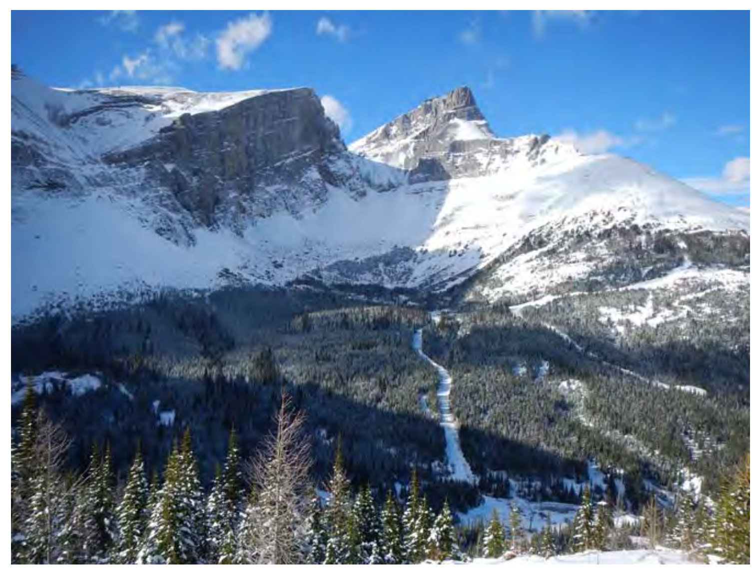
INARCH:
International Network for Alpine Research Catchment Hydrology

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

www.usask.ca/hydrology john.pomeroy@usask.ca

Urgency

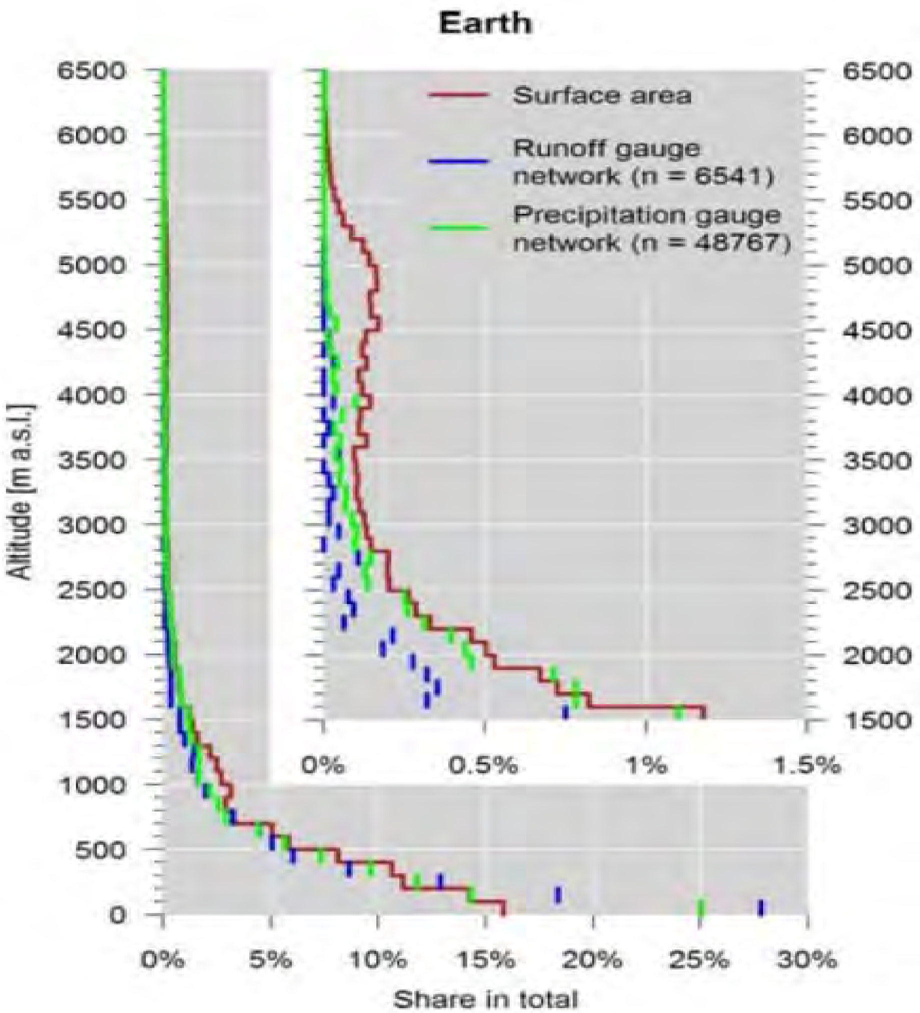
- to IPCC (2014) WG II report – "***In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality"***
- Alpine catchments receive and produce a disproportionately large fraction of global precipitation and runoff.
- Snowfall *does not equal accumulation on the ground!*
- Snow, ice, and phase change domination of alpine hydrology means that it is especially sensitive to temperature change.

