HBV-EC in Raven: Practical Insights and Applications across Western Canada

Raven User Conference

May 29, 2025

Outline

- HBV and HBV-EC
- Typical Changes
- Representation of…
  - Lakes
  - Glaciers
  - Rainfall Events

Hydrologiska byråns vattenbalansavdelning

- Developed by Sten Bergstrom at the Swedish Meteorological and Hydrological Institute
- Earliest version of the model date back to 1972
- Goals:
  - Sound physical description but not complex
  - Data demands met by observational network
  - Avoid overparameterization
- Numerous model variations – many applications, publications

HBV-EC Origins

Estimating Winter Streamflow Using Conceptual Streamflow Model

By A. S. Hamilton,[1] D. G. Hutchinson,[2] and R. D. Moore[3]

Abstract: Ice-affected periods represent a significant portion of the annual hydrograph for most Canadian hydrometric stations. Because the stage-discharge relation is not reliable under ice-cover conditions, Water Survey of Canada subjectively interpolates winter streamflow from as few as two observations of discharge during the ice-covered season, which may last 6 months or longer. An alternative method of producing discharge estimates is proposed that uses a combination of conceptual and statistical hydrological modeling to overcome limitations in both the availability of data and our understanding of relevant processes. A conceptual hydrological model is tested to evaluate the utility of this approach for data-sparse regions. When model predictions were adjusted to fit two winter measurements, 79% of all verification measurements were within 20% of predicted estimates. There was a seasonal bias to the error distribution, with most measurements within the first 30 days after freeze-up being less than predicted and most measurements after April 1 being greater than predicted. These deviations probably result from hydraulic and hydrologic processes not represented within the model.

Application of a conceptual streamflow model in a glacierized drainage basin

R.D. Moore

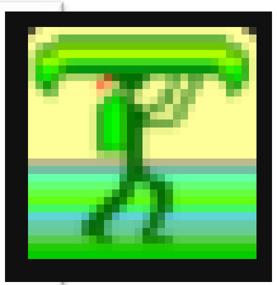
Geography Department, Simon Fraser University, Burnaby, B.C. V5A 1S6, Canada

(Received 31 July 1992; revision accepted 26 December 1992)

Green Kenue

Reference Manual

September 2010



Canadian Hydraulics Centre
National Research Council
Ottawa, Ontario, Canada

Water Survey Canada
Environment Canada
Ottawa, Ontario, Canada

HBV-EC

Why do we like HBV-EC?

- Limited forcing inputs
- Simple, easy to understand
- Limited parameters
- Does well in snowmelt dominated basins

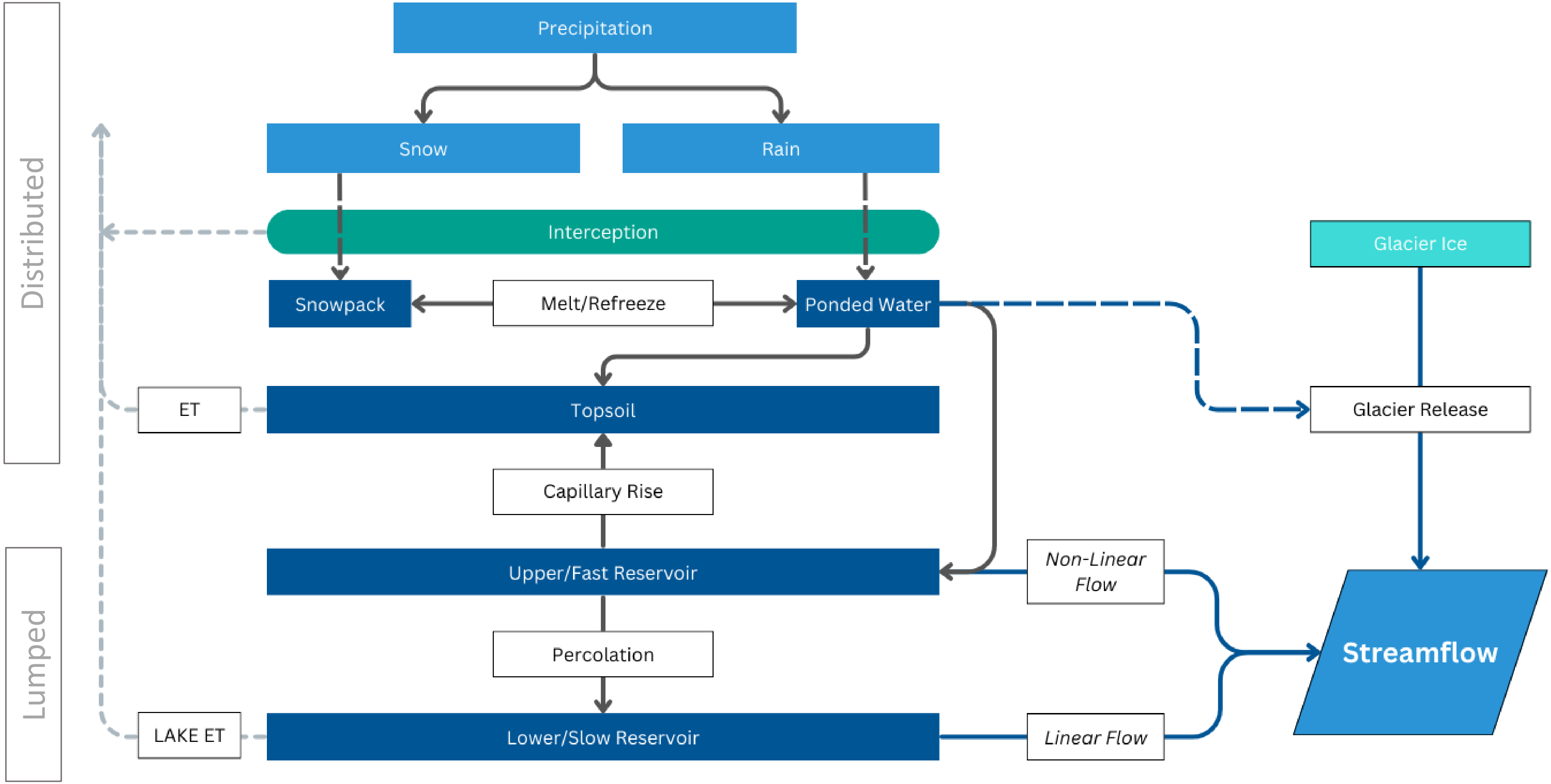
What could use improvement?

