NSERC/Rio Tinto Industrial Research Chair on Climate Change and Water Security

Annual Report – Year 4

(1 July 2022 – 30 June 2023)

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2022-2023 IRC Annual Report

Preamble

June 30th, 2023 marks the completion of the fourth year of the Natural Sciences and Engineering Research Council of Canada (NSERC)/Rio Tinto Industrial Research Chair (IRC) in Climate Change and Water Security at UNBC. The 5-year program of research started on July 1st, 2019 with the objective to better understand and quantify the roles of climate variability, climate change, and water management on the long term water security of the Nechako Watershed. Among other research topics, we are elucidating some of the complex interactions between climate change and human interventions on flow volumes and water temperatures in the Nechako River using a combination of in situ observations and computer modelling. This annual report provides a progress update on personnel recruitment and training, program management, our field activities and research, communication strategy and community engagement, and the budget.

Personnel and Training

During the third year of activity, a number of highly-qualified personnel (HQP) were retained or recruited to support the IRC program of research. In supporting roles, Kelly Hurley (until 16 September 2022) and Justin Kokoszka (as of 17 October 2022) acted as the research managers (RMs) for the group while Justin also took on the role of outreach coordinator (OC) and data manager (DM). In February 2023, Jade Reynolds was recruited to act as Data Administrator in support of our data management efforts.

Training of graduate and undergraduate students is central to the objectives of the IRC. An undergraduate student from UNBC, Jade Reynolds, and a coop student from Okanagan College, Meghan Hunter-Gauthier, were recruited as field assistants to support our spring/summer 2022 field activities while a research skills trainee recruited in summer 2022, Gracie Wilson, led the effort to collate and quality control water temperature data for the Nechako Watershed. Abhishek Arora was also recruited as an undergraduate research assistant in summer 2022 to act as Data Administrator. During the winter of 2023, three undergraduate students, Dylan Broeke, Jade Reynolds and Laura-Anne Browning, were recruited as field and research assistants. Their positions will run until the end of August 2023. They are responsible for conducting field work across the Nechako Watershed including site visits for data collection. During the 2022/2023 academic year, Spencer Woyke completed an undergraduate thesis titled “Hydrometeorological analysis of landfalling atmospheric rivers in the upper Nechako Watershed” using data collected during the TRARE field campaign in autumn 2021. Finally, each HQP has been trained on data management to enhance their skills and proficiency in handling and organizing data efficiently including: data entry, data validation, and general database operations.

Two graduate students have been recruited so far under the IRC umbrella. As of May 2020, a MSc student, Justin Kokoszka, leads a project on the naturalization of flows in the Nechako River using a water balance approach. Meanwhile, Bruno Sobral began in 2020 his PhD program investigating

atmospheric rivers affecting the Nechako Watershed. Two post-doctoral fellows (PDFs) continued working for the IRC program of research over the past year. Dr. Rajtantra Lilhare (until 31 March 2023 on a part-time position) led the historical hydrological modelling efforts while Dr. Jingwen Wu worked on hydrological modelling in the context of future climate projections. Dr. Tamar Richards-Thomas has also joined the team as a part-time Research Skills Trainee exploring three atmospheric rivers that impacted the upper Nechako Watershed during the TRARE field campaign in autumn 2021. Recruitment of graduate students will continue this summer to ensure all IRC projects are completed in two years.

Research Management

The Science Advisory Board (SAB) formed in late 2019 oversees the progress of the IRC program of research and met on two occasions during the reporting period. The SAB comprises five members: Mr. Andy Lecuyer (Rio Tinto), Dr. Ellen Petticrew (UNBC), Mr. James Rakochy (Cheslatta Carrier Nation), Mr. Chelton van Geloven (BC Ministry of Forests), and Dr. Francis Zwiers (Pacific Climate Impacts Consortium). The SAB along with representatives from the UNBC Office of Research and Innovation, Mrs. Jacqui Dockray and Mr. Mark Barnes, met on 23 November 2022 and on 25 May 2023, respectively, to hear and evaluate progress thus far with the IRC program of research through online presentations by Dr. Déry and the IRC team. The SAB will continue meeting with the Chairholder and his personnel twice annually to ensure the IRC objectives are met, to provide feedback, and to assess progress. The SAB reports to the UNBC Interim Vice-President of Research and Innovation, Dr. Kathy Lewis.

