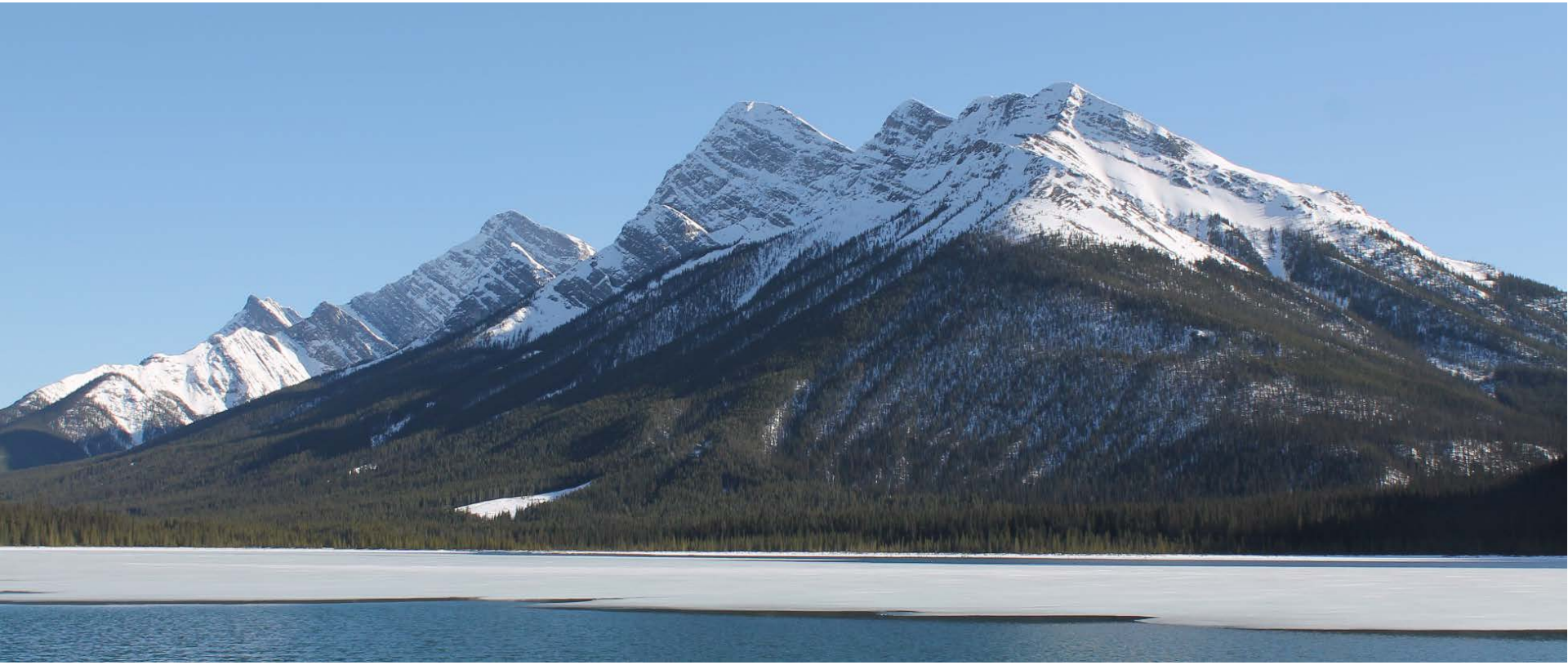
GPM-IMERG Snowfall Estimates in Cold Mountainous Regions

André L. S. Bertoncini, John W. Pomeroy, Zilefac Elvis Asong



Global Water Futures Annual Science Meeting - Hamilton, ON - June 5th, 2018

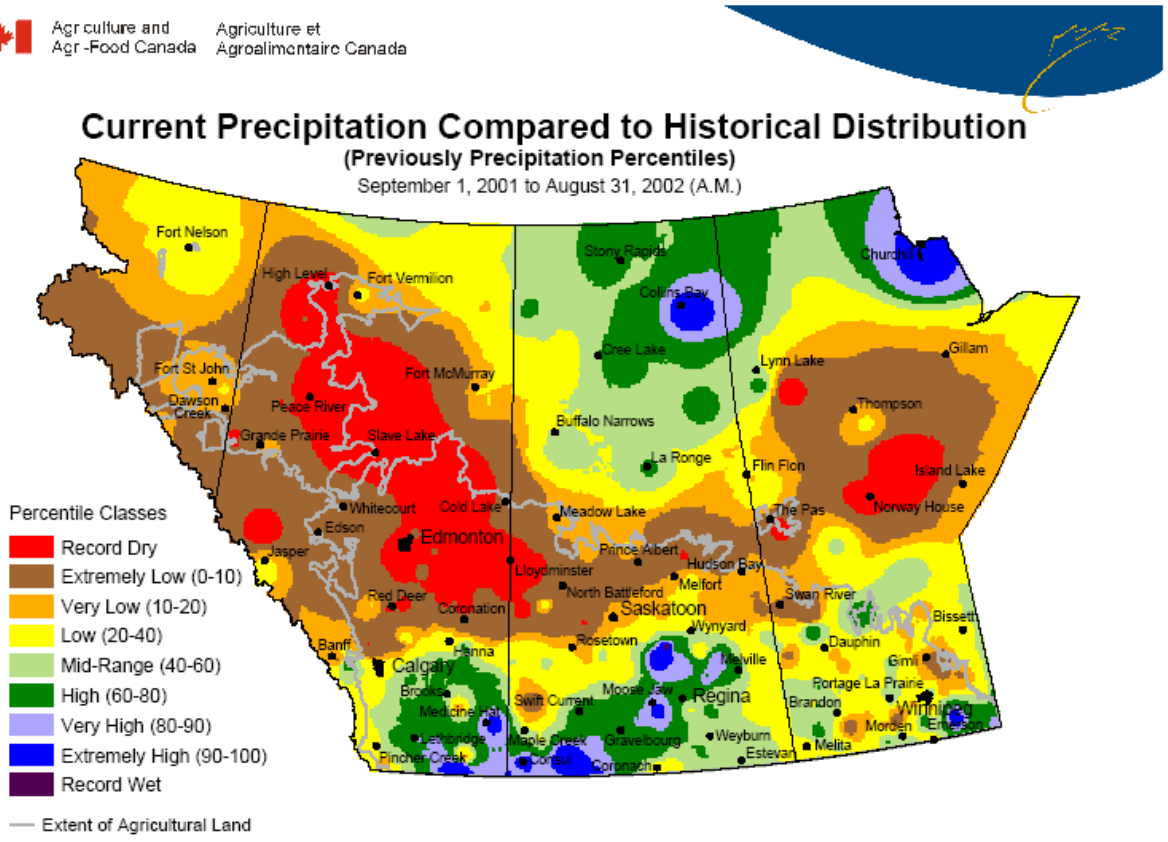
GLOBAL WATER FUTURES
SOLUTIONS TO WATER THREATS IN AN ERA OF GLOBAL CHANGE

UNIVERSITY OF SASKATCHEWAN

CENTRE FOR HYDROLOGY

Snow Accumulation Importance for Hydrology

- Droughts:
  - 1999 – 2004 drought in the Prairies
  - Massive losses in the agricultural sector



Snow Accumulation Importance for Hydrology

- Water Resources Management:
  - Supply for hydropower electricity generation
  - Supply for irrigation

