INARCH:
International Network for Alpine Research Catchment Hydrology

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INARCH Objectives

To better

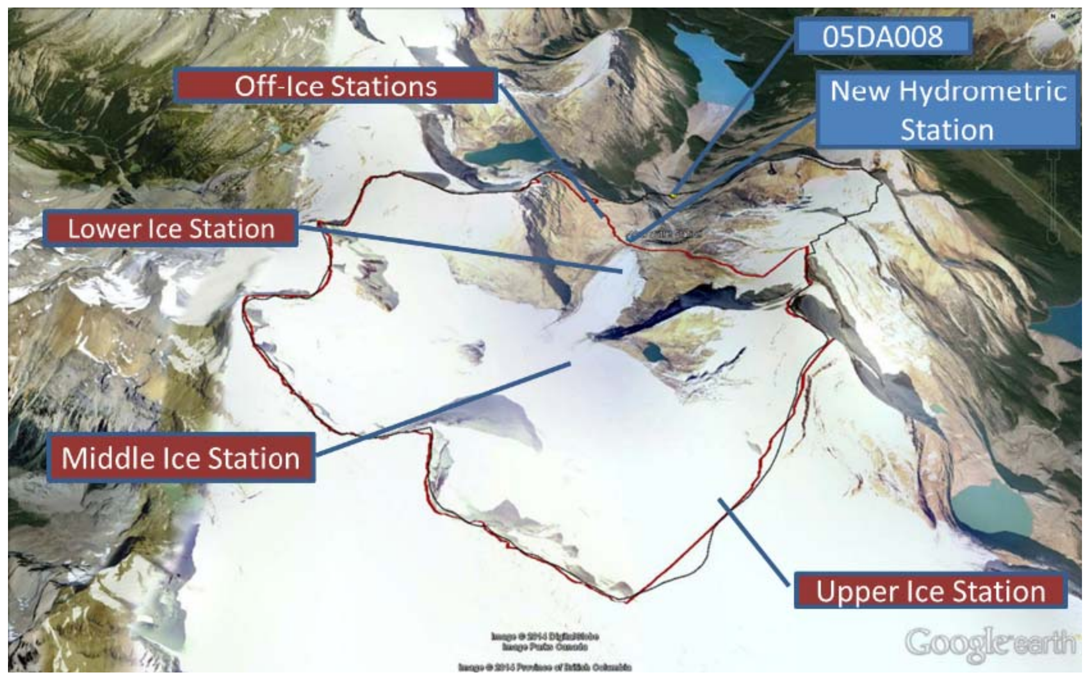
-understand alpine cold regions hydrological processes,

-improve their prediction,

-diagnose their sensitivities to global change

and

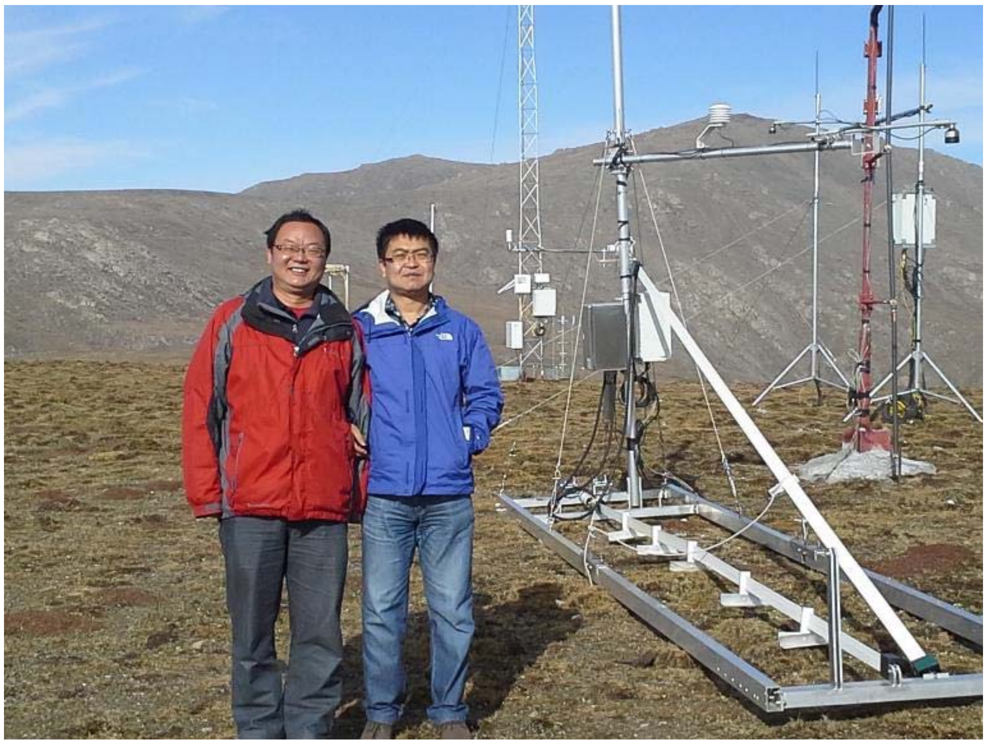
to find consistent measurement strategies.



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?

International Collaboration through Field & Model Experiments



Upper Heihe River Basin, 4150 m China

Zugspitze, 2650 m Germany

INARCH Scientific Steering Group

- Matthias Bernhardt (BOKU, Austria)
- Ethan Gutmann (NCAR, USA)
- Tobias Jonas (SLF, Switzerland)
- Xin Li (CARERRI-CAS, China)
- Ignacio Lopez Moreno (IPE, Spain)
- Yaoming Ma (ITP-CAS, China)
- Danny Marks (USDA-ARS, USA)
- James McPhee (Univ de Chile, Chile)
- Thomas Painter (NASA JPL, USA)
- John Pomeroy (Univ Saskatchewan, Canada)*
- Ulli Strasser (Univ Innsbruck, Austria)
- Vincent Vionnet (Meteo-France, France)

*chair

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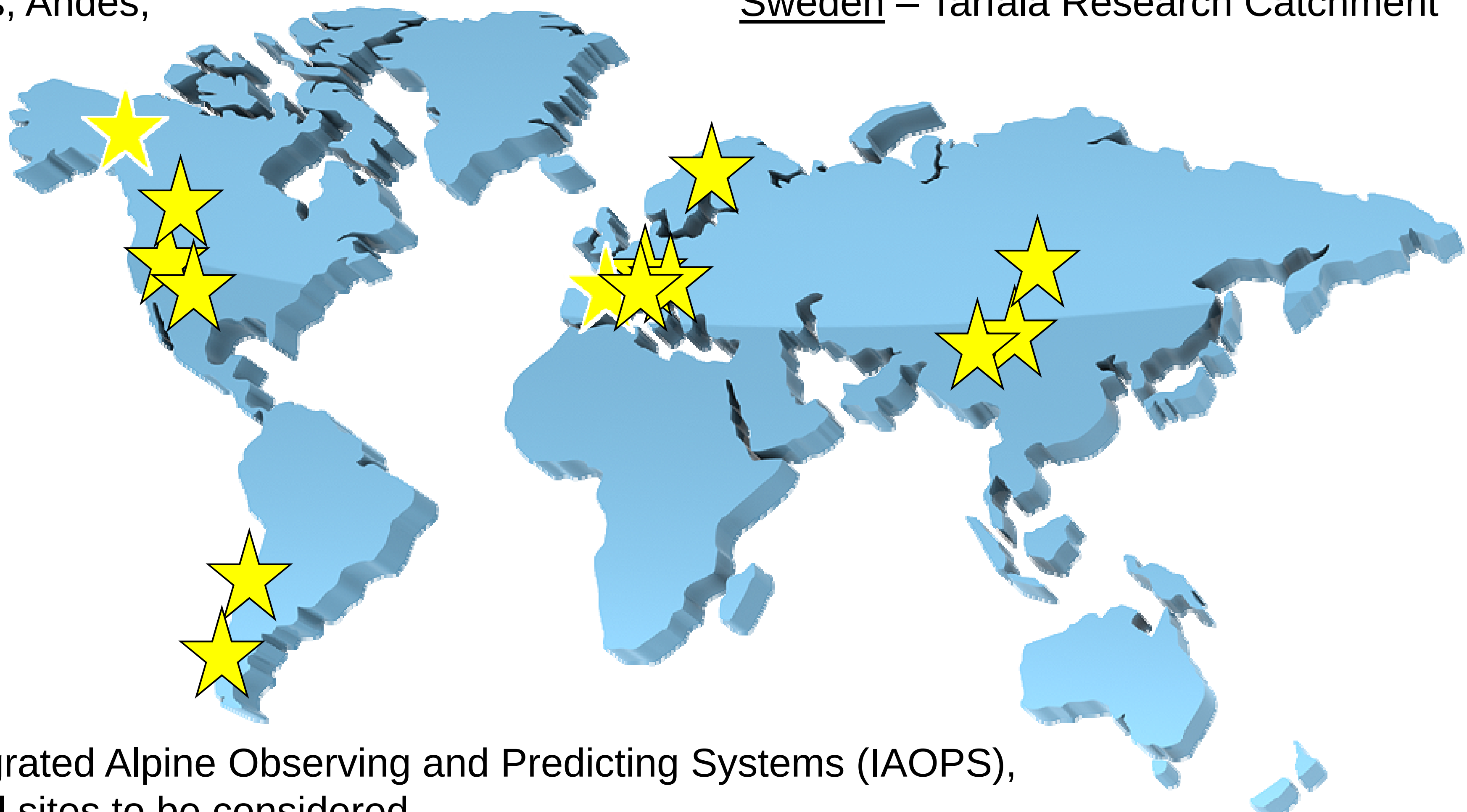
INARCH: International Network for Alpine Research Catchment Hydrology

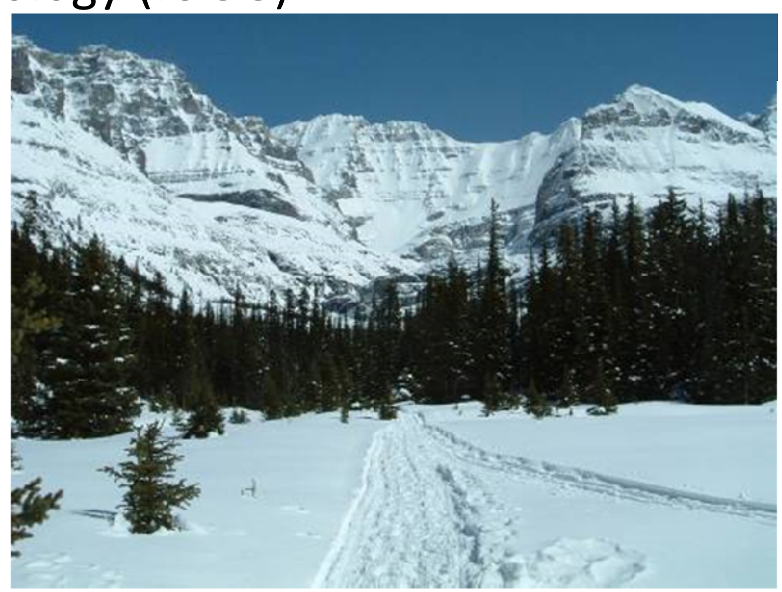
Canada – Canadian Rockies, BC & Yukon;
USA – Reynolds Creek, ID; Senator Beck, CO, Niwot Ridge, CO.
Chile - Upper Maipo & Upper Diguillín River Basins, Andes,
Germany – Schneefernerhaus & Zugspitze;
France – Arve Catchement, Col de Porte & Col du Lac Blanc;
Switzerland – Dischma & Weissfluhjoch;
Austria - OpAL Open Air Laboratory, Rofental
Spain – Izas, Pyrenees;
China – Upper Heihe River, Tibetan Plateau,
Nepal – Langtang Catchment, Himalayas
Sweden – Tarfala Research Catchment



Integrated Alpine Observing and Predicting Systems (IAOPS), initial sites to be considered

Linkages

- GEWEX GHP Projects
  - Precipitation phase
  - Mountain precipitation
  - Changing Cold Regions Network
- Global Cryosphere Watch
- TPE
- WMO-SPICE
- 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'.***
- International Commission for Snow and Ice Hydrology (IUGG)



INARCH Update – May 2016

- INARCH was approved as a Cross-cut Project by the GEWEX Hydroclimate Panel at Pasadena, California in December 2014
- INARCH provides mountain snow and ice water security information for UNESCO's International Hydrological Programme
- INARCH's objective is to better understand alpine cold regions hydrological processes, improve their prediction, diagnose their sensitivities to global change and find consistent measurement strategies.
- INARCH held its inaugural workshop at Kananaskis, Alberta in October 2015, which was attended by 30 scientists from Canada, US, China, Nepal, Chile, UK, Spain, France, Germany, Switzerland and Austria.
- INARCH held a Poster Session C33A & an Oral Session C43F, "Improved Understanding and Prediction of Mountain Hydrology through Alpine Research Catchments", on 16-17 Dec. 2015 at the American Geophysical Union Fall Meeting in San Francisco, California.
  - https://agu.confex.com/agu/fm15/meetingapp.cgi/Session/8067
  - https://agu.confex.com/agu/fm15/meetingapp.cgi/Session/10888

INARCH Workshop in Alberta, Canada Oct 2015

GEWEX's INARCH is launched and has broad participation and support from scientists studying mountain regions around the world.

