

Impact of a Snow Drought on the Hydrology of Headwater Basins in the Canadian Rockies

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2026 Annual INARCH Workshop,
Kananaskis, Alberta, Canada, September 8-10, 2026



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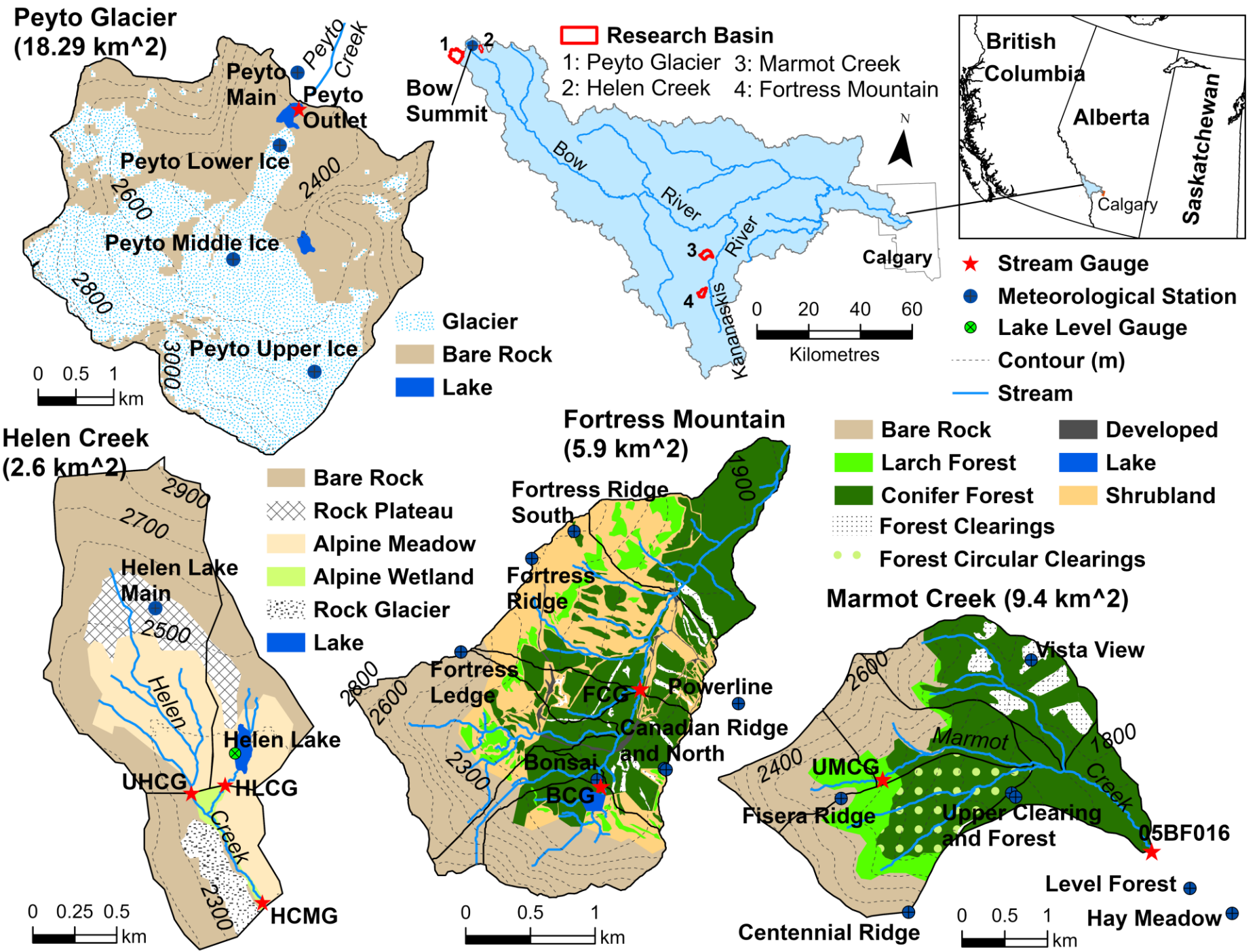


GLOBAL WATER FUTURES
OBSERVATORIES

Purpose

- Examine anomalies during 2022-2023 snow drought using station observations
- Assess basin-scale hydrological impact of 2022-2023 snow drought using CRHM model simulations
- Evaluate the sensitivities of snow hydrology to air temperature and precipitation anomalies using CRHM model simulations

Well-instrumented headwater basins



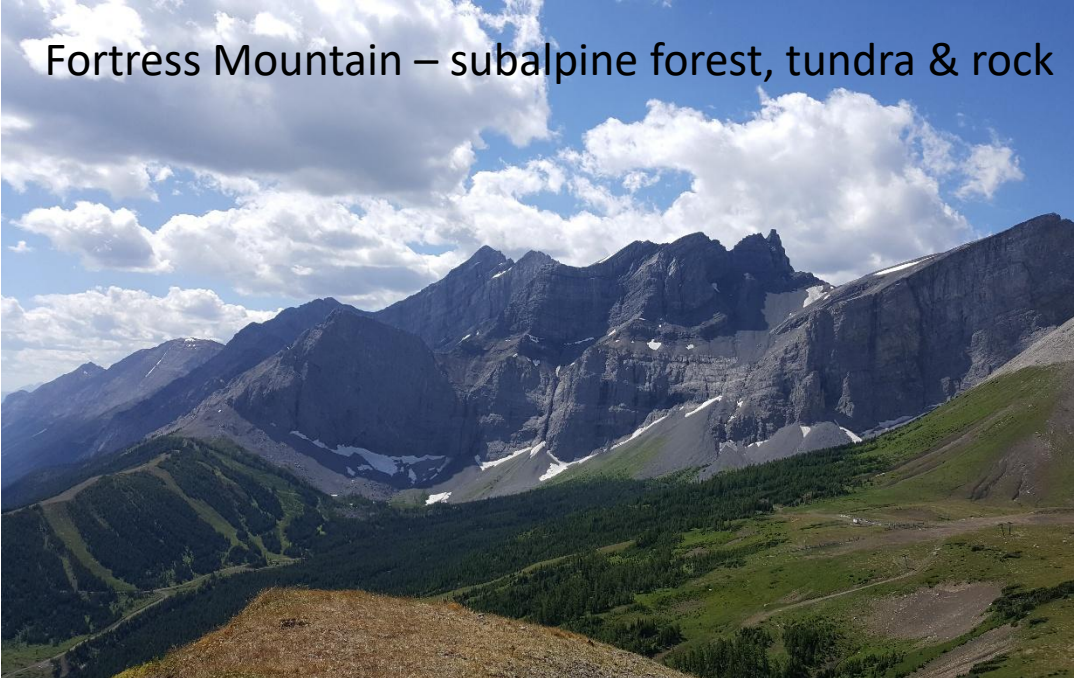
Peyto Glacier – glacier and rock



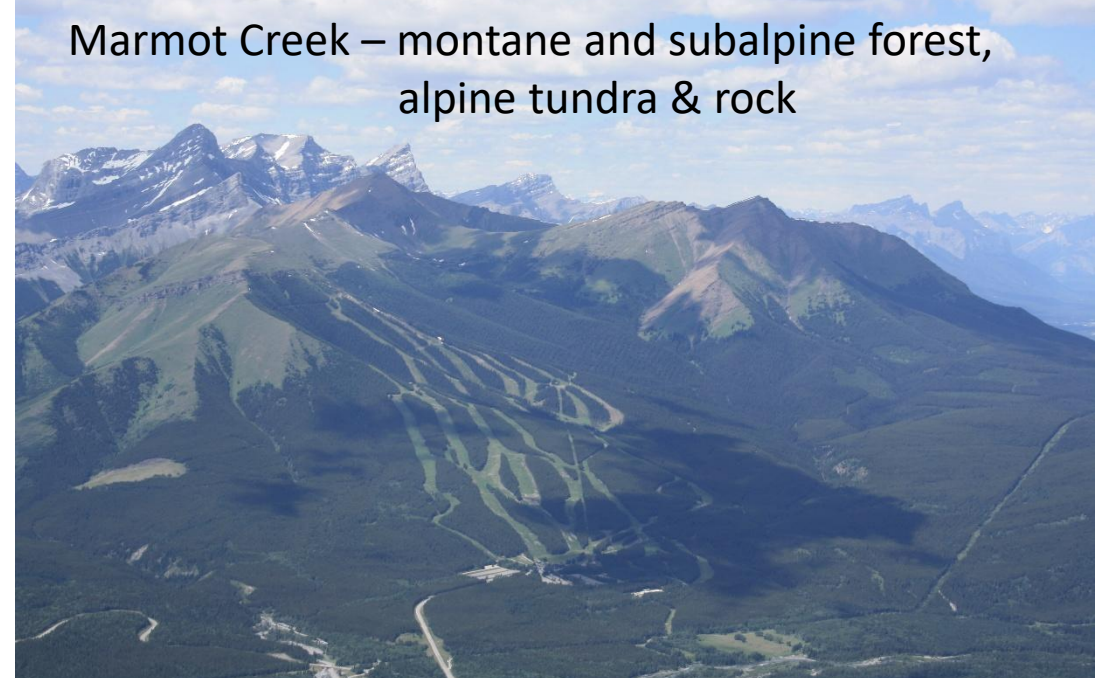
Helen Creek – alpine tundra & rock, lake, wetland, rock glacier



