INARCH:
International Network for Alpine Research Catchment Hydrology

John Pomeroy and INARCH colleagues

Centre for Hydrology & Global Institute for Water Security,
University of Saskatchewan, Canada

www.usask.ca/inarch

GHP Annual Meeting, Online, 26 – 27 November, 2020

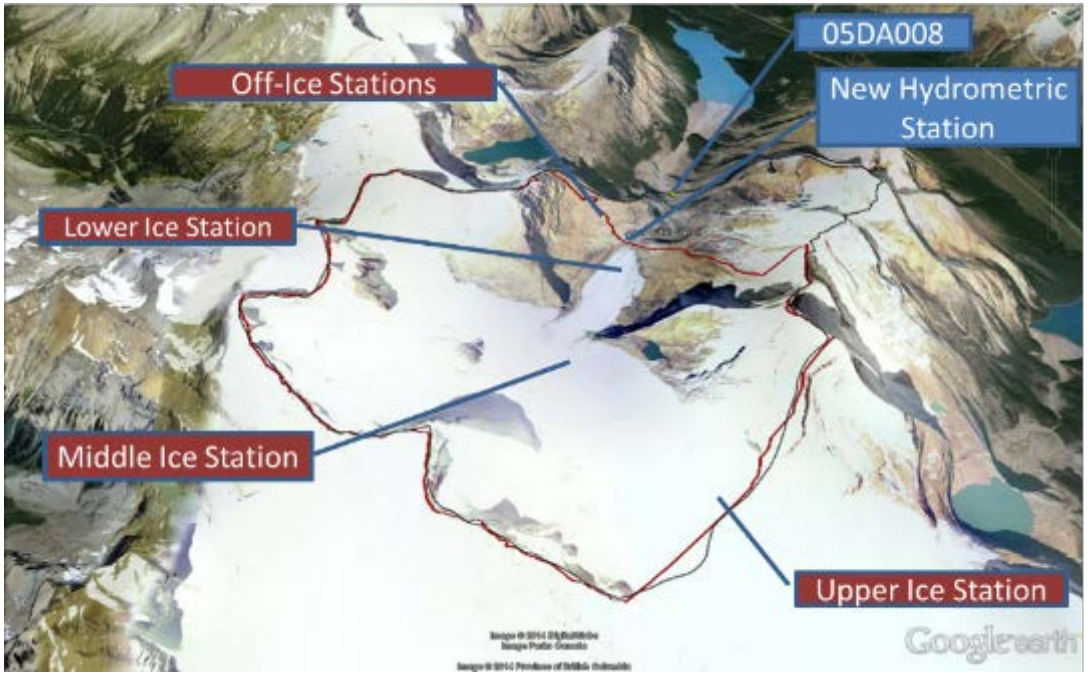
INARCH Objectives

To better

- understand alpine cold regions hydrological processes,
- improve their prediction,
- diagnose their sensitivities to global change

and

To find consistent measurement strategies.