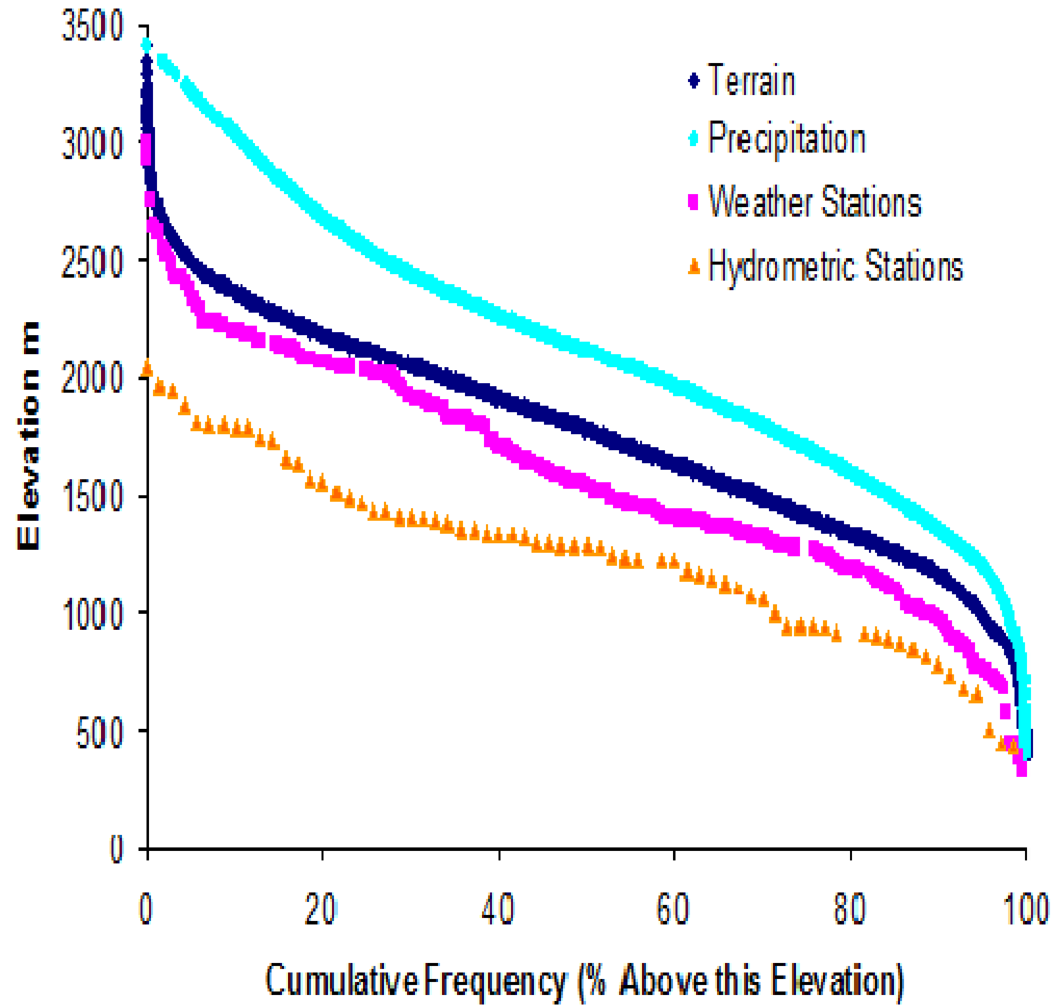


Significance

- Ongoing change in climate has already resulted in shorter seasonal snowcover duration, earlier spring hydrographs, greater rainfall fraction of total precipitation, glacier volume decline, ground thaw and woody vegetation increase in many alpine catchments.
- Some alpine catchments are contributing to higher frequency of floods and/or droughts.

Alpine Regions are Data Scarce





Left Side: (Viviroli et al. 2011).
Right Side: (Pomeroy, Sinclair – in preparation).

Objective

To better understand alpine cold regions hydrological processes, improve their prediction, diagnose their sensitivities to global change and find consistent measurement strategies.

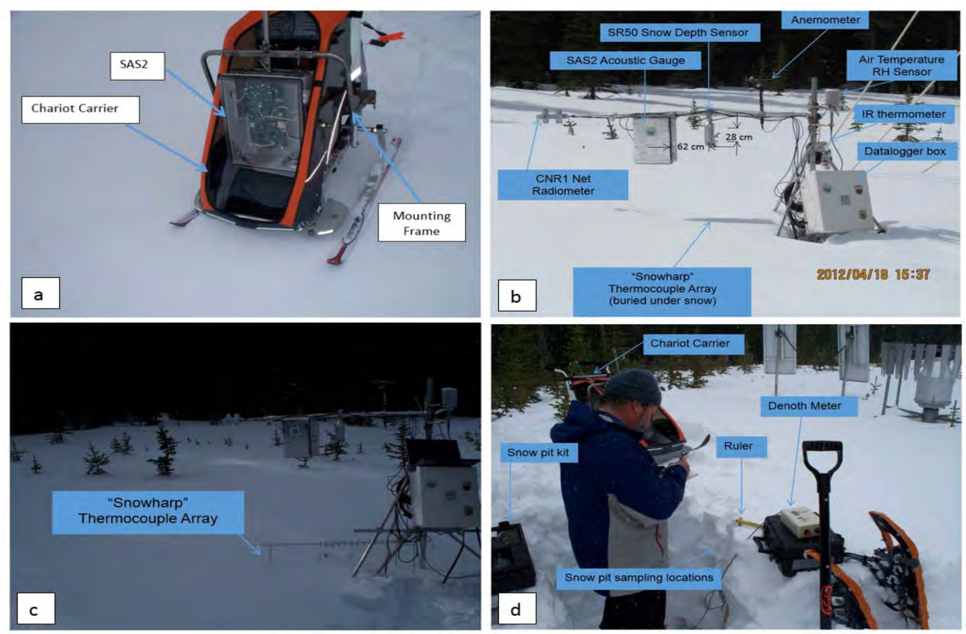
Sub-Objectives

1. How different are the measurement standards and how do these affect scientific findings?
2. How do the predictability, uncertainty and sensitivity of alpine catchment energy and water exchange vary with changing atmospheric dynamics?
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 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?

Data Requirements

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

- openly-available detailed meteorological and hydrological observational archives from long-term research catchments at high temporal resolution in selected heavily instrumented alpine regions,
- atmospheric model reanalyses,
- downscaled climate model as well as regional climate model outputs.



Activities

1. Facilitate exchange and collaboration
2. Improve algorithm development.
3. Examine hydrological model sensitivity to atmospheric change.
4. Demonstrate improvements to model predictability.
5. Evaluate mountain forcing fields.
6. Evaluate downscaling schemes.
7. Foster research and development.
8. Facilitate education and training.