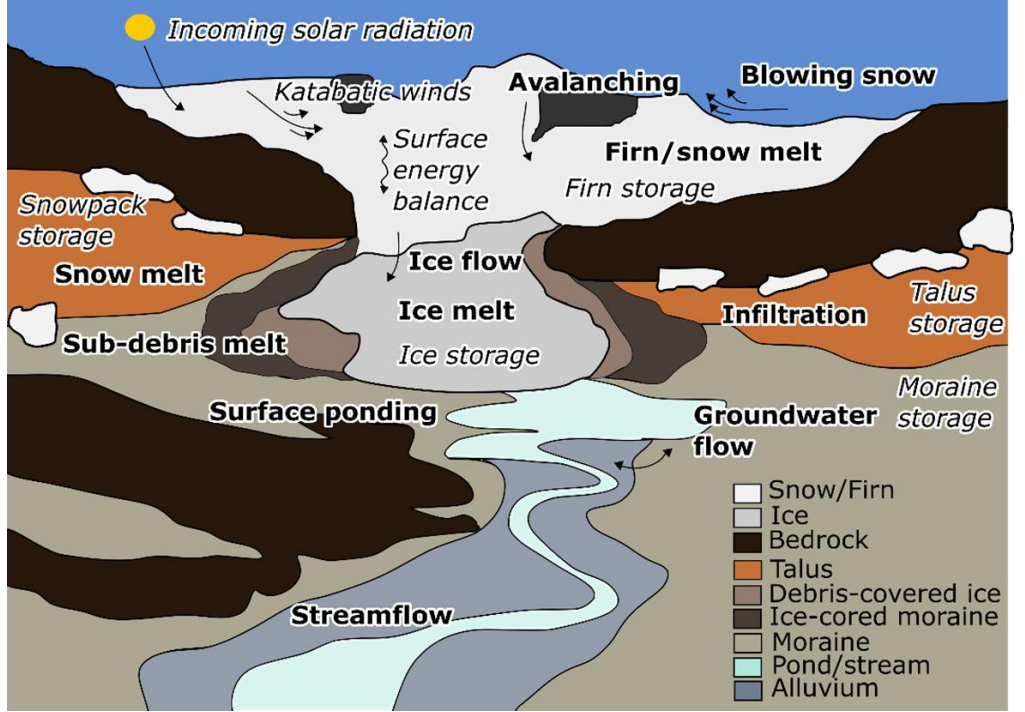
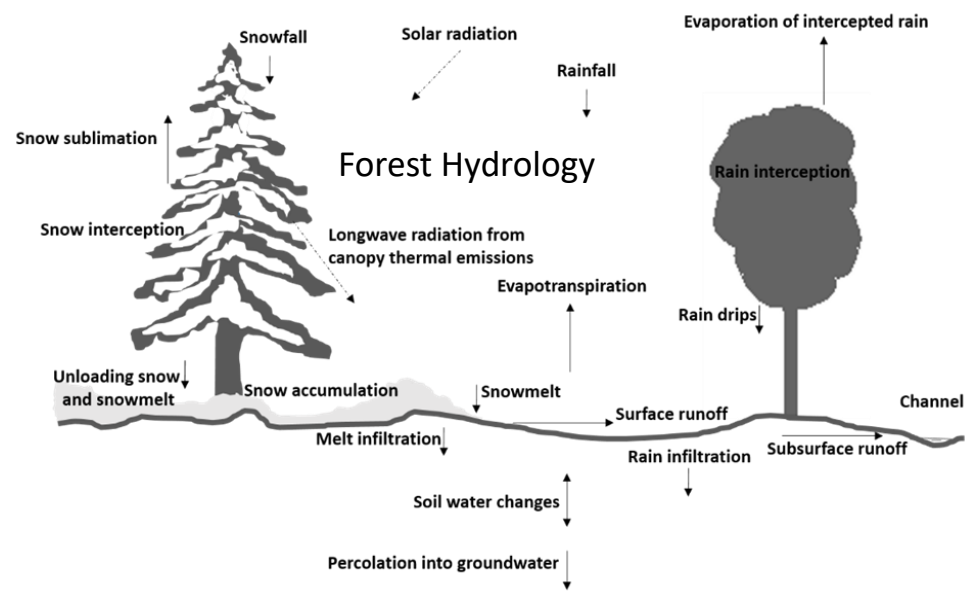
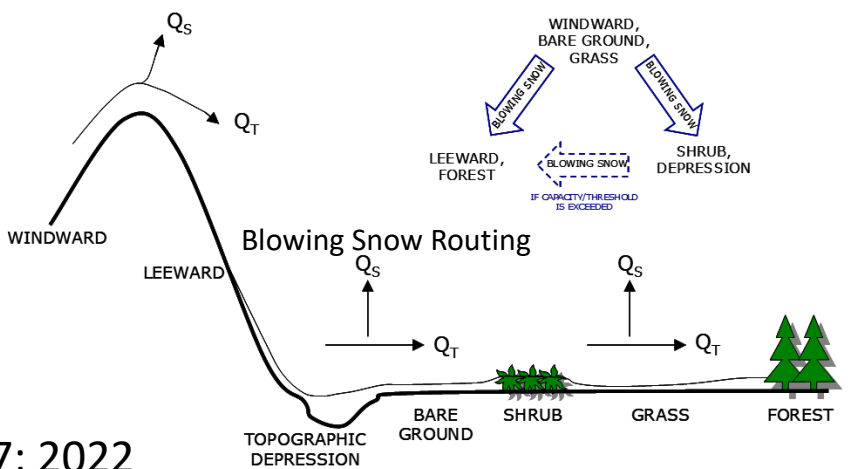
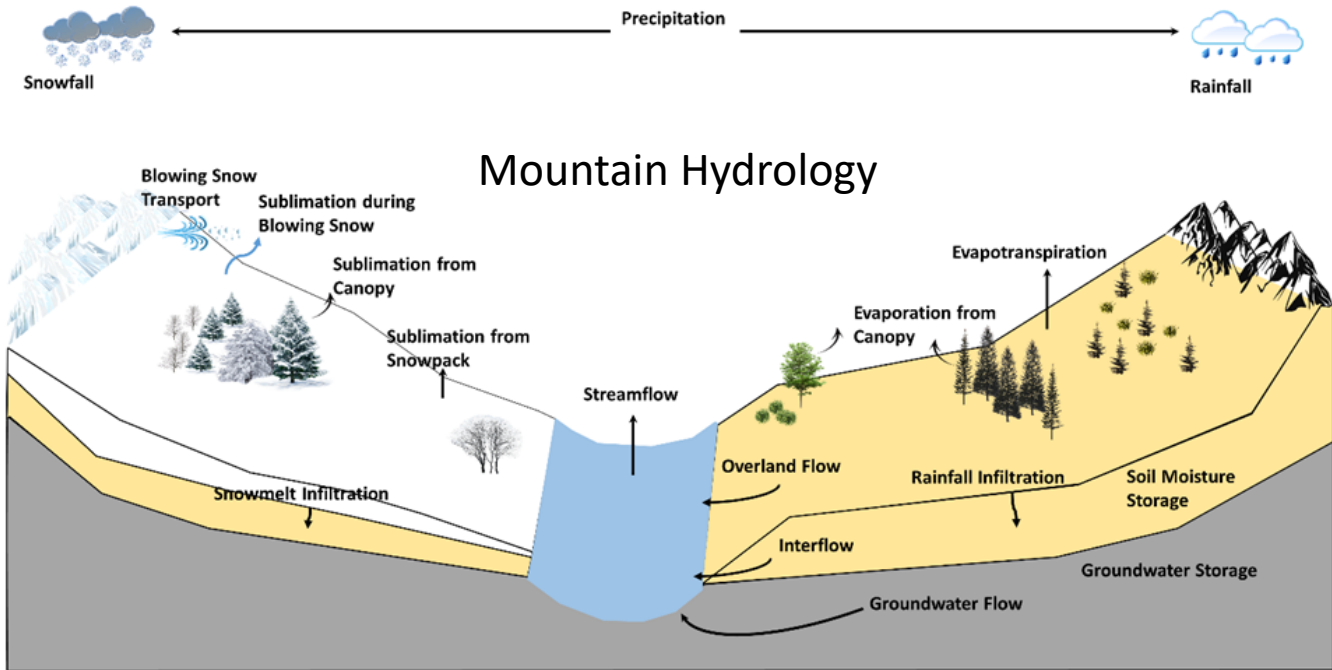
Fortress Mountain – subalpine forest, tundra & rock