- Original model did not consider non-stationarity
- Process representation
  - Lakes
  - Vegetation
  - ….

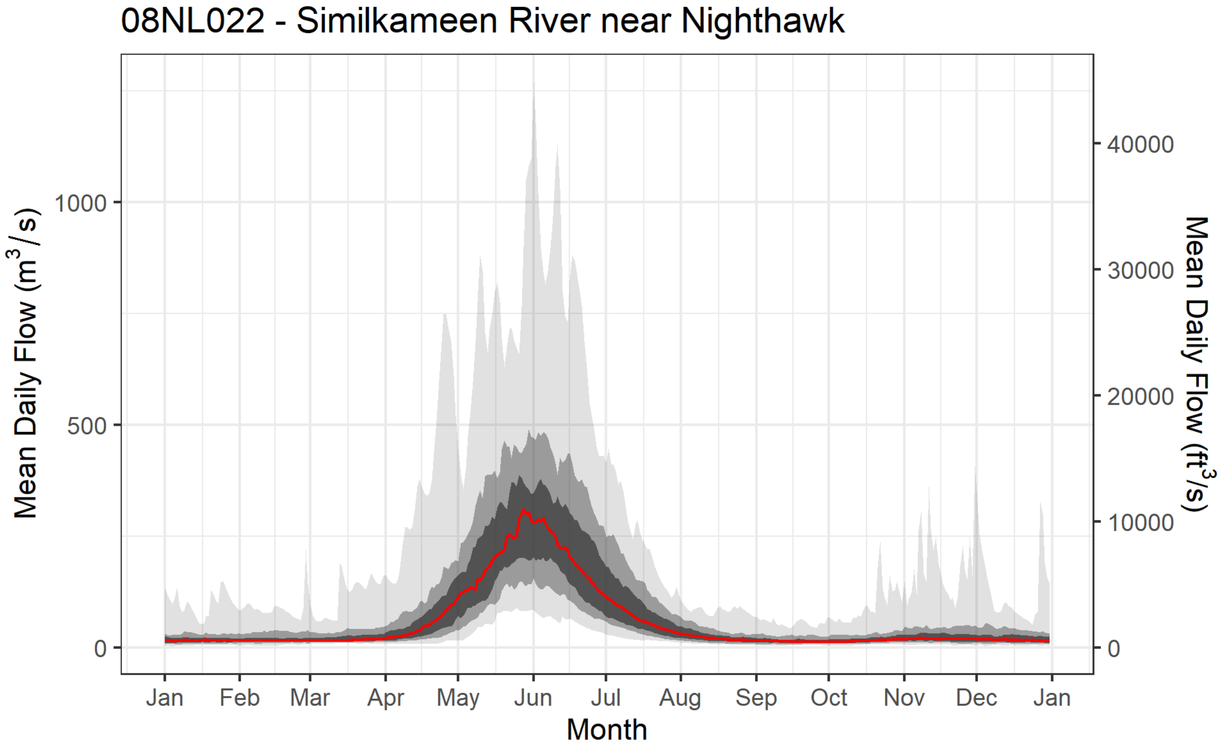
What are we using it for?

