

# Evaluation of Process-based Hydrological Modelling in Canadian Rockies Headwater Basins

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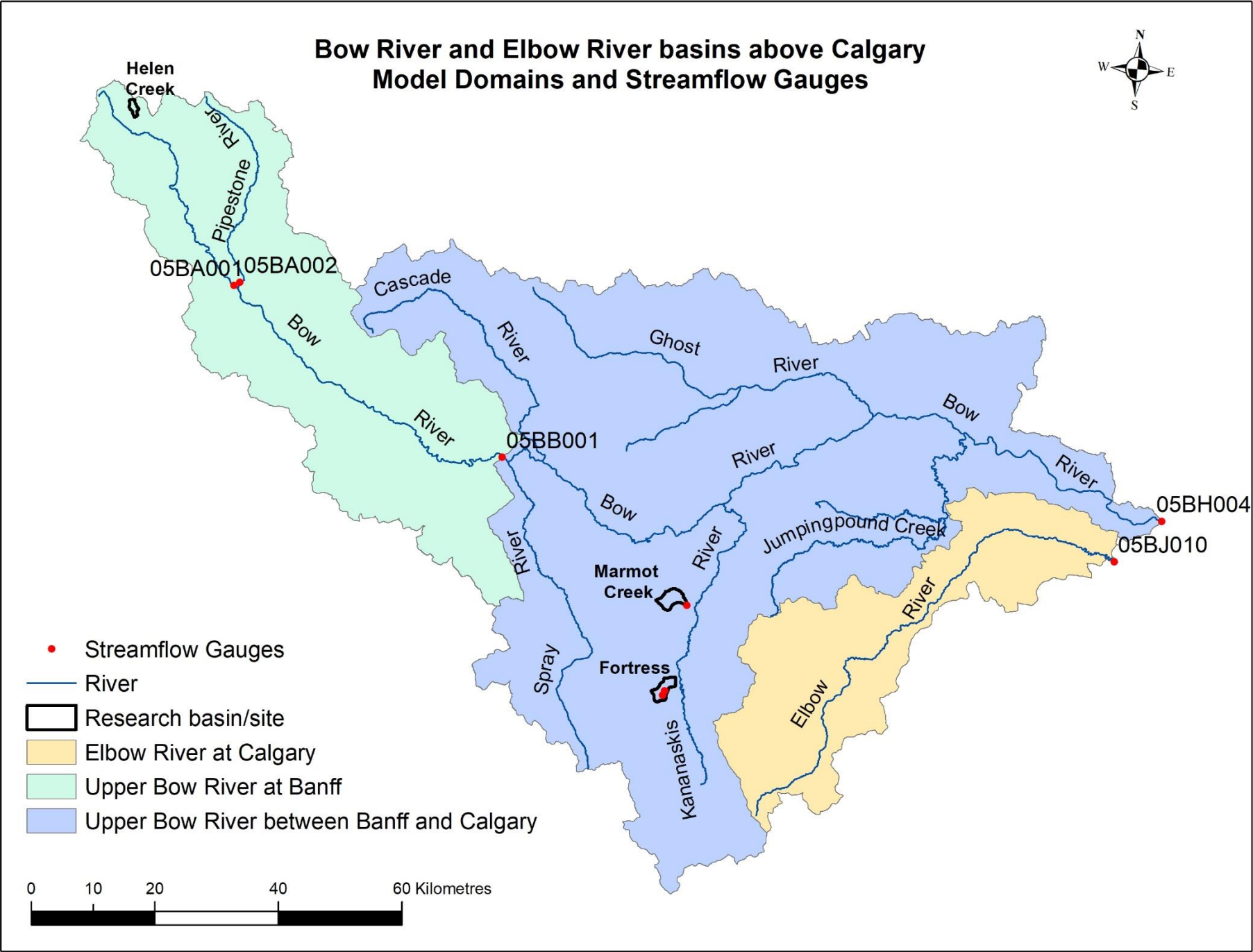


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# Purpose

- Evaluate an uncalibrated, physically based hydrological process model for prediction of SWE, snow depth and streamflow in the Canadian Rockies at multiple scales.
  - Point scale at automatic weather station sites,
  - Headwater research basin scale,
  - River basin scale

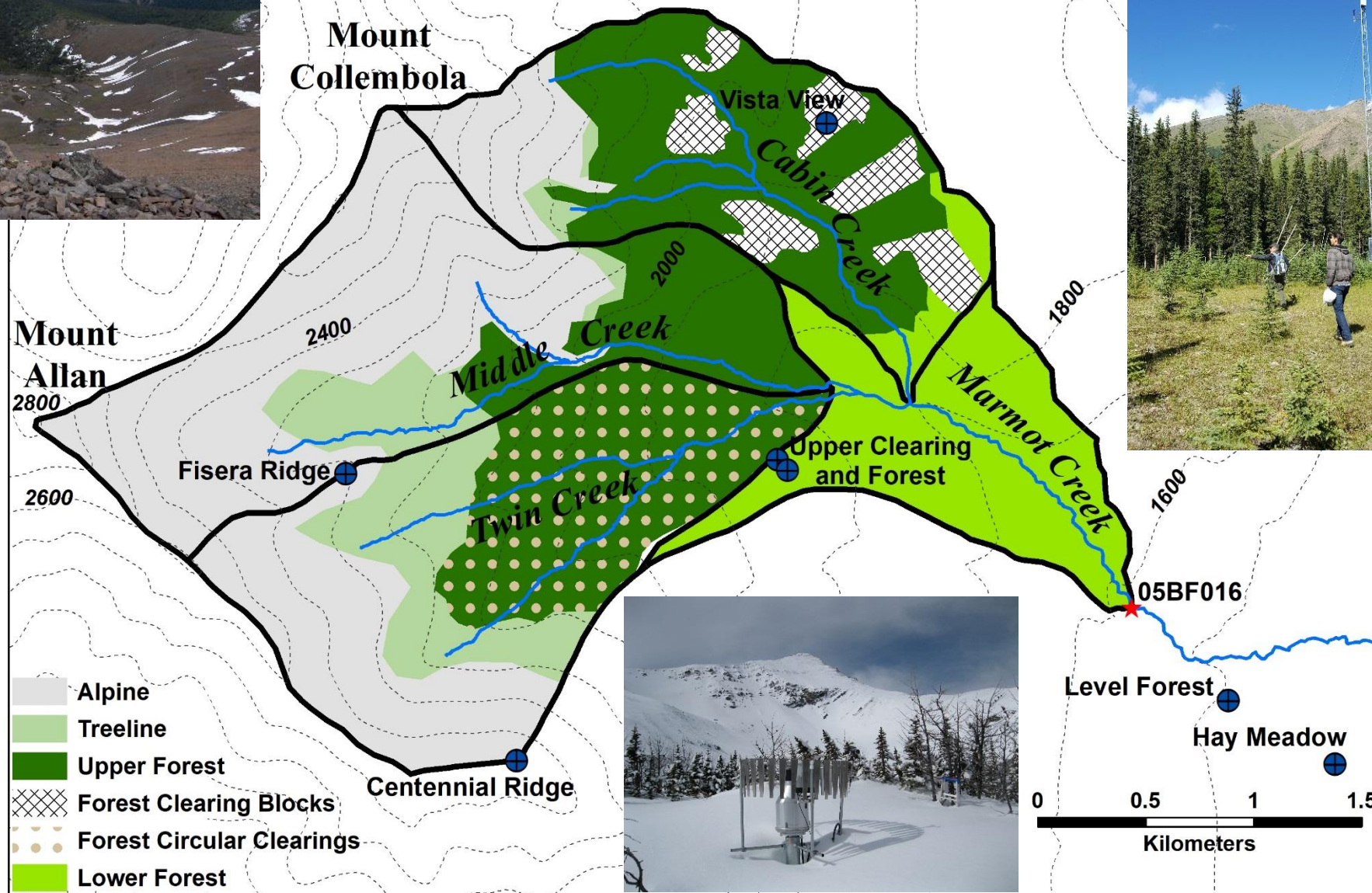
# Model domains:





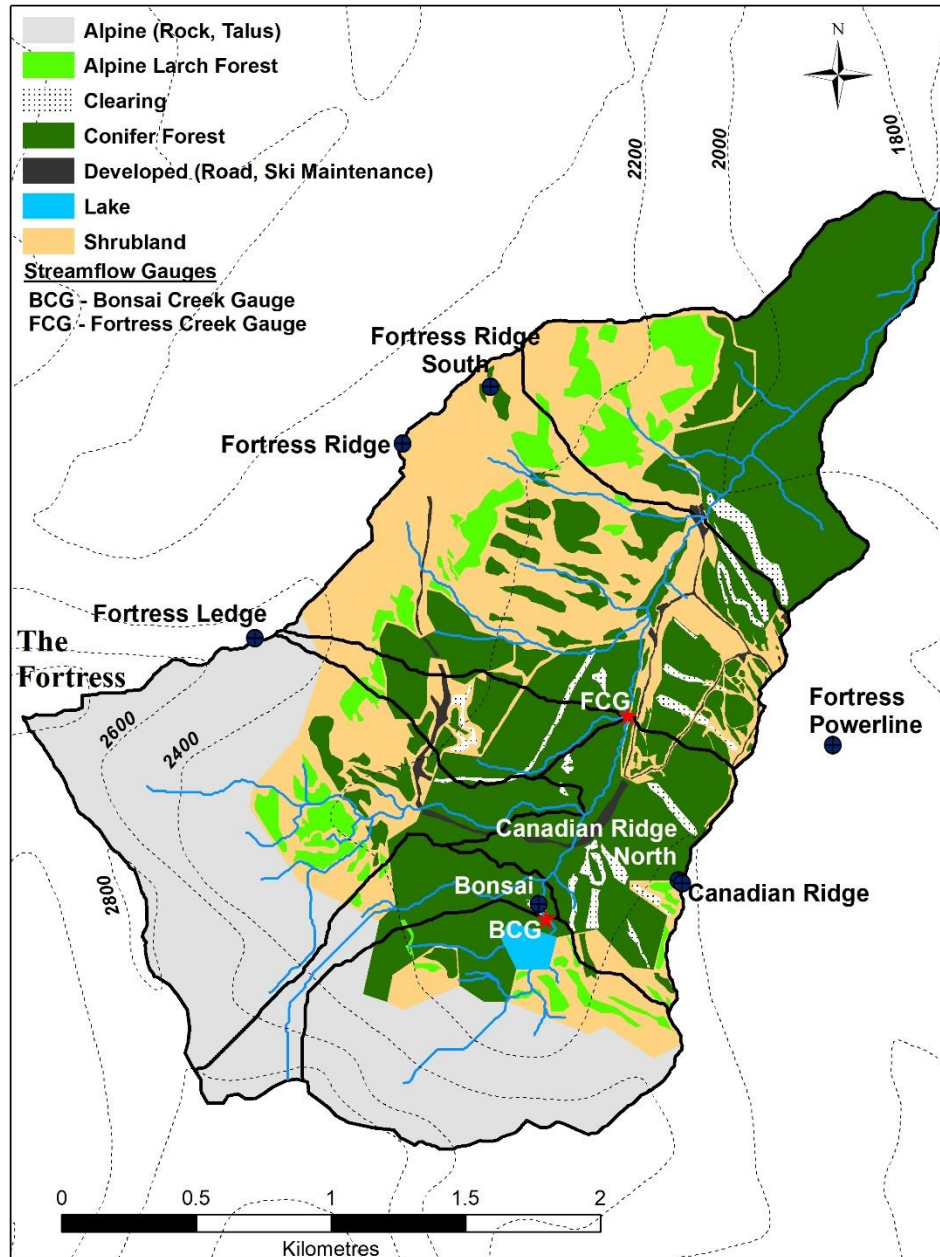


# Marmot Creek Research Basin (~9.4 km<sup>2</sup>)





# Fortress Mountain Basin (~5.9 km<sup>2</sup>)





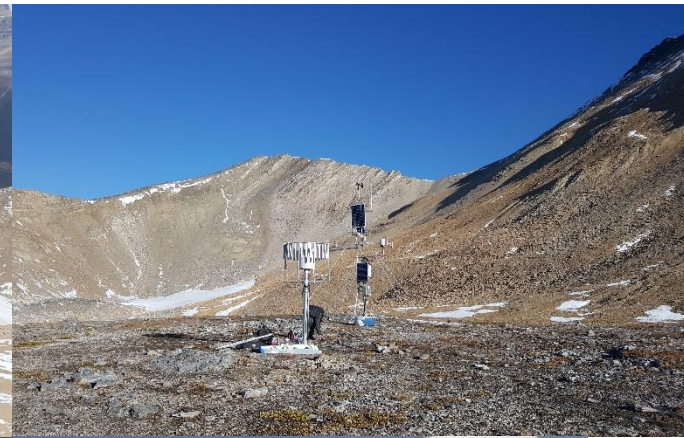
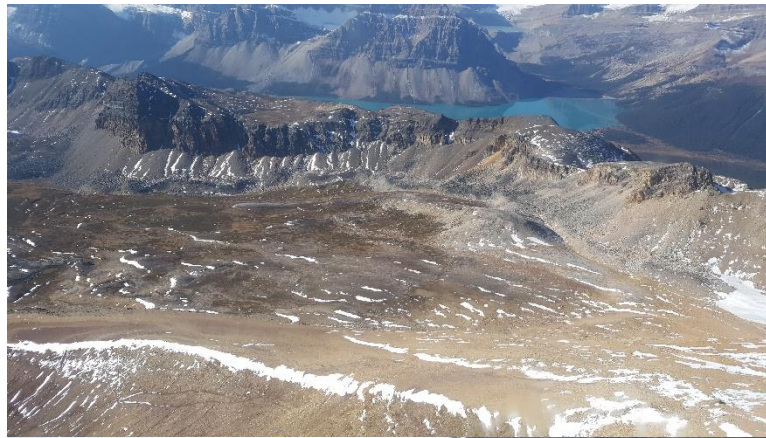
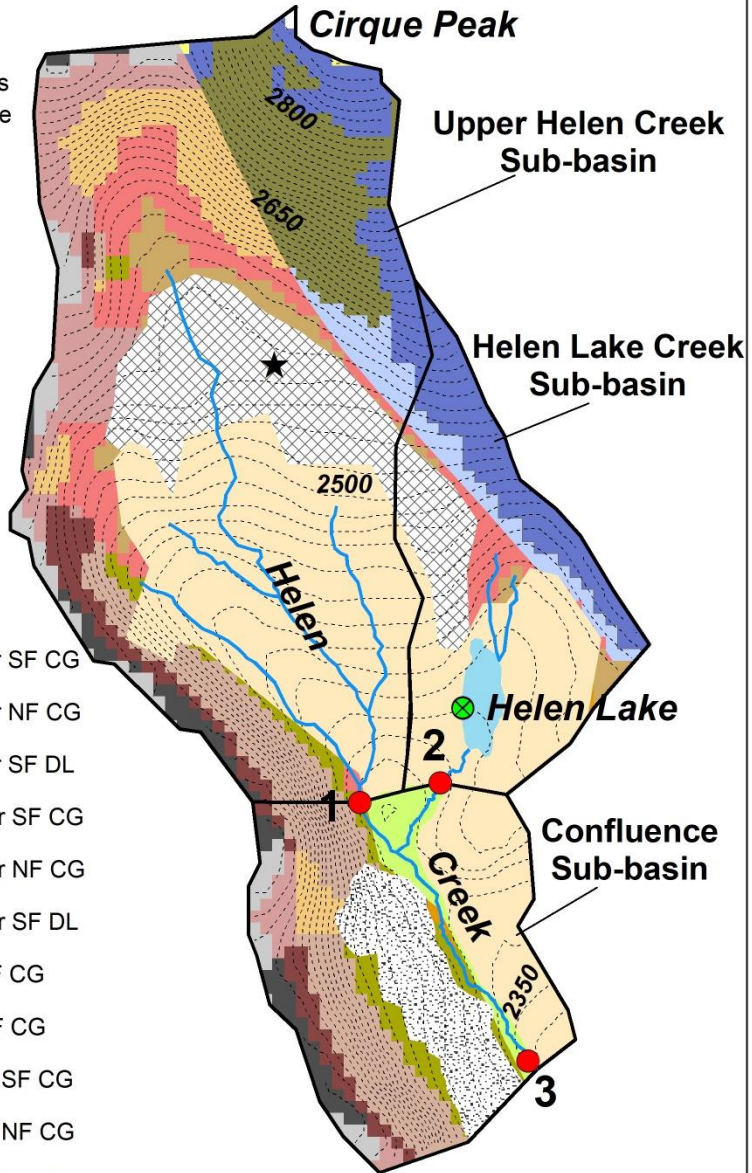
# Helen Creek Research Basin



- ★ Weather station
- ⊗ Helen Lake Level Site
- Streamflow Gauge Sites
  - 1 - Upper Helen Creek Gauge
  - 2 - Helen Lake Creek Gauge
  - 3 - Helen Creek Research Basin Main Gauge

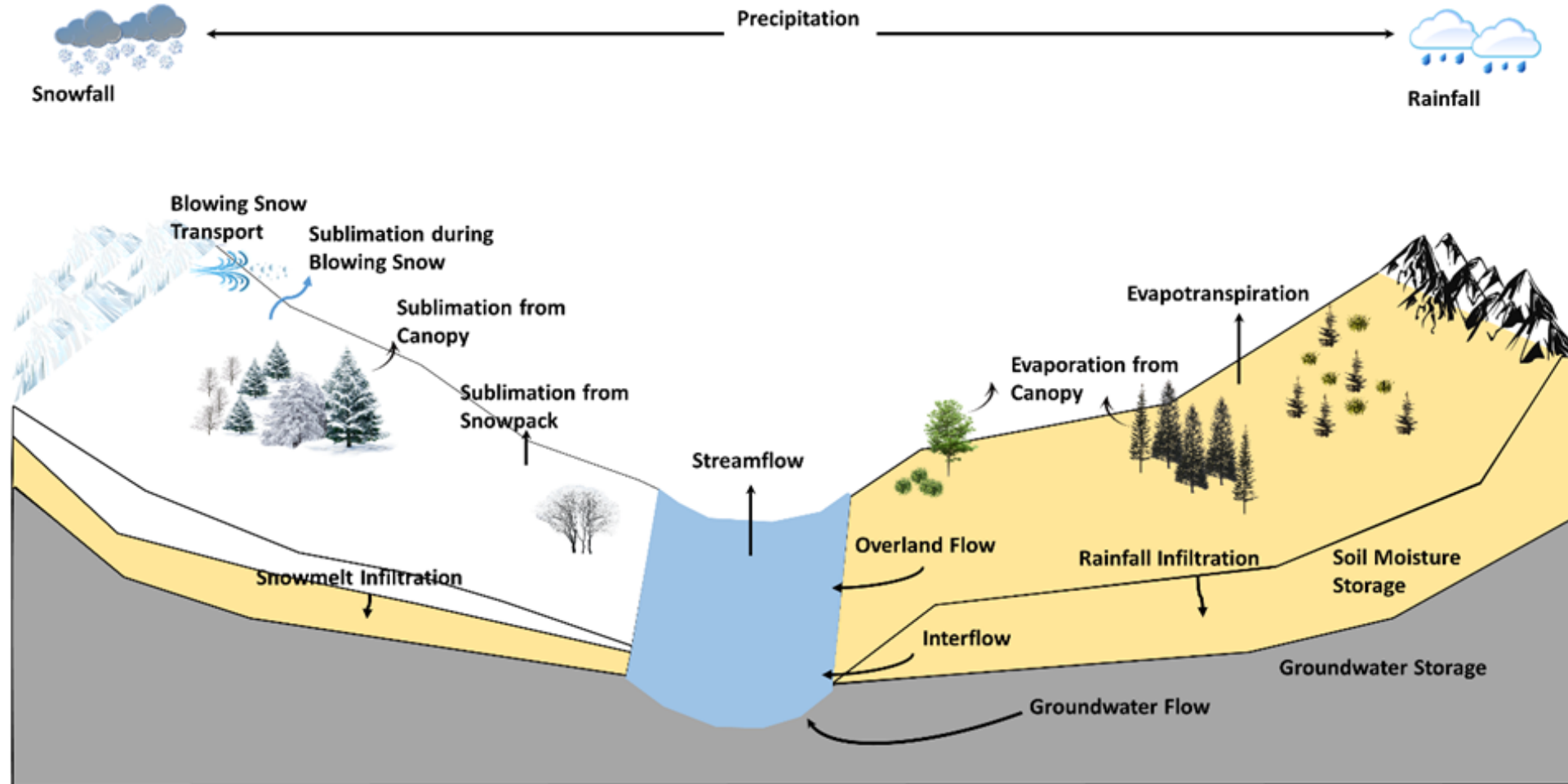
- Creek
- Alpine meadow CG
- Alpine wetland CG
- Rock glacier CG
- Rock plateau CG
- Rock steep SF CG
- Rock steep NF CG
- Rock steep SF DL
- Rock moderate lower SF CG
- Rock moderate lower NF CG
- Rock moderate lower SF DL
- Rock moderate upper SF CG
- Rock moderate upper NF CG
- Rock moderate upper SF DL
- Rock gentle lower SF CG
- Rock gentle lower NF CG
- Rock gentle ridgetop SF CG
- Rock gentle ridgetop NF CG
- Rock gentle ridgetop SF DL