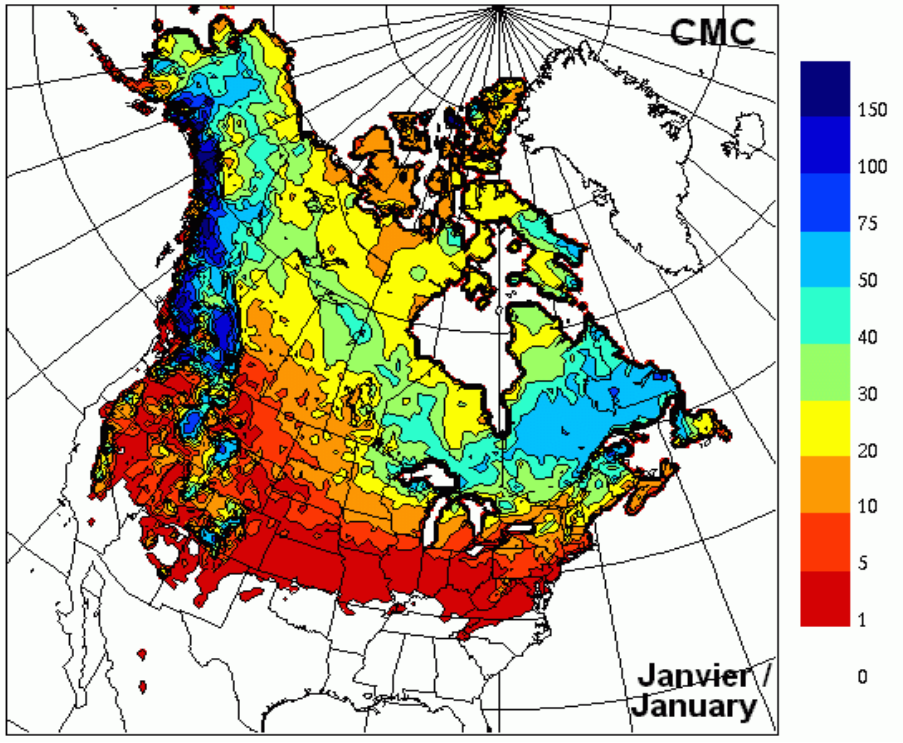
Courtesy of Dr. John Pomeroy

http://aipa.ca/who-we-are/

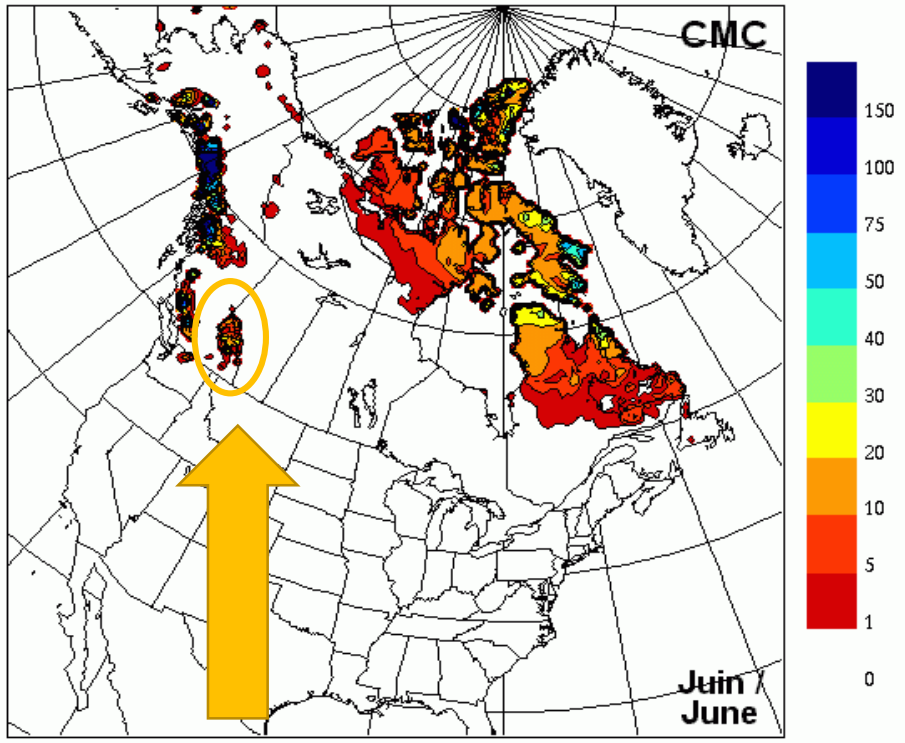
Snow Accumulation Importance for Hydrology

- Canadian Rockies snow accumulation is an important water supply in the summer

Snow Depth January



Snow Depth June



Canadian Meteorological Centre

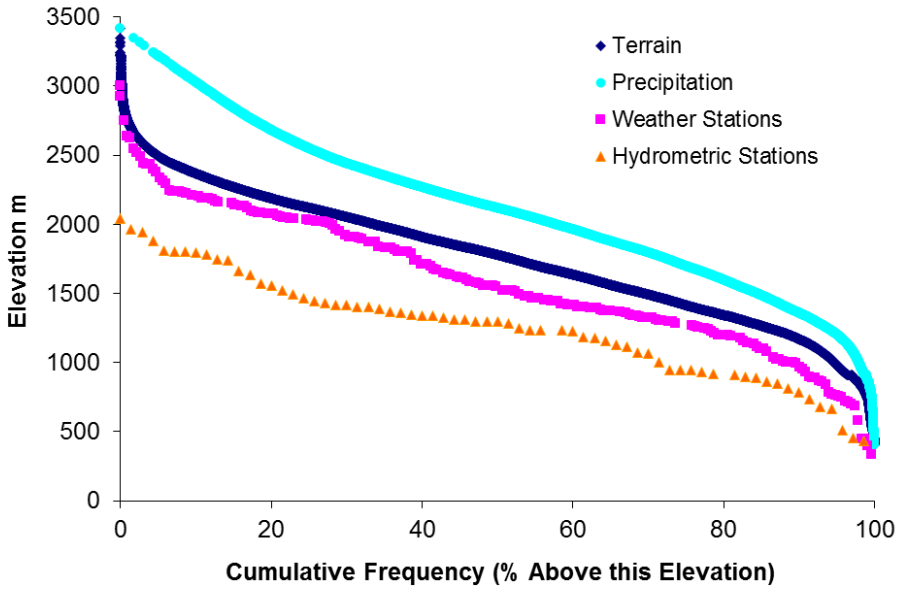
Snow Accumulation Importance for Hydrology

- Important not only for the Prairies, but also for major river basins in North America

https://upload.wikimedia.org/wikipedia/commons/1/15/NorthAmerica-WaterDivides.png

Do we have sufficient information to estimate snowfall?