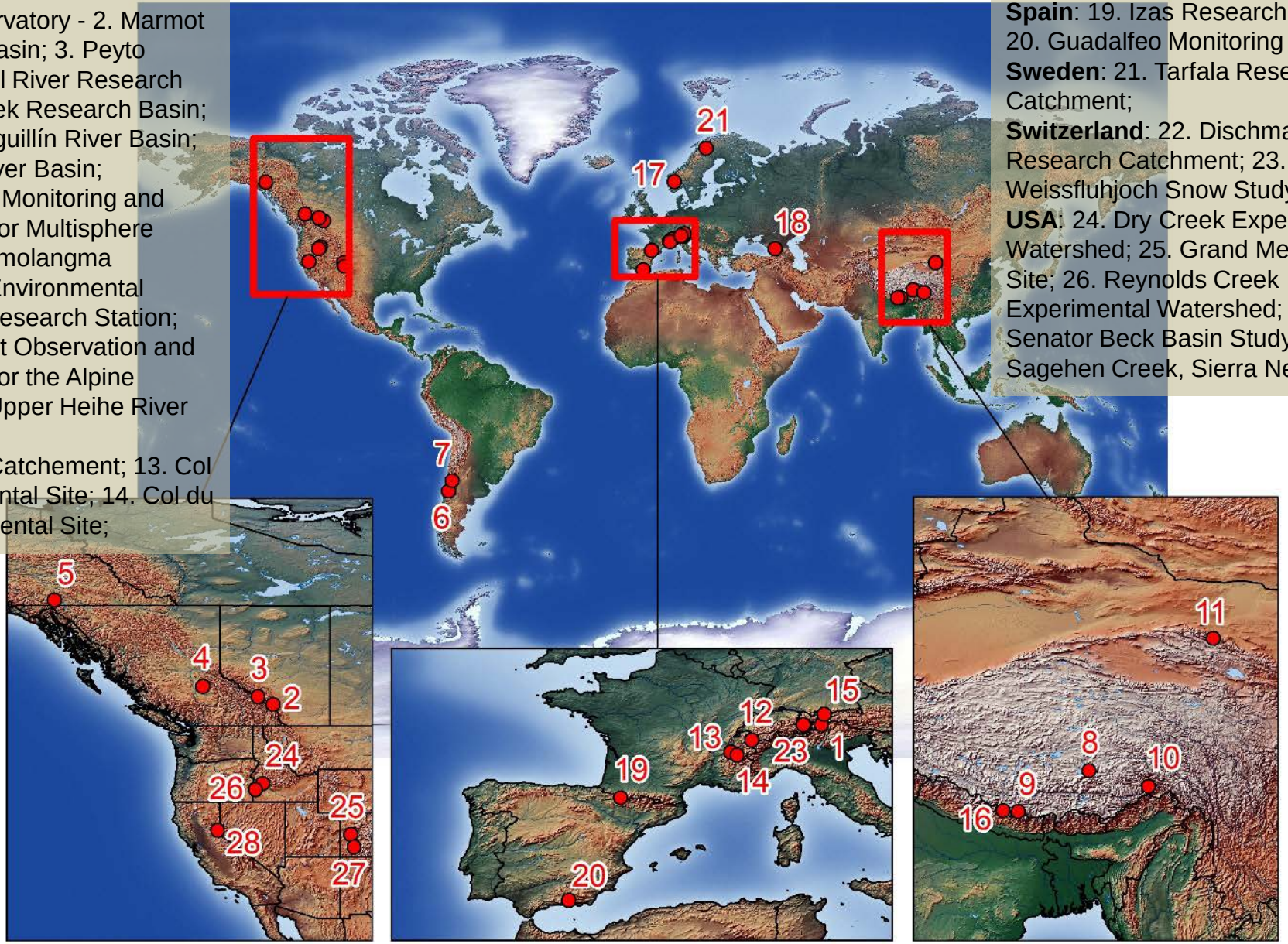
INARCH Questions

1. How do varying **mountain measurement standards** affect scientific findings around the world?
2. What control does **changing atmospheric dynamics** have on the predictability, uncertainty and sensitivity of alpine catchment energy and water exchanges?
3. What improvements to alpine energy and water exchange predictability are possible through **improved physics, downscaling, data collection and assimilation in models**?
4. Do existing mountain model routines have **a global validity**?
5. How do **transient changes** in perennial snowpacks, glaciers, ground frost, soil stability, and vegetation **impact alpine water and energy models**?

INARCH Research Basins

Austria: 1. Open Air Laboratory (OpAL);
Canada: Canadian Rockies Hydrological Observatory - 2. Marmot Creek Research Basin; 3. Peyto Glacier; 4. Quesnel River Research Basin; 5. Wolf Creek Research Basin;
Chile: 6. Upper Diguillín River Basin; 7. Upper Maipo River Basin;
China: 8. Nam Co Monitoring and Research Station for Multisphere Interactions; 9. Qomolangma Atmospheric and Environmental Observation and Research Station; 10. Southeast Tibet Observation and Research Station for the Alpine Environment; 11. Upper Heihe River Basin;
France: 12. Arve Catchement; 13. Col de Porte Experimental Site; 14. Col du Lac Blanc Experimental Site;

Germany: 15. Zugspitze Basin and Schneefernerhaus Research Station;
Nepal: 16. Langtang Catchment;
Norway: 17. Finse Alpine Research Centre;
Russia: 18. Djankuat Research Basin;
Spain: 19. Izas Research Basin; 20. Guadalfeo Monitoring Network;
Sweden: 21. Tarfala Research Catchment;
Switzerland: 22. Dischma Research Catchment; 23. Weissfluhjoch Snow Study Site;
USA: 24. Dry Creek Experimental Watershed; 25. Grand Mesa Study Site; 26. Reynolds Creek Experimental Watershed; 27. Senator Beck Basin Study Area; 28. Sagehen Creek, Sierra Nevada.



Data Requirements

Surface based data requirements for this project will primarily be met by:

1. openly-available detailed meteorological and hydrological observational archives from long-term research catchments at high temporal resolution (at least 5 years of continuous data with hourly sampling intervals for meteorological data, daily precipitation and streamflow, and regular snow and/or glacier mass balance surveys) in selected heavily instrumented alpine regions
2. atmospheric model reanalyses
3. downscaled climate model as well as regional climate model outputs

Data Requirements

The ideal is for sites to be Integrated Alpine Observing and Predicting Systems (IAOPS). A provisional classification scheme for IAOPS is:

CLASS A: sites receiving technology transfer and developing towards CLASS B to E

CLASS B: Single measurement points with highly accurate driving data and snow or glacier data

CLASS C: gauged catchments that contain Class B sites and detailed vegetation coverage, soils, topography, snowcovered area, glacier mass balance or permafrost information

CLASS D: domains for which high resolution gridded meteorological data is available that includes CLASS C sites

CLASS E: the same as CLASS D but gridded meteorological data is also available as climate change scenarios.

Linkages

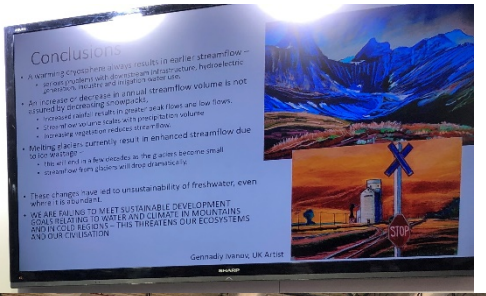
- GEWEX GHP Projects
  - Cold/Shoulder Season Precipitation Near 0ºC project
  - Changing Cold Regions Network and Global Water Futures
  - Western US RHP & Water for Foodbaskets
- Global Cryosphere Watch
- WMO-SPICE and WMO High Mountain Summit
- TPE (Third Pole Environment)
- Future Earth, Sustainable Water Futures Programme (SWFP)
- International Commission for Snow and Ice Hydrology (IUGG)
- UNESCO-International Hydrological Programme efforts on climate change impacts on snow, glacier and water resources within the framework of IHP-VIII (2014-2021) ***'Water Security: Responses to Local Regional and Global Challenges'.***

WMO High Mountain Summit

- The World Meteorological Organization (WMO) convened the High Mountain Summit from 29 to 31 October 2019 at its headquarters in Geneva, Switzerland. The Summit was concluded with a Call to Action which includes a roadmap to science-based, user-driven knowledge and information systems supporting sustainable development and risk reduction in mountain and downstream regions.