Marmot Creek – montane and subalpine forest, alpine tundra & rock

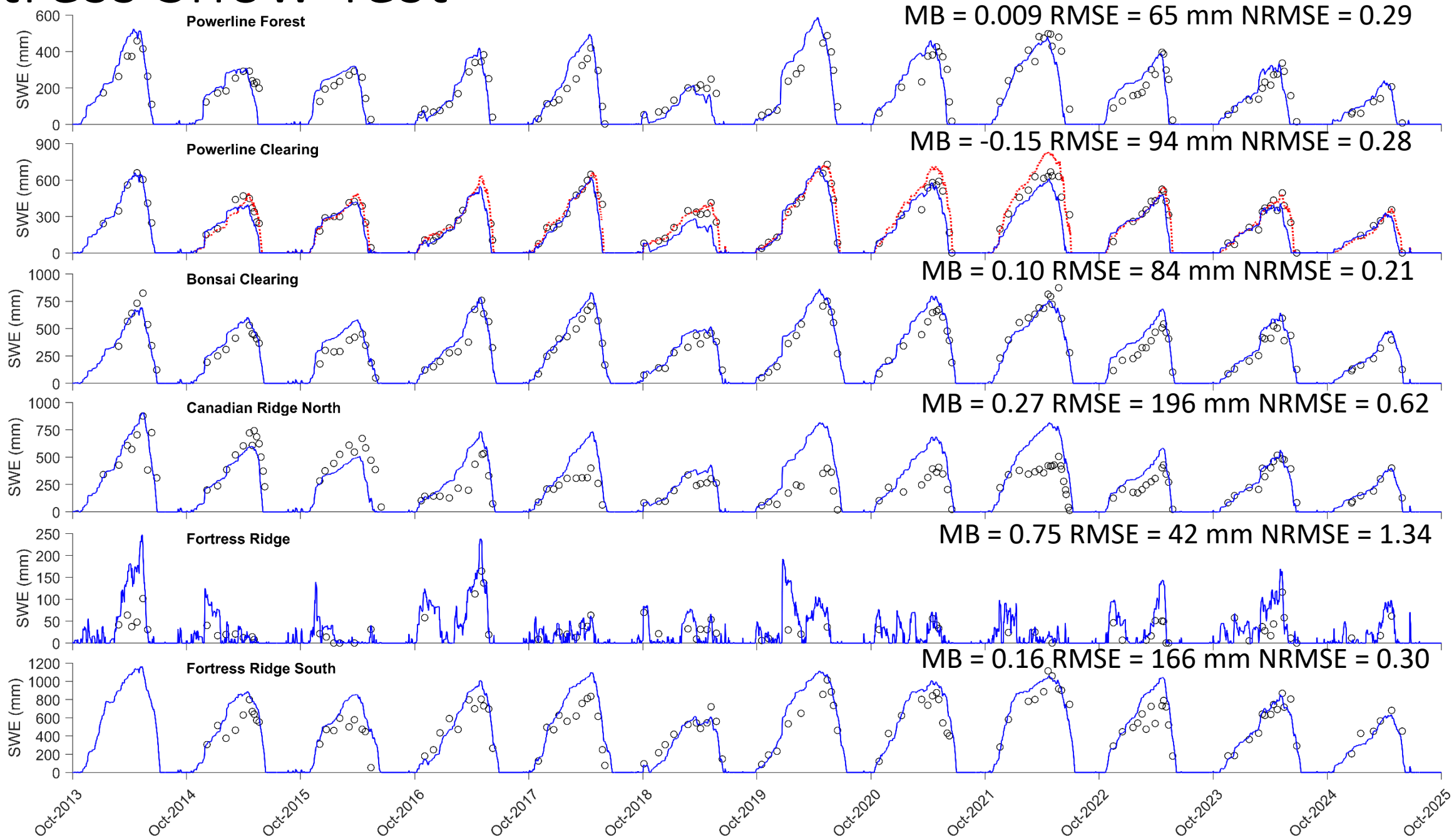


CRHM modelling



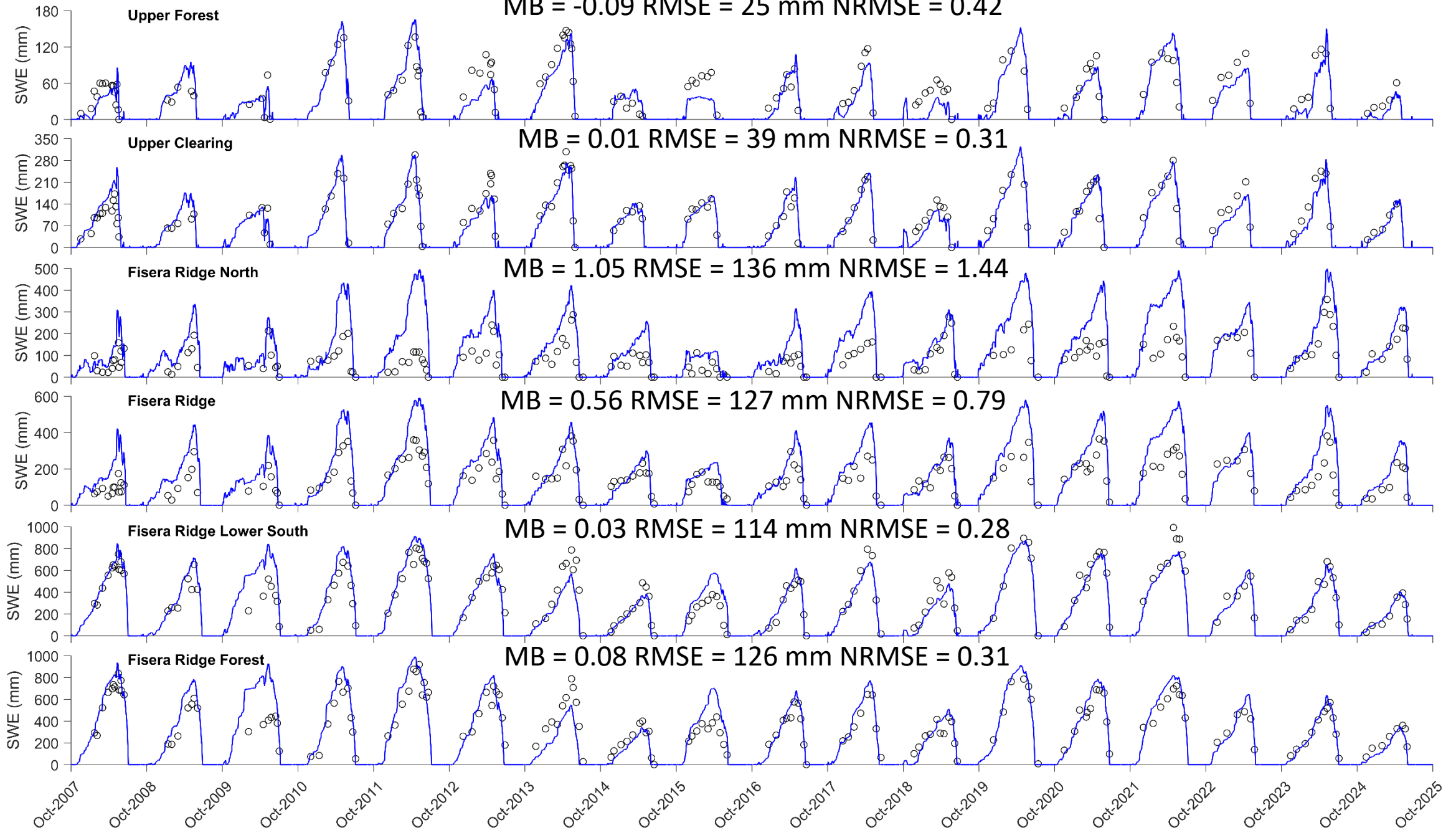
Fortress Snow Test

○ Observation (Snow Survey) Observation (Snow Scale) — Simulation

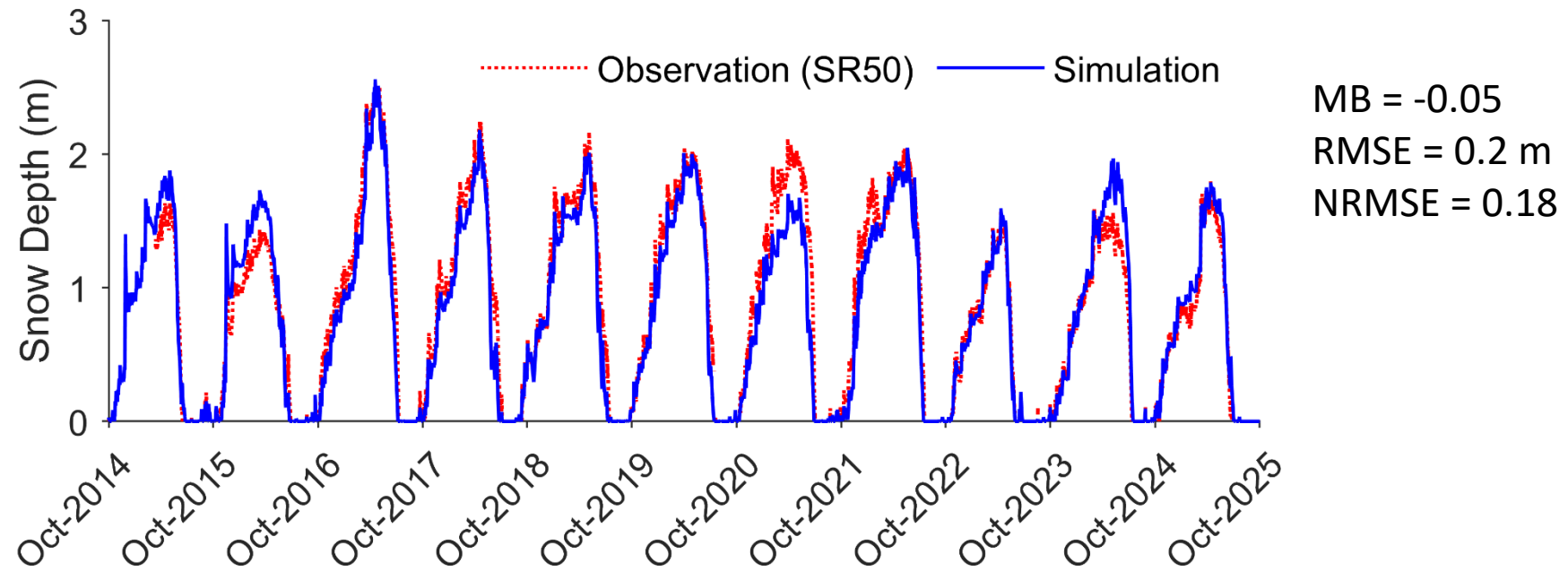
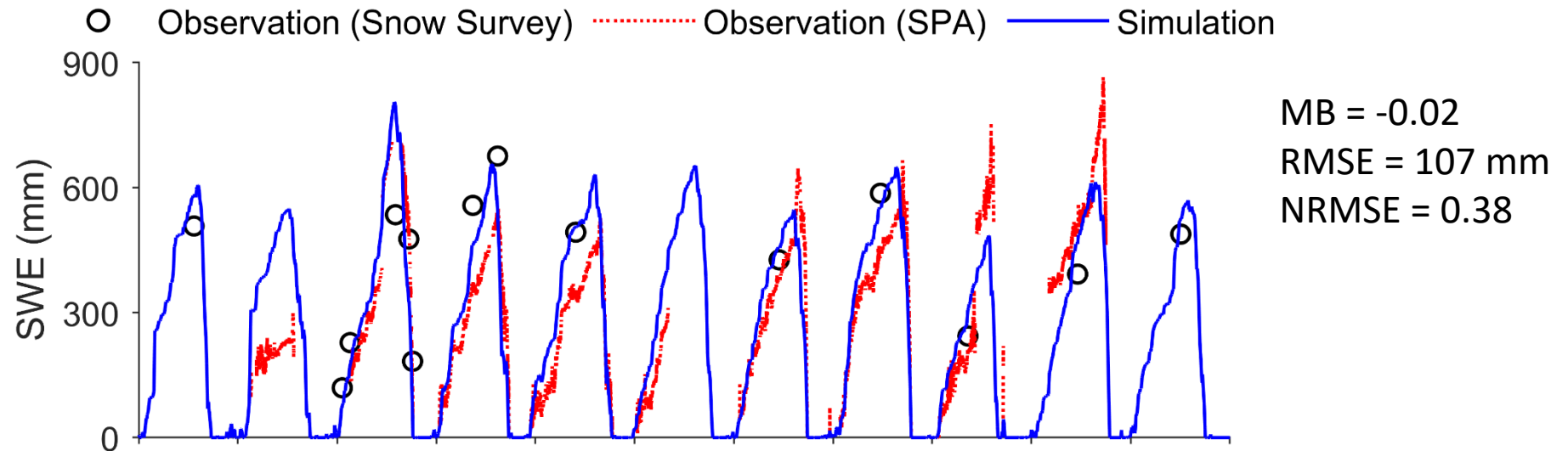


