

The Impacts of Climate Change on Canada's Snow and Ice Resources

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Mountain Snow and Ice are Critical for Canada's Water Resources



https://upload.wikimedia.org/wikipedia/commons/1/15/NorthAmerica-WaterDivides.png

High Mountains: Where the rapidly changing atmosphere intersects with the cryosphere, key ecosystems, diverse societies and the headwaters for rivers that support over half of humanity



Dichotomy of Mountain Water Security – sustenance and risk

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- Mountains provide water supply for over half of humanity.
 - Diminishing supplies due to climate change and consumption, both in mountains and downstream
- Increasing mountain flood deaths and damage from unprecedented precipitation and streamflow -







Urgency and Significance

- Melting cryosphere already past many tipping points.
- Changing ecosystems treeline and shrub advance into alpine tundra, warmer streams, increasing snow/glacier algae
- Loss of snow and glacier damming effect is challenging current approaches to mountain water management

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- High mountains hydrological cycle activation is advancing streamflow timing and increasing flood risk
- Sustainability of mountain and downstream communities for water, food and energy security requires better information and predictions.



Global Mountain Climate and Water Security Challenges



Rising temperatures at high elevations Drought, increasing ET, wildfire Impacts on snow, ice, water Mountain snowcover decline in many regions Earlier, slower melt Restricted redistribution Rapid deglaciation of high mountain regions Changing water supply GLOFs Rising sea levels

Global Mountain Climate and Water Security Challenges



Degradation of water quality – agricultural runoff, industry, sewage Increasing competition for water resources – transboundary issues. Increasing risk from extreme events Decoupling of streamflow from snowmelt and glacier melt timing Unsustainable use of water – food, energy, industry, drinking.

Unprecedented environmental change.

Amplified climate change in high mountains – rapid glacier melt, declining snowpacks, more rainfall.

International Collaboration

- -enhanced observations -data sharing -prediction services -water management
- -communication



Upper Heihe River Basin, 4150 m China



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Schneefernerhaus, Zugspitze, 2650 m Germany





Gullfoss, Iceland, 195 m

Athabasca Glacier, 2200 m Canada

Integrated High Mountain Observations & Predictions











Snow Redistribution and Ablation Model www.snowcast.ca





Societal Relevance of a High Mountain Integrated Observation and Prediction Initiative

How can scientific results be mobilized so that they are relevant for decision making?

How can we promote sustainable development under conditions of rapid social, agricultural, industrial, cryospheric, hydrological and climate change?

How can we build capacity to manage and adapt for the impacts of climate change in high mountain regions?





Wolf Creek Research Basin (WCRB), YT subarctic tundra



Marmot Creek Research Basin (MCRB), AB subalpine forest



Reynolds Mountain East (RME), Idaho mountain rangeland



North American Cordilleran Transect



NARCCAP Pseudo-future Climate SWE from 11 Downscaled RCM-GCMs for 2040-2070 from 1970-2000



CRHM-Modelled Streamflow

Climate Change: reduced, earlier streamflow Vegetation Change: reduced streamflow

Climate Change: **enhanced**, earlier streamflow Vegetation Change: reduced streamflow

Climate Change: reduced, much earlier streamflow Vegetation Change: reduced streamflow



Rasouli et al., 2019

Peyto Glacier







CRHM Glacier Modelling







Peyto Glacier Snow and Ice Ablation



Pradhananga & Pomeroy, in preparation

Simulation with and without glacier

Peyto Glacier: Mean Discharge [2013-2017]



Pradhananga & Pomeroy, in prep.

Water Piracy in the High Mountains!



Kluane Lake and Slims River Basins, Yukon Territory, Canada



Loukili and Pomeroy, 2019

Where is the Water?



Slims River Valley June 2018

Observed lake levels - Water Survey of Canada

Coupled Atmospheric-Hydrological-Glaciological-Lake Modelling for Mountains



4 km grid size. GRU set up for slope, aspect, elevation. Glacier component of MESH used for first time on a major icefield



-Decline in Kluane Lake Basin area from 5,969 to 4,822 km².

-Decline in glacier coverage in Kluane Lake Basin from 908 to 63 km².

-Decline in Slims River median peak flow from 350 to 60 m³ s⁻¹.

-Reduction in median Kluane Lake peak level of 1.6 m.

-Forward shift in timing of peak lake levels from July to early June

-Lake levels in the future will not be notably higher or lower than the current projections.

Marmot Creek Research Basin, Canadian Rockies



CRHM Simulation of Streamflow





0.133

0.52

0.71

-0.03

All seasons

Pseudo-Global-Warming 2070-2099



to give new WRF model initial and lateral boundary conditions

Future Marmot Creek Snowpack - less snow, earlier melt

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Future Marmot Creek Streamflow – greater, earlier discharge



Fang and Pomeroy, 2019

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Conclusions

- A warming cryosphere results in earlier streamflow
 - serious problems with downstream infrastructure, hydroelectric generation, industry and irrigation water use.
- An increase or decrease in annual streamflow volume is not assured by decreasing snowpacks,
 - Increased rainfall results in greater peak flows and low flows.
 - Streamflow volume scales with precipitation volume
 - Increasing vegetation reduces streamflow.
- Melting glaciers currently result in enhanced streamflow due to ice wastage, but not always and this is changing –
 - this has changed for Kluane Lake will end elsewhere in a few decades as the glaciers retreat
 - streamflow from glaciers will drop dramatically.
- These changes have led and will lead to unsustainability of freshwater, even where it is abundant.
- WE ARE FAILING TO MEET SUSTAINABLE DEVELOPMENT GOALS RELATING TO WATER AND CLIMATE IN MOUNTAINS AND IN COLD REGIONS – THIS THREATENS OUR ECOSYSTEMS AND OUR CIVILISATION





To address these problems we need a Canada Water Agency

FUNCTION

A water policy, science and technical centre of excellence to provide centralized observation, creation, collection and dissemination of water information between federal, provincial and territorial agencies, Indigenous governments and organizations, river basin organizations, universities, industries and the public.

GOAL

Predict and respond to water security problems and opportunities.

- Coordinate all water monitoring
- National water info repository
- Modeling, forecasting and prediction service for streamflows, lake levels, floods, droughts, water quality
- Collaborative, large scale river basin planning

Integrated river planning and

management.

GOAL

- Strengthen rivers basin institutions
- Support traditional knowledge collaboration (e.g Guardians program)

The Future?



We need this future



Not this future

Artwork courtesy Gennadiy Ivanov, UK



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