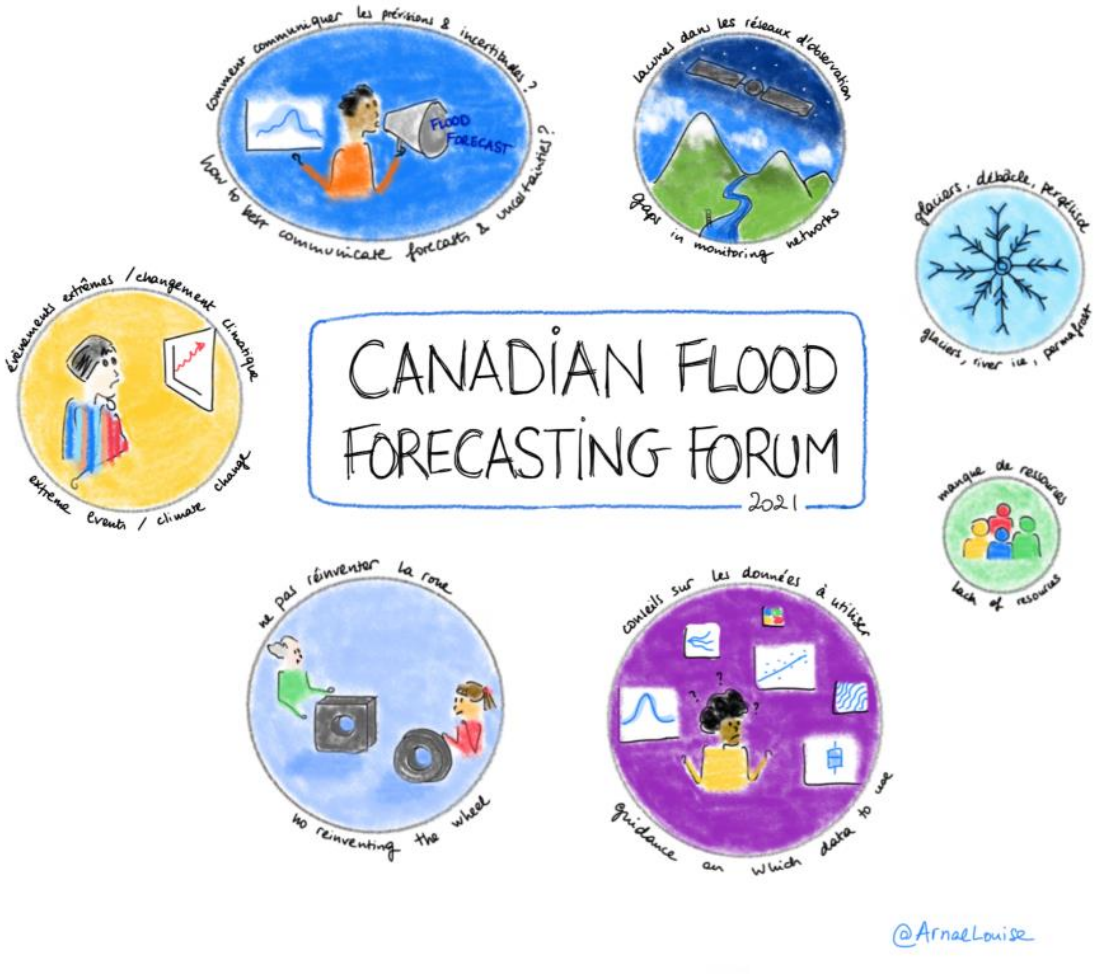
SUMMARY REPORT

2ND ANNUAL CANADIAN FLOOD FORECASTING FORUM



The second annual Canadian Flood Forecasting Forum was held virtually from February 22 to 24, 2021. Environment and Climate Change Canada (ECCC) and the Global Water Futures (GWF) Program jointly cohosted the event. This meeting was a follow-up to the "National Streamflow Forecasting Workshop" that was held at Simon Fraser University in 2019. The forum continued efforts to foster more communication and collaboration between provincial and territorial governments, ECCC, academia, and their partners nationwide towards the establishment of a "National Flood Forecasting Community of Practice", for which there was widespread support. The workshop also focused on recent global advances in flood and flow forecasting, including a dedicated information session from colleagues from the United States National Oceanographic and Atmospheric Administration and from the European Centre for Medium Range Forecasting. Advances in hydrological prediction and modelling within GWF and the ECCC research and development communities, were also highlighted, alongside the operational provincial and territorial forecasting systems. The forum also facilitated discussions on provincial and territorial forecasting operational needs, recent advancements to data products and services, and how they could be improved to support flood forecasting initiatives across the country.

Day 1

Hydrological forecasting has become a global enterprise, and Canada must establish both its role and develop an understanding of what other countries are doing, as well as determine how it should contribute to this global effort. Canada must also make the best use of these global scientific advances to serve its provincial and territorial partners, who are responsible for issuing flood forecasts and warnings. In this context, **day one** of the event focused on flood forecasting within the larger global framework, where developments at ECCC were presented alongside similar efforts happening in the United States (US) and the European Union (EU). The event was jointly opened by David Harper, the Director General of the Monitoring and Data Services Directorate of ECCC, and Prof. John Pomeroy, the Director of the GWF Program.

The morning session highlighted forecasting systems from the US and Europe. Representatives from the National Oceanic and Atmospheric Administration (NOAA) provided an overview of the National Water Centre (NWC) and flood inundation mapping initiative. NOAA's strategic plan (2019-2022) was presented, which aims to deliver water information from national to street levels at all time scales. The National Water Model (NWM) was also presented, which is a continental-scale land model used to produce high resolution, spatially continuous estimates of hydrological states and fluxes. The European Centre for Medium-Range Weather Forecasts (ECMWF) environmental prediction strategy was also presented, which includes atmospheric monitoring, climate change assessment, flood forecasting and fire forecasting. The ECMWF is moving towards the implementation of an Earth System Model (ESM), with the aim to simulate realistic global representations of water, energy, and carbon cycles by 2030. This is expected to further reduce model biases and produce physically realistic variables.

