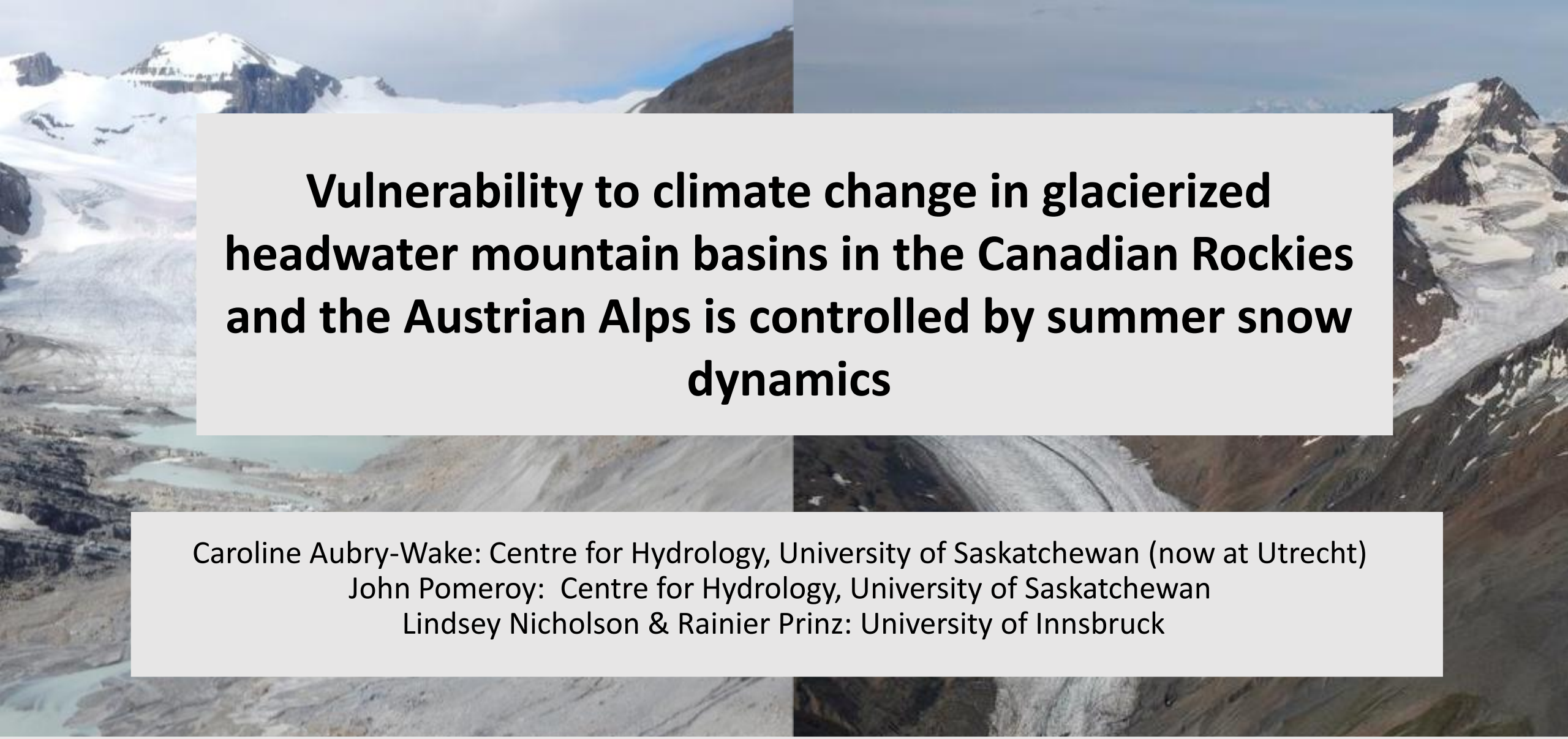


Vulnerability to climate change in glacierized headwater mountain basins in the Canadian Rockies and the Austrian Alps is controlled by summer snow dynamics

Caroline Aubry-Wake: Centre for Hydrology, University of Saskatchewan (now at Utrecht)
John Pomeroy: Centre for Hydrology, University of Saskatchewan
Lindsey Nicholson & Rainier Prinz: University of Innsbruck

@CryoCaro
@cryo.caro
caroline.aubrywake@gmail.com

UNIVERSITY OF SASKATCHEWAN

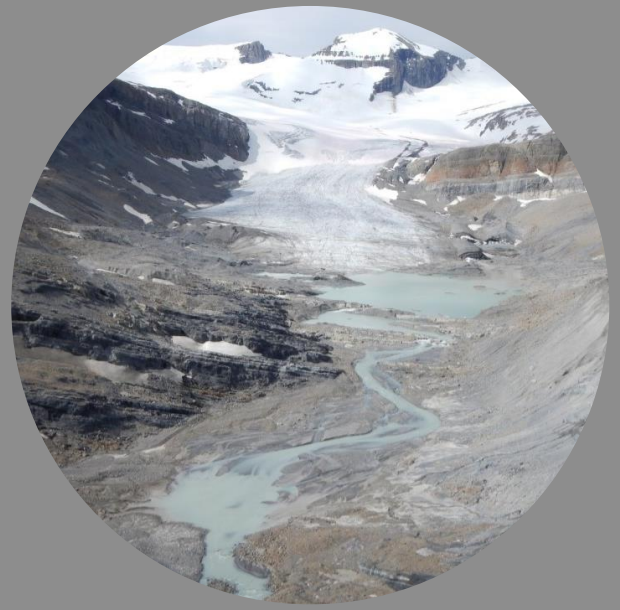
www.usask.ca/hydrology

Motivation

Mountains are changing…

With different datasets and modelling approaches, comparisons of predicted changes across mountains ranges is difficult.

Peyto



- Canadian Rockies, Western Canada
- 19 km^2
- ~50% glacierized in 2000
- 1907-3152 m a.s.l.
- Above vegetation line

Rofental

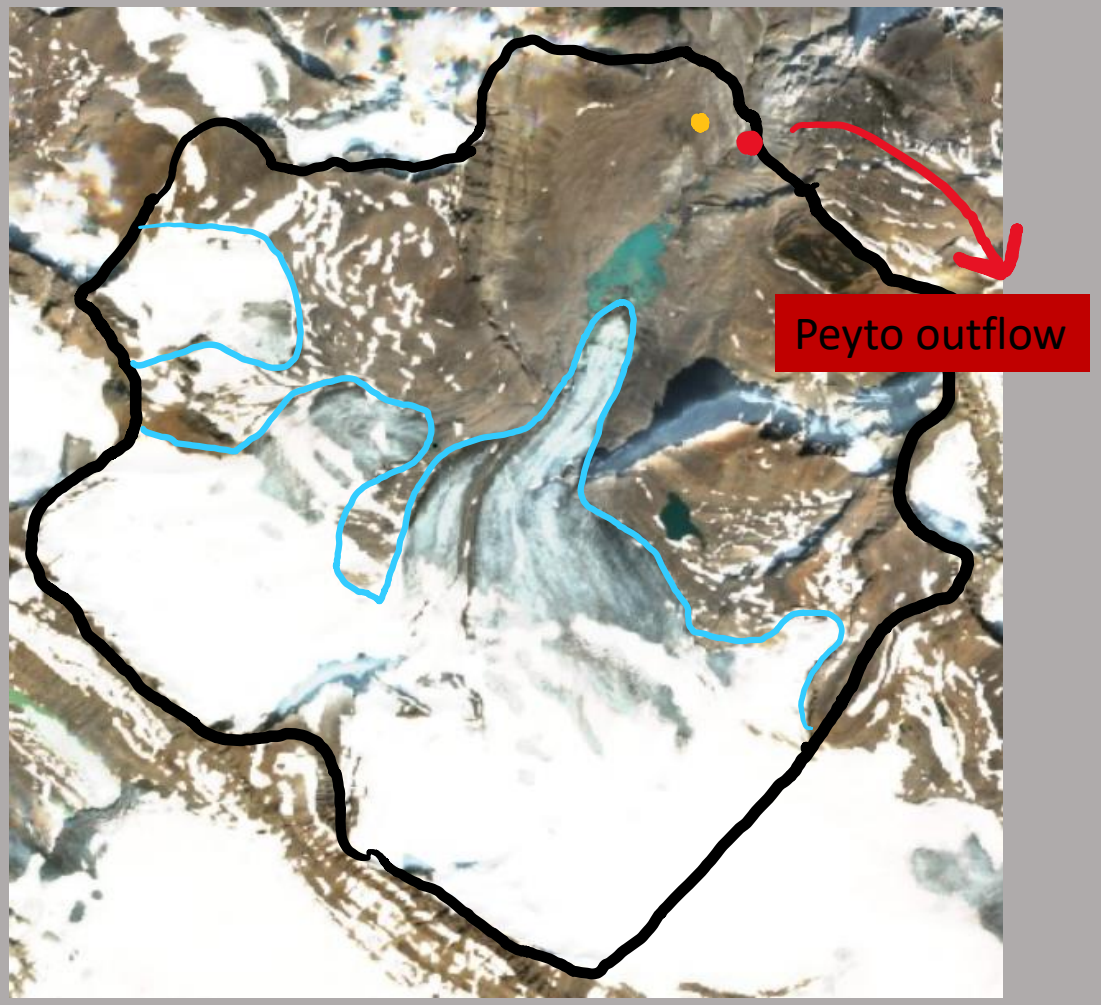
- Ötztal Alps, Austria
- 99 km^2
- ~30% glacierized in 2008
- 1891–3772 m a.s.l.
- Vegetation in lower slopes