NF: north-facing    SF: south-facing  
CG: Cog Group    DL: Dolomite Limestone



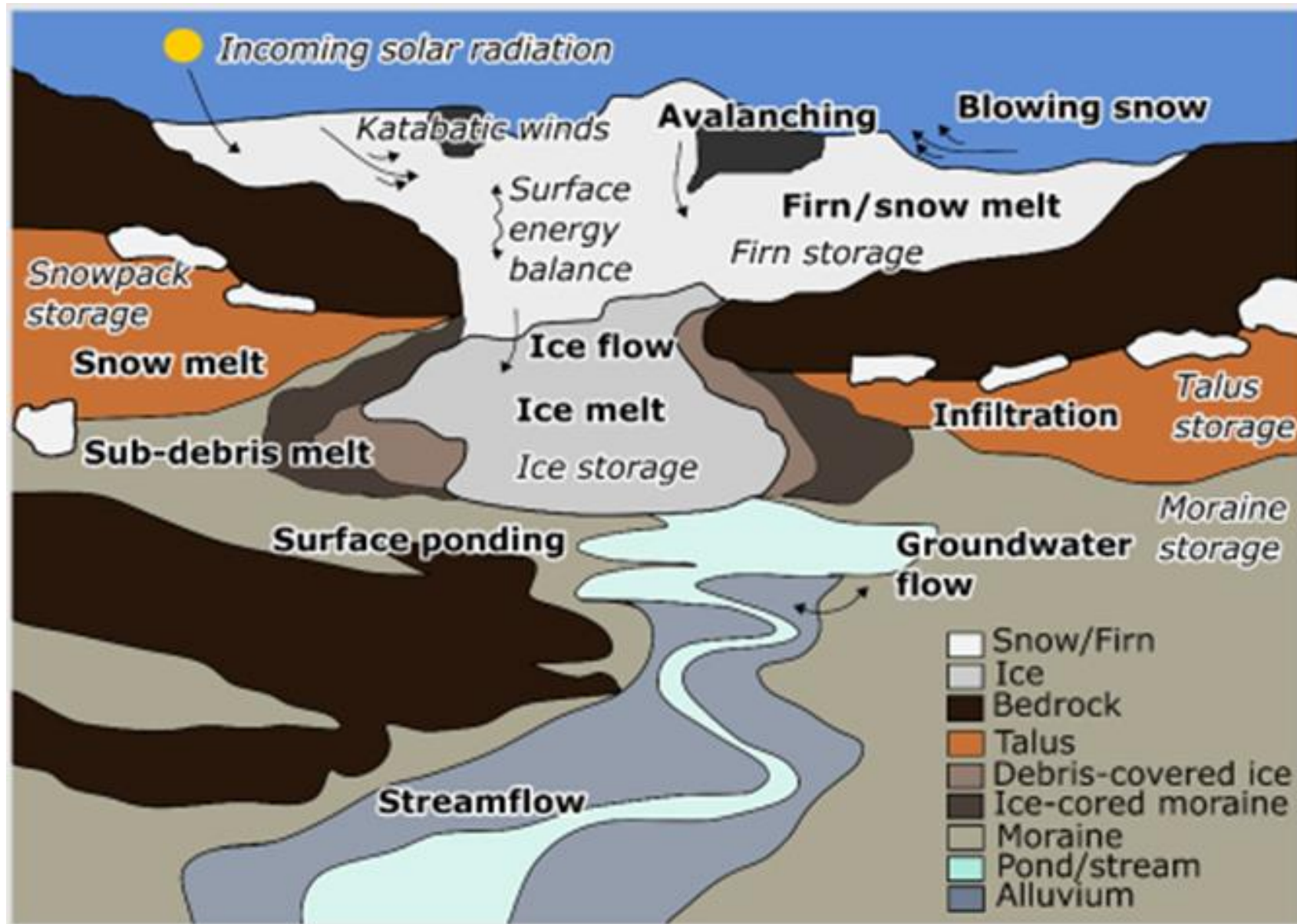


# CRHM modelling alpine hydrological processes



(Pomeroy et al., 2022)

# CRHM modelling glacier hydrology



(Pradhananga & Pomeroy, 2022; Aubry- Wake & Pomeroy, 2022)



# Parameterisation: DIA Approach\*

- Deduction (rule based / top-down): allows deriving  $\beta$  from  $\alpha$  only where  $\beta$  is a formal logical consequence of  $\alpha$ . ***The volume flow rate through a saturated porous medium is X and the gradient is Y, therefore we can find the saturated hydraulic conductivity.***
- Induction (observation based / bottom-up): allows inferring  $\beta$  from  $\alpha$ , where  $\beta$  does not follow necessarily from  $\alpha$ . ***The snowpack is observed to melting and the air temperature is T, therefore the melt factor is f.***
- Abduction (opportunistic / lateral): allows inferring to the best explanation from regional information even when local information is incomplete. ***Crop X reaches maturity in early July and provides peak ET then in research basin Q, therefore it also does in river basin P.***
- CRHM relies primarily on deducted and abducted parameters. No calibration or optimisation of parameters from streamflow is shown here. Learn from mistakes!

\* Pomeroy, Fang, Shook, Whitfield, PUB Workshop Proceedings, 2013, CWRA/IAHS

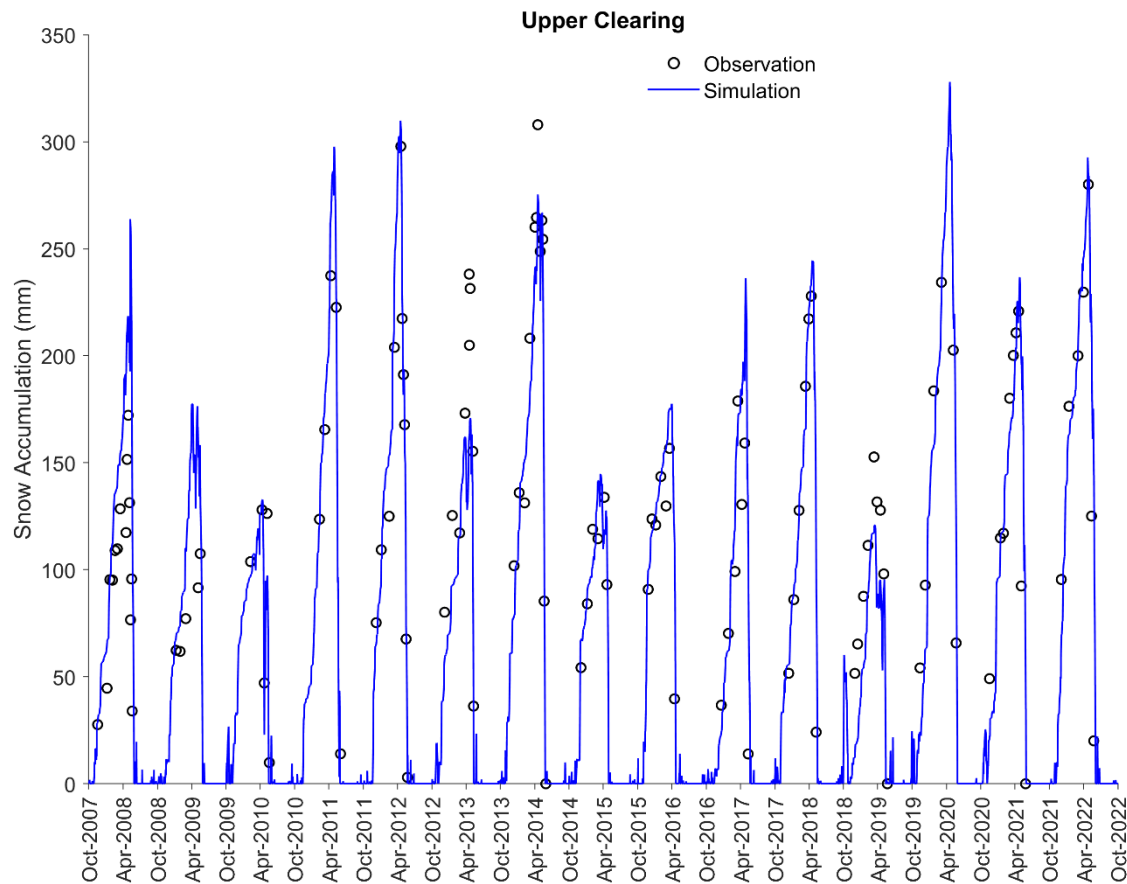
# SWE Evaluation at Marmot Creek Research Basin