Theme 1: Hydrometeorological Monitoring and Data Collection

During our fourth year of activity and despite ongoing challenges with COVID-19, we maintained a network of 30 water temperature loggers, five tipping bucket rain gauges (although two were damaged), and two complete meteorological stations across the entire Nechako Watershed (Figure 1). Improved monitoring of water temperatures and hydrometeorological conditions across the Nechako Watershed is central to Theme 1 of the IRC program of research. Not only are these data providing high-resolution information on the spatio-temporal variations in water temperatures and rainfall in the Nechako Watershed but are also assisting with modelling efforts (Themes 2 and 3).

Servicing of the water temperature loggers, tipping bucket rain gauges and meteorological stations was once again generously supported by several First Nations and by Rio Tinto. Cheslatta Carrier Nation provided boat access to reach sites in the upper Nechako Watershed including streams flowing into Tahtsa Lake and to the south shore of the Nechako Reservoir. Tl'azt'en First Nation also provided boat support and staff time to reach Kazchek Creek and the Middle River where water temperature probes were also deployed. Nak'azdli Whut'en provided staff support when accessing streams near Fort St. James. Finally, two staff members from Stellat'en First Nation joined some of the field visits at the Endako and Stellako rivers.

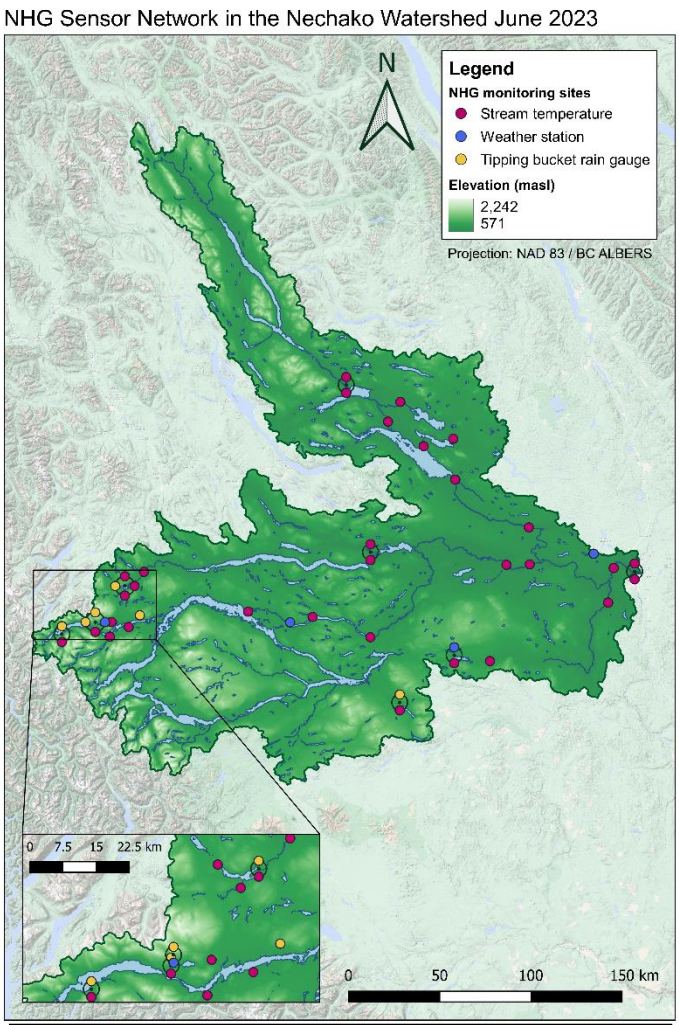

Figure 1: Map of current water temperature logger, tipping bucket rain gauge and meteorological station sites across the Nechako. Watershed.

Following collaborative planning efforts between the Northern Hydrometeorology Group and members of the Cheslatta Carrier Nation, a weather station was successfully installed on the unceded territory of the Cheslatta Carrier Nation on 15-16 May 2023. The new weather station is located off the west end and the northern side of Cheslatta Lake, and it is now fully operational. This station consists of a variety of sensors, a data logger, and a solar panel installed on a 3 m tripod. Sensors include a snow depth sensor, two temperature probes, a net radiometer, and a compact digital weather sensor (ClimaVUE50). Together, these instruments measure the following parameters: snow depth, soil and air temperature, net radiation, relative humidity, vapour pressure, barometric pressure, wind speed, wind direction, total precipitation, and lightning strikes. The new station will provide useful meteorological data in an area where a data gap previously existed. It will also help us understand atmospheric drivers of water temperature fluctuations in the Cheslatta system. This project will also serve to promote continued data-sharing and collaboration with our partners at the Cheslatta Carrier Nation, whom we are very grateful for.

