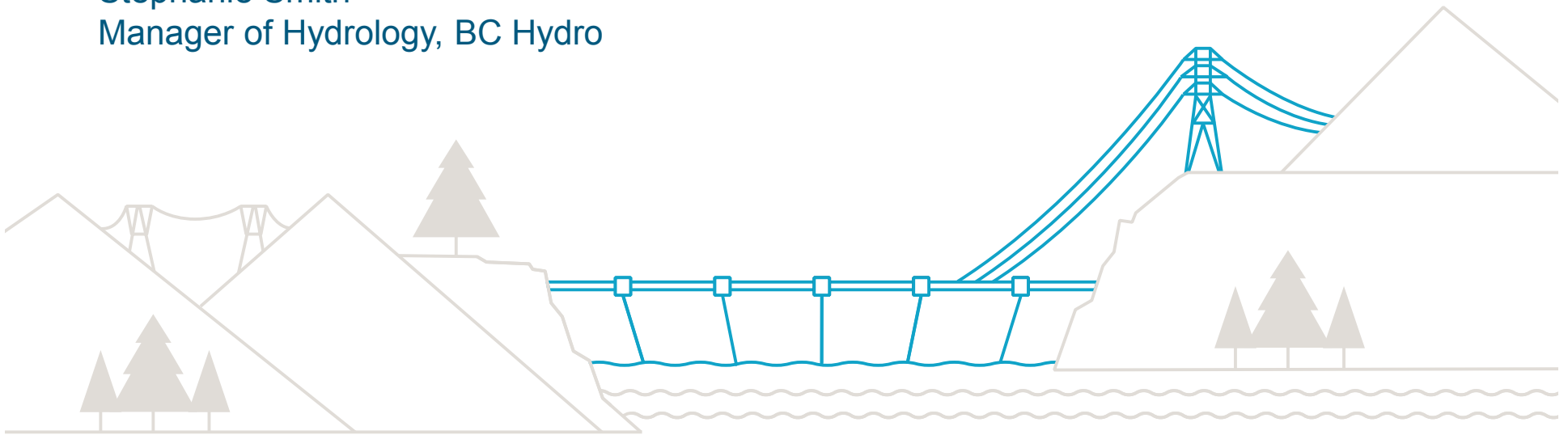


Climate Change in the Columbia Basin

Stephanie Smith
Manager of Hydrology, BC Hydro



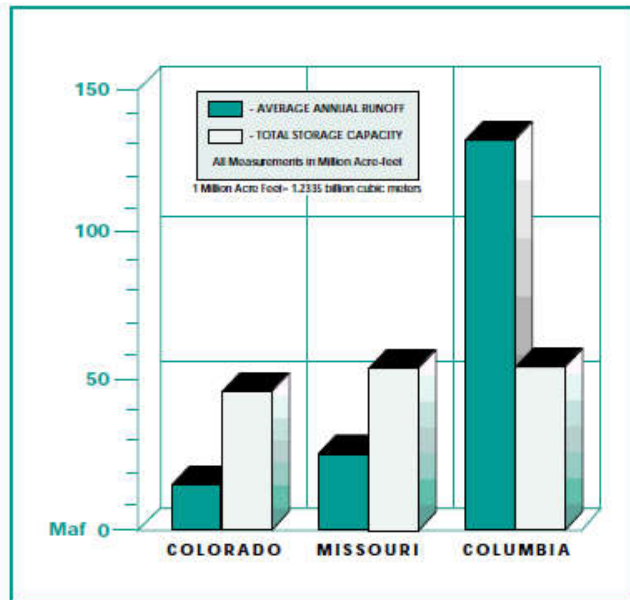
June 20, 2017

Outline

- Climate change in the Columbia River basin
- What has happened?
- What could happen?
- What can we do about it?

COLUMBIA RIVER BASIN

Columbia River Runoff and Storage Compared to the Colorado and Missouri Rivers



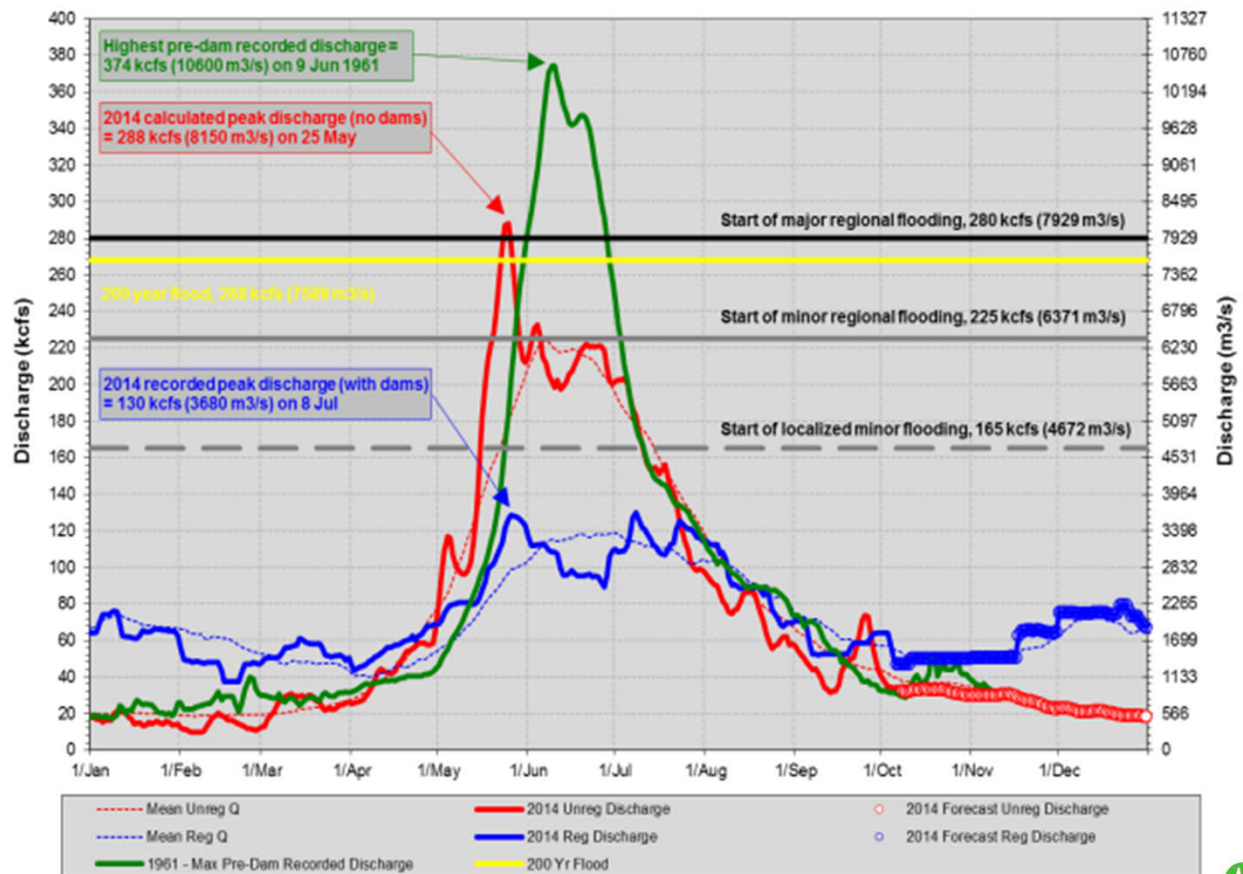
The Columbia River has high runoff and a small amount of storage compared to two other large river systems, the Colorado and Missouri.



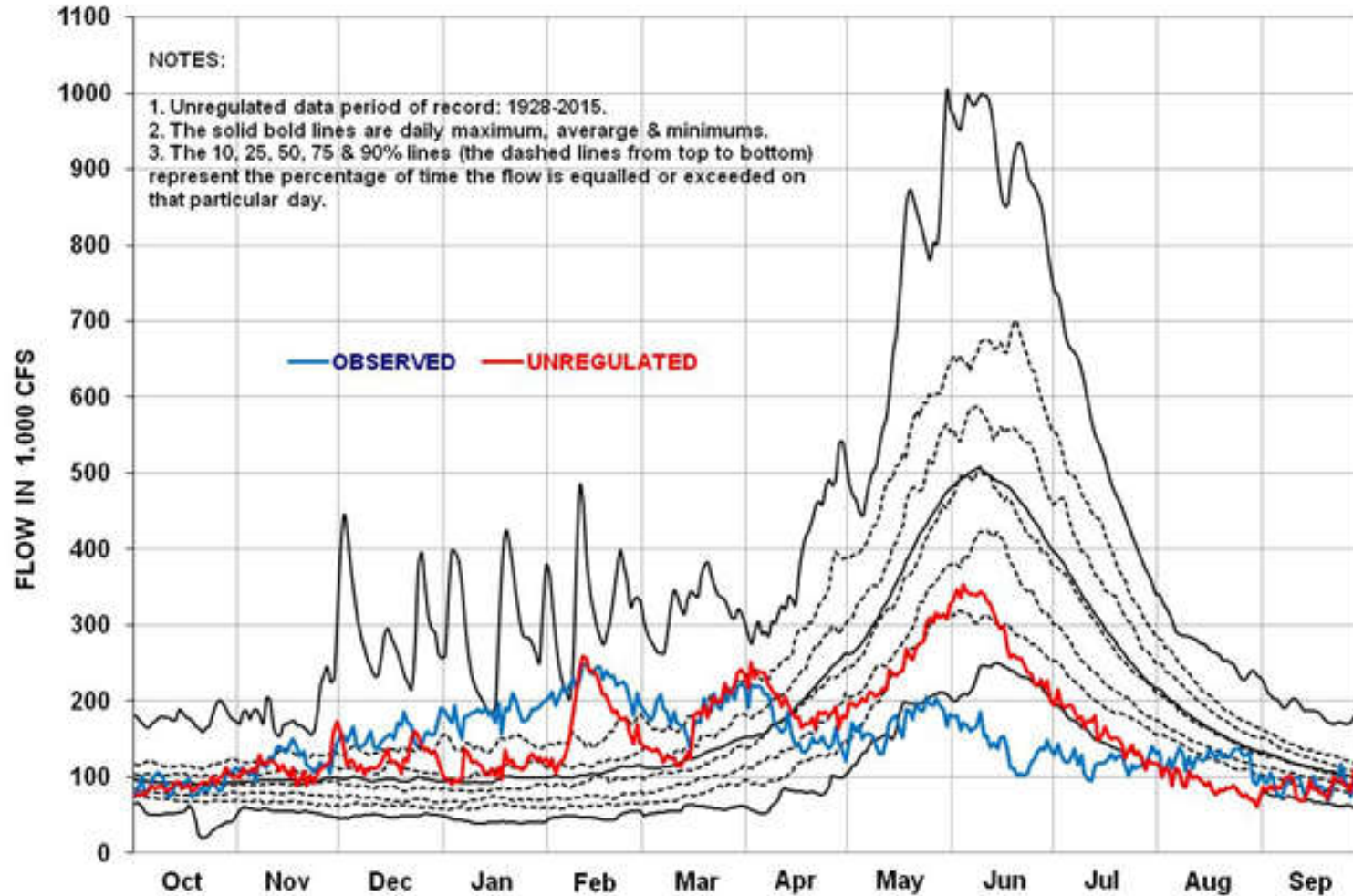
Source: US Army Corps of Engineers

Columbia River at Birchbank

COLUMBIA RIVER AT BIRCHBANK AVERAGE DAILY DISCHARGE
 (Brilliant Project + Brilliant Expansion + Brilliant Spill + Arrow Lakes Hydro + Hugh Keenleyside)
 Summary 1937 - 2013 (unregulated) & Summary 1967 - 2013 (regulated) and Actual / Forecast 2014