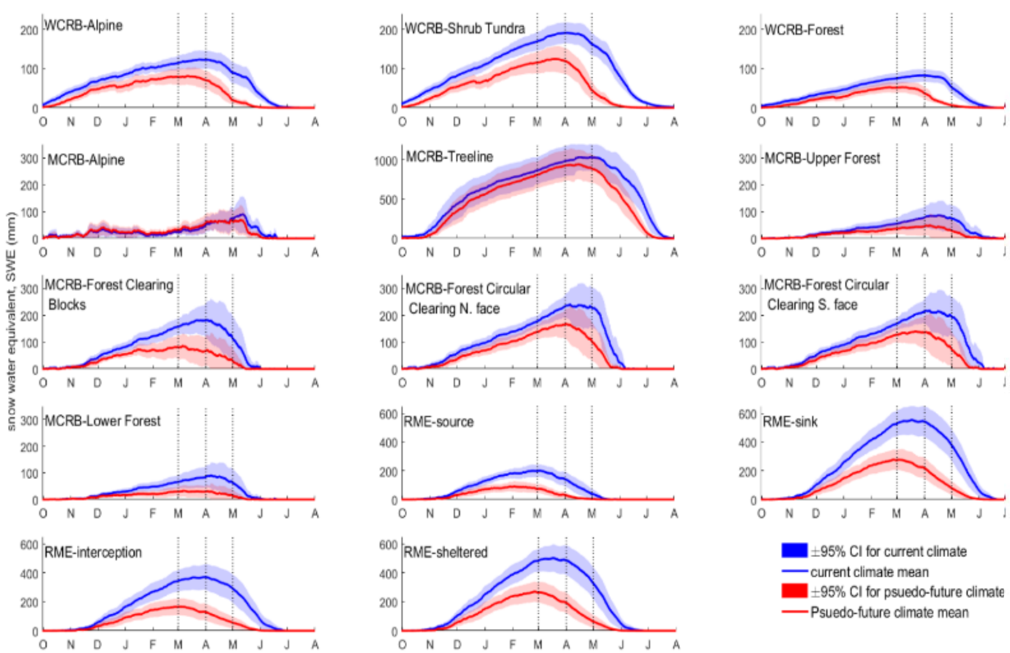
INARCH Workshop 2015
Observations and Data

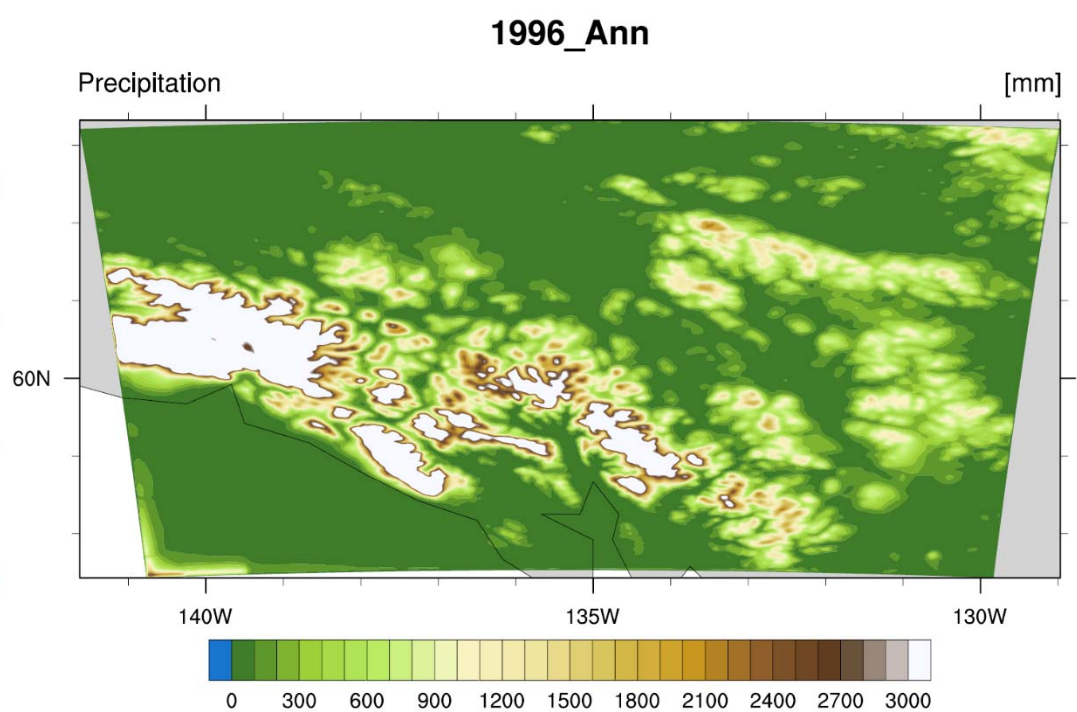
- *Enhance mountain hydrometeorological and cryospheric observations with open availability of data, and reduced measurement uncertainty.*

INARCH Workshop 2015

Uncertainty and Models

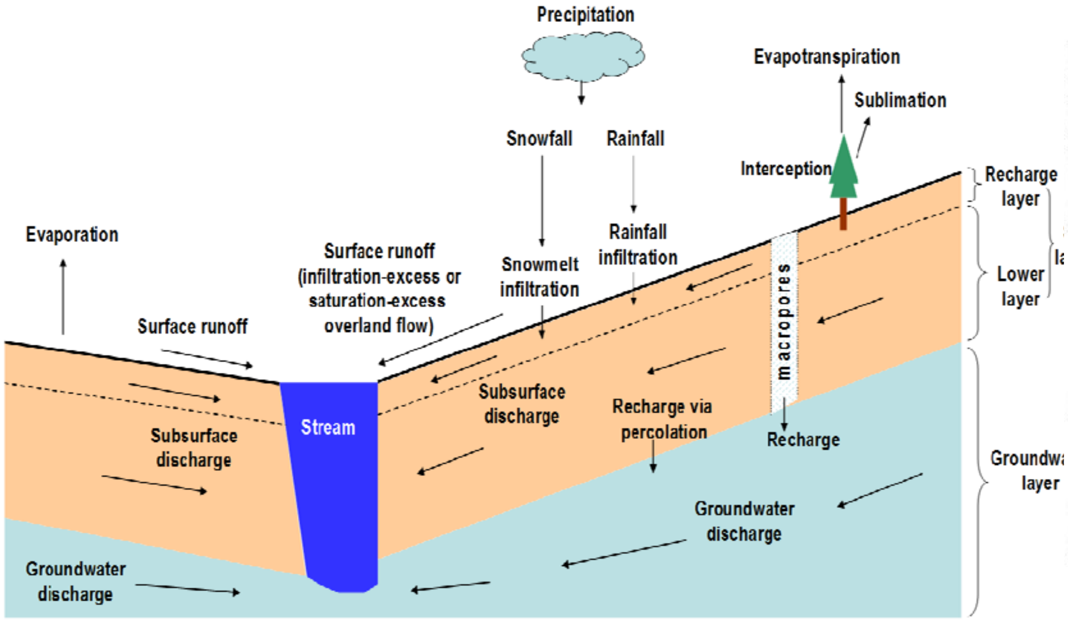
- *Improve the capability and range of downscaling methods to drive models,*
- *Improve representation of exchange processes with frozen surfaces*
- *Calculate impacts of dynamic climate and transient vegetation and hydrological and cryospheric storage at various scales.*