AGU Fall Meeting 2015 - Session C027: Improved Understanding and Prediction of Mountain Hydrology through Alpine Research Catchments

Earth Syst. Sci. Data, 4, 13–21, 2012
www.earth-syst-sci-data.net/4/13/2012/
doi:10.5194/essd-4-13-2012

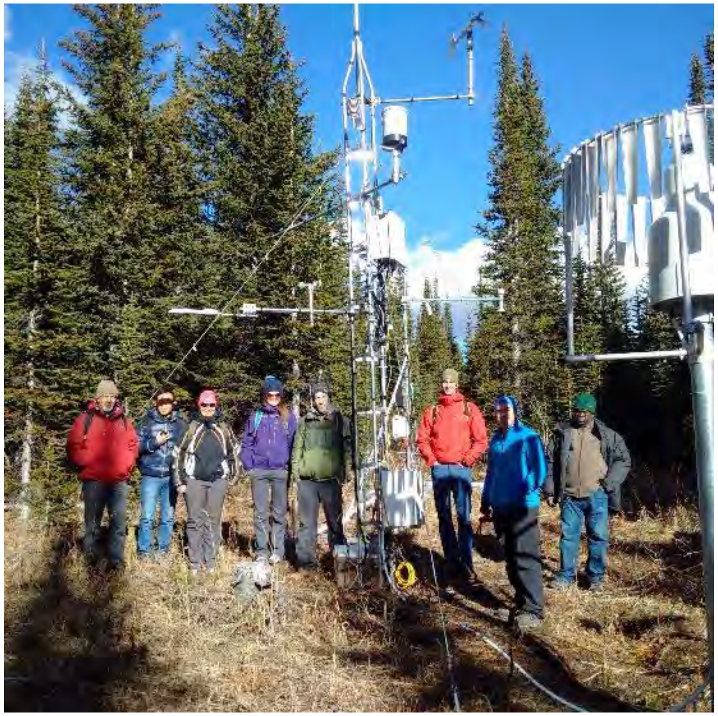
Open Access Earth System Science Data

An 18-yr long (1993–2011) snow and meteorological dataset from a mid-altitude mountain site (Col de Porte, France, 1325 m alt.) for driving and evaluating snowpack models

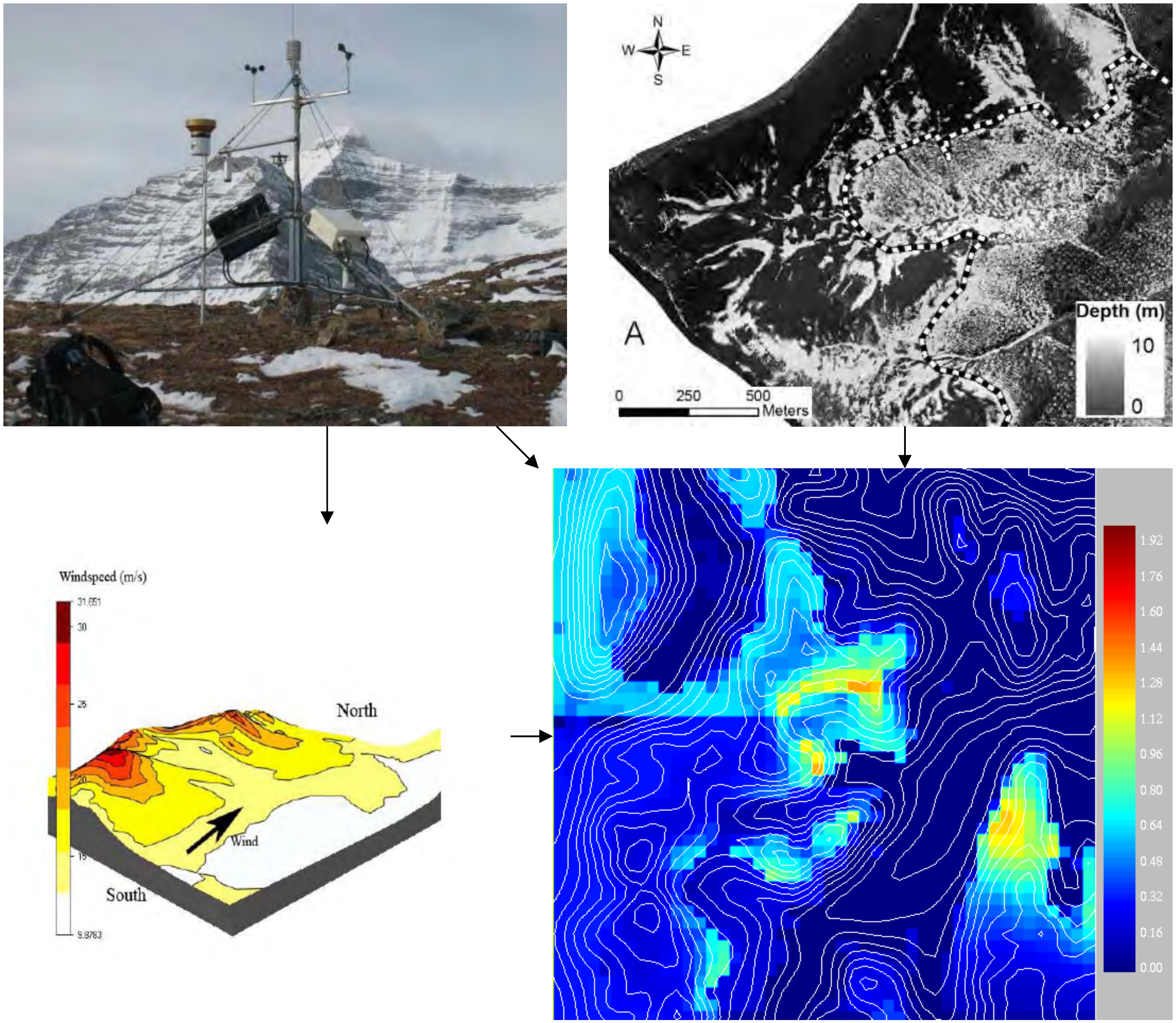
S. Morin[1], Y. Lejeune[1], B. Lesaffre[1], J.-M. Panel[1], D. Poncet[1], P. David[1,†], and M. Sudul[1,†]
[1]Météo-France – CNRS, CNRM-GAME, URA1357, CEN, Grenoble, France
[†]deceased