COLUMBIA RIVER STREAM FLOWS AT THE DALLES



Climate Change Assessments

1995 - IPCC second assessment

1990s- early 2000s – Canadian Climate Impacts and Adaptation Research Network (C-CIARN) – initial assessments of change and impacts

2001 – IPCC third assessment / 2007 – fourth assessment

2007-2011 – PCIC /BCH Hydrologic Impacts Assessment

2008-2011 – WC2N Columbia Glacier assessment

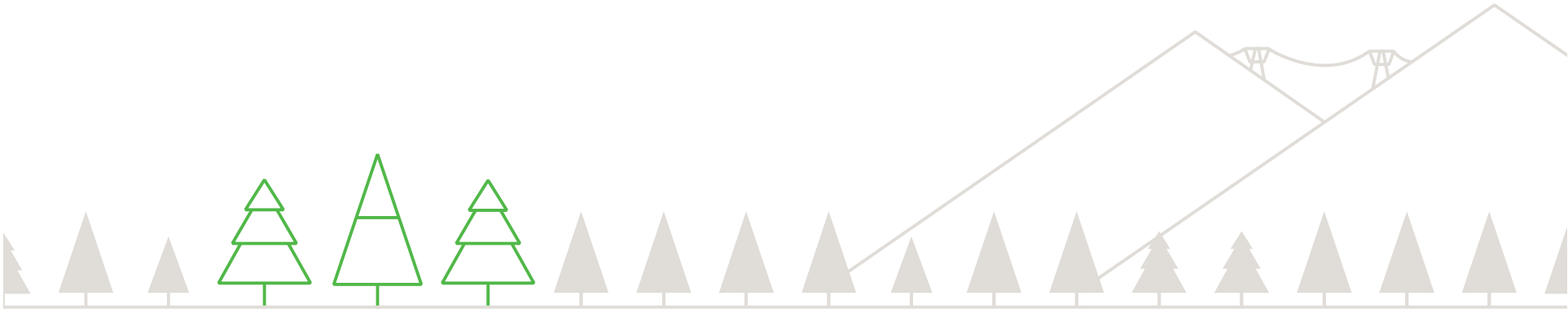
2008-2011 – RMJOC Joint U.S. Studies

2013 – IPCC fifth assessment

2014-2017 – RMJOC II Joint U.S. studies

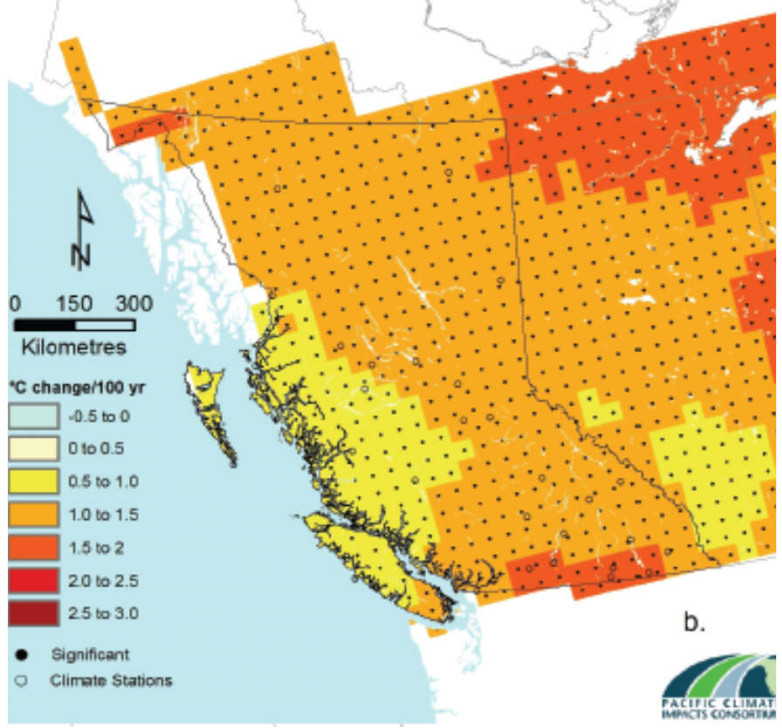
2015-2018 – PCIC / BC Hydro Updated assessments

2007 - 2012 Studies

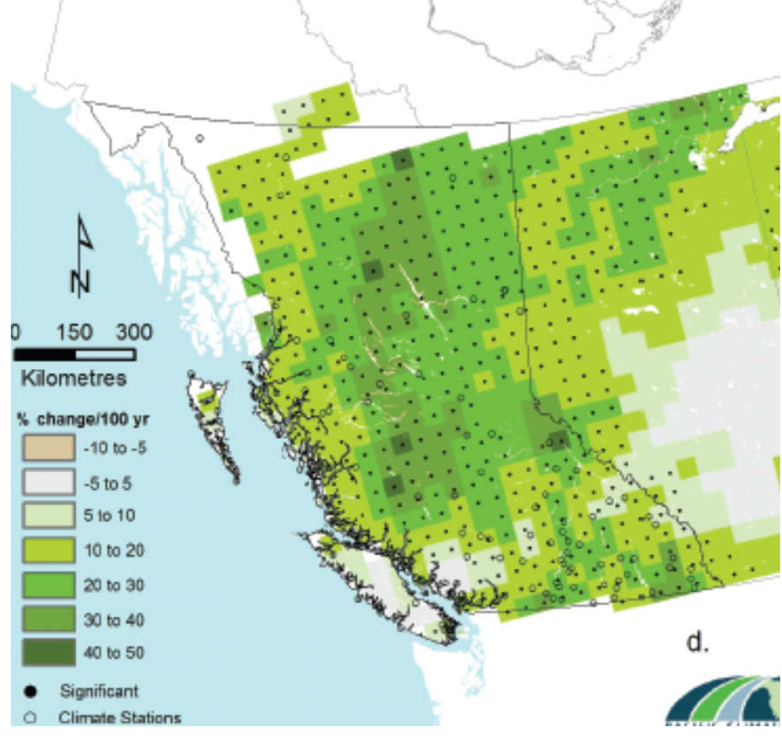


Historical Trends in BC

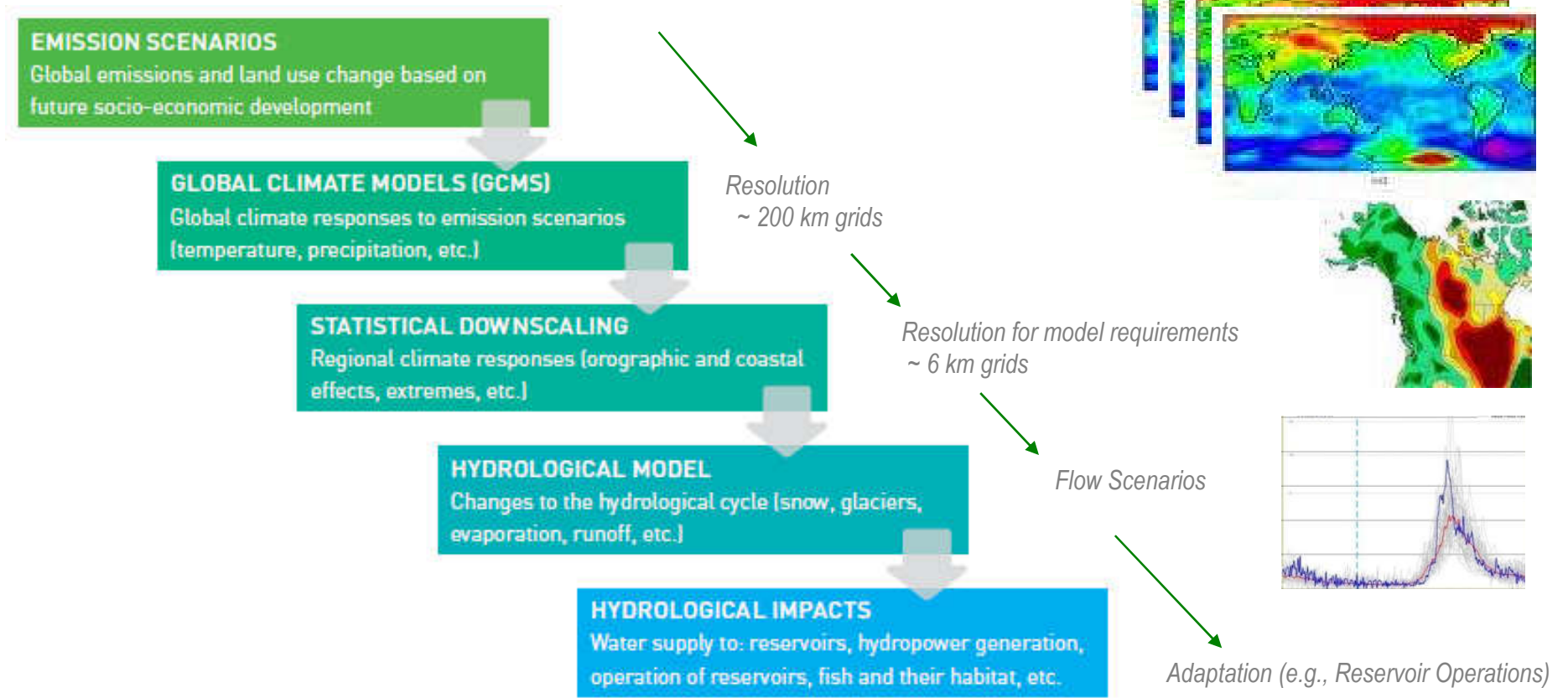
Annual mean temperature (1900 - 2004) trend



