GHP Working Group (Project) Reports for the 33rd GEWEX SSG Meeting 2021

Working Group (Project) Name : Global Water Futures (GWF)
Reporting Period : 01 January – 31 December 2020
Starting Date : 2016
End Date (where appropriate) : 2024
URL : https://gwf.usask.ca/

Membership

Contact(s) : John Pomeroy (Director)
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see website for full details on memberhsip and participation

Working Group Objectives, Goals & Accomplishments during Reporting Period

Overall Working Group Objective(s)

GWF's overarching goal is to deliver risk management solutions—informed by leading-edge water science and supported by innovative decision-making tools—to manage water futures in Canada and other cold regions where global warming is changing landscapes, ecosystems, and the water environment. The scientific activities focus on three main goals: 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 stakeholders. This will enable us, for example, to assess risks to human health from changing flood, drought and water quality; 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. This will, for example, enable farmers to plan for crop development and improved efficiencies in water and nutrient management while delivering improved productivity and environmental benefits, enable the hydropower industry to optimize future investments while protecting ecosystems, enable stakeholders to assess vulnerabilities and to take purposeful action related to their water futures scenarios, and enable government to address trans-jurisdictional water issues and balance economic development with environmental protection. New models will define changing risk from floods and drought, and allow end-users to plan sustainable infrastructure investment to manage future risk.

GWF focusses on all of the GEWEX Science Questions and addresses all of the GEWEX Imperatives, and given GWF's geographic focus from coast to coast in southern Canada, and up to Hudson Bay and the Arctic Ocean in the North and West, it addresses distinctive cold regions and transboundary aspects that are of unique interest to GEWEX. The GWF geographic domain includes five major regions: 1) the Great Lakes and St. Lawrence in eastern Canada and the Maritimes (including the Saint John Basin), ii) the prairies in central and western Canada (western Nelson River Basin), iii) the

Boreal Forest across much of northern Canada (northern St. Lawrence, eastern Nelson, Churchill, and southeastern Mackenzie Basins), iv) the western Cordillera from the U.S. Pacific northwest up to the Sub-Arctic Mountains of the Yukon and Alaska (Columbia, Fraser, and Yukon Basins, and the headwaters of the Nelson and Mackenzie Rivers), and v) the Sub-Arctic Taiga, Tundra, and southern Arctic in the North (northern Mackenzie Basin). This vast domain includes large lakes and an E-W as well as N-S transect from temperate-humid to semi-arid to mountain glaciated to boreal and then polar climates. Each of the individual regions feature unique aspects in terms of the environmental and societal challenges faced, while some issues span multiple regions (e.g. agriculture, urbanization, etc.), and others span all regions (e.g. water management, governance, policy, etc.).

GWF is now at its mid-term point in the seven-year program, and we have prepared a full report to our funding agency, the Canada First Research Excellence Fund (CFREF). This can be found at https://gwf.usask.ca/outputs-data/midterm-report-2020.php.

List of Working Group Goals

Adjust yearly

- GWF's science goals are addressed through three inter-related strategic pillars of activity:
- Pillar 1: Diagnosing and Predicting Change in Cold Regions - This pillar of activity is delivering transformative, transdisciplinary science, leading to a more complete understanding of physical and ecological systems, and providing the observational data to underpin cutting-edge technology and forecasting models. Activities here also contribute strongly to Pillar 3.
- Pillar 2: Developing 'Big Data' and Decision Support Systems - This pillar of activity is creating new and improved data, sensing and modelling systems, and deploying them across Canada and the world. These systems increase our observational capabilities to unprecedented levels and lead to the generation of the 'big data' needed to uncover key insights and support user needs.
- Pillar 3: Designing User Solutions - Guided by GWF's users and partners and supported by Pillars 1 & 2, Pillar 3 aims to provide tools and solutions that Canada and similar cold regions currently lack, but urgently need, to manage water in the face of unprecedented change.
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- Essential Scientific Questions as a GEWEX Regional Hydroclimate Project
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- Several key science questions were considered as direct contributions to the GEWEX Hydroclimate Panel. Integrating the insights and capabilities from a large and diverse team representing a number of disciplines to address water and climate issues across Canada and other cold regions, the research will strive to answer the following science questions:
- 1. How will extreme atmospheric events and other changes to the climate system be translated by the hydrological system into hydrological extremes?
- 2. How will hydrological storage in lakes, managed reservoirs, glaciers, permafrost, groundwater and wetlands interact with a changing climate and shifting terrestrial ecosystems to create new hydrological regimes?
- 3. How can humans better manage, mitigate and adapt to this change and conserve ecosystems through water and land management, prediction, and governance?
- Our various pillars of activity described above will provide significant interdisciplinary research thrusts in the areas necessary to answer these questions.