Marmot Snow Test

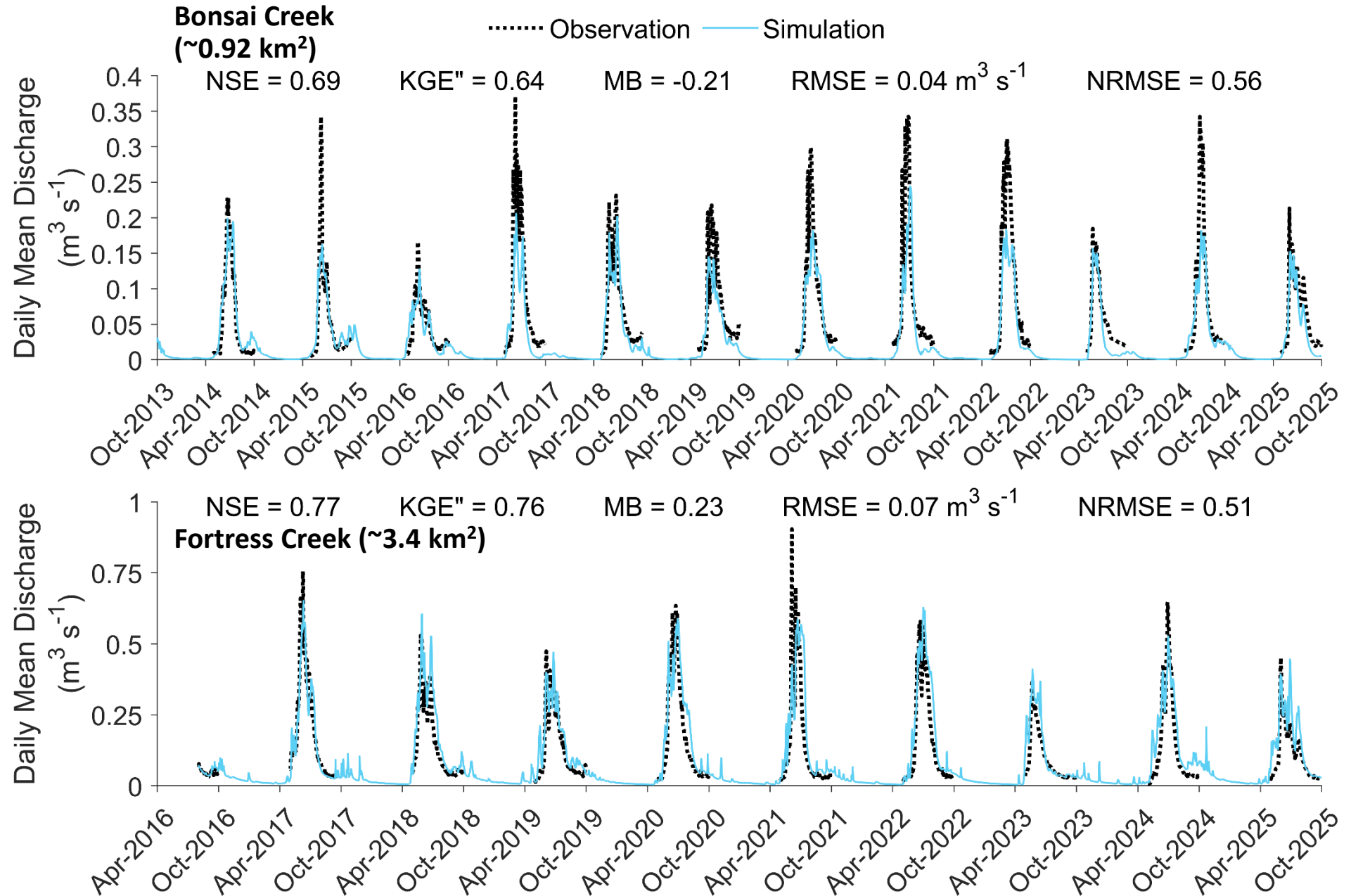
○ Observation — Simulation



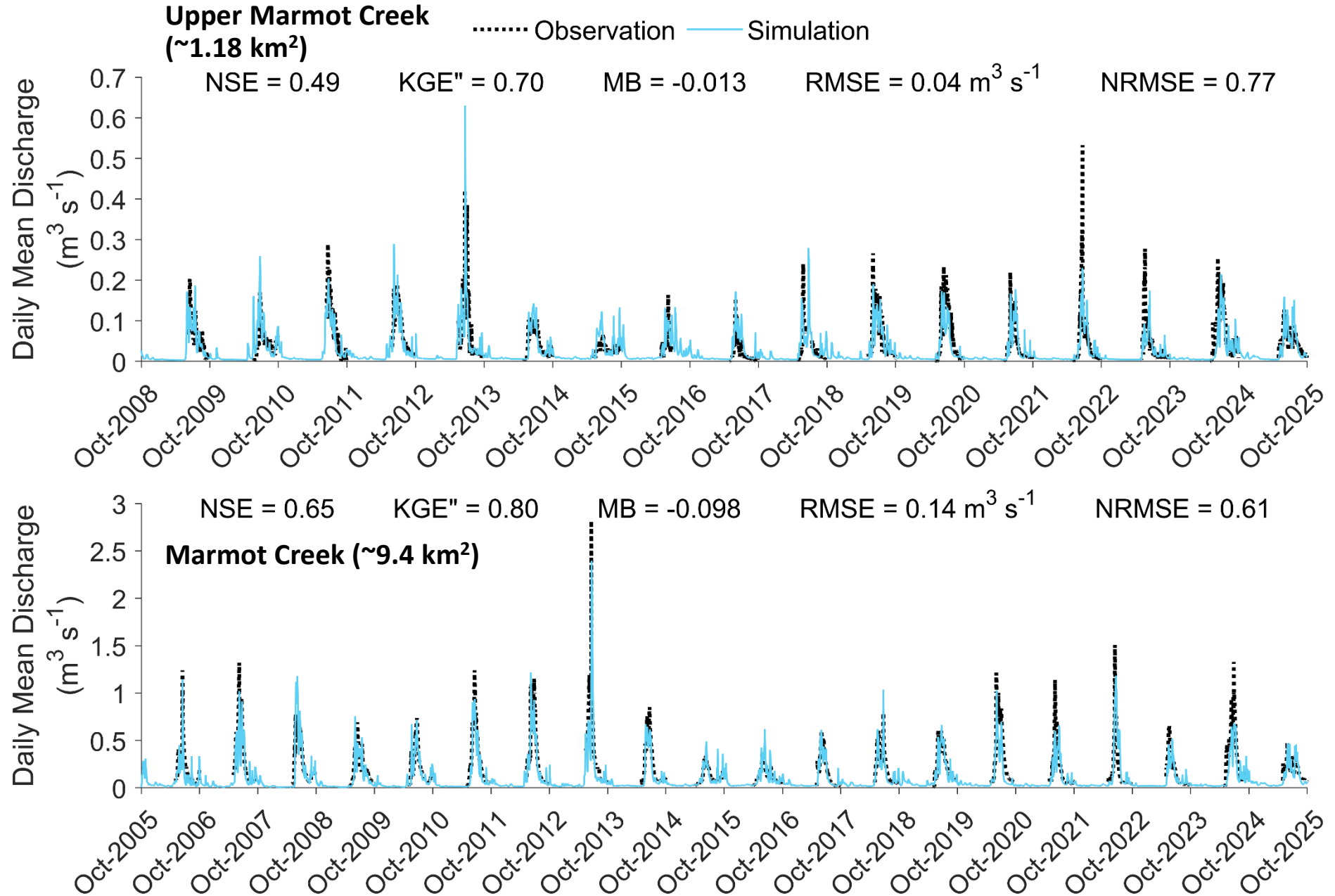
Helen Snow Test



Fortress Streamflow Test

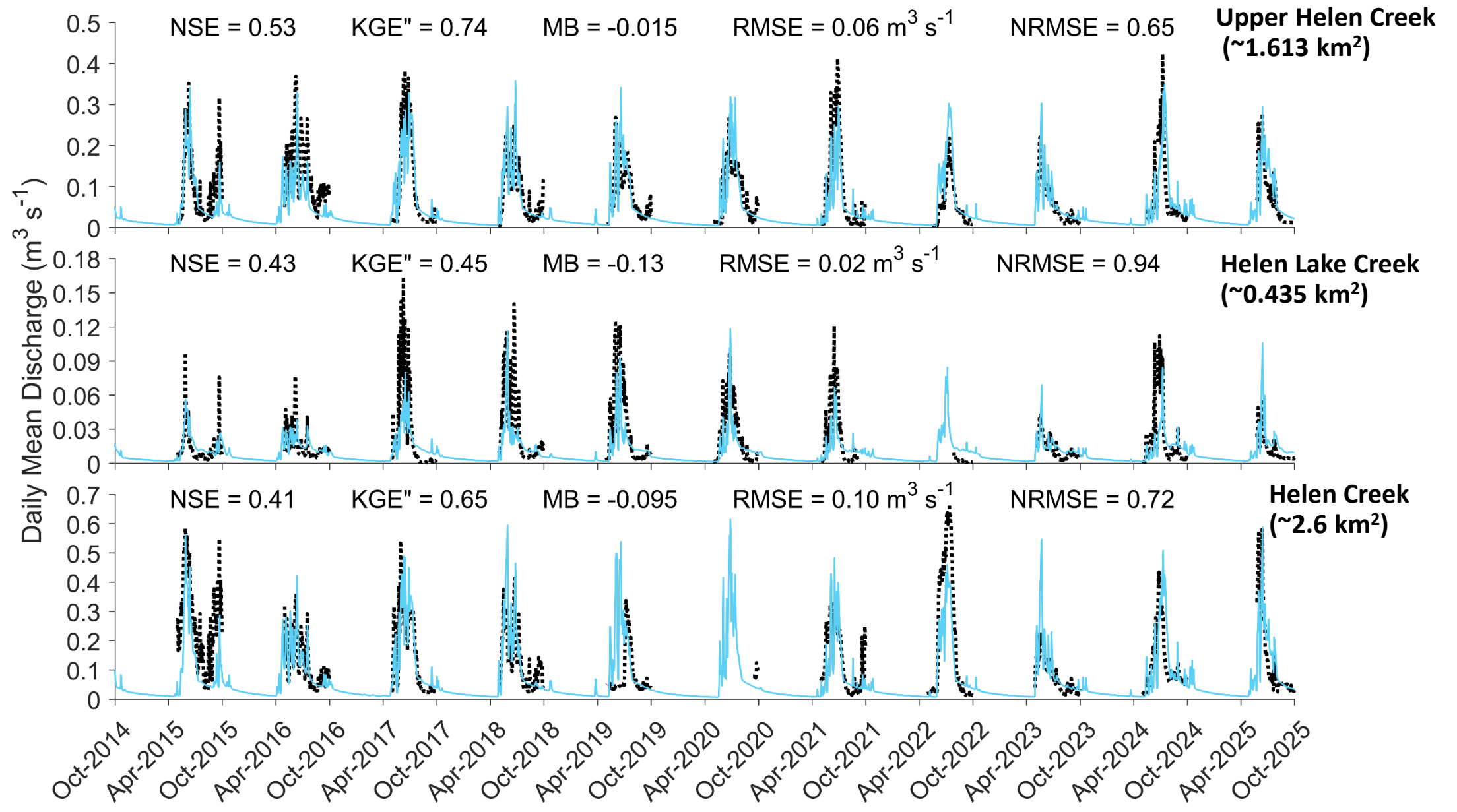


Marmot Streamflow Test

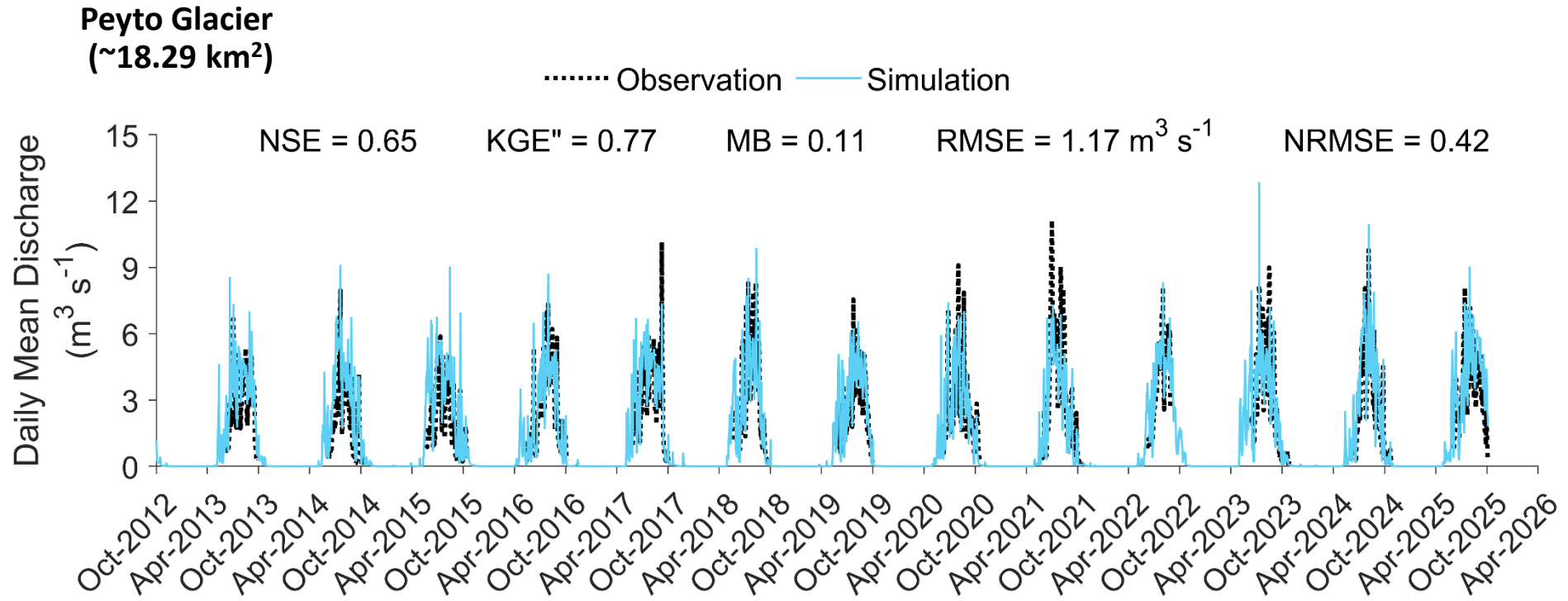


Helen Streamflow Test