Vernagtbach

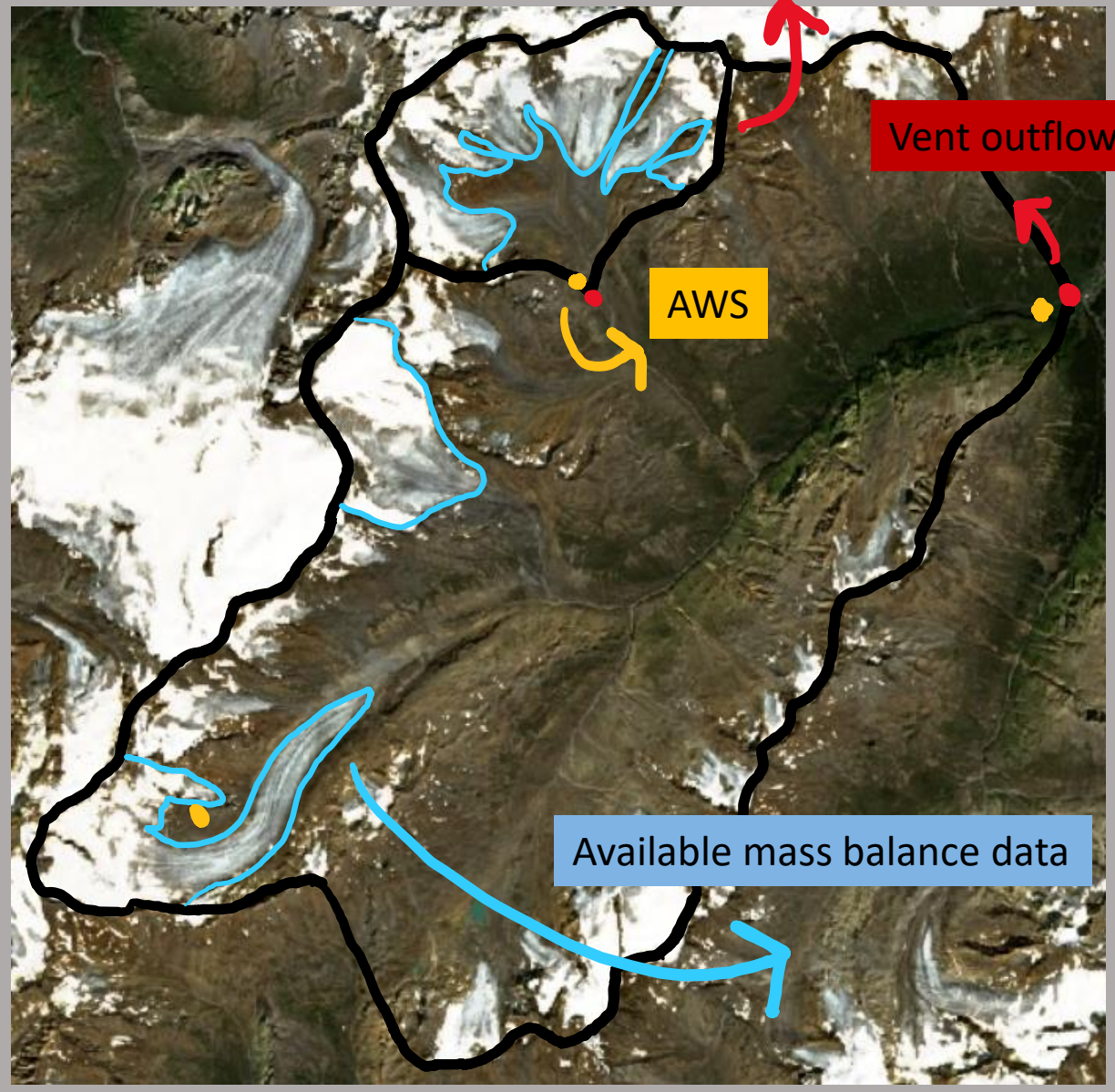
- 11.4 km^2
- ~71% glacierized in 2006
- 2635 - 3635m a.s.l.

Vernagtferner image: https://geo.badw.de/vernagtferner-digital/webcam.html

Peyto



Rofental



The Cold Region Hydrological Modelling Platform

- Modular with explicit, physically-based process representation for snow and ice melt, blowing snow transport and sublimation, avalanching, evaporation, surface and subsurface storage and routing
- Spatial discretization based on elevation, aspect and land cover type
- Parameters from fieldwork, past studies and literature - uncalibrated

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Simulations:

1990-2020 with AWS data (Pradhananga et al., 2021)

Earth Syst. Sci. Data, 13, 2875–2894, 2021
https://doi.org/10.5194/essd-13-2875-2021

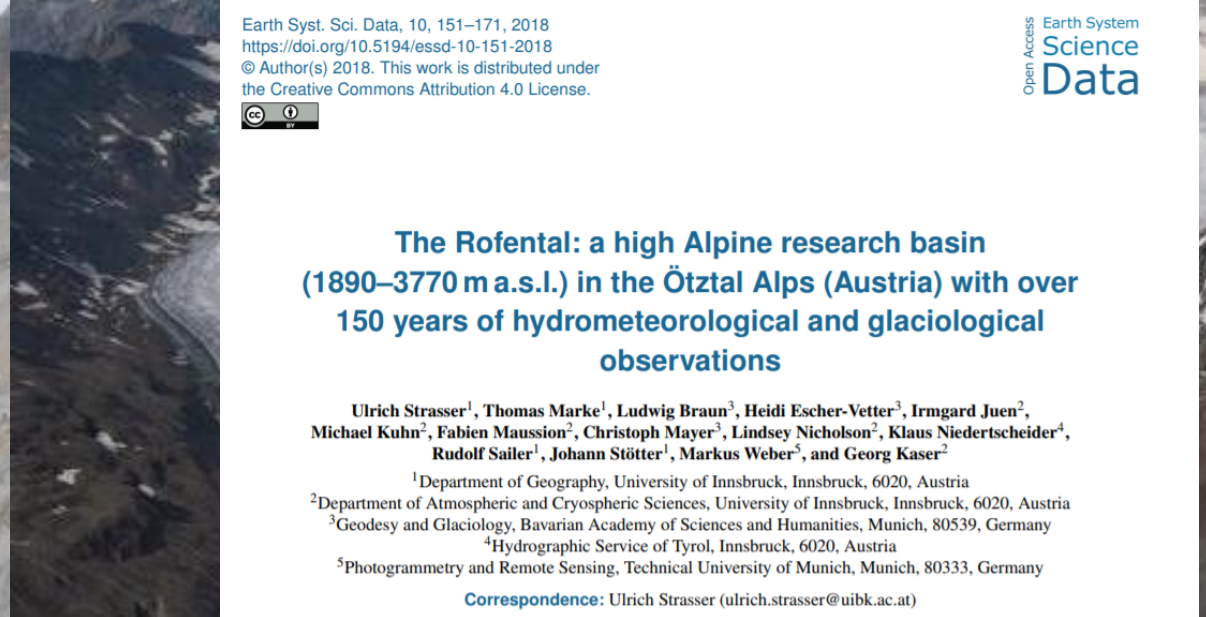
Open Access Earth System Science Data

Hydrometeorological, glaciological and geospatial research data from the Peyto Glacier Research Basin in the Canadian Rockies

Dhiraj Pradhananga[1,2,3], John W. Pomeroy[1], Caroline Aubry-Wake[1], D. Scott Munro[1,4], Joseph Shea[1,5], Michael N. Demuth[1,6,7], Nammy Hang Kirat[3], Brian Menounos[5,8], and Kriti Mukherjee[5]

[1]Centre for Hydrology, University of Saskatchewan, 116A 1151 Sidney St, Canmore, AB, T1W 3G1, Canada
[2]Department of Meteorology, Tri-Chandra Multiple Campus, Tribhuvan University, Kathmandu, Nepal
[3]The Small Earth Nepal, P.O. Box 20533, Kathmandu, Nepal
[4]Department of Geography, University of Toronto Mississauga, 3359 Mississauga Road, Mississauga, ON, L5L 1C6, Canada

1999-2021 with AWS data (Strasser et al., 2018)



Earth Syst. Sci. Data, 10, 151–171, 2018
https://doi.org/10.5194/essd-10-151-2018

Open Access Earth System Science Data

The Rofental: a high Alpine research basin (1890–3770 m a.s.l.) in the Ötztal Alps (Austria) with over 150 years of hydrometeorological and glaciological observations

Ulrich Strasser[1], Thomas Marke[1], Ludwig Braun[3], Heidi Escher-Vetter[3], Irmgard Juen[2], Michael Kuhn[2], Fabien Maussion[2], Christoph Mayer[3], Lindsey Nicholson[2], Klaus Niedertscheider[4], Rudolf Sailer[1], Johann Stötter[1], Markus Weber[5], and Georg Kaser[2]

[1]Department of Geography, University of Innsbruck, Innsbruck, 6020, Austria
[2]Department of Atmospheric and Cryospheric Sciences, University of Innsbruck, Innsbruck, 6020, Austria
[3]Geodesy and Glaciology, Bavarian Academy of Sciences and Humanities, Munich, 80539, Germany
[4]Hydrographic Service of Tyrol, Innsbruck, 6020, Austria
[5]Photogrammetry and Remote Sensing, Technical University of Munich, Munich, 80333, Germany

Correspondence: Ulrich Strasser (ulrich.strasser@uibk.ac.at)

The Cold Region Hydrological Modelling Platform

- Modular with explicit, physically-based process representation for snow and ice melt, blowing snow transport and sublimation, avalanching, evaporation, surface and subsurface storage and routing
- Spatial discretization based on elevation, aspect and land cover type
- Parameters from fieldwork, past studies and literature - uncalibrated

Simulations:

The Cold Region Hydrological Modelling Platform

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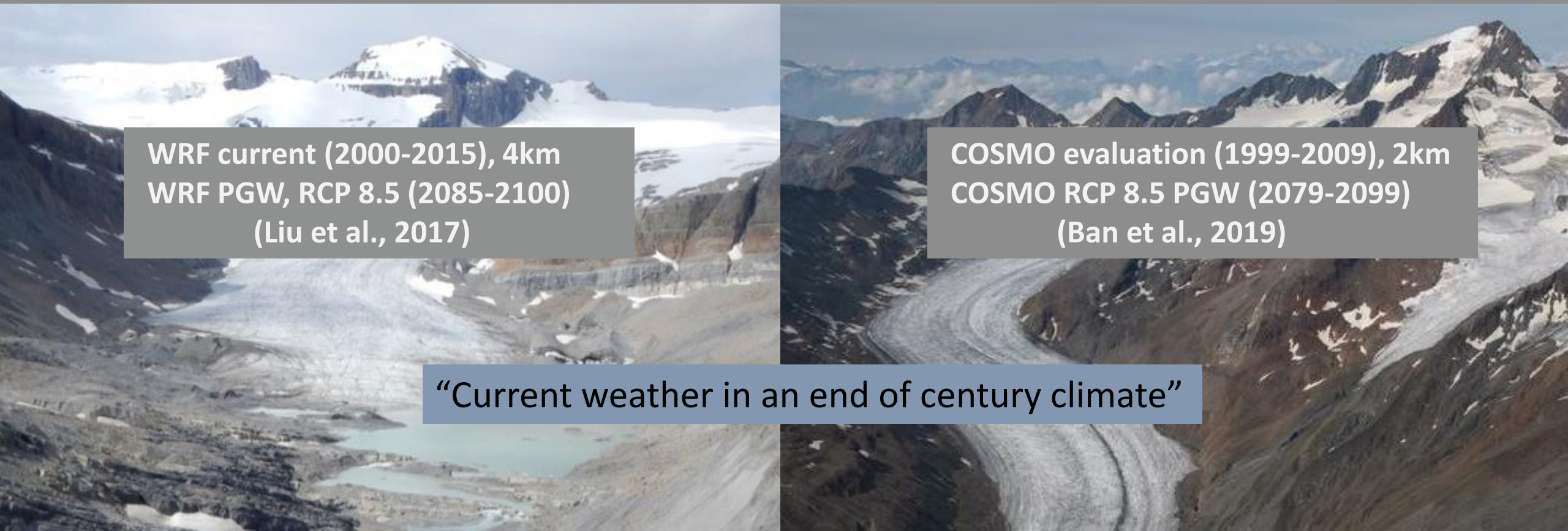
Simulations:



WRF current (2000-2015), 4km
WRF PGW, RCP 8.5 (2085-2100)
(Liu et al., 2017)

COSMO evaluation (1999-2009), 2km
COSMO RCP 8.5 PGW (2079-2099)
(Ban et al., 2019)

