human activities on water ecosystems. Many studies employed advanced techniques such as remote sensing, supercomputer-based modelling, environtmental DNA, and isotopic analysis. Overall, the interconnectedness of GWF research areas and their relevance to pressing local and global challenges has been remarkable. GWF researchers have not only contributed to research, but have also worked with hundreds of partner groups and led numerous international research programs and committees, as well as started key science-art and other initiatives such as Transitions, the Virtual Water Gallery, and Women Plus Water. Major contributions to the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Climate Research Programme, the World Meteorological Organization, and Future Earth have led to the UNESCO Chair in Mountain Water Sustainability, Ecohydrology Demonstration sites for UNESCO's Intergovernmental Hydrology Programme, the International Year for Glaciers' Preservation – 2025, and the UN's Decade of Action for Cryospheric Sciences (2025–2034).

After nine years of operation, GWF came to its conclusion in August 2025. Its advances and achievements are being compiled into a comprehensive synthesis and a series of topical and regional science papers, plain language summaries, and easy-to-visualize infographics. This will be a legacy of the programme and a contribution to GEWEX as the RHP for Canada. However, despite the end of GWF, Canada's involvement in GEWEX will continue—much of the observational, laboratory, and data management components of GWF carry on as part of the nine-university Global Water Futures Observatories facility (GWFO; *www.gwfo.ca*), launched in April 2023, and in the national research that GWFO supports.

The Global Water Futures Observatories Facility and Its Contribution to GEWEX

GWFO is a national, multi-university water research facility supported by the Canada Foundation for Innovation's (CFI) Major Science Initiatives (MSI) Fund from 2023 to 2029 with possibility of renewal in 2029. Led by USask, GWFO is a $40.5M research facility of 64 in situ instrumented observation sites in strategically selected water bodies and research basins; 15 deployable measurement systems that are mobile and used for specialised measurement campaigns such as snow surveys, lake aquatic ecology and chemistry surveys, evaporation, and other intensive observations; and 18 university-based environmental and aquatic analysis facilities. It operates as a partnership between USask, University of Waterloo, McMaster University, Wilfrid Laurier University, University of Windsor, Trent University, Carleton University, Western University, and University of Toronto. This sustains GWF's unique freshwater observing network and sophisticated data telemetry, storage, management, and visualisation systems as a national facility, and brings in new partners from the Real-Time Aquatic Ecosystem Observation Network (RAEON; https://raeon.org/) in the Great Lakes region. GWFO is expanding its observatories across Canada through partnerships with additional institutions in Quebec, Alberta, and British Columbia to make this a truly coast-to-coast-to-coast network. GWFO provides the infrastructure and resulting open and publicly available water data, which informs the development and testing of water prediction models, monitors changes in water sources, underpins diagnosis of risks to water security, and helps design solutions to ensure the long-term sustainability of Canadian and global water resources.

GWFO is funded as an observational and analytical facility but leverages other sources of support to maintain a world-class science programme around the observatories. The network of Canadian water experts who operate the facility are global leaders in their specific fields and they contribute key insights and novel scientific advances. GWF's broad science questions remain relevant and provide direction for ongoing work as new and emergent issues arise, and GWFO relies on a User Advisory Panel comprised of representatives from a wide range of end-user groups who provide insights and guidance on the user science and decision support needs underpinned by GWFO. Intensive water research supported and carried out by GWFO and its members contributes to essential Canadian initiatives, such as a national hydrological and streamflow prediction system and strategies for flood and drought forecasting, and to the new Canada Water Agency, a federal agency that is responsible for coordinating the management, protection, and sustainability of Canada's freshwater resources across all regions and jurisdictions. GWFO provides leadership internationally through the International Year for Glaciers' Preservation – 2025, the Decade of Action for Cryospheric Sciences, the UNESCO Chair in Mountain Water Sustainability, and the International Network for Alpine Research Catchment Hydrology, a GEWEX cross-cutting project. Through these activities and other new opportunities, our vision is to carry on as a GEWEX RHP and the premier national water research facility for Canada, and a global leader in cold regions water observation, understanding, modelling, and prediction.

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The GLASS Panel at 25 Years

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Introduction

Land modeling has shown rapid development in recent decades. While characterizing energy and water fluxes were the primary focus of studies through the 1990s, the 2000s brought increasing attention to coupled land–atmosphere (L-A) interactions and to the global carbon cycle, triggering the development of model characterizations of vegetation phenology, dynamic vegetation structure, and carbon pools. Continued development through the 2010s and into the 2020s broadened the capacity of those models with improved representations of soil physics and related soil hydraulic properties, plant water stress (including plant hydraulics) and root water extraction, wetlands, urban areas, irrigation, soil water and ground water, nutrient cycles, cryosphere processes, and more.

This expanding scope is driven by the growth of interdisciplinary studies of the Earth system, including efforts to understand processes from the sub-surface (e.g., impacts of soil characteristics on groundwater recharge), to the surface (e.g., impacts of soil moisture on surface flux partitioning), to the near-surface atmosphere (e.g., impacts of turbulent surface fluxes on the convective boundary layer). However, additional drivers of land model development stem from the recognition of the role of the land in impacting and modulating extremes (heatwaves, floods, droughts, etc.), and the emerging needs of policy-makers examining adaptation and mitigation measures that are responsive to climate projections. Modern land models are often employed to examine regional vulnerability to changing water resources, heat extremes, or flood risks. They are increasingly being used to map a range of human interventions in the land system, including land use change (Findell et al., 2017), agricultural practices (McDermid et al., 2023), surface radiation management (Seneviratne et al., 2018), or various alterations of local nutrient cycles (Sinha et al., 2017).

For 25 years, the Global Land-Atmosphere System Studies (GLASS) Panel has been encouraging such developments by coordinating the evaluation and intercomparison of each new generation of land models and their applications to scientific queries of broad interest. Here we revisit that 25-year history, highlighting key developments in land process representation and understanding, modeling and understanding land-atmosphere interactions, and improvements in land-relevant observations and the land model benchmarking efforts those efforts enable. We conclude with some thoughts on the immediate future of GLASS.

Land Model Development Prior to GLASS

In the late 1980s and early 1990s, numerical models of the land were designed to provide lower boundary conditions to