..... Observation — Simulation



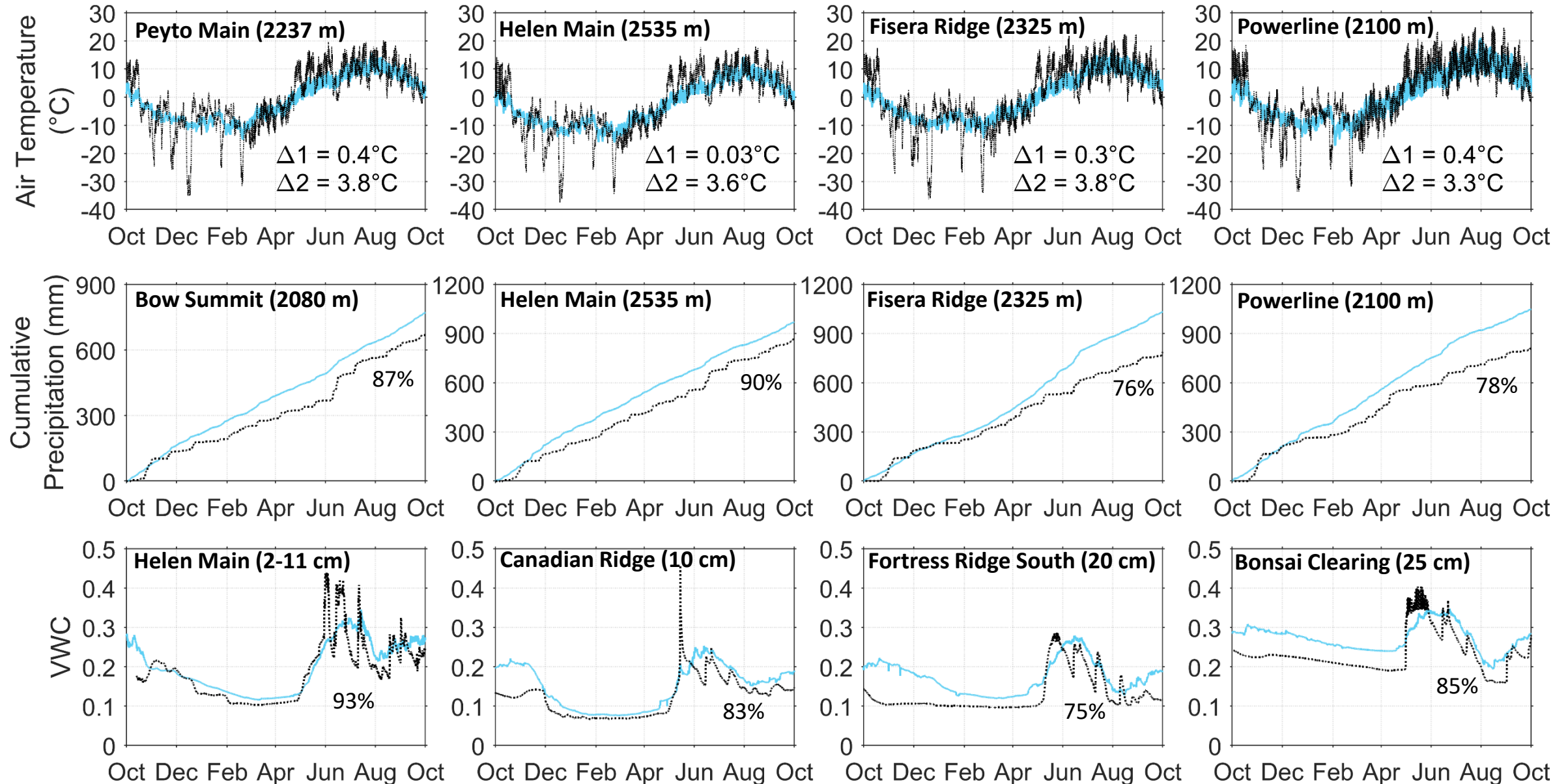
Peyto Streamflow Test



2022-2023 Observed Anomalies

$\Delta 1$: annual difference
 $\Delta 2$: difference for
months May to June

— Mean 2022-2023

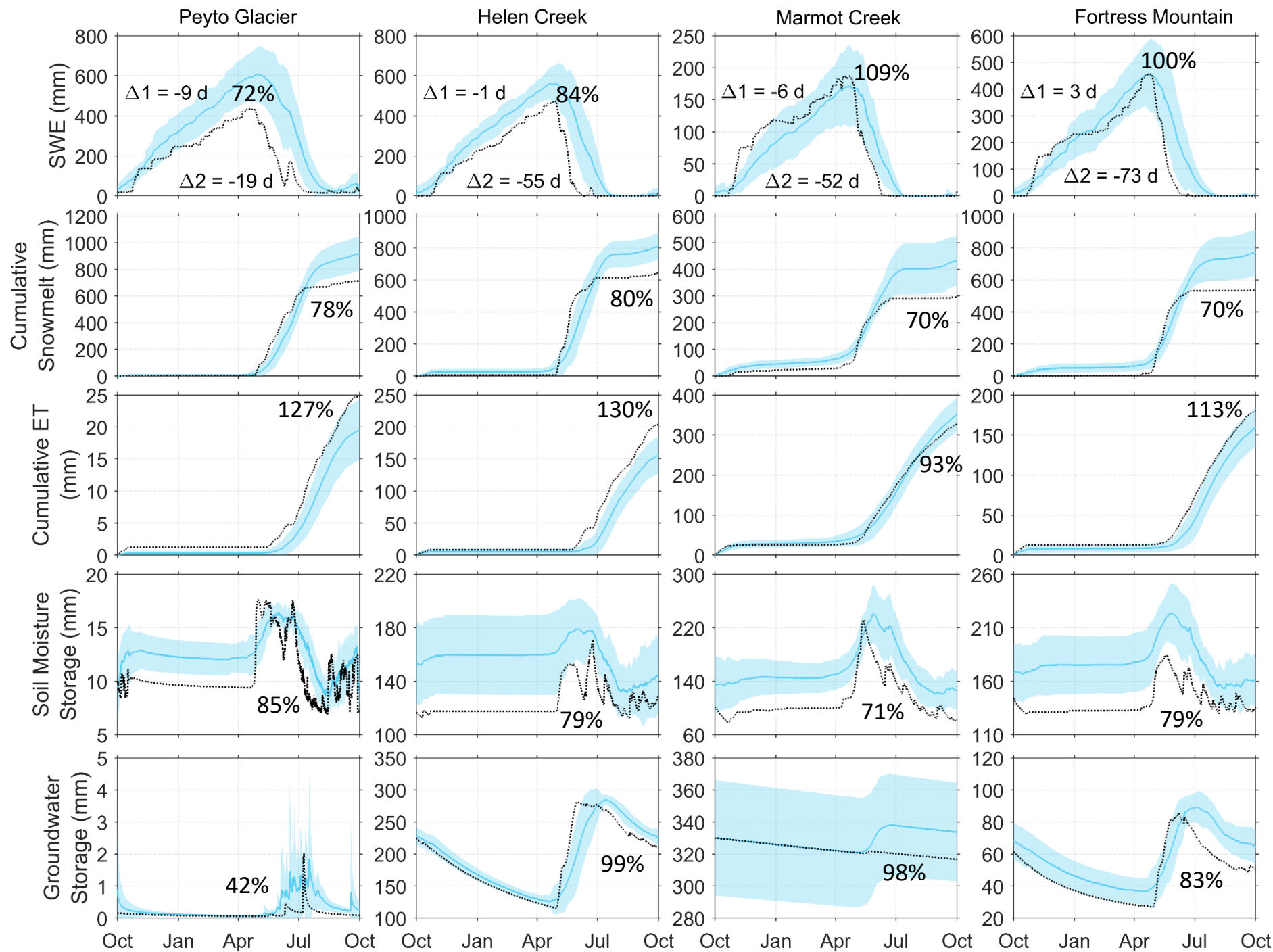


2022-2023 Simulated Anomalies