Annual precipitation (1900 - 2004) trend



Hydrologic Impact Assessment Process



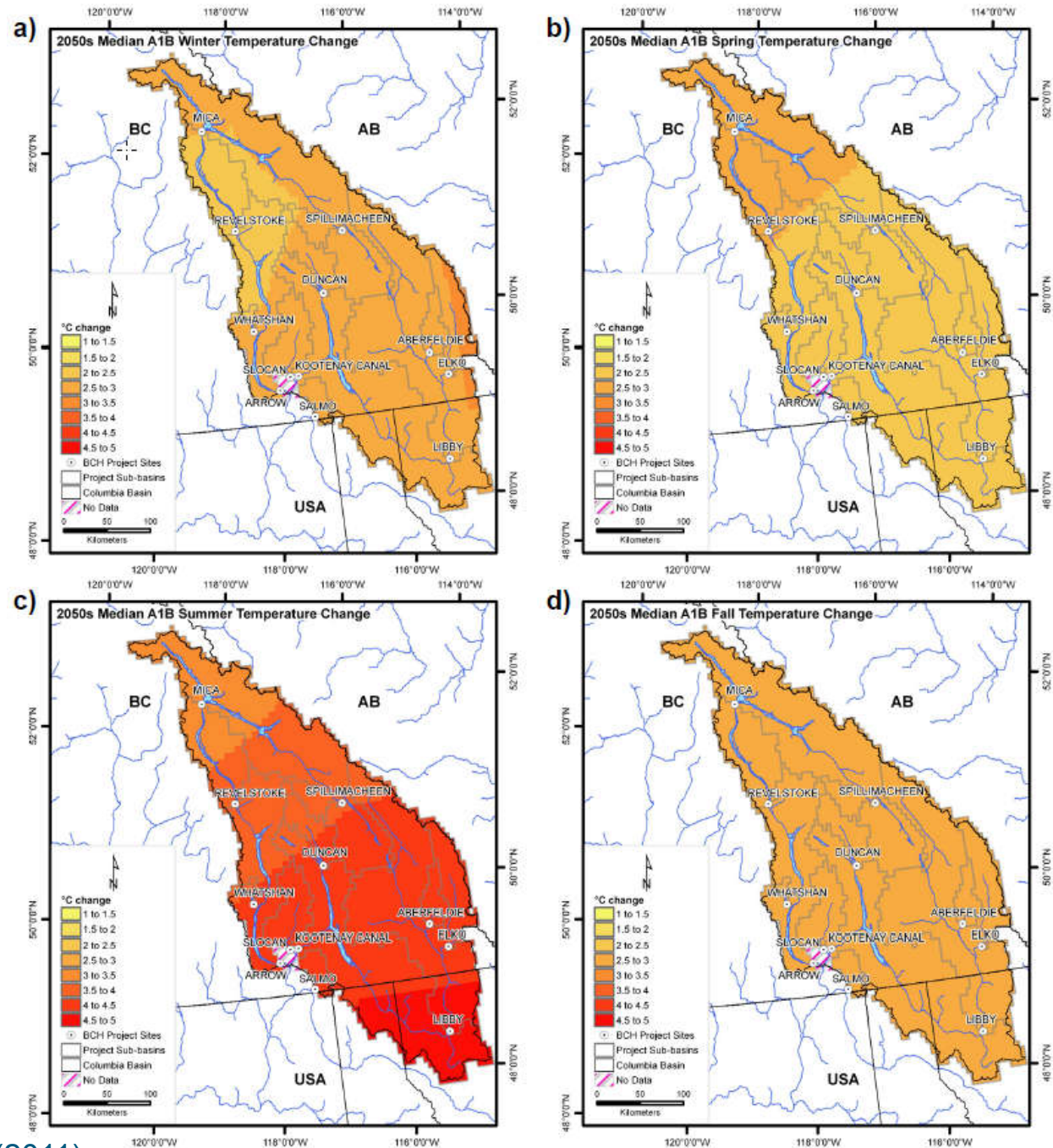
You can't do it alone

- Pacific Climate Impacts Consortium (PCIC)
 - BC-wide hydro-climatic trend analysis
 - Multi-watershed modeling study
- Western Canadian Cryospheric Network (WC2N)
 - Modeling study of coupled glacier & hydrologic change at Mica basin
- University of Washington (UW) & River Management Joint Operating Committee (RMJOC)
 - Multi-watershed modeling study
 - Development of planning data sets for US agencies in Columbia River basin



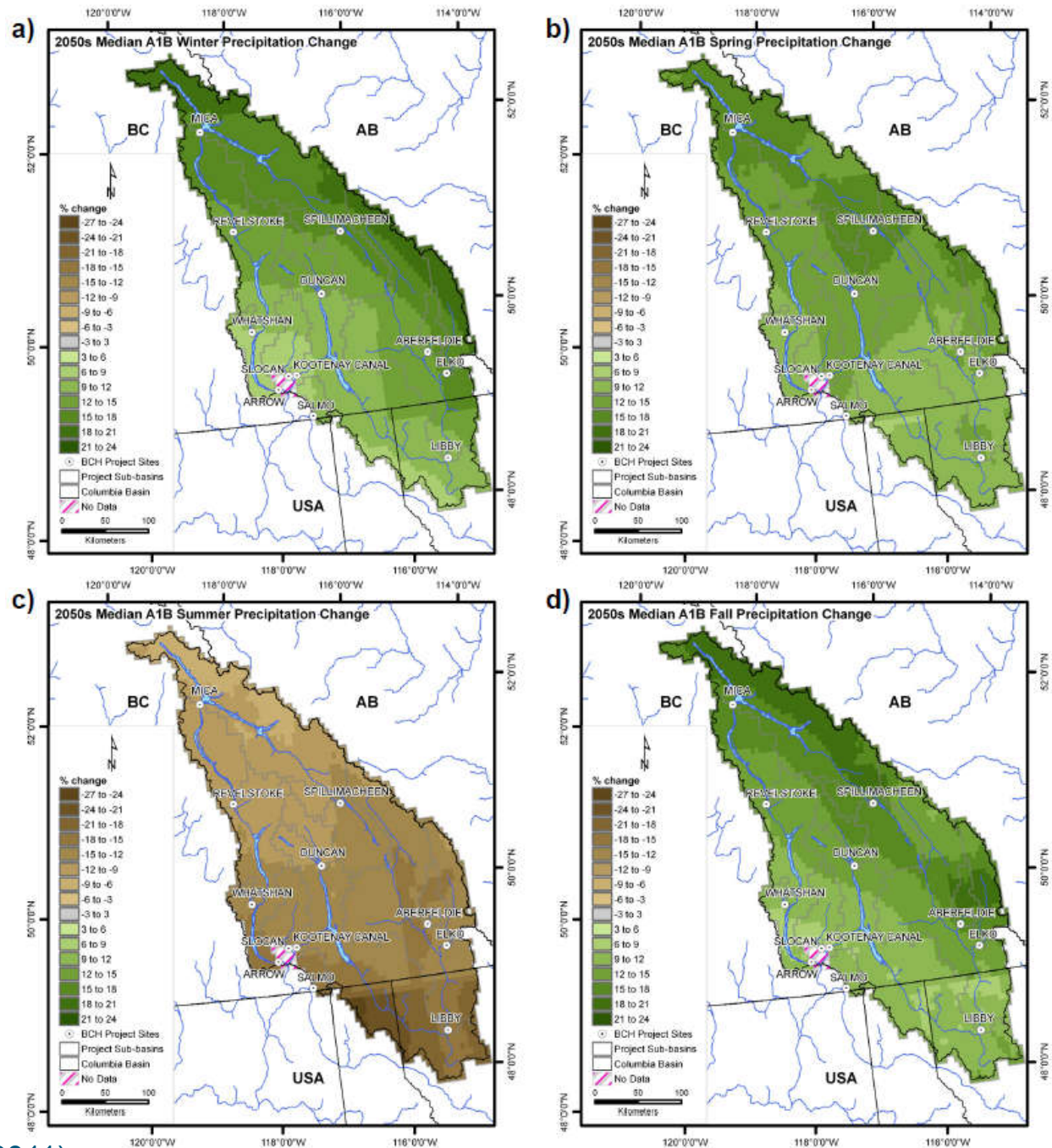
Projected Climate Trends

Change to median
temperature in
2050's
(compared to 1961-
1990)



Projected Climate Trends

2050s Precipitation

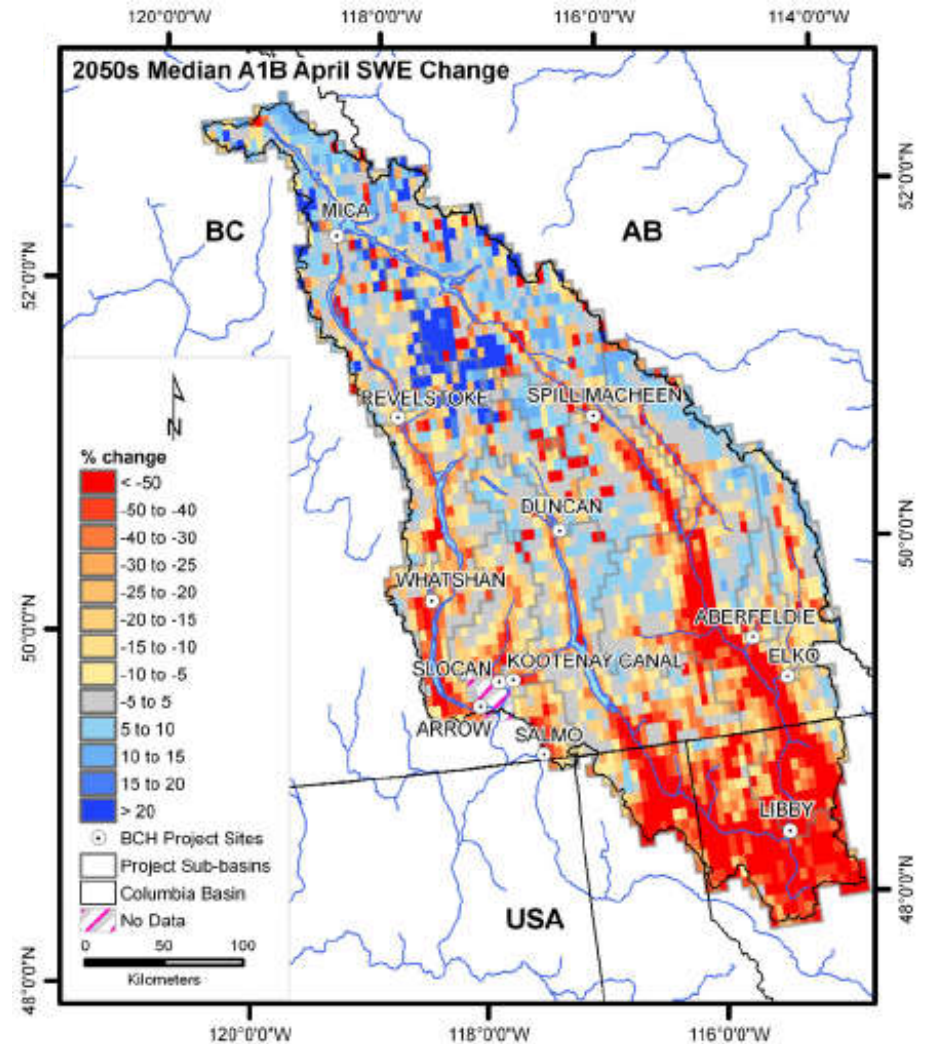


Projected Trends in April Snowpack

Median April 1 Snow Water

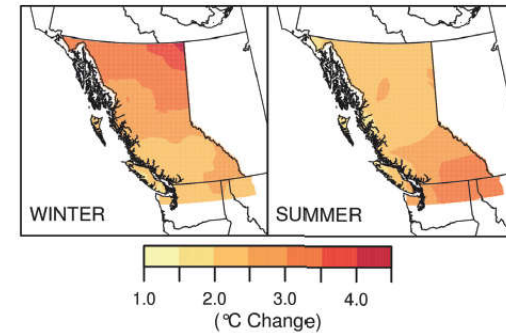
Equivalent anomaly

- North-south and vertical gradient
- On average across the basin, median 2050s anomaly of April 1 SWE is (only) -30 mm
- SWE decreases at low elevations are offset by increases at high elevations
- Snow covered area will likely decrease

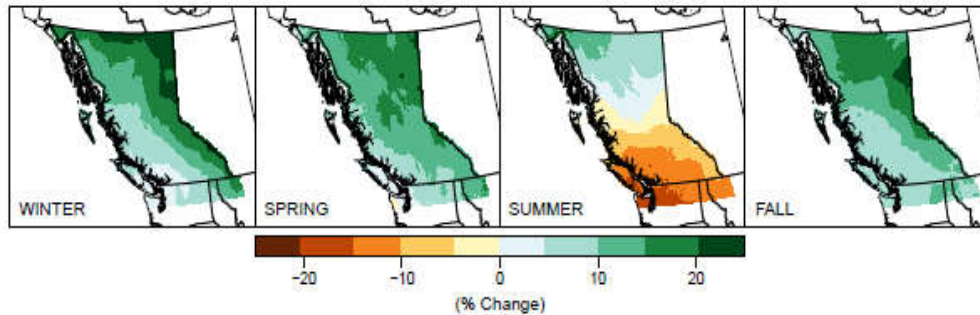


Hydrologic Impacts - Results

Median Temperature Change Projected for the 2050s



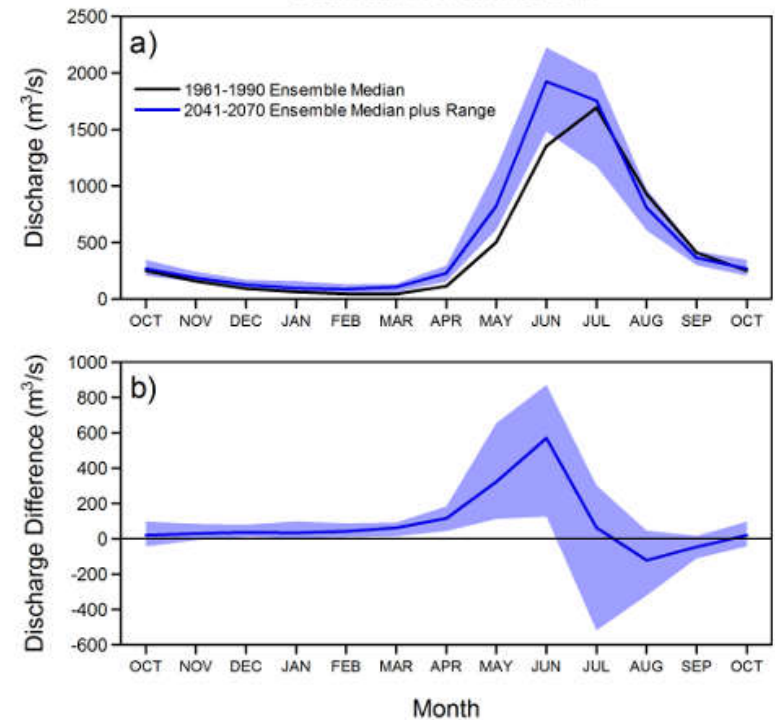
Median Precipitation Change Projected for the 2050s