United Nations Climate Change Conference, COP25

- INARCH Chair, John Pomeroy, was invited by WMO to attend the United Nations Climate Change Conference, COP25, as an Observer and to make two presentations on climate change and water in relation to the Sustainable Development Goals and to the Changing Cryosphere in Madrid, Spain in December 2019.



https://news.usask.ca/media-release-pages/2019/the-world-is-losing-its-cool-with-the-loss-of-snowpacks-and-glaciers,-posing-threats-to-water-security.php

Institute of Tibetan Plateau Research, Chinese Academy of Sciences

Scientific activities in 2020:

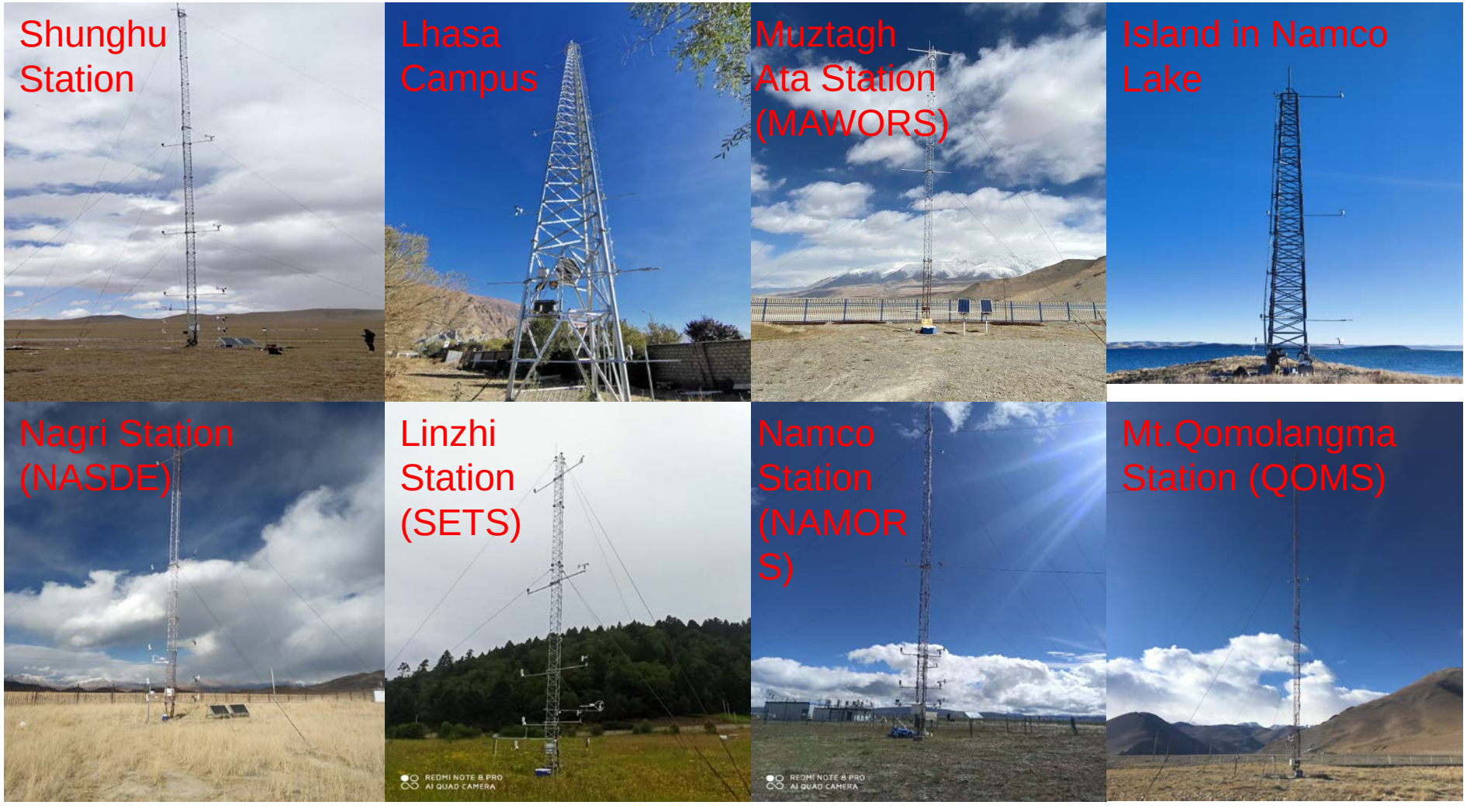
- PBL tower measurements over the Kuoqionggangri glacier
  - 5 layers of air temperature, air humidity, wind speed and direction;
  - four component radiation and rain gauge;
  - automatic weather station;
  - ice temperature profiles and ice movement measurements;



Institute of Tibetan Plateau Research, Chinese Academy of Sciences

Scientific activities in 2020:

- 8 land-atmosphere interaction systems updated with new sensors



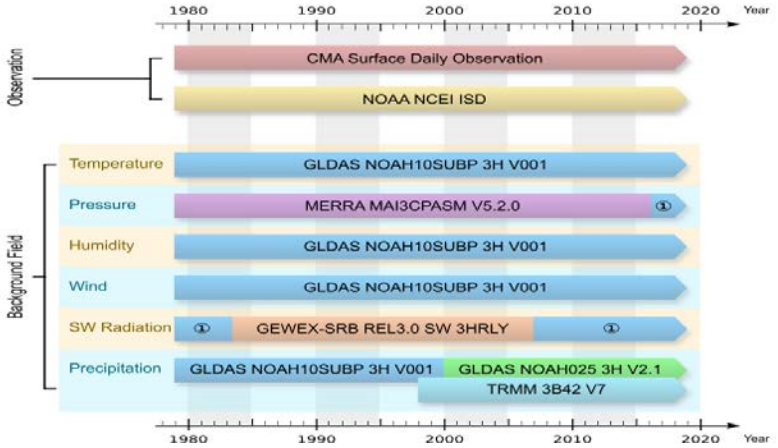
Institute of Tibetan Plateau Research, Chinese Academy of Sciences

Scientific activities in 2020:

- **9 new land-atmosphere interaction measuring systems are being installed**

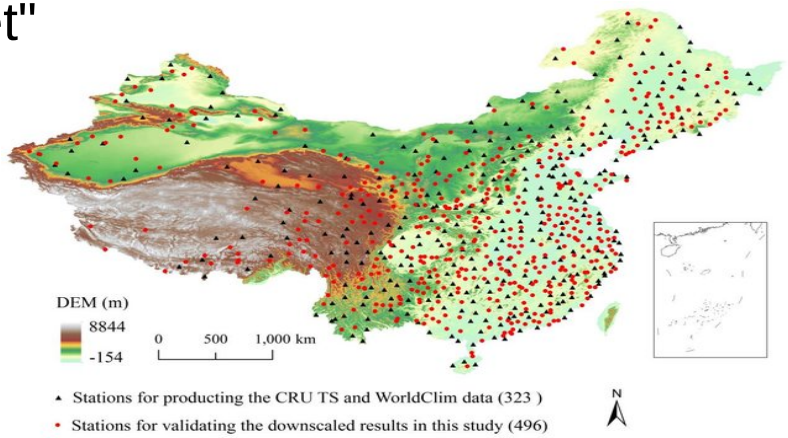
ITP/CAS Published Datasets

- "China Meteorological Forcing Dataset"



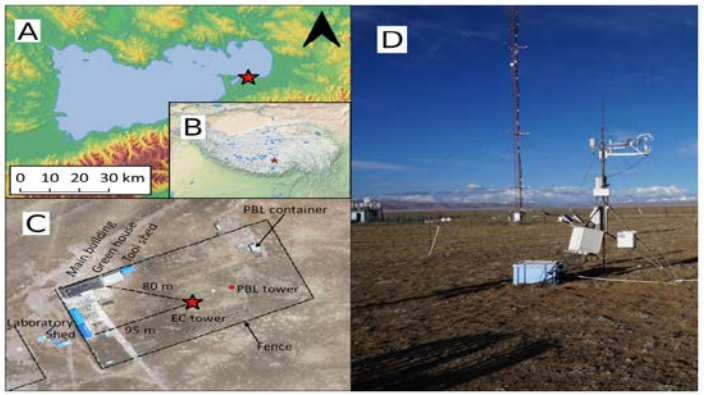
He, J., K. Yang, W. Tang, H. Lu, J. Qin, Y. Chen, and X. Li, 2020: The first high-resolution meteorological forcing dataset for land process studies over China. Scientific Data, 7, 25.

- "New Downscaled 1901-2017 Climate Dataset"



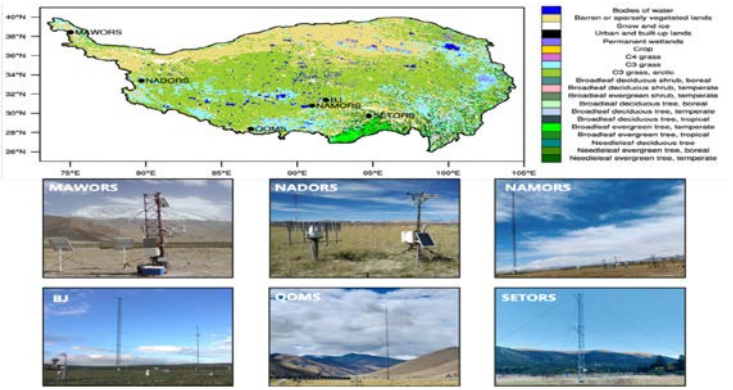
Peng, S., Y. Ding, W. Liu, and Z. Li, 2019: monthly temperature and precipitation dataset for China from 1901 to 2017. Earth Syst. Sci. Data, 11, 1931-1946.

- "long term CO_2 and H_2O dataset"



Nieberding, F., C. Wille, G. Fratini, M. Asmussen, Y. Wang, Y. Ma*, and T. Sachs, 2020: A Long Term (2005–2019) Eddy Covariance Data Set of CO2 and H2O Fluxes from the Tibetan Alpine Steppe, Earth Syst. Sci. Data.

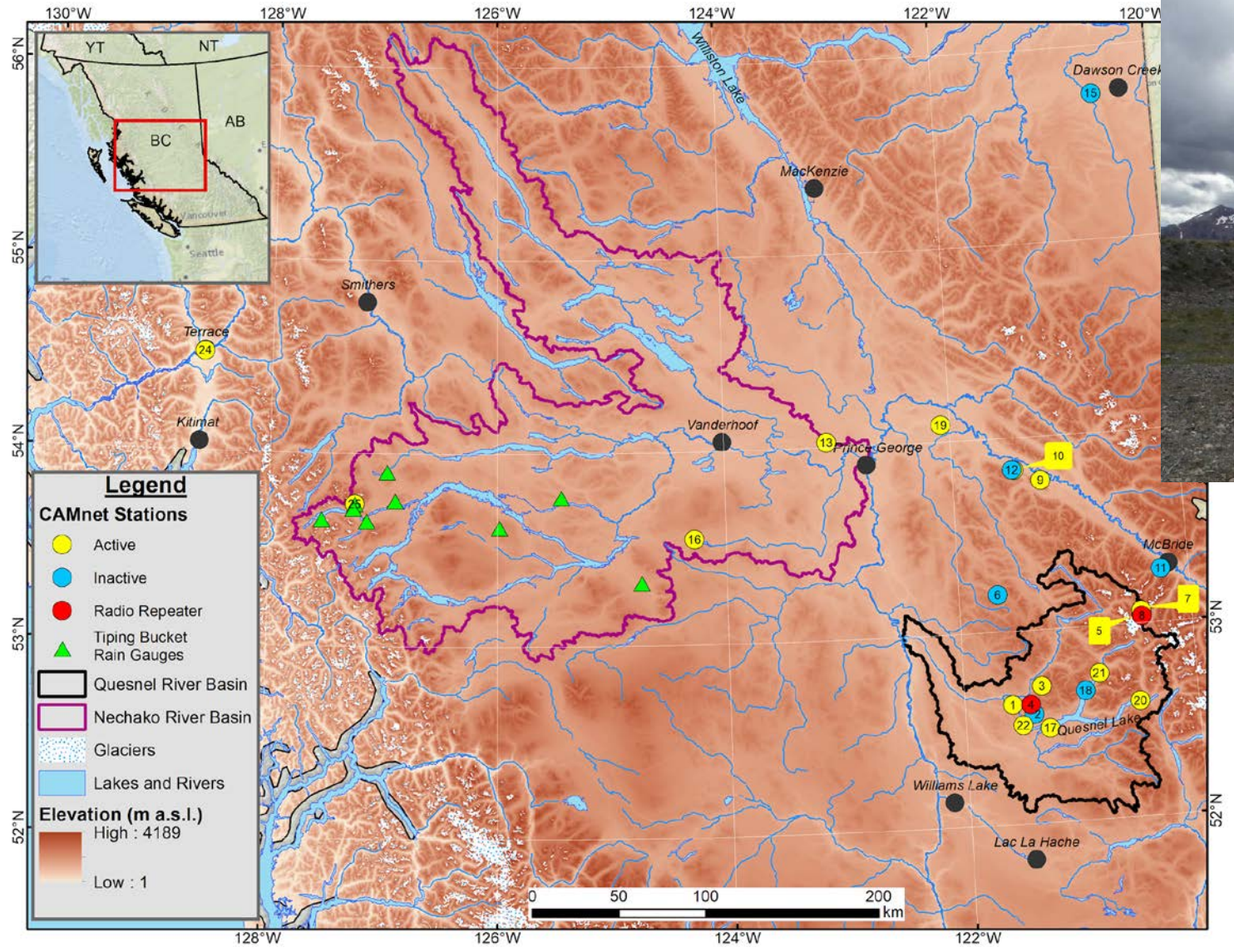
- "Integrated 2005-2016 in-situ observation datasets



