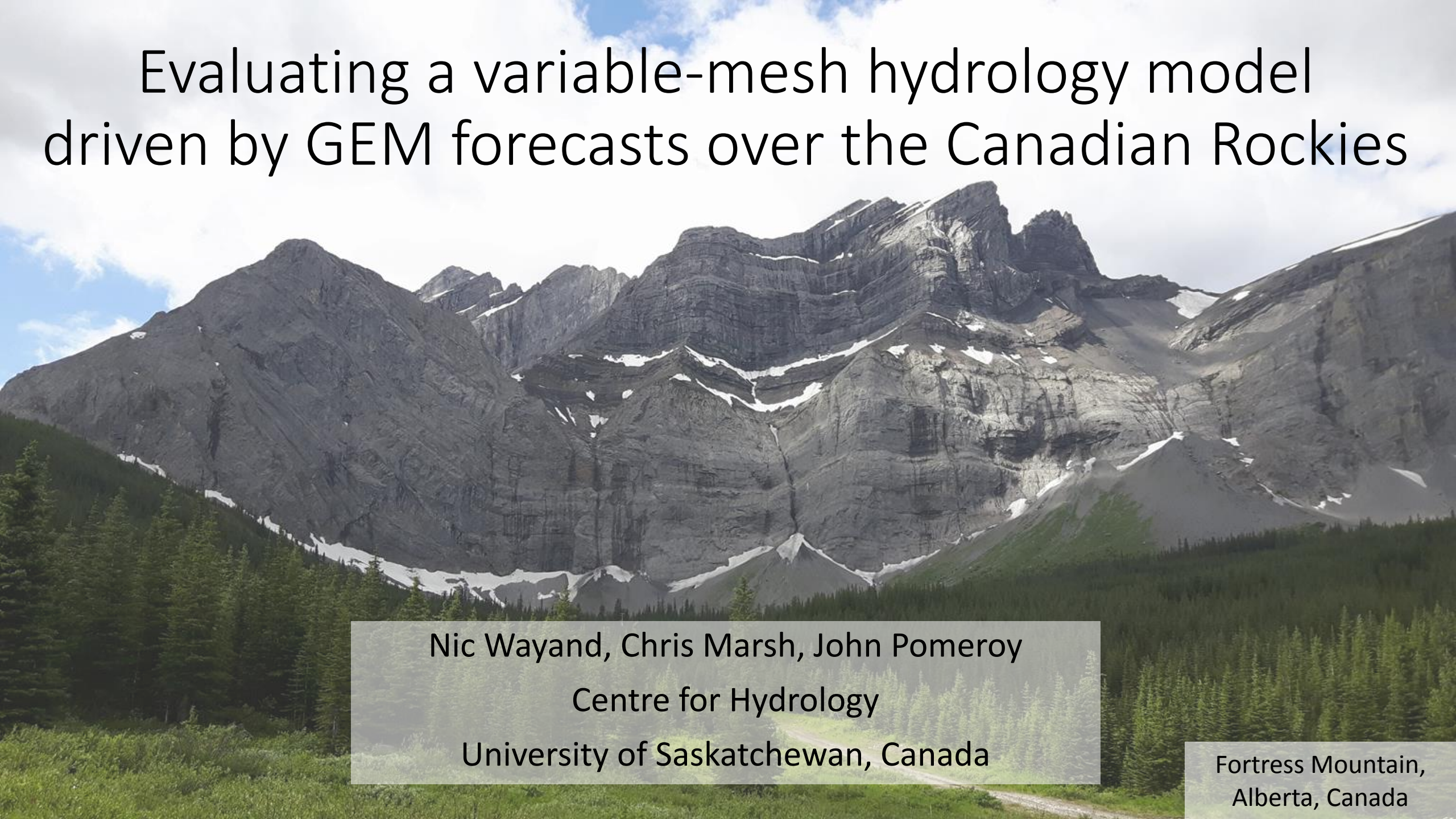
Evaluating a variable-mesh hydrology model driven by GEM forecasts over the Canadian Rockies



Nic Wayand, Chris Marsh, John Pomeroy

Centre for Hydrology

University of Saskatchewan, Canada

Fortress Mountain, Alberta, Canada

Study Goals:

- Develop a spatially-flexible large-extent hydrological model for cold regions
- Test NWP forecasts over Canadian Rockies Mountain Observatory
- Develop/Evaluate snow-process parameterizations across spatial scales

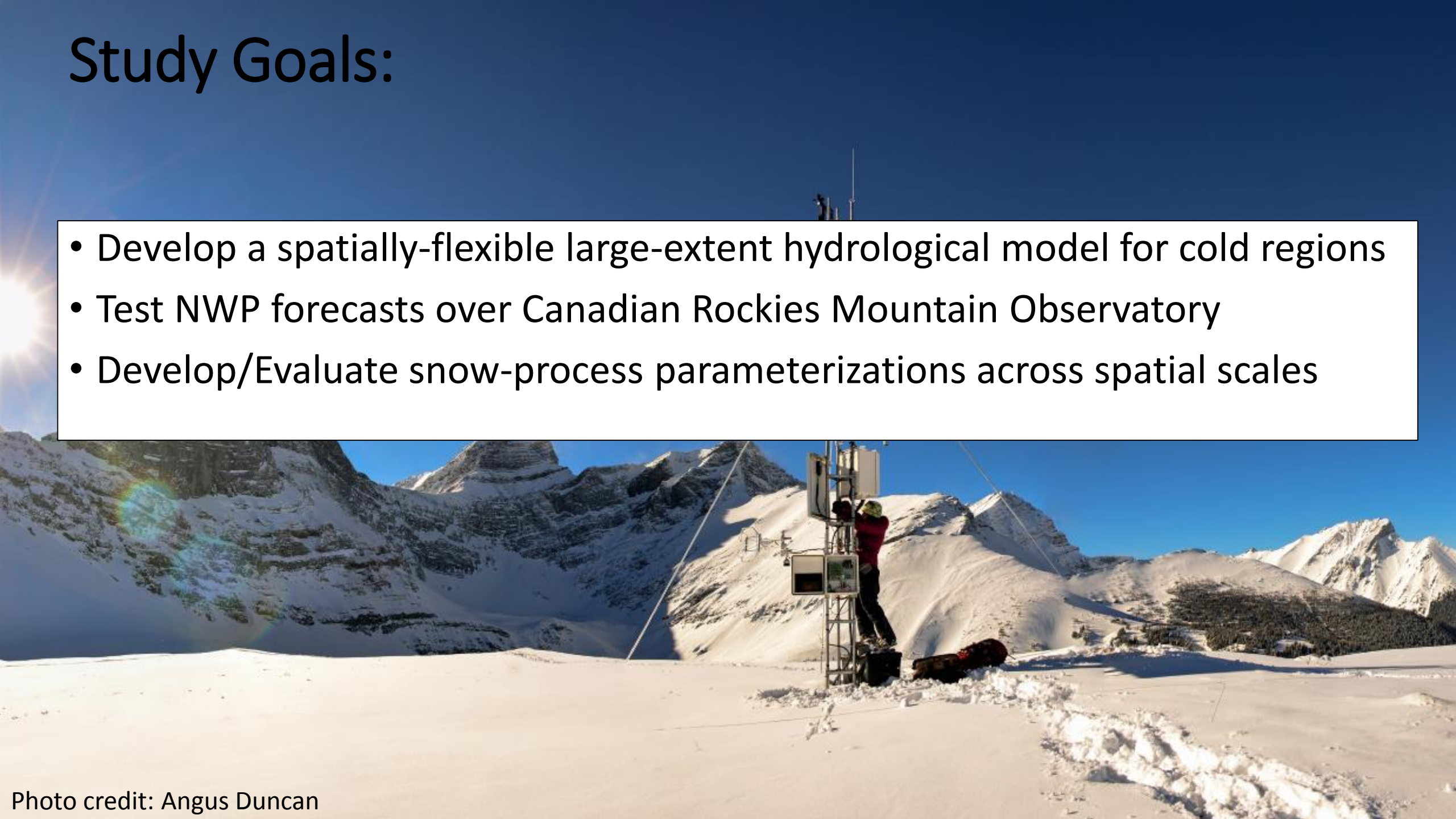


Photo credit: Angus Duncan

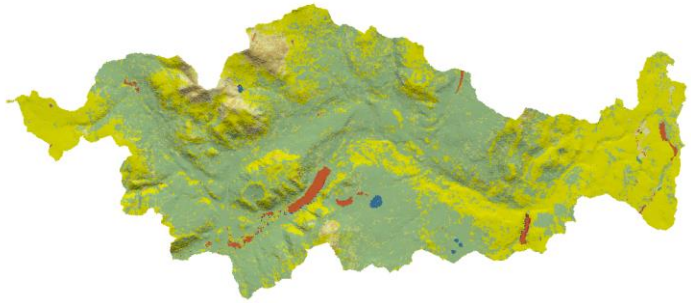
Canadian Hydrological Model (CHM)

- Multiple Hypothesis Framework
- Test the impact of model structure and complexity
- Spatially distributed via variable resolution unstructured meshes
- Full command line (scriptable) support to change all model aspects
- Interpolates / downscales driving meteorological data

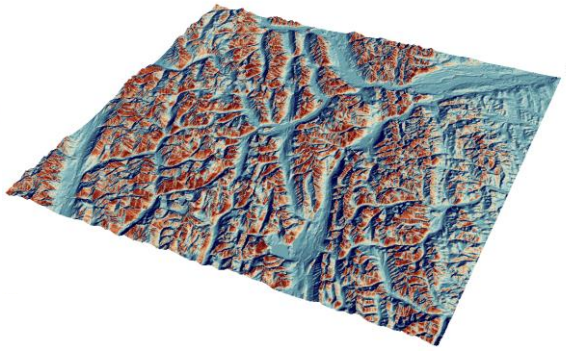
Represents:

Canopy
Vertical snow processes
Soil (in progress)
Runoff Routing (in progress)
Blowing snow (in progress)

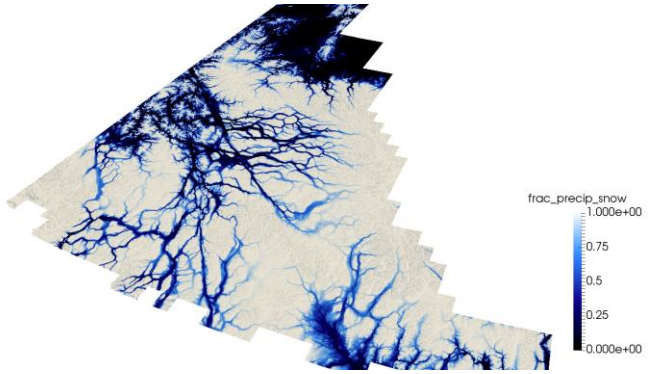
Basin (100 km^2)