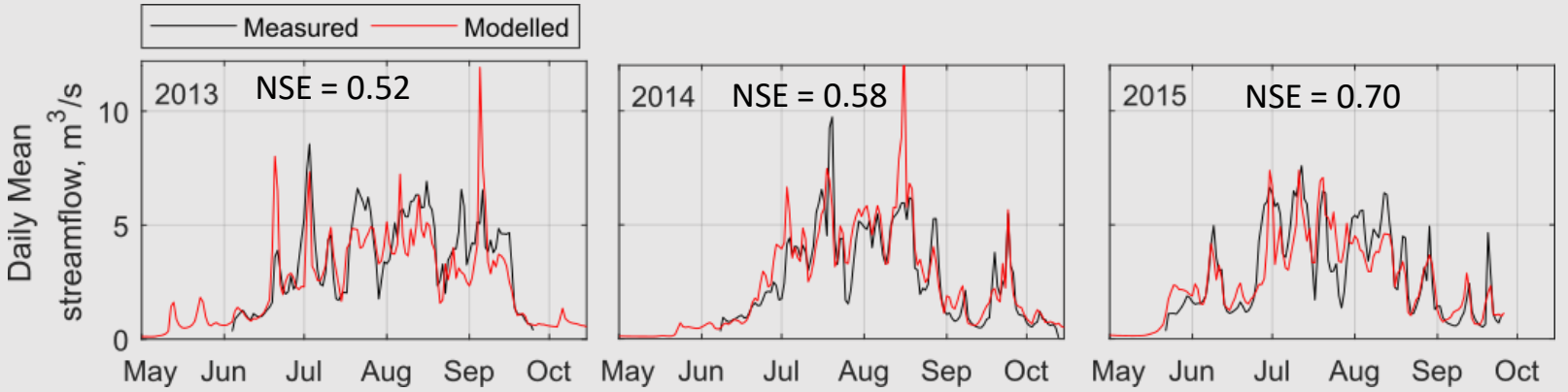
"Current weather in an end of century climate"

