USE OF GLACIOLOGICAL DATA FOR RUNOFF FORECASTING

Lake Louise, Alberta, Canada
17 October 2009

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ABSTRACT

- As a power utility with operations & revenues based largely on river flows, climate variability & change can ultimately affect every aspect of BC Hydro’s business.
- WC²N is unique in its capabilities to model coupled glacier-streamflow responses.
- The data produced by WC²N has been of immense value to hydrologic modeling.
BC HYDRO BACKGROUND
BC HYDRO SYSTEM

- Serving about 95% of BC’s customers
- 90% from hydroelectric
  - 41 dam sites (75 dams)
  - 80 generating units
  - 30 hydroelectric facilities
- Secondarily, also thermal generation (9 units at 3 plants)
- Plus purchases: BC-sourced run-of-river & wind power IPP; market purchases
RUNOFF FORECASTING

RESPONSIBILITY

- Provide accurate hydrologic forecasts to BC Hydro planners in a timely manner

WHY FORECAST INFLOWS?

- Reservoir inflow = product supply ~ revenue... revenue forecast!
- Inflow forecast essential input to reservoir operation, which is a constrained optimization problem

“The trouble with forecasting is that it's right too often to ignore it and wrong too often to rely on it.”
Patrick Young

[Diagram showing relationships between ecological needs, dam safety, meet domestic load, market opportunity, social needs, and reservoir inflow]
BC HYDRO BASINS WITH ‘LARGE’ GLACIERMELT CONTRIBUTION

LaJoie: 19% glacier area
Cheakamus: 8% glacier area
Stave: 3% glacier area
Duncan: 6% glacier area
Revelstoke: 4% glacier area
Mica: 5% glacier area
INFLOW FORECASTING

- For example, Lajoie inflows, September 11-18, 2009
- Glacial melt is an additional source of water (i.e., hydroelectric power, aquatic habitat, etc.)
- Most pronounced in late summer, when other runoff-generating mechanisms wane
- Buffers short-term, year-to-year climatic variations
- Modulates climate variability (e.g., ENSO) responses
HYDROLOGIC MODELLING
2005 GLACIER EXTENTS

- WC²N 2005 Landsat-based glacier extent: Bolch et al. 2008

Lajoie Basin, S. Coast Mountains
Cheakamus Basin, S. Coast Mountains
UBC WATERSHED MODEL CALIBRATIONS
CONSTRAINING GLACIER- & SNOWMELT SIMULATIONS

ESTIMATES OF EQUILIBRIUM LINE ALTITUDE (ELA)

- ABSYNTHE constraints
  - 1 day of the year of all years, SWE in the elevation band below the ELA band = 0 mm
  - RMSE for simulated April 1 SWE < threshold

- For example, Mica ELA estimates are based on
  - Peyto glacier ELA
  - Glacier distribution in Mica basin
  - Knowledge of local climate


CONSTRaining glaciEr- & snowmelt simulAtions

estimates of glacial runoff contribution from glacier mass balance

- Useful for constraining what is a ‘reasonable’ glacial melt component in the ABSYNTHE calibrations for these basins
- Back of the envelope calculation of annual total glacial runoff component, based on Peyto Glacier net annual & summer balance data

- Mica
  - Annual glacier melt component: 49 mm/yr - 96 mm/yr
  - Q-glacier: 6% to 11% [UBCWM 8%]
- Revelstoke
  - Annual glacier melt component: 42 mm/yr - 83 mm/yr
  - Q-glacier: 3% to 6% [UBCWM 6%]
- Arrow
  - Annual glacier melt component: 16 mm/yr - 32 mm/yr
  - Q-glacier: 1% to 3% [UBCWM 2%]
UBC WATERSHED MODEL CALIBRATION - OLD
UBC WATERSHED MODEL CALIBRATION - NEW
GLACIER- & SNOWMELT MODELLING

- Lack of data to constrain glaciarmelt in hydrologic models
- High uncertainty in glacier- and snowmelt simulations
- Inaccurate inflow forecasts from glaciated basins
SNOW COVERED AREA & SNOWLINE ELEVATION & ELA

ANALYSIS OF MODIS IMAGERY TO EXTRACT GLACIER SNOWLINES IN SUPPORT OF HYDROLOGIC MODELLING (Joe Shea 2009-2011)

Objectives

- Obtain historic snowline data (2000-2009) to constrain hydrological models during calibration/validation
- Develop a software for near real-time data extraction and processing in support of operational forecasting

Why MODIS?