Regional (8000 km^2)



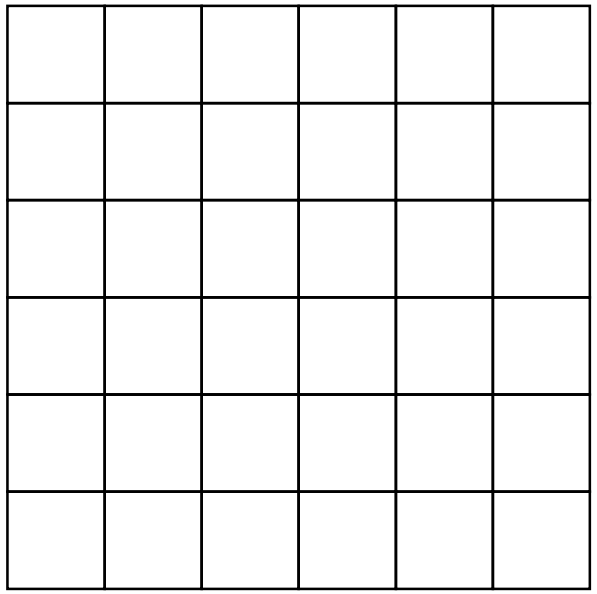
Provincial (500 000 km^2)



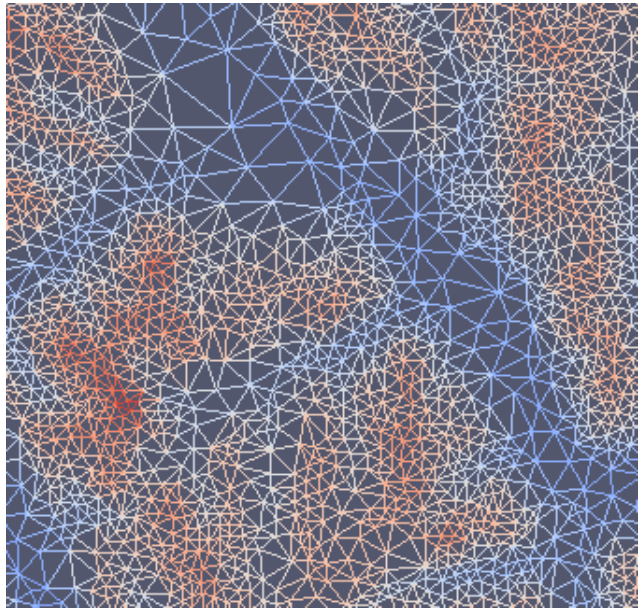
Unstructured Triangular Mesh

- Unstructured meshes reduce total number of computational elements vs. a grid
- Appropriate basin discretization

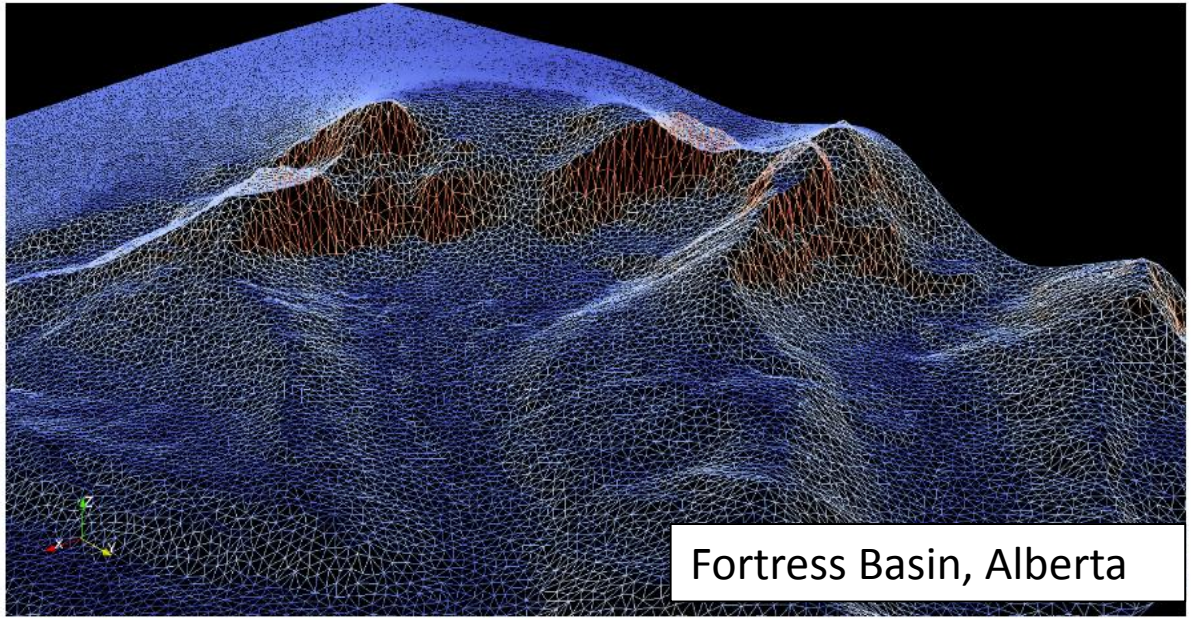
Grid



Triangular Mesh



Example

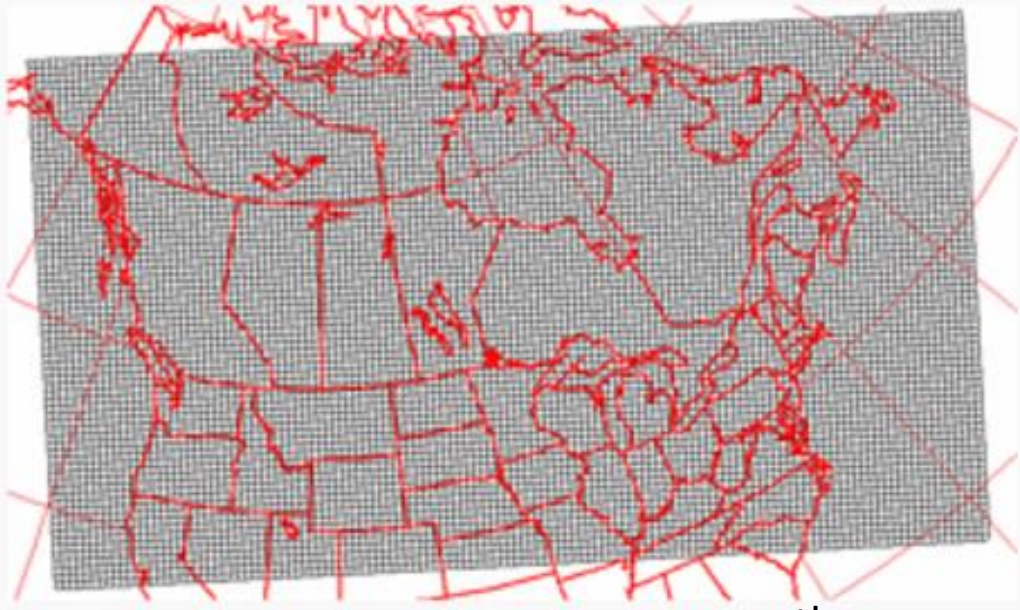


Global Environmental Multiscale (GEM) model

- 2.5 km resolution
- 48 Hour forecasts 4 times daily (00,06,12,18 UTC)
- Archived output (2014-2015)

1. What surface forecast variables are well predicted?
2. Can downscaling techniques compensate for persistent GEM issues?
3. Are higher GEM resolutions needed?

Continental GEM domain



weather.gc.ca

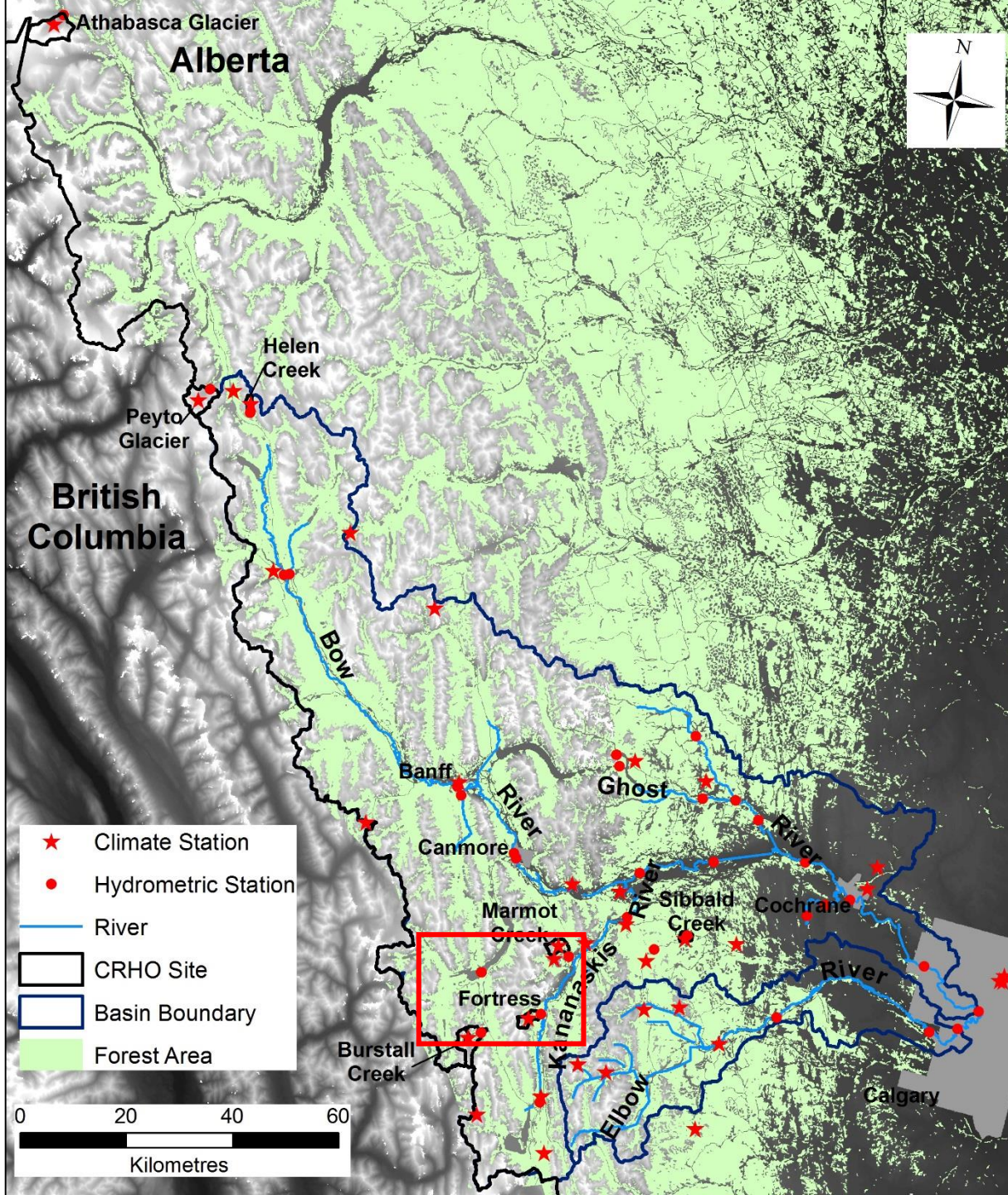
Canadian Rockies Hydrological Observatory (CRHO)