## - montane coniferous forest sites

MB = 0.07

RMSD = 42 mm

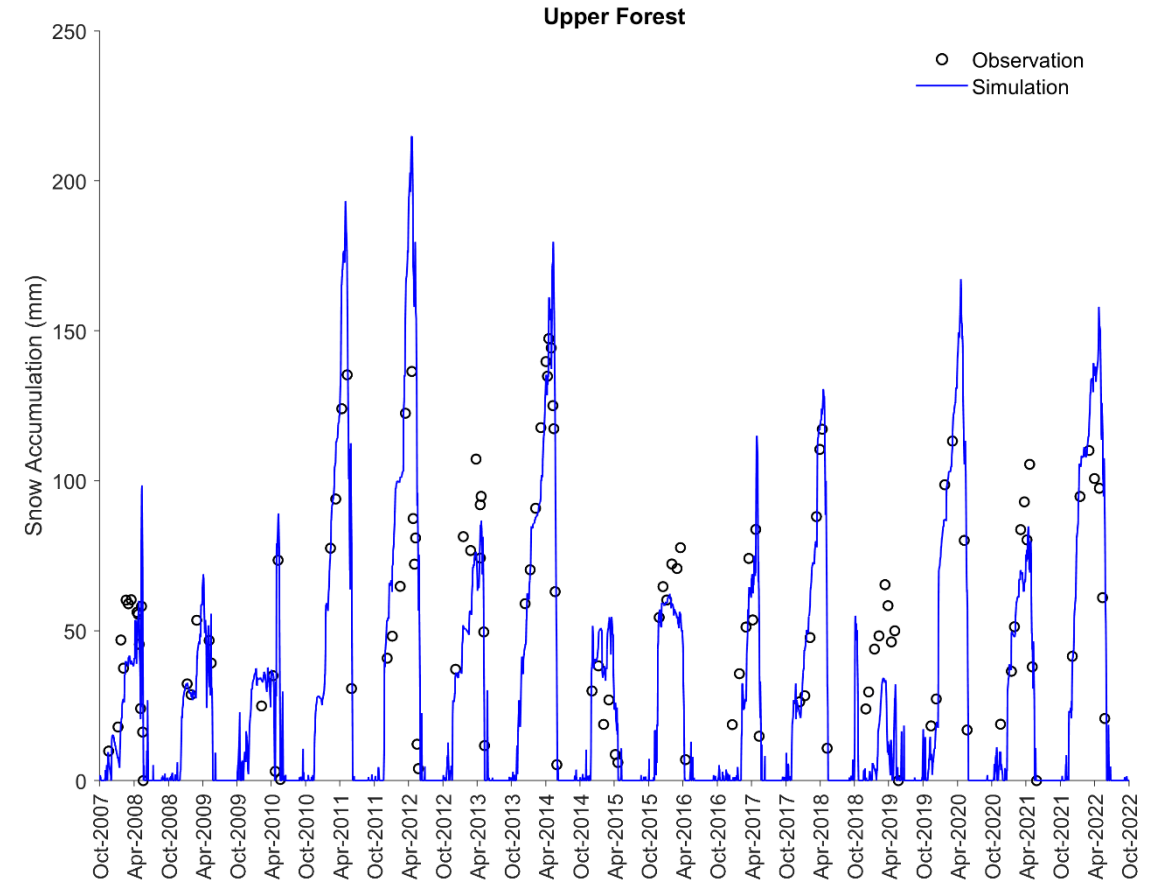
NRMSD = 0.33



MB = 0.11

RMSD = 30 mm

NRMSD = 0.51





# SWE Evaluation at Marmot Creek Research Basin

## - alpine ridge sites

MB = 0.6

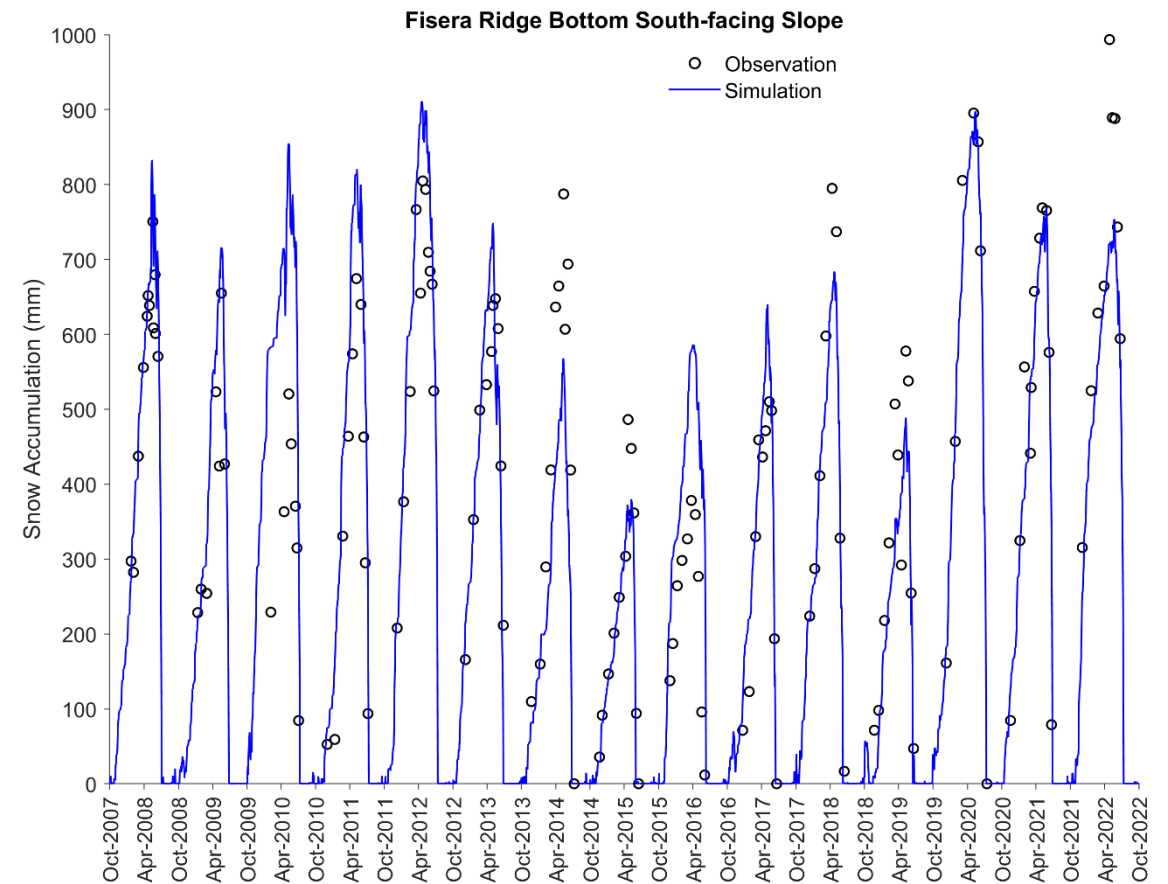
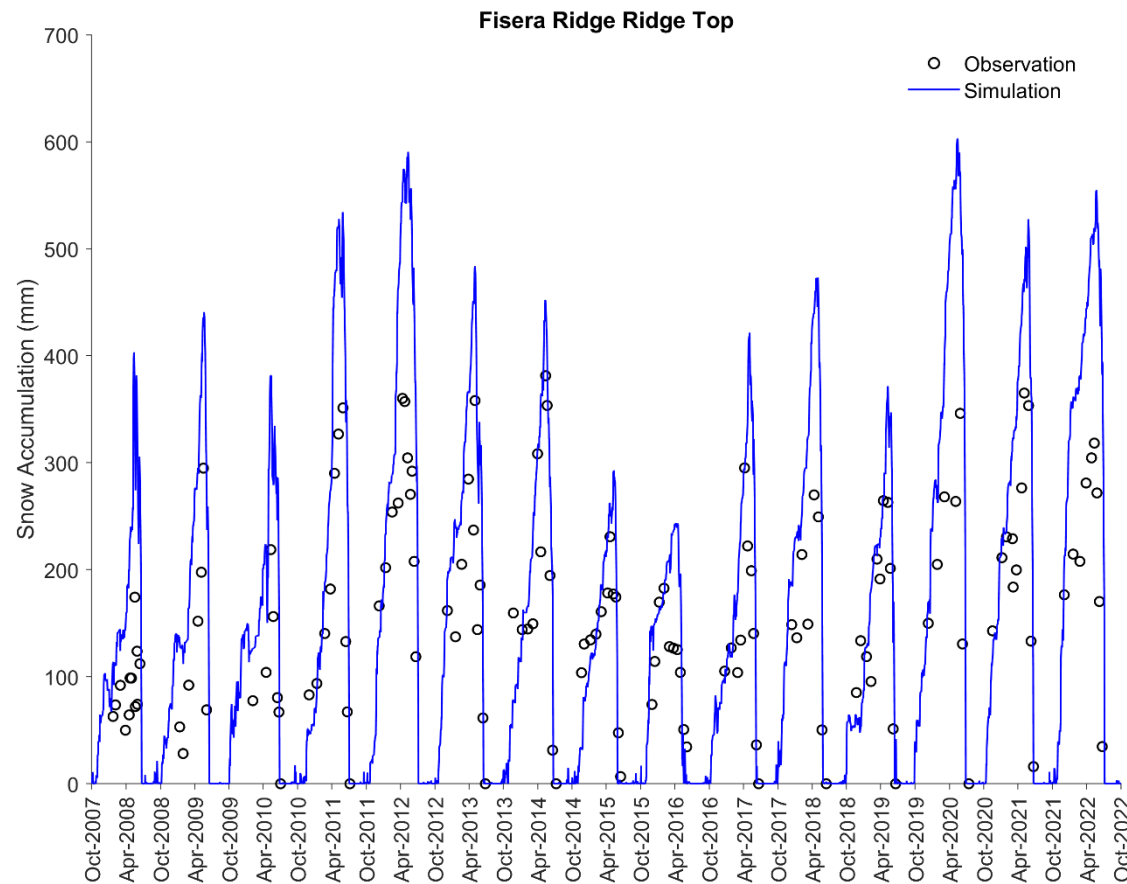
RMSD = 135 mm

NRMSD = 0.84

MB = 0.06

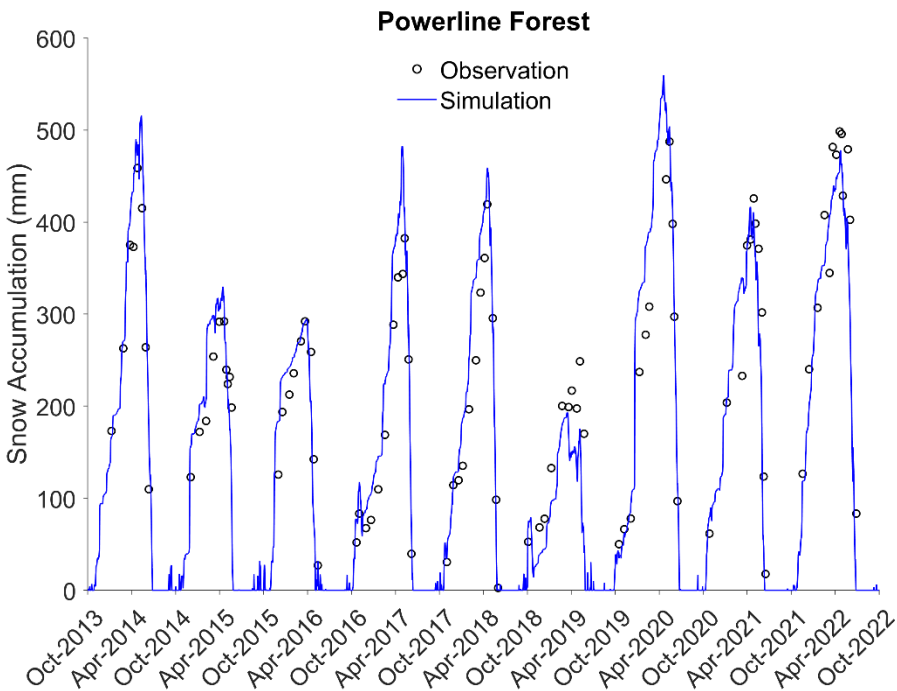
RMSD = 130 mm

NRMSD = 0.3

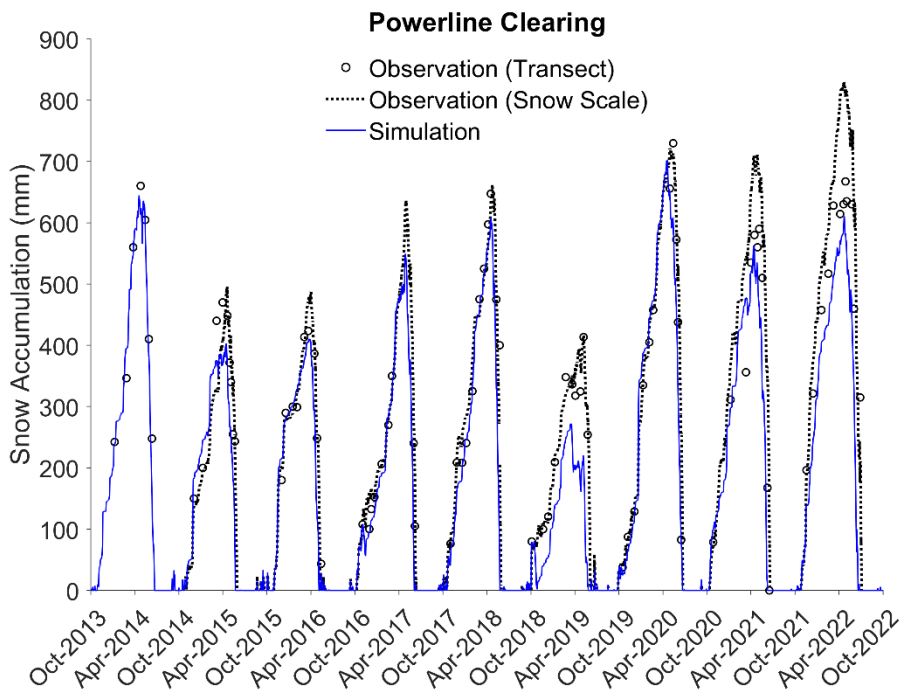
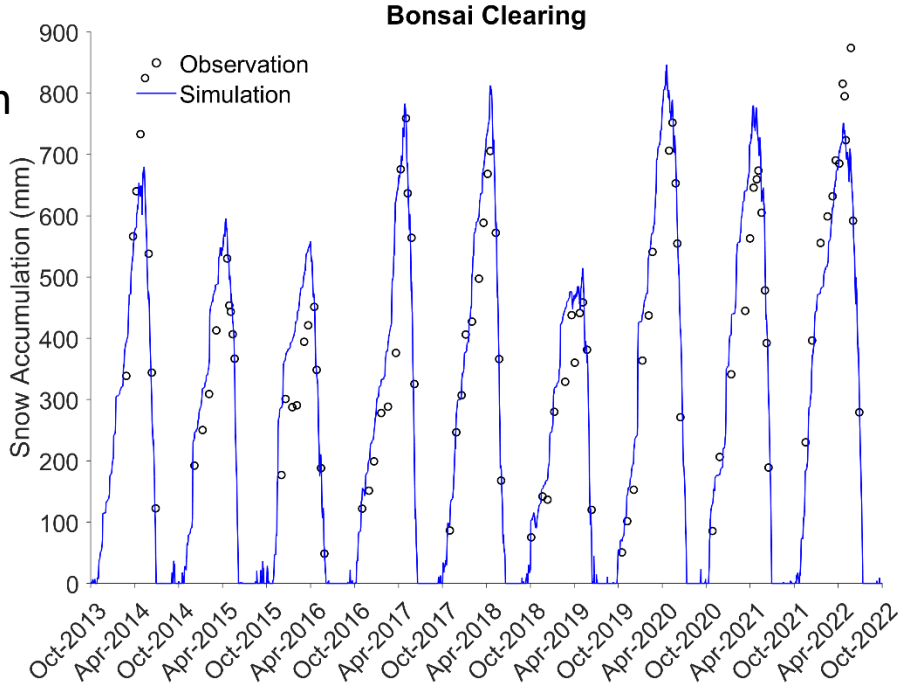