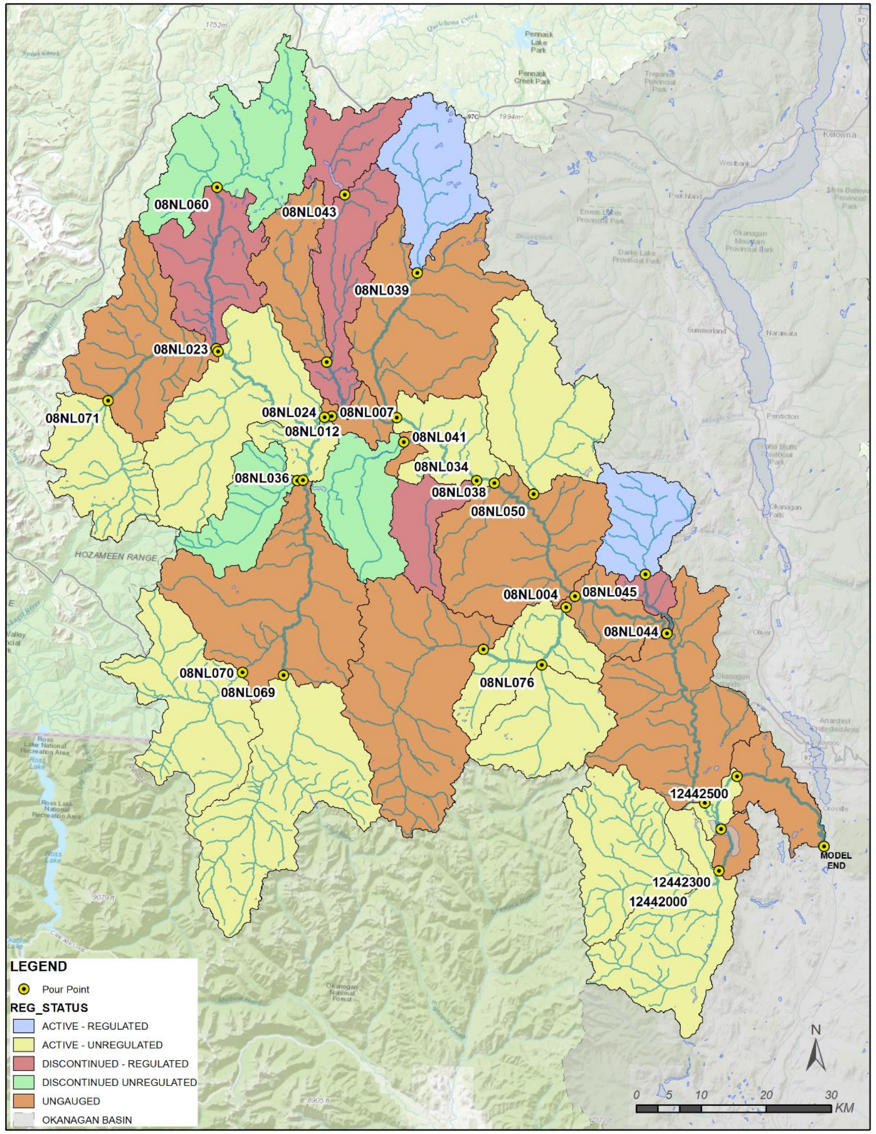
- Climate change assessments
- Forecasting
- PMF

HBV-EC Emulation in Raven



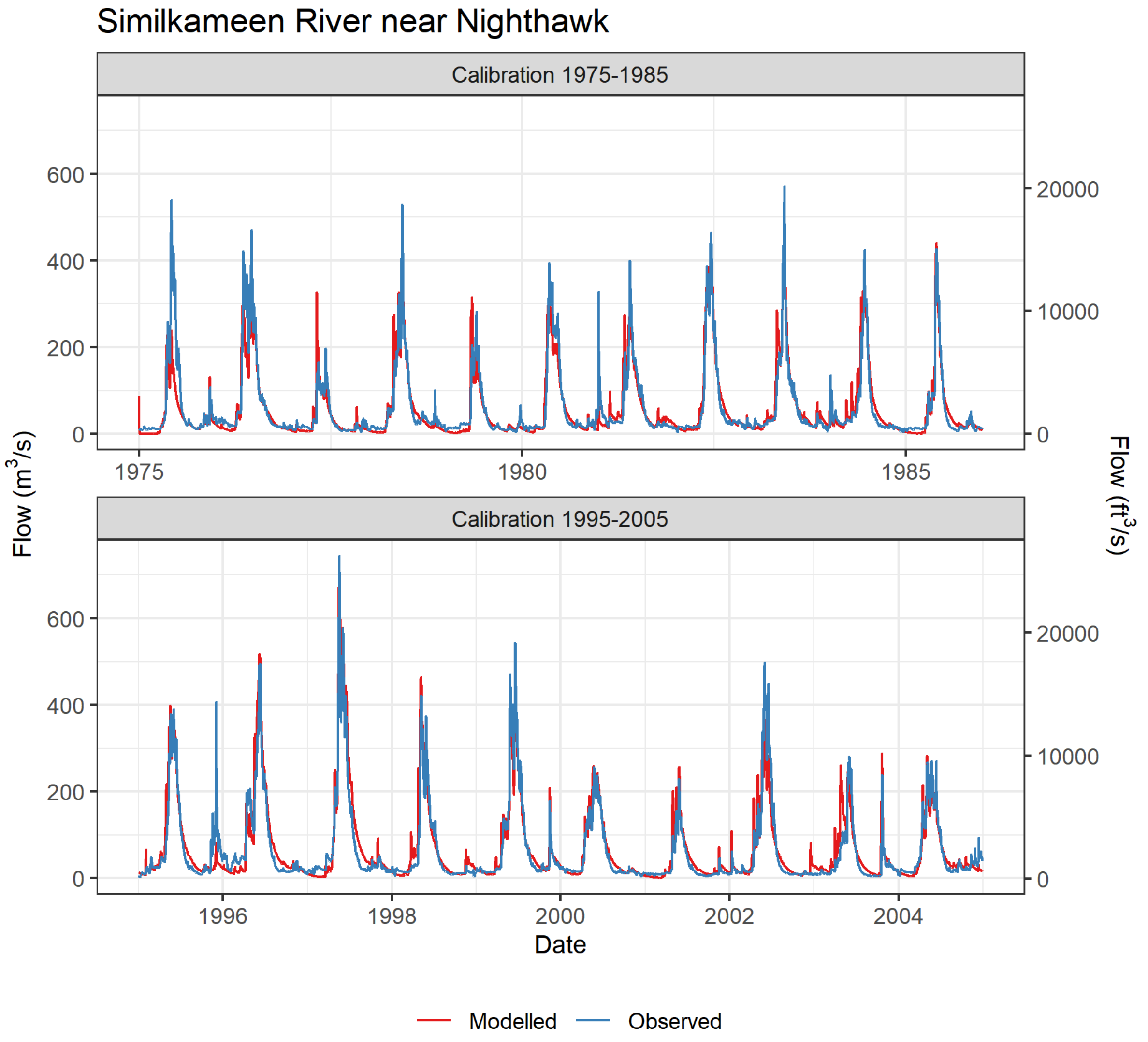
Similkameen Watershed – Some simple changes