- New Quality controlled data set available for water years 2013 -2016

A typical CRHO weather station includes:

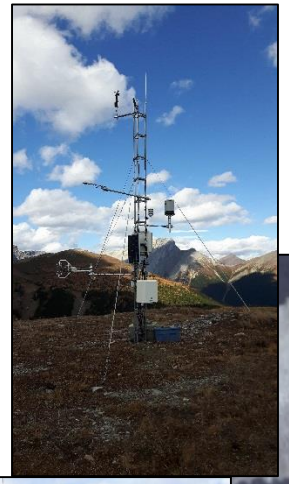
Meteorological sensors:

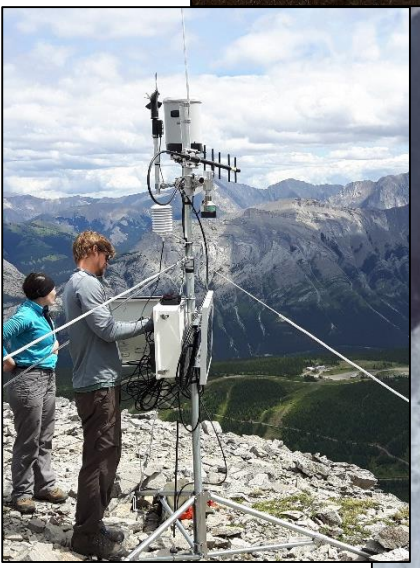
Air temperature and relative humidity *(Rotronic HC2-S3)*
Wind speed and direction *(RM Young 05103)*
Radiation *(Kipp & Zonen CNR4)*
Snow depth *(Campbell Scientific SR50A)*
Barometric pressure *(Vaisala PTB110)*
Soil heat flux *(Huskeflux HFP01)*
Soil moisture and temperature (*Campbell CS650)*
Weighing Precipitation Gauge *(Geonor TB200)*

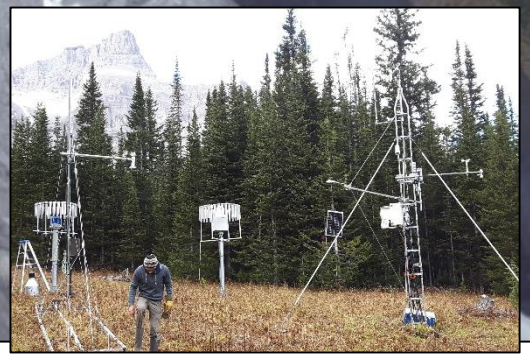


Fortress Basin Observatory

Area: 6 km²
Elevation:
2000-3000 m







Fortress Ridge South

Fortress Ridge

Drift Sink

Fortress Ledge

Sheltered sites in "Gaps"