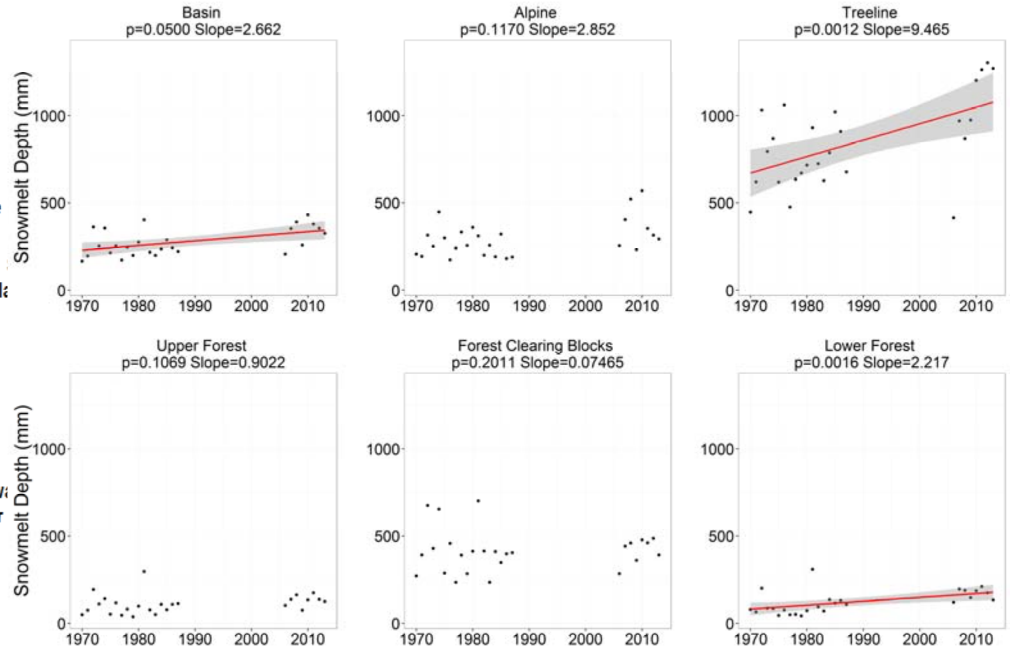




INARCH Workshop 2015
Climate Change

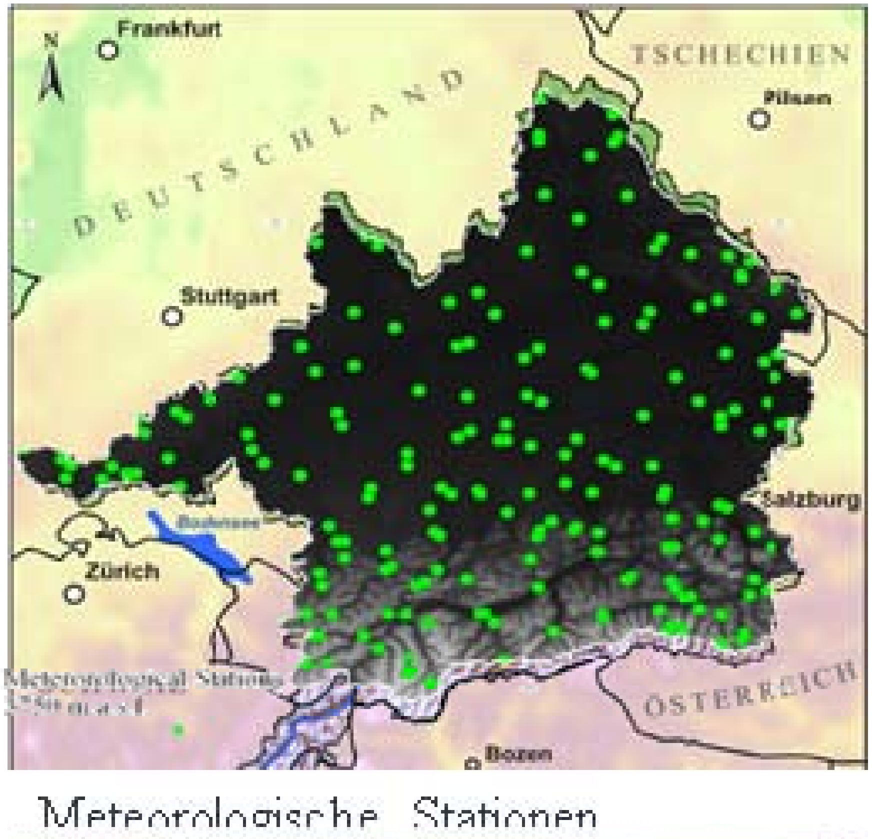
- *Evaluate the changing prospects for mountain water resources through diagnostic modelling experiments using INARCH instrumented catchments*
- *Quantify and improve the prognostic potential of these models for predicting the water security impacts of global change in mountain regions.*

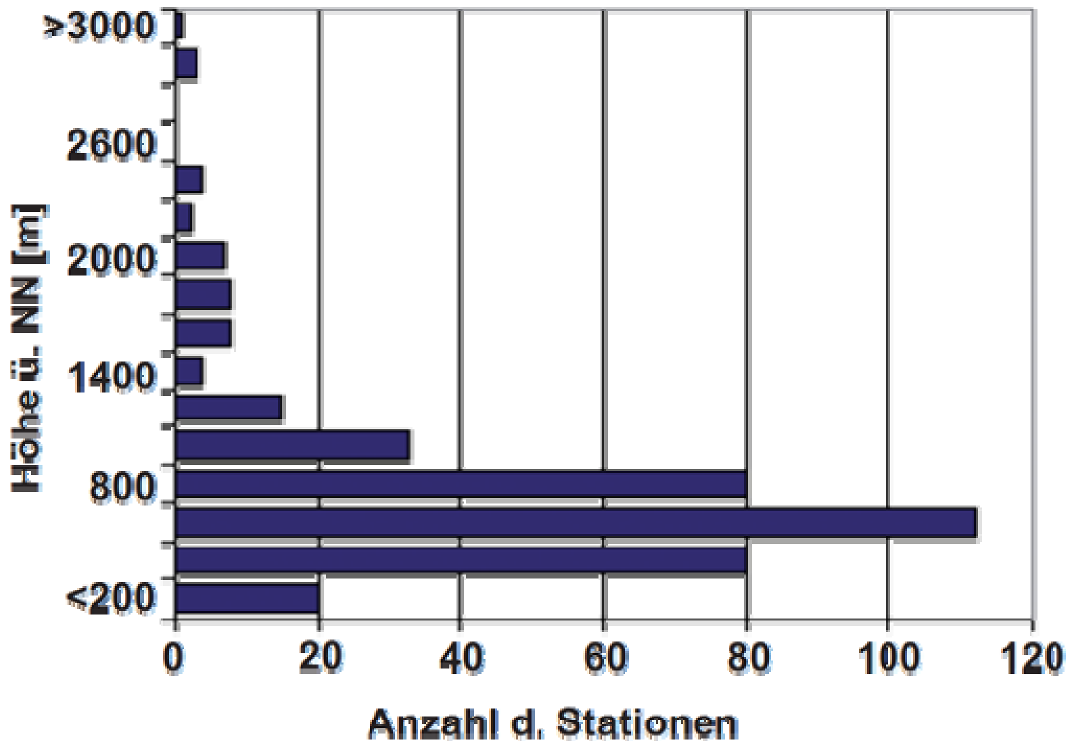




GSQ1: Observations and Predictions of Precipitation

Alpine precipitation measurements are insufficient. Upper Danube River Basin (Matthias Bernhardt, BOKU).



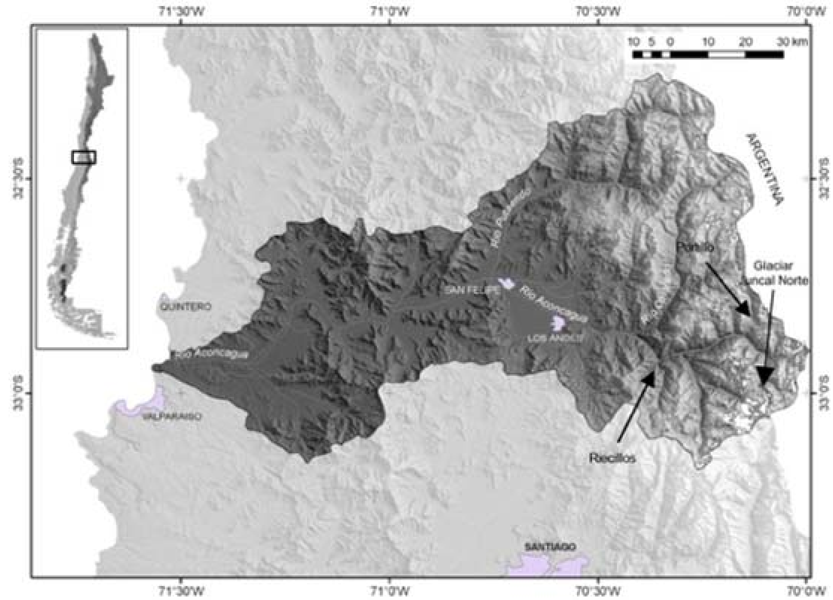


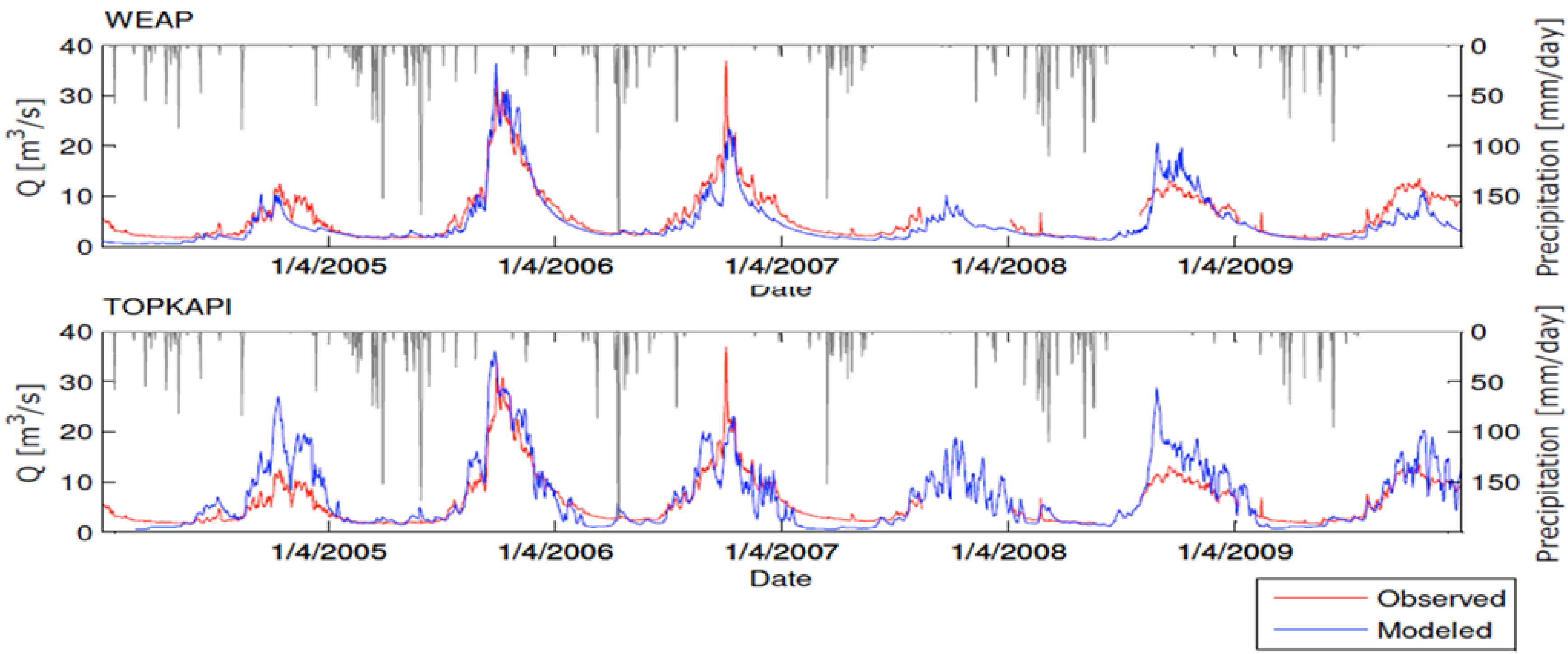
GSQ2: Global Water Resource Systems

Alpine hydrological models for large scale water resource assessments require improved physical basis.

-Example is the Rio Aconcagua in Chile which receives most of its water from the high elevations of the Andes

