DR STEPHEN DÉRY

Cheslatta River at Cheslatta Falls, tributary and source of the Nechako River, northwestern British Columbia.

Canadian climate change

Dr Stephen Déry, Canada Research Chair in Northern Hydrometeorology, discusses research projects on the Quesnel River Basin in British Columbia and wider concerns for freshwater supply in the area

Could you outline your background and how you came to be Canada Research Chair in Northern Hydrometeorology?

I hold a BSc, MSc and PhD in Atmospheric Science. Prior to arriving at the University of Northern British Columbia (UNBC), I was a postdoctoral fellow at the Lamont-Doherty Earth Observatory of Columbia University, New York, and then a visiting research scientist at Princeton University in New Jersey. I began my position as Canada Research Chair in Northern Hydrometeorology upon arrival at UNBC in 2005. I am also Associate Professor in Environmental Science and Engineering, and Natural Resources and Environmental Studies; and I lead the Northern Hydrometeorology Group (NHG) at UNBC.

You are working on a range of different research projects. Can you provide an overview of the areas you are investigating?

My research focuses on the impacts of climate change on Canada's northern and alpine regions. The anthropogenic emission of greenhouse gases has caused the global surface air temperature to rise by ~0.6 °C during the 20th Century, and it is expected to rise further this century. The temperature rise in the polar and alpine regions of the Northern Hemisphere is projected to be greater than anywhere else on Earth. I am thus investigating the consequences of climate change on the water cycle in these regions. In particular, I am attempting to determine what effect climate change will have on the environment in Canada's northern and alpine regions: on snow, ice and water.

One of your main research endeavours is to quantify the changing role of snow and ice in the water cycle of the Quesnel River Basin (QRB), located in the Cariboo Mountains of BC. What are the aims of this endeavour?

The QRB is a large sub-watershed of the Fraser River Basin. The QRB has the world's largest fjord lake (Quesnel Lake) and its major tributary experiences one of the largest salmon runs of the entire Fraser River Basin. UNBC operates the Dr Max Blouw Quesnel River Research Centre in the heart of the watershed, providing a base for field activities and research within the QRB. We aim to determine long-term fluctuations, trends and feedbacks in the hydroclimate of the QRB using a network of 10 automatic weather stations. These are located at elevations of between 750 m and 2,100 m, giving information on the air temperature, precipitation and snow accumulation gradients in this highly remote region. This will also yield data on the state, and fate, of the region's seasonal snowpacks and glaciers, which are expected to recede at an accelerating rate with global warming.

What have you achieved during your analysis of the QRB?

Research shows that the QRB has experienced significant warming during the 20th Century, which has led to large declines in snow depth in Quesnel, on the western margin of the watershed. Concurrently, streamflow has risen by 8-14 per cent across the watershed in response to more abundant precipitation. Snow cover duration across the QRB varies linearly with elevation, and melts earlier as spring air temperatures are warmer than average. The timing of the spring freshet for the Quesnel River at its outlet to the Fraser River occurs one month after snow covers only half of the Basin, providing predictability for floods.

Freshwater supply is a very real concern in BC. What has your research into snowpack characteristics in northeastern BC revealed?

Northeastern BC is undergoing rapid development in the oil and gas sectors with subsurface extraction (through fracking) requiring abundant freshwater. This is often sourced from readily available surface waters in lakes, ponds, rivers and wetlands. These bodies of water are replenished annually in the spring following snowmelt (snow forms a large component of the annual surface water budgets of these systems). However, analysis shows significant changes in recent decades. Snowpack annual peak accumulation has risen by 14 per cent during late winter and early spring. A key objective of our work is to develop a comprehensive water budget for Coles Lake of northeastern BC, where our industrial partner is extracting surface water for natural gas extraction.

How are you engaging students in your research and encouraging them to take up a career in hydrometeorology?

I have supervised 35 undergraduate and graduate students, postdoctoral fellows, and research and field assistants. My approach varies considerably from one person to the next. In all cases, I spend as much time as required with each student, providing encouragement and support along the way. I also foster group interactions to enhance the sharing of knowledge and skills.