- By 2050:
 - 1.4 – 3.7 °C increase in mean temperature
 - 0 – 18% increase in annual precipitation
 - Modest increase in annual water supply
 - Significant change in timing of runoff

- By 2100:
 - 44 – 100% loss of glaciers in Upper Columbia River

Columbia River at Mica Dam

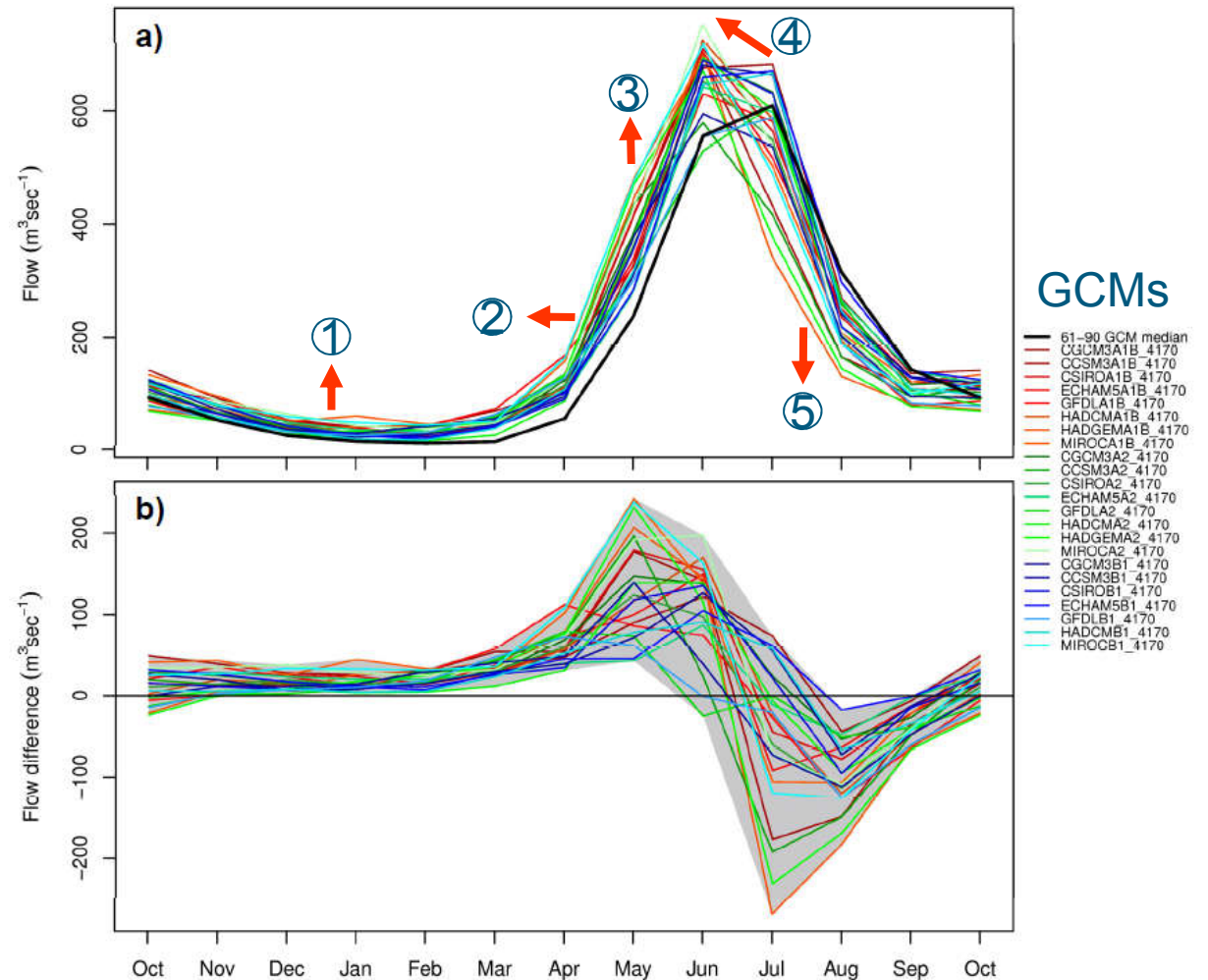


Projected Trends in Monthly Inflows

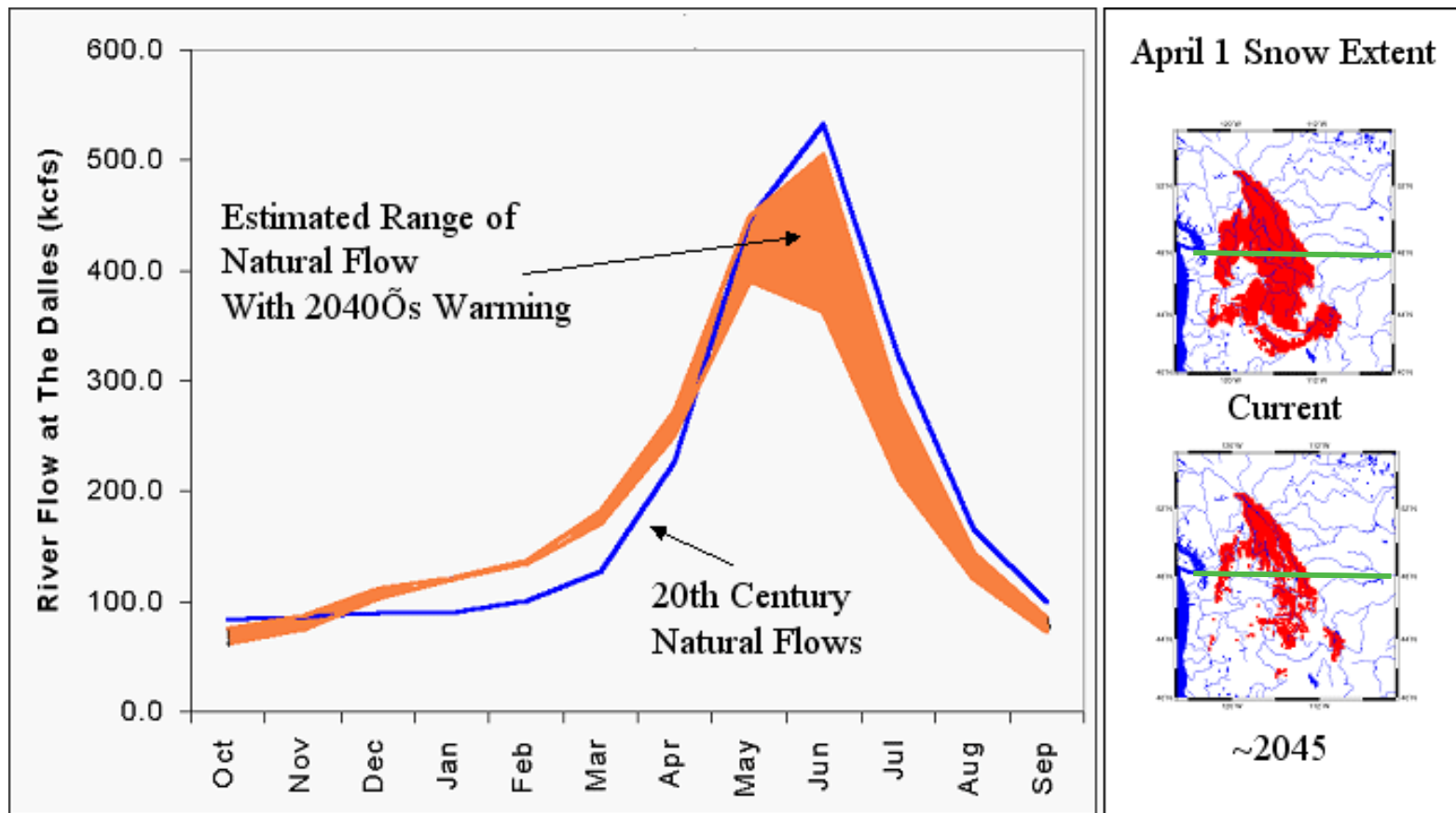
BCHRE REVELSTOKE

REVELSTOKE

- 1) Higher winter baseflow
- 2) Earlier spring melt
- 3) Higher spring melt
- 4) Earlier peak
- 5) Lower summer flow

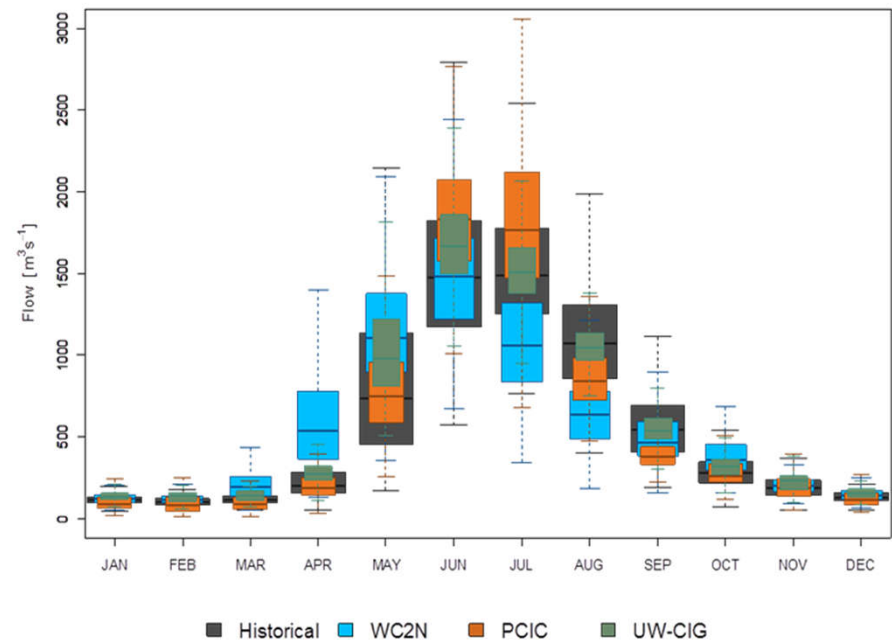
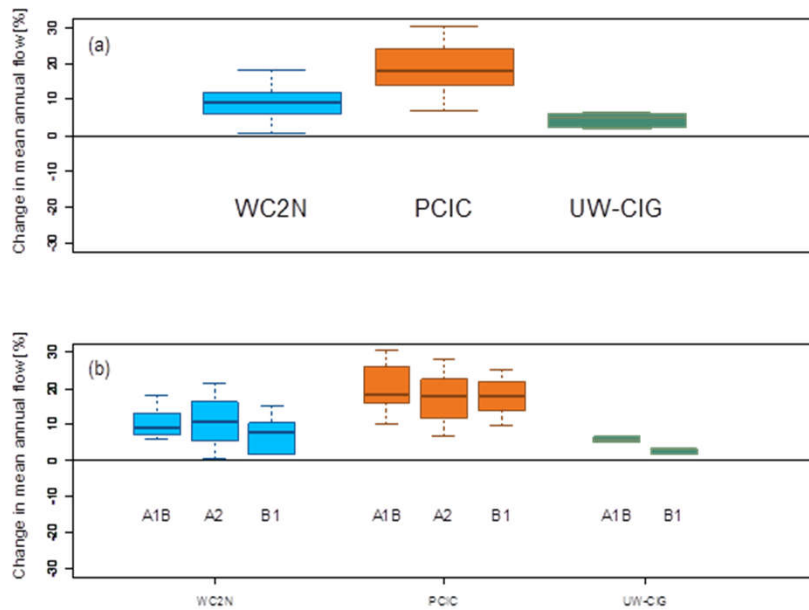