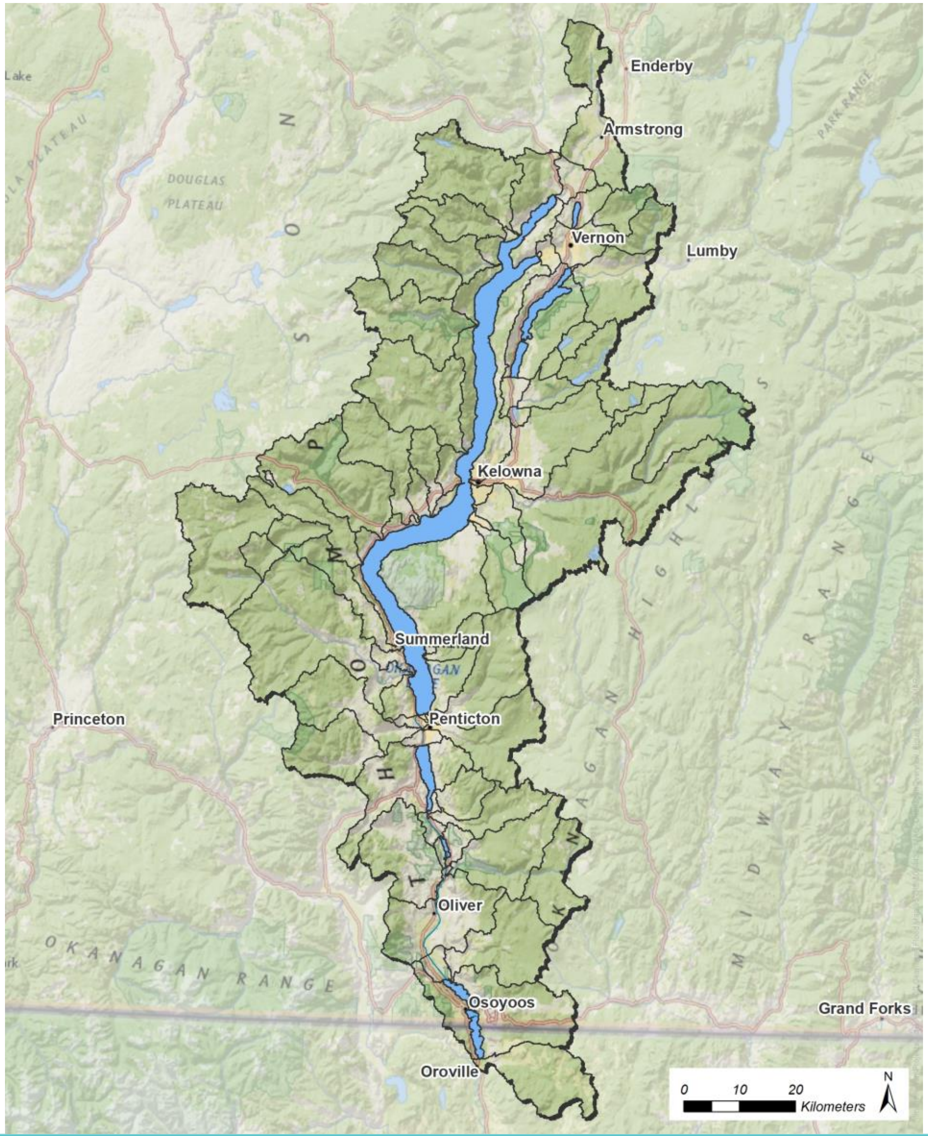
Similkameen Watershed – Some simple changes

- Project purpose: understand climate change impacts to Similkameen near Nighthawk gauge (influencing Osoyoos Lake operations)
- Key Model Structure Changes:
  - Change PET from monthly values to Hargreaves 1985
  - Eliminate lateral equilibrate for fast and slow reservoir
  - Use Raven lake release/evaporation instead of soil 2 reservoir



Representation of Lakes and Reservoirs

- Traditional HBV-EC structure is not ideal for watersheds with significant lakes and reservoirs
- Hydrologic model of the Okanagan mainstem uses HBV-EC as the basis but with power of Raven’s other lake and reservoir representation
- Project goal: Understand implication of climate change to lake inflows, outflows, levels
- 11 lakes/reservoirs and 3 operating schemes