Canadian perspectives at the national level were then summarized, along with updates on recent developments of ECCC's national hydrologic prediction systems. These systems have been designed and are well-positioned to provide support and model guidance to the provinces, territories and other authorities responsible for flow and flood forecasting across Canada. A brief overview of various ECCC predictive analysis and reanalysis systems, including the National Surface and River Prediction System (NSRPS), the Water Cycle Prediction System (WCPS) and the Operational Hydrodynamic Prediction System (SHOP), was provided. It was emphasized that these systems have resulted from collaborative research and development efforts in partnership with academia and other groups within ECCC, including the National Hydrological Service, the Meteorological Research Division, and the Canadian Centre for Meteorological and Environmental Prediction. From invited academic speakers, advances in the GWF 'Core Modelling' efforts and how that contributes to national and global forecasting initiatives were highlighted, with a brief summary given on some of the scientific advancements achieved across different modelling themes, such as enhanced meteorological forcing data, geospatial intelligence, next generation hydrological modelling and water resources modelling. It was stressed that an aim through these collaborative projects is to establish Canada as a global leader in water sciences in cold regions and it was noted that other academic groups in Canada who are also contributing to these initiatives should be included in future forums.

Representatives from NOAA presented on the current and next generations of the National Water Model (NWM). The NWM is a first of its kind operational water prediction model running on NOAA's supercomputing system, which provides short and medium range streamflow forecasts (up to 10 days). The next generation NWM is under development and aims to combine computer science, hydrologic science, and geoscience data standards. The focus is largely on hydrologic predictability, model agnostic infrastructure, flexible modularity, enhanced interoperability, and multi-objective modelling. The Community Hydrologic Prediction System/Flood Early Warning System (CHPS/FEWS) used by their regional River Forecast Centers (RFC) was also discussed. The system is able to provide what-if scenarios, includes the 'snow 17' model, and is implemented on a distributed architecture. It was noted that the Northeast RFC has partnered with the River Watch Centre of New Brunswick in Canada to coordinate these efforts on shared transboundary rivers.