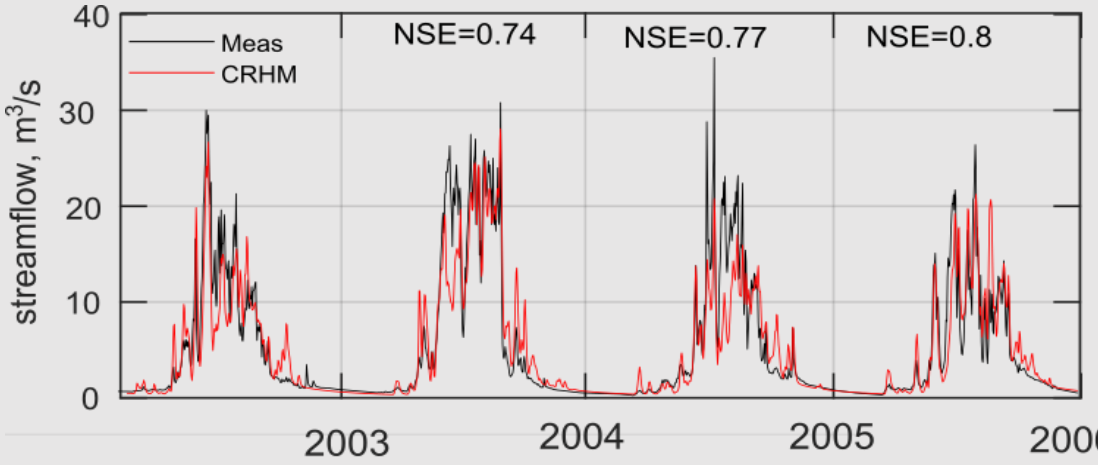
Model performance: Streamflow

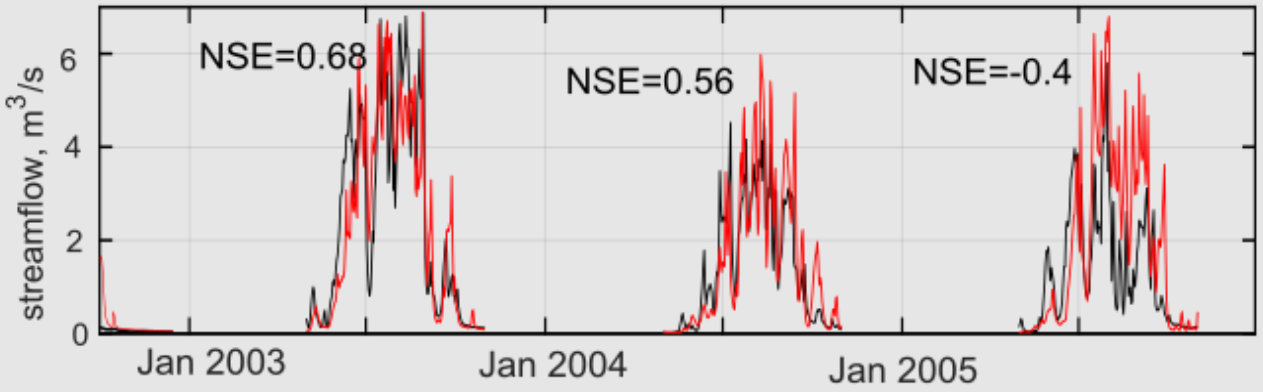
Peyto

Rofental @ Vent

Vernagtbach

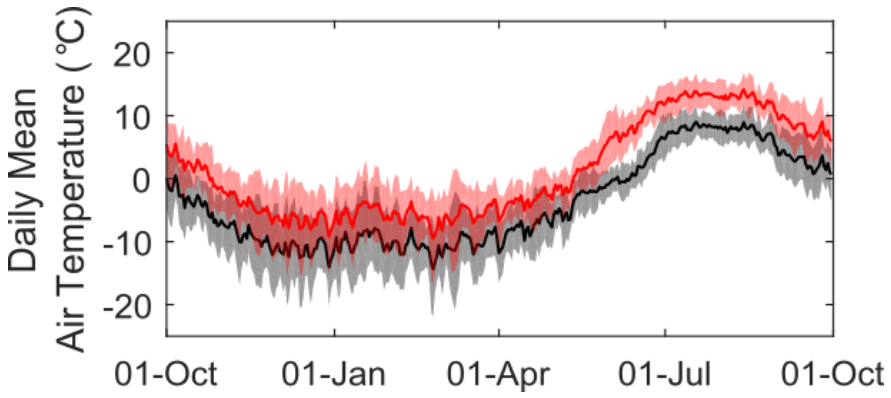




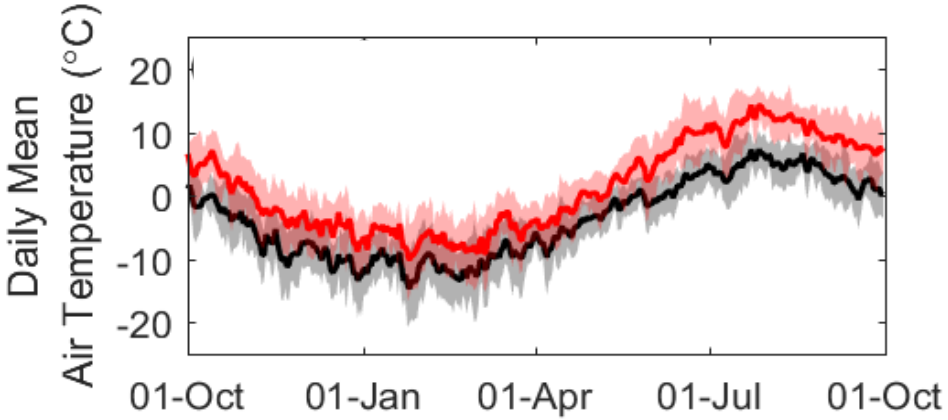


End-of-century weather

Peyto: **5˚C** warmer

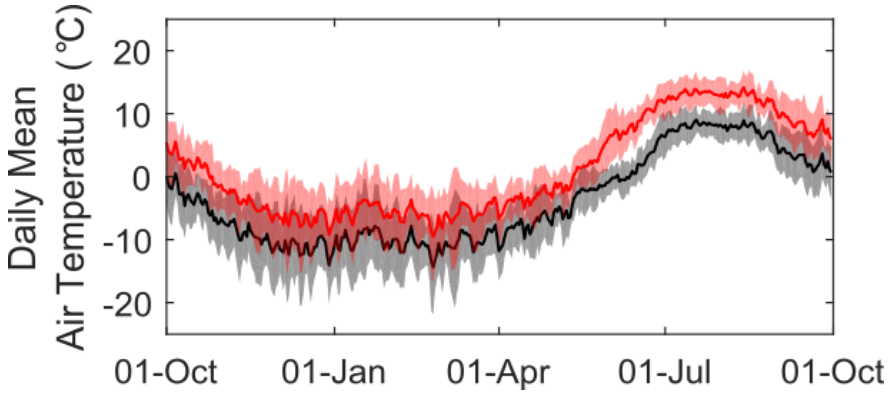


Rofental: **5˚C** warmer

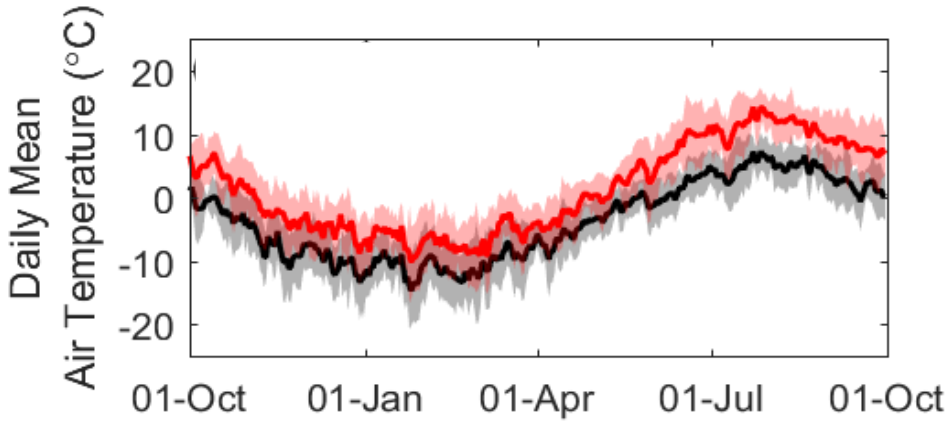


End-of-century weather

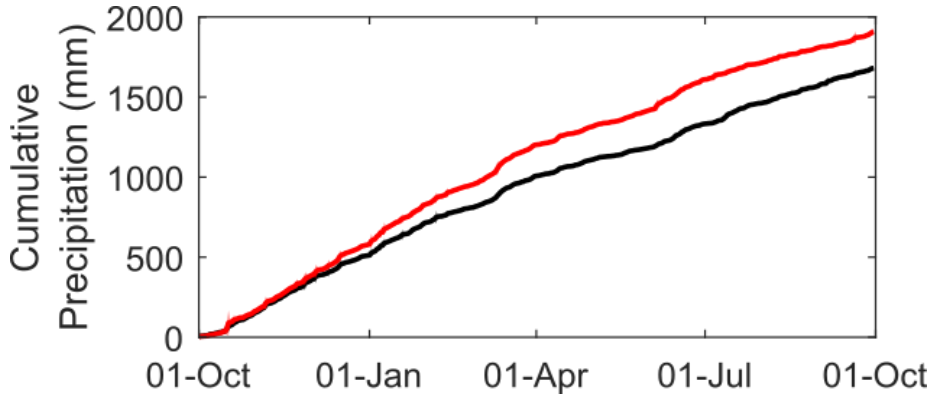
Peyto: **5˚C** warmer



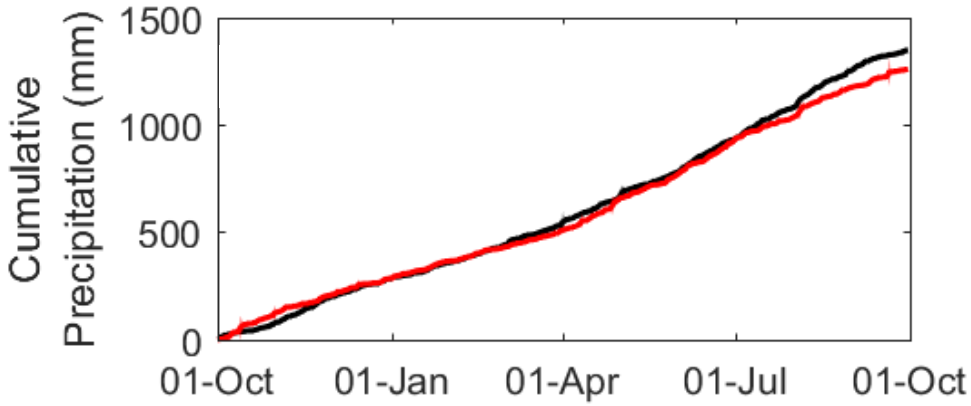
Rofental: **5˚C** warmer



16% more precipitation



7% less precipitation



Basin configuration in PGW

CUR average
PGW average
CUR st. dev.
PGW st. dev

Peyto: 3% glacierized (Clarke et al. 2015),
Ponds + proglacial lake

Rofental @ Vent : <1% glacierized (Zekkolari et al., 2019)