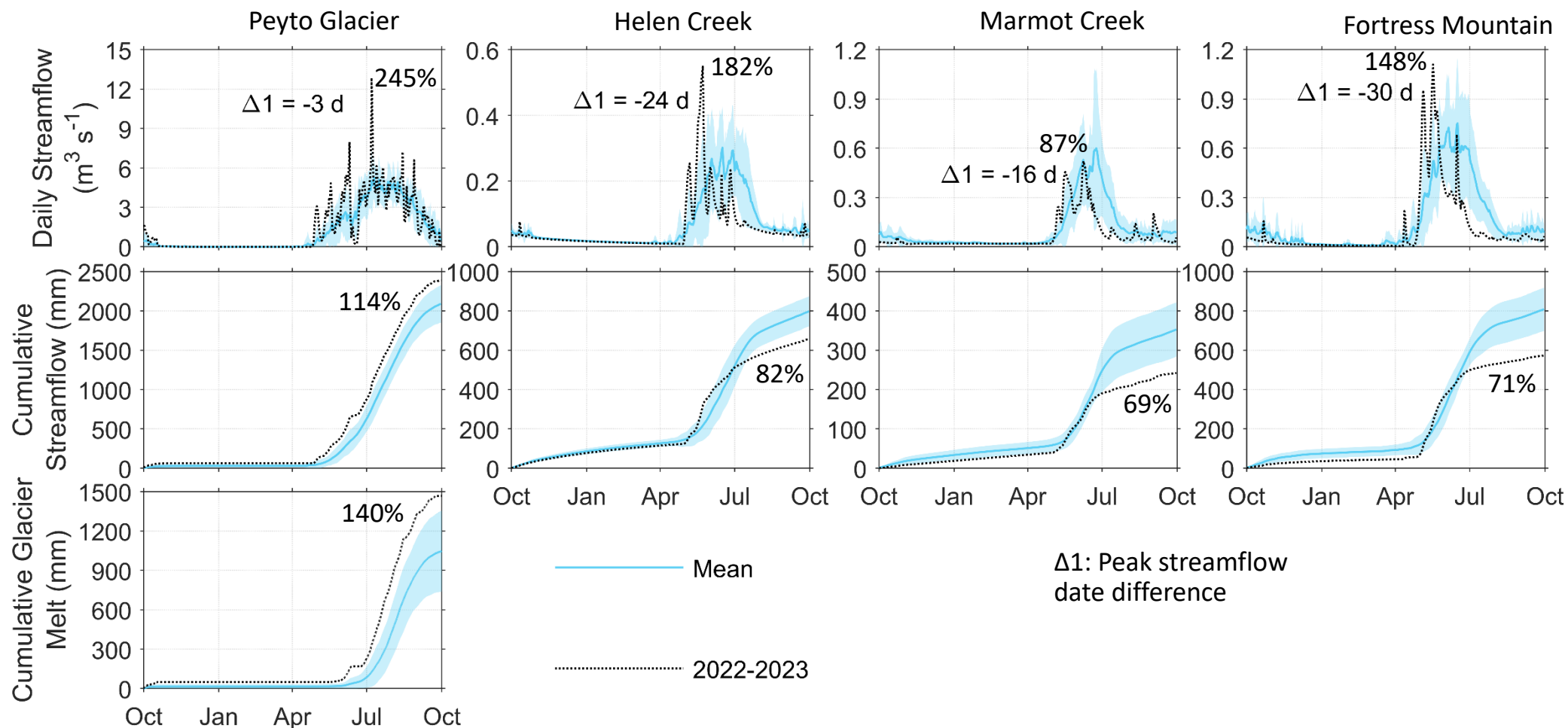
$\Delta 1$: Peak SWE date
difference
 $\Delta 2$: snowcover duration
difference

— Mean

..... 2022-2023



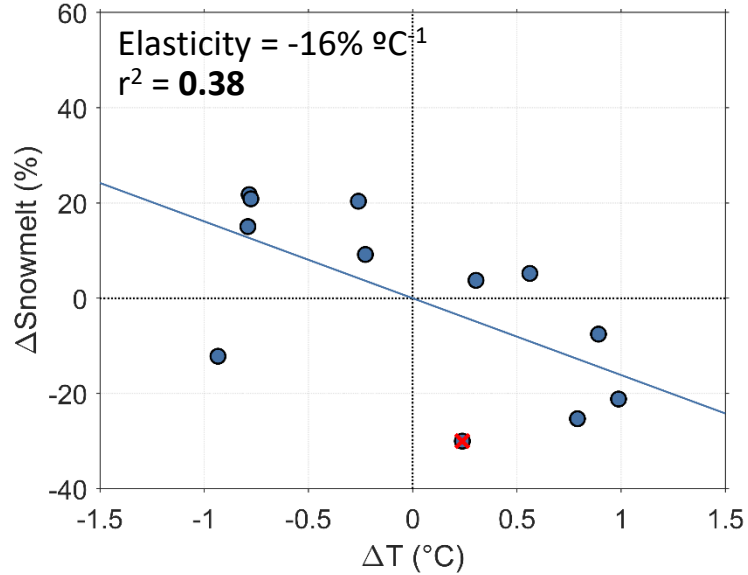
2022-2023 Simulated Anomalies



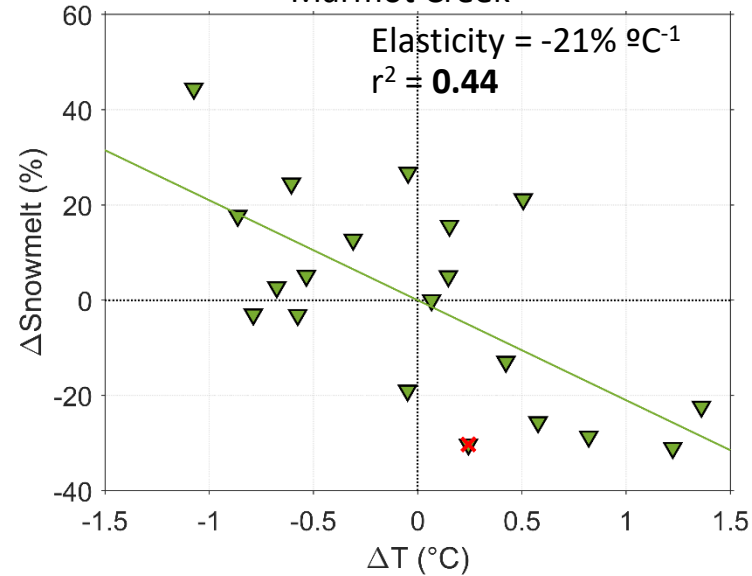
Temperature Sensitivity of Basin Snow/Glacier Melt