GWF presented an overview of the Canadian Hydrological Model (CHM), currently in development at the University of Saskatchewan as its next generation hydrological modelling tool. The model can capture complex topography by using an unstructured triangular mesh to represent the land surface, has modular flexibility, possesses built-in algorithms to downscale meteorological forcing data, and is capable of simulating 3D blowing snow transport, re-distribution and sublimation, which are of particular importance in Canada's mountains. A flexible hierarchical coupler is currently under development that will support mixing process representation at different resolutions within the same model domain.

A representative from Deltares provided an overview of the Flood Early Warning System (FEWS), which is used by several provinces and territories in Canada as a framework for handling hydrologic data and managing workflows in their operational hydrological forecasting systems. The FEWS framework was presented as a system that enables forecasters to integrate continental-scale, large domain data with regionally-based models and local, operationally-focused knowledge, to apply different forcing data and update systems when new information becomes available. Future developments will include the integration of the RIVICE model and data from the RADARSAT Constellation missions to improve the monitoring and modelling of river ice processes.

The last session of the day started with a presentation by ECCC on various operational products and services designed to provide guidance for flood forecasting. In particular, the integration of the Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (IMERG) satellite constellation into the Canadian Precipitation Analysis (CaPA) was highlighted. The Regional Deterministic Prediction System (RDPS), the High-Resolution Deterministic Prediction System (HRDPS), and the NSRPS, WCPS and SHOP systems were also introduced.

The final two presentations of the day were focused on international transboundary issues. Representatives from the International Joint Commission (IJC) presented an overview of the IJC and Collaborative Flow Forecasting along the US-Canada Transboundary Region. The IJC mandate and their organizational structure were highlighted, along with specific challenges that have been faced for forecasting on transboundary rivers that cross the US-Canada border. Issues with data availability, data harmonization, as well as a brief overview of their existing

resources, tools and skills, bi-national cooperation, forecast integration and stakeholder engagement were also shared. NOAA also spoke to transboundary data challenges in their approach to integrate CaPA data with their Multi-Radar/Multi-Sensor (MRMS) data to produce a bi-national gridded dataset with seamless transition across North America. The importance of bi-nationally coordinated, transboundary hydrological science was stressed, using the example of the Great Lakes, where efforts are ongoing to replace legacy gauge data-based area-weighted datasets with the best science from each country to create a coordinated near real-time gridded precipitation dataset. Similar approaches for improved transboundary snow information are also being considered.

Day 2

Day two included presentations focused on research and operations on a provincial, territorial, and regional scale. Additionally, ECCC presented information on the current developments of hydrologic prediction products useful to support provinces, territories and other partners in their flood and flow forecasting responsibilities. The intent of the second day of the workshop was to give a sense of the current state of predictive systems across Canada, where some of the challenges and emerging issues could be highlighted, as well as to open the conversation on data and model sharing between jurisdictions.

The morning session contained presentations by representatives from academia, select provinces, and industry. These presentations focused on novel and innovative systems, which have been used to inform decision making in various jurisdictions. Representatives from the University of Saskatchewan presented on developments of an operational flood forecasting system for the Yukon Territory and on flow analyses at sub-seasonal to seasonal scales. This demonstrated how a traditionally non-operationally focused group was able to pilot and run an operational system on behalf of the jurisdiction to help in the development of a new state-of-the-art forecasting system.

The former Executive Director of the National Hydrological Service presented a recent project where universities, industry, ECCC and provincial and territorial partners collaborated to diagnose and assess an extreme hydrological event that occurred in 2020, where Northern communities have been subjected to vulnerable conditions resulting from record high water levels persisting on Great Slave Lake. The work demonstrated how various groups between academia, industry and different governmental jurisdictions could quickly come together to collectively address arising and critical issues regardless of jurisdiction. The project also highlighted where jurisdictions benefit from the engagement of other external partners and groups to provide guidance or added support during critical flow events.