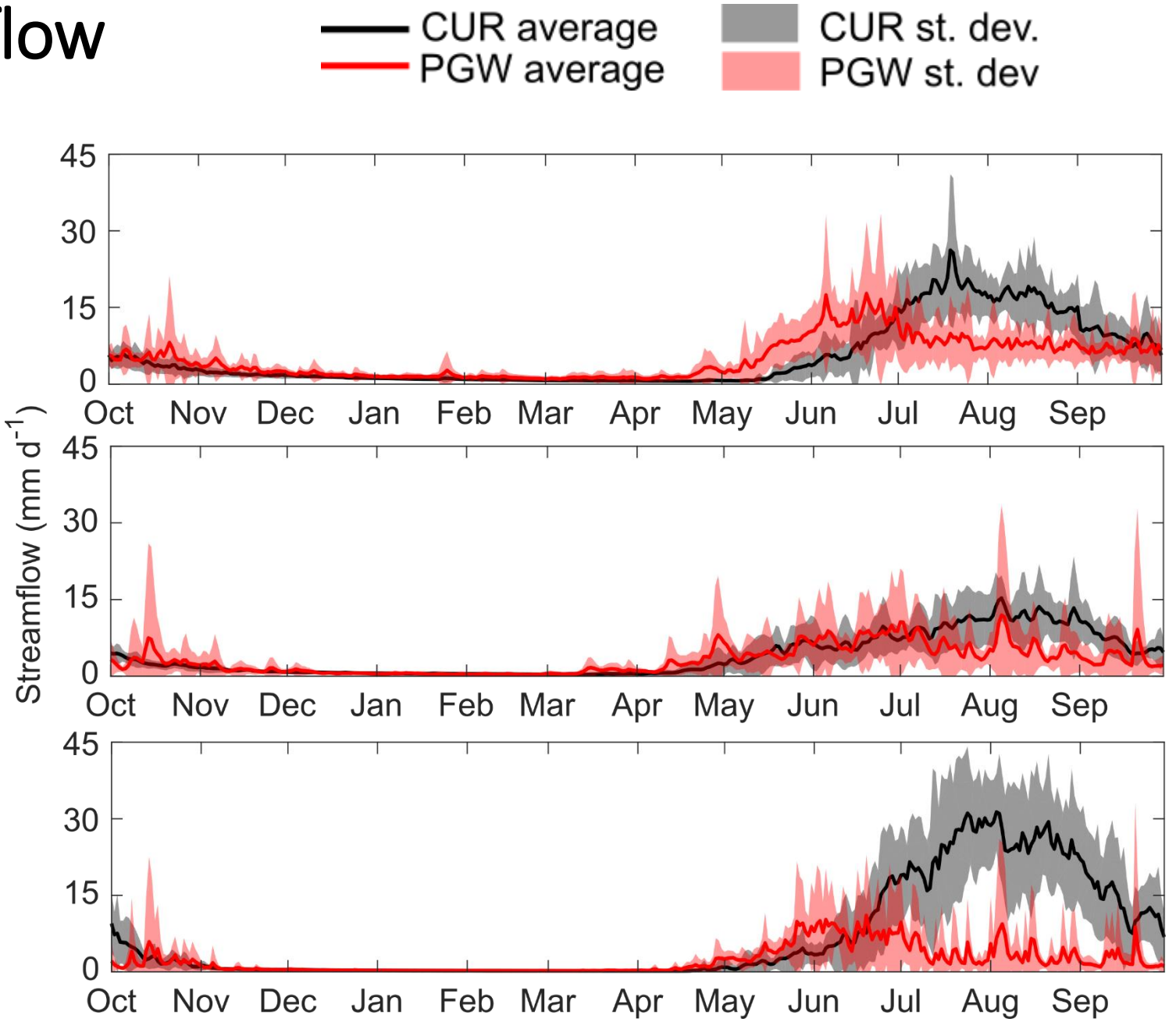
Vernagtbach: 0% glacier

End-of-century streamflow

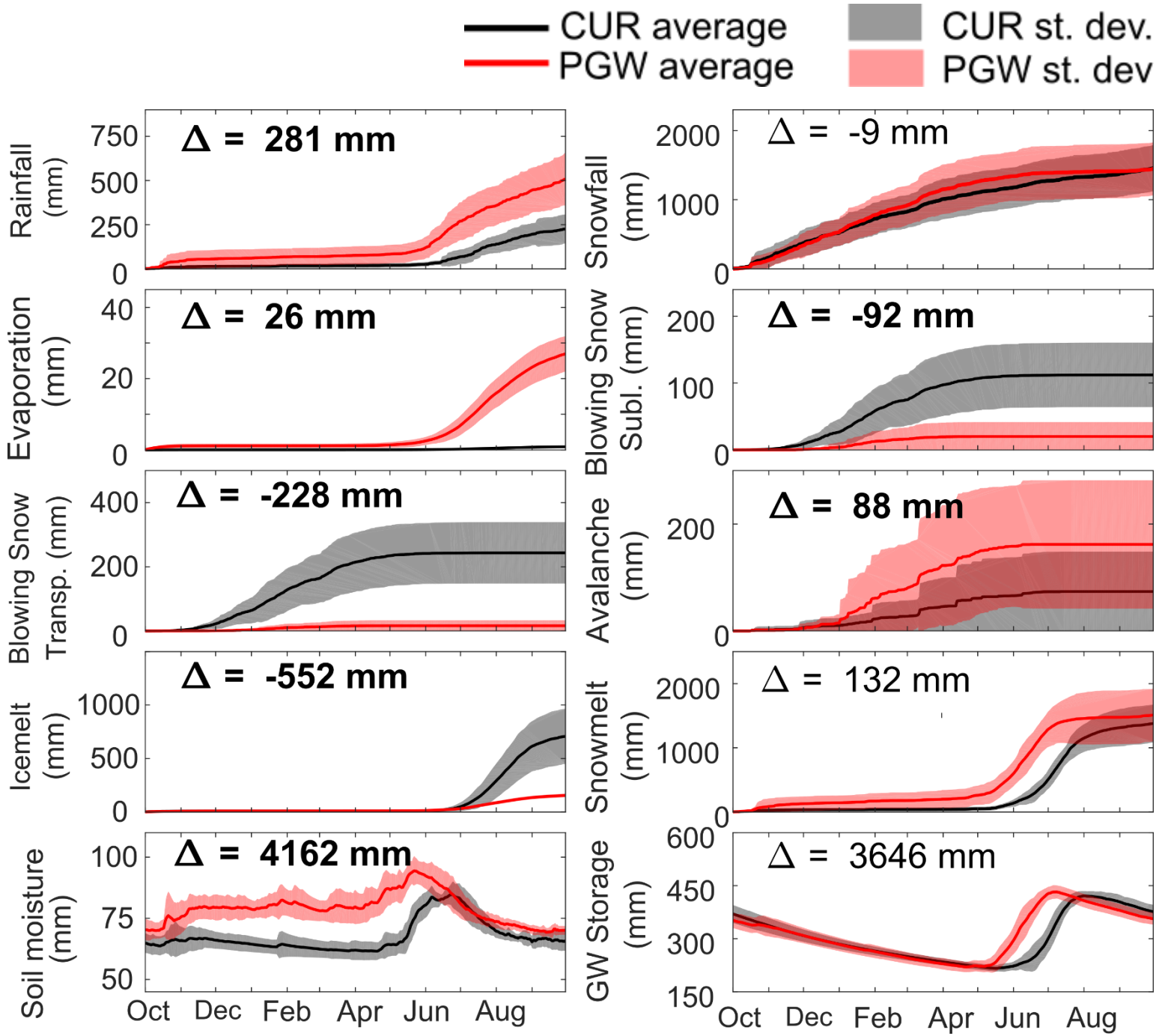
Peyto: +7%

Rofental @ Vent : -33%

Vernagtbach: -67%

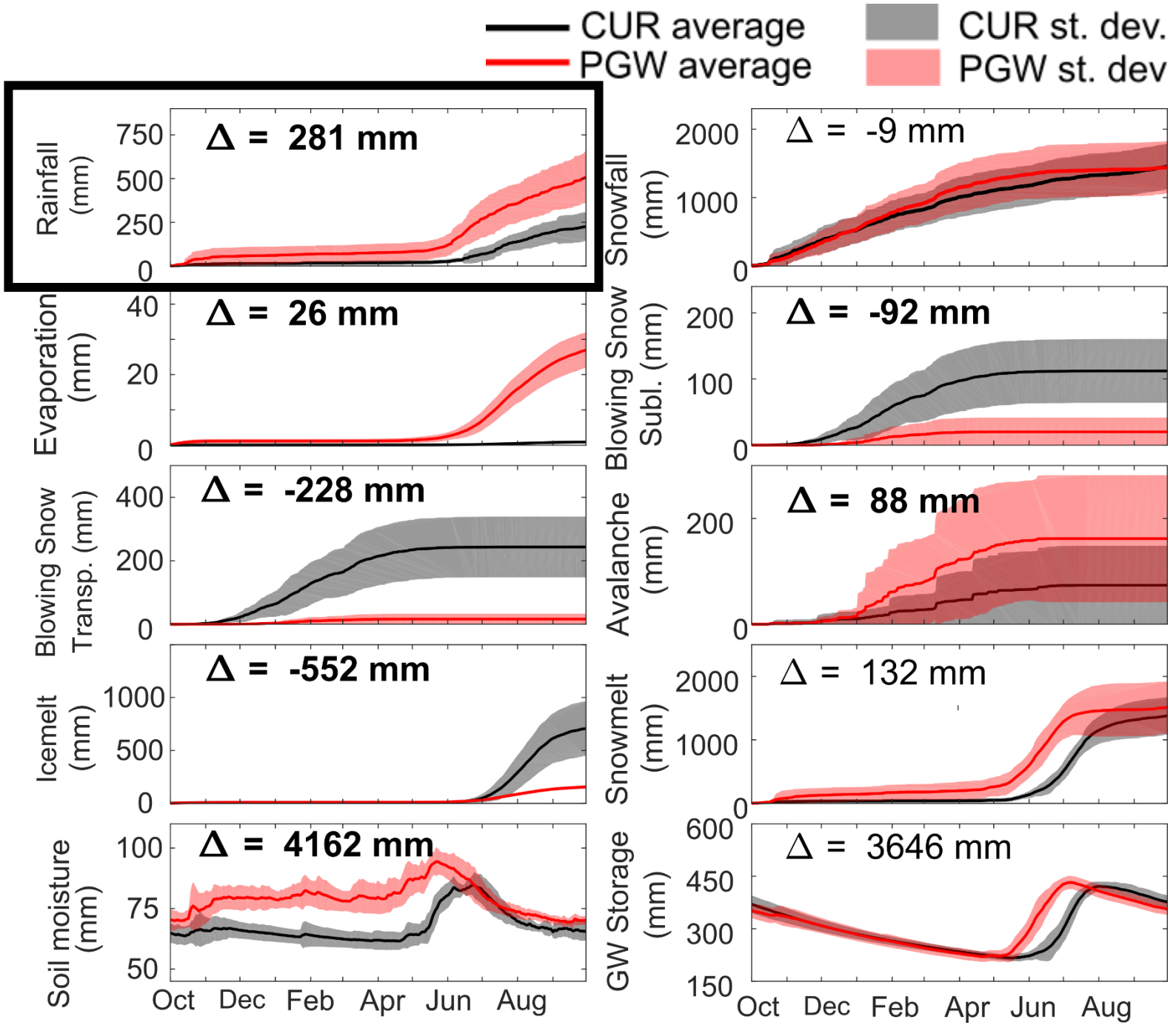


Peyto WRF-PGW simulation shows:



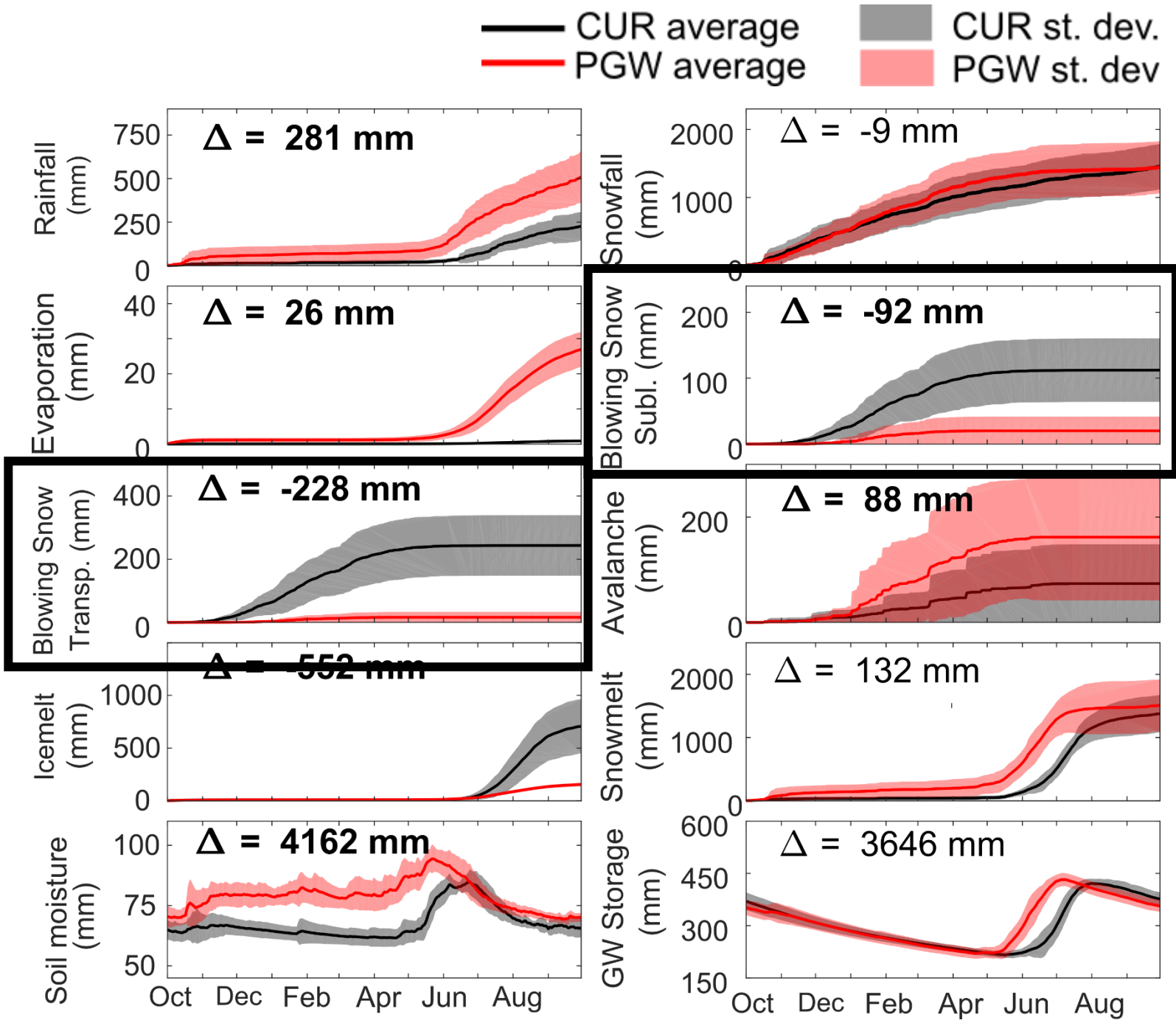
Peyto WRF-PGW simulation shows:

- **A doubling of rainfall**



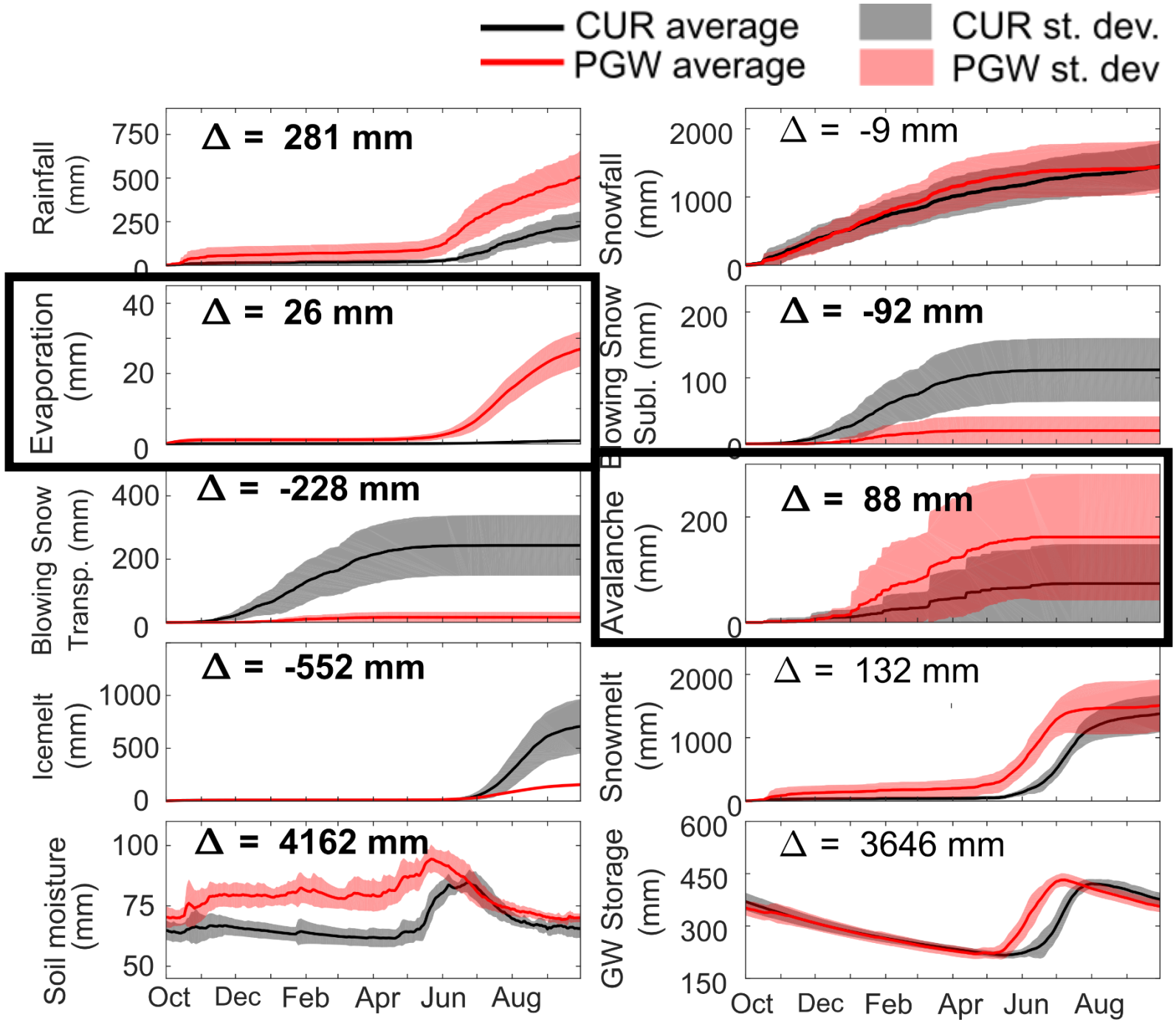
Peyto WRF-PGW simulation shows:

- **A doubling of rainfall**
- **Suppression of blowing snow transport and sublimation**