US Columbia Basin Projected Impacts



Modelling Uncertainty

Example: Multi-Agency ensemble of Mica flow projections



Glacier Dynamics

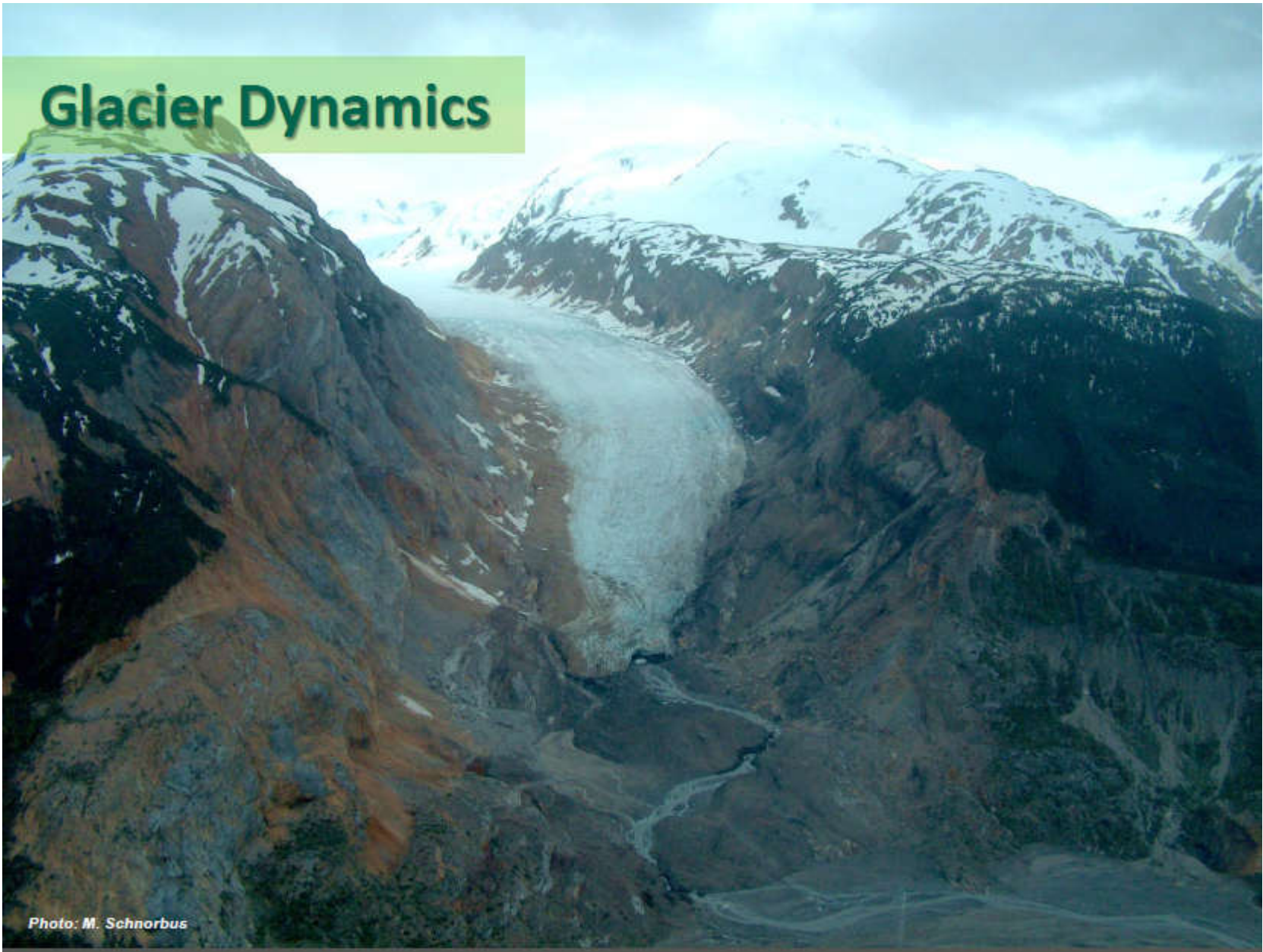
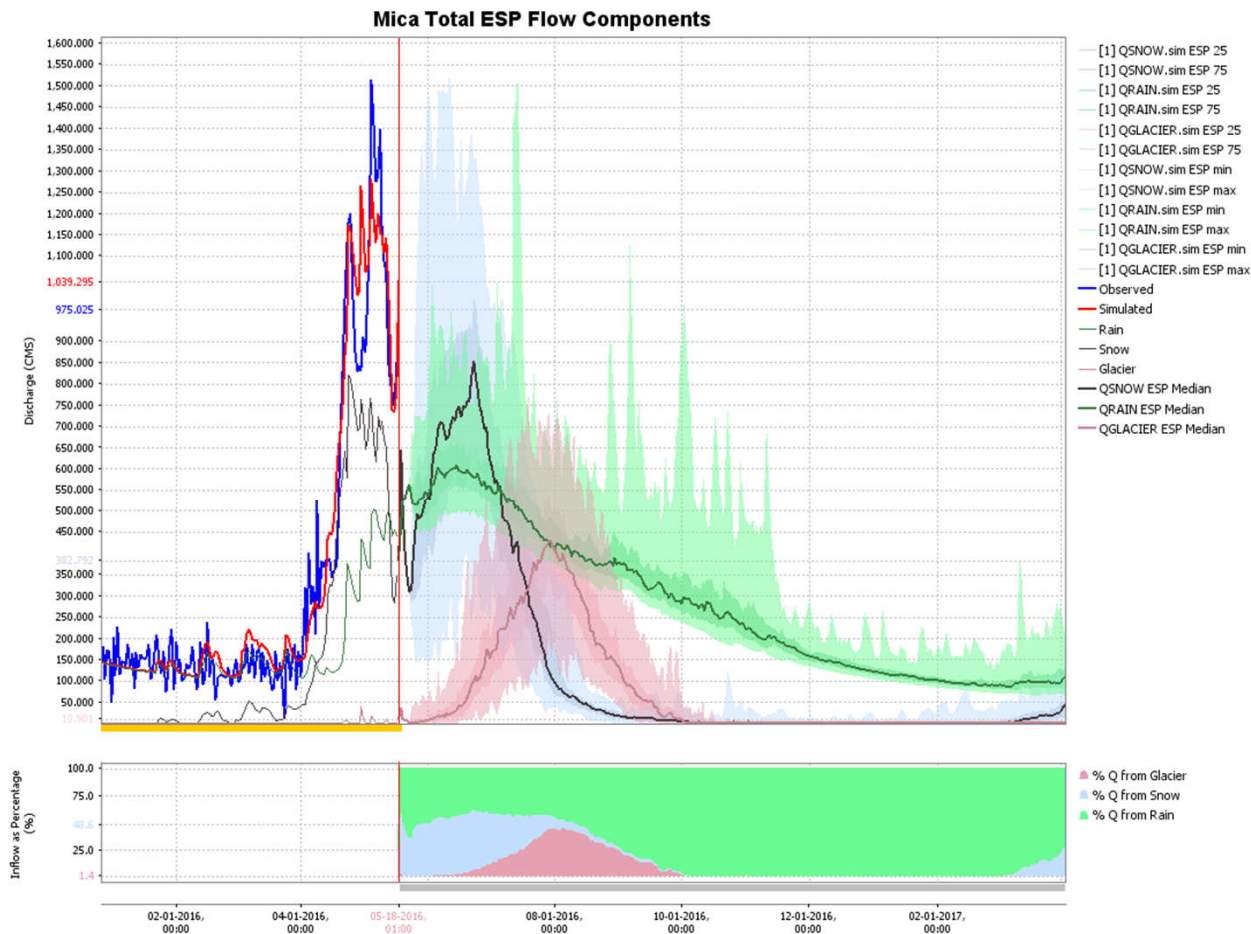


Photo: M. Schnorbus

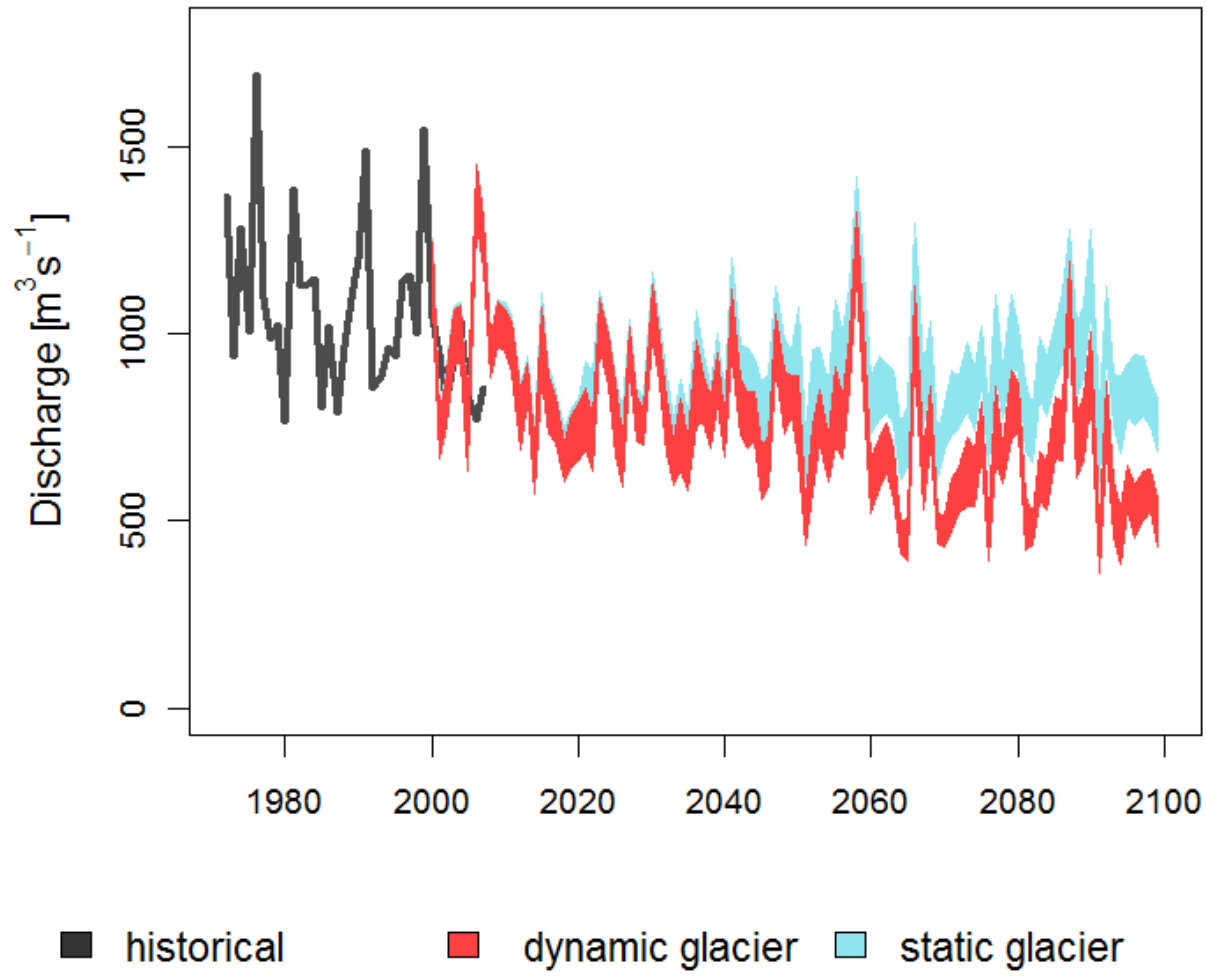
Flow components

Expect high glacier contribution....