● Fortress Mountain ▼ Marmot Creek ■ Helen Creek ◆ Peyto Glacier

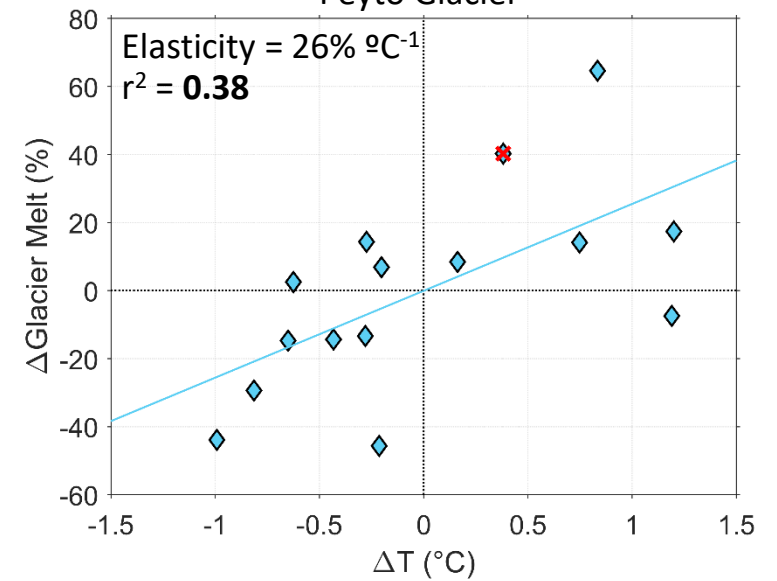
Fortress Mountain



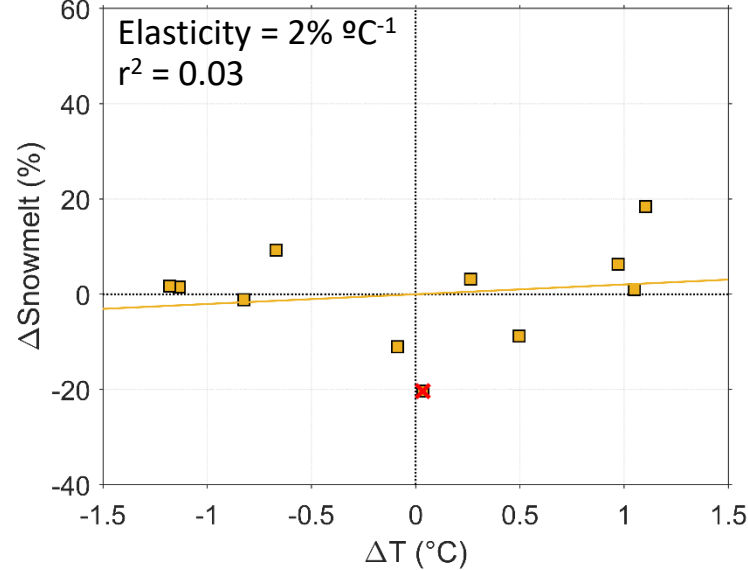
Marmot Creek



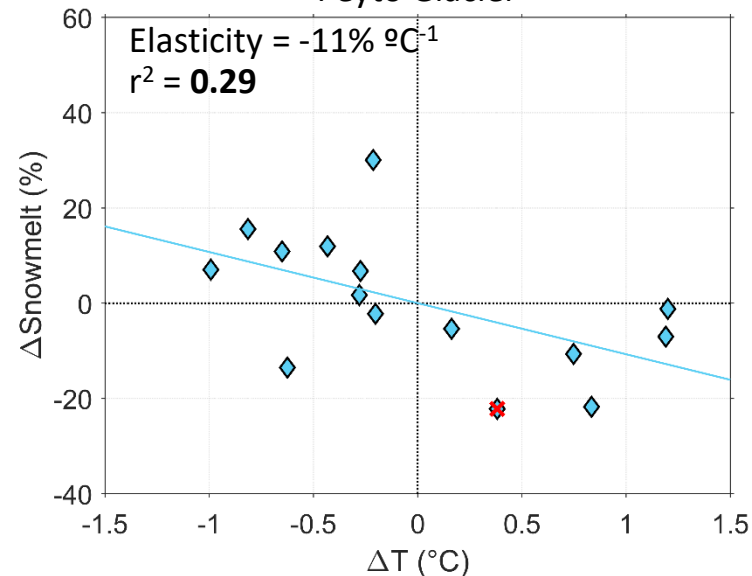
Peyto Glacier



Helen Creek



Peyto Glacier



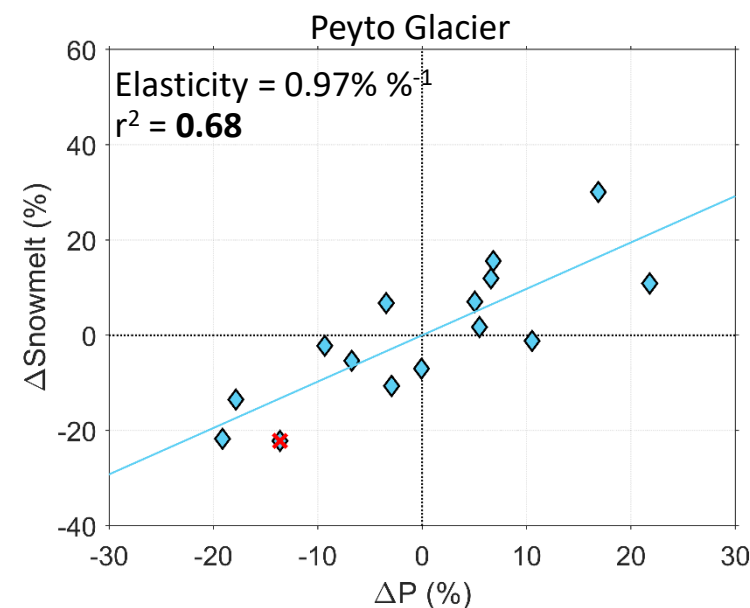
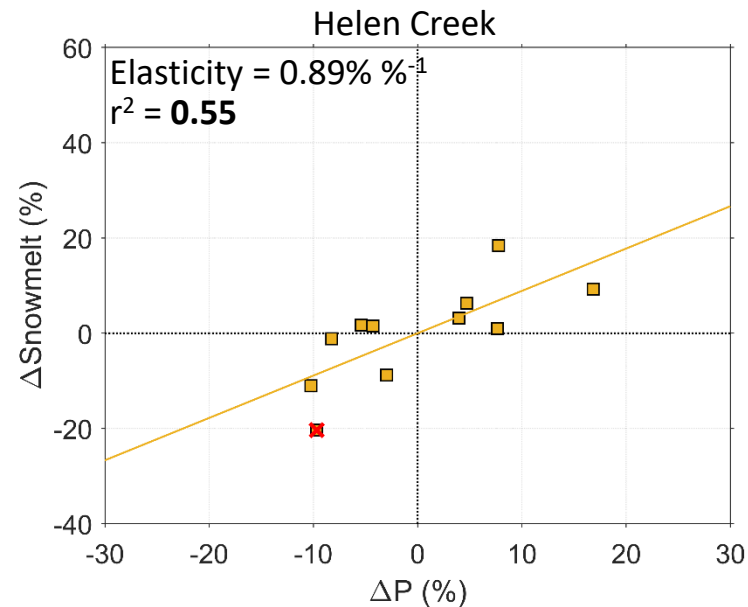
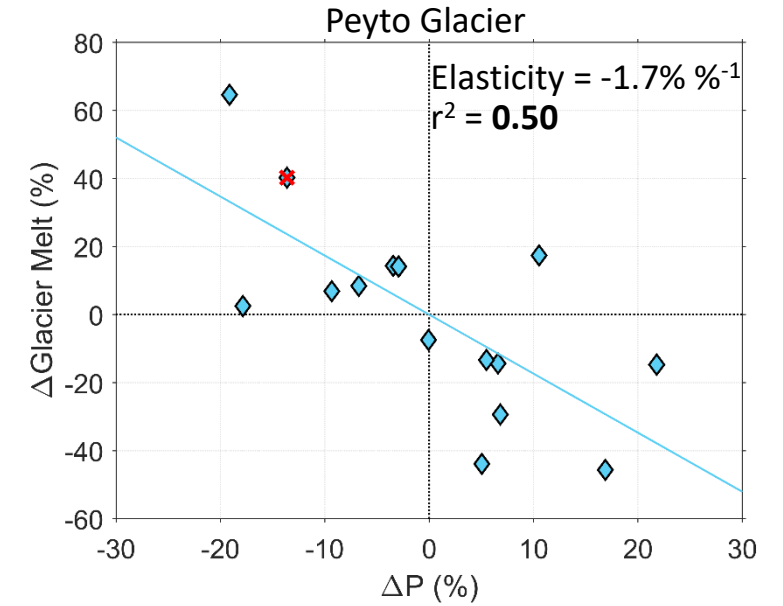
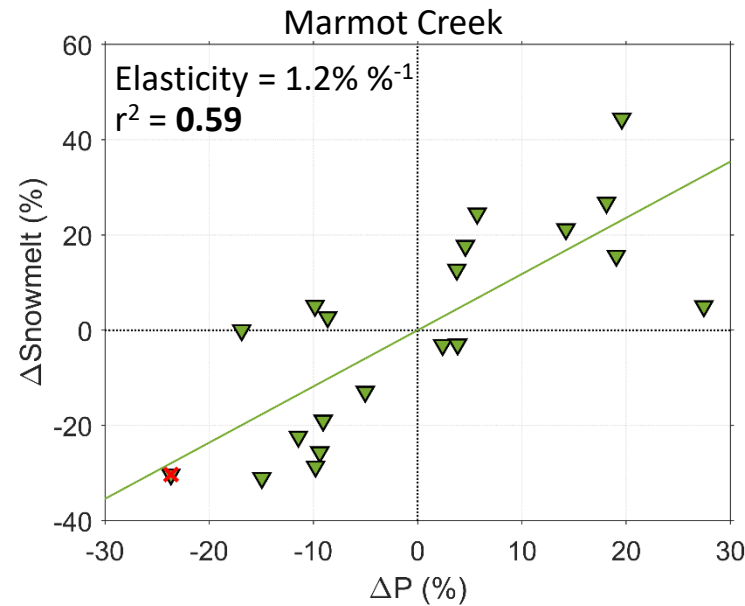
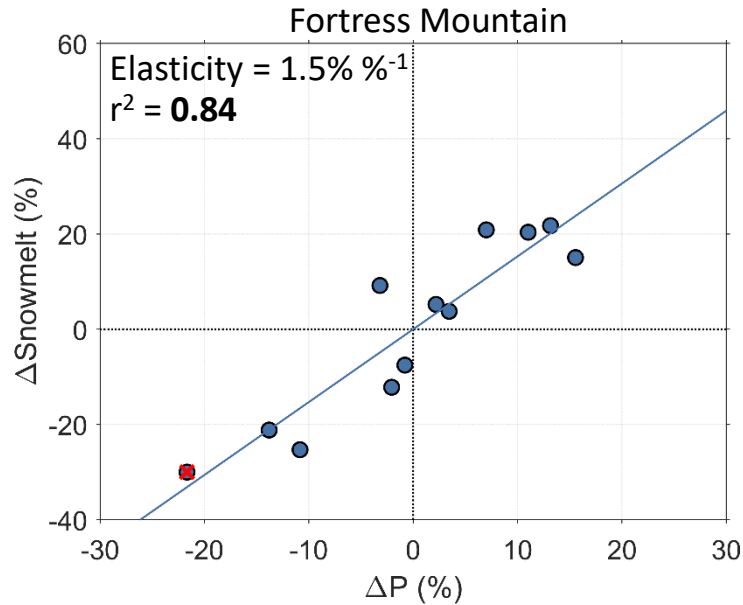
Elasticity = $\Delta\text{Snowmelt} / \Delta T$, or $\Delta\text{Glacier Melt} / \Delta T$

Note: r^2 values **bold** when statistically significant ($p \leq 0.05$)

Note: Point with **x** is for 2022-2023 water year.

Precipitation Sensitivity of Basin Snow/Glacier Melt

● Fortress Mountain ▼ Marmot Creek ■ Helen Creek ◆ Peyto Glacier



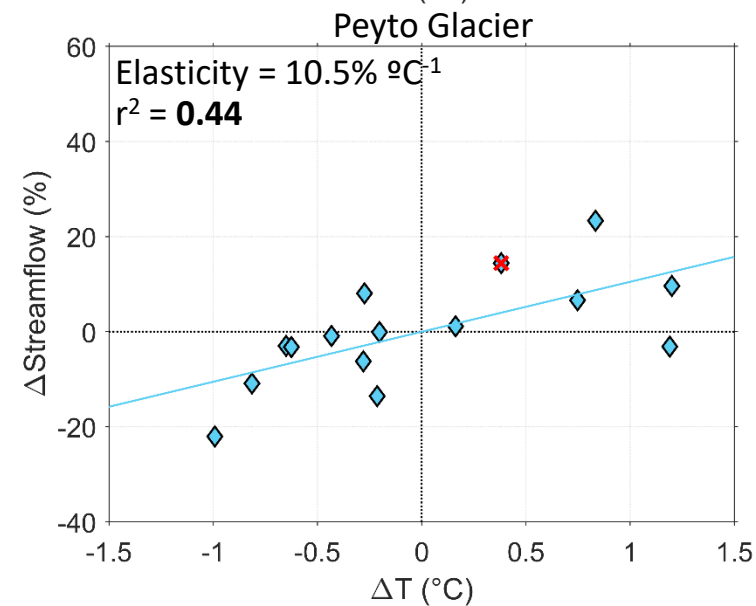
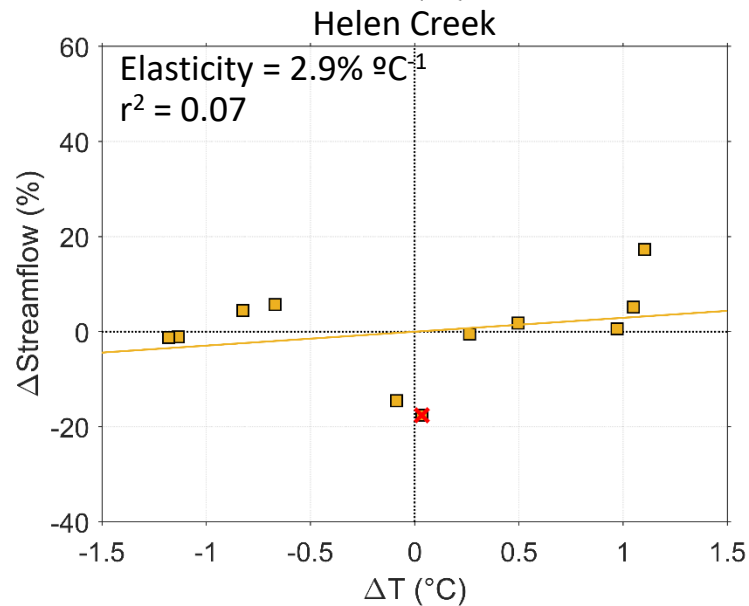
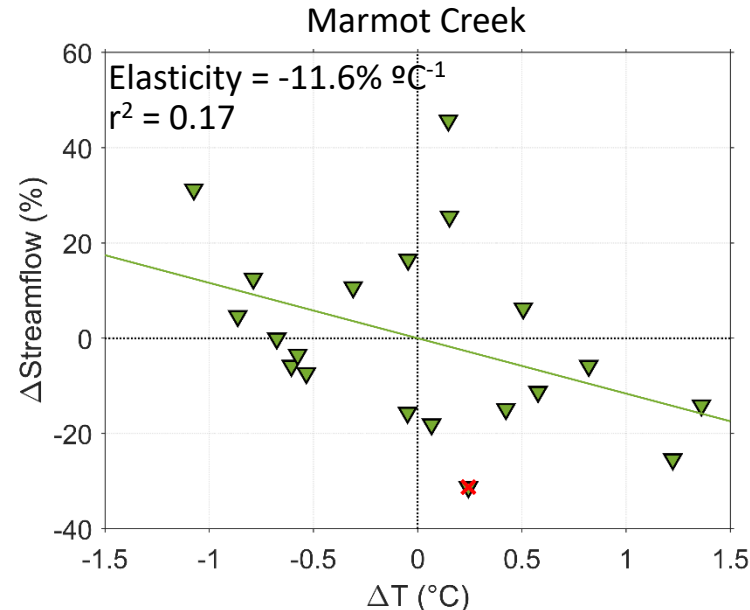
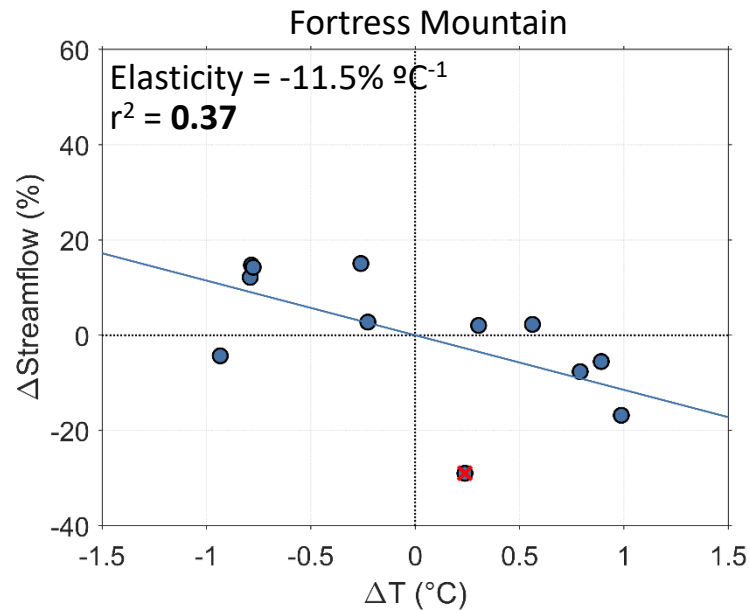
Elasticity = $\Delta\text{Snowmelt} / \Delta P$, or $\Delta\text{Glacier Melt} / \Delta P$