Lake Storage and Evaporation

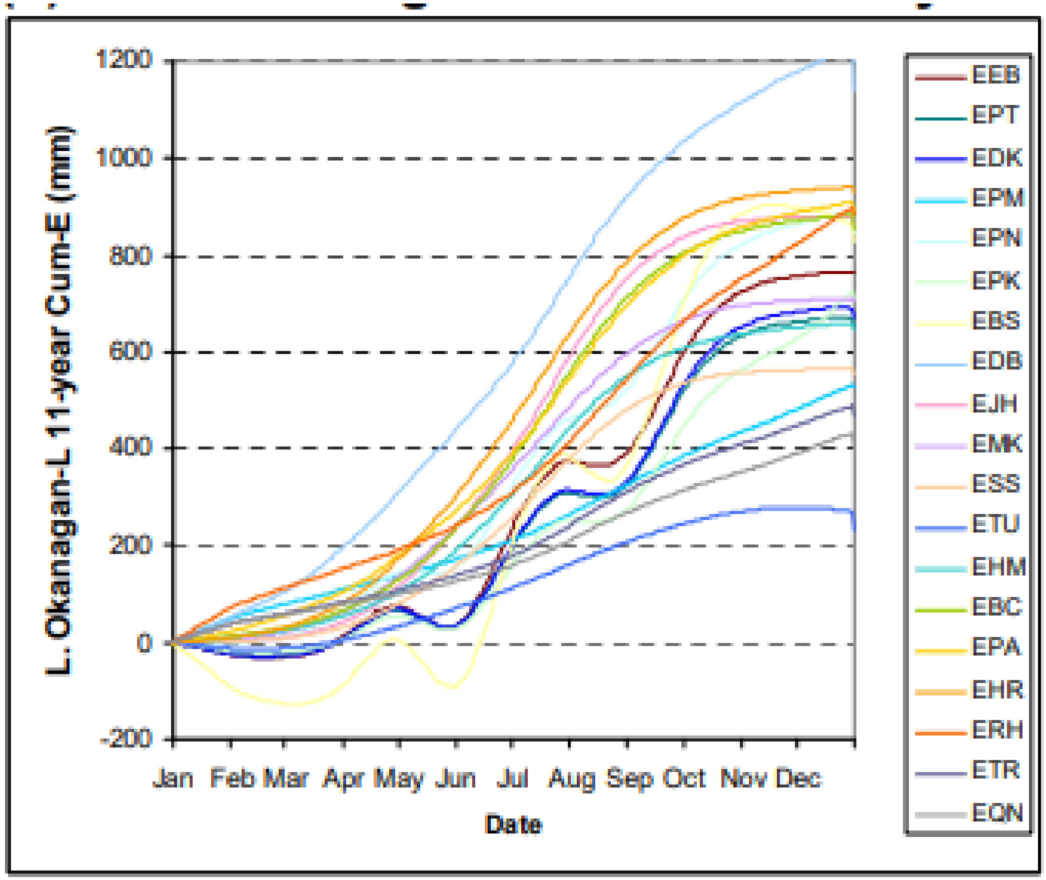
```
# non-HBV:
:LakeStorage LAKE_STORAGE

# --Hydrologic Processes-------------------------
:Alias FAST_RESERVOIR SOIL[1]
:Alias SLOW_RESERVOIR SOIL[2]

:HydrologicProcesses
    :SnowRefreeze        FREEZE_DEGREE_DAY          SNOW_LIQ        SNOW
    :Precipitation       PRECIP_RAVEN               ATMOS_PRECIP    MULTIPLE
    :CanopyEvaporation   CANEVP_ALL                 CANOPY          ATMOSPHERE
    :CanopySublimation   CANEVP_ALL                 CANOPY_SNOW     ATMOSPHERE
    :SnowBalance         SNOBAL_SIMPLE_MELT         SNOW            SNOW_LIQ
    :Overflow            OVERFLOW_RAVEN             SNOW_LIQ        PONDED_WATER
    :Flush               RAVEN_DEFAULT              PONDED_WATER    GLACIER
        :-->Conditional HRU_TYPE IS GLACIER
    :GlacierMelt         GMELT_HBV                  GLACIER_ICE     GLACIER
    :GlacierRelease      GRELEASE_HBV_EC            GLACIER         SURFACE_WATER
    :Infiltration        INF_HBV                    PONDED_WATER    MULTIPLE
    :Flush               RAVEN_DEFAULT              SURFACE_WATER   FAST_RESERVOIR
        :-->Conditional HRU_TYPE IS_NOT GLACIER
        :-->Conditional HRU_TYPE IS_NOT LAKE
    :SoilEvaporation     SOILEVAP_HBV               SOIL[0]         ATMOSPHERE
    :CapillaryRise       CRISE_HBV                  FAST_RESERVOIR  SOIL[0]
    :LakeEvaporation     LAKE_EVAP_BASIC            LAKE_STORAGE    ATMOSPHERE     #non hbv
    :LakeRelease         LAKEREL_LINEAR             LAKE_STORAGE    SURFACE_WATER #non hbv
    :Percolation         PERC_CONSTANT              FAST_RESERVOIR  SLOW_RESERVOIR
    :Baseflow            BASE_POWER_LAW             FAST_RESERVOIR  SURFACE_WATER
    :Baseflow            BASE_LINEAR                SLOW_RESERVOIR  SURFACE_WATER
:EndHydrologicProcesses
```