UBCW_Mica_Forecast_ESP: [1] Run long range forec... 05-18-2016, 01:00 PDT Current
 UBCWM_Donald_UpdateStates_ESP: [2] Spinup Run: Donald 05-18-2016, 01:00 PDT Current

Projected Mean August Inflow at Mica static vs. dynamic glaciers



Results & Reports

Glacier and Streamflow Response to Future Climate Scenarios,

nature geoscience LETTERS
PUBLISHED ONLINE: 6 APRIL 2015 | DOI: 10.1038/NGE02407

Projected deglaciation of western Canada in the twenty-first century

Garry K. C. Clarke^{1*}, Alexander H. ...

Retreat of mountain glaciers is a significant contributor to global sea-level rise and a potential threat to water availability and ecosystems. Like most of Earth's mountain glaciers, North America is experiencing rapid mass loss. Here we use a high-resolution regional glaciology and coupling physics-based ice dynamics with a mass balance model, to project the fate of glaciers in western Canada. We use twenty-first-century climate projections from an ensemble of global climate models. The results indicate that by 2100, the ice in western Canada will shrink by 70% to 2005. According to our simulations, glaciers in the Interior and Rockies regions will remain in the Interior and Rockies regions, but glaciers in the northwestern region will survive in a diminished state. We estimate that the maximum rate of ice volume loss, corresponding to deglacial meltwater to streams and lakes, will occur around 2020–2040. Potential implications for aquatic ecosystems, agriculture, forestry, and water quality.

Recent global-scale estimates using simple ice dynamics (refs 3–6) indicate that mountain glaciers will retreat by 0.39m by 2100 (ref. 7). At regional-to-continental scales, projected glacier mass changes have varied from 10% to 90% (refs 8,9) to those with greater geographical detail (ref. 10). At regional-to-continental scales, empirical scaling¹¹, scaling in combination with ice dynamics^{12–18} or sub-grid scale ice dynamics^{19–22} at these spatial scales the main effects of deglaciation are changes in the hydrologic cycle²³ and on water availability, aquatic habitat, hydroelectricity, recreation and tourism.

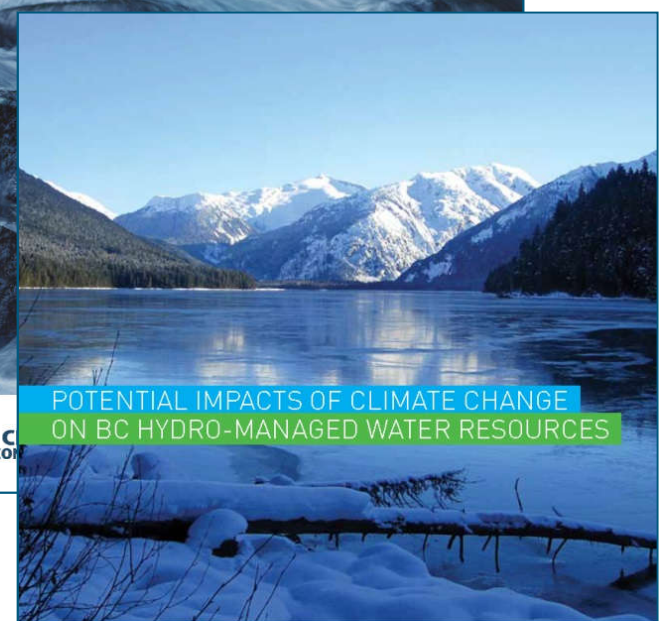
Projections of glacier surface mass balance (ablation) can reveal the ultimate fate of glaciers. Information on rates of change of thickness and area individually respond to changes in the surface mass balance and may survive an adverse climate by stabilizing at a lower elevation. This stabilization due to changes in ice area (ice area altitude distribution) has been represented empirically in all current models of glacier

¹Department of Earth, Ocean and Atmospheric Sciences, University of Kelowna, Kelowna, BC, Canada. ²Natural Resources and Environmental Studies, University of British Columbia, Kelowna, BC, Canada. *e-mail: c. Clarke@eos.ubc.ca

NATURE GEOSCIENCE | ADVANCE ONLINE PUBLICATION

Hydrologic Impacts of Climate Change on BC Water Resources

Summary Report for the Campbell, Columbia and Peace River Watersheds



POTENTIAL IMPACTS OF CLIMATE CHANGE ON BC HYDRO-MANAGED WATER RESOURCES

Georg Jost, Ph.D., Senior Hydrologic Modeller, BC Hydro
Frank Weber, M.Sc., P. Geo., Lead, Runoff Forecasting, BC Hydro
Updated July 2013

BC Hydro
FOR GENERATIONS



Hydrologic Impacts of Climate Change in the Peace, Campbell and Columbia Watersheds, British Columbia, Canada

Hydrologic Modelling Project
Final Report (Part II)

1 April 2011

Markus A. Schnorbus
Katrina E. Bennett
Arelia T. Werner
Anne J. Berland



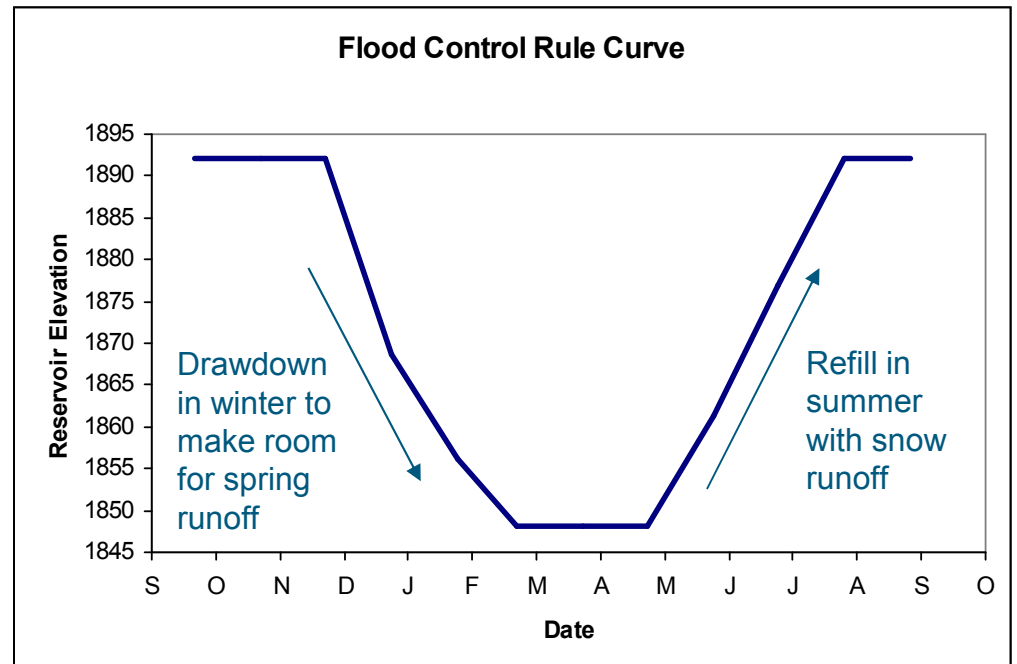
What does this mean for the Treaty Review?

US and Canada agree:

- Same or more water available, particularly in Canadian Columbia
- Timing of runoff is changing
 - Potential impacts for Flood Control
 - Lesser impacts to Generation
 - Potential impacts to fish flows
 - Snow pack storage decreasing – particularly in the U.S.

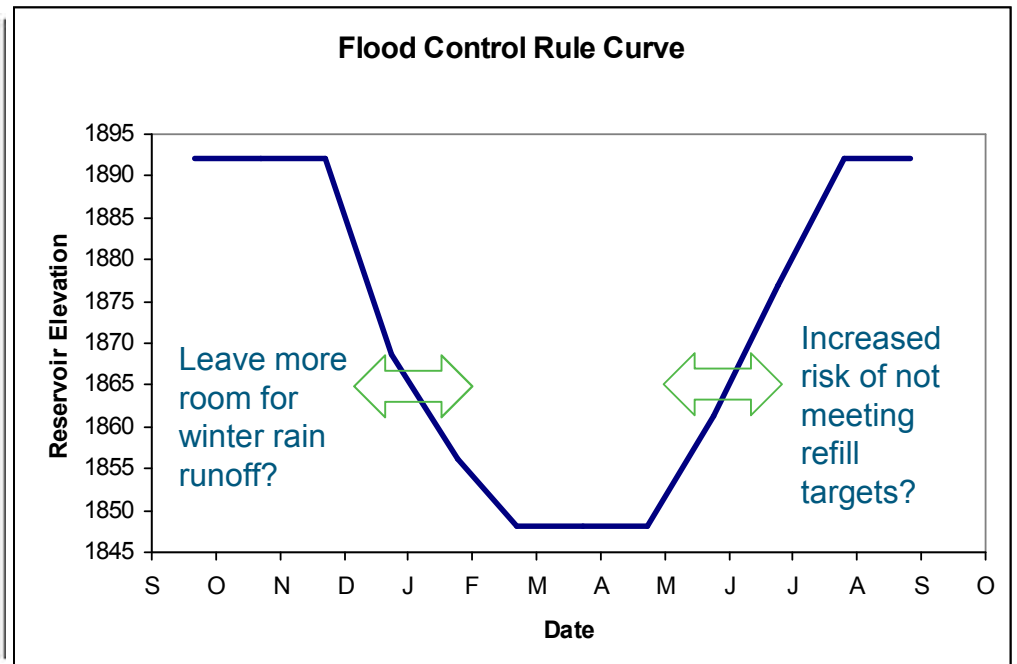
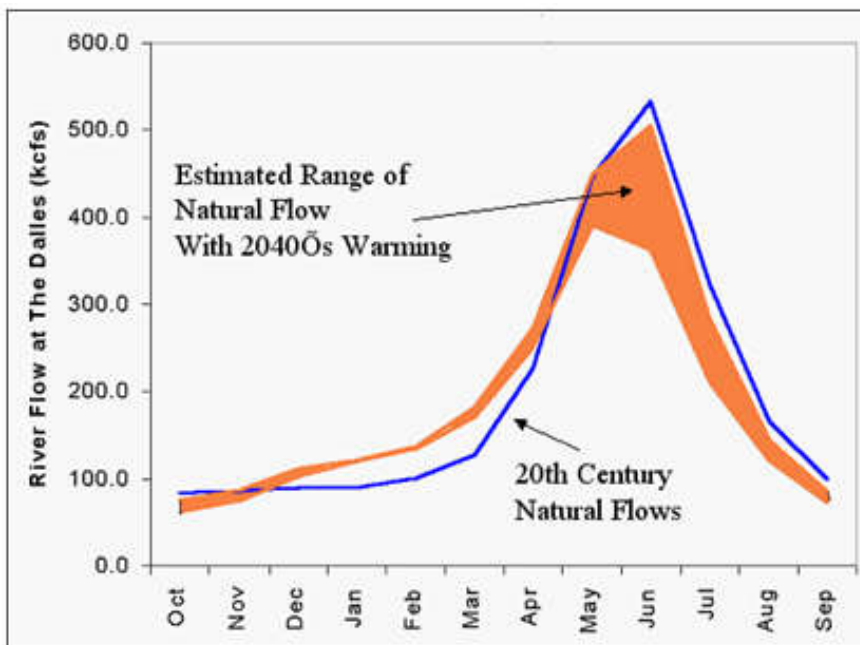
Considerations for Flood Control