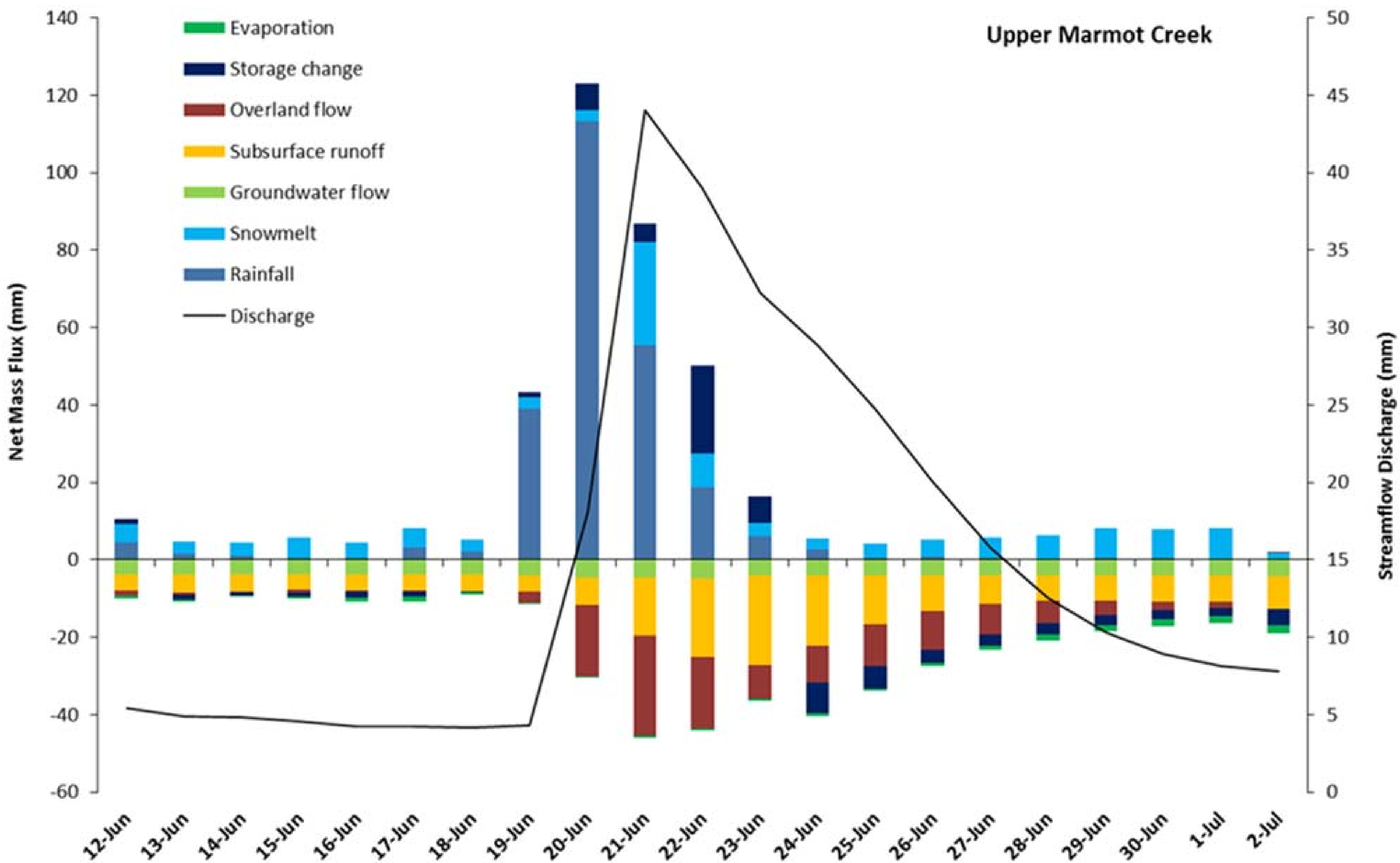
- Conceptual (WEAP) and process-based (TOPKAPI) modelling of the upper Rio Aconcagua Basin (James McPhee, U Chile).



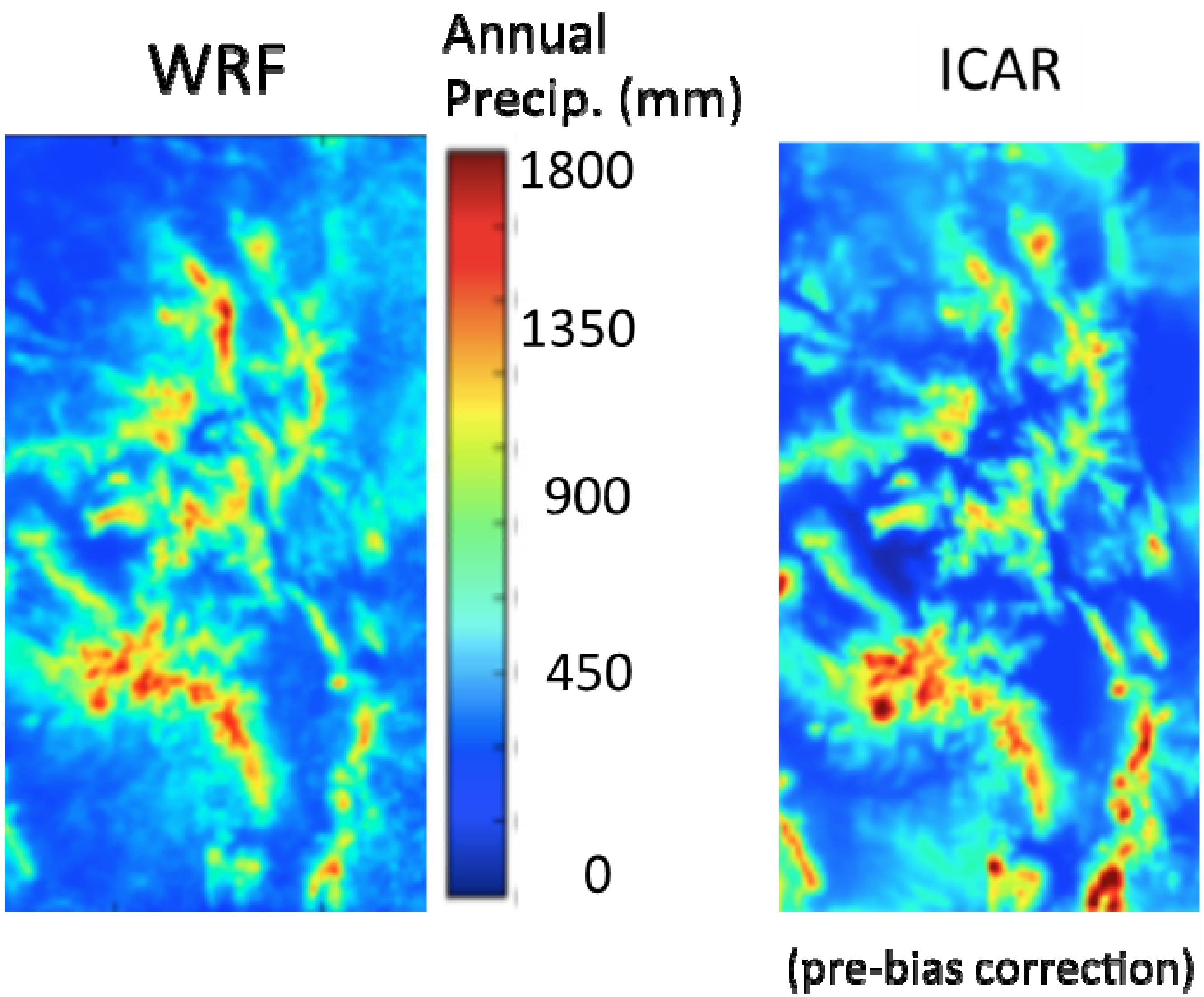


GSQ3: Changes in Extremes

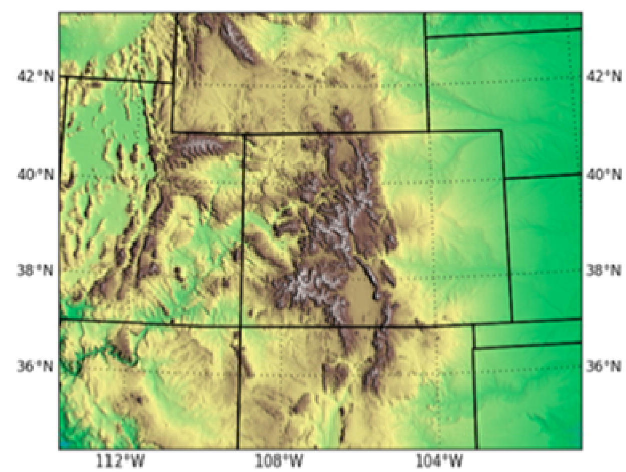
mountain flooding and drought. An example of model diagnosed rain-on-snow mass budgets that contributed to record damaging floods in Canada downstream of the Rocky Mountains in June 2013.



GSQ4: Water and energy cycles

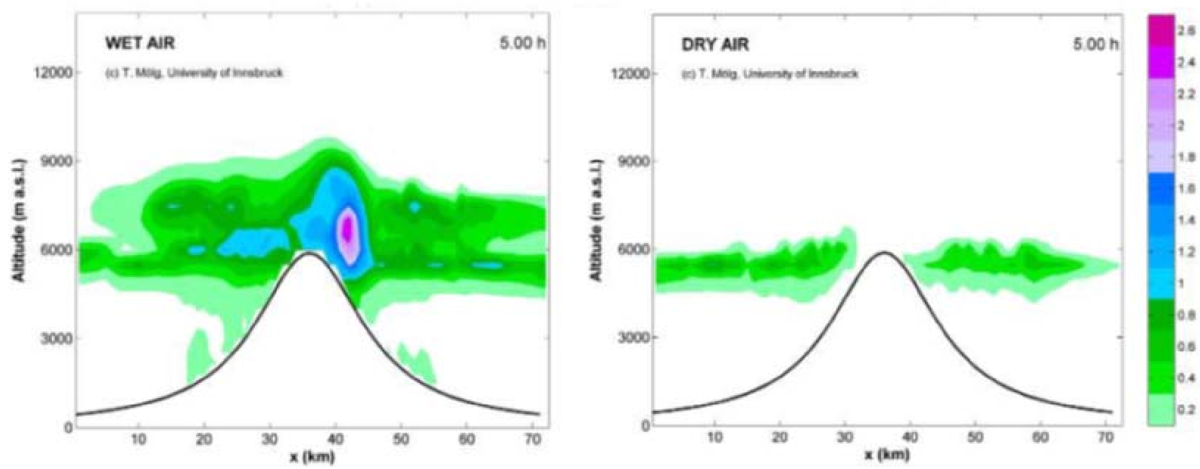


A new Intermediate Complexity Atmospheric Research Model (ICAR) developed at NCAR shows promise at realistic precipitation downscaling at modest computation cost (Ethan Gutmann, NCAR)



WCRP Grand Challenges

Clouds, circulation and climate sensitivity are very uncertain over mountain topography



Mölg et al., **QJRMS** *(2009)*

ACINN
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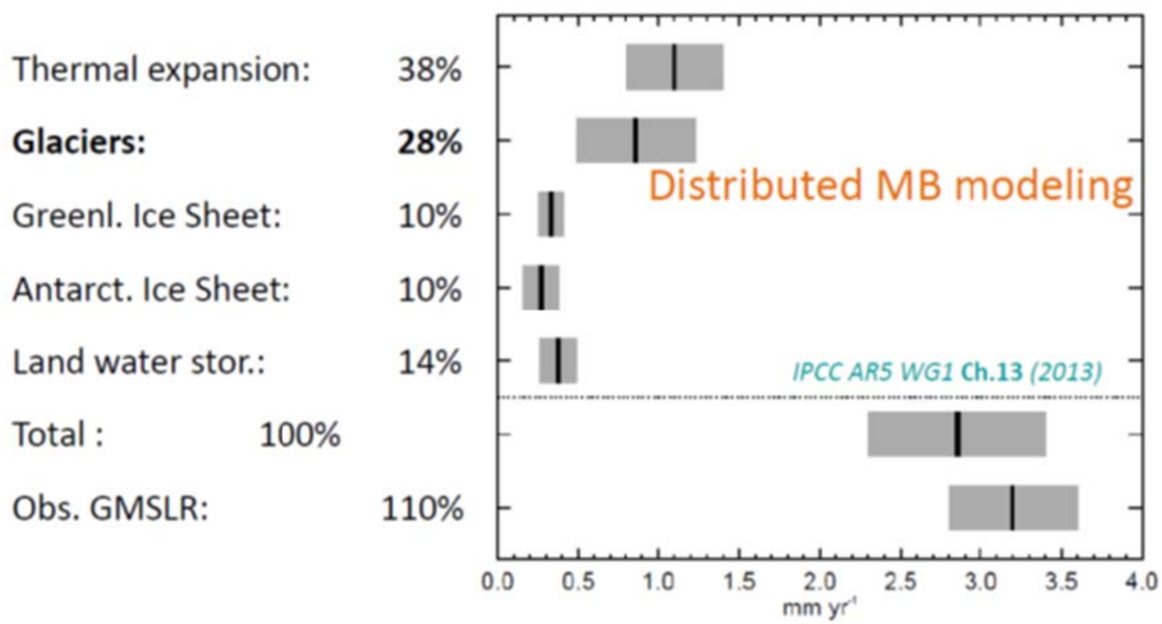
Melting ice and global consequences. The largest ice component is that by mountain glaciers (28% of sea level rise)