- Station density is insufficient for most purposes
  - Important in data scarce regions such as high elevations in the mountains and areas of low population density
- Station spatiotemporal data consistency is variable



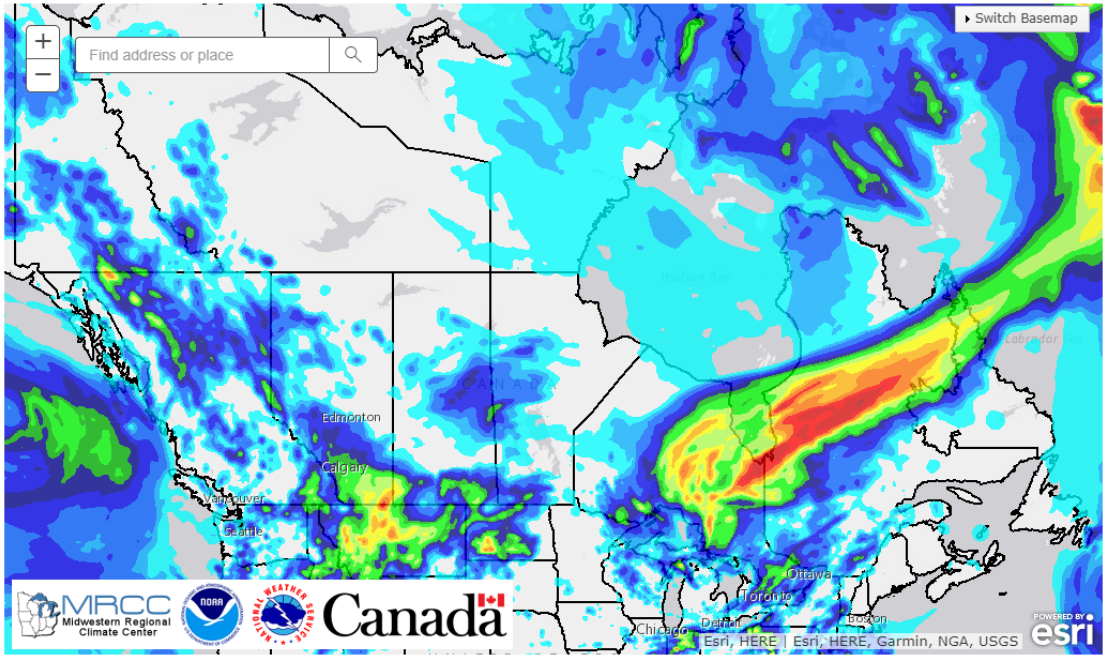
(Pomeroy & Sinclair)

Geonor gauge at Fortress Ridge (26 Apr 2018)

Do we have sufficient information to estimate snowfall?

- An alternative source of information is the use of precipitation reanalysis
- Canadian Precipitation Analysis (CaPA)
- Uses the outputs from the Global Environmental Multiscale (GEM) atmospheric model as a precipitation background
- Assimilates stations and ground-based weather radar precipitation
- Product 10 km/6 hours:

CaPA: June 1st – 12 UTC

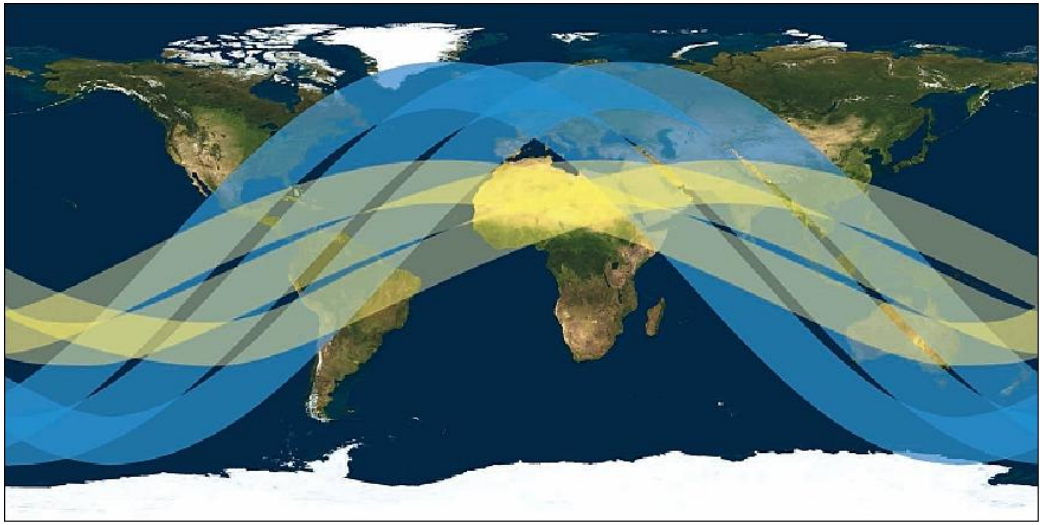


Do we have sufficient information to estimate snowfall?

- Satellite precipitation was limited to tropical and subtropical regions with the Tropical Rainfall Measurement Mission (TRMM) (35º N and S)
- In Feb 2014 the Global Precipitation Measurement (GPM) mission core platform was launched
- The GPM constellation provides better coverage (68º N and S) and spatial resolution (0.05 and 0.1 degrees) – opportunity to use this source of information in cold mountain regions such as the Canadian Rockies
- Is this data source reliable or comparable to the reanalysis product (CaPA) used in Canada to estimate snowfall?

TRMM

GPM



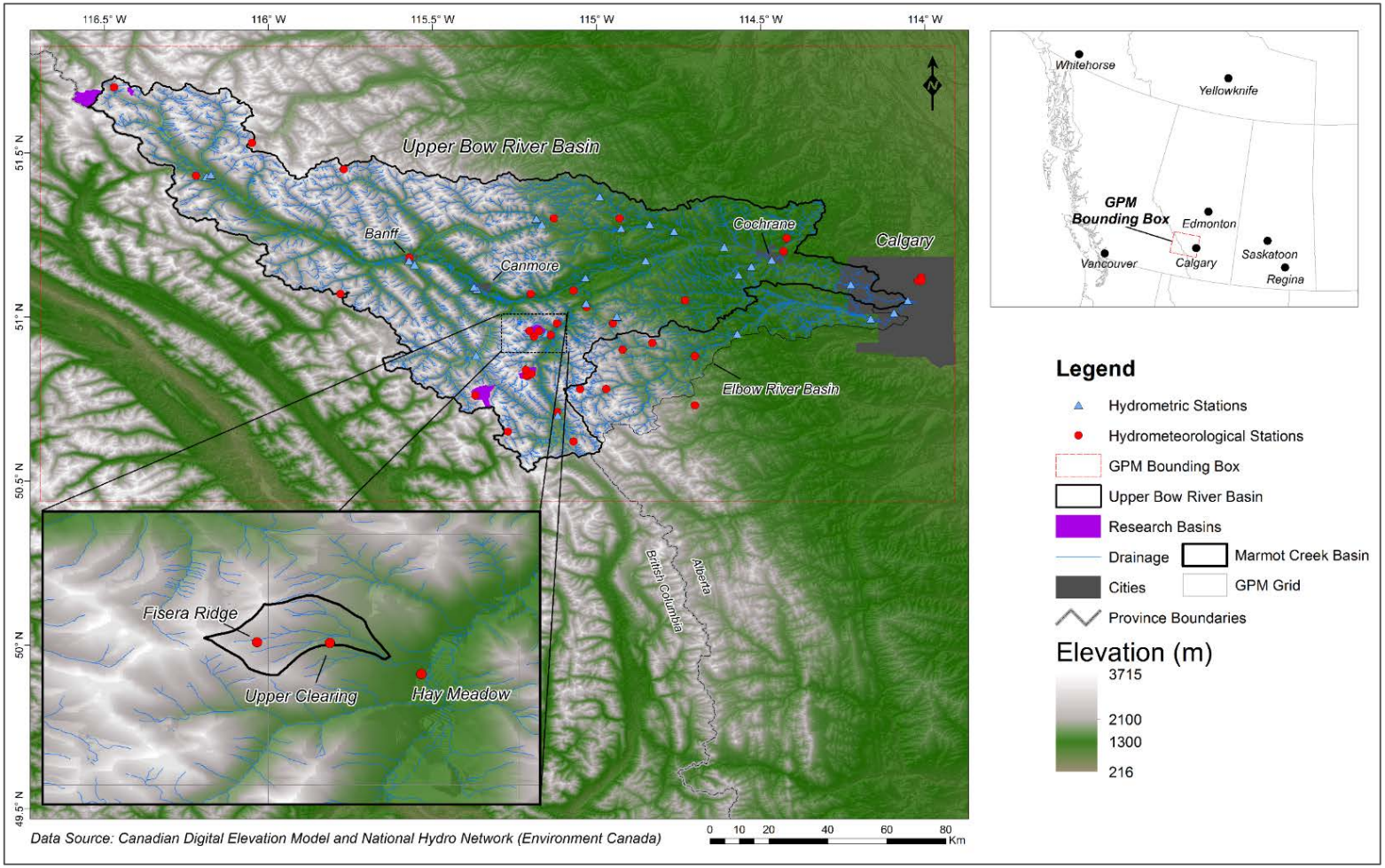
https://directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/gpm