Two presentations were given on the current status of provincial flood forecasting in Canada, including representatives from Québec and from Newfoundland and Labrador. Flood forecasting in the province of Québec has evolved from an initial system developed to provide inflow forecasts to dam managers in 2000, to an online system, with interactive forecast graphics deployed publicly. Additionally, a prototype map service is under development where uncertainty in flood forecasts are currently incorporated. A unique and critical aspect of the

province's flood forecasting program involves the coordination between the Ministère de l'Environnement et de la Lutte contre les Changements Climatiques (MELCC), who is responsible for hydrometric monitoring, hydrologic forecasting, and communication, and the Ministère de la Sécurité Publique du Québec (MSP), who is responsible for flood notification, coordination and response actions. It was noted that all elements of the province's flood forecasting system are currently implemented for both gauged and ungauged rivers, and that it is active in coordinating research and development activities, including with academic groups, to continuously improve this system. In this context, the impact and value of new ECCC products and capacities can be considered as additions to potentially improve current operational systems, and in this light, studied through ongoing research activities and partnerships.

In Newfoundland and Labrador, flood forecasting systems for three unique river basins (Lower Churchill, Exploits and Humber), plus their Hurricane Season Flood Alert System were presented. Ice monitoring and ice jam forecasting was highlighted as an important and particularly unique aspect of flood forecasting in the province, with operational systems deployed on the Churchill and Exploits Rivers. It was also shown how the jurisdiction is using ECCC products, although not without challenges. For example, the province has used some ECCC products with success, but has had to commission custom products from an external engineering consultancy for their forecasting needs where they found deficiencies in others.

To conclude the morning session, a representative from 4DM demonstrated their near real-time community flood risk awareness tool for river environments (HydrologiX II), which has been adopted by the province of Newfoundland and Labrador. The presentation of the HydrologiX II framework highlights that while many jurisdictions may be exploring FEWS, others have explored and demonstrated success using alternate options, and that a community of practice should be generic enough to not favor one particular software. Further, the presentation from 4DM introduced the system to participants currently in an exploratory, development or re-development phase of an operational flood forecasting or early warning system, who might not have been aware of the system.

The afternoon session contained presentations from representatives from the research, development and operational teams of ECCC on various products available or in development to provide guidance for flood forecasting. Updates were presented on recent advancements in CaPA, which include the development of a high-resolution version of the product covering Canada at a spatial resolution of 2.5-km, which is in contrast to the 10-km product offered for North America, the addition of the assimilation of new precipitation networks in Ontario and Manitoba, and from 29 S-band radars in the US and five new S-band radars in Canada, and the inclusion of IMERG satellite information. An updated processing technique to improve the product in mountainous regions and an ensemble version currently in development were also highlighted.

A 10-km precipitation and land surface reanalysis product was presented that will provide 39-years of hourly atmospheric and surface variables that run from 1980, which can be used to condition forecasting models that will use ECCC forecasts. A subset of 18 years of the record

from 2000-2017 are already accessible from the Canadian Surface Prediction Archive (CaSPAr: https://caspar-data.ca/caspar).

The timelines associated with advancements in NSRPS, along with details of its land surface model, assimilation, and river and reservoir routing systems were also presented. These products are currently operational in the domains of the Great Lakes, and the St Lawrence, Nelson, Churchill, Mackenzie and Yukon Rivers, as well as the Gulf of St Lawrence. Products are currently in development for the Skeena, St John and Columbia Rivers. Other advancements of this system include an ensemble version, an updated land surface model, and improvements in the assimilation of satellite information and flow data. Additionally, a hydrodynamic model will be incorporated for the St Lawrence and Lake Erie domains.

Day 3

The final day of the forum contained presentations from representatives from the provinces and territories and included breakout sessions to facilitate focused discussions in smaller groups. The aim of the presentations was for the jurisdictional representatives to provide updates on recent advances, discuss existing challenges, and identify emerging issues faced at the regional and local scales in their flood forecasting and early warning systems.