Power line

Exposed, Drift source

Canadian Ridge

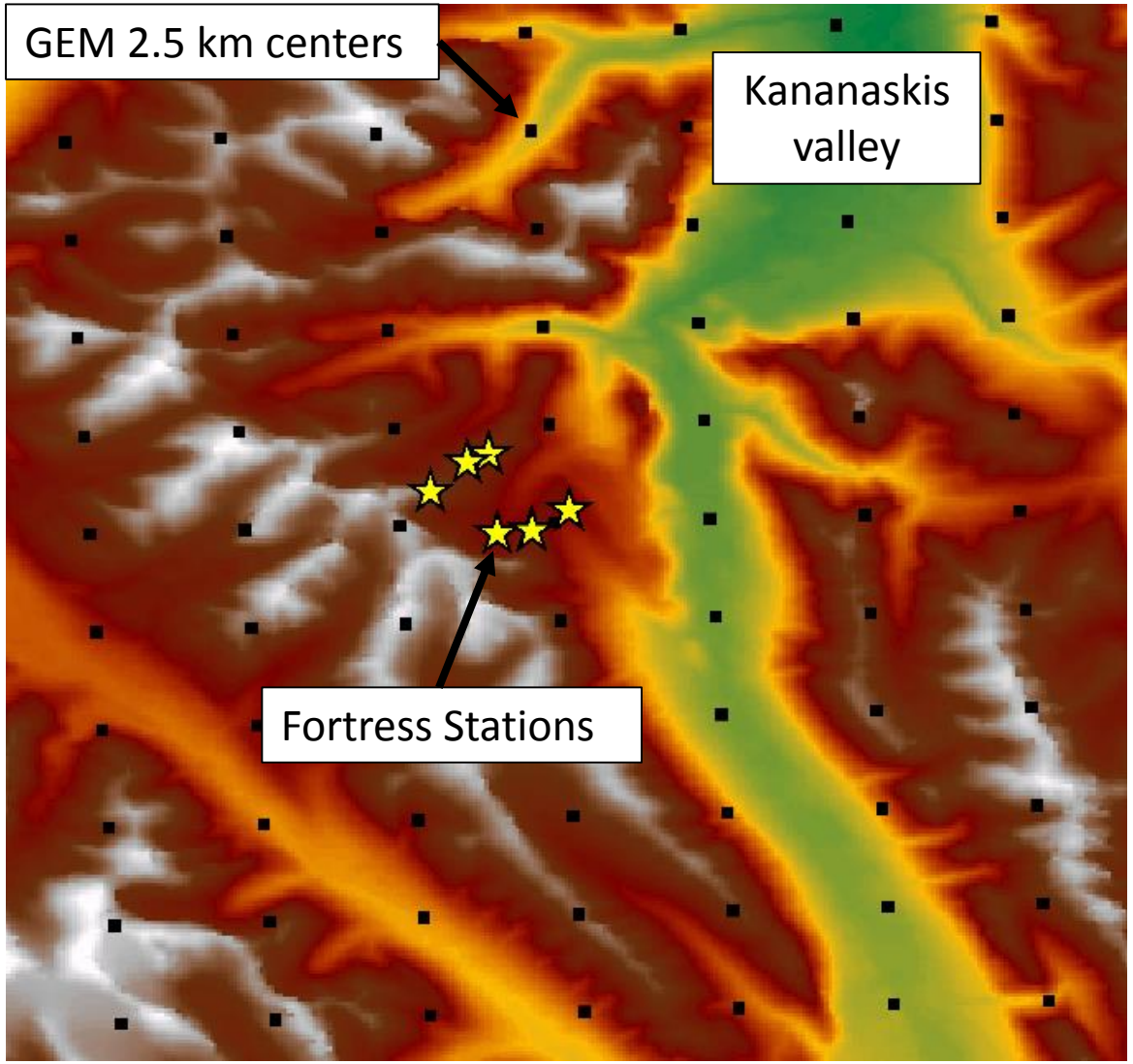
Canadian Ridge North

Bonsai

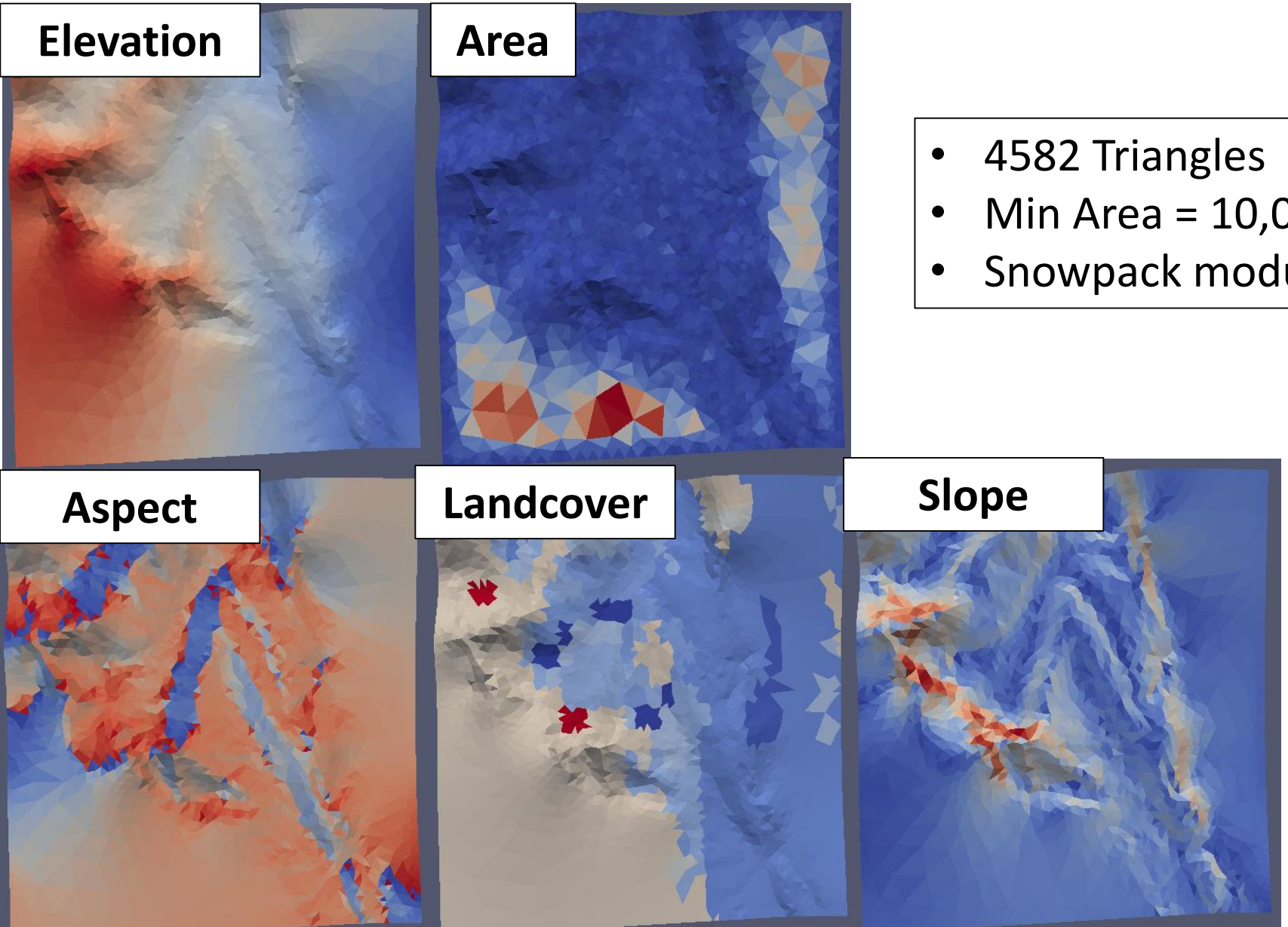
Range Road 9

Near-Real time data:
http://giws.usask.ca/cfh/telemetry/

GEM 2.5 km forcing just resolves Kananaskis Valley



CHM configuration for Fortress basin



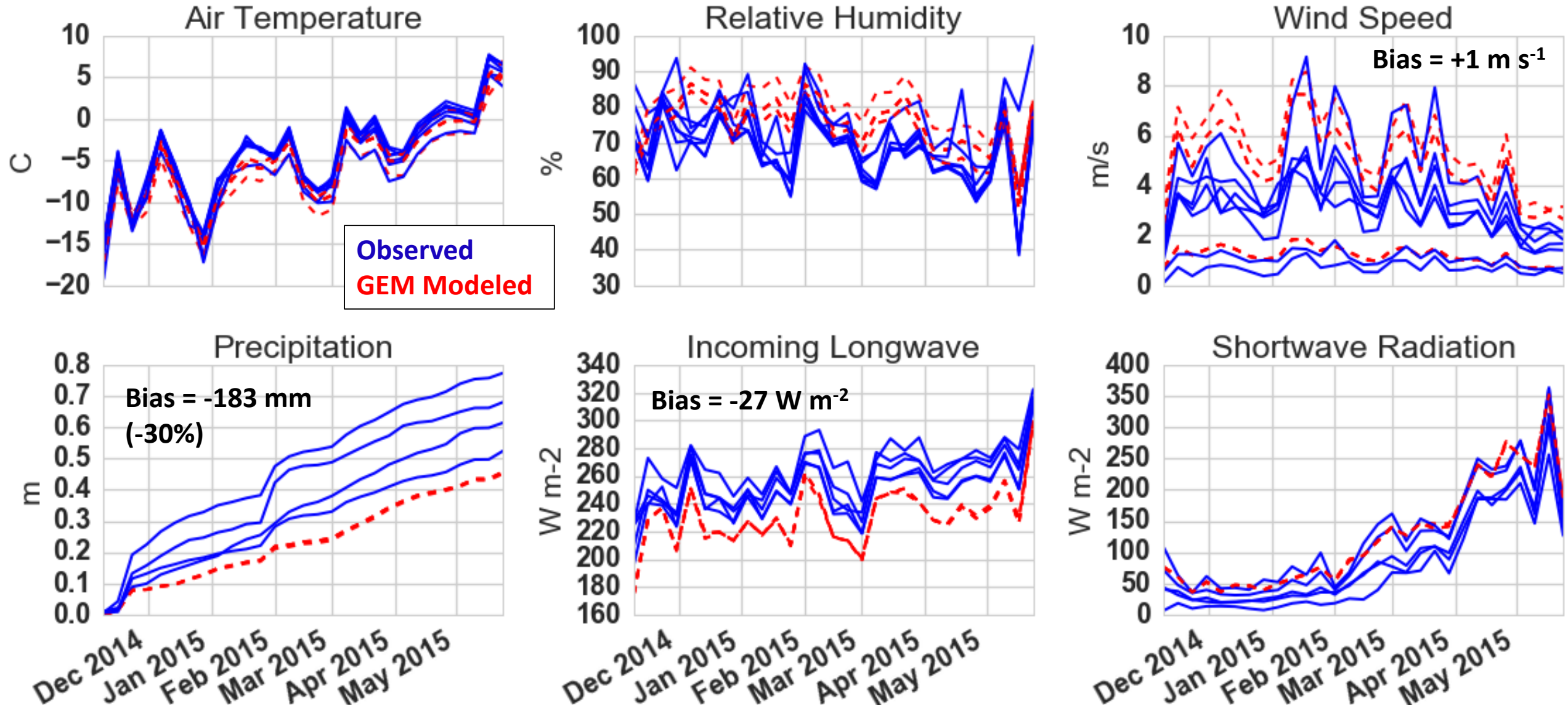
- 4582 Triangles
- Min Area = 10,000 m^2 (~~ 100mX100m)
- Snowpack module

Two Experiments:

1) No downscaling of GEM
2) Downscaling to mesh resolution

GEM output (no downscaling) VS. Fortress Station Observations

(Weekly averages)



Downscaling Methods currently within CHM

Air Temperature

- No adjustment
- Constant Lapse Rate
- Monthly lapse Rate
- Hourly Lapse rate from GEM lower levels

Relative Humidity

- No adjustment
- Constant Lapse Rate
- Monthly lapse Rate

Wind Speed

- Vertical:
  - Log/Exp (Open/Forest)
- Horizontal:
  - No adjustment
  - Liston and Elder (2006)

Precipitation

- No adjustment
- Constant Lapse Rate
- Monthly lapse Rate

Incoming Longwave

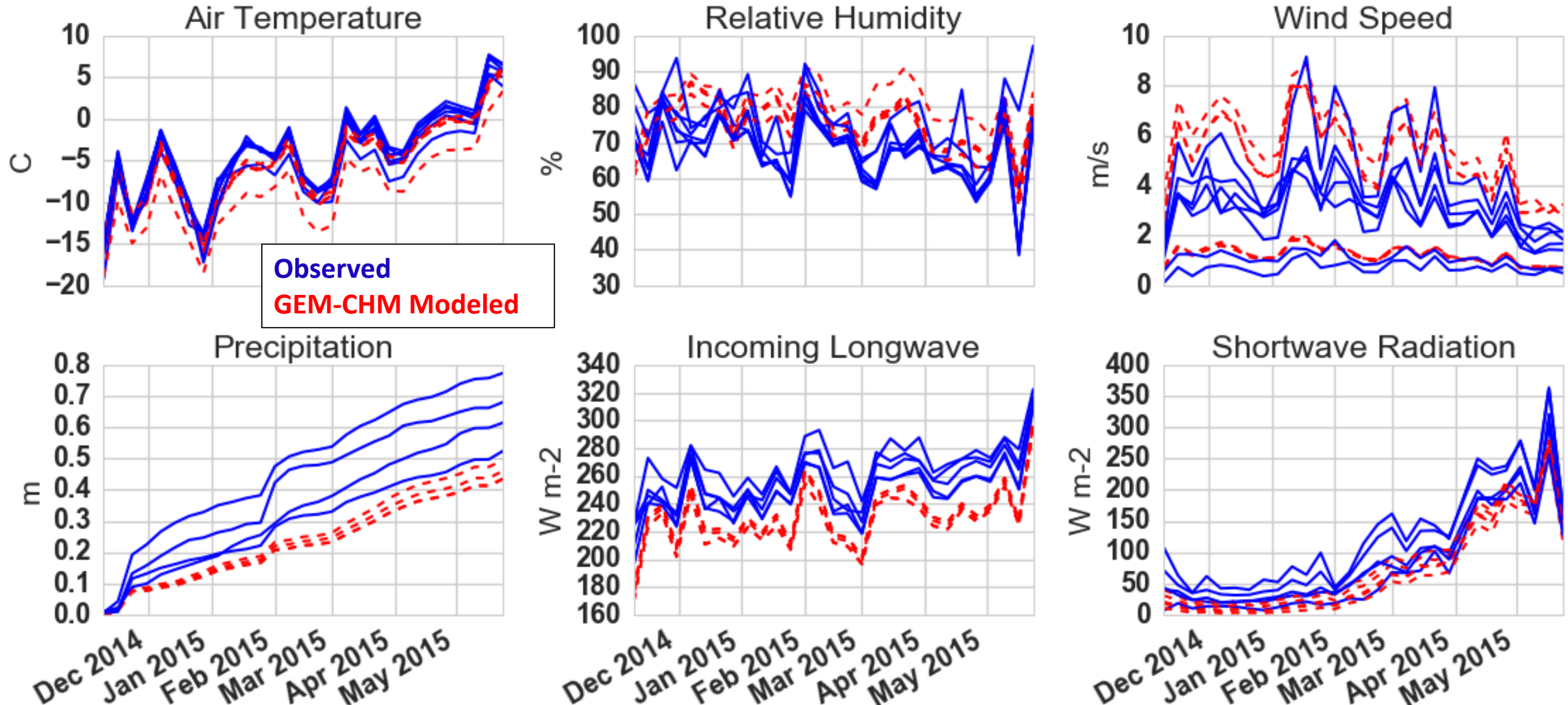
- No adjustment
- Constant Lapse Rate (Marty et al. 2002)

Shortwave Radiation

- No adjustment
- Slope adjustment
- Terrain shading (Marsh et al. 2012)

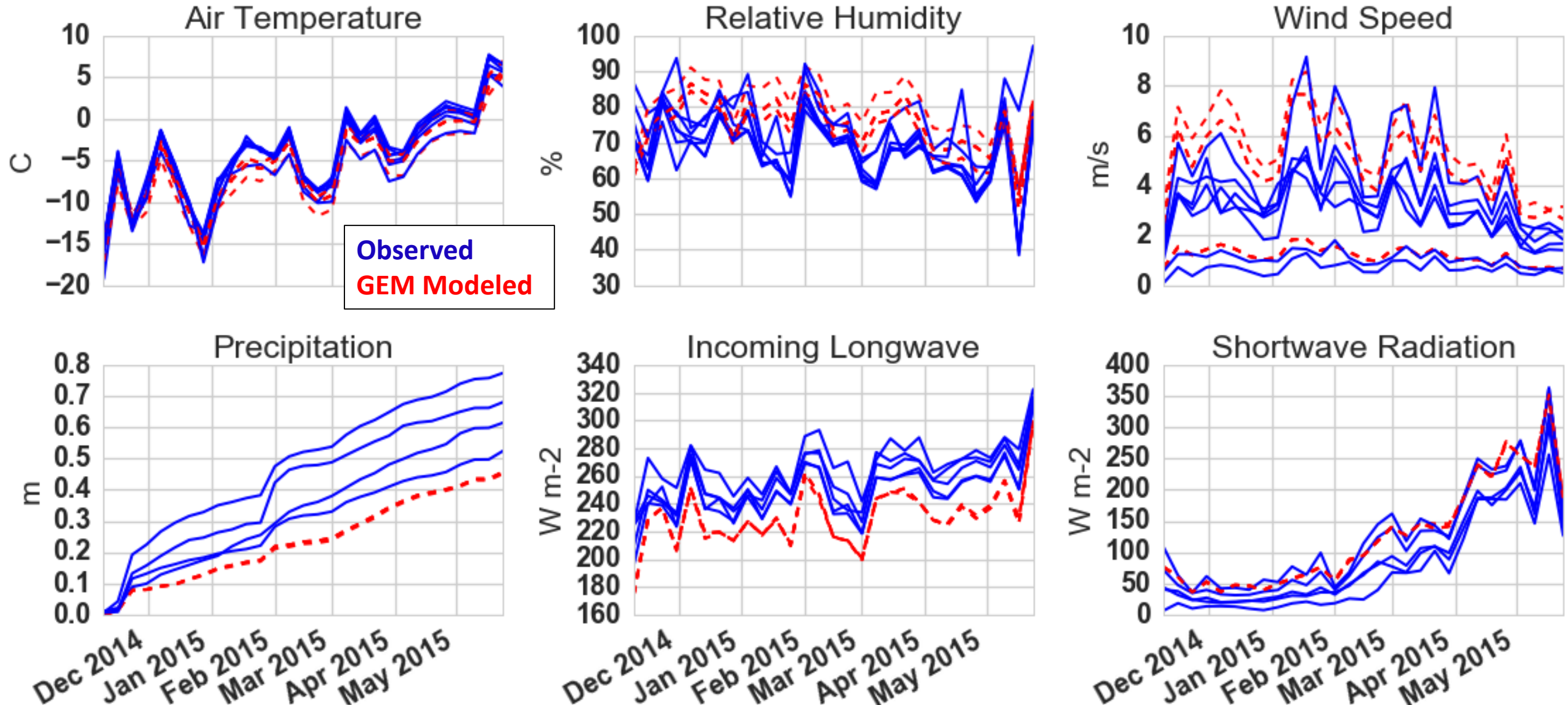
GEM output (WITH downscaling) VS. Fortress Station Observations