- Space required for flood control is based on:
 - snowpack,
 - rainfall during the refill season (spring and summer), and
 - shape and timing of the runoff.
- Based on April – August water supply forecast



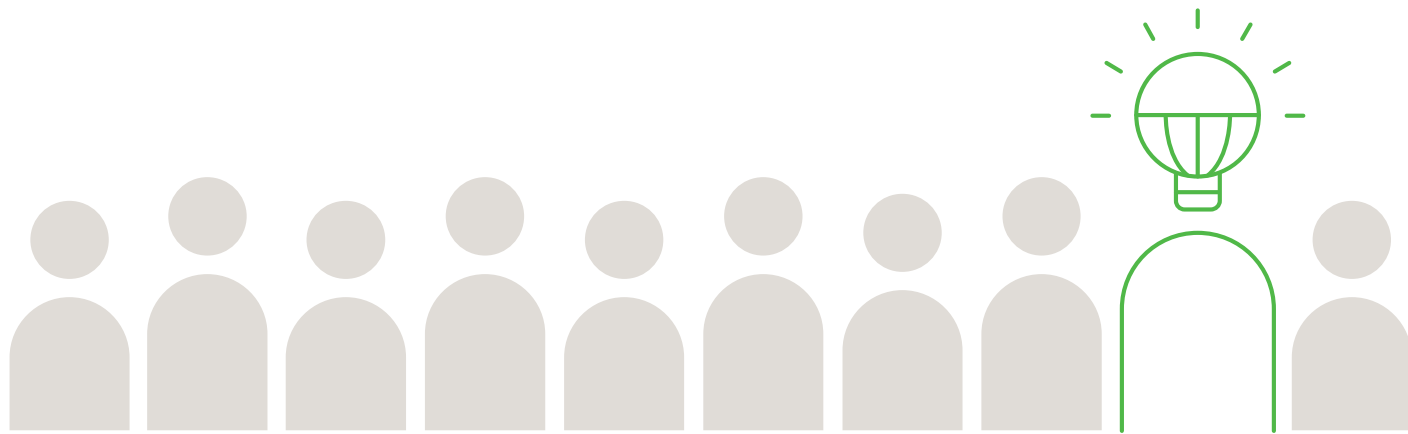
Currently

Considerations for Flood Control



How might flood control planning change?

What can we do?



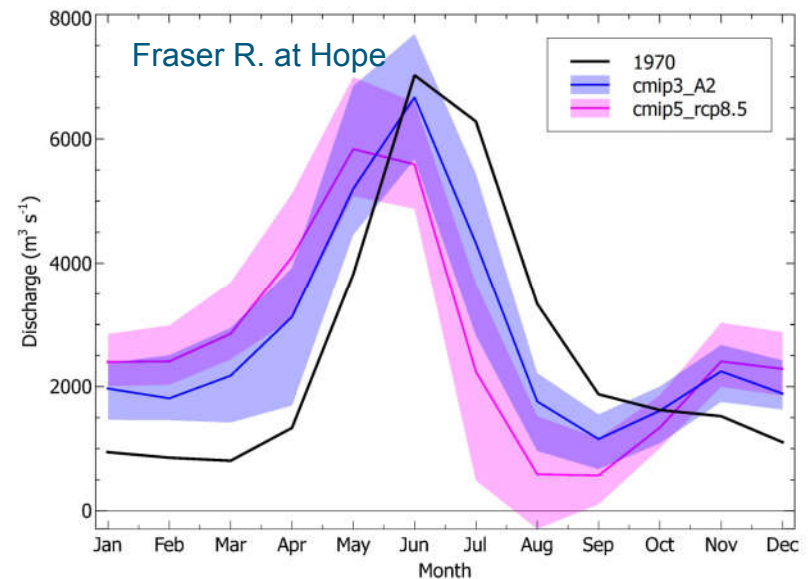
Use New Climate Science

Climate update

Intergovernmental Panel on Climate Change released their 5th Assessment Report

- Updated emissions scenarios (RCPs)
- Updated global climate models (CMIP5)
- Preliminary assessment of the results show consistent results with previous studies, but with accelerated timing

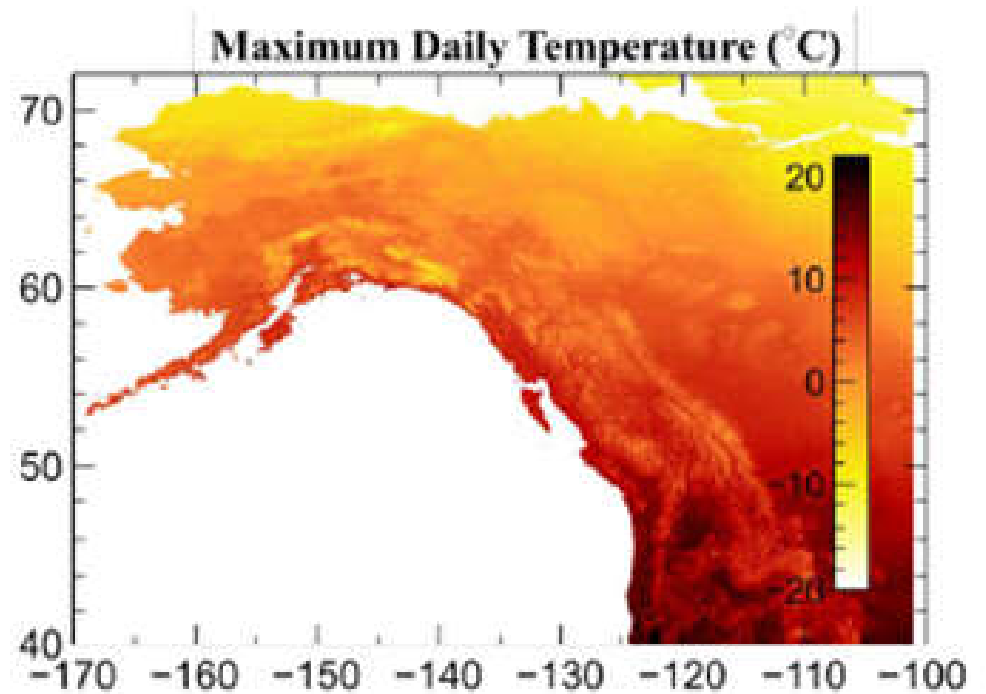
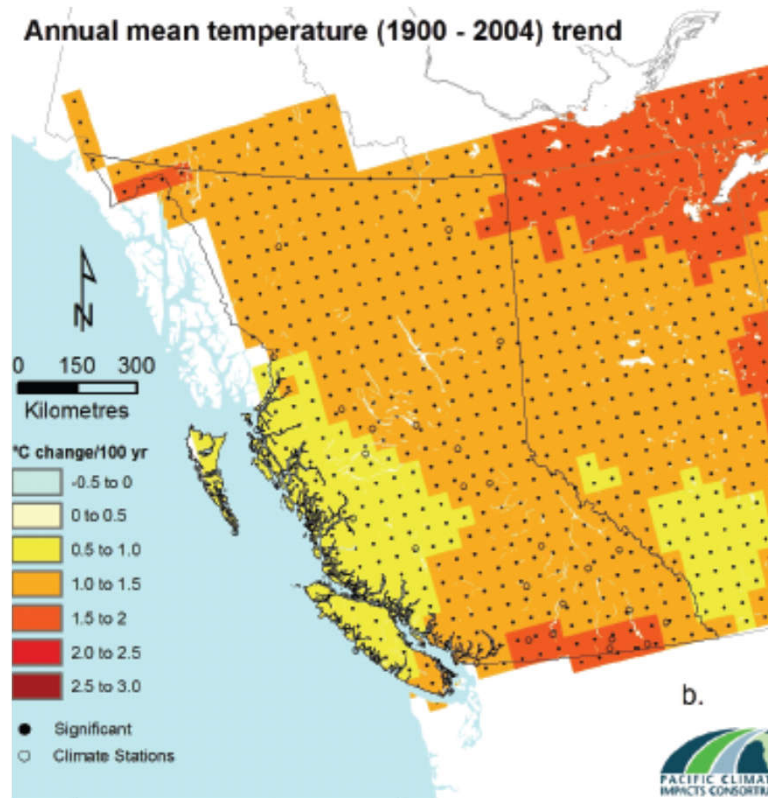
Projected Streamflow 2080s CMIP3 A2 versus CMIP5 RCP8.5



Source: PCIC

Expand Domain of interest

Improve resolution



Learn from previous research

BC Hydro renewed funding for Pacific Climate Impacts Consortium



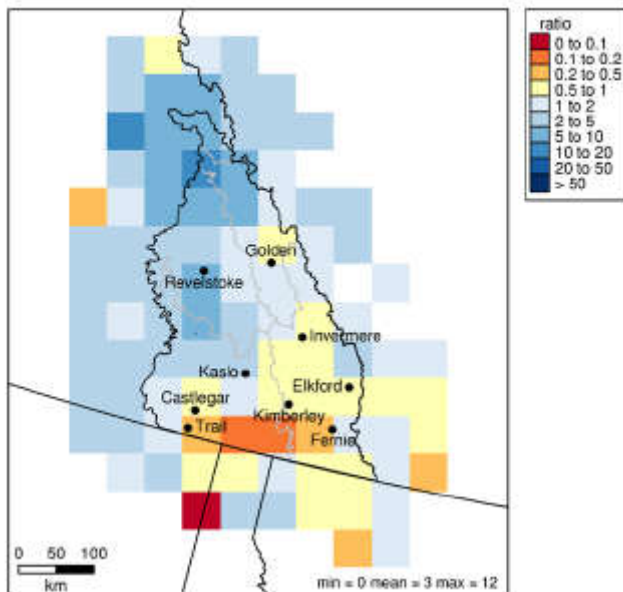
PCIC 2015-2018

- Expand region to whole Columbia Basin
- Incorporate new CMIP5 emission scenarios / GCMs
- Improve hydrologic model
- Incorporate glacier dynamics
- Explore impacts to severe / extreme events
- Investigate potential changes to low frequency dry sequences
- Quantify uncertainty

Stretch the science

Climate “Extremes” and Variability

CGCM3-driven WRF 2050s daily precipitation:
Projected frequency of baseline 25-year wet event



From: “Climate Extremes in the Columbia Basin”
– PCIC with funding from Columbia Basin Trust

Assessments of changes to variability and extremes

- Still emerging science
- Assessing impacts to climate indices (eg growing degree days), quantile projections, storm patterns, return periods

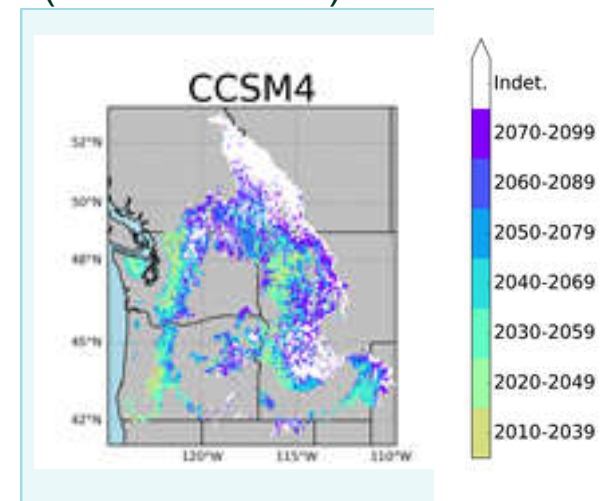
Continue to Work with U.S.