Correspondence to: S. Morin (samuel.morin@meteo.fr, col_de_porte@meteo.fr)

Received: 16 January 2012 – Published in Earth Syst. Sci. Data Discuss.: 6 February 2012
Revised: 31 May 2012 – Accepted: 9 June 2012 – Published: 6 July 2012

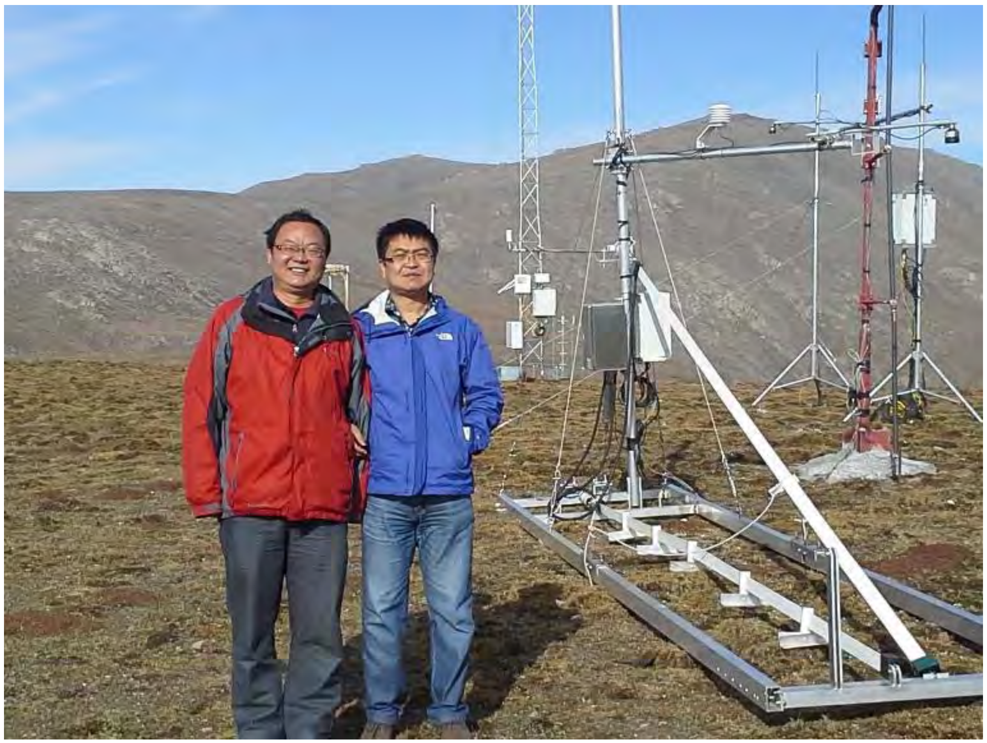


Integrated Alpine Observing & Predicting Systems - IAOPS



Instrumented alpine catchments with, remote sensing, atmospheric modelling, downscaling, data assimilation in order to better evaluate mountain water and energy exchange.

International Collaboration through Field & Model Experiments



Upper Heihe River Basin, 4150 m China

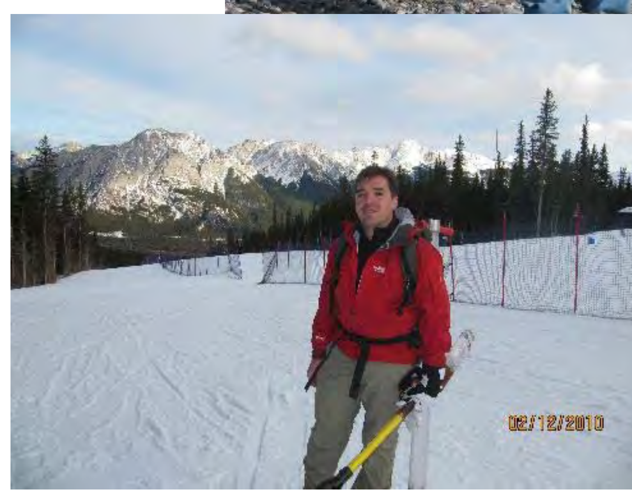
Zugspitze, 2650 m Germany

INARCH Scientific Steering Group

- •Matthias Bernhardt (BOKU, Austria)
- •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)
- •John Pomeroy (Univ Saskatchewan, Canada)*

*chair

- •Ulli Strasser (Univ Innsbruck, Austria)
- •Vincent Vionnet (Meteo-France, France)