(Weekly averages)

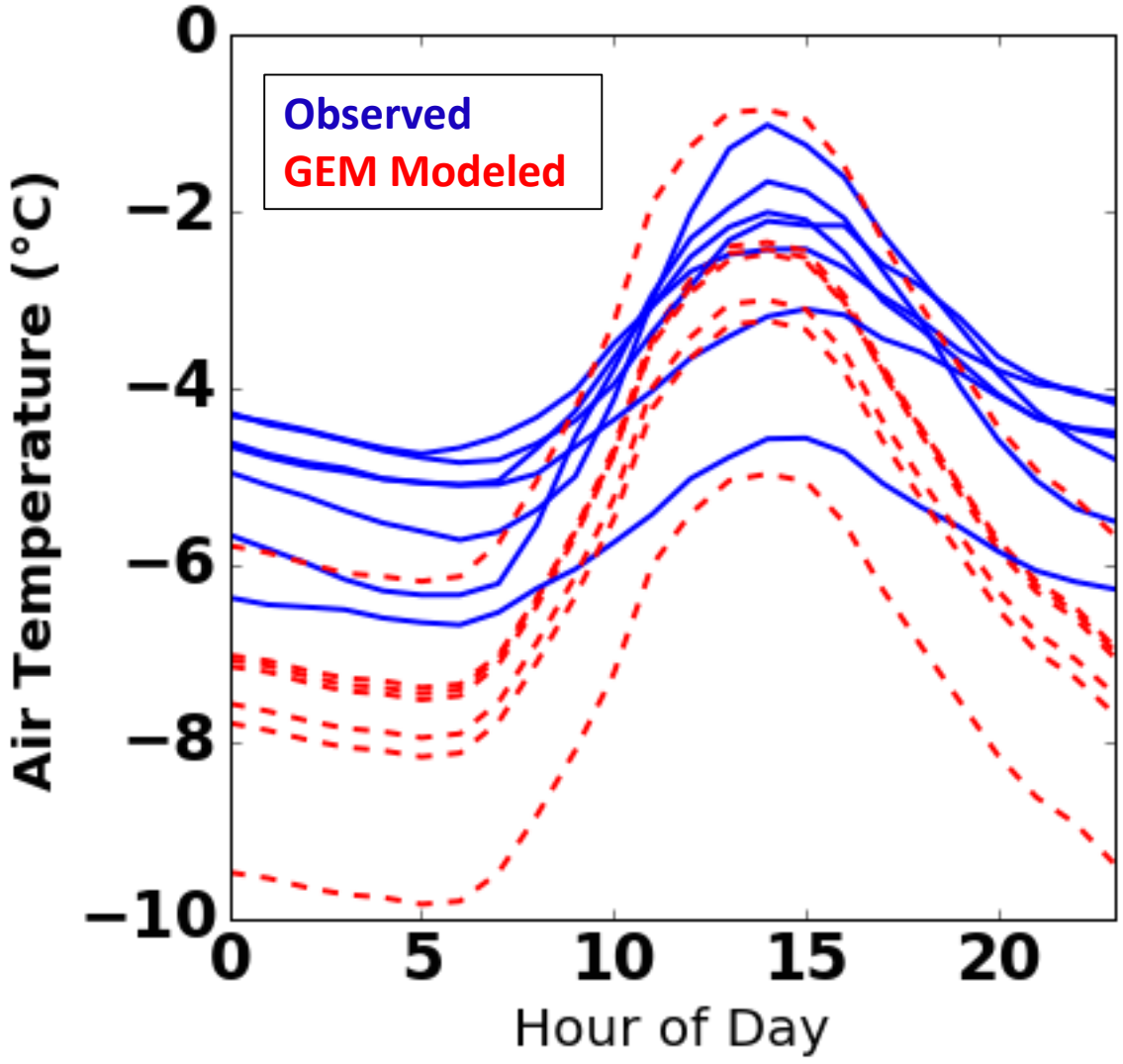


GEM output (no downscaling) VS. Fortress Station Observations

(Weekly averages)



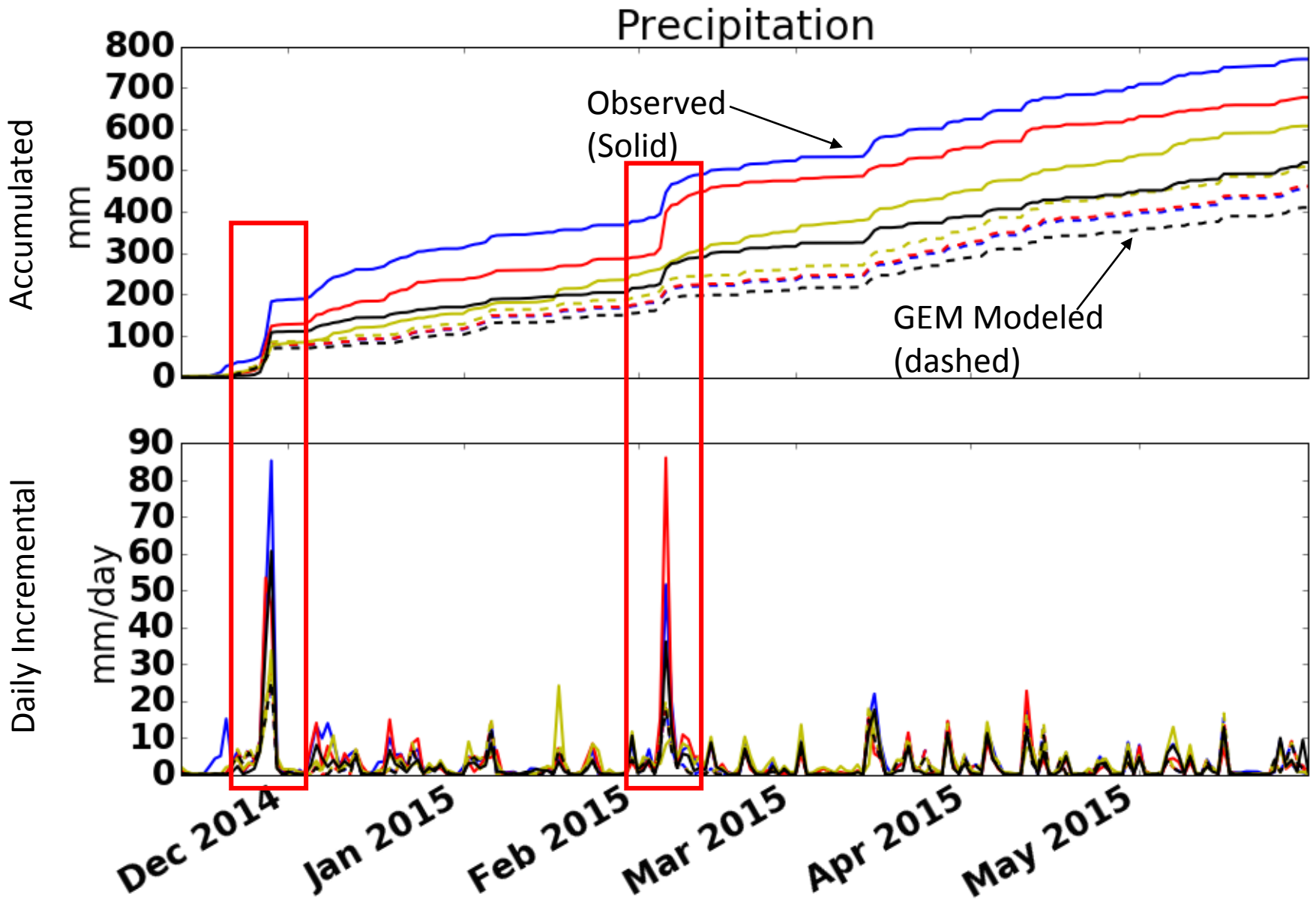
GEM predicted 2-m Air Temperature biased Cold at night



(Nov. 2014 to May 2015 average)

- Possible issue with feedback from land surface model bias in GEM's land surface model ISBA-ES?