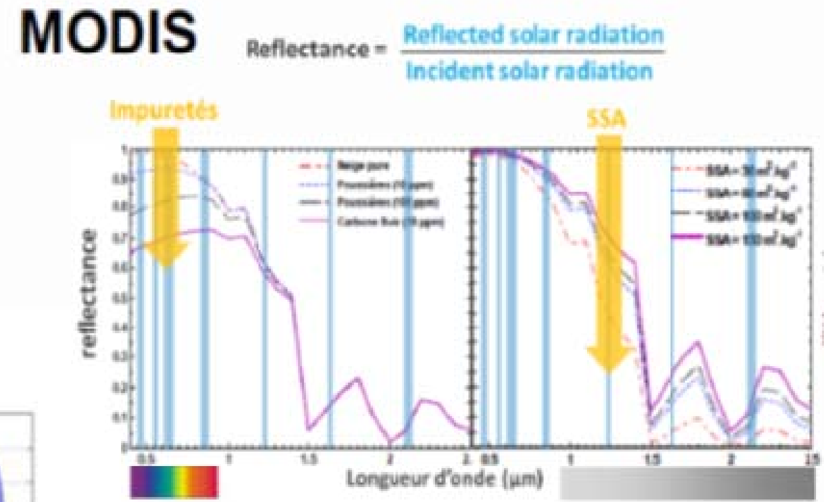
(Georg Kaser)

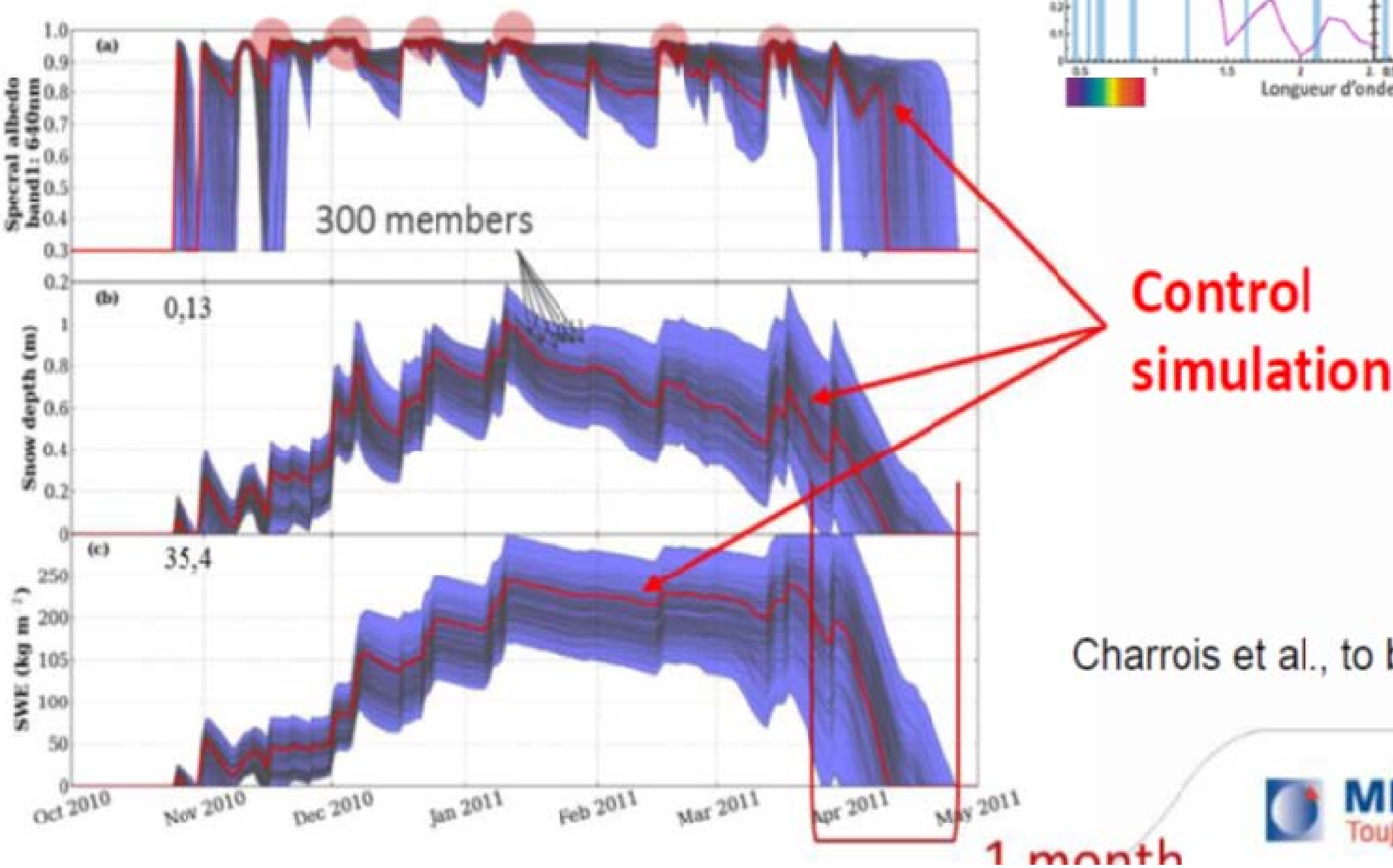
Observes sea level rise 1993-2010:
3.2 mm/year