Evaporation from Lakes

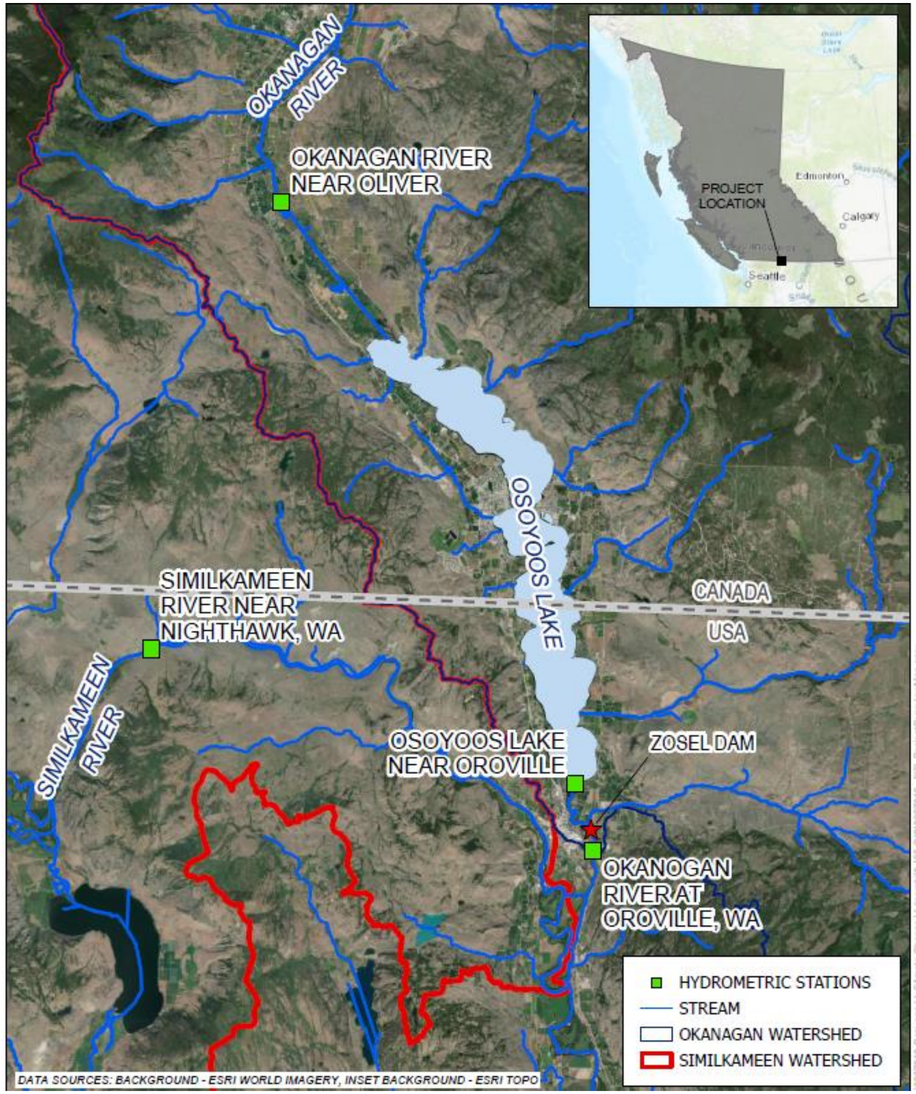
- Lake evaporation is a significant portion of the water balance
- External model developed for Okanagan mainstems used to calculate Lake evaporation
- Used PET_DATA and gauge weights to apply external model results within the Raven model



From Schertzer and Taylor, 2010

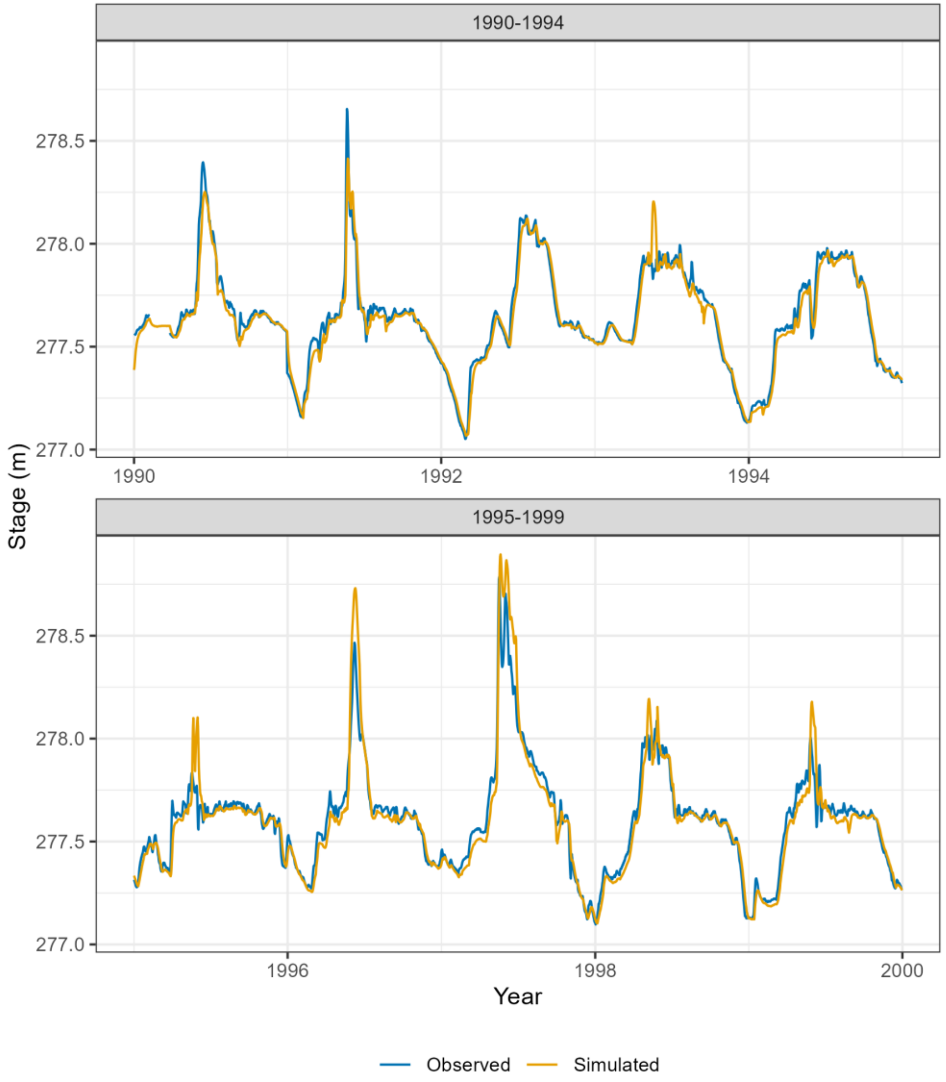
Backwater Effect on Lake Osoyoos

- Under normal conditions Osoyoos Lake levels determined by inflow from the Okanagan River and operations of Zosel dam
- Under certain conditions Osoyoos Lake levels become backwatered by Similkameen River with backflow occurring in extreme conditions