GEM Precipitation biased low due to Nov. and Feb. Storms

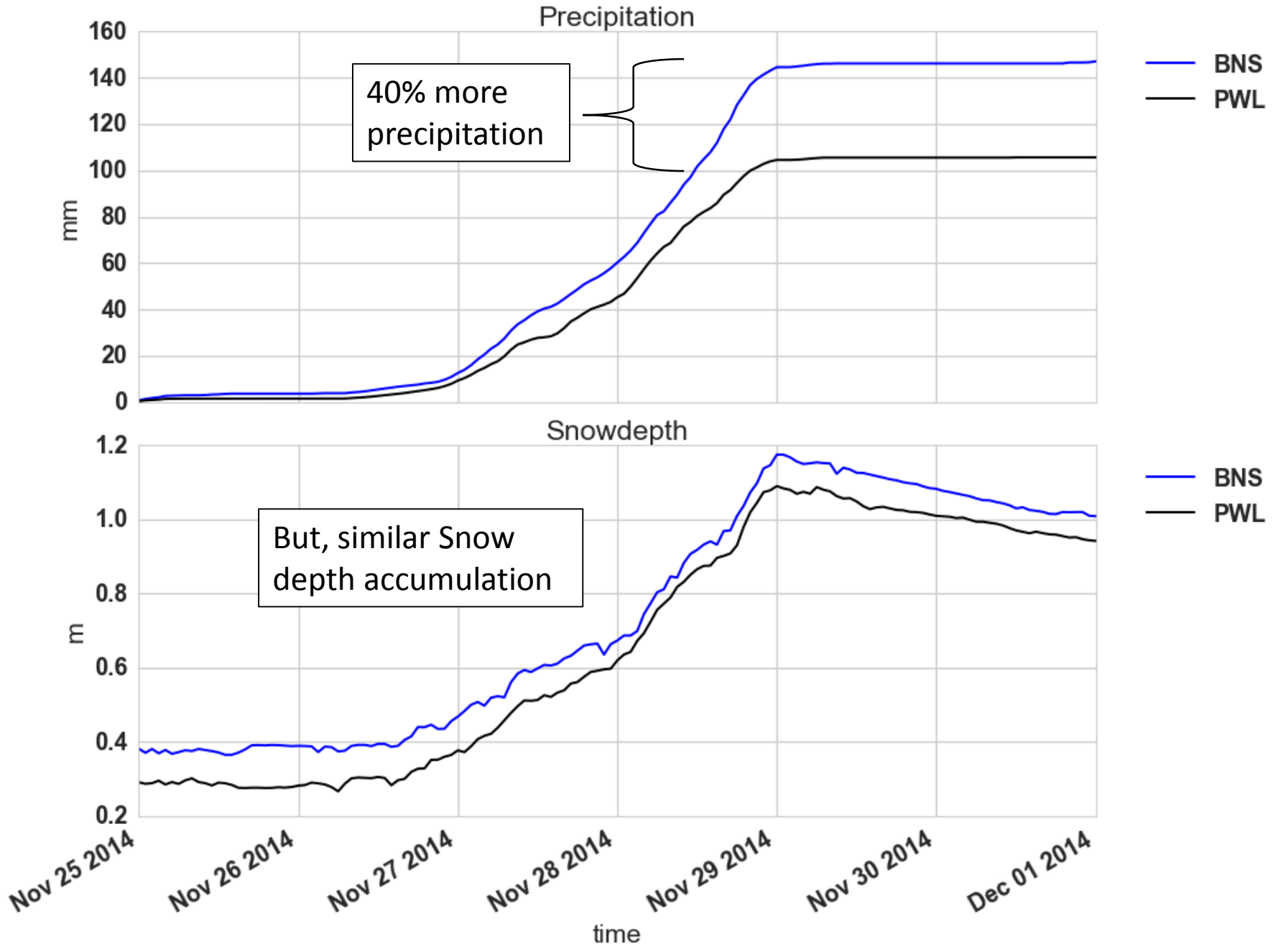


Fortress Stations

- BNS
- CRN
- FRS
- PWL

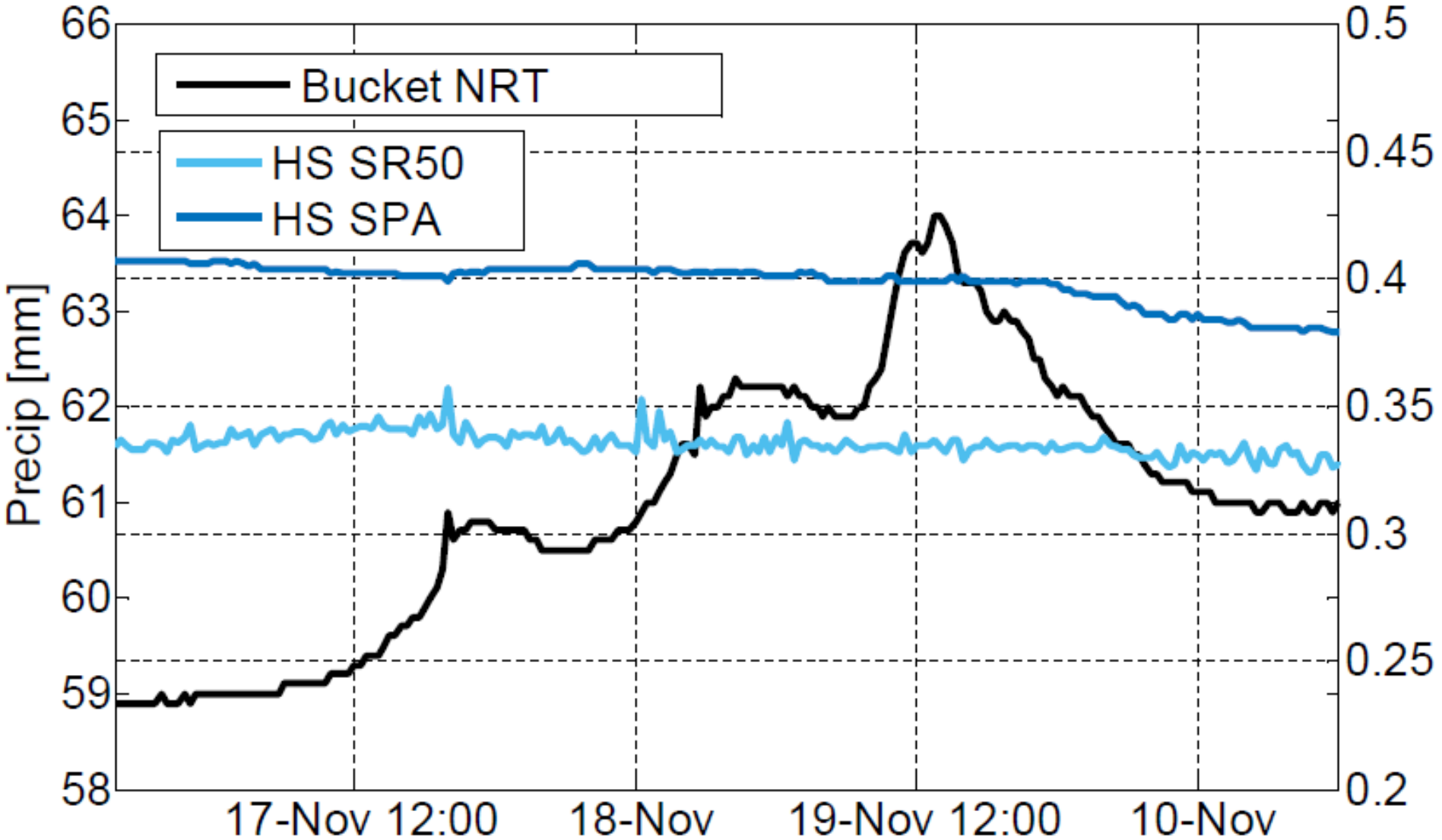
- Majority of GEM bias due to Nov. and Feb. Storms
- Questionable BNS Pluvio measurements during Nov. Storm?