U.S. Studies



Joint studies: River Management Joint Operating Committee (RMJOC II)

- Incorporate new CMIP5 emission scenarios (RCP 4.5 & 8.5)
- Improve hydrologic model
- Snow pack trend projections
- Quantify uncertainty
- Update Hydro-regulation studies
- Assess impacts to water temperature
- Assess impacts to forecast procedures → Flood risk management

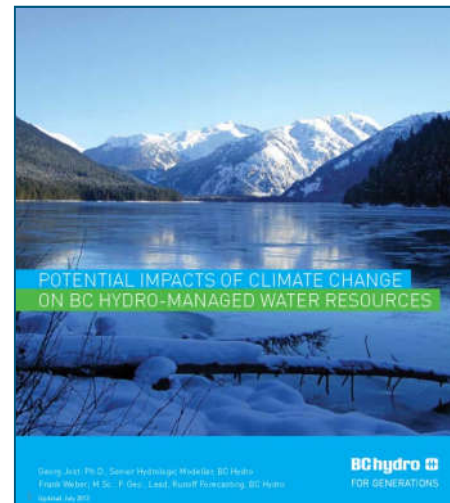


U. Washington

Incorporate and Communicate Results

BC Hydro

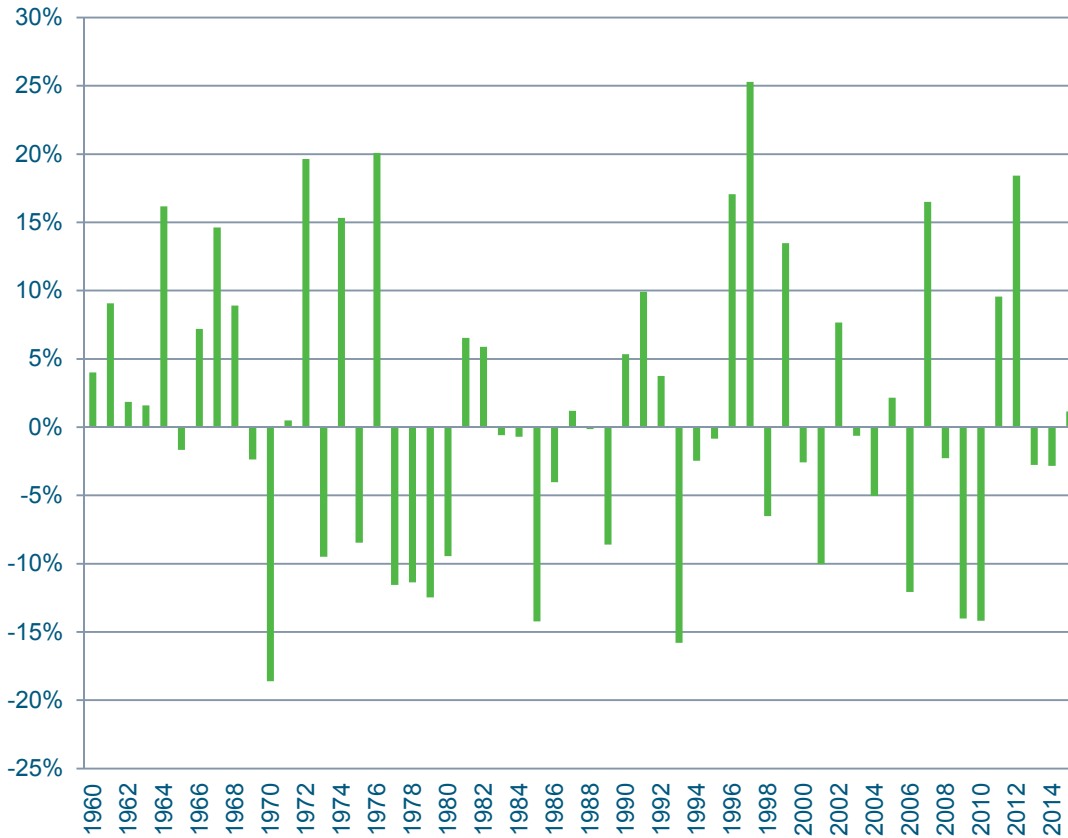
- Update historical inflow trend assessment
- Future scenarios → BC Hydro Planning Models
 - Integrated Electricity Plan
 - Environmental assessments
 - Water license renewals
 - Columbia River Treaty
- Update Communications



Resilience

BC Hydro has the tools, plans, and expertise to manage across a wide range of conditions and situations

Are we ready?



Improve our tools

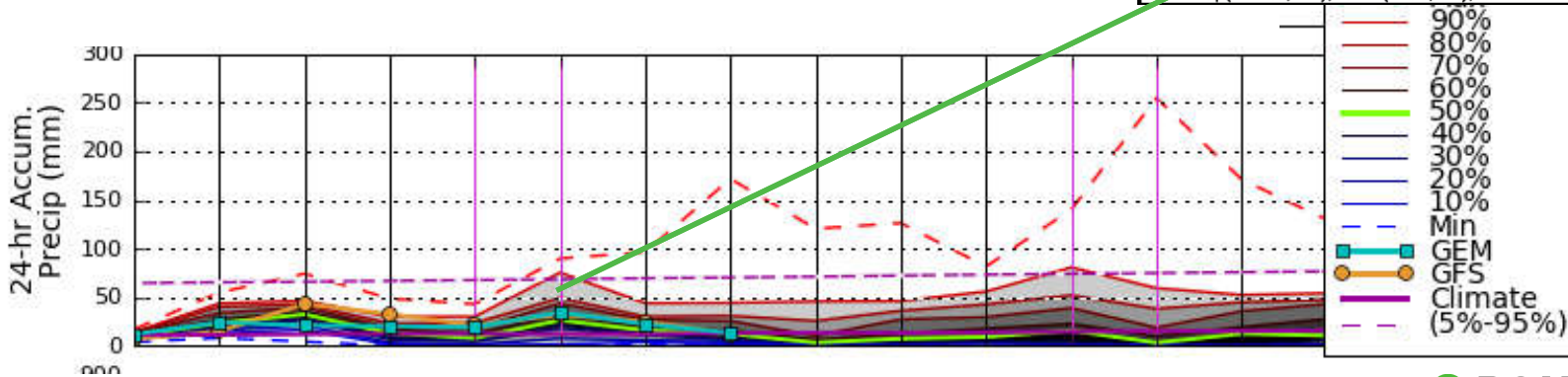
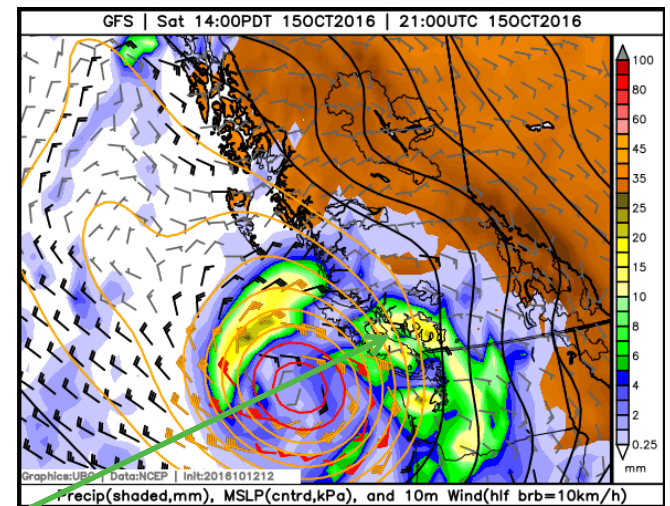
Investing in new and improved forecasting and planning tools

Enhanced weather forecasting

Flexible hydrologic models

Incorporating uncertainty

Point Precipitation forecast range



Monitoring – what we measure



Climate



Snow



Surface Water



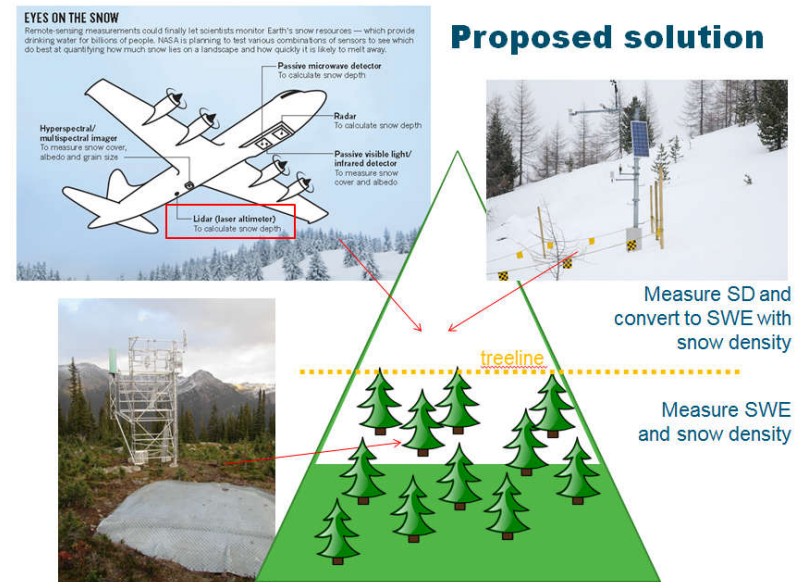
Glaciers



Adding new monitoring

Traditional and innovative technologies

- Increased monitoring
 - Four new snow monitoring stations
 - Columbia glacier research network
 - High elevation snow monitoring
 - MODIS satellite - snow cover
 - LIDAR remote sensing



Answering Key Questions

New Communications Plan

Are storms getting stronger/ more frequent?

What is the probability of extended drought?

How might demand change?

What information should we include in design decisions?

How will climate change impact water temperature? Will it impact fish?

Was that storm attributable to climate change?

What is the variability in future projections?

How certain are you?

What does it mean to be a climate-resilient business?

Understand your risks and vulnerabilities

Involve your stakeholders (internal/external)

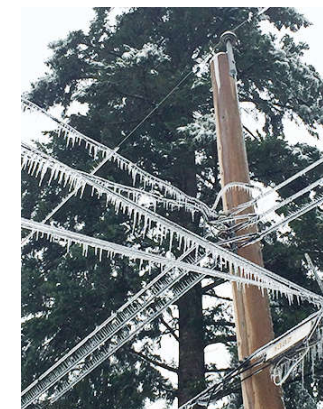
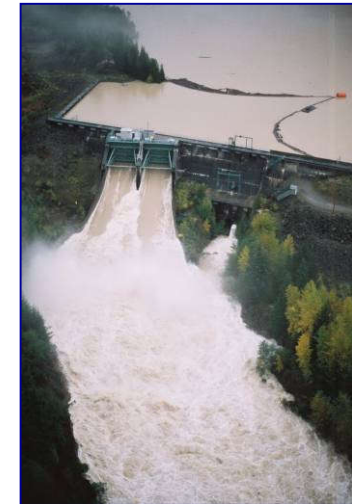
Start with highest impact areas

Leverage and share resources (government / academic / industry associations)

Build local capacity / innovation

Adapt existing tools / practices

Take advantage of times of renewal



Questions