- High repeat coverage (1-2 days)
- Reasonably high spatial resolution in the visible spectrum (~250 m)
- Free data
CLIMATE-GLACIER-STREAMFLOW MODELING
CURRENT MESSAGE IS QUALITATIVE

For example, potential impacts of climate-glacier changes in the Mica Basin

[Diagram showing historical median flows from 1984-2007 with peaks indicating increased frequency and magnitude of peak flows.]

Legend:
- 1984 - 2007
- 2008 Inflow year
- Historical median
- Frequency of peak flows increases
- Magnitude of flows increases
- Magnitude of flows decreases
- Spring runoff (freshet) starts earlier
CLIMATE-GLacier-STREAMFLOW MODELING

Flow scenarios

Global Circulation Model (CGCM3)
Observed 1986–2004
Statistical Downscaling to Point Locations
- stochastic weather generator LARS-WG

Hydrological model
- HOpel-EC (Hydrologiska Byråns Vattenbalansmodell – Environment Canada, Hamilton et al. 2000)
- CANMET model

Glacier Mass Balance
Simple Glaciological model
- Volume-area scaling based on a decade's cumulative mass balance


August streamflow
CLIMATE-GLACIER-STREAMFLOW MODELING
MICA BASIN, COLUMBIA/ROCKY MOUNTAINS, BC

Global Circulation Models
- Daily resolution
- SRES A1B, B1

Statistical Downscaling to Point Locations
- Treegen

Hydrological model
- HBV-EC (Hydrologiska Byråns Vattenbalansmodell – Environment Canada, Hamilton et al. 2000)
  - originally Scandinavian model
  - Canadian version

Interpolation to NARR-consistent Grid

Glaciological model
- Glacier Dynamics: Glacier masks and DEM’s would be extracted from these outputs for a set of 10-year time slices

Moore, Clarke et al. 2009-2010
COUPLED CLIMATE-GLACIER-STREAMFLOW CHANGE

ALL OTHER THINGS BEING EQUAL, POTENTIAL IMPLICATIONS INCLUDE:

- Lower reservoir inflows
- Lower hydroelectric generation capacity, fewer $n$
- Lower aquatic habitat availability, esp. in late summer (can use reservoir storage from other seasons to maintain fish flows, but involves foregoing generation at those other times)
- Decreased buffering of interannual flow variability
- Potentially changed responses to ENSO & PDO
- Perhaps changes in capacity to accommodate flood regulation
- Implications for cross-border agreements
TELL A STORY!
Overall, mountain glaciers have receded under warming temperatures over ~last century.

Robson Glacier, near Mica headwaters

from Moore et al. 2009, Hydrological Processes
North lateral moraines

Recessional moraine complex

North terminal moraines

South terminal moraines

1495-153

1908-1931

1664-1684

1873-1886

South lateral moraines

1323-1384

1426-1

455

D.Smith, UVIC
CORE SCIENCE QUESTIONS
CORE SCIENCE QUESTIONS

- Extraction of snow cover extent (historical & operational)
- Development of improved technologies for in-situ real-time SWE data acquisition and/or
- Development of cost-efficient techniques for remote sensing of SWE
- Ongoing monitoring of glacier extent and glacier mass balance and/or
- Ongoing modeling of glacier mass balance
- Development of hydrological models that can handle nonstationary land cover, i.e. glaciers, forests
- Improved algorithms for rain-on-snow events for flood forecasting purposes
- Quantitatively assess net reservoir inflow impacts of coupled climate & land cover changes; quantify uncertainty in the predictions
THANKS!