# SWE Evaluation at Fortress Mountain Basin - montane coniferous forest sites

MB = 0.02  
RMSD = 53 mm  
NRMSD = 0.22



MB = 0.07  
RMSD = 77 mm  
NRMSD = 0.18



Transect:  
MB = -0.17  
RMSD = 98 mm  
NRMSD = 0.28

Snow Sale:  
MB = -0.33  
RMSD = 220 mm  
NRMSD = 0.67



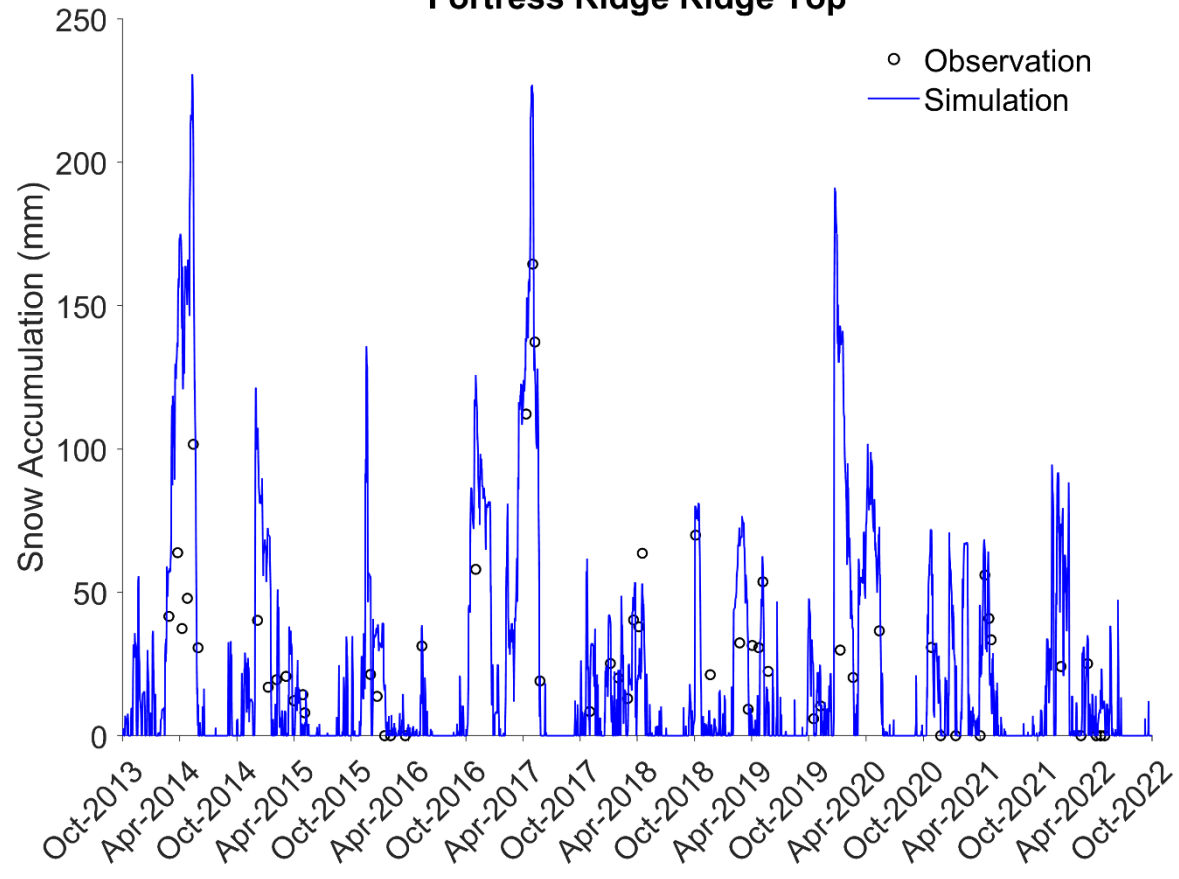
# SWE Evaluation at Fortress Mountain Basin - alpine ridge sites