Ma Yaoming, and coauthors, 2020: A long-term (2005–2016) dataset of integrated land–atmosphere interaction observations on the Tibetan Plateau, Earth Syst. Sci. Data

Quesnel and Nechako Watershed developments, Cariboo Mountains, Canada

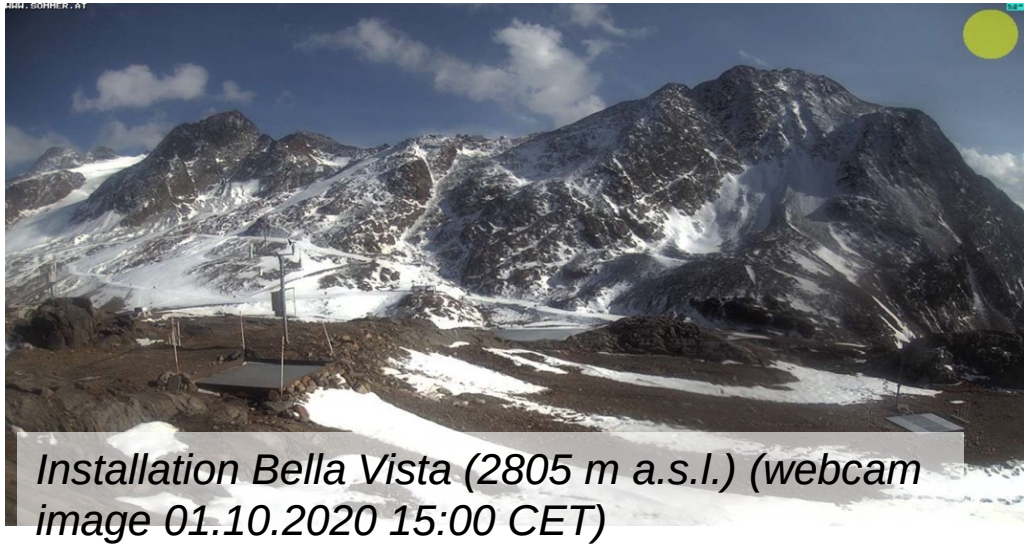
Cariboo Alpine Mesonet (CAMnet)



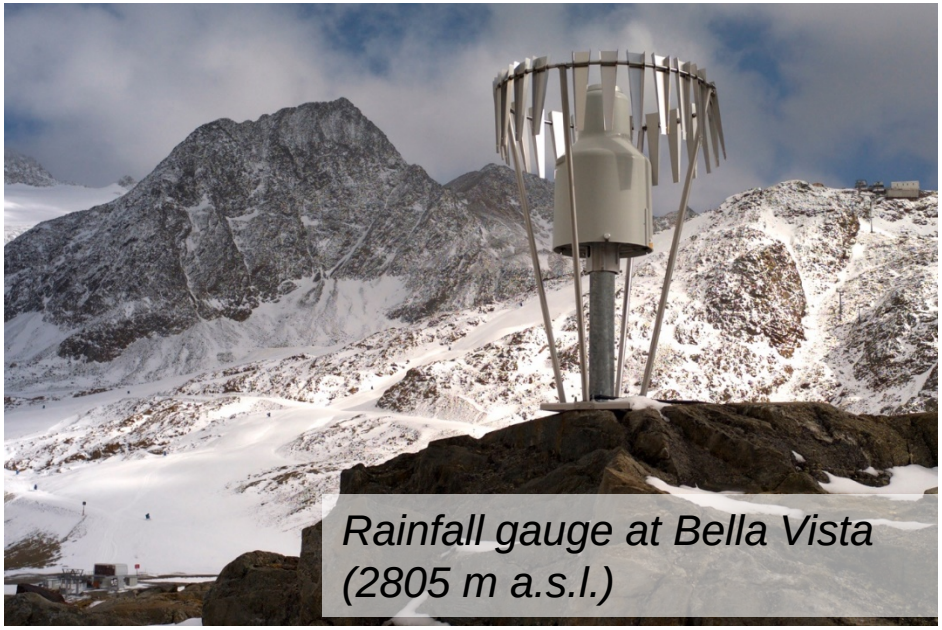
Above: Mount Sweeney weather station located in the Nechako Watershed