A representative from British Columbia shared their success in upgrading and expanding the CLEVER model. These advancements included automating quality assurance/quality control (QA/QC) and gap filling in data streams, plus revising PCA statistical models for key provincial watersheds. Current work towards forecasting using weather ensembles, real-time watershed snow cover analysis, improved snowpack modelling and FEWS development were also highlighted.

In the Prairies, updates from Alberta included upgrades in its public-facing website (https://rivers.alberta.ca/), the status of its updated FEWS implementation, some results from their multi-model assessment project, and initiatives related to publicly available flood awareness mapping. The Saskatchewan update included the details of their flood forecasting and operations planning (FFOP). Information was presented on collaborations with academic partners to identify and address modelling gaps, the development of new forecasting tools and models, their strategy for prioritizing and selecting watersheds for new developments, and the timeline for implementing a FEWS system, as well as their overall next steps and future plans. Manitoba was invited to participate but not able to attend the morning session.

From the territories, the Yukon highlighted challenges in prediction and monitoring due to limited resources, sparse data and complex hydrological processes, and provided updates on the progress of hydrometric and meteorological data collection (including field measurements), as well as recent work on satellite imagery and ice products for river ice monitoring. Additionally, streamflow forecasting initiatives that were developed in collaboration with GWF for the Yukon and Porcupine Rivers were also presented. They also highlighted upcoming efforts to develop a FEWS pilot for the Yukon River using the MESH model. In their presentation, the Northwest Territories shared that they do not currently provide flood or flow forecasting services due to limited staffing capacity, sparse data, limited monitoring

capabilities, and knowledge gaps. Their focus is currently on field work to collect data and install monitoring stations at high priority locations, as well as to develop programs to analyze real-time hydrometric and climate conditions. They also highlighted efforts with academic and industry partners to integrate the Raven hydrological model within a FEWS environment for the Liard River Basin for open water conditions. Nunavut was invited to participate but did not have an update to share.

Ontario presented its unique approach where the Surface Water Monitoring Center supports flood forecasting at the provincial/regional scale, but also partners and coordinates with 36 conservation authorities, who have their own forecasting capabilities and responsibilities for flood messaging. Its "Flood Strategy" to provide a more resilient response to flooding was presented, which provides an overarching guide to current and future projects. Jurisdictional updates from Québec included a live 'online' demonstration of their forecasting system, which is based on FEWS and includes an interactive water level forecast and a prototype version of interactive GIS flood mapping. Québec is also striving towards an ensemble, probabilistic version of existing products.

In the Atlantic provinces, New Brunswick's flood forecasting system was presented, which combines the WISKI and FEWS systems. A brief demonstration of the system was provided during the forum and current forecasting work on the Saint John River was highlighted. Nova Scotia shared that they do not have a flood forecasting system or the capability to issue model-based flood predictions currently but do provide some flood estimates and related messaging based on past similar conditions (anecdotal community knowledge). Some ongoing initiatives include the improved provincial coverage of LiDAR, municipal flood mapping, and estimating and exploring resiliency and adaptive capacity. Newfoundland and Labrador presented on Day 2, while Prince Edward Island was invited to participate but chose not to attend since flood forecasting is not something they currently do, owing to the small size of their inland watersheds.

There were many areas of common interests as well as similar challenges across the provinces and territories. Many are increasingly using ECCC products, and some are actively partnering with groups in academia, industry and other communities on improving or development forecasting systems. There were also common challenges found, such as sparse data in large ungauged areas, inadequate human resources, limited skills, and the complexity of some basins.

The second half of the final day included **breakout sessions** of smaller focused groups where representatives of ECCC had the opportunity to directly engage with provincial and territorial partners and share information and perspectives across jurisdictions. Discussions were focused on highlighting priorities and identifying gaps and barriers regarding existing ECCC data products and services for flood forecasting, as well as soliciting feedback on products or services that could be improved or developed to better support them in their regional roles and responsibilities. Specific topics that were covered included the development of a Community of Practice, the current status of data services, hydrometric operations, and other related issues. Each group was asked three questions. These questions and a summary of the related discussions are summarized below.

What are key problems or barriers that exist now in relation to your jurisdiction providing hydrological flood forecasts?