Purpose

- To improve estimation of snowfall in the Canadian Rockies headwaters of major river basins

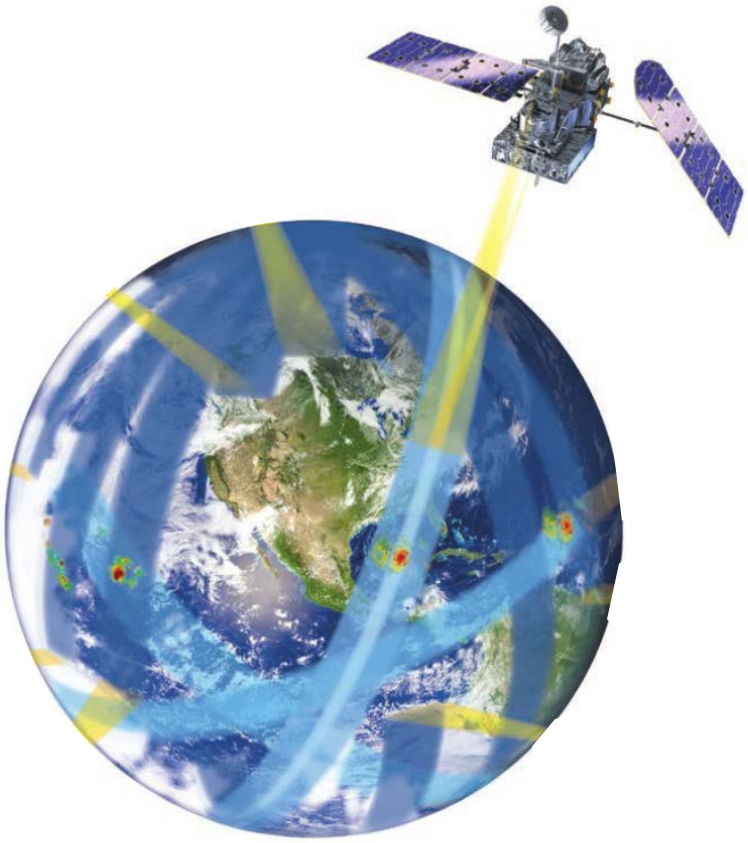
Study Region and Period

- Bow and Elbow River Basins, Alberta
- Validation in Marmot Creek Research Basin
- October 2014 to September 2017

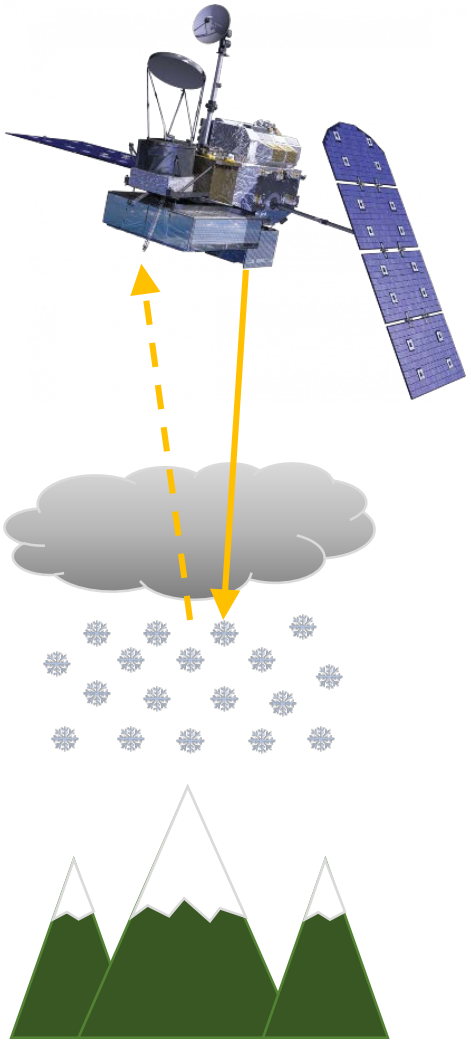


Global Precipitation Measurement (GPM)

- Core: Radar (Dual Frequency Precipitation Radar)
- Spatial resolution: 0.05º for radar

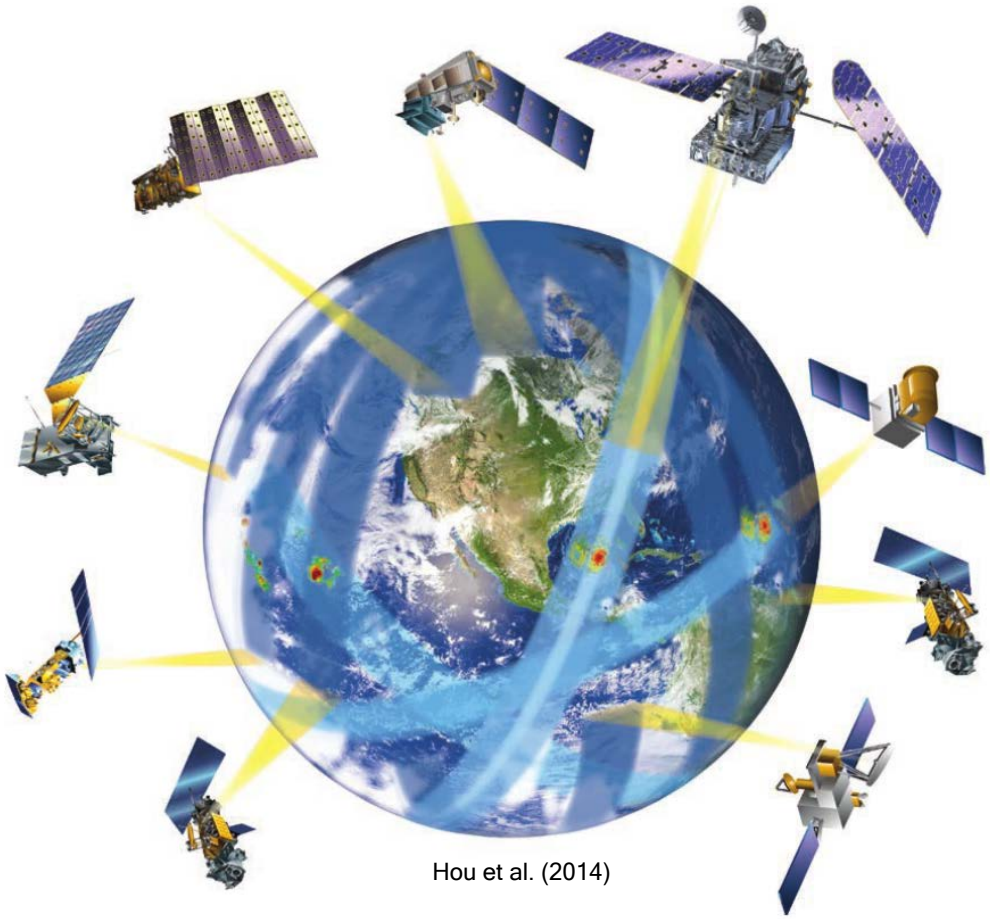


Hou et al. (2014)