Hydrologic cycles

Researchers from the **University of Northern British Columbia** are providing fresh insights into snow and ice processes in Canada, and the impact of climate change on these processes. Their recommendations will aid water resources management, flood predictions and inform policy on issues such as adaptation measures

HYDROMETEOROLOGY, THE STUDY of the cycle of water in the Earth-atmosphere system and the water budget (the inputs, outputs and net changes to a water resource), forms the basis of flood control and water-usage structures. Water quality and supply are of growing importance to the field with the advent of climate change and the expansion of industrial practices.

Snow and ice are ever-present and vitally important features of the Canadian landscape. Processes involving snow and ice have a large bearing on the hydrometeorology of high latitude and elevation watersheds (areas which separate waters flowing to different rivers/basins). Despite advanced knowledge of these processes, there remain many fundamental areas that require further study. Addressing these areas is urgent, as northern high latitudes are experiencing an unprecedented period of climate change. This in turn generates a pressing need to quantify the role of snowcover on surface energy and water budgets, both now and in the future.

In response, the University of Northern British Columbia (UNBC) Northern Hydrometeorology Group (NHG), led by Canada Research Chair in Northern Hydrometeorology Dr Stephen Déry, has geared its research efforts towards better understanding the processes that govern snow and ice.

DIVERSE PROJECTS

The NHG's research concentrates on the role of climate change in the high-latitude and alpine water cycle. Current NHG projects include Cariboo Alpine Mesonet (CAMnet), a network of automatic weather stations positioned at strategic locations within the Quesnel River Basin in central BC. Déry's own research within the NHG is specifically focused on developing a better understanding of the water balance in the Quesnel, Nechako and Fraser River watersheds of BC.

MOUNTAINS AS WATER TOWERS

Mountains receive a disproportionate amount of precipitation, giving them the appellation of 'water towers'. They store freshwater in snowpacks and glaciers, providing meltwater that feeds many streams and rivers. The changing climate brings with it increased demands for freshwater resources, and understanding the role of mountains in the water cycle of watersheds is crucial to ensure these resources can be provided.

This particular research programme, entitled 'Climate change and the water towers of western Canada', aims to quantify the changing role of snow and ice in the Quesnel River Basin (QRB). The NHG's work will be placed in the wider context of the entire Fraser watershed, providing valuable data on the evolution of western Canada's mountains. Although great progress has been made, particularly in showing large declines in snow depth and greater variations in streamflow, more research is needed. Determining the effects of deforestation, industrial activities and climate change on the QRB water resources is crucial. The resultant projections will shape climate change adaptation measures.