There are large differences across the country between jurisdictions in terms of capacity, expertise, available time and priorities, roles, and responsibilities, as well as institutional differences. Some provinces and territories have year-round forecasting centers with dedicated staff, who have identified specific, immediate needs they wish to pursue. Other jurisdictions are at earlier stages of developing or are expanding their forecasting systems. Some have much smaller teams and resources, and only offer flood forecasting on a seasonal basis and/or for a small number of river systems.

Several participants identified limited resources and existing organizational capacity as barriers. Some participants also noted that their flood forecasting centers are operationally focused with little time to explore experimental products or to directly engage with research communities. It was noted that the current approach to obtaining forecasting solutions is broadening, for example, with the use of remote sensing products, global climate models, diverse hydrological models, and programming packages. This presents challenges in balancing their primary requirement of providing ongoing, real-time forecasting operations with the additional need to allocate time and resources to conduct research, investigate new products, perform assessment of suitability, and generally improve systems through new innovations or products. It was noted that some provinces do not have the same limitations in this regard and have partially to fully-sufficient resources to explore and engage in varying levels of research and development activities while supporting their operational duties. They also have interest in the Community of Practice concept and collaboration with ECCC, but with different goals such as collaborating on more extensive developments and innovations that could benefit many provinces and territories, including those with lesser resources.

A related barrier is the concern about the consistency and confidence in available data and products, as well as the sparseness of monitoring locations, particularly in northern regions. Coordination and communication surrounding the dissemination of ECCC products could be better, though this must be done by acknowledging the capacity issues of users to identify and assess the added value of new products as they become available. Many jurisdictions expressed limited resources and time availability as concerns. A desire was also expressed for more opportunities to discuss and evaluate products, and to implement and address issues collectively.

A shared challenge that was identified was the communication of materials to the public in an accessible and concise format. Communicating forecast uncertainty, to allow stakeholders to better assess their risk, is particularly challenging. Concerns were raised regarding the possibility of having multiple forecast products available and the potential for confusion with public awareness and consumption. It has been reiterated that ECCC does not plan to provide flow among their suite of forecast products publicly, but rather offer these data to the provinces and territories directly as added guidance to support their forecasting operations. Nonetheless, there are additional jurisdictional complexities or other unique situations across the country

(e.g., provincial, municipal; bi-national, inter-provincial; academia) that present challenges where a single national strategy may not meet the needs of every jurisdictional partner.

How can ECCC, through new products and services or improvements to existing ones, assist in helping solve or overcome these problems and barriers?

Many of the provinces and territories identified priorities or concerns in common. These included improvements to real-time flow and water level information, developments in ice jam monitoring and forecasting, the timeliness of corrected winter flow measurements, and improved and more readily accessible precipitation and snow-related products (SWE, snowmelt) and the clear quantification of their uncertainties. These concerns were common for many jurisdictions, but not universal. For example, some jurisdictions operate their own monitoring networks or produce their own regional analyses and do not share the same concerns. The question of how ECCC products are validated, particularly against what data, was also brought up.

Although the capacity to employ products varies, most provinces and territories are interested to see forecasts and analyses augmented with specific metrics to quantify uncertainty. Doing so may add confidence and address concerns about the quality of the data. For example, many partners noted discrepancies between precipitation products, such as CaPA when compared to observations. Further, some noted that regional station data was not being assimilated into CaPA or they were not sure if it was. Similar concerns about the quality of snow/SWE datasets and how snow observations are used in various products were raised. Improvements to both the CaPA and snow/SWE datasets are desired, so they provide better performance in hydrological modelling applications, particularly in mountainous terrain.

Partners noted that they have observed similar issues with other non-ECCC products as well, but also noted that they may not have the time or resources to conduct the analyses required to address these issues. Related to this, some partners noted that they would need to better understand the accuracy and reliability of products before applying them operationally. While it was understood that ECCC does a validation of its products, the results of this process and the methodologies used are not readily accessible or communicated in intuitive ways.