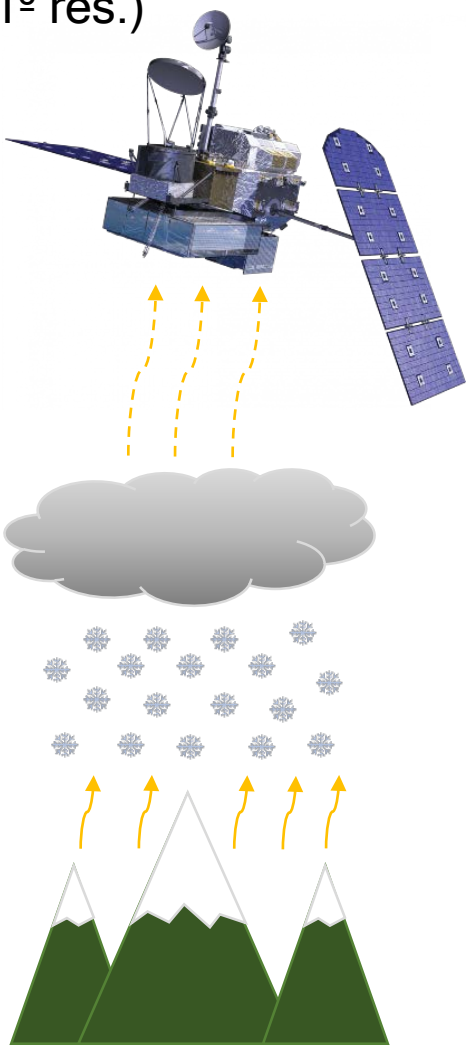


Global Precipitation Measurement (GPM)

- Constellation of passive microwave sensors/satellites (3 hours)
- Geostationary satellites (infrared) track storm movement each 30 minutes
- Integrated Multi-satellitE Retrievals for GPM (IMERG) (0.1º res.)



Hou et al. (2014)



Methodology

GPM-GEM

- Extracted GPM precipitation for stations through bilinear interpolation
- Phase partitioning (Harder & Pomeroy, 2013) using T and RH from GEM
- Aggregate to daily scale

GPM-GEM precipitation & snowfall

CaPA-GEM

- Resample CaPA to GPM grid
- Extracted CaPA precipitation for stations through bilinear interpolation
- Phase partitioning (Harder & Pomeroy, 2013) using T and RH from GEM
- Aggregate to daily scale

CaPA-GEM precipitation & snowfall

Observed

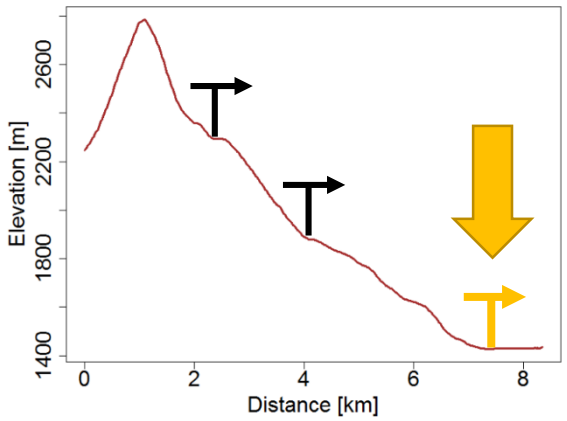
- Phase partitioning (Harder & Pomeroy, 2013) using observed T and RH
- Undercatch snowfall (Smith, 2007) with observed wind speed
- Aggregate to daily scale

Observed precipitation & snowfall

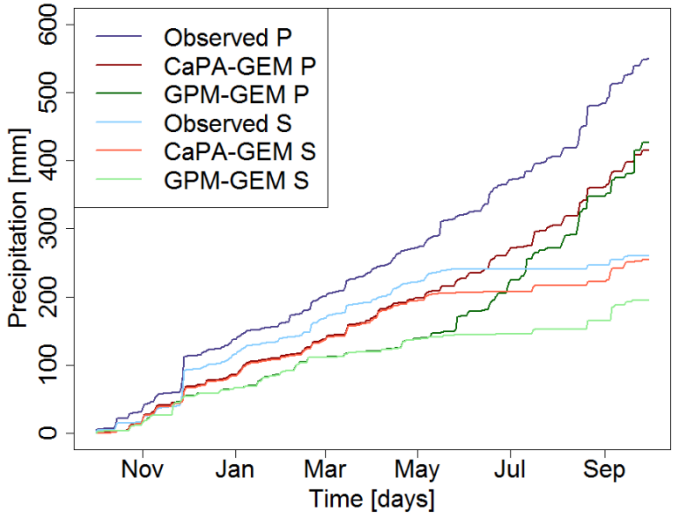
Valley Bottom

- Yearly snowfall volume accumulation was estimated relatively well
- Best estimates in 2015/16 water year
- Higher agreement with total precipitation