We continue our efforts to organize our monitoring data into a centralized database, promoting data shareability, and enhancing data quality. This initiative ensures easy access to information, facilitates collaborative research, enables efficient analysis, and ensures the longevity of data collected through the IRC program. Additionally, the database includes a system to track and maintain equipment, ensuring accurate and reliable data collection.

Theme 2: Atmospheric and Terrestrial Rivers

Justin Kokoszka has been working on his graduate thesis project which is currently in the data

analysis and thesis writing phase. The project seeks to naturalize streamflow along the Nechako River, evaluate the impact of regulation on ecologically significant variables, assess the long-term changes caused by climate change, and examine the relationship between streamflow and hydroclimate teleconnections. Through an extensive literature review and a successful proposal defense on May 23rd, 2023 the project has established a solid foundation.

Data collection and data analysis development have been major accomplishments, encompassing historical streamflow within the Nechako River Basin as well as extraction of various climate variables, from the ERA5-Land Reanalysis dataset, relevant to streamflow alteration, climate change, and climate variability. These datasets are crucial for the ongoing data analysis, which utilizes a water balance approach for naturalization and advanced statistical techniques to investigate alterations in ecologically significant variables resulting from regulation, climate change, and climate variability. Concurrently, Justin is actively engaged in thesis writing and interpretation of results. The completed project aims to provide insights valuable for water resource management that are linked to ecological significance within the Nechako River Basin. Justin aims to defend his thesis in December of 2023.

During the academic period of 2022-2023, PhD student Bruno Sobral focused on submitting two manuscripts to peer-reviewed journals. In early 2023, chapter 2 of his dissertation, titled "Spatio-temporal Distribution and Trend Analyses of Atmospheric River Activity in British Columbia's Nechako Watershed," was submitted to the *International Journal of Climatology*. This manuscript uses 72 years (1950-2021) of climate data from the ERA5-Land product and reveals a decrease in mid-intensity and an increase in low-intensity atmospheric river (AR) events near the Nechako River Basin (NRB). It also highlights the rising trend in total precipitation and rainfall associated with low-intensity ARs, while snow and snow water equivalent show no significant trends. The manuscript further explores the impact of low-intensity ARs on the snow/rainfall ratio in the Upper Nechako and Upper Stuart sub-basins, potentially affecting seasonal snowpacks in the future. In late May, chapter 3 of his dissertation, titled "Contributions of atmospheric rivers to the hydroclimatology of British Columbia's Nechako Watershed", was submitted to the *Journal of Hydrology: Regional Studies* and is currently under review. This manuscript uses the same climate data and indicates that the NRB experiences AR influence on its climate variables for an average of 33 days per year, mainly in fall and winter. ARs contribute to just over one-fifth (21% - 152 mm) of the annual total precipitation, 26% (97 mm) of rain, 15% (55 mm) of snow, and 13% (43 mm) of snow water equivalent in the NRB. The seasonal analysis reveals that ARs are linked to 10% (14 mm) of total precipitation during spring, 16% (26 mm) during summer, 37% (82 mm) during fall, and 17% (32 mm) in the winter.

Theme 3: Water Temperature and Hydrological Modeling

Since July 2022, Dr. Jingwen Wu has utilized various tools and datasets to examine the future hydrometeorological conditions in the Nechako River Basin (NRB) under two greenhouse gas

emission scenarios. He collected projected climate data from 17 climate models and calculated the average changes in precipitation and air temperature for future periods (2041–2070 and 2071–2100) compared to historic climate (1981-2010). Findings indicate that the NRB is likely to experience a warming of approximately 3.38°C during 2041-2070 and 5.68°C for 2071-2100, accompanied by a wetter climate with projected annual precipitation increases of 12% and 19% for both periods under a high greenhouse gas emission scenario. The Variable Infiltration Capacity (VIC) hydrological model was also implemented in the NRB. After calibration and validation, the model produced reliable simulations (1950—2100) of hydrological processes. The results indicate a 2.8% and 8.2% increase in annual mean streamflow for both periods (2041–2070 and 2071–2100) compared to historical streamflow (1981-2010) in the NRB under the high greenhouse gas emission scenario. Furthermore, the peak flow magnitude decreased by approximately 6% and 20% for both periods, mainly due to increased temperatures causing earlier snowmelt. The gradual release of water from snowmelt over an extended period leads to a reduction in peak flow.