MB = 0.52

RMSD = 38 mm

NRMSD = 1.2

**Fortress Ridge Ridge Top**

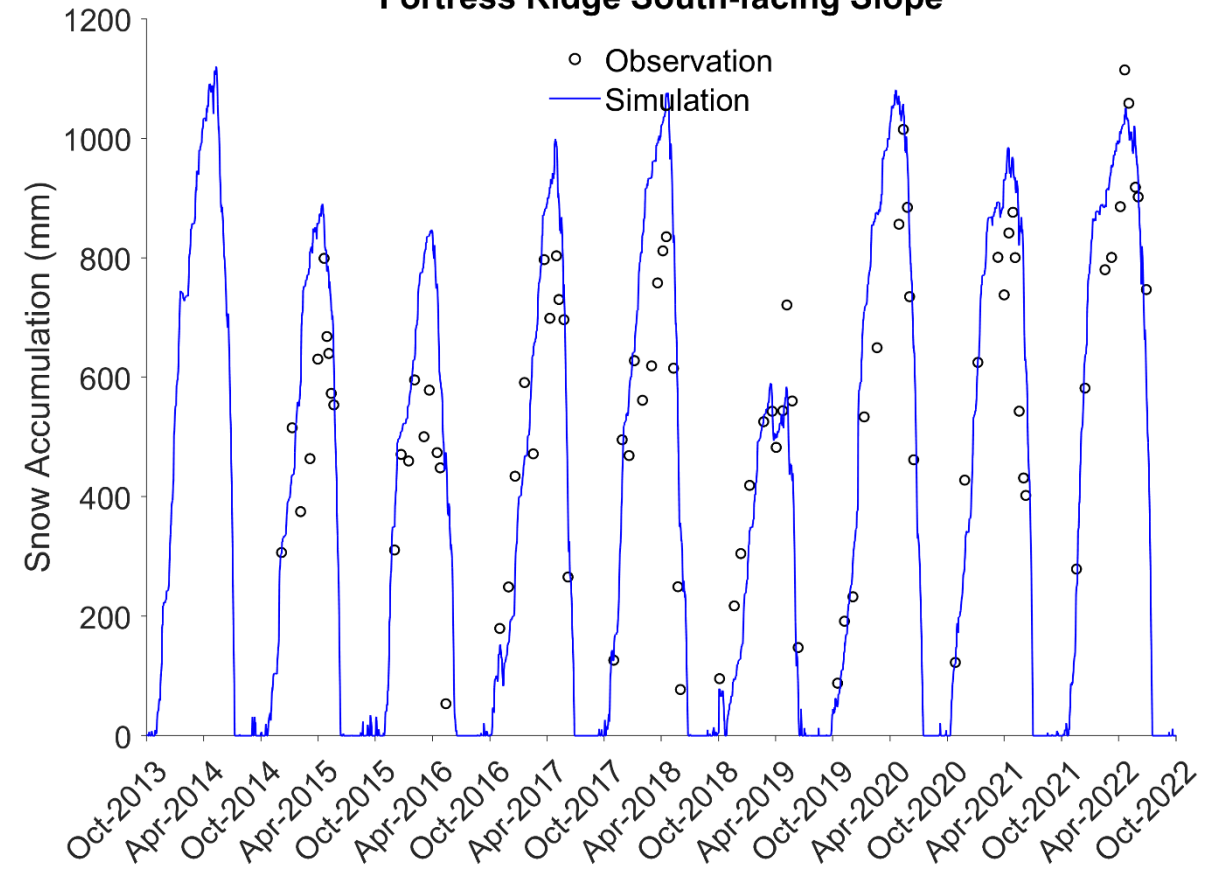


MB = 0.16

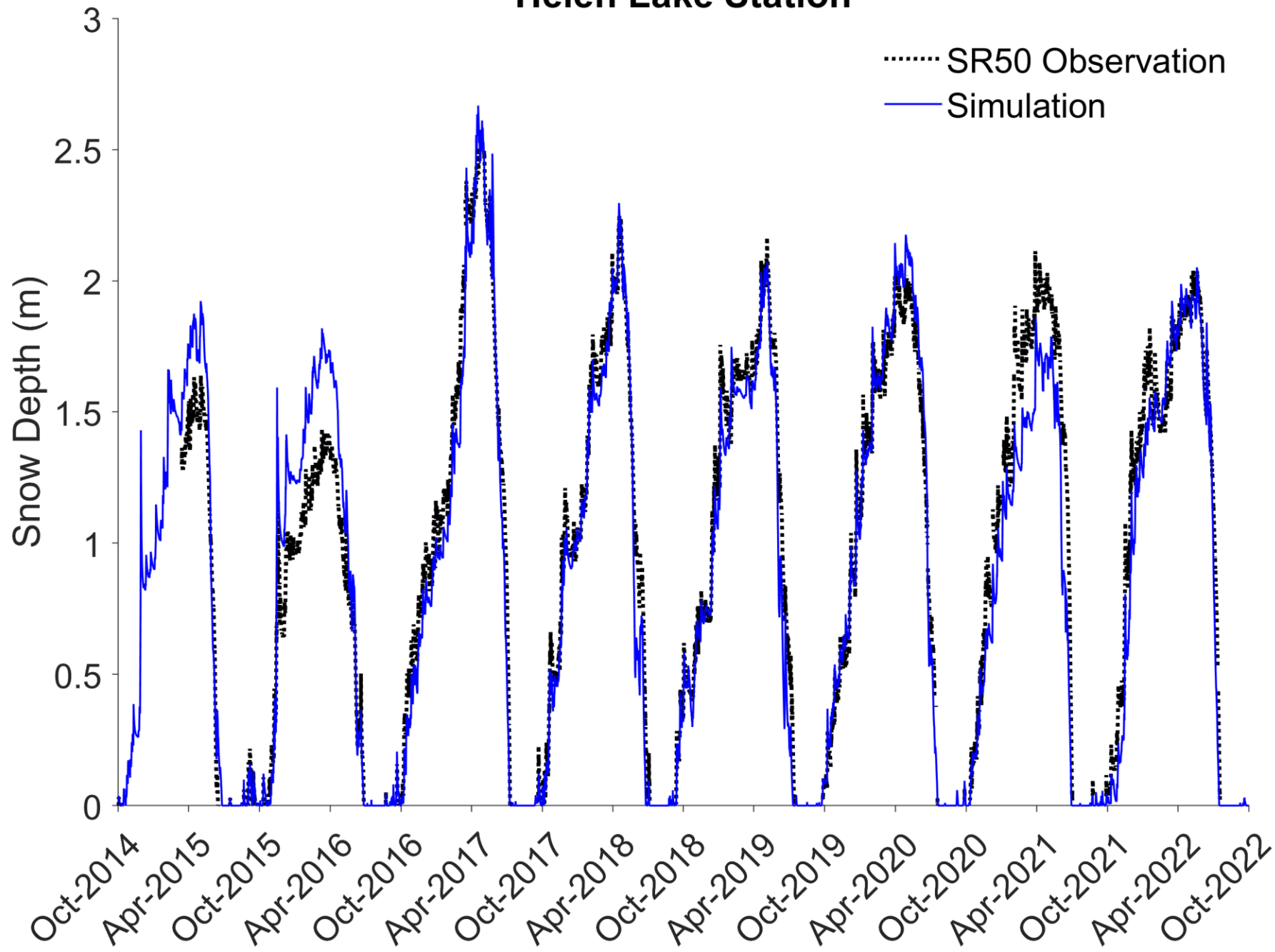
RMSD = 163 mm

NRMSD = 0.29

**Fortress Ridge South-facing Slope**



# Helen Lake Station



..... SR50 Observation

— Simulation

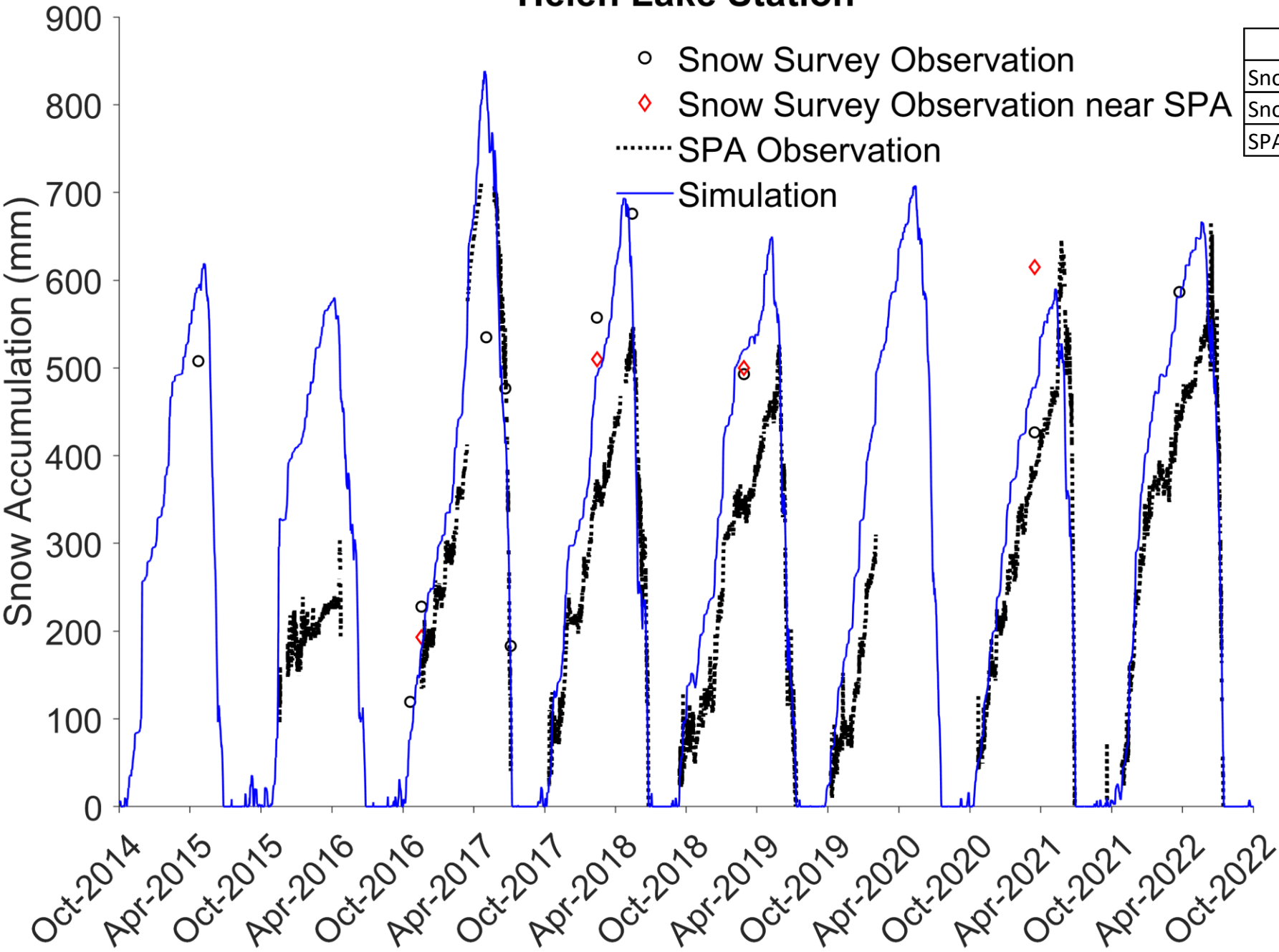
MB = -0.02

RMSD = 0.18 m

NRMSD = 0.15



# Helen Lake Station



	MB	RMSD (mm)	NRMSD
Snow Survey	0.02	104	0.24
Snow Survey near SPA	-0.08	71	0.16
SPA sensor	0.33	131	0.45