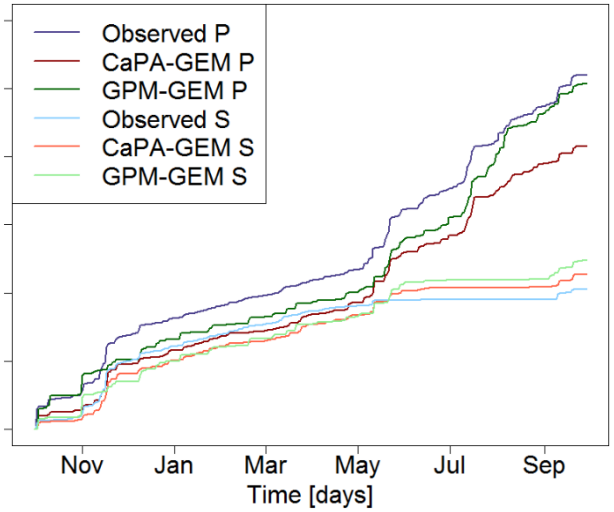
Elevation Profile



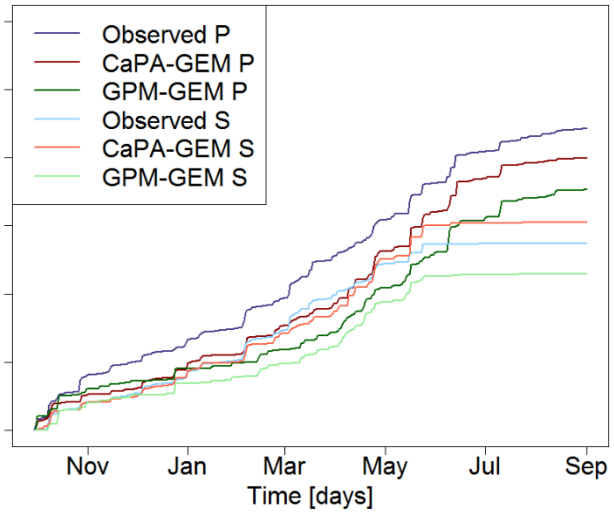
2014-2015



2015-2016



2016-2017

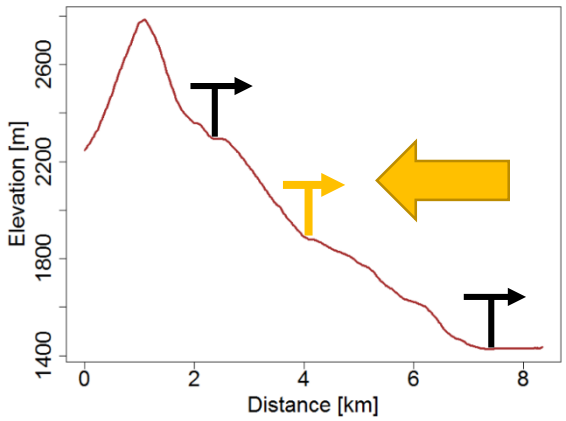


P = total precipitation
S = snowfall

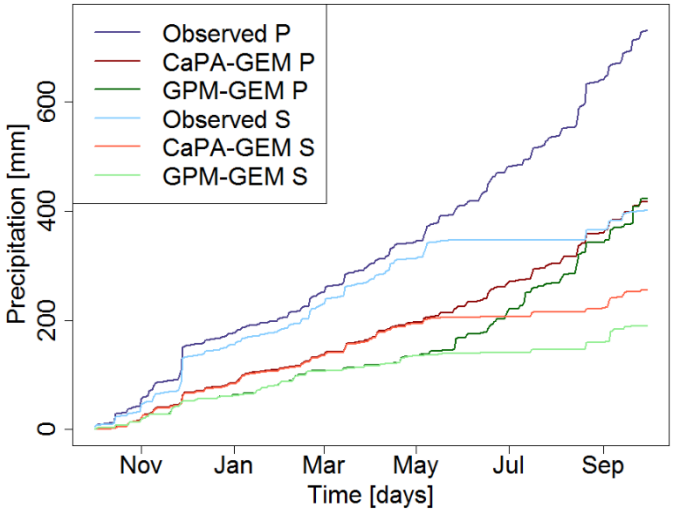
Sub-Alpine

- Yearly snowfall volume accumulation is underestimated compared with the stations
- GPM-GEM is still in good agreement with CaPA-GEM

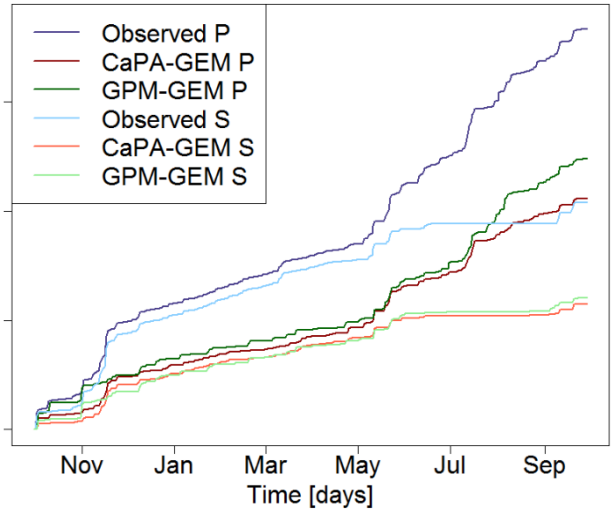
Elevation Profile



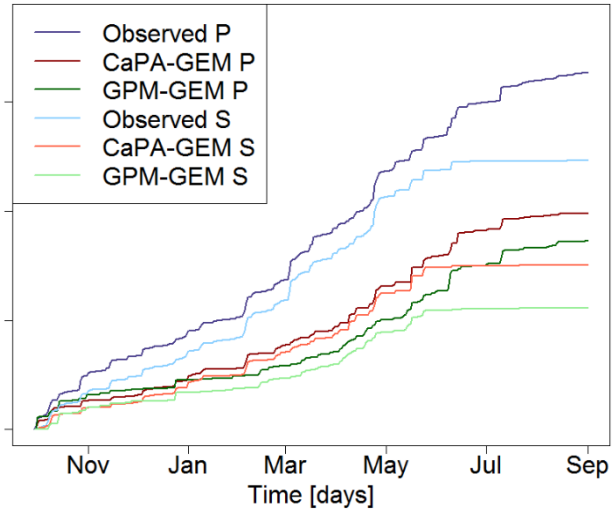
2014-2015



2015-2016



2016-2017

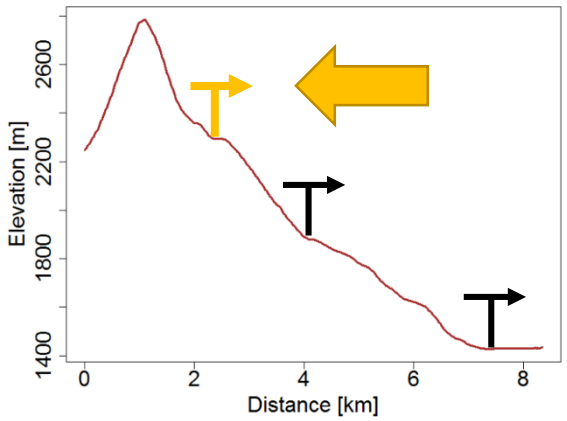


P = total precipitation
S = snowfall

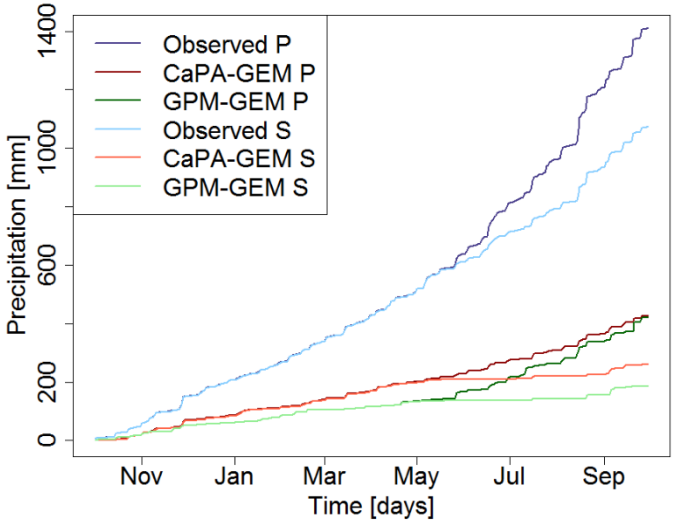
Alpine

- Yearly snowfall volume accumulation is poorly estimated
- Exacerbated underestimation by both GPM-GEM and CaPA-GEM
- Unable to capture orographic enhancement and temperature gradient
- Blowing snow can also contribute for this pattern