Despite the issues identified, there was an overwhelmingly positive reception to ECCC products overall, and most encouragingly, an expressed desire from partners to collaborate with ECCC further. Several partners offered to work with ECCC to ensure available observations were assimilated, and help was also offered to “ground truth” and validate currently available products. ECCC would welcome such efforts, noting these improvements would benefit all involved.

Most parties would welcome efforts to make ECCC products more accessible to provinces and territories, perhaps through a centralized, standardized and searchable product inventory and/or a user-friendly GIS display/visual dashboard, and with more streamlined, searchable and easier-to-find documentation. Partners are generally aware of some or many of the products available, and where to find them, but more concise and better organized product information

is desired. Complex websites that are difficult to navigate or are not searchable pose barriers for more widespread product use and discovery.

Additional improvements that were noted that would improve the usability of these products and services included reducing the latency/delay in their dissemination, ensuring 24/7 up-time/support, more timely data gap filling, and other back-end systems-related optimizations or improvements. It was noted that beyond making products and general documentation available, ECCC could also play a more direct role in providing guidance for establishing standards on the integration processes for different products, as well as coordinating the development and implementation of QA/QC approaches across jurisdictions.

How should a Community of Practice be set up and what key areas should it focus on in the next 3-5 years?

There was widespread support for a Community of Practice. Participants expressed a strong desire to be able to connect with other practitioners, engage in ongoing constructive conversations, particularly focused on addressing immediate priorities and needs and delivering results. The ability for practitioners to have focused direct lines of communication to other jurisdictions was expressed as well, as there are often few opportunities to do so. It was recognized that in order to improve flood forecasting across Canada, it is important to continue sharing information on evolving products, tools, applications, common experiences, best-practices, and evolving ideas across jurisdictions. It has been noted that there are a wide variety of issues and approaches across the country for dealing with flood forecasting, but some common elements as well. While some jurisdictions may choose to deal with the same issue differently, there are still benefits to continuing to understand what is working and what is not, so that others facing the same issues can learn from previous knowledge and experience.

Considering the expanding skillset required to produce forecasts, with the limited operational capacity at forecast centers to meet these expanding demands, ECCC and a Community of Practice could play a pivotal role in levelling the playing field. There seemed to be an interest, particularly from groups with smaller capacity, to leverage the larger community and benefit from the knowledge and experience residing in other jurisdictions who have faced similar issues and/or with more established systems. These collaborations could serve to overcome existing barriers.

There was no overall consensus on key focal topics owing to the wide variety of different concerns and challenges faced by different jurisdictions. There was, however, a recognition of this diversity and suggestions were given to address this by developing subgroups within a Community of Practice. This would allow jurisdictions to coordinate efforts aimed at common issues and concerns.

Several participants expressed a desire for more frequent communications, noting it was difficult to ingest a large amount of information within a short period of time. Ongoing communications were noted as being important for maintaining the momentum needed to follow up further and apply the information presented to real-world applications. Some suggested this could be achieved through additional webinars, which could be held semi-

regularly every three to six months. While the larger webinar format of an annual forum is useful, it was reiterated that a smaller format would be better suited for more focused, topical group meetings. Many are comfortable with virtual meetings, which they felt work well and help address the travel burden and restrictions that apply across the country.

Alternative communication approaches were also suggested, including newsletters, online discussion forum, and community-based repositories. Some suggestions included a semi-regular newsletter to highlight the latest research and products being developed at ECCC, protected but accessible collaborative tools to ease sharing and co-development and facilitate feedback, and online tools where emerging issues can be discussed, such as web-forums, Wikis and/or managed code repositories, like GitHub.

It was highlighted that jurisdictions would welcome the opportunity to use a Community of Practice to provide feedback to ECCC on its products and services, and that a formal system for the provincial and territorial partners to do this would be valuable. However, providing constructive feedback is often time-consuming and difficult. The existing feedback mechanisms must be streamlined and strategically aligned with the objectives of both the jurisdictional partners and ECCC.

Finally, it was noted that there are similar examples of the Community of Practice approach already implemented by other groups or in different countries, and these should be used to inform how to make this work efficiently and effectively (i.e., learn by example).