WCRP Grand Challenges

Understanding and predicting weather and climate extremes



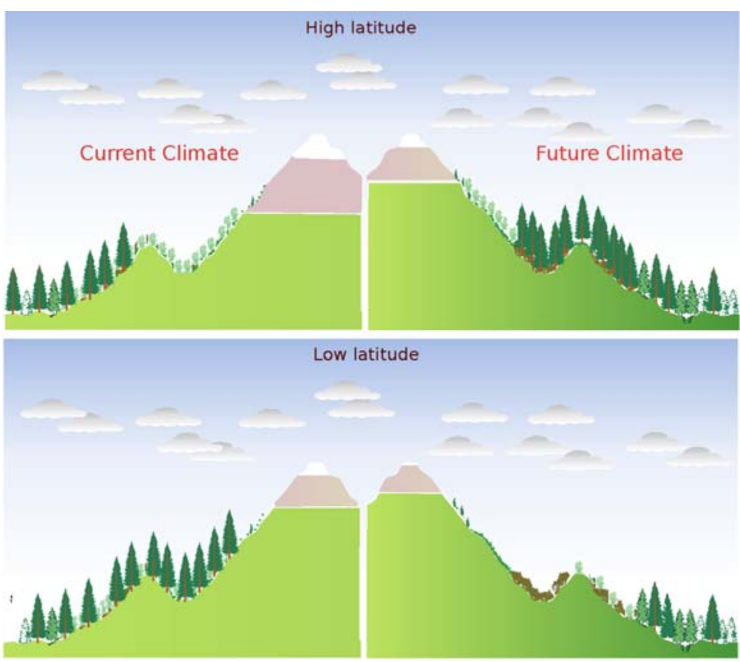


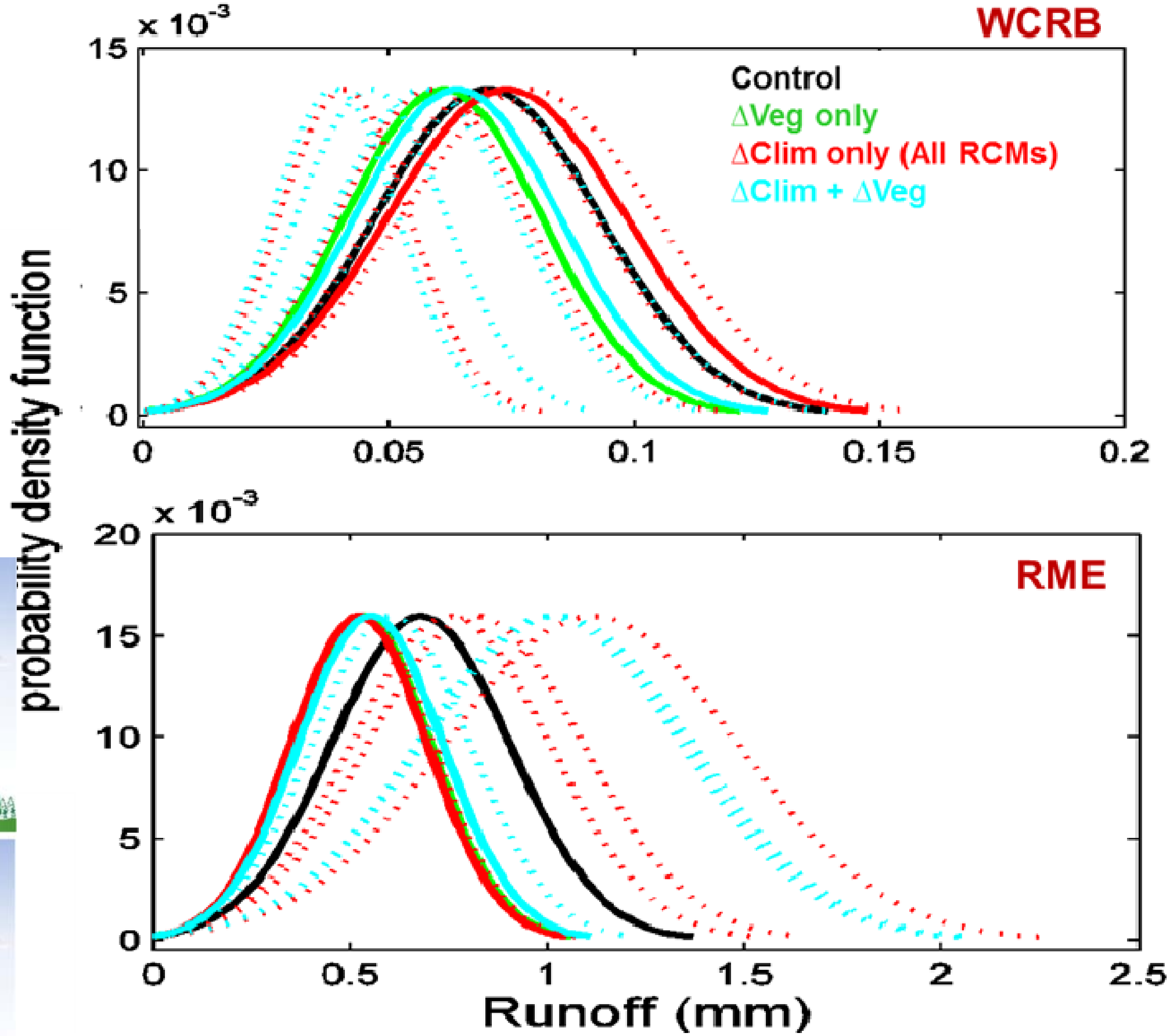
Charrois et al., to be submitted

METEO FRANCE
Toujours un temps d'avance

WCRP Grand Challenges

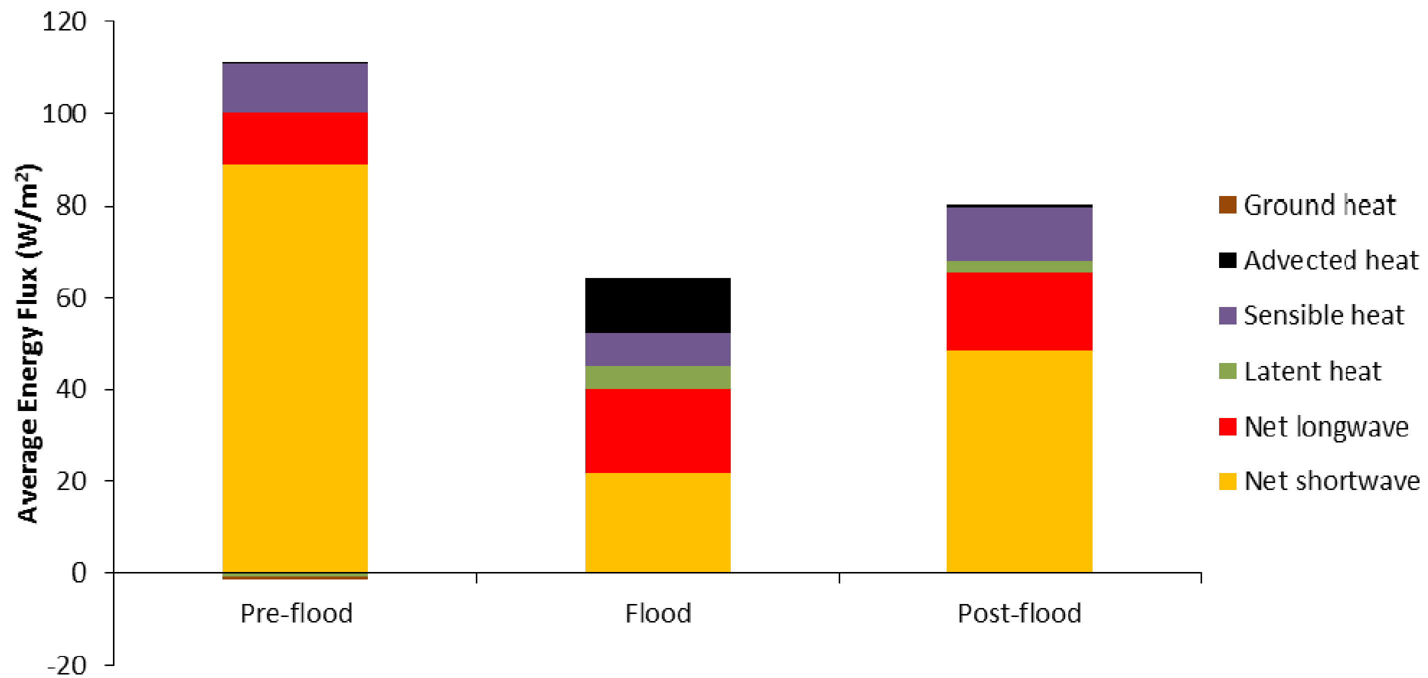
Changes in water availability with rising temperature, changing precipitation and transient changes to vegetation cover in mountains.
Wolf Creek Research Basin, Yukon, Canada (61 oN)
Reynolds Mountain East Basin, Idaho, USA (43 oN)





Kabir Rasouli

Estimating Atmospheric Transmittance for Radiation Simulation in Mountain Environments (Dhiraj Pradhananga, UofS)

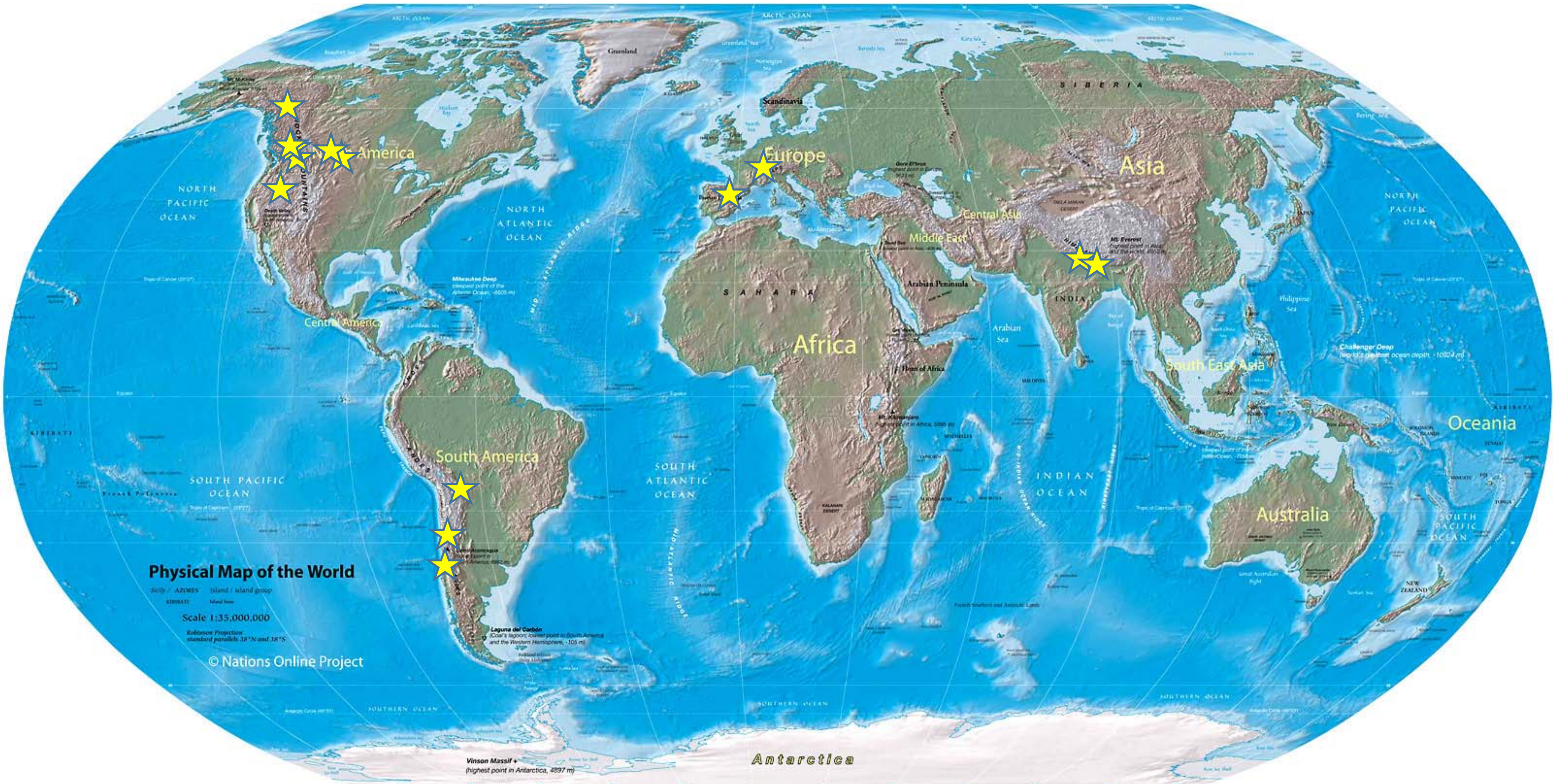


$$\tau = f(\sqrt{\Delta t}, \overline{RH}, Alt)$$

Temperature-Humidity-Elevation (THE) Model

THE Model Test and Development:

- Solar radiation, T, RH measurements at 22 sites from North America (Canada & USA)
- 5 sites from Europe and South America
- 3 sites in Nepal Himalaya