Backwater Effect on Lake Osoyoos

- Implemented latest reservoir management methods in Raven
- Used regression that describes relationship between Osoyoos Lake Levels, Okanagan Flow, and Similkameen Flow
- When specific criteria met typical operations stop and regression equation used to determine "target water level"



Representation of Glaciers

```
:GlacierMelt        GMELT_HBV                    GLACIER_ICE    GLACIER
:GlacierRelease     GRELEASE_HBV_EC              GLACIER        SURFACE_WATER
```

GMELT_HBV = POTMELT*HBV_MELT_GLACIER_CORR

$GRELEASE = -K^{*}\phi_{Glac}$ $\qquad$ $K^{*} = K_{MIN} + (K - K_{MIN})^{-AG(SN+SNLiq)}$

Representation of Glacier Retreat – Historic Conditions

Incorporate Glacier Retreat into HRU discretization

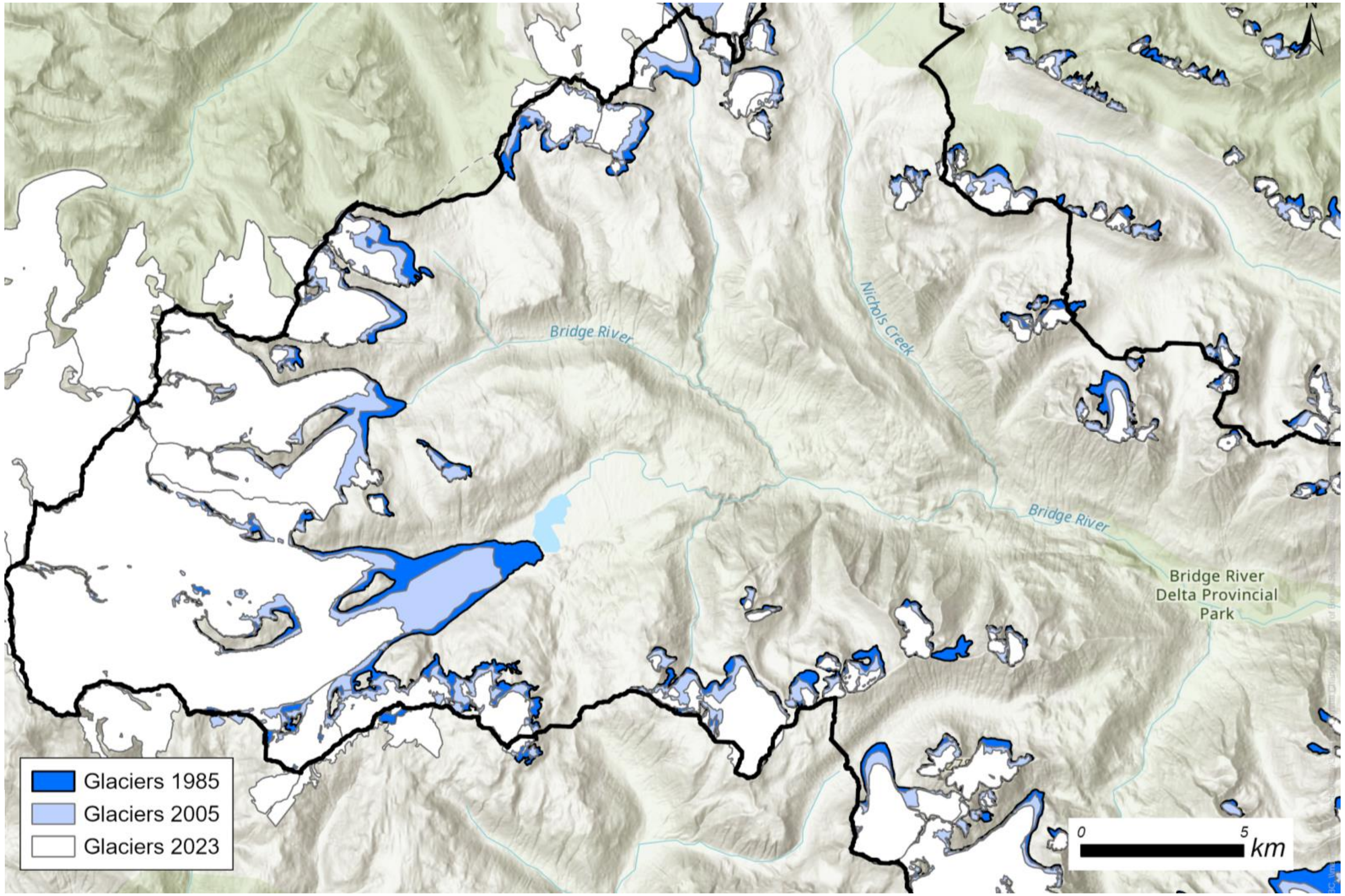
↓

Define Glacier HRU groups by time period

↓

Change LandUse, Vegetation, HRU Type

```
# Landuse changes
:LandUseChange Glaciers_1985 BARE 2005-01-01
:VegetationChange Glaciers_1985 BARE 2005-01-01
:HRUTypeChange Glaciers_1985 STANDARD 2005-01-01
```