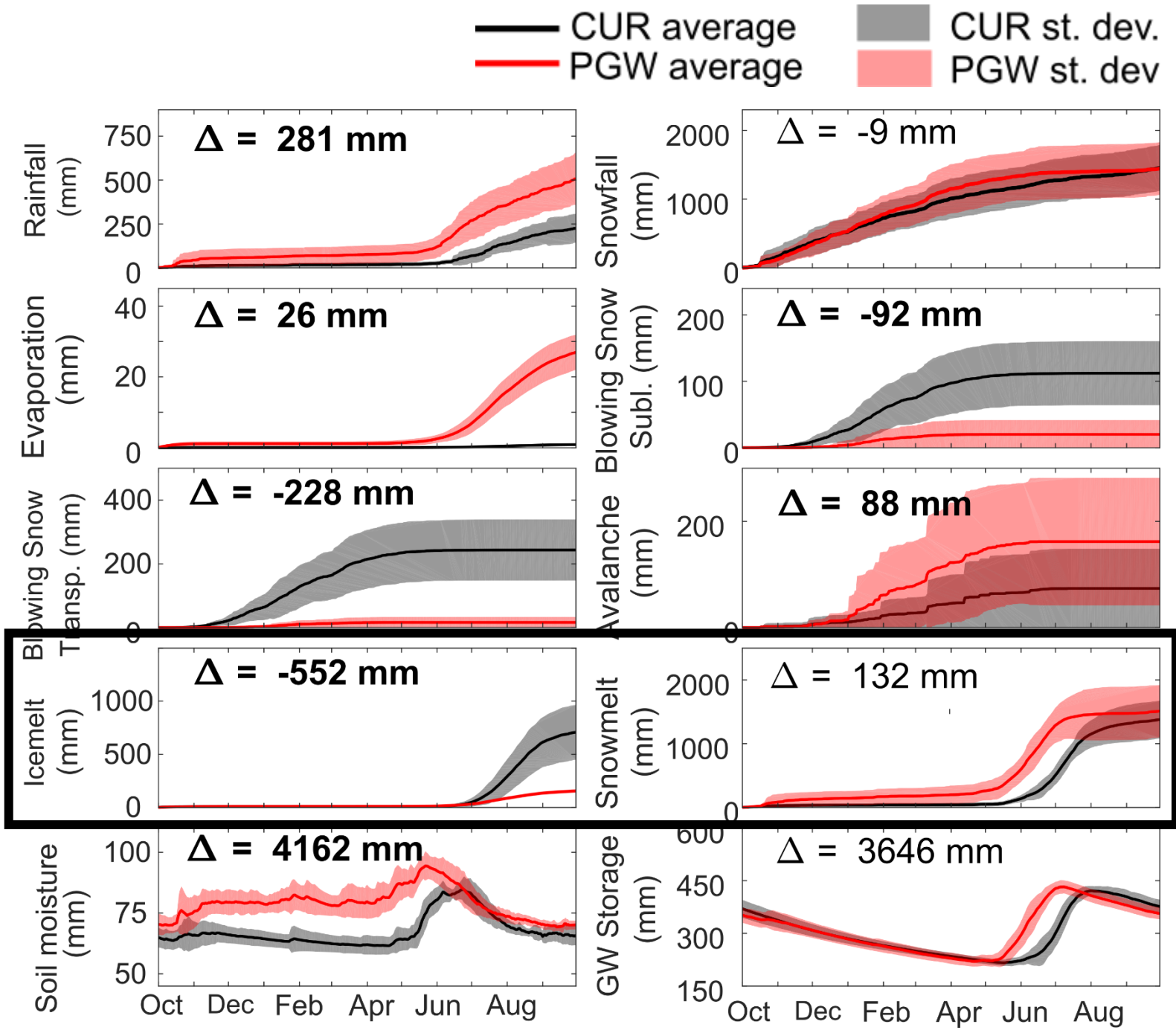
Peyto WRF-PGW simulation shows:

- **A doubling of rainfall**
- **Suppression of blowing snow transport and sublimation**
- **An increase in evaporation and avalanche activity**



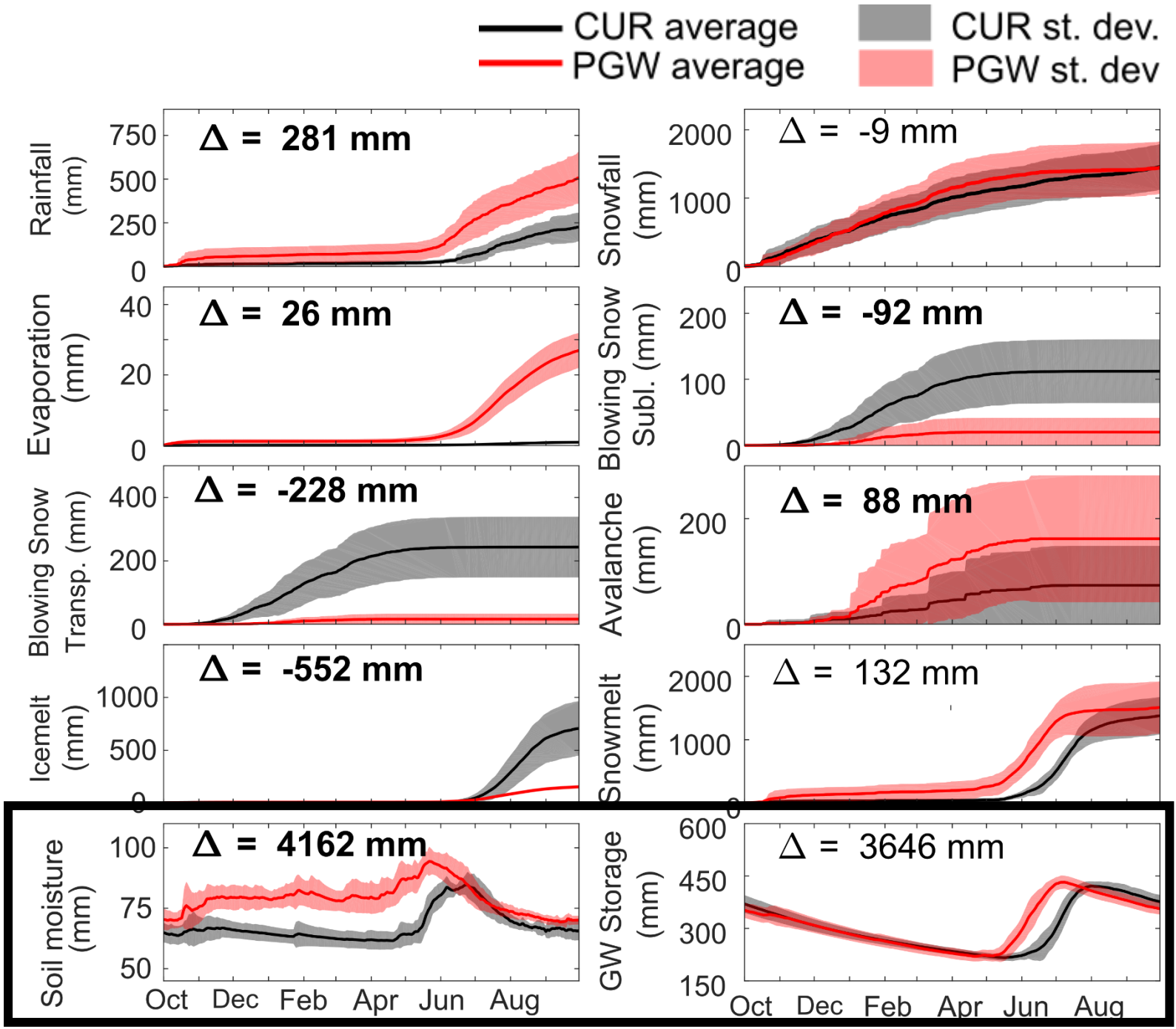
Peyto WRF-PGW simulation shows:

- **A doubling of rainfall**
- **Suppression of blowing snow transport and sublimation**
- **An increase in evaporation and avalanche activity**
- **A large reduction in ice melt combined with an earlier snowmelt component**

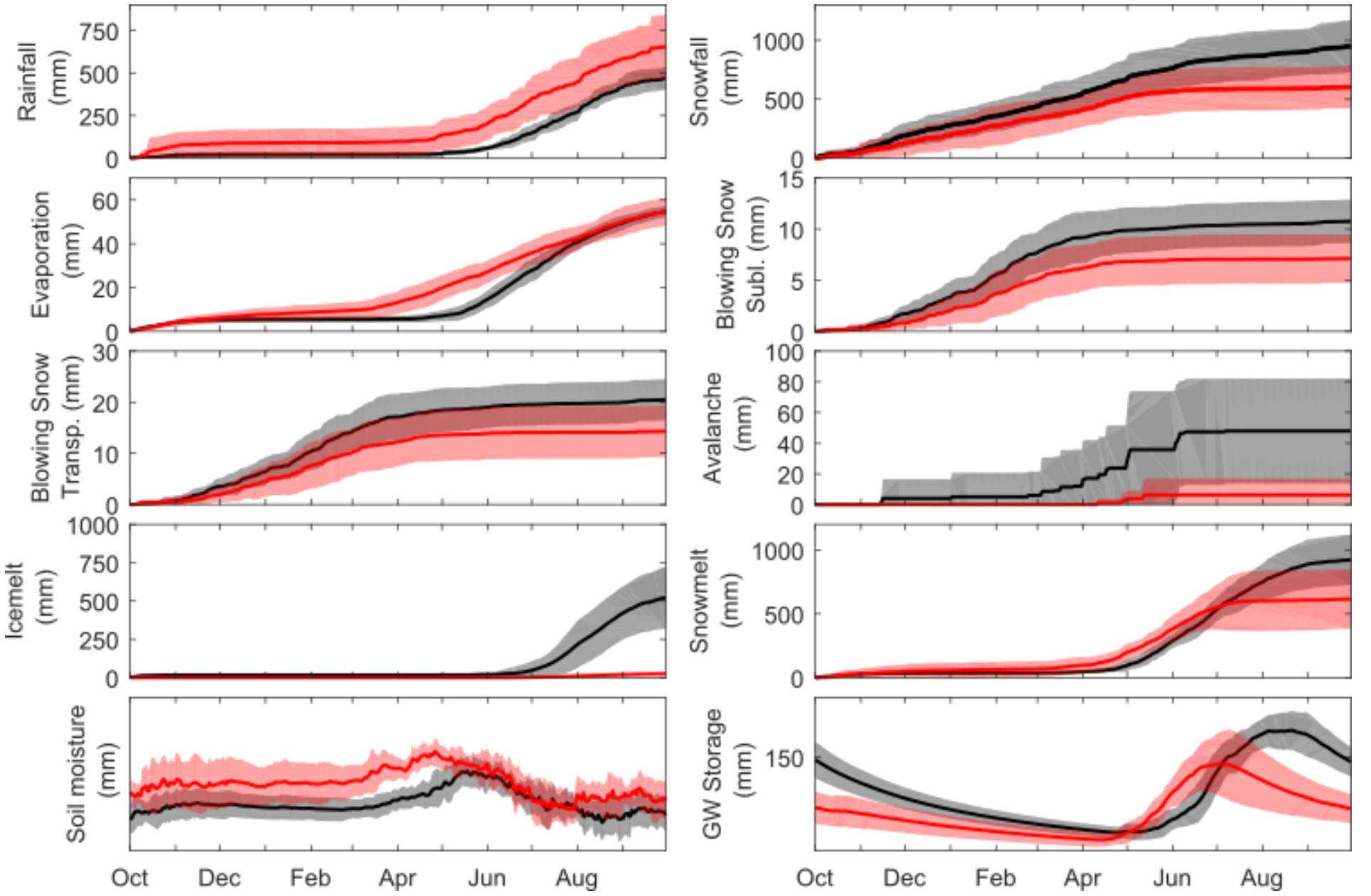


Peyto WRF-PGW simulation shows:

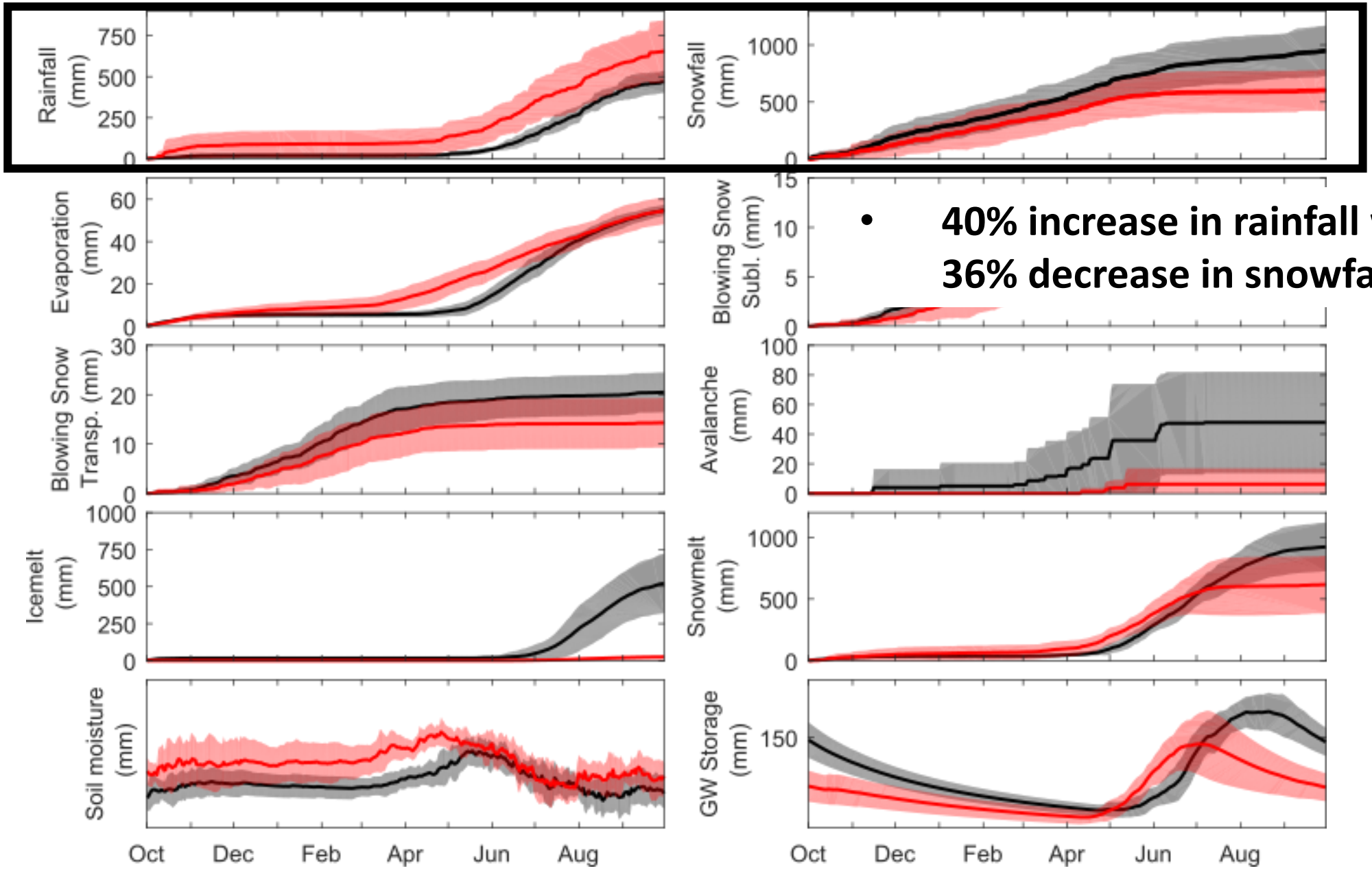
- **A doubling of rainfall**
- **Suppression of blowing snow transport and sublimation**
- **An increase in evaporation and avalanche activity**
- **A large reduction in ice melt combined with an earlier snowmelt component**
- **A increase in winter soil moisture, and an earlier recharge to groundwater storage.**



Rofental WRF-PGW simulation shows:

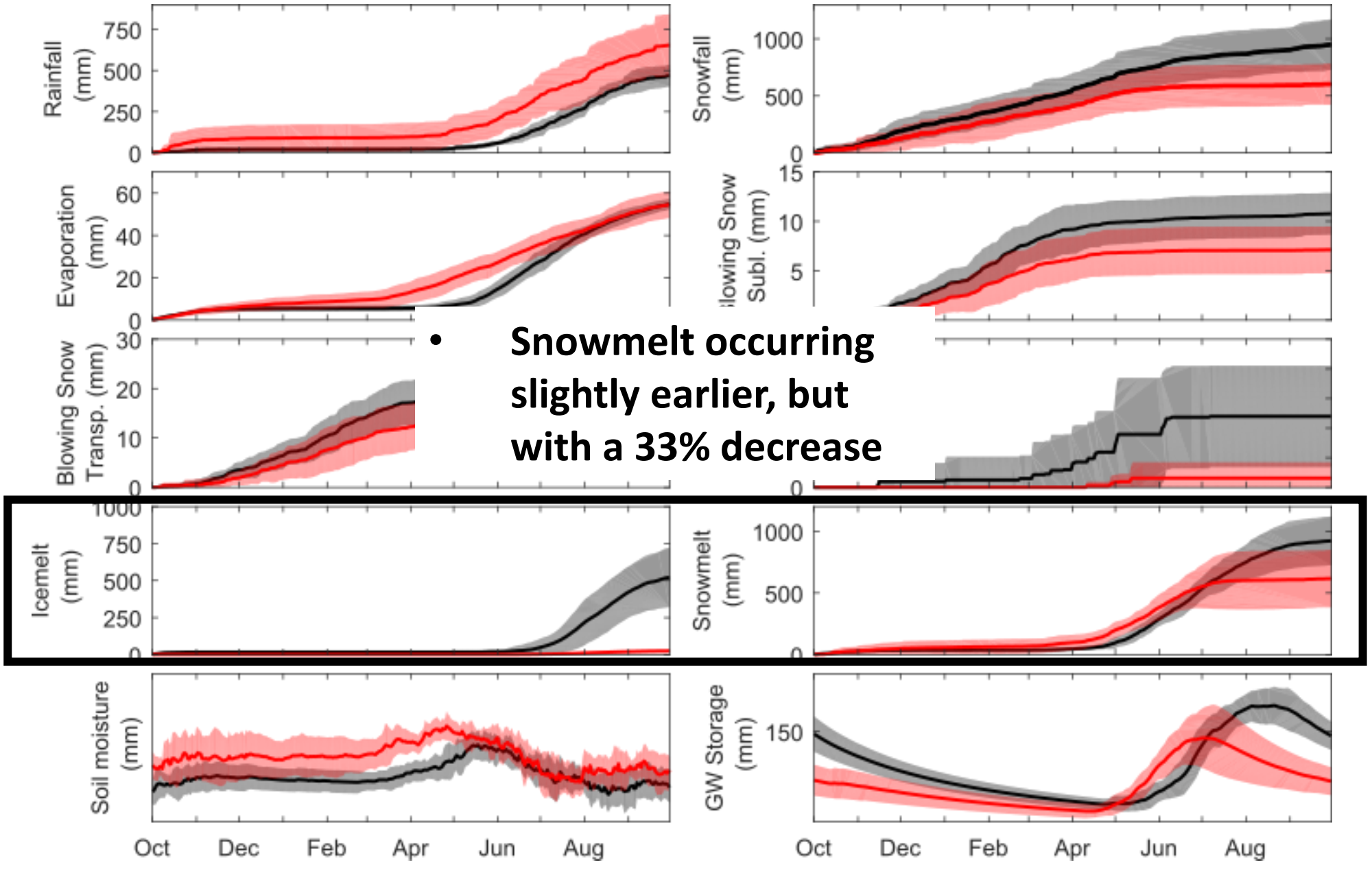


Rofental WRF-PGW simulation shows:



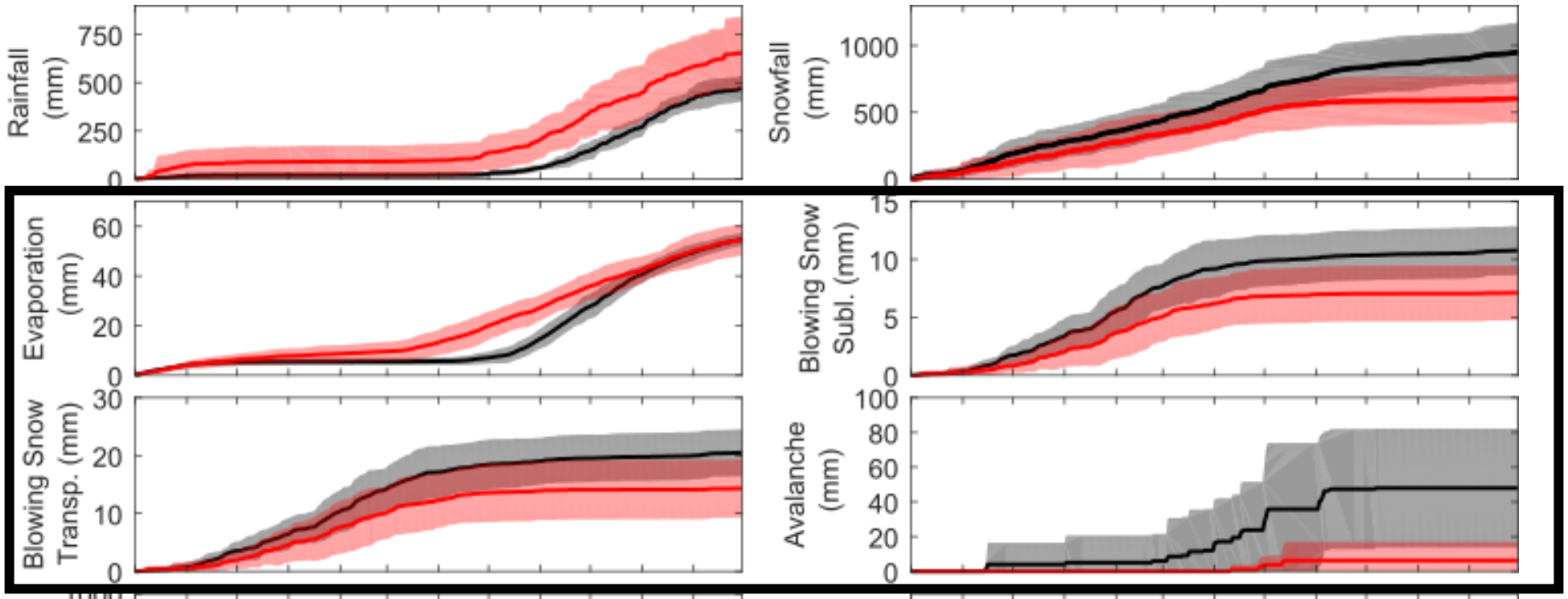
- 40% increase in rainfall with 36% decrease in snowfall