Left: Map of north-central BC showing the CAMnet weather stations and tipping bucket rain gauges in the Nechako and Quesnel Watersheds

University of Innsbruck: Research team Human-environment systems research / Alpine Hydroclimatology (Prof. Ulrich Strasser, Dr. Michael Warscher)



Installation Bella Vista (2805 m a.s.l.) (webcam image 01.10.2020 15:00 CET)



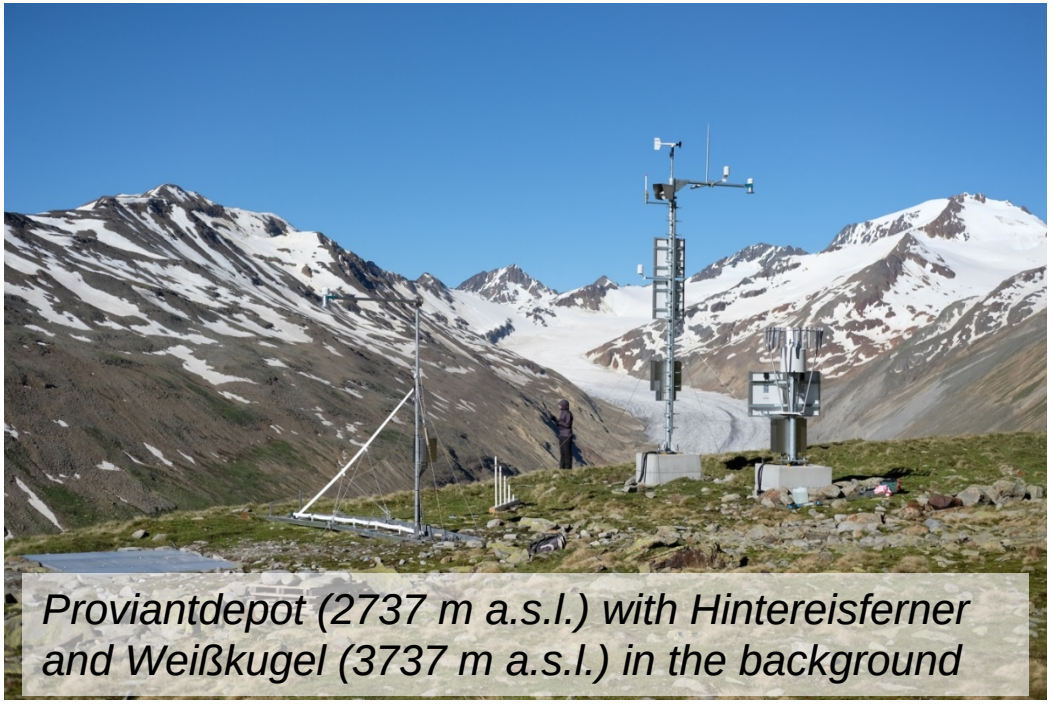
Rainfall gauge at Bella Vista (2805 m a.s.l.)

New installations in the Rofental High Alpine Research Basin, Ötztal Alps, Austria

Acoustic snow drift sensor and highest snow pillow in the European Alps at Bella Vista (2805 m a.s.l.)

University of Innsbruck: Research team Human-environment systems research / Alpine Hydroclimatology (Prof. Ulrich Strasser, Dr. Michael Warscher)

Latschbloder (2919 m a.s.l.)



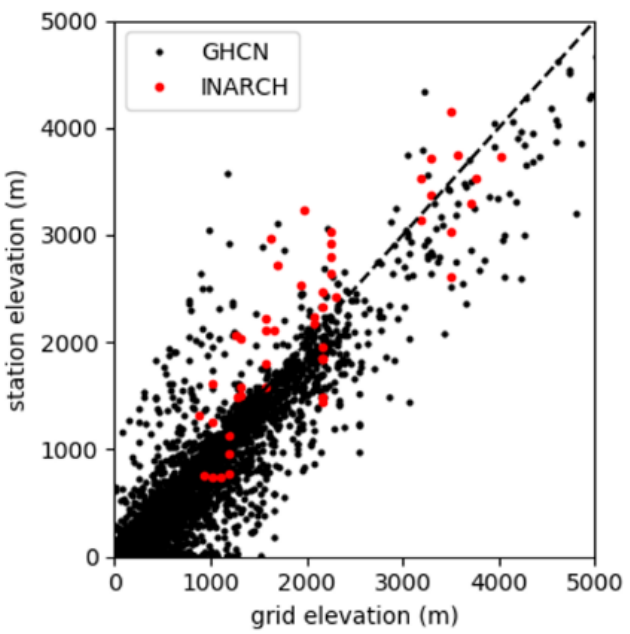
Proviantdepot (2737 m a.s.l.) with Hintereisferner and Weißkugel (3737 m a.s.l.) in the background