# Streamflow Evaluation – Marmot Creek

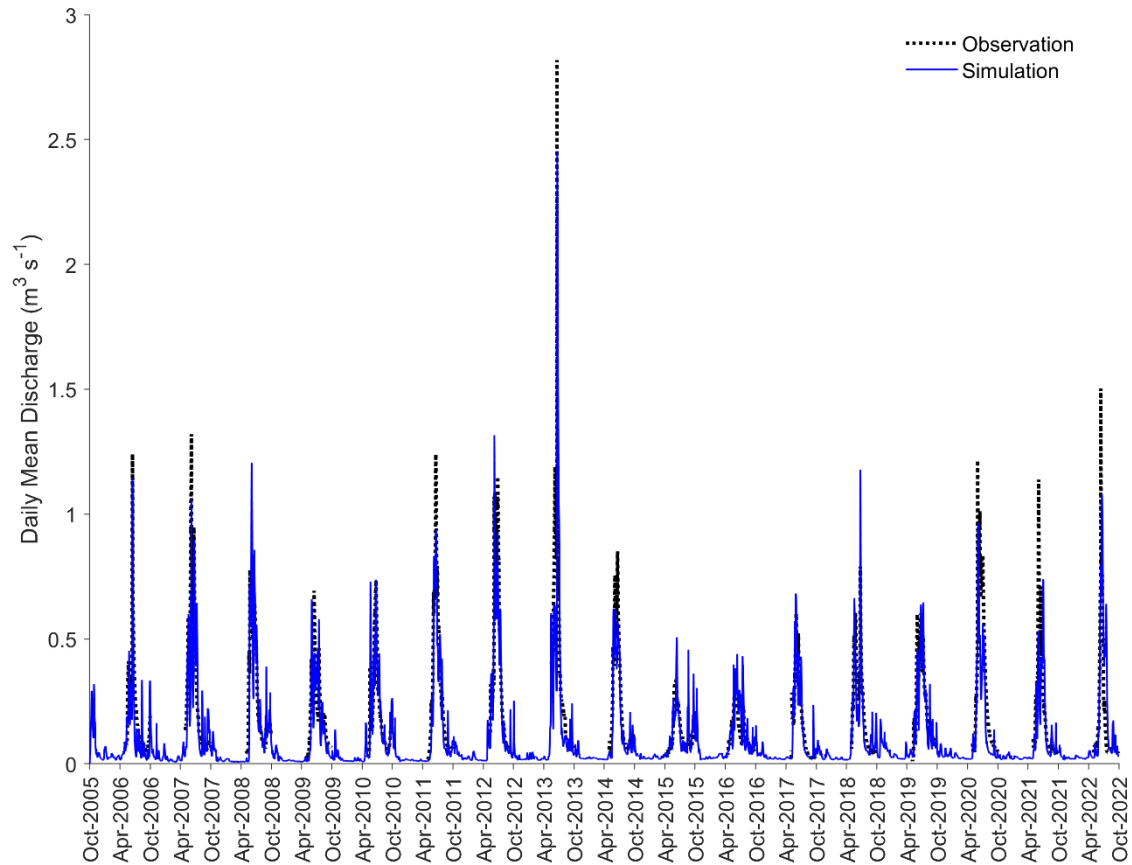
NSE = 0.63

MB = -0.077

RMSE = 0.15 m<sup>3</sup>/s

NRMSD = 0.64

**Marmot Creek (~9.4 km<sup>2</sup>)**



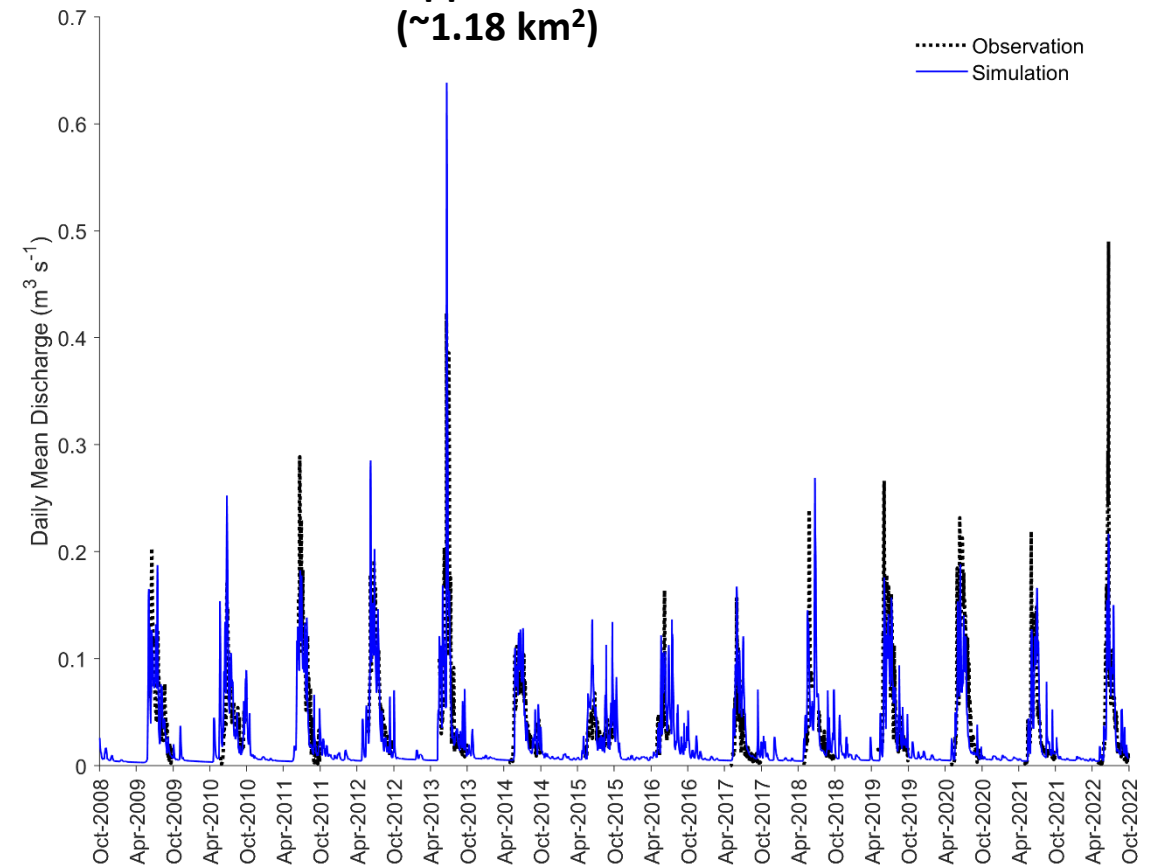
NSE = 0.5

MB = -0.014

RMSE = 0.04 m<sup>3</sup>/s

NRMSD = 0.78

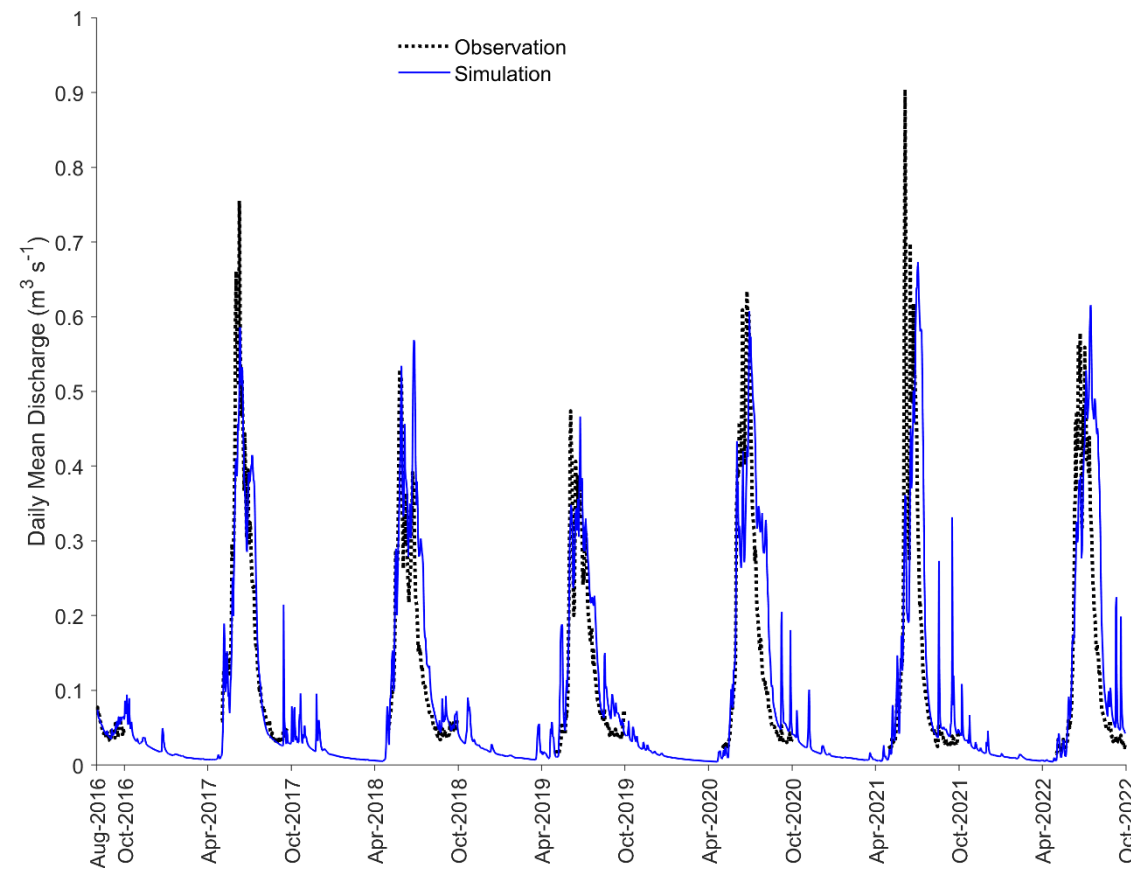
**Upper Marmot Creek (~1.18 km<sup>2</sup>)**



# Streamflow Evaluation - Fortress Mountain Basin

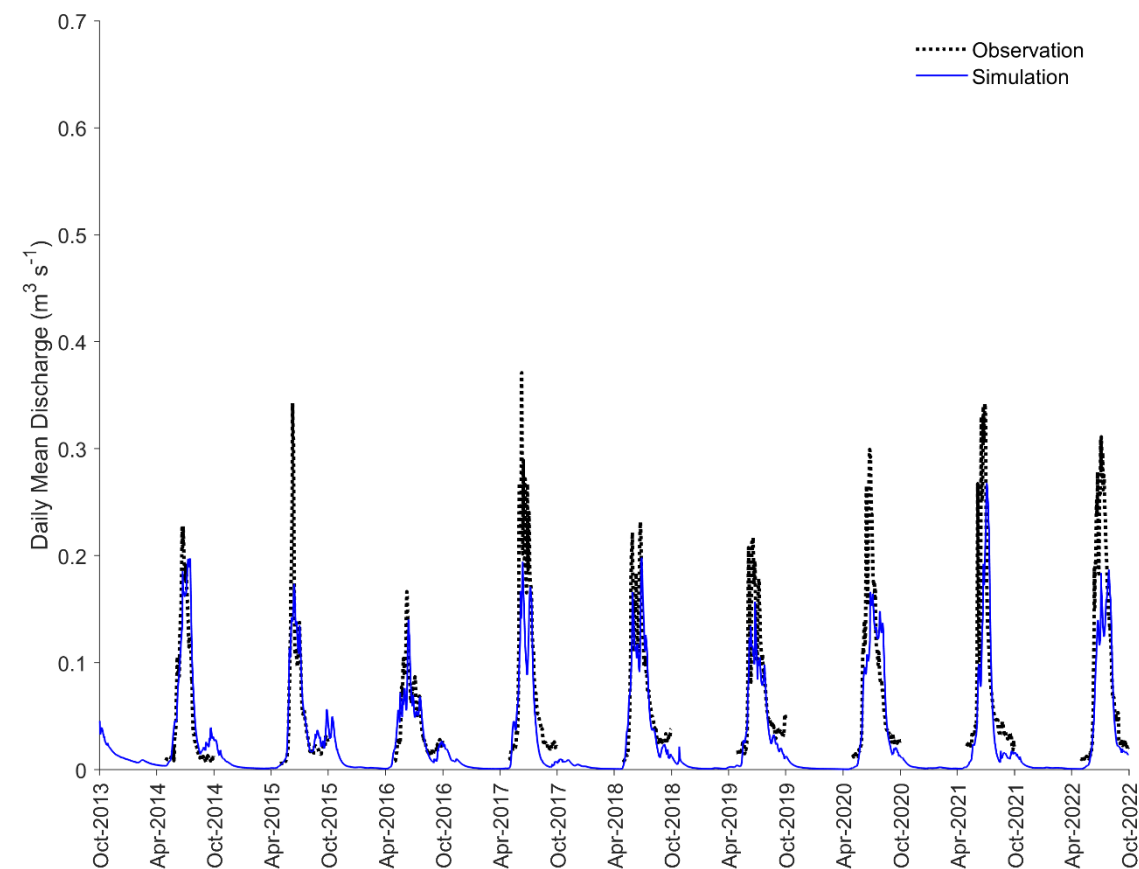
NSE = 0.63  
MB = 0.17  
RMSD = 0.1 m3/s  
NRMSD = 0.64

Fortress Creek (~3.4 km<sup>2</sup>)



NSE = 0.63  
MB = -0.21  
RMSD = 0.05 m3/s  
NRMSD = 0.62

Bonsai Creek (~0.92 km<sup>2</sup>)

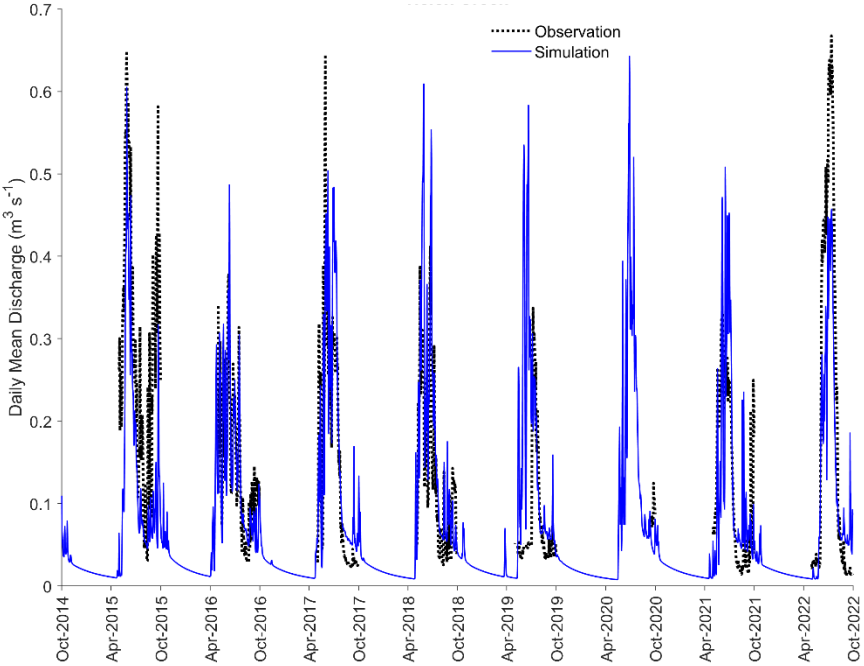




# Streamflow Evaluation – Helen Creek

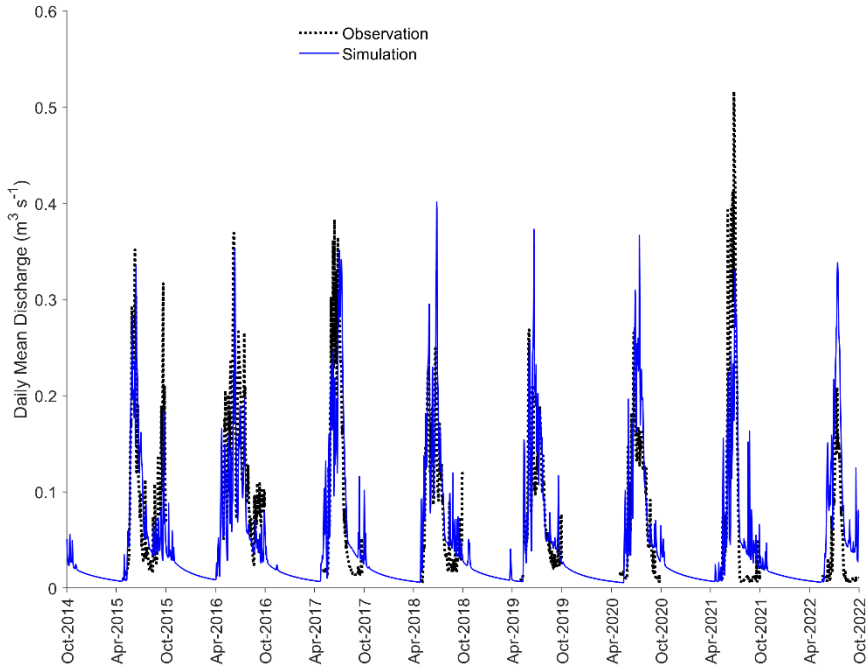
NSE = 0.39  
MB = -0.07  
RMSD = 0.11 m3/s  
NRMSD = 0.7

Helen Creek (~2.6 km<sup>2</sup>)

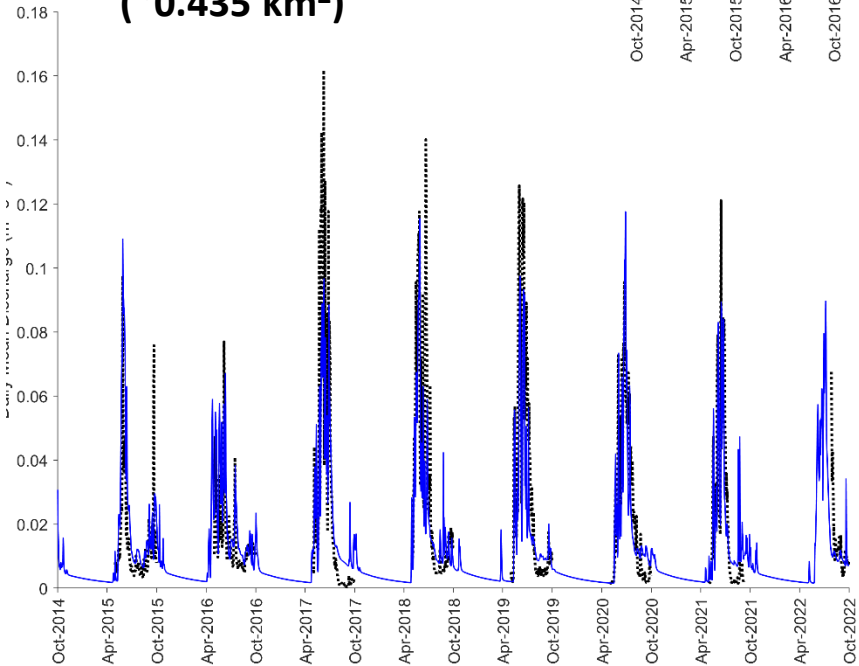


NSE = 0.51  
MB = 0.09  
RMSD = 0.06 m3/s  
NRMSD = 0.69

Upper Helen Creek (~1.613 km<sup>2</sup>)