Communication Strategy

We maintain a comprehensive communication strategy to ensure information on the IRC program of research is disseminated widely and in a timely fashion. This includes a new website, presence on social media (e.g. Twitter, ResearchGate and Rio Tinto's Facebook page), and a Slack workspace to facilitate interactions between the IRC team members. Dr. Déry is also profiled on NSERC's online Chairholder database. The IRC team prepares a quarterly newsletter posted on the IRC website and emailed to our extensive distribution list (135 individuals and organizations) to disseminate further information on the IRC to the general public. Dr. Déry was interviewed about a dozen times over the past year by various media outlets including on his perspectives of recent unusual weather and streamflow conditions in northern BC. Furthermore, a distinct effort continued over the past year to develop short videos focusing on the TRARE field campaign after 3 days of filming by the UNBC Communications Office in the upper Nechako (an example video produced during TRARE is available here: https://www.youtube.com/watch?v=Pq6zda71Zp0).

Dr. Déry delivered several presentations over the past year to a range of stakeholders in the Nechako Watershed and beyond. For instance, he delivered two online public presentations on IRC-related research for the Climate Science Informal Seminars held at UNBC in February 2023 and during UNBC's Research Week in March 2023. The latter event included an interactive presentation by six members of the IRC team with a trivia game focused on various aspects of the Nechako Watershed. Dr. Déry and Bruno Sobral delivered a total of five guest lectures in various courses at UNBC during which IRC-related research was profiled. Finally, they both presented the findings of their IRC research at the 2023 annual meeting of the Canadian Geophysical Union in Banff, Alberta in early May 2023.

As results are now emerging from the IRC program of research, conference presentations and peer-reviewed publications are in development. The following provides a list of recently submitted papers and others in preparation in addition to conference presentations from the past year.

Journal Articles

Déry, S. J., Martins, E. G., Owens, P. N., and Petticrew, E. L., 2023: Freshwater temperature response to four extreme hydrometeorological events in 2021 across the Pacific Northwest of North America, in preparation.

Gilbert, D. E., Morris, J. E., Kaveney, A. R., and Déry, S. J., 2022: Sub-hourly water temperature data collected across the Nechako Watershed, 2019-2021, *Data in Brief*, **43**, 108425.

Hurley, K. M., Morris, J. E., Cardinal, É., Gilbert, D. E., Kaveney, A. R., Sobral, B., Thompson, H. D., Thériault, J. M., and Déry, S. J., 2022: Hydrometeorological data collected during the Tahtsa Ranges Atmospheric River Experiment (TRARE), to be submitted to *Earth System Science Data*.

Sobral, B. S. and Déry, S. J., 2023: Spatio-temporal and trend analysis of atmospheric river activity in British Columbia's Nechako Watershed, *International Journal of Climatology*, in revision.

Sobral, B. S. and Déry, S. J., 2023: Contributions of atmospheric rivers to the hydroclimatology of British Columbia's Nechako River Basin, submitted to *Journal of Hydrology: Regional Studies*.

Conference Presentations

Déry, S. J., Gilbert, D. E., Morris, J. E., Kaveney, A. R., Kokoszka, J., Browning, L.-A., and Reynolds, J., 2023: Nechako Watershed stream temperature monitoring and research, 2019-2023, 2023 annual meeting of the Canadian Geophysical Union, 9 May 2023.

Déry, S. J., Martins, E., Owens, P. and Petticrew, E., 2023: Freshwater temperature response to four extreme hydrometeorological events in 2021 across the Pacific Northwest of North America, 2023 annual meeting of the Canadian Geophysical Union, 10 May 2023.

Sobral, B. S. and Déry, S. J. 2023: Atmospheric river contribution to hydroclimatic variables in the Nechako Watershed, 2023 annual meeting of the Canadian Geophysical Union, 9 May 2023.

Community Engagement

The success of the IRC relies on a broad communication strategy and community engagement. To that end, efforts are routinely made to communicate with First Nations as to where field work and other research is being undertaken as part of the IRC. Over the past year, we maintained our engagement with four First Nations: Cheslatta Carrier Nation, Stellat'en, Nak'azdli Whut'en, and Tl'azt'en First Nations. This has been of particular importance due to concerns expressed by some First Nations relating to outside activities in traditional territories during the COVID-19 pandemic. As well, Dr. Déry and Justin Kokoszka participated in the Koh Learning event held at Stellat'en

First Nation on 31 May 2023. The entire IRC team attended an online presentation titled "Nechako Reservoir 101" by representatives from Cheslatta Carrier Nation on 4 May 2023.