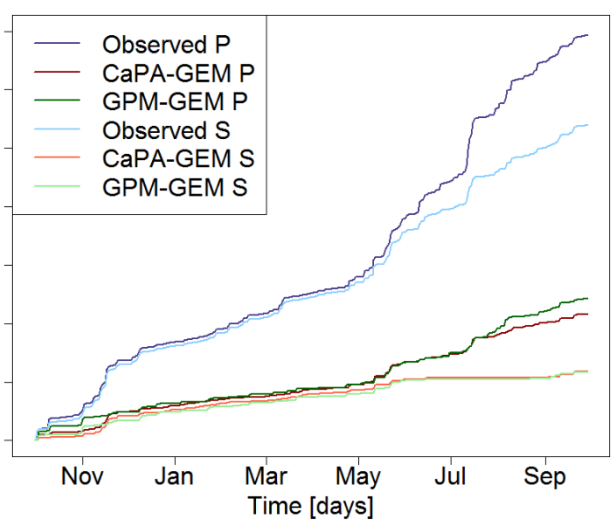
Elevation Profile



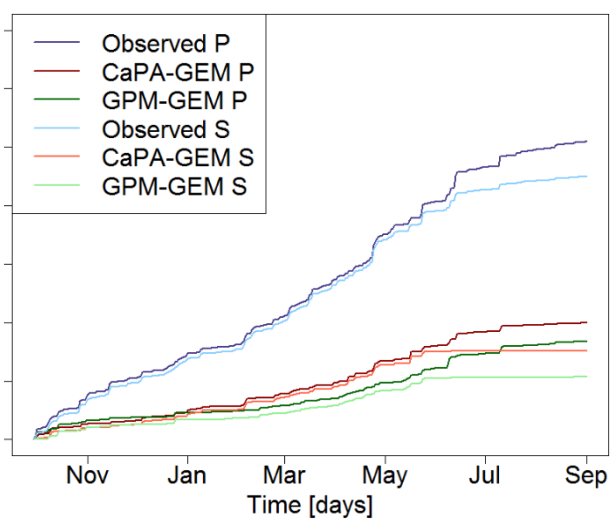
2014-2015



2015-2016



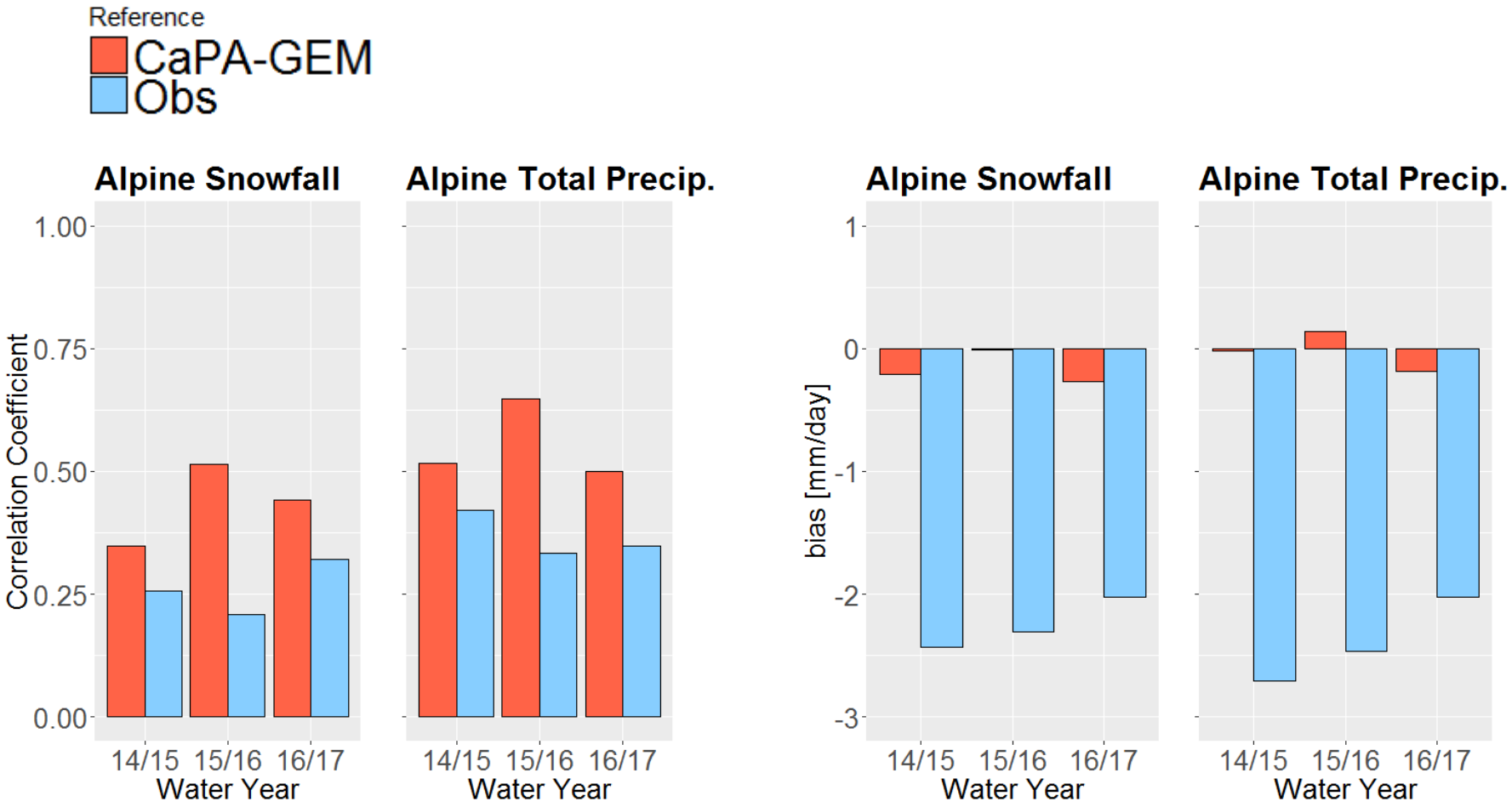
2016-2017



P = total precipitation
S = snowfall

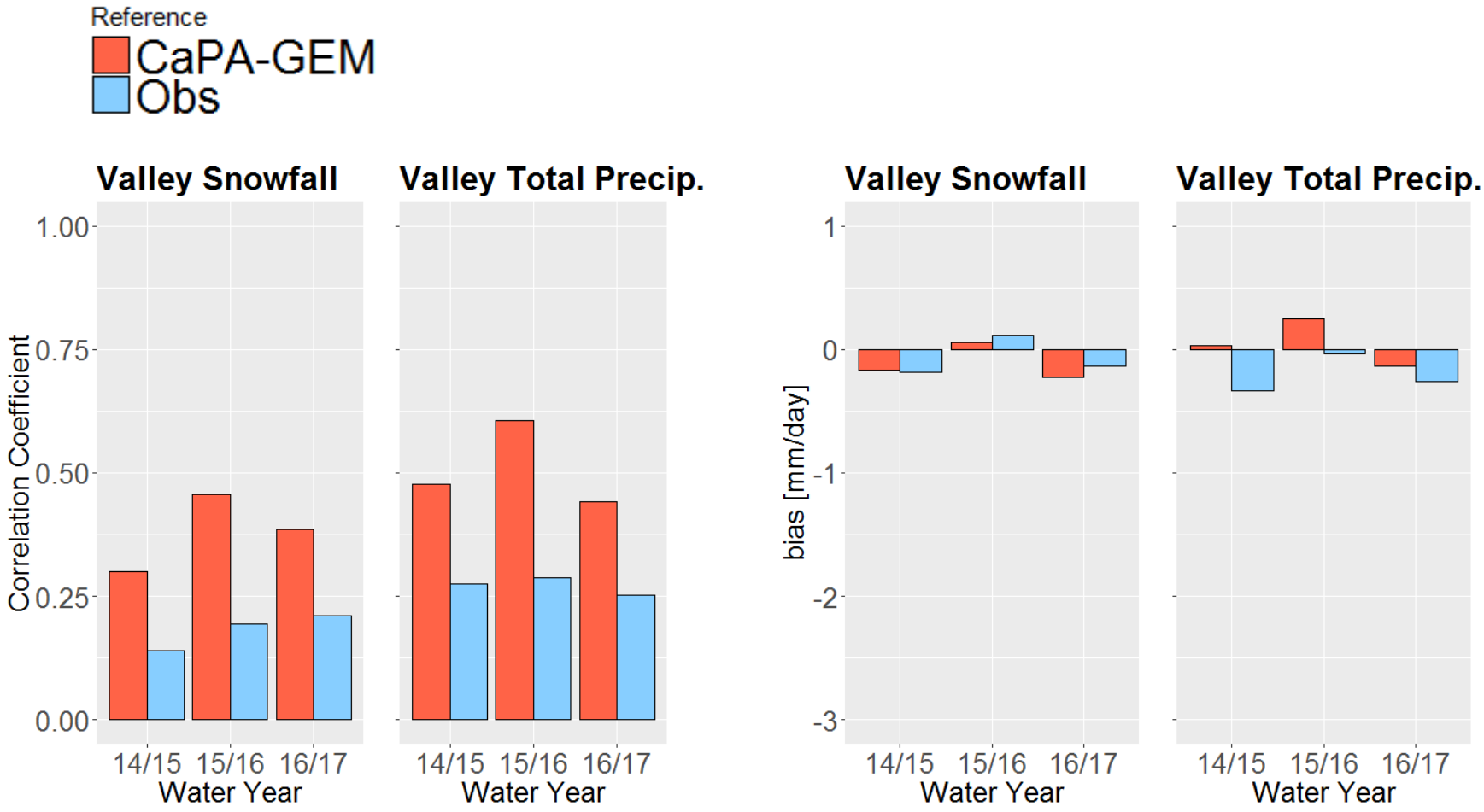
Evaluation Metrics

- In the Alpine correlations are higher (0.42 – Observed) and (0.65 – CaPA-GEM)
- Correlations increased for total precipitation compared to snowfall
- High negative bias against observed snowfall and total precipitation 2.5 mm/d



Evaluation Metrics

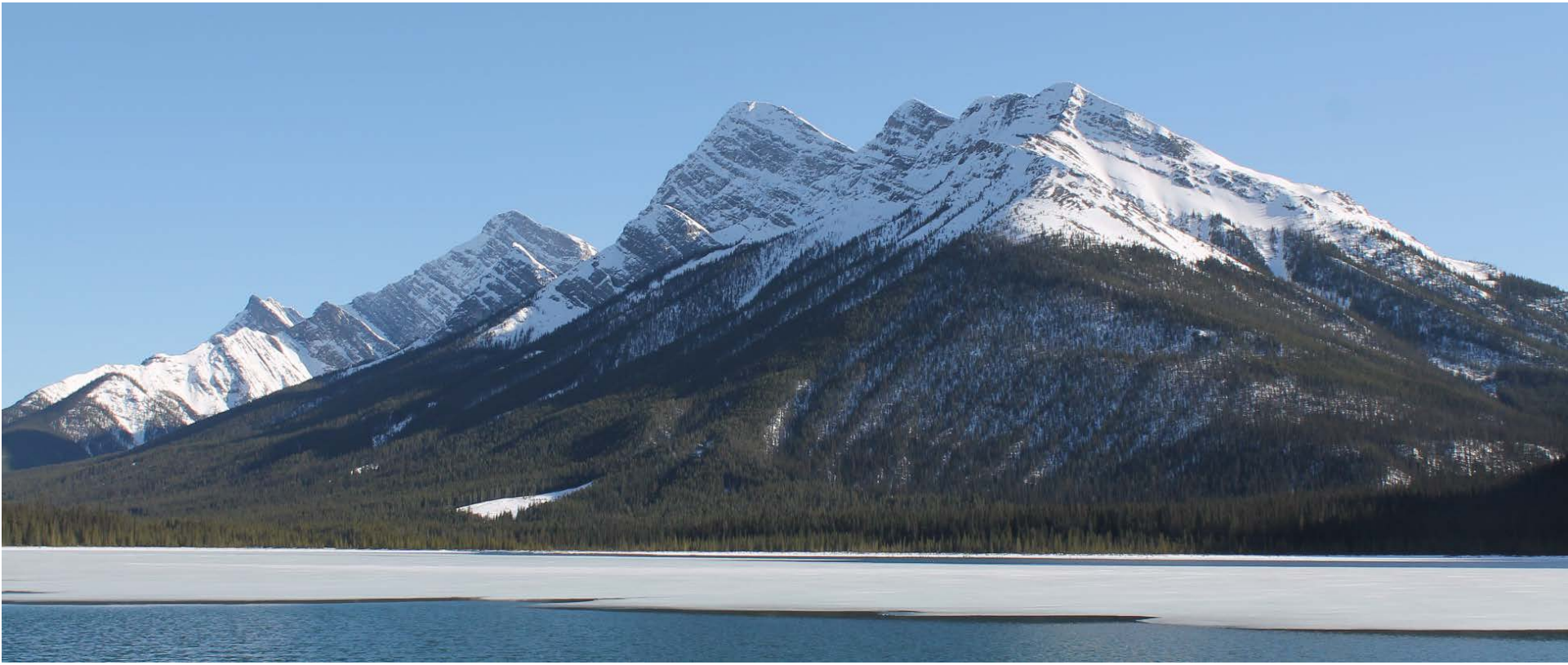
- In the valley bottom station volume is estimated well (low bias: -0.2 and 0.2 mm/d)
- Lowest correlations between the 3 stations



Summary

- GPM-GEM estimated yearly snowfall volume accumulation relatively well for the low elevation station (valley bottom)
- Yearly snowfall volume accumulation was poorly estimated at higher elevations by GPM-GEM – partly due to coarse resolution, i.e., inability to detect orographic enhancement of precipitation
- GPM-GEM was in better agreement with GEM-CaPA than with the observed snowfall at higher elevations
- Correlations were higher for total precipitation indicating that phase calculation can introduce biases in this type of analysis or that GPM estimates liquid precipitation with higher accuracy
- Although GPM-GEM grossly underestimated snowfall accumulation in high elevations, surprisingly the higher correlation happened for the alpine station (possibility to lapse precipitation to high elevations)
- We recommend the application of algorithms to adjust GPM precipitation for orographic enhancement in mountain regions, as well as to use T and RH at finer resolution and at multiple atmospheric levels to better determine precipitation quantity and phase

Thank you!



Questions?

andre.bertoncini@usask.ca

Special thanks to Daniel Princz for the processing of CaPA-GEM data and the Global Water Futures Programme