Nov 2014 Storm



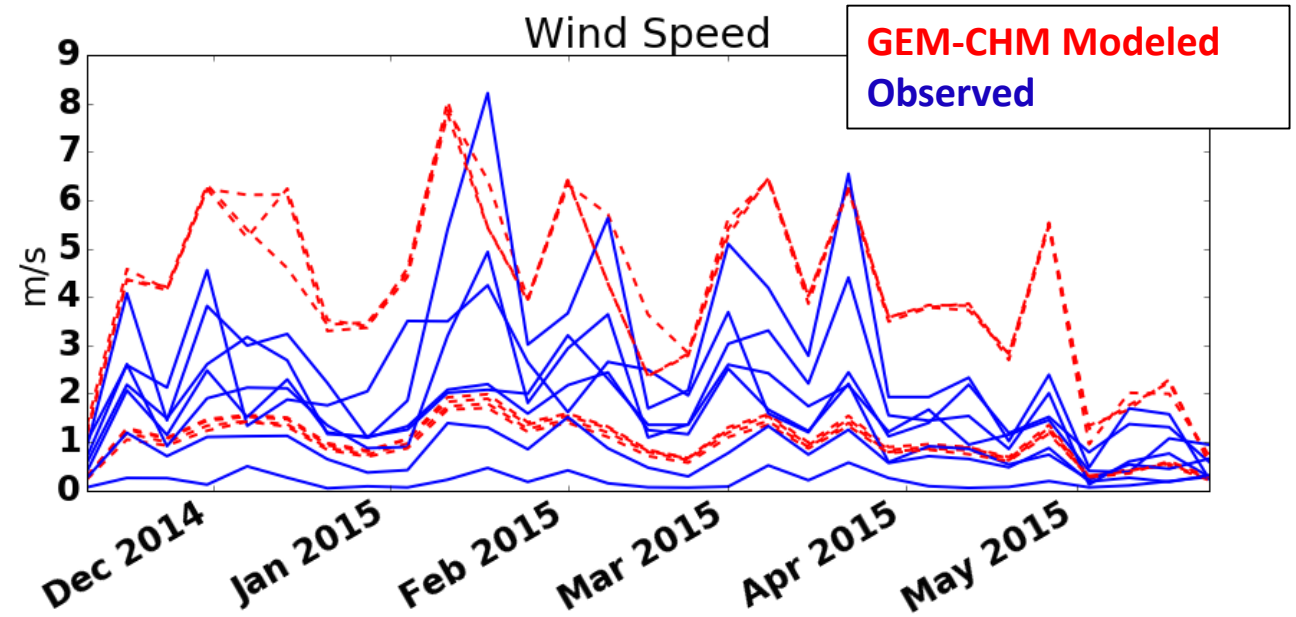
- Issues with BNS Pluvial gauge

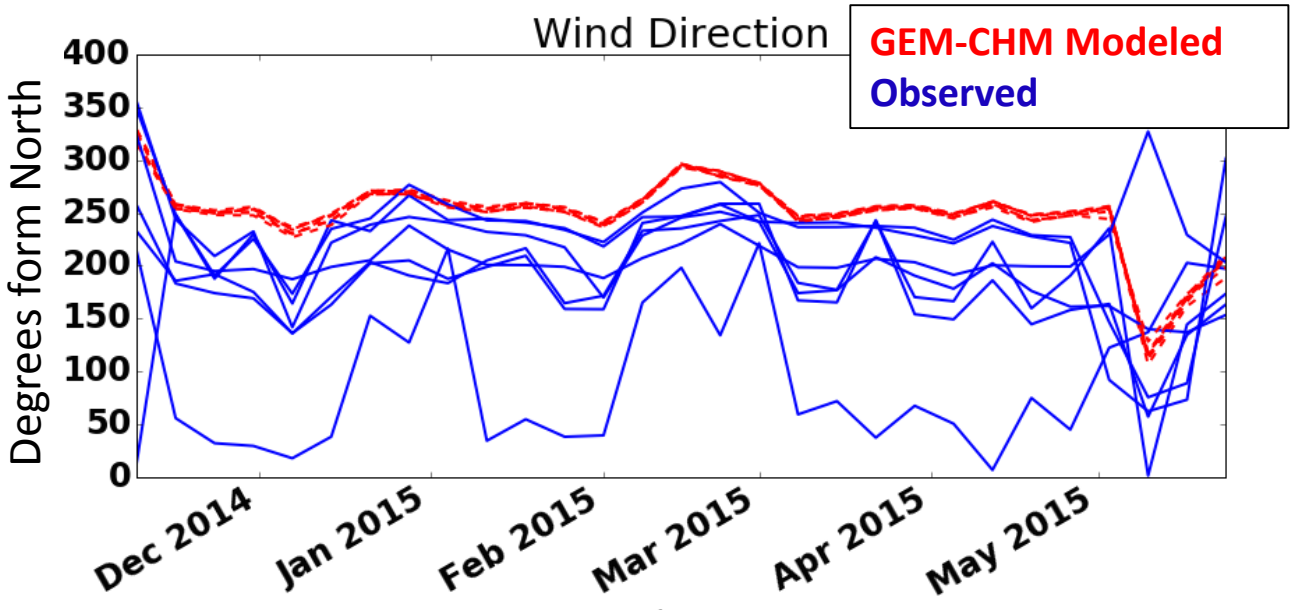
Nov 2014 Storm



Issues with BNS
Pluvial gauge

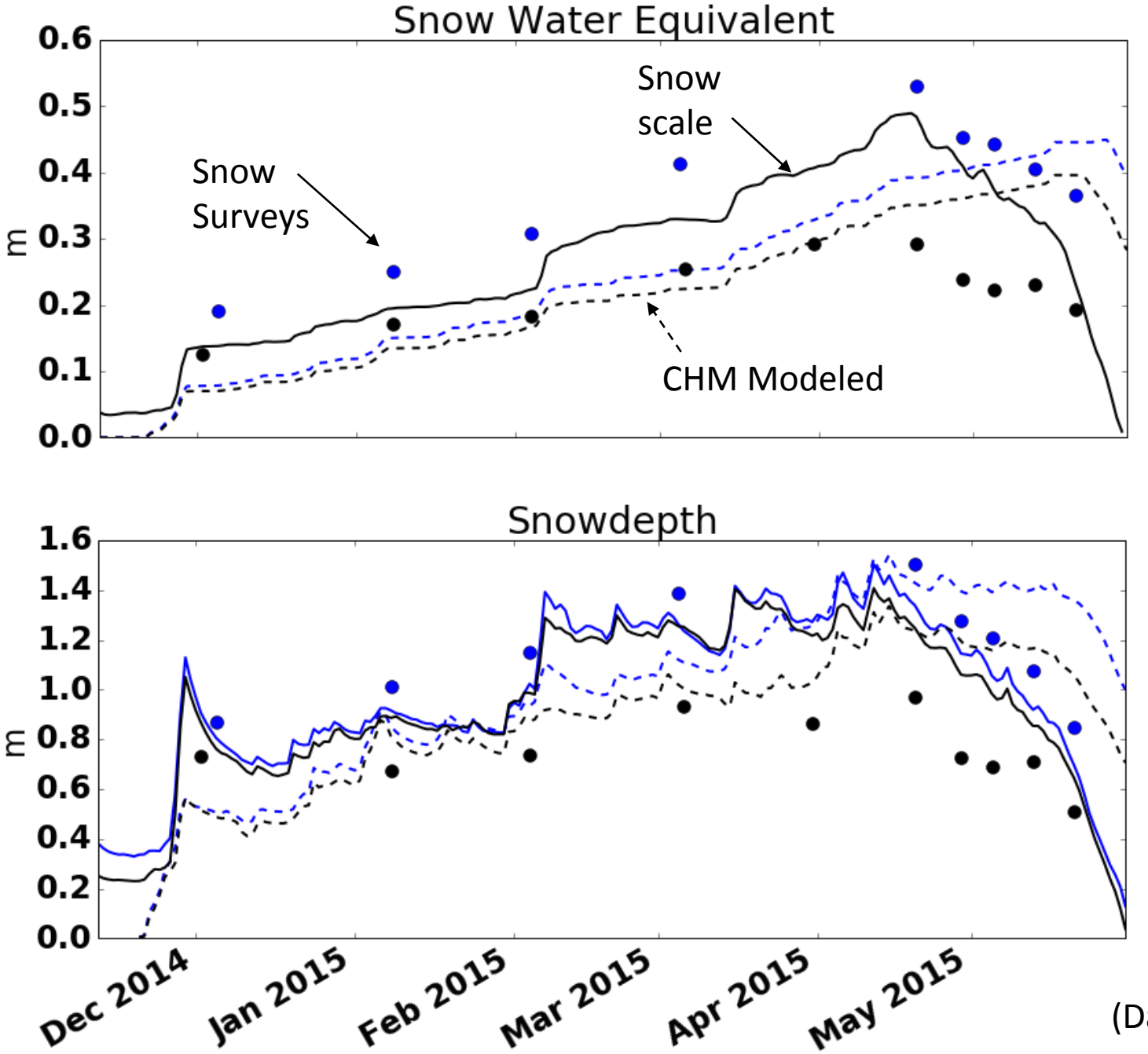
Using Liston and Elder (2006) to downscale GEM 40 m wind fields





- GEM Wind speed biased high, or downscaling incorrect?
- Observed wind direction variance not captured by 2.5 km GEM
- Need more physical representation of wind flow over terrain (Windsim, Mason-Skyes, ?)

GEM-CHM Simulated SWE and Snow depth



BNS

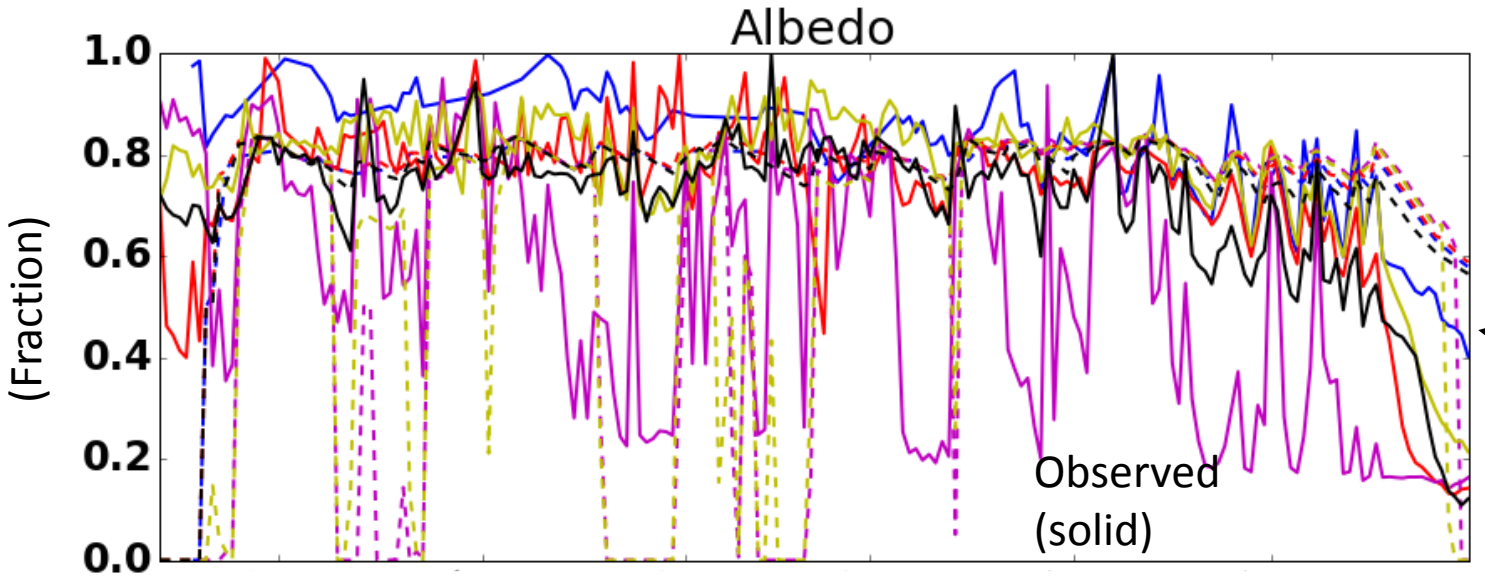
PWL

Sheltered Stations

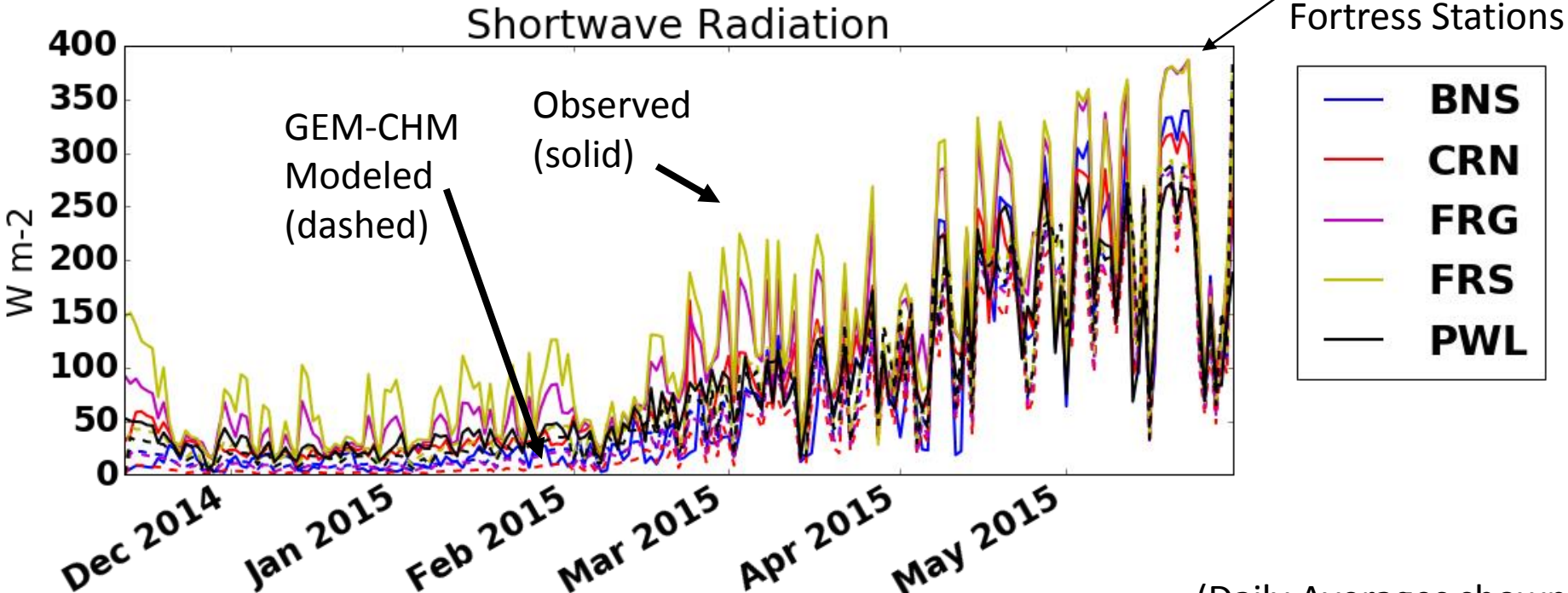
- GEM-CHM Accumulation within observation variance
- Timing issues in Spring