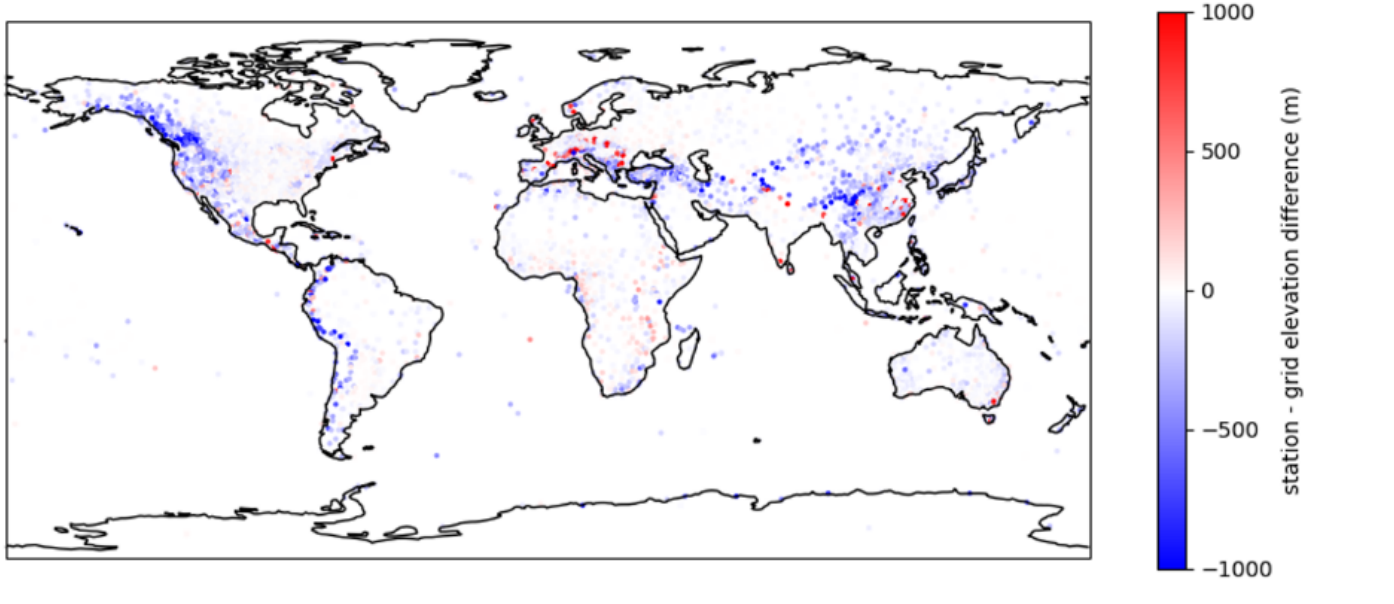
New installations in the Rofental High Alpine Research Basin, Ötztal Alps, Austria

ISCO water sampler at gauge Vent (1891 m a.s.l.)

Use of INARCH data in ESM-SnowMIP

- A challenge for snow models as components of Global Earth Systems is bridging the scales over which site measurements are representative to the large scales of global model grid boxes (larger than 0.5° in all but a few models).
- The 7138 Global Historical Climatology Network stations below show the network is sparse above 2500 m and the majority of stations in high elevation grid cells are located in valleys lower than the average grid elevation.

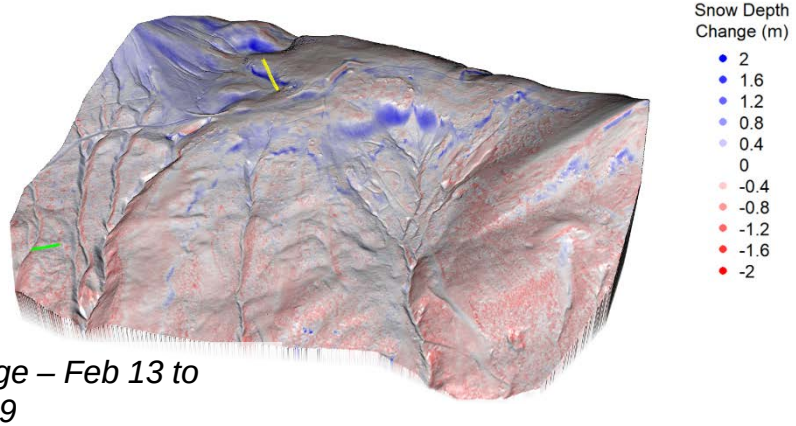




As alpine research catchments, several INARCH sites have hydrometeorological stations spanning a wide range of elevations within a small area.

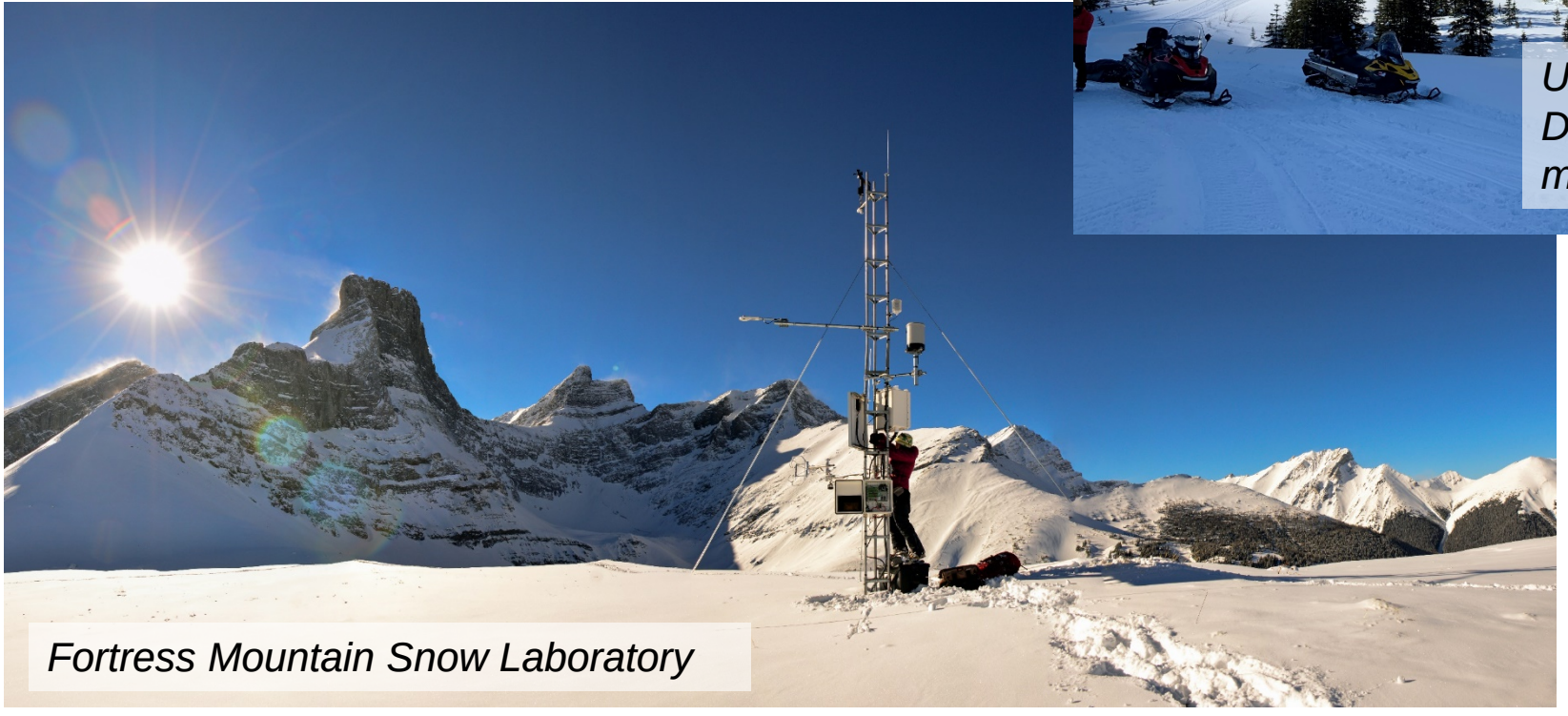
Canadian Rockies Hydrological Observatory