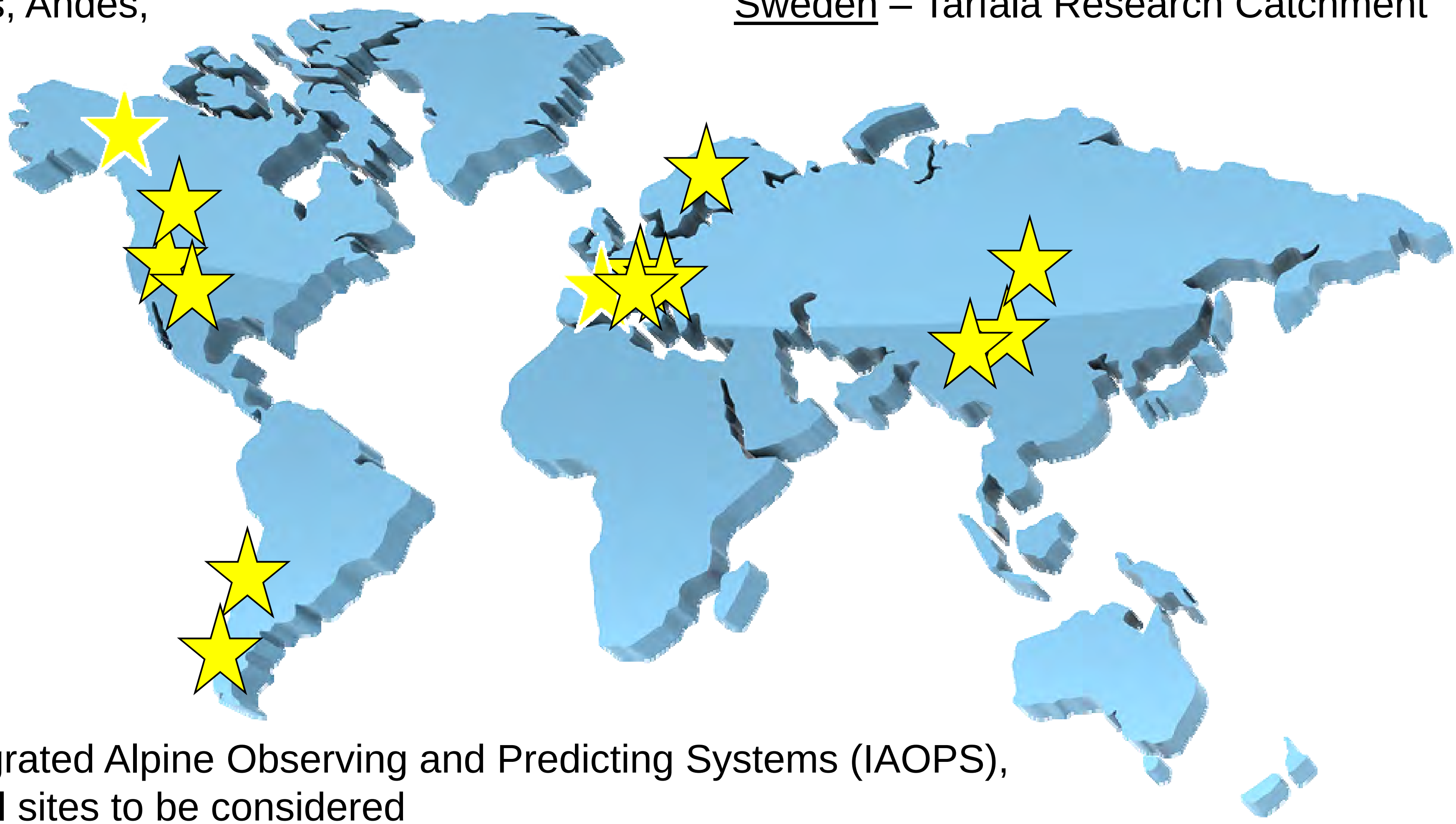


INARCH Participants

- Lugwig Braun, Bavarian Academy of Sciences & Humanities, Germany
- Karsten Schulz, BOKU, Vienna, Austria
- Matthias Bernhardt, BOKU, Vienna, Austria
- Xin Li, CAREERI, Chinese Academy of Sciences, Lanzhou, China
- Richard Harding, Centre for Ecology & Hydrology, Wallingford, England
- James McPhee, Dept. of Civil Engineering, University of Chile, Santiago, Chile
- Nick Rutter, Dept. of Geography, University of Northumbria, Newcastle, England
- Peter Jansson, Dept. of Physical Geography, Stockholm University, Sweden
- Joseph Shea, ICIMOD, Nepal
- Ignacio Lopez Moreno – CSIC, Institute for Pyrenean Ecology, Zaragoza, Spain
- Yaoming Ma, Institute for Tibetan Plateau, Chinese Academy of Sciences, Beijing, China
- Vincenzo Levizzani, Institute of Atmospheric Sciences & Climate, Bologna, Italy
- Thomas Painter, NASA JPL, Pasadena, USA
- Francesca Pellicciotti, ETH, Zurich, Switzerland
- Samuel Morin, CNRM, Meteo-France, Grenoble, France
- Ethan Gutmann, NCAR, Boulder, USA
- Sara Skiles, NASA JPL, Pasadena, USA
- Ulrich Strasser, Institute of Geography, University of Innsbruck, Austria
- Georg Kaser, Institute of Meteorology & Geophysics, University of Innsbruck, Austria
- Anil Mishra, International Hydrological Programme, UNESCO, Paris, France
- Isabella Zin, LTHE, Grenoble, France
- Vincent Vionnet, Meteo-France, Grenoble, France
- Martyn Clark, NCAR, Boulder, USA
- Roy Rasmussen, NCAR, Boulder, USA
- Richard Essery, School of Geosciences, University of Edinburgh, Scotland
- Tobias Jonas, SLF, Davos, Switzerland
- Walter Immerzeel, Universiteit Utrecht, Netherlands
- Danny Marks, USDA ARS, Boise, USA
- Alain Pietroniro, Water Survey of Canada, Environment Canada
- Rick Janowicz, Yukon Environment, Canada
- Alexander Gelfan, Russian Academy of Sciences, Moscow, Russia
- Howard Wheater, Global Institute for Water Security, University of Saskatchewan, Canada
- Julie Theriault, Université du Quebec a Montreal, Montreal, Canada
- Koen Verbist, UNESCO, Santiago, Chile
- Stephen Dery, University of Northern British Columbia, Prince George, Canada

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 Crysophere Watch
- 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)