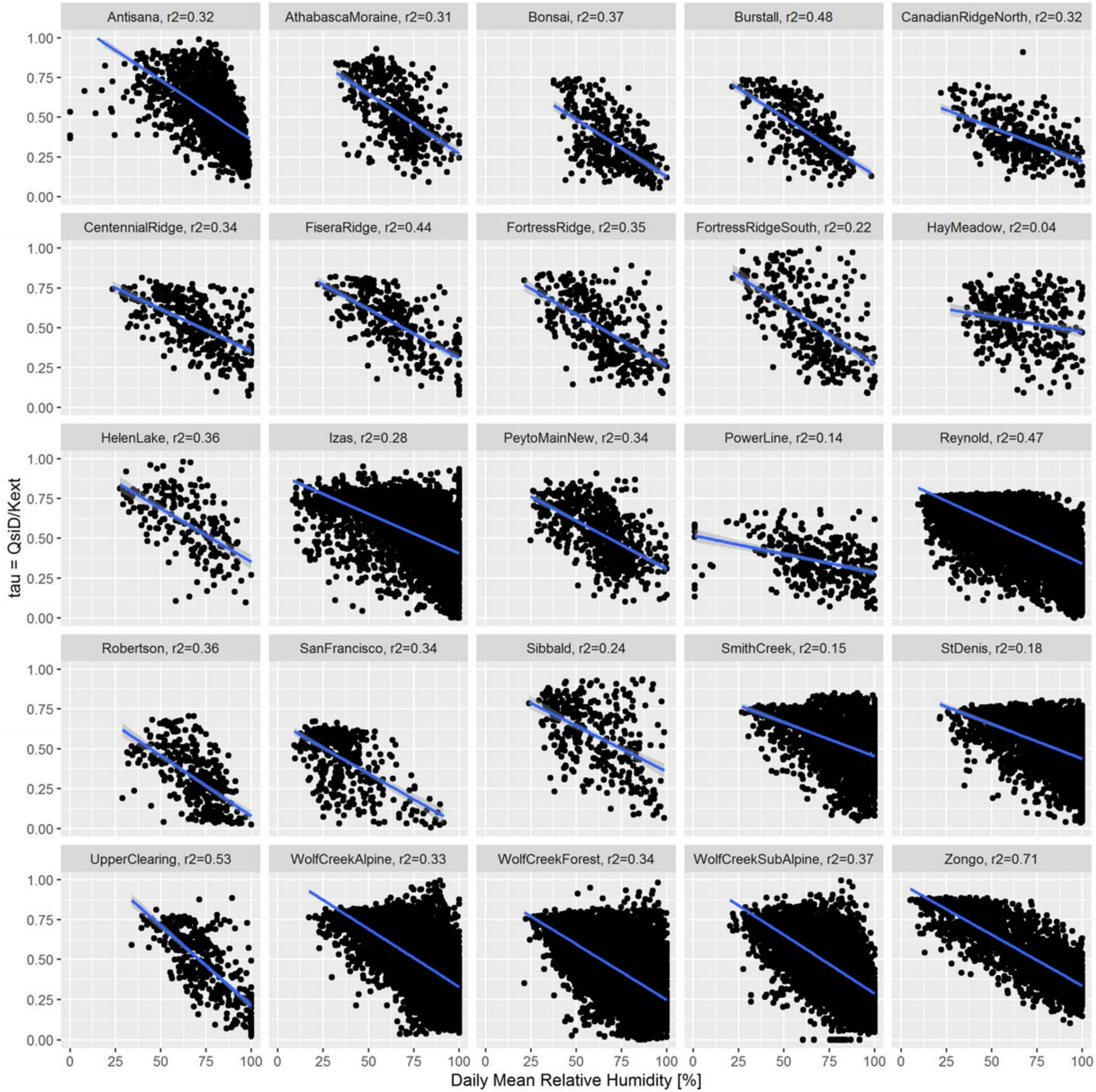


Transmittance declines with RH

τ

vs

$\overline{RH}$

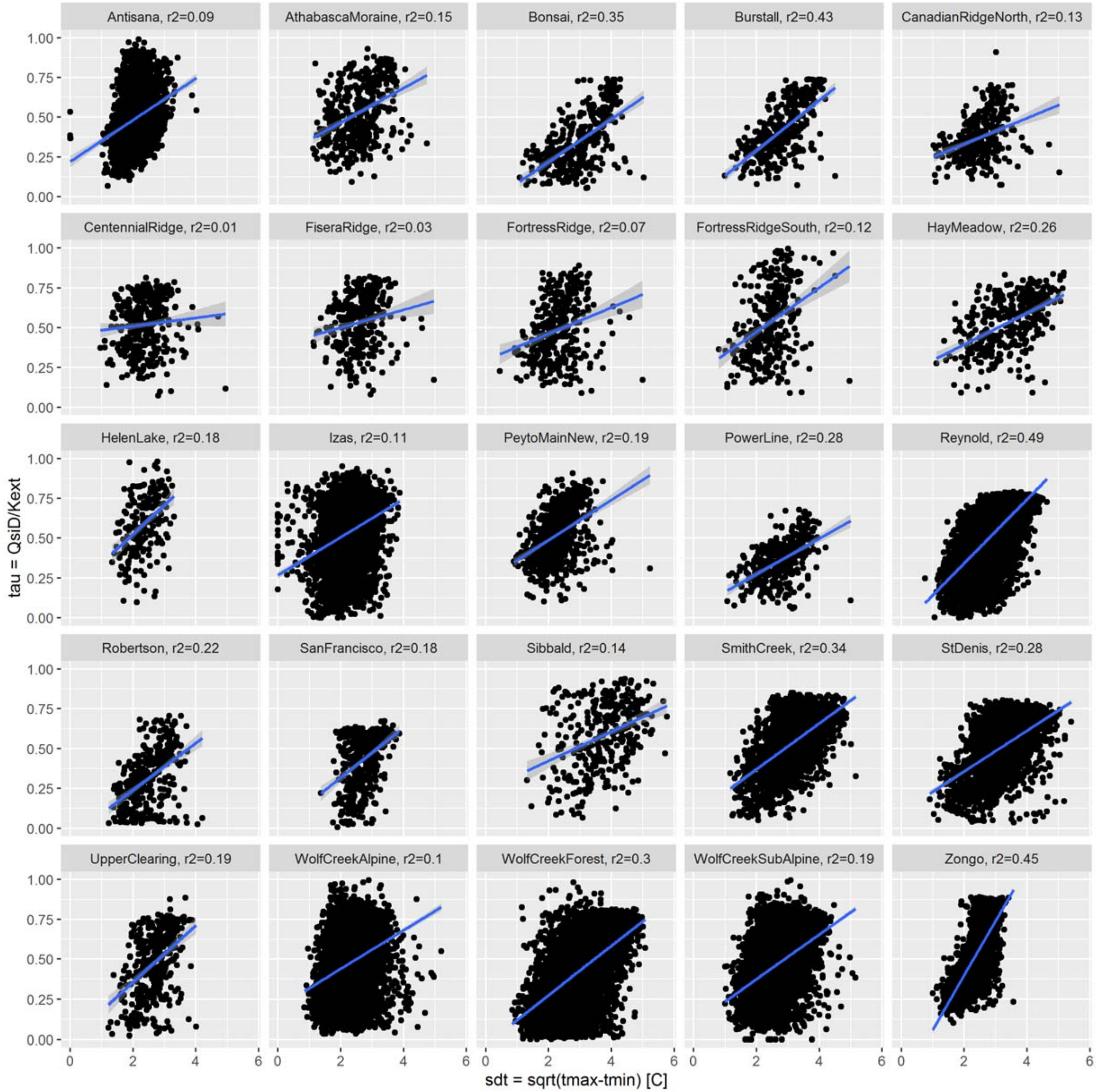


Transmittance increases with daily temperature range

τ

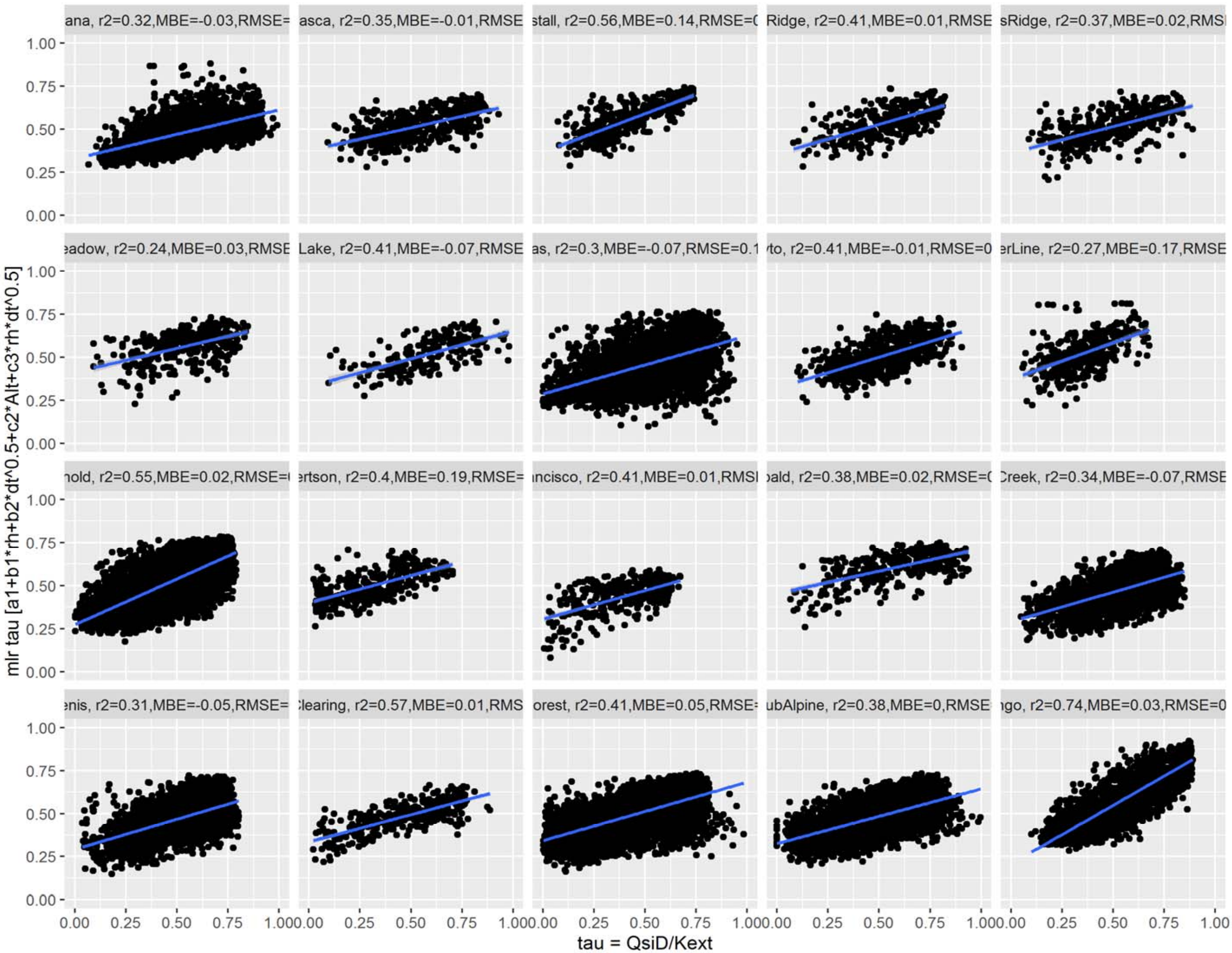
vs

$\sqrt{\Delta T}$

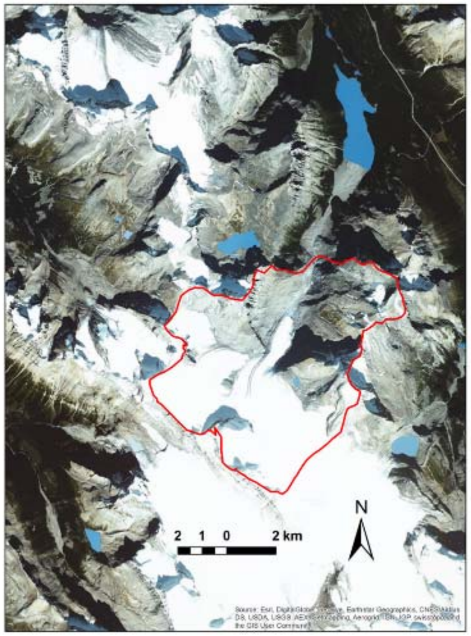


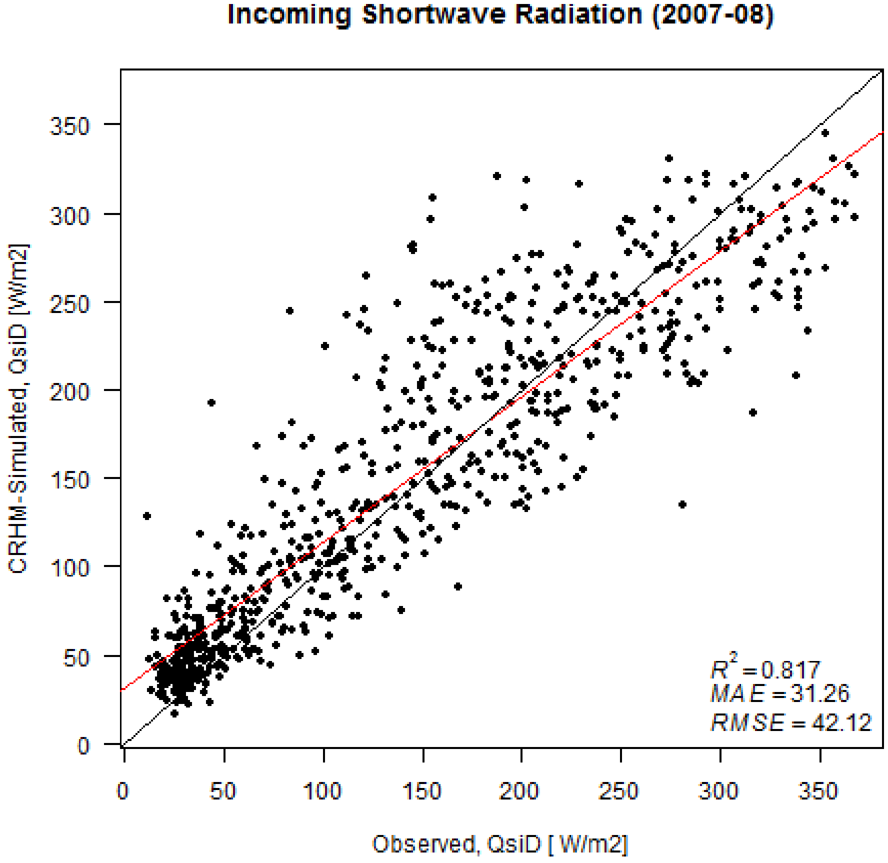
Obs τ vs *THE Model* τ

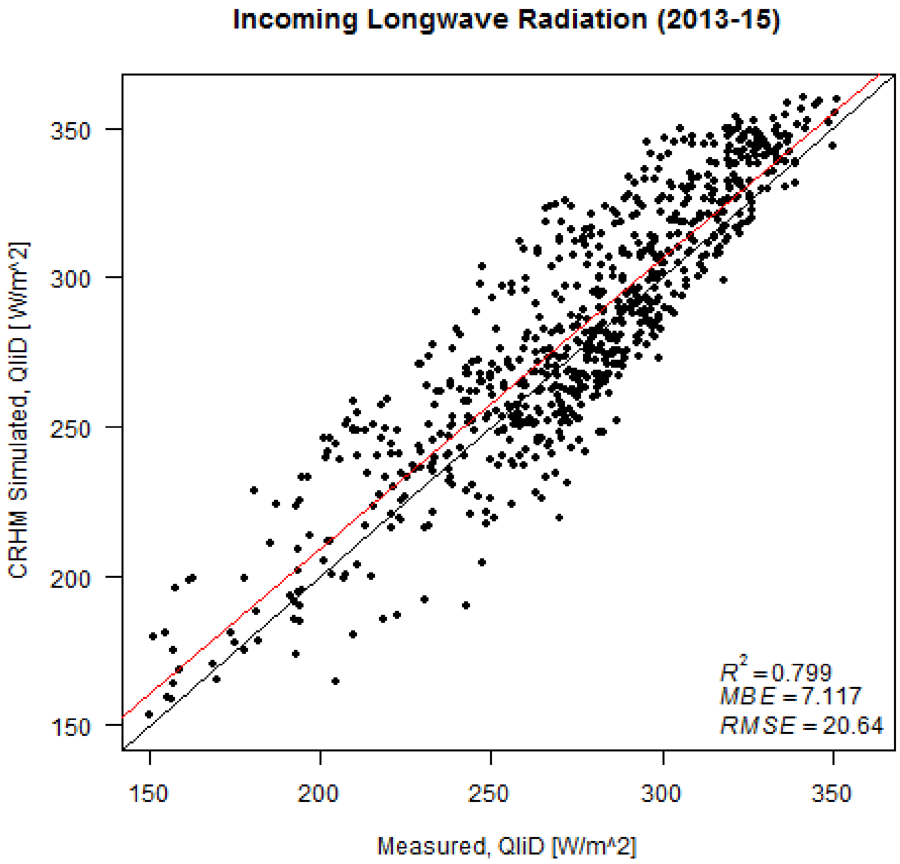
$\tau = a_1 + b_1 \cdot rh + b_2 \cdot \Delta T^{0.5} + c_2 \cdot Alt + c_3 \cdot rh \cdot \Delta T^{0.5}$