FLOOD WARNINGS

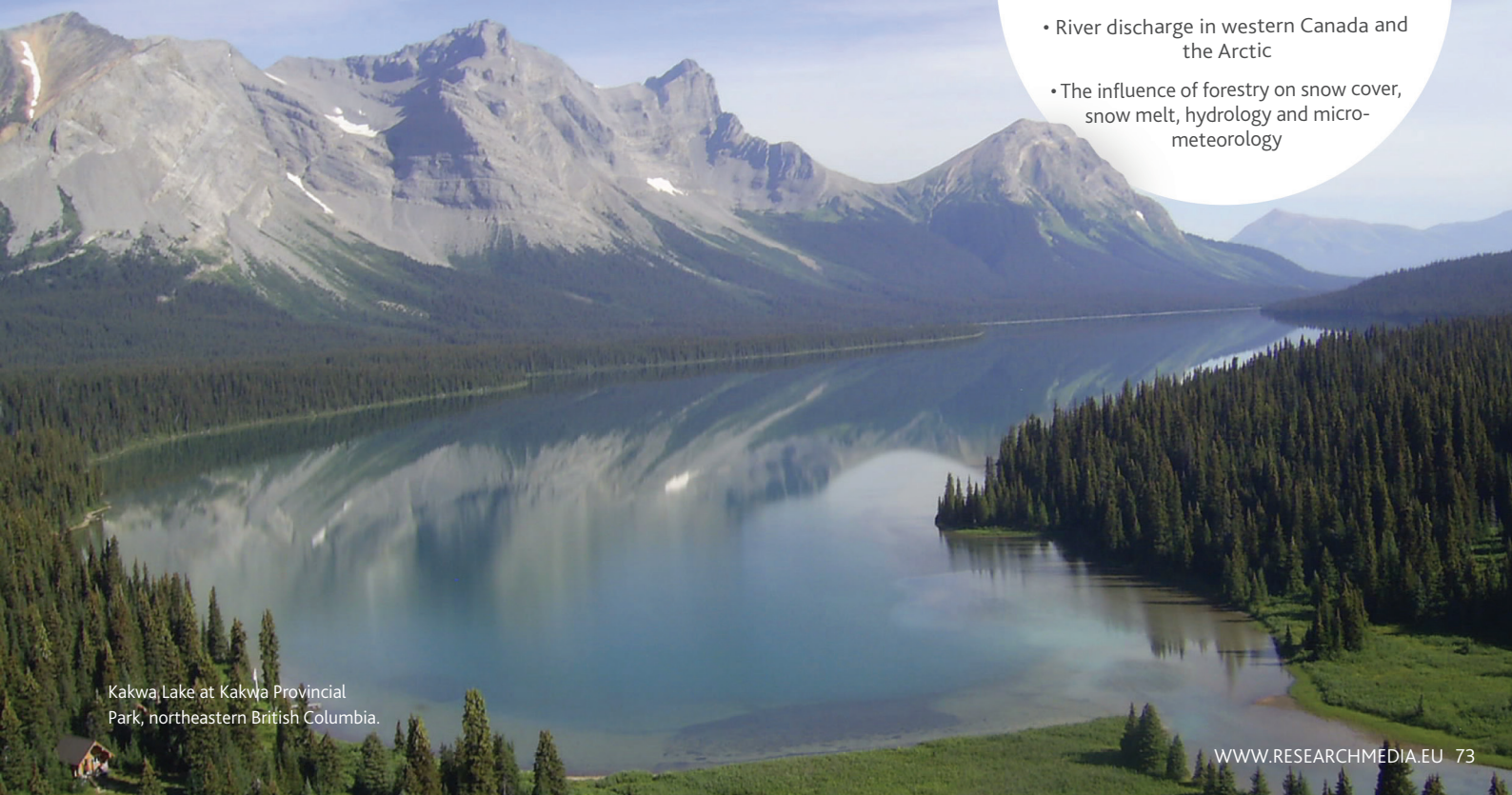
An important focal point of the NHG's work is the Fraser River, the longest waterway in BC. The Fraser River is economically vital to BC, as Déry elaborates: "The Fraser River is the largest salmon river in the world and freshwater extracted from there is used in many industries, including forestry, agriculture and mining".

Previous work has shown the Fraser River Basin to be a snow-dominated system. However, this

Diverse expertise

By virtue of its diverse members, the NHG has expertise in:

- Meteorology and meteorological monitoring
- Snow physics – redistribution of snow by wind and remote sensing of snow covers
- River discharge in western Canada and the Arctic
- The influence of forestry on snow cover, snow melt, hydrology and micro-meteorology



Kakwa Lake at Kakwa Provincial Park, northeastern British Columbia.

NORTHERN HYDROMETEOROLOGY

OBJECTIVES

- To quantify the water budgets and streamflow variability and trends of northern and alpine watersheds
- To establish the impacts of climate change on snow, ice and water resources
- To monitor weather and climate in the mountainous terrain of north-central British Columbia

KEY COLLABORATORS

The UNBC Integrated Watershed Research Group: **Dr Stephen Déry**; **Dr Philip Owens**; **Dr Margot Parkes**; **Dr Ellen Petticrew**

Other key UNBC collaborators: **Dr Darwyn Coxson**; **Dr Peter Jackson**; **Dr Brian Menounos**; **Dr John Rex**