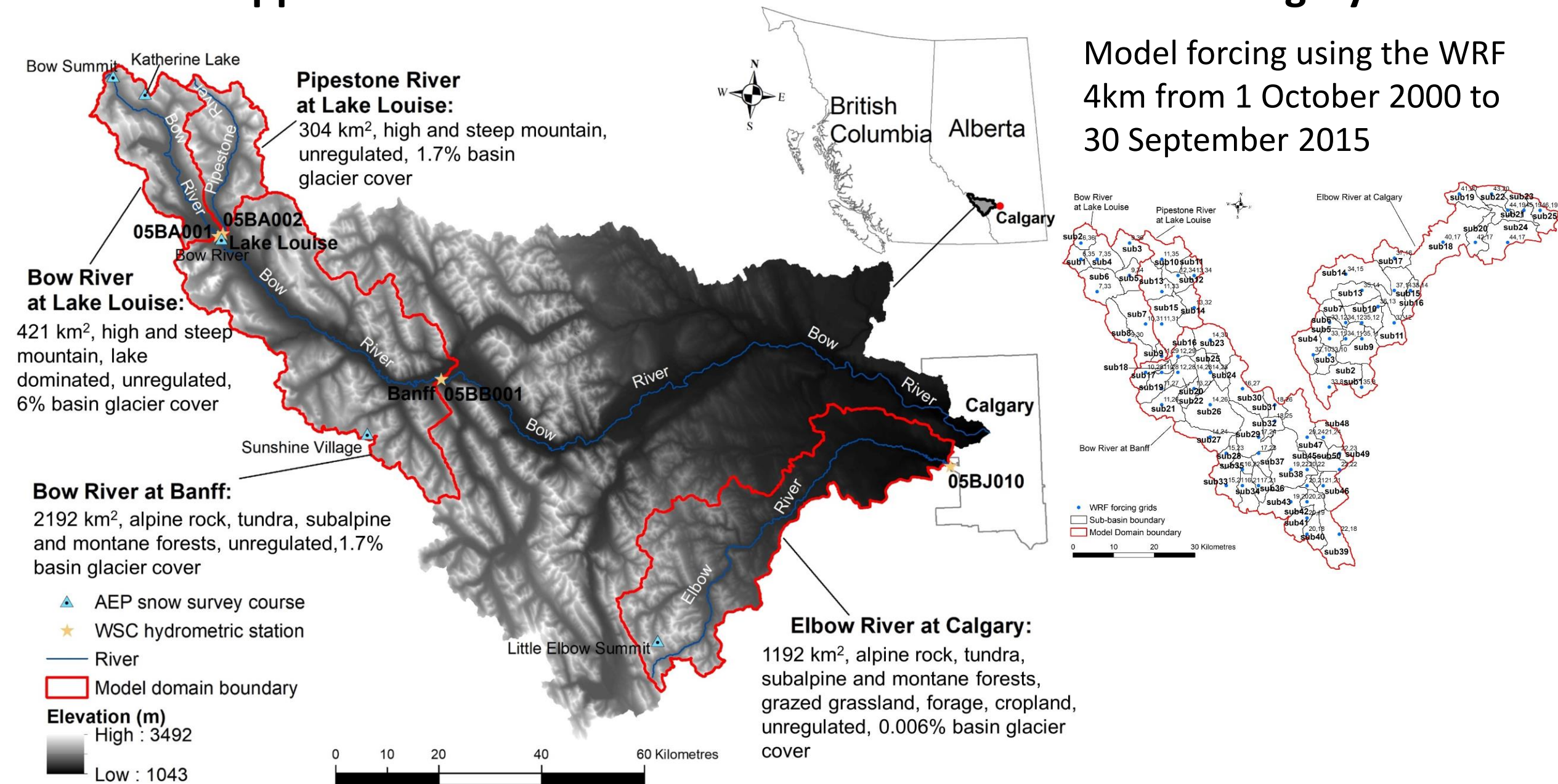
Helen Lake Creek (~0.435 km<sup>2</sup>)



NSE = 0.58  
MB = -0.02  
RMSD = 0.02 m3/s  
NRMSD = 0.77

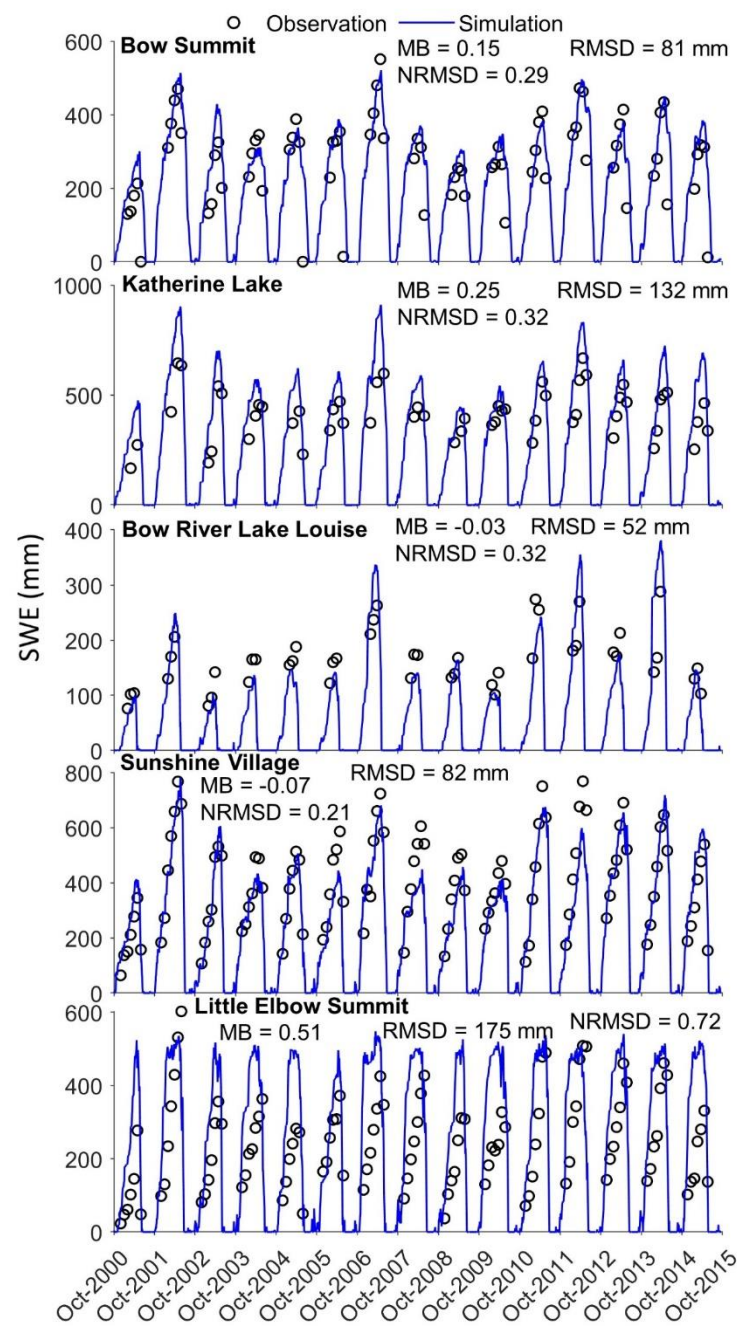
# Upper Bow River Basin and Elbow River Basin above Calgary

Model forcing using the WRF  
4km from 1 October 2000 to  
30 September 2015

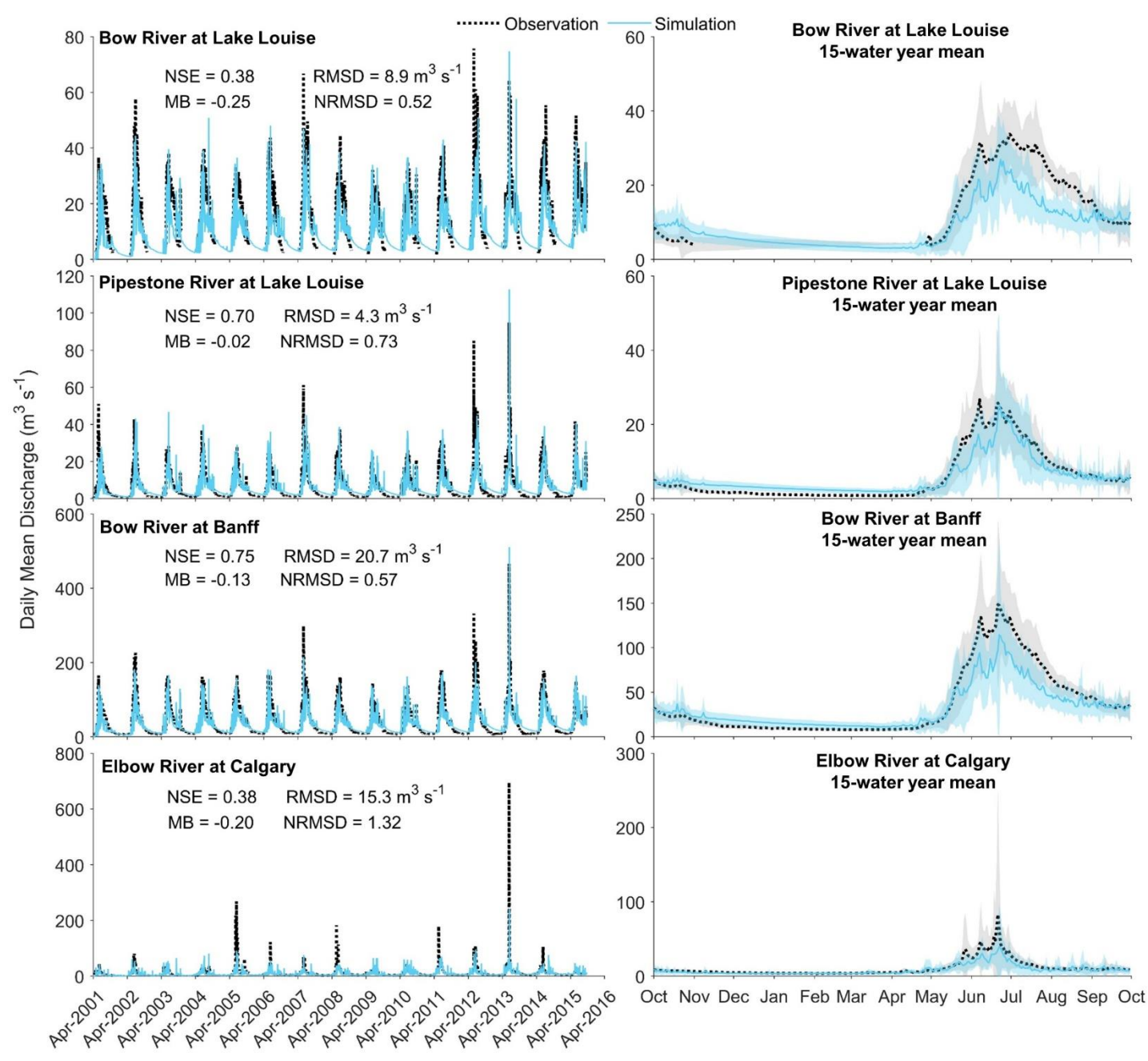




Modelled SWE vs observed SWE from AEP snow courses



Modelled streamflow vs observed streamflow from WSC hydrometric stations





# Conclusions

- Model parameters for physically based models can be measured *in-situ*, estimated from remote sensing and DEMs, transferred from other research sites or estimated from process observations in research basins.
- These parameters can be applied in spatially distributed models at multiple scales to basins in highly variable mountain environments with reasonable predictability for snow and streamflow outcomes.
- CRHM models performance without calibration from streamflow suggests sufficient robustness for diagnostic purposes and climate and land use change analysis in Canadian Rockies river basins.

Thank you!