(Daily Averages shown)

Spring Albedo too High, decay too slow



Largest albedo errors when Solar radiation is largest

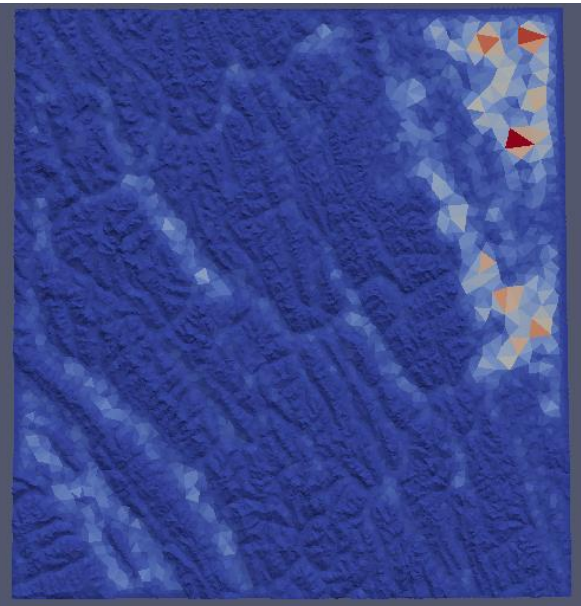


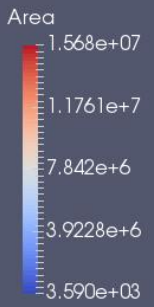
Fortress Stations

(Daily Averages shown)

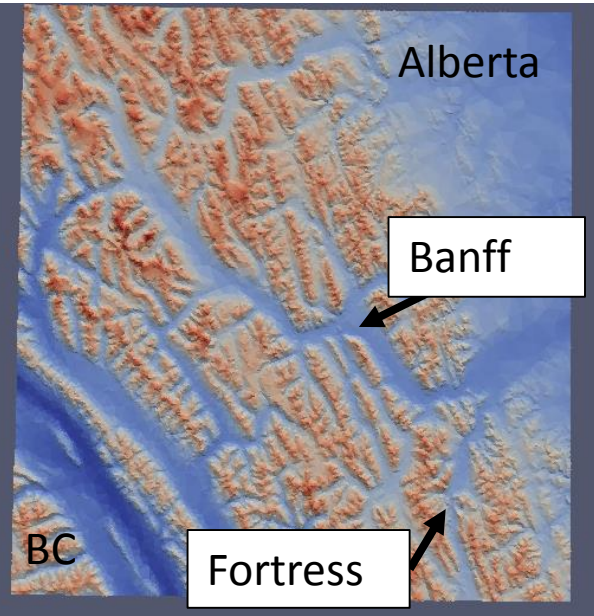
GEM-CHM operational forecasts over Rockies

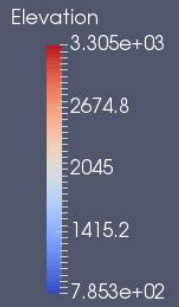
AREA



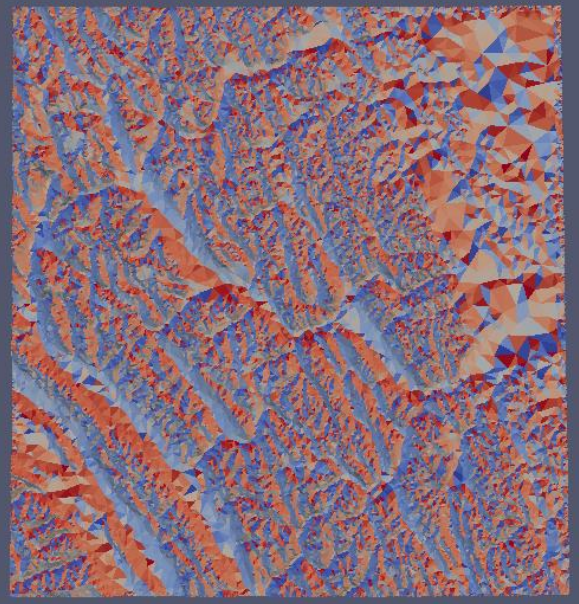


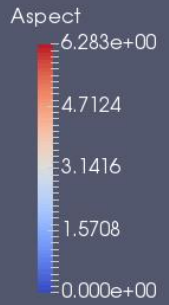
Elevation



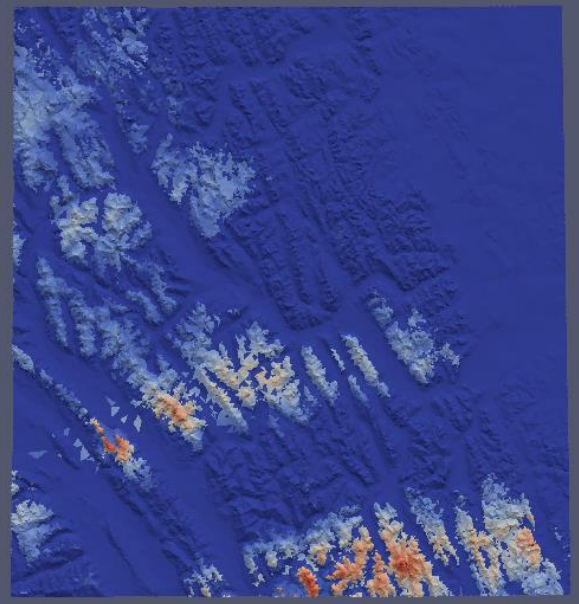


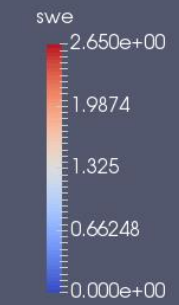
Aspect





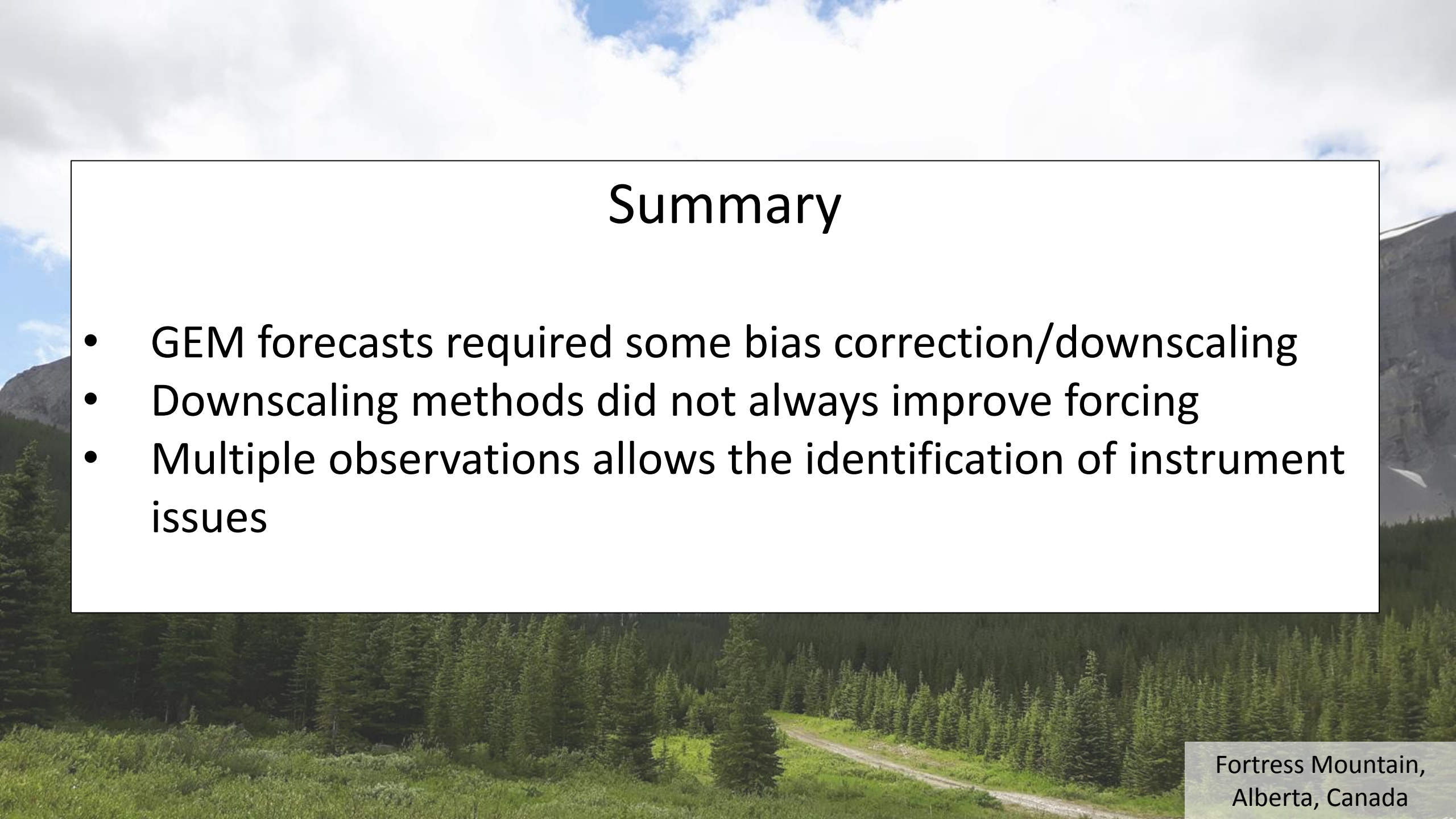
SWE





Summary

- GEM forecasts required some bias correction/downscaling
- Downscaling methods did not always improve forcing
- Multiple observations allows the identification of instrument issues



Fortress Mountain, Alberta, Canada

Thank you. Questions?

Fortress Mountain, Alberta, Canada