BC HYDRO - QUICK FACTS

- Provincial crown corporation
- Serves 95% of BC (1.8 million customers)
- 11,300 MW capacity (3rd largest in Canada)
- 99% hydroelectric and 1% thermal
- 85% of generation from Peace and Columbia
OUTLINE

- Forecasting system
- Hydrograph separation
- Super Ensemble Forecast
- Climate change studies
- Ensemble verification
WHY DO WE FORECAST?

Water is the fuel for our plants. We don’t want to spill water – but we also don’t want to run out of water.
FORECASTING SYSTEM

FEWS

Deltares USA

Raven

BC Hydro
Power smart
THE RAVEN MODEL

- Modelling platform
  - extensive library of process algorithms
  - Flexible spatial discretization
  - powerful & intuitive I/O
  - Netcdf support (new FEWS adaptor)
- Build different models on the fly
- Build your own model by choosing from library of process algorithms
- Build your own model by adding your own equations to library of process algorithms
FORECASTING AT BC HYDRO

25 watersheds over a range of hydroclimates

- Short range deterministic forecasts
- Short range probabilistic forecasts
- Long range ensemble forecasts
- Long range statistical forecast
- Forecasts during construction work (e.g. Site C)
- Climate change projections
DETERMINISTIC FORECAST

Predicting exactly what the inflows will be - will always be wrong!

RDPS up to day 2; Medium range ensembles to day 30

NAEFS median from day 3 to 15

Medium range ensembles plus climatology from day 15 to 30
DETERMINISTIC FORECAST

Hourly forecasting for all Coastal watersheds
PROBABILISTIC FORECAST: WEATHER

All forecasts 50% off – get them today!

- Raw NAEFS forecast
  - North American Ensemble Forecasting System
  - Total of 42 members

- Preprocessing
  - Bias correction
  - Dispersion correction

- FEWS/Raven
  - Scheduled runs

- FEWS
  - Postprocessing
PROBabilistic forecast: weather

Impossible to give accurate forecasts – we can only try to address and minimize the uncertainty in our forecasts.
PROBABILISTIC FORECAST: GLUE

Generalized likelihood uncertainty estimation (GLUE)
LONG RANGE FORECASTS

We use snow observations, weather forecasts, and historical weather to predict inflows over the next few months.

Historical years (1968-2018)

Probabilities of exceedance

Historical precipitation and temperature
SNOW DATA ASSIMILATION

We use snow observations, weather forecasts, and historical weather to predict inflows over the next few months.

Measure snow
- surveys
- pillows

Update model

Forecast
- Weather forecast
- Historical weather sequence
MOTIVATION

- We spend more and more time with communicating our forecasts (e.g., Internally, First Nations, Public Relations)
- How much do glaciers contribute to runoff?
- How good is our forecast?
- How much does snowmelt contribute to runoff?
- Coded transport model into Raven
WHAT CAN WE AND WHAT CAN'T WE PREDICT?

Most of the skill in seasonal forecasting comes from knowing how much snow we have

Snow (blue) can be measured

Rain (green) can be forecasted for about one week

Glacier melt (pink)
Most of the skill in seasonal forecasting comes from knowing how much snow we have.
SUPER ENSEMBLE FORECAST
MOTIVATION

- Extreme scenarios for Energy Planning
- Constraint to use historical (i.e., observed) and not synthetic forcings
- Needed to relate other predictors to dates in the forecast
SUPER ENSEMBLE FORECAST

Seasonal forecasts usually (not always) underestimate the uncertainty.

Complex Decision Tree

Current Month

Next Month

Future Months ...

36 Potential System States due to Weather Variability

1296 Potential System States due to Weather Variability

After 5 years: $2 \times 10^{93}$ Potential System States!
ESP OF ESP

Seasonal forecasts usually (not always) underestimate the uncertainty
**ESP OF ESP**

Seasonal forecasts usually (not always) underestimate the uncertainty

### Seasonal forecast for Mica issued on 2019-02-07

**Remainder of Feb - Sep Runoff Volume (Mil. Cu. M)**

<table>
<thead>
<tr>
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**Remainder of Feb - Sep Runoff Volume (Percent of Normals)**

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CLIMATE CHANGE IMPACT ASSESSMENTS
MOTIVATION

- Quality controlling third party climate change projections is not super
- Scientific community usually reports anomalies (i.e., changes)
- Operational models (Energy demand, Energy supply, Fish flow, etc) require absolute numbers.
HOW ROBUST ARE PROJECTED CHANGES TO EXTREMES?

Direct model output vs observed (don’t just look at GOF stats!)
TIMING OF FRESHET?

Direct model output vs observed (don’t just look at GOF stats!)
# ANNUAL INFLOW PROJECTIONS

## Mica

<table>
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<th></th>
<th>1980</th>
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<td><img src="image5.png" alt="Graph" /></td>
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**Mean Annual Inflow (m³/s)**

- **RCP 4.5**
- **RCP 8.5**
SEASONAL INFLOW PROJECTIONS

RCP 8.5

Period
1980
2050
2080

mean daily inflow [m$^3$/s$^{-1}$]

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
EFFEKT OF +2 DC T FOR DOWNTON LAKE

Glaciers fill in the gap from early snow melt. But for how long?
EFFECT OF \( +2 \) DC T FOR CARPENTER

No glaciers to fill the gap from early snow melt -> lower summer flows

Earlier melt

Lower summer flows
ESP HINDCASTING (LONG RANGE)
MOTIVATION

- Columbia River Treaty official seasonal forecasts are currently based on statistics
- Tasked to look into switching to ESPs
- Need to compare uncertainties between statistical and ESP forecasts
HOW TO DO HINDCASTS IN FEWS

- In the standalone
- Empty local datastore
- Separate update states workflow
- Separate snow data assimilation in batch mode
- Calculate bias correction factors
- ESP runs in batch mode with added export to archive and xml.
MANUAL OR WITH MACRO
MACRO

- From empty datastore to ‘ready for ESP’ batch runs
- Waiting for enhancement to run in monthly intervals. Will allow to create start to end scrips for each experiment
Continuous Ranked Probability Skill Score (CRPSS) by forecast lead time.
Arrow.Inflow (reference forecast: Sample climatology)
Ensemble quantile-quantile plot.
Arrow.Inflow at lead hour 720.0
Modified box plot of ensemble forecast errors against forecast time for one lead time.
Arrow.Inflow at lead hour 720.0
Rank histogram.
Arrow.Inflow at lead hour 720.0

Cumulative relative frequency

Bin separating ranked ensemble members

All data
WHAT ARE WE WORKING ON?

- Hourly ensemble forecasting
- Gridded forcing (forecast)
- 30 day forecasts
- Improve model
- Evaluation of ensemble forecasts
- LIDAR snow state estimation
- Real time snow data assimilation
Mass Balance Monitoring

- Stake method
- Lidar: LIDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.
The goal of working with scenarios is not to predict the future, but to better understand uncertainties in order to reach decisions that are robust under a wide range of possible futures.