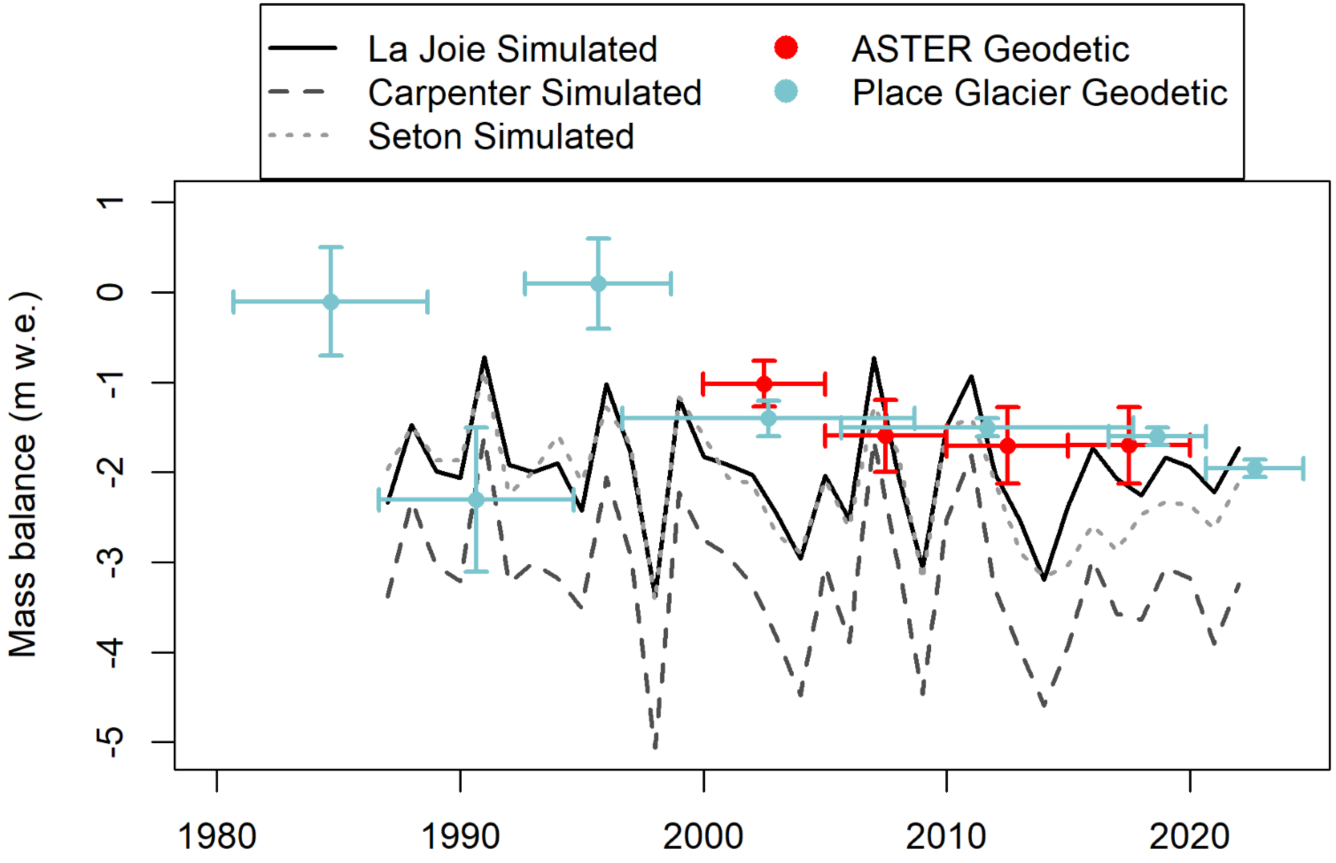
Representation of Glaciers – Reality Checks

$$B_a = Ice_{wastage} + \Delta SWE$$

$$Ice_{wastage} = \min\_ice_{yi} - \min\_ice_{yi-1}$$

$$\Delta SWE = \min\_SWE - \min\_SWE_{yi-1}$$

Custom Outputs – Yearly minimum glacier ice and yearly minimum SWE



Representation of Glaciers – Parameter Ranges

GMELT_HBV = POTMELT*HBV_MELT_GLACIER_CORR

- HBV_MELT_GLACIER_CORR should always be greater than 1
- Typical Range 1-2

GRELEASE = $-K^*\phi_{Glac}$ $K^* = K_{MIN} + (K - K_{MIN})^{-AG(SN+SNLiq))}$

- $K_{min} < K$ (Tied parameter in Ostrich)
- Both Kmin and K < 1
- K_{min}: 0.05 default
- K: 0.1 default
- AG: 0 – 0.2 (Green Kenue Manual)

Table 3. Melt factors for snow (k_s) and ice (k_i) and static mass-balance sensitivities (S_T) to a 1 K temperature increase, calculated from the model run (15 May–30 September, 6.0°C km^{-1})

Glacier	k_s mm °C^{-1} d^{-1}	k_i mm °C^{-1} d^{-1}	R^2	n	S_T m w.e. a^{-1} K^{-1}
Bench	2.81	4.17	0.80	52	–0.43
Bridge	3.21	4.22	0.86	94	–0.55
Helm	3.62	5.27	0.65	35	–0.56
Peyto	2.32	5.57	0.90	239	–0.49
Place	2.71	4.69	0.81	165	–0.55
Sykora	3.27	4.22	0.84	37	–0.54
Tiedemann	2.97	4.79	0.83	67	–0.54
Woolsey	3.21	4.58	0.75	67	–0.45
Zavisha	3.23	3.61	0.37	28	–0.52
Mean	3.04	4.59			–0.51

Shea et al. 2009

Wrap Up

- HBV-EC is a great model choice, particularly in snowmelt dominated systems
  - Works well at hourly and daily timestep
- Add complexity as needed – make the model fit for purpose

Thank you!

gbrown@nhcwater.com