Snow Depth Change from UAV LiDAR



Fortress Ridge – Feb 13 to April 25, 2019

UAV LiDAR
DJI M600 Pro Riegl miniVUX-1UAV



Fortress Mountain Snow Laboratory

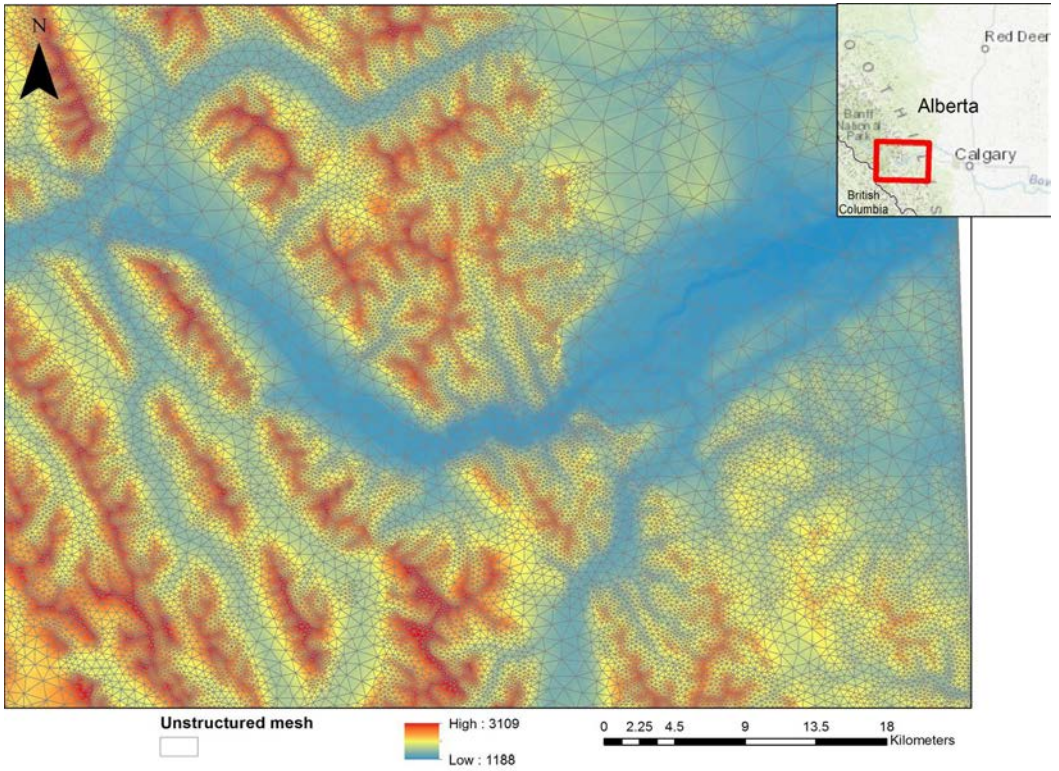
Canadian Hydrological Model (CHM)

- **Unstructured triangular mesh** depending on topography and vegetation complexity

- Flexible structure to test multiple hypothesis, assessment of uncertainty
- Incorporation of existing code

- Algorithms for downscaling meteorological data (e.g., from NWP)

- Accounts for:
  - **slope** and **aspect**; terrain **shading**
  - **gravitational redistribution**
  - **blowing snow (**redistribution + sublimation**)**
  - **snow/canopy interactions**



Marsh et al. (2020 GMD)

Earth System Science Data Special Issue

- **Hydrometeorological data from mountain and alpine research catchments**
- https://www.earth-syst-sci-data.net/special_issue871.html
- Guest Editors: J. Pomeroy, D. Marks, I. Lopez-Moreno

- 23 data papers contributed and more coming in

"*Data sets contributed to the special issue should support and promote research on the effects of mountain snowpacks and glaciers on water supply as well as study of variations in energy and water exchange amongst different high-altitude regions. …The guest editors invite contributions of openly available detailed meteorological and hydrological observational archives from long-term research catchments at high temporal resolution (at least 5 years of continuous data with hourly sampling intervals for meteorological data, daily precipitation and streamflow, and regular snow and/or glacier mass balance surveys) in well-instrumented mountain regions around the world*."

GEWEX INARCH

Next Steps

- Carry on in spite of COVID-19
- Build linkages with other GEWEX cross-cuts and RHPs
  - US Water for Foodbaskets, Canada - GWF, ANDEX, TPE
- Plan next phase of INARCH (when meetings are possible, we will reconvene and discuss the next steps and objectives moving on), and produce synthesis papers on key INARCH science topics and questions