We continued to entertain a wide range of discussions with many individuals and organizations across the Nechako Watershed during field work across the upper Nechako Watershed. This included a site visit in August 2022 at Huckleberry Mine for discussions with the mine's general manager, Mr. Marke Wong. We also connected with staff members of the Fisheries and Oceans Canada's Nadina River Spawning Channel where a tipping bucket rain gauge is installed. As well, we interacted on a daily basis with Brad and Wendy Thompson at Nadina Lake Lodge during our stay there while undertaking field work. We anticipate continued interactions with members of the community this summer as we return to our field sites for data collection and as we prepare for the deployment of the MECHE observatory at Huckleberry Mine.

Dr. Déry remains fully engaged in Rio Tinto's Water Engagement Initiative (WEI) and participates in main table and technical working group meetings. He has also participated in periodic meetings related to climate change research in the Nechako Watershed in support of the WEI process. The annual reports and the IRC quarterly newsletters are distributed to the entire WEI mailing list. Additional information on the IRC is posted on Rio Tinto's Get Involved website. Further, Dr. Déry and Justin Kokoszka participated in the Nechako Watershed Roundtable's (NWR's) annual meeting on 26 October 2022 while Dr. Déry also attended the morning session of the NWR's spring technical meeting on 25 May 2023. Dr. Déry has also engaged in the UNBC-Nechako Valley Working Group by attending its bi-monthly meeting and participating in an ad hoc group on weather stations in the Vanderhoof agricultural belt.

Industrial Partner Engagement

Dr. Déry interacts on a regular basis with the industrial partner via email, phone, online and in person meetings. The principal contact person at Rio Tinto for research is Andy Lecuyer, while for outreach, interactions are facilitated by Lianne Olson (Advisor Communications/Communities) and Devrie Sanghera (Communities & Social Performance Advisor). Additional communication with Alec Mercier and Marco Latraverse on the water management team proceeds on a periodic basis for the exchange of data and metadata, information on Rio Tinto's operations and system in the Nechako Watershed, and to identify monitoring and information gaps in the basin. Drs. Déry and Wu each met in March 2023 with staff from Rio Tinto to discuss ongoing research and exchange recent findings.

Over the past year we maintained close collaboration with Scott Klassen of Avison Management Services for periodic site visits of UNBC meteorological equipment at Chedakuz Creek, Eutsuk Narrows and at Mt. Sweeney. Jenifer Bond at Triton and Alec Mercier also have provided access to water temperature data for several sites in the Nechako, Cheslatta and Kemano Watersheds. Alec Mercier also provided up-to-date streamflow data at the Kemano Powerhouse and inflow data

for the Nechako Reservoir that are being integrated into multiple IRC projects. Finally, Andy Lecuyer has provided continuous support by sharing his knowledge on Rio Tinto's operations across the Nechako Watershed.

Budget

The IRC program of research is supported equally by NSERC and Rio Tinto with a total budget of $1.5M over five years. Approximately half of this budget is allocated to support Dr. Déry's salary and benefits. With the release of these funds and to fulfil the requirements of NSERC's IRC program, UNBC hired in September 2020 a new tenure-track faculty member (Dr. Siraj ul Islam) to build institutional capacity in hydrometeorology. As of 19 June 2023, available funds for Year 4 were disbursed mainly for the support of HQP (87.6%) with other expenses related to field work, materials and supplies, travel to conferences, etc. (12.4%). As of 19 June 2023, we expended 99.5% of the overall allocated funds for Year 4 of the IRC with any year-end surplus or deficit of funds to be carried to Year 5. To date, we have expended 101% of the Years 1-4 proposed budget.

While NSERC and Rio Tinto provide the bulk of the funding for the IRC program of research, extra support was provided through Project Learning Tree Canada (two successful applications totaling $12K in 2023). An application to Global Water Futures has secured additional funding that is partly supporting Bruno Sobral's PhD project focusing on the terrestrial response to atmospheric rivers in the Nechako Watershed. A proposal for a $194K equipment grant to the Canada Foundation for Innovation and the BC Knowledge Development Fund was successful. This will provide additional resources to monitor atmospheric rivers in the upper Nechako Watershed and to assess components of the water budget for Nechako headwater catchments. In late spring 2022, we secured $15K through to the Partnering Fund of the Real Estate Foundation of BC to purchase a complete meteorological station for Cheslatta Lake. The meteorological data collected in Cheslatta territory will benefit the IRC program of research by providing additional observations in the upper Nechako Watershed that will be especially useful in interpreting water temperature fluctuations in the Cheslatta system.