Note: r^2 values **bold** when statistically significant ($p \leq 0.05$)

Note: Point with **x** is for 2022-2023 water year.

Temperature Sensitivity of Basin Streamflow

● Fortress Mountain ▼ Marmot Creek ■ Helen Creek ◆ Peyto Glacier



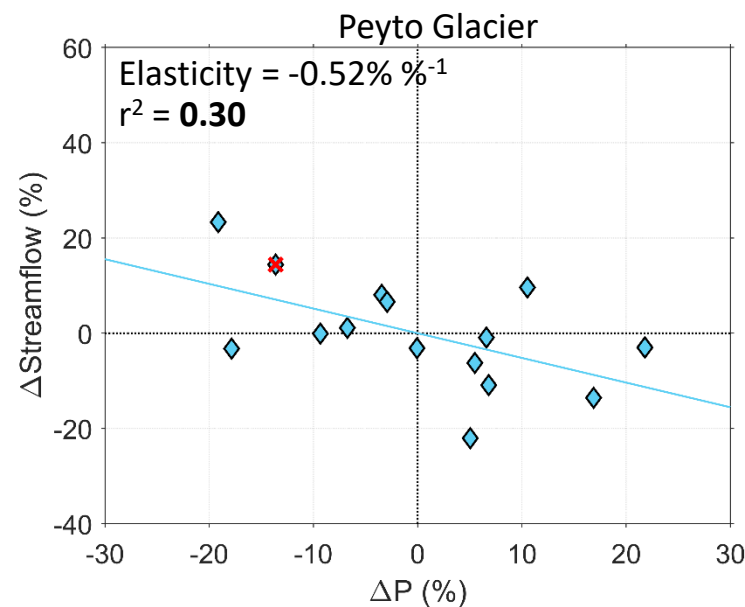
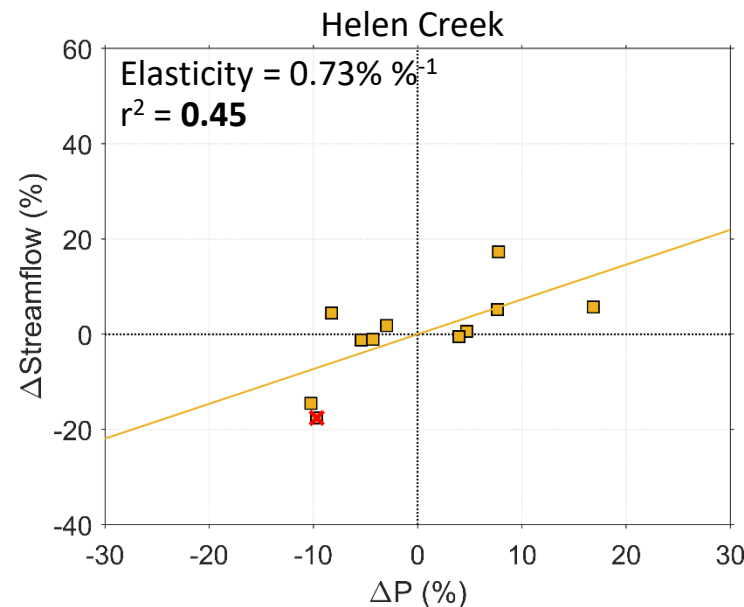
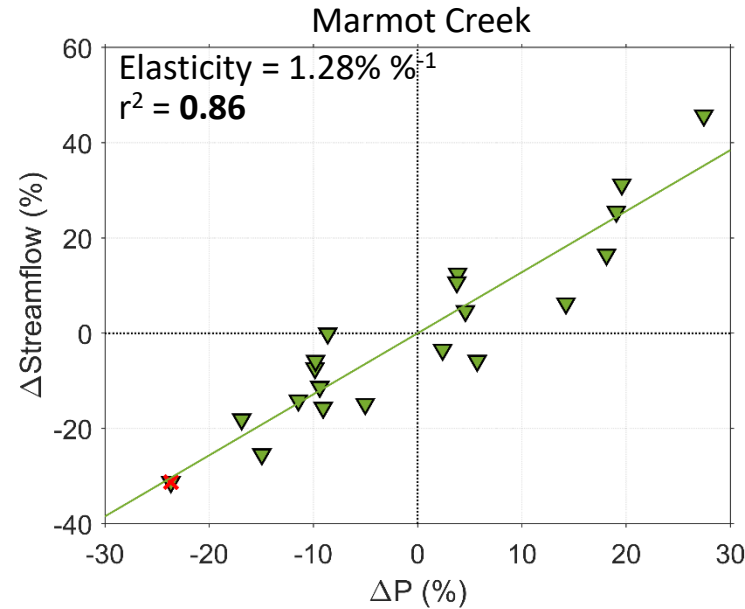
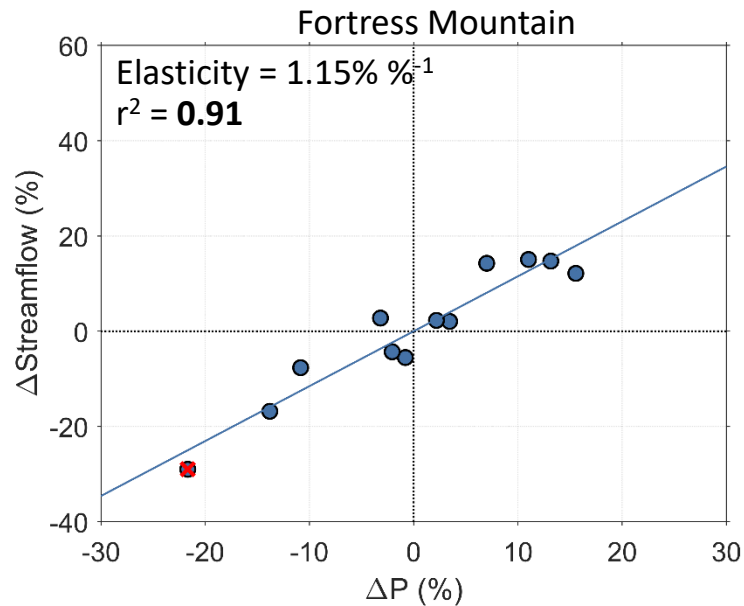
Elasticity = $\Delta\text{Streamflow} / \Delta T$

Note: r^2 values **bold** when statistically significant ($p \leq 0.05$)

Note: Point with **x** is for 2022-2023 water year.

Precipitation Sensitivity of Basin Streamflow

● Fortress Mountain ▼ Marmot Creek ■ Helen Creek ◆ Peyto Glacier



Elasticity = $\Delta \text{Streamflow} / \Delta P$

Note: r^2 values **bold** when statistically significant ($p \leq 0.05$)

Note: Point with **x** is for 2022-2023 water year.

Conclusions

- During the Hydrological Year of 2022-23, two mostly forested, one alpine and one glaciated headwater basins in the Canadian Rockies were intensely observed and diagnostically modelled with the CRHM models. Data quality was high and model performance was good.
- During May and June 2023,
 - Air temperatures were warmer than normal by 3.3 to 3.8° C
 - Cumulative water year precipitation was lower than normal by 10 to 24%.
 - Snowpacks were about 74% of normal and melt timing advanced by 3 to 7 weeks – a Snow Drought.
- Headwater Basins showed divergent hydrological responses to Snow Drought
 - Shorter snowcover duration, decreased snowmelt volume, higher ET, lower soil moisture and groundwater storage for all basins
 - Earlier spring freshet and reduced annual streamflow for alpine and forested basins
 - Higher annual streamflow for the glaciated basin due to enhanced glacier melt that could more than compensate for decreased snowmelt.
- Elasticity analysis for **snowmelt** and **streamflow** showed negative elasticity with temperature for all basins except for the alpine basin and streamflow in the glaciated basin which were positive and positive elasticity with precipitation except for streamflow in the glaciated basin which was negative.
- Elasticity analysis for **glacier melt** showed positive elasticity with temperature and negative elasticity with precipitation which is consistent with the positive temperature elasticity and negative precipitation elasticity for **streamflow**.
- The **elasticity reversal** for the glaciated basin demonstrates the strong buffering capacity of glaciers during snow droughts. The reduced snow duration on the ice enhanced icemelt.

“Earlier summer” hiking photo taken on May 28,
2023, looking at Johnston Creek valley, Banff
National Park
Thank you!