1st Workshop - October, 2015

- Global Review of Alpine Observations
  - Recommend common measurement strategies
  - Promote collaboration
  - Assess archiving and access to datasets
- Review role of groundwater, glaciers and snow in alpine hydrology
  - What are persistent uncertainties?
  - How might these be reduced?
- Assessment of modelling
  - How can we test and improve model physics, downscaling and parameterisation?\
- Modelling Changing Alpine Hydrology and Climate
  - How sensitive are alpine snow and ice regimes around the world to global change?
- Network structure and future activities
- "Statement" for Year 1 of INARCH

INARCH Update – Nov 17 2015

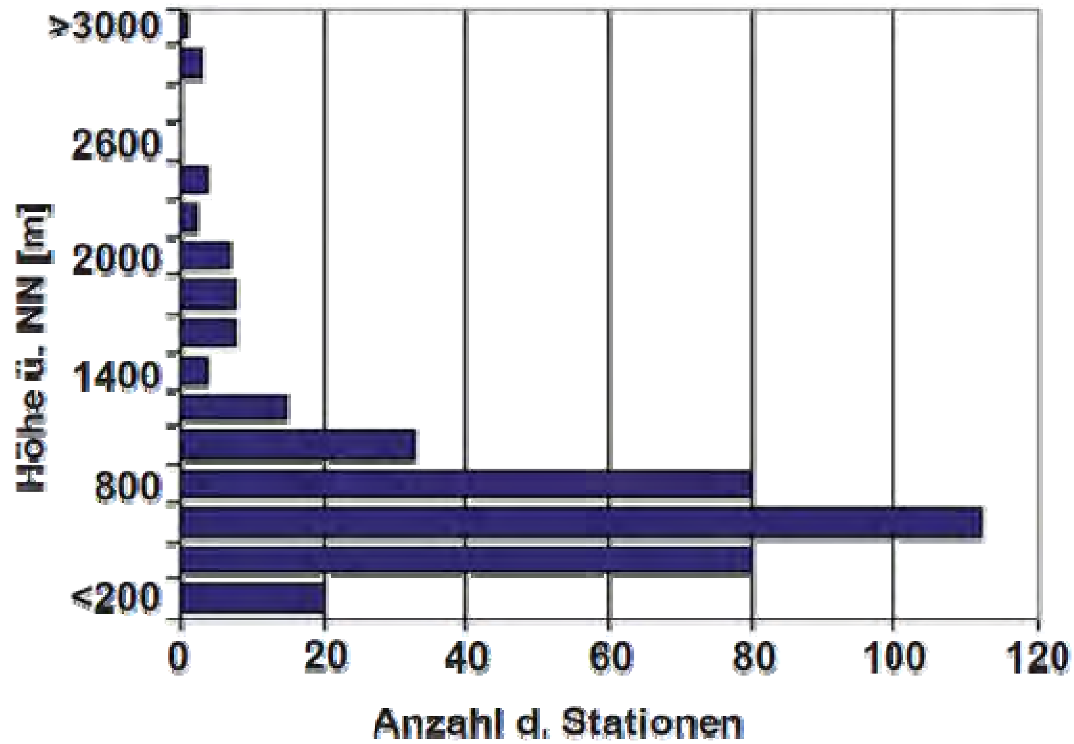
- INARCH was approved as a Cross-cut Project by the GEWEX Hydroclimate Panel at Pasadena, California in December 2014
- INARCH provides mountain snow and ice water security information for UNESCO's International Hydrological Programme
- INARCH's objective is to better understand alpine cold regions hydrological 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 will hold its next scientific activity as Poster Session C33A & 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

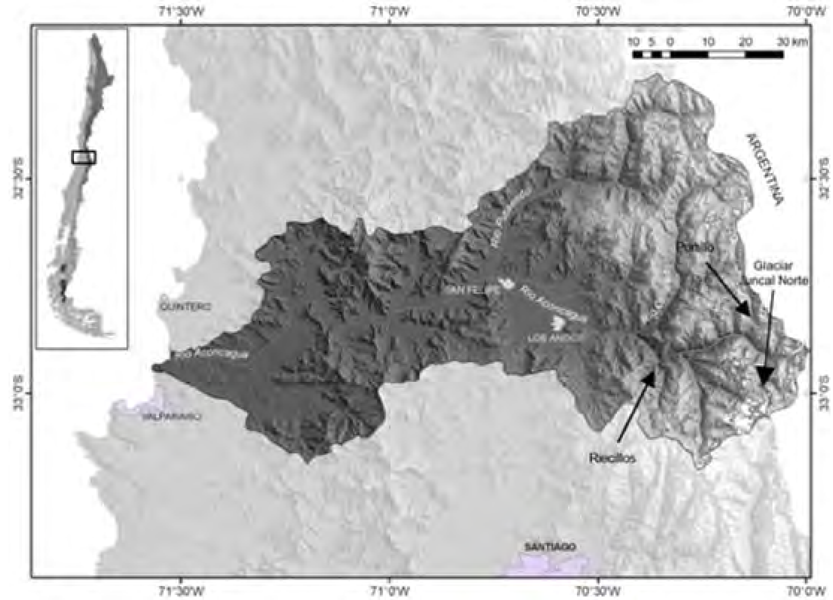
GEWEX's INARCH is launched and has broad participation and support from scientists studying mountain regions around the world.