Key collaborators at other institutions: **Dr Ross Brown**, Environment Canada, Ouranos • **Dr Chris Derksen**, Environment Canada • **Dr Paul Kushner**, University of Toronto • **Dr Laxmi Sushama**, University of Quebec at Montreal • **Dr Dennis Lettenmaier**, University of Washington • **Dr Eric Wood**, Princeton University • **Dr Tim Stott**, Liverpool John Moores University • **Dr Francis Zwiers**, Pacific Climate Impacts Consortium

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STEPHEN DÉRY has three degrees in Atmospheric Science: a BSc and MSc from York University and a PhD from McGill University. He joined UNBC in 2005 as Canada Research Chair in Northern Hydrometeorology, focusing on how rising temperatures affect the water cycle. He also has appointments as Associate Professor in the Environmental Science and Engineering undergraduate programme and the Natural Resources and Environmental Studies graduate programme at UNBC.

could be affected by climate change. In light of this, the NHG aims to evaluate the changing contribution of snow to the hydrology of the watershed. Hydrological model simulations from 1950-2006 have revealed significant declines in the contribution of snow to runoff generation in the major sub-watersheds. Changes in snow accumulation have also been shown to cause a 30-day advance of the spring freshet (the flood of a river from heavy rain or melted snow).

Analysis of streamflow at 139 sites across the Basin revealed a trend of greater year-to-year variations in streamflow, developed in response to a temperature increase in the Basin. The century worth of data suggest intense flooding experienced in recent springs may become more common. Paradoxically, but equally damaging, extremely low water flows are being observed in some parts of the Basin. The research, published in *Environmental Research Letters*, showed that these extreme fluctuations are negatively affecting salmon returns, water quality and resident safety. Continued efforts on behalf of the NHG will examine climate projections for the 21st Century. The future of the Basin is a great source of concern to Déry: "As the climate continues to warm, ecological processes and human usage of natural resources in the Basin may be substantially affected by its transition from a snow to a hybrid, and even a rain-dominated, watershed". Aside from climate change, there are other factors exacerbating this process, including the recession of glaciers and a mountain pine beetle outbreak.

THE NECHAKO RIVER BASIN

The Nechako River forms the second largest tributary of the Fraser River. It is a productive salmon and white sturgeon river, and its freshwater is used in a plethora of industries within the watershed. Despite its significance, very little is known about streamflow trends, including flood occurrence. To address this knowledge gap, the NHG has established a research project to examine the annual, monthly and daily discharge data of the River. The data will be used to answer the following questions: is climate change leading to more or less surface water availability?; and what is the impact of anthropogenic over natural influences on the Basin's water resources?

Déry explains how he will integrate his research efforts with others in this project: "Our research team will build on relationships with

Automatic weather station deployed by Stephen Déry (left) and Ben McGrath (right) at Coles Lake, northeastern British Columbia.

researchers, government partners, regional health authorities and local First Nations. Conducting research with others working in the watershed facilitates a more comprehensive understanding of the system, during this project and beyond". Data from 12 hydrometric gauges will be extracted from the Water Survey of Canada's Hydrometric Database (HYDAT) and the hydrological extremes at each will be assessed using methods developed by the NHG. Analysis will generate important information on historical flood frequencies, and allow comparisons with model projections.

Although the project is in its infancy, preliminary findings have already revealed warming of 1.7-2.3°C between 1970 and 2009, which has significantly changed the amount and phase of precipitation. Déry describes his hopes for the project: "Future work will establish a full water budget for the entire Nechako River Basin and explore potential future climate change".

INFLUENTIAL FINDINGS

Looking ahead, Déry will continue to seek a better understanding of streamflow variability and trends. He will also forge ahead with his existing research projects analysing climate change in the Cariboo Mountains, and is working to provide real-time access to meteorological data from CAMnet.

More recently, it has been revealed that the UNBC will form part of two inter-university research networks, which have the potential to influence climate change policy. Déry will be co-investigator in the Canadian Sea Ice and Snow Evolution (CanSISE) Network, where he will explore the effects of climate change on weather phenomena in North Canada. He will also partner with the new Canadian Network for Regional Climate and Weather Processes, where he will be part of a team working to improve the simulation of snow. The results will be important for citizens and policy makers alike.

Premier Range of the Cariboo Mountains, British Columbia.

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