THE Model permits synthesis of short and longwave radiation in high altitude environments

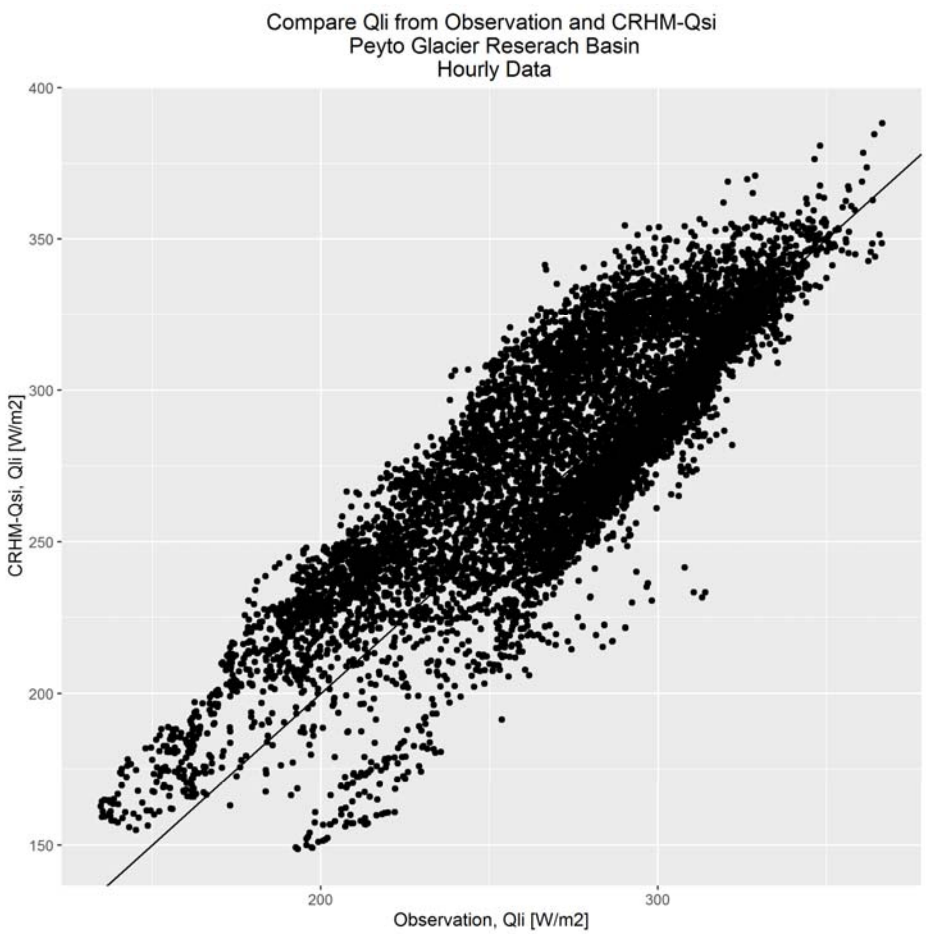


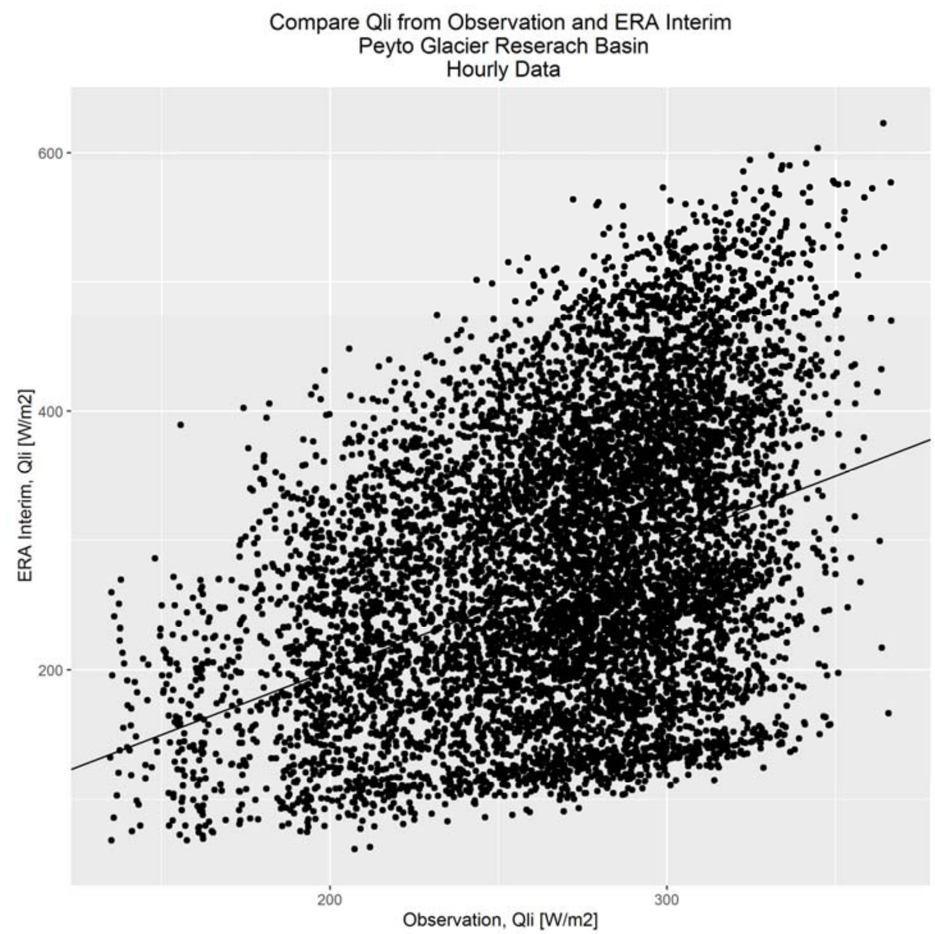




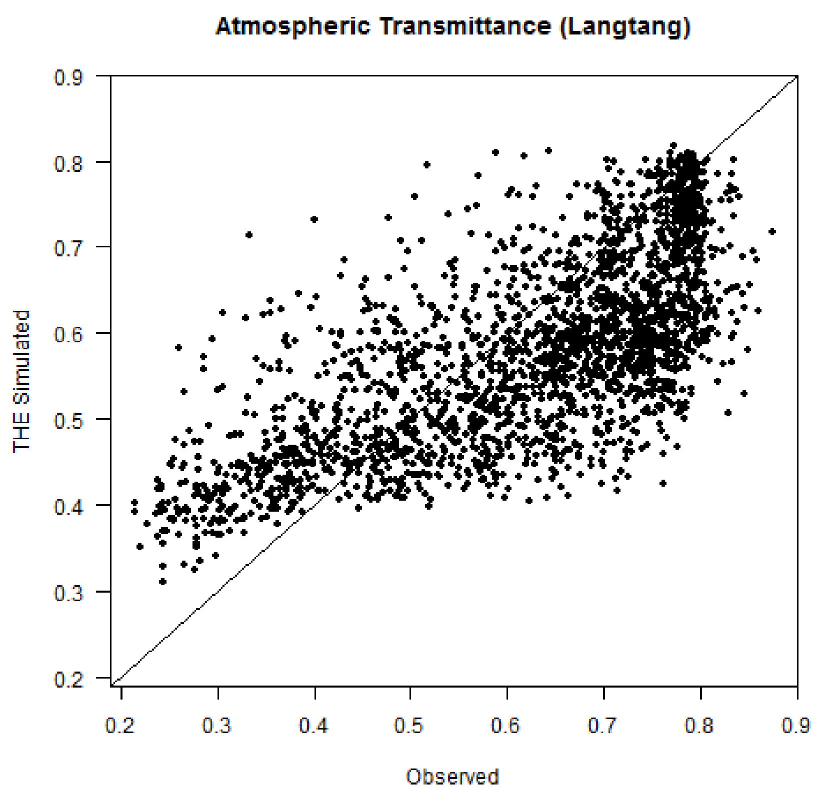
Tests at Peyto Glacier, Canada

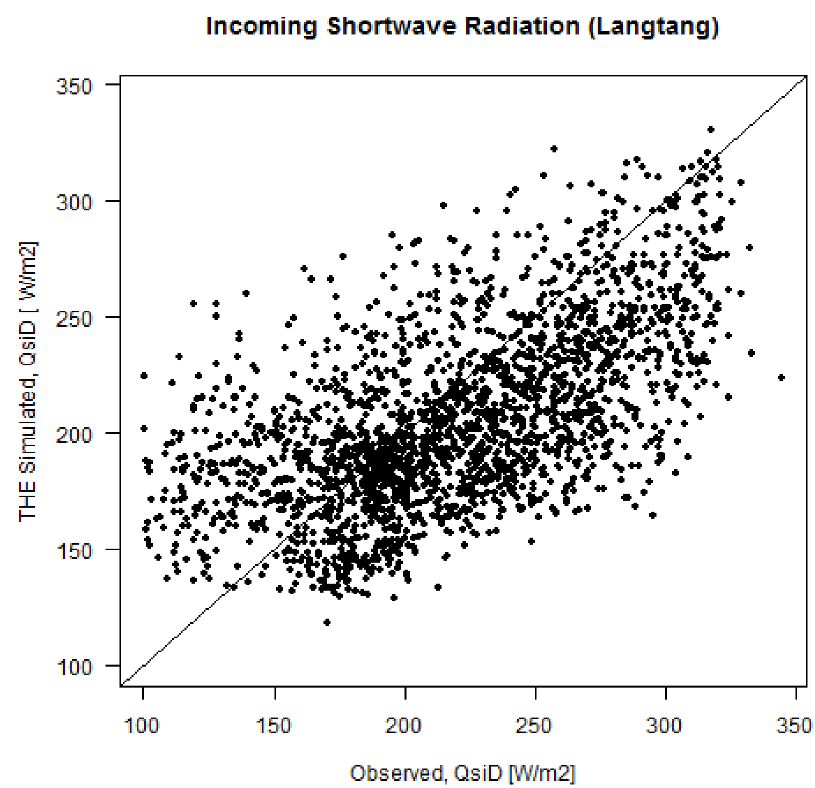
Compare Qli from THE with Sicart algorithm in CRHM with ERA-Interim





Initial Tests in TPE: Langtang (Kyangjin)





INARCH Next Steps

- Special Issue of *Earth System Science Data.*
- Mountain downscaling toolbox – CORDEX, May 2016
- Synthesis paper on diagnosing the sensitivity of global alpine snow regimes to warming temperatures.
- Review paper on advances in alpine hydrology.
- Encourage expansion of global hydroclimate projects to mountain areas

- Second workshop 6-7 Oct 2016 – Grenoble, France

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