In parallel to the above breakout sessions, a separate **GWF modelling breakout** was also held to discuss how the research community can meaningfully contribute to national forecasting needs and global systems. Several research advances have been made and are continuing in developing forecasting capability. For example, while for many forecasts the focus is on sub-daily streamflow, GWF has been developing both statistical and process-based seasonal forecasting systems for North America in partnership with ECCC and NCAR. These larger timescale forecasts will be beneficial for planning and management of water resources, particularly for reservoir operation, agriculture, and drought forecasting.

New advances in ice jam flood forecasting were also discussed. Canada and many cold-region countries are susceptible to ice jam flooding, but due to process complexity, limited data and inadequate modelling capability, ice jam flood forecasts are rarely provided. Recent advances through GWF have provided some potential avenues for operational forecasting of ice jam floods. River ice model has been embedded in the operational forecasting of the lower Churchill River in Labrador, which is probably the world's first ‘operational’ ice jam flood forecasting system. Real-time ice-cover breakup and ice jam flood forecasting systems were also developed and tested for the Athabasca River in Alberta. Ongoing work includes the development of an agnostic ice-jam forecasting system, so it can be coupled with any model for any region across Canada.

Another area of active research has been on the assimilation of snow data in operational forecasting. Several GWF researchers are actively working to develop an improved data assimilation system, generate distributed SWE forecasts for ungauged catchments and improve

forecast skill. These advances could directly contribute to the forecasting needs of provinces and territories. However, it was noted that there is often some disconnect in translating research outcomes into useful products based on operational needs.

It was noted that future forums would benefit from extending the breakout sessions. Further, that additional breakout sessions should mix practitioners and researchers so that ongoing research would be better informed by the knowledge and lengthy experience of the provincial and territorial forecasters. The suggestion of semi-regular topically-driven meetings and/or subgroups within a Community of Practice could potentially serve this purpose.

Plenary

The forum concluded with a **plenary** to discuss the feedback from the breakout sessions. It was identified that a continuous and engaging process is needed to foster collaboration between provinces and territories, ECCC, and academia, and their partners nationwide. For example, the forecasting work done by GWF in coordination with ECCC on the Yukon River, where an operational model was setup in collaboration with the territory, is an example of research-practitioner collaboration. Another notable example is the collaborative and ongoing work between ECCC, the Northwest Territories and provincial partners related to the recent Great Slave Lake high water levels that have impacted many Northern communities. As a final example, the province of Québec and ECCC have a long-established relationship of advancing research and applying developments and innovations in practice that has benefited both parties, and a similar strategy could benefit other provinces and territories as well.

While several provinces and territories are still struggling with their forecasting needs due to limited human resources or skills, there may be opportunities for them, ECCC and the research community to more closely collaborate, share resources, and create synergies to advance flood forecasting in spite of these limitations. Where provinces and territories do not face such limitations, it allows these collaborations to focus more directly on advancing sciences and producing novel results using or building on existing systems, which can benefit the community as a whole. The “National Flood Forecasting Community of Practice” should facilitate this type of information sharing and collaborative efforts for addressing common problems and continuing to develop state-of-the-art flood forecasting and early warning systems. Some of the advances Canada is making in hydrological forecasting in cold regions could also be of a global interest, so continuing to engage with global partners should be another critical aspect of this process.

Contributors:

Alain Pietroniro[1], Brenden Disher[2], Charmaine Hrynkiw[2], Daniel Princz[2], Evan Friesenhan[2], Francois Nzokou Tanekou[2], Jacob Bruxer[2], Matthew Noteboom[2], Sheila Ball[2], Prabin Rokaya[3]

[1] Department of Civil Engineering, Schulich School of Engineering, University of Calgary, Calgary, Alberta, Canada

[2] Environment and Climate Change Canada

[3] Global Institute for Water Security, University of Saskatchewan, Saskatoon, Saskatchewan, Canada

Cover Photo: Louise Arnal, Centre for Hydrology, University of Saskatchewan, Canada