Rofental WRF-PGW simulation shows:

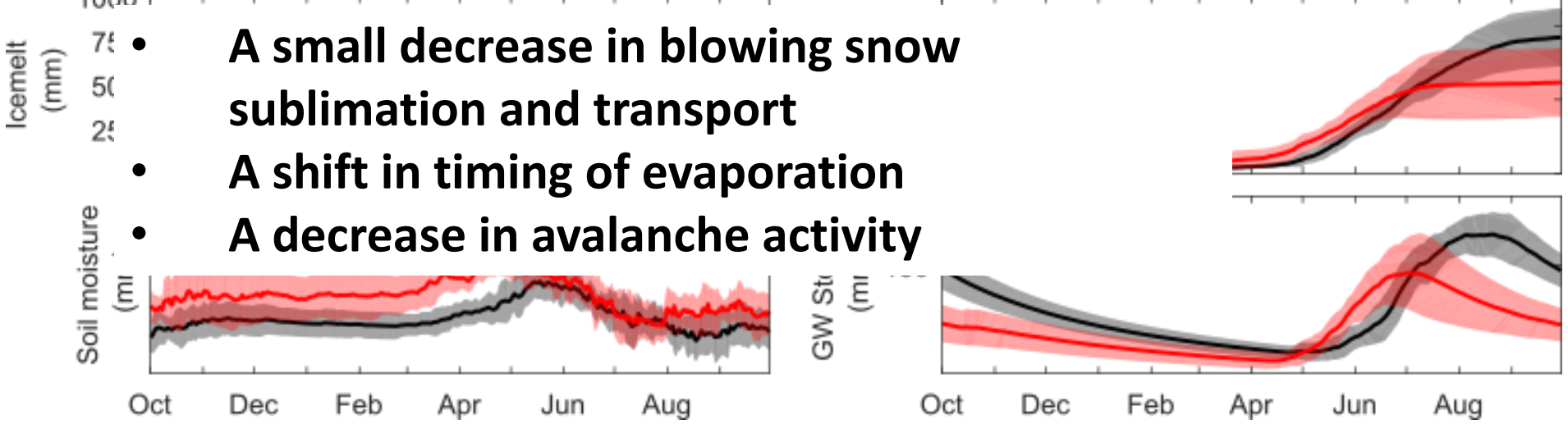


- **Snowmelt occurring slightly earlier, but with a 33% decrease**

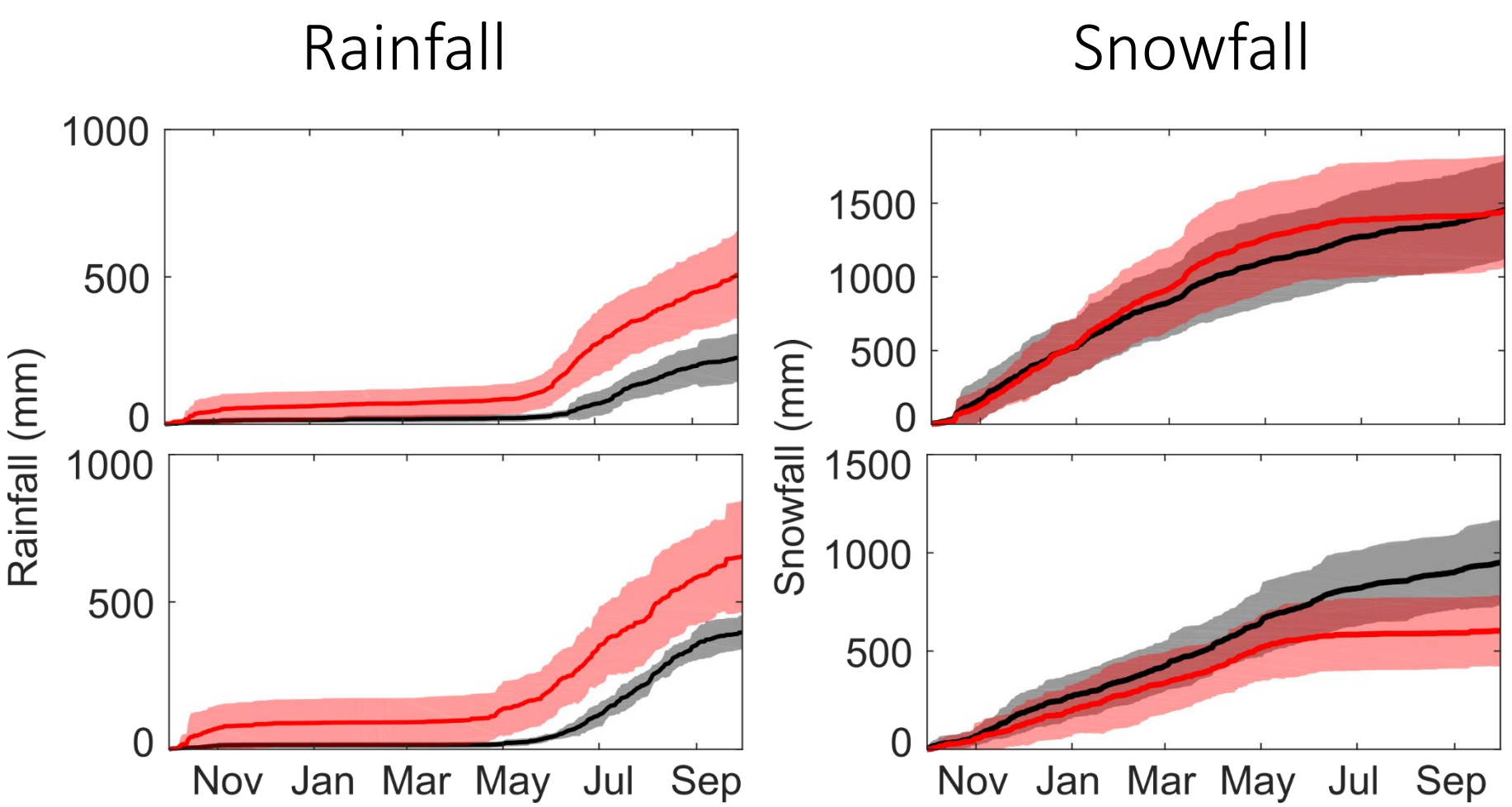
Rofental WRF-PGW simulation shows:



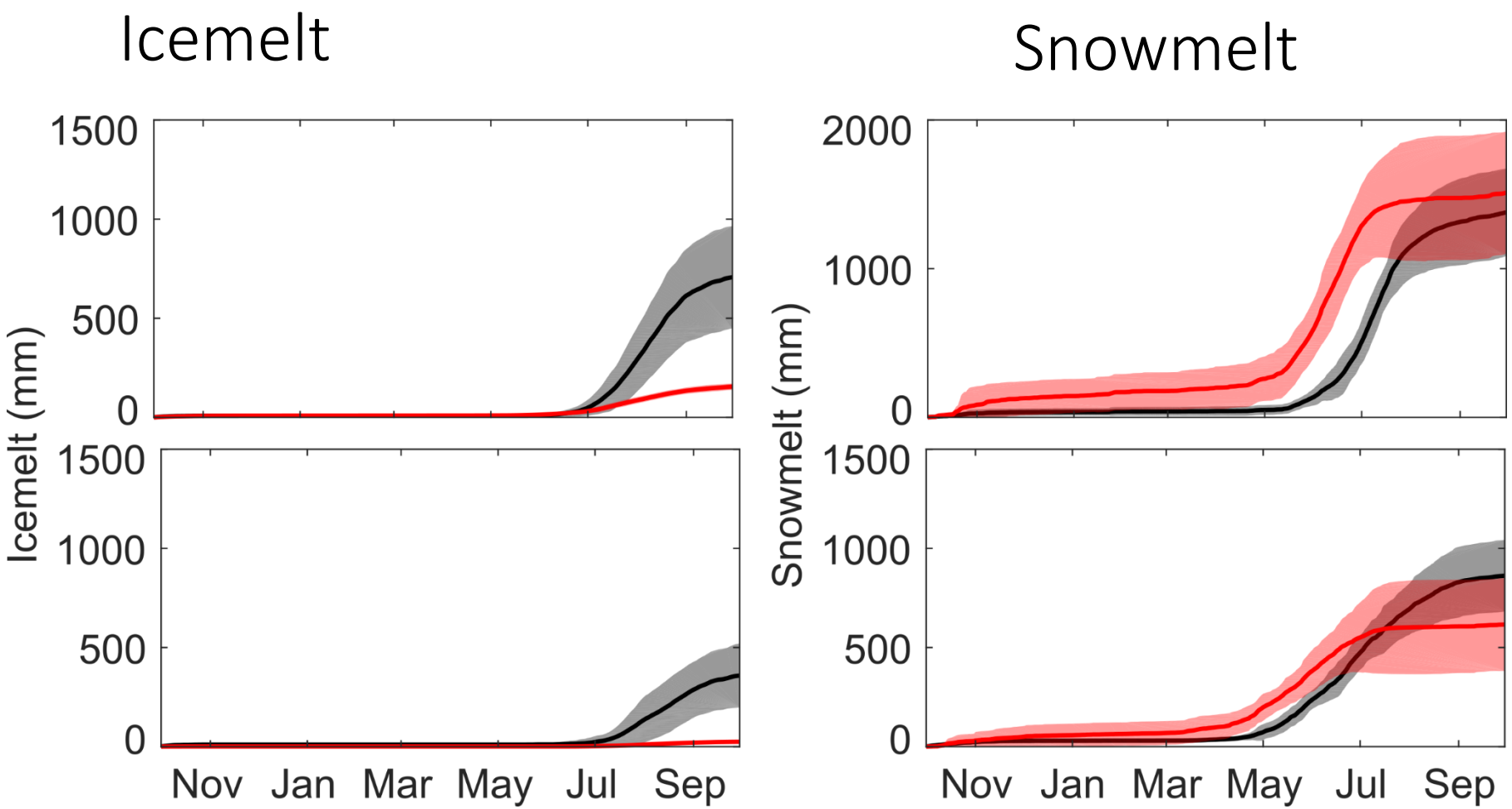
- A small decrease in blowing snow sublimation and transport
- A shift in timing of evaporation
- A decrease in avalanche activity



Precipitation partitioning



Melt partitioning



Conclusion

- Applied a similar process-oriented, modular modelling framework with high resolution atmospheric forcings to similar glacierized basins in the Canadian Rockies and the Alps to gain insights into end-of-century flows
- Substantial deglaciation, similar warming (+5C), but different precipitation responses between Peyto and Vent, lead to similar icemelt losses, but vastly different streamflow changes (-7% in Peyto, -33% in Vent, -67% Vernagtbach)
- Process diagnosis with CRHM suggests the different responses stem from differences in summer snowfall and snowmelt.
- The decrease in snowfall and snowmelt in the Alps leads to substantially greater vulnerability to climate change than in the Canadian Rockies.

@CryoCaro
@cryo.caro
caroline.aubrywake@gmail.com

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