GSQ1: Observations and Predictions of Precipitation

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



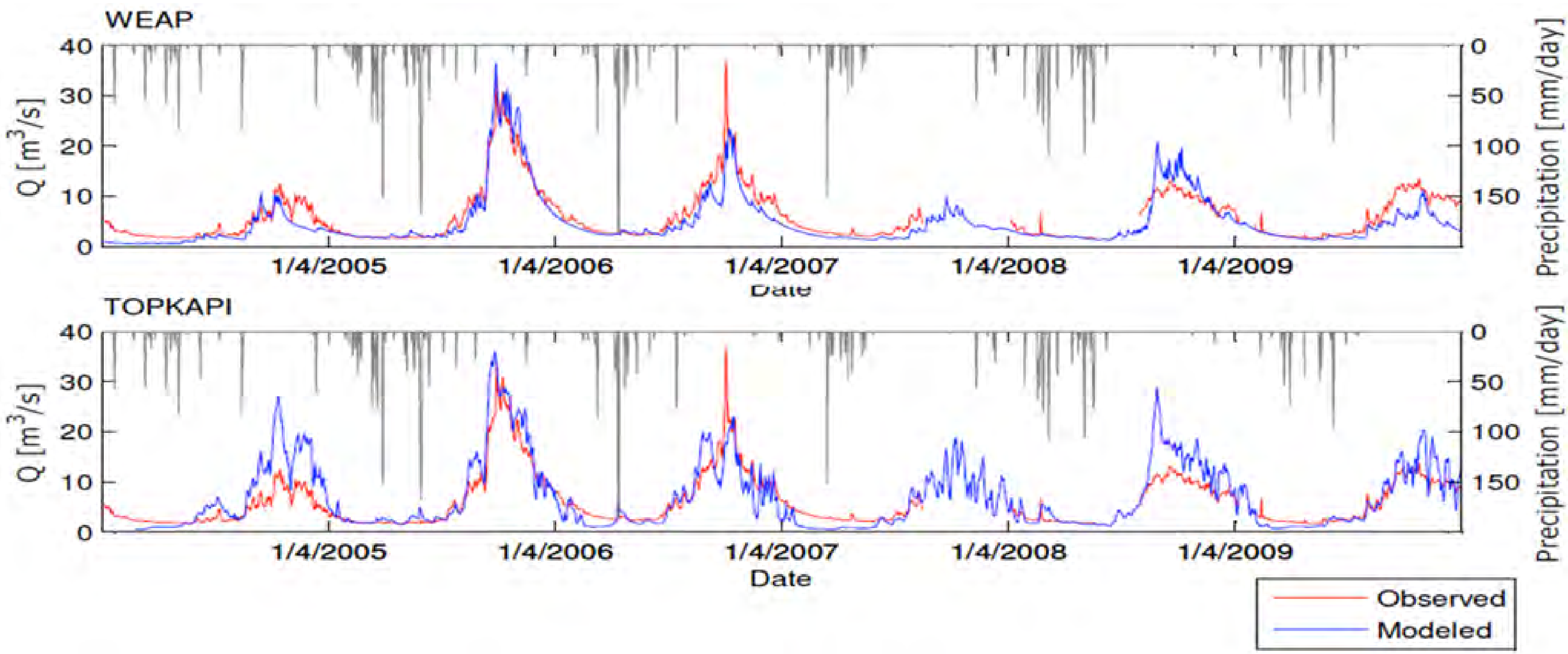
GSQ2: Global Water Resource Systems



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

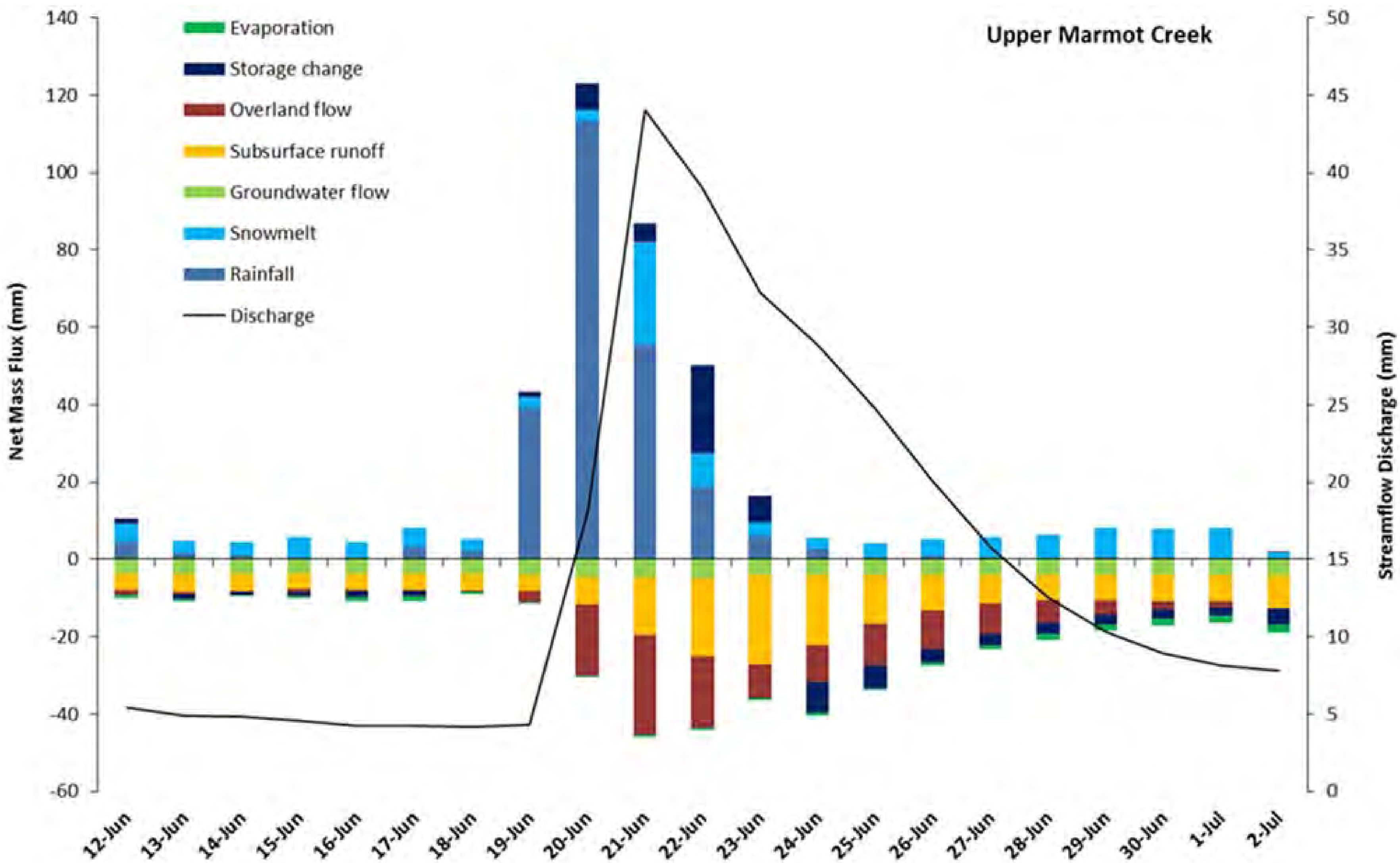
-Example is the Rio Aconcagua in Chile which receives most of its water from the high elevations of the Andes

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

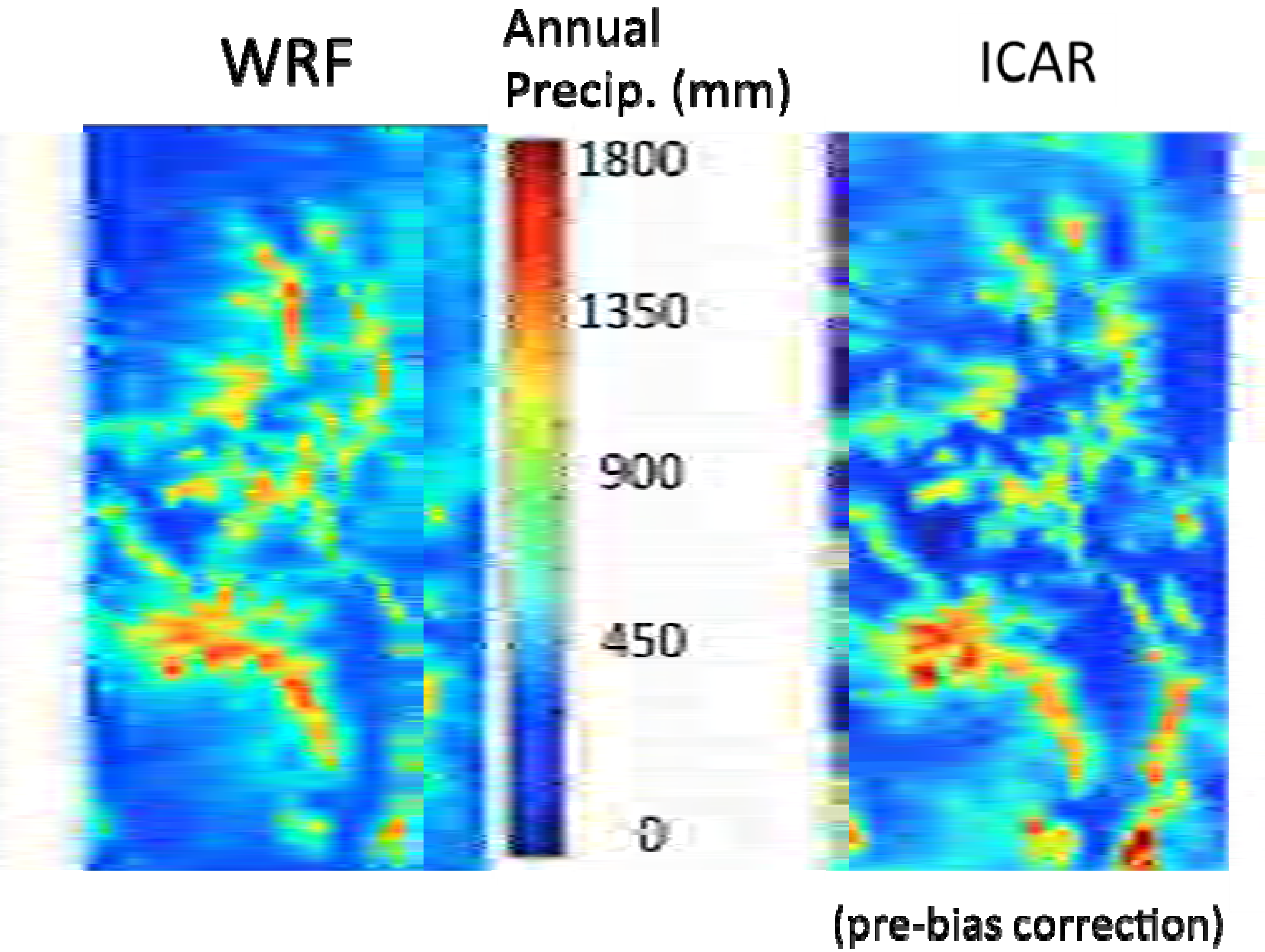


GSQ3: Changes in Extremes

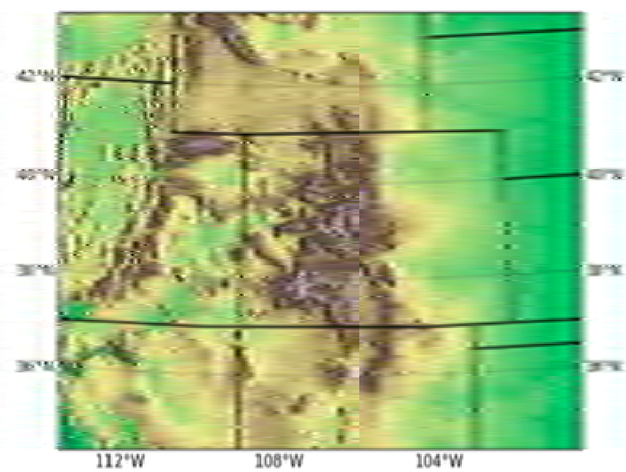
mountain flooding and drought. An example of model diagnosed rain-on-snow mass budgets that contributed to record damaging floods in Canada downstream of the Rocky Mountains in June 2013.



GSQ4: Water and energy cycles