List of 2 to 3 Major Key Results

Adjust yearly with respect to goals

- Co-Creating Water Research with Indigenous Communities: An important issue for GWF is the extraordinary water challenges facing Indigenous communities (ICs). Canada is changing rapidly and Indigenous Nations are taking their place as managers of water resources, co-developers of science and management tools, and custodians of nature. GWF has partnered with ICs to develop an IC Water Research Strategy to share knowledge, develop solutions to water problems, and advance concepts of water governance. Many of its projects accomplish this through fostering engagement and participation by ICs, respectful sharing and co-learning of different knowledge systems, and co-created research outputs, as exemplified by this recent article on Climate, Community, and Indigenous Resilience (https://gwf.usask.ca/outreach/science-features/climate-indigenous-resilience.php). The goal is to foster a greater appreciation and create a solid bridge between Indigenous and Western ways of knowing. GWF has funded 6 new IC water research projects, each of which were co-created with and are co-led by an IC and a GWF academic Co-Principal Investigator. The review process and criteria for these projects were co-created with IC from across Canada. These Indigenous-led water research projects involve 14 ICs and 11 GWF universities and are training 36 HQP using $1.6M of funding from GWF. Advancing water solutions and management for ICs is one the most critical and unique advances that GWF is making.
- Big Data for Water: An early priority for GWF was to develop a national network of water research observatories. This was achieved by integrating existing sites operated by GWF partner institutions into the network and supplementing these sites with CFI funding grants. Maintenance and logistics are supported by a GWF Core Technical Team, comprised of 20 research technicians across the 4 partner institutions (University of Saskatchewan, University of Waterloo, McMaster University, Wilfrid Laurier University). Most of the sites have a history of research that has produced extensive and long-term hydrometric, hydrometeorological, ecological, and geophysical datasets. The network now includes 60 water observatories in different physiographic settings and ecological regions across Canada's major river basins (https://gwf.usask.ca/projects-facilities/research-facilities/Core%20basins%20and%20observatories.php). Hydrometeorological and hydrometric data is collected hourly and is used for bias correction of weather and climate model products; it is essential for the development, testing, and validation of predictive Earth system models. The scope and scale of this long-term observational network is unprecedented for a university-led water research program, and is a fundamental program strength. This also supports and links to global research initiatives, in particular, GWF's contributions to GEWEX. GWF is developing a custom data management platform, GWFNet that takes into consideration the unique aspects of water and associated data including sharing and privacy concerns when human data and Traditional Knowledge are involved (http://gwfnet.net/).
- GWF Core Modelling and Forecasting: Two of the major science goals of GWF are to deliver new capability for providing disaster warning and to develop new models, tools, and approaches to manage water-related risks for water users. This core team was formed to address these goals, in collaboration with the projects. GWF has partnered with Environment and Climate Change Canada (ECCC) to develop a Canadian national water modelling strategy, advancing and applying the Modélisation Environmentale Communautaire (MEC) – Surface and Hydrology (MESH) model to Canada's major river basins. Physical process representations of snow, permafrost, glaciers, evapotranspiration, runoff generation, and human activity simulations such as reservoir operation and water withdrawal, have been improved substantially. MESH has been applied under future climates and land cover scenarios to explore water futures. Full implementation of the MESH model (10-km resolution) on the Mackenzie, Saskatchewan-Nelson, Yukon, and St. John River basins is an unprecedented advance towards national water modelling for Canada. Initial runs for future hydrological conditions have been completed for the Saskatchewan and Smoky River basins and are underway for the Mackenzie, Yukon, and St. John River basins. A higher resolution MESH model (4-

km) was set up for more detailed process understanding of the Bow and Elbow Rivers (Alberta) and Kluane Lake Basin (Yukon), forced with Weather Research and Forecasting (WRF) model outputs (4-km) to derive future conditions (2086–2100) in response to user needs for flood plain mapping in Calgary and infrastructure design in Kluane Lake.

Other Science Highlights

Not part of the 2-3 major key results

- GWF is an expanded follow-on project from the previous RHP, the Changing Cold Regions Network (CCRN; www.ccrnetwork.ca) in western Canada. Work duirng CCRN helped to advance diagnosis of change and prediction of water futures, addressing the question of how extreme atmospheric events and other changes to the climate system be translated by the hydrological system into hydrological extremes. A two-part synthesis has been contributed to the journal, Hydrology and Earth System Sciences (HESS). The first, by Stewart et al. (2019), examines future atmospheric-related phenomena across the interior of western Canada associated with a business-as-usual climate scenario. Changes in large-scale atmospheric circulation and extent of warming vary with season, and these generally lead to increases, especially after mid-century, in factors associated with winter snowstorms, freezing rain, drought, forest fires, as well as atmospheric forcing of spring floods, although not necessarily summer convection. The second, by DeBeer et al. (2020), examines future changes in land cover and hydrological cycling across the interior of western Canada under climate conditions projected for the 21st century. Key insights into the mechanisms and interactions of Earth system and hydrological process responses are presented, and this understanding is used together with model application to provide a synthesis of future change. This has allowed more scientifically-informed projections than have hitherto been available.
- Some of the CCRN and GWF science advancements have been complied in a special issue of HESS, "Understanding and predicting Earth system and hydrological change in cold regions" (https://hess.copernicus.org/articles/special_issue919.html). The issue contains 33 papers that address recent advances in understanding, diagnosis, and prediction of past and future changes in cold-region Earth systems either as part of the CCRN and GWF initiatives, or from other studies around the world. The development and use of numerical models to diagnose past change and predict future sensitivity and response under various climate and land-cover scenarios is a particular focus. Key questions of relevance include whether cold-region hydrological processes and their interactions have changed in response to climatic drivers, what the feedbacks and thresholds leading to cold-region Earth system changes are, and/or what factors impart hydrological resilience or sensitivity to change in cold regions.
- CCRN and GWF published a special issue of the journal Earth System Science Data, called "Water, ecosystem, cryosphere, and climate data from the interior of Western Canada and other cold regions" (https://essd.copernicus.org/articles/special_issue901.html). The issue contains 13 datasets/papers from the network's set of long-term water, ecosystem, cryosphere, and climate (WECC) observatories, with datasets often spanning several decades. With this ESSD special issue, the Canadian network promotes the establishment, long-term maintenance, validation, description, accessibility, and distribution of high-quality cold-region data sets through a coordinated publication effort.
- Hydrometeorology and Climate Change: Under Pillar 1, this theme improves understanding of how climate change influences water availability and extreme events through the development and application of high-resolution atmospheric models. Thematic research is in collaboration with both the US National Center for Atmospheric Research (NCAR) and ECCC. The WRF climate model has been run at unprecedented high-resolution (4 km), providing realistic climate simulations over Canada for historical (1995–2015) and future (2080–2100) periods. These form the basis for coupled modelling of

water futures and provide key insights on precipitation extremes and dynamics that are being used to downscale and interpret a wide range of climate change models. In western Canada, WRF simulations have been described, verified, and used to characterize extreme precipitation events and to drive hydrological models at higher resolution and with greater veracity than previously possible (Almonte and Stewart, 2019; Chen et al., 2019; Kurkute et al., 2020; Li et al., 2019; Scaff et al., 2019). Results are available to the public and partners using the GWF Cuisinart model data output management system (http://cuisinart.io/), and have been used in atmospheric and hydrological research across GWF. This provides foundational knowledge for understanding subsequent impacts of climate change on water and of land–atmosphere feedbacks in changing cold environments.

- Hydrology and Terrestrial Ecosystems: Here, under Pillar 1, the focus is on improving understanding of how hydrological and terrestrial ecosystems will co-evolve under a changing climate, with diagnosis and prediction of hydro-ecological change being central to many of the projects. This work has utilized a vast network of instrumented research observatories across the country, in conjunction with the coordinated application of the Cold Regions Hydrological Modelling (CRHM) platform at many of these sites to analyze complex interrelationships between climate, vegetation, snow, glaciers, permafrost, land management, surface–atmosphere fluxes, and runoff (Fang and Pomeroy, 2020; Krogh et al., 2017; Krogh and Pomeroy, 2018; Krogh and Pomeroy, 2019; Rasouli et al., 2019; Rasouli et al., 2019). Work has led to the development and improvement of coupled atmospheric-hydrological-cryospheric and flow forecasting models, and has demonstrated substantial variations in the sensitivity of hydrological regimes to climate and vegetation change across the country. There have been notable advancements in understanding ecosystem dynamics in the face of rapid climate change, permafrost thaw, and increasing wildfire (Baltzer and Sonnentag, 2020; Coogan et al., 2019; Day et al., 2019; Day et al., 2020; Day et al., 2020; Helbig et al., 2020; Robinne et al., 2019; Sniderhan et al., 2020; Turetsky et al., 2017; Turetsky et al., 2019; Walker et al., 2019; Walker et al., 2020; Wallace and Baltzer, 2019; Wilkinson et al., 2019; Wilkinson et al., 2020; Wilcox et al,. 2019), which have profound impacts on water quantity and quality.
- GWF committed to develop a national water forecasting and prediction system, and to work with ECCC on their national flow guidance system. To that end, ECCC has adopted the MESH modelling framework used in the Mackenzie River in their own operational system. A pilot project in partnership with ECCC and Yukon Environment set up, calibrated, validated, and operationalized a coupled version of GEM-MESH as an operational streamflow forecasting system for the Yukon River and its tributaries. The forecast system is run on Amazon Web Services to provide daily streamflow predictions to the Yukon Government. This system is novel and cutting-edge for Canada, representing unprecedented technological sophistication, including glaciers and frozen soil impacts on streamflow, and a strong collaboration with a territorial flood-forecasting agency. Next steps are to extend this approach to other river basins in Canada and other parts of the world.
- GWF's Core Modelling team has advanced many other computer modelling tools to aid in infrastructure planning, design and decision support, and risk management. A water management model has been completed for the Saskatchewan River Basin (SaskRB), and, in light of the transboundary agreement requirements between AB, SK and MB, is being used to generate a range of hydro-climate scenarios for the SaskRB using weather generators and RCMs. CRHM was used to generate future hydrological conditions (representing a full range of cold region processes) due to changing climate or land use in small to medium mountain, glaciated, forest, tundra, and agricultural basins in YT, NT, BC, AB, SK, MB, ON, and QC. The Canadian Hydrological Model (CHM), is a new, next generation, multiphysics hydrological model that was developed to advance prediction across a range of spatial scales (Marsh et al., 2020). The model allows for large (70%+) reductions in computational elements while preserving critical land-surface heterogeneity. A new component, WindMapper, has been developed to downscale wind fields over large complex topography, a critical

component for estimating land surface processes in mountains. New numerical solutions to problematic thermal-hydraulic-mechanical processes have been developed, which have practical applications in assessing the threats of water main breaks in urban centres as well as buried petroleum pipeline infrastructure in the North.

Working Group Activities during Reporting Period

List of Working Group Activities and Main Result

- National-Scale Water Prediction and Forecasting: GWF has worked closely with federal, and provincial/ and territorial partners to develop national-scale capability and consistency. In February 2019, GWF led and organised with ECCC and NSERC's FloodNet, a unprecedented National Workshop on Flow Forecasting (https://gwf.usask.ca/outputs-data/major-outcomes/national-flow-forecasting.php). The workshop included presentations by streamflow forecasters from every Canadian province and territory, many from industry, ECCC, the GWF Core Modelling Team and the Integrated Modelling Program for Canada GWF project. Workshop participants found advantages to pooling information products and resources for a Canada-wide community of practice to support forecasting as well as linking provinces/territories, federal government, and universities to help with development and co-ordination. GWF is committed to enhancing models for forecasting systems (see Part-1a) and is strengthening partnerships to test and implement these systems with the provinces, industry, and ECCC.
- Water Security for Canadians, and towards a Canada Water Agency: GWF's goal is to contribute to a revitalized water strategy for Canada. GWF has partnered with the Forum for Leadership on Water, the Centre for Indigenous Environmental Resources, the POLIS Program on Ecological Governance, and the UN University to directly engage parliamentarians and inform policy through the translation of GWF science outcomes. This has involved national-level discussions, roundtables, webinars, media engagement, and strategic briefing documents as part of the Water Security for Canadians: Solutions for Canada's Emerging Water Crisis initiative (https://gwf.usask.ca/outputs-data/major-outcomes/water-security-4-canada.php). This has contributed to a mandate to the federal Ministers of ECCC and AAFC to develop a Canada Water Agency that will centralize water information, prediction, and decision-support services; strengthen intra- and inter-national transboundary water management; strengthen reconciliation with Indigenous Peoples; and, improve collaborative river basin planning with provinces, territories, and Indigenous communities. GWF is currently consulting with regional and sectoral stakeholders/practitioners across Canada on the issues, concerns, and the collaborative responses needed to tackle the emerging water-climate crisis through a Canada Water Agency.

List of New Projects and Activities in Place and Main Objective(s)

- GWF is launching the second phase of its seven-year mission with a $2.5-million investment in 12 new critically important water security projects (https://gwf.usask.ca/articles/2020/usask-led-global-water-futures-announces-12-new-projects-to-advance-water-security-across-canada.php). The new projects - which include research into climate projections, water-borne diseases, and metal release in thawing permafrost environments - are led by investigators from USask and its partners McMaster University, Wilfrid Laurier University, and the University of Waterloo, as well as the University of Quebec at Montreal and McGill University. Further details on these projects are at https://twitter.com/GWFutures/status/1321480218268217346

List of New Projects and Activities Being Planned, including Main Objective(s) and Timeline, Lead(s)

- Planetary Water Prediction Initiative: This internationalizes GWF's modelling capabilities by contributing sophisticated hydrological modelling products and geospatial intelligence approaches to expand the direct impact of GWF beyond Canada. This initiative focusses on better predicting vulnerable cold region water sources globally in the high altitudes and high latitudes and in their downstream river basins that support over half of humanity. Canada has shown global leadership through its GWF modelling efforts and can make a major contribution to predicting the changes occurring in global hydrological and energy cycles. By advancing the computational infrastructure (datasets, modeling capabilities) necessary to produce global-domain simulations and predictions of hydrological risks, this initiative uses state-of-the-art modeling capabilities to develop new and strategic collaborations with organizations and countries through mutually beneficial, internationally focused projects. The program involves collaboration with countries in the Americas, Asia, and Europe to develop, support, test, and apply coupled climate–hydrology and eventually water quality–water management models globally with an emphasis on river basins where high mountain water supplies feed local and downstream water demands and ecosystem needs. This will put greater capacity behind GWF's commitments to the WCRP through GEWEX, Future Earth through the Water Futures initiative, UNESCO through the IHP, and the WMO through its High Mountain Initiative and Polar Prediction Program.

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives.

a. Data Sets
   - See the ESSD special issue "Water, ecosystem, cryosphere, and climate data from the interior of Western Canada and other cold regions" (https://essd.copernicus.org/articles/special_issue901.html).
   - We have generated a substantial amount of observational Earth system data and model ouput data over Canada. See our Data Management page on our website (https://gwf.usask.ca/outputs-data/data.php)

b. Analysis
   - see above

c. Processes
   - see above

d. Modeling
   - see above

e. Application
   - see above

f. Technology Transfer
   - GWF works directly with partners at ECCC to help imporve their modelling and forecasting capabilities. There are two elements: 1) the GWF modelling exercise, which involves prototyping, making advances in science, and going into new frontiers. This leads to 2) the more operational system that ECCC is developing on numerical weather prediction and hydrology. The contribution from GWF is to improve the modelling framework to include most of the important physical attributes that these models need to have. GWF focusses on cold regions processes (i.e., improving glacier representation, how to deal with snowpack, handling high-relief, complex terrain, etc.), which are being added to the operational system. This is a system that is mimicking what is being developed in GWF. ECCC has started developing the MESH model in a number of key basins in Canada (Great Lakes–St. Lawrence, Saskatchewan–Nelson, and the Mackenzie). Many of the findings from GWF and its predecessor networks (CCRN, http://www.ccrnetwork.ca/; IP3,

http://www.usask.ca/ip3/; MAGS, http://www.usask.ca/geography/MAGS/index_e.htm) have been used to develop ECCC's system.

g. Capacity Building
   - see above

List contributions to the GEWEX Science Questions and plans to include these.

a. Observations and Predictions of Precipitation
   - We have several projects and elements of our core modelling program focused on predicting precipitation (Climate-Related Precipitation Extremes, https://gwf.usask.ca/projects-facilities/all-projects/p3-climate-extremes.php; Storms and Precipitation Across the Continental Divide Experiment, https://gwf-spade.weebly.com/; Short-Duration Extreme Precipitation in Future Climate, https://gwf.usask.ca/projects-facilities/all-projects/p1-extreme-precipitation.php).
   - Our network of over 65 intensive observatories across Canada provide detailed measurements and observations of precipitation (https://gwf.usask.ca/projects-facilities/research-facilities/Core%20basins%20and%20observatories.php).

b. Global Water Resource Systems
   - This is an important focus for GWF; in particular, our advancements to the MESH modelling system to include reservoir operations, irrigation, and diversions, in addition to cutting-edge science developments on cold regions process representation, are a significant contribution. This has potential for application around the world and is a key strength of our planetary water prediction initiative.

c. Changes in Extremes
   - Changes in climate and extreme events such as flood forecasting and drought prediction are a core focus of our program, with many of our projects directly addressing this.

d. Water and Energy Cycles
   - This is a primary focus for GWF. Our core modelling program is dedicated to improving the modelling capability and prediction of water and energy cycles over much of Canada, and through our planetary water prediction initiative, many cold and high mountain regions around the world.

Other Key Science Questions

List 1 - 3 suggestion that you anticipate your community would want to tackle in the next 5-10 years within the context of a land-atmosphere project

- 1. How will extreme atmospheric events and other changes to the climate system be translated by the hydrological system into hydrological extremes?
- 2. How will hydrological storage in lakes, managed reservoirs, glaciers, permafrost, groundwater and wetlands interact with a changing climate and shifting terrestrial ecosystems to create new hydrological regimes?
- 3. How can humans better manage, mitigate and adapt to this change and conserve ecosystems through water and land management, prediction, and governance?

Contributions to WCRP including Current Grand Challenges

Briefly list any specific areas of your panel's activities in particular to the grand challenges "Extremes" and "Water for the Food Baskets" which is not covered under 2.

- Several GWF projects focus on climate change and extreme events

Cooperation with other WCRP Projects, Outside Bodies and links to applications

e.g. CLIVAR, CliC, SPARC, Future Earth, etc.

- Through GWF's international scientific engagement and profile, the partner institutions are well poised to shape global water research and are regularly called upon to lead global initiatives. GWF has developed a number of important relationships with leading UN organizations and research initiatives to expand its activities and influence well beyond Canada to address the issues of global climate and Earth system change and water security. Key linkages include:
- • UNESCO's International Hydrological Programme (IHP) and UN Water through its International Water Action Decade: Water for Sustainable Development, 2018–2028. GWF is leading a Canadian contribution to the Decade that is addressing the targets of Sustainable Development Goal 6 (Ensure the availability and sustainable management of water and sanitation for all) of the 2030 Agenda for Sustainable Development (see the report Water Futures for the World We Want; https://gwf.usask.ca/sdgreport/).
- • GWF interacts closely with the GWF's International Network for Alpine Research Catchment Hydrology (INARCH), which is a GEWEX cross-cut project that links to other GEWEX research in the Andes, Tibetan Plateau, and Eastern Europe.
- • A memorandum of understanding for cold regions research between GWF and the Chinese Academy of Sciences' Third Pole Environment (TPE) initiative—a proposed RHP under GEWEX that is resulting in joint research, faculty exchange, and publications.
- • GWF as the Canadian node of the Sustainable Water Future Programme (SWFP) of Future Earth, leading important Canadian and international research initiatives focussing on water resources and climate change in cold regions..
- • Formal linkages to the World Meteorological Organization (WMO). GWF co-chaired a High Mountain Summit in Switzerland in October 2019 and attended by 44 nations. A Call to Action was issued, with commitment for an Integrated High Mountain Observation and Prediction Initiative, organized as campaigns of analysis and prediction in high mountains headwaters around the world.
- • Collaboration with the Arctic Council, currently led by Iceland. GWF has been asked to shape one of the keystone elements, Polar Prediction.

Workshops and Meetings

List of Workshops and Meetings Held in 2020

Meeting title, dates and location.

- GWF Annual Open Science Meeting
- GWF2020 Website: https://gwf.usask.ca/events-meetings/upcoming-events/gwf2020.php
- The Global Water Futures 3rd Annual Open Science Meeting had been planned to take place on the campuses of the University of Waterloo and Wilfrid Laurier University in May, 2020. Unfortunately due to COVID-19, the in-person meeting had to be cancelled, but as an alternative, GWF proceeded with a virtual event in the form of a book of published abstracts and an online poster session. The virtual GWF2020 kicked off with an online National Water Policy Panel discussion event on May 13th (https://gwf.usask.ca/events-meetings/past-events/nwpp-2020.php).
- Before the in-person events were cancelled, 264 abstracts had been submitted for oral and poster presentations, which were organized by the following themes:
- 1) Climate-driven changes of water environments in cold regions,
- 2) From anthropogenic pressures to ecosystem services,
- 3) Turning research into policy and management solutions,
- 4) Innovations in water science and technology, and
- 5) Knowledge co-creation with Indigenous communities.

- Several cross-cutting challenges and opportunities were also specified in order to support the themes, which authors could identify with:
- i) Transferable knowledge and tools,
- ii) Predictive modelling and forecasting,
- iii) (Big) data science and management,
- iv) Social, economic and health determinants and impacts, and
- v) Stakeholder engagement and knowledge mobilization.
- The abstracts were reviewed for scientific merit and relevance, and subsequently, most authors were invited to have their abstract included among the published abstracts and to contribute a virtual poster using iPosterSessions (https://gwf2020-gwf.ipostersessions.com/Default.aspx?s=gwf_2020_gallery). 178 posters have been published on the gallery, and they will be hosted and remain active through the remainder of the GWF program.

List of Workshops and Meetings Planned in 2021 and 2022

*Meeting title, dates and location and anticipated travel support needs***.**

- We are planning to hold our 2021 GWF annual open science meeting this spring. Due to COVID-19, it is expected this will be a virtual event.

Other Meetings Attended On Behalf of GEWEX or Panel in 2020

- WMO High Mountain Summit, Geneva Oct 2019
- Iceland/WMO/Arctic Council Earth System Modelling Workshop, Reyjavik, Nov 2019

Publications during Reporting Period

List of Key Publications

- See all GWF research publications here: https://gwf.usask.ca/outputs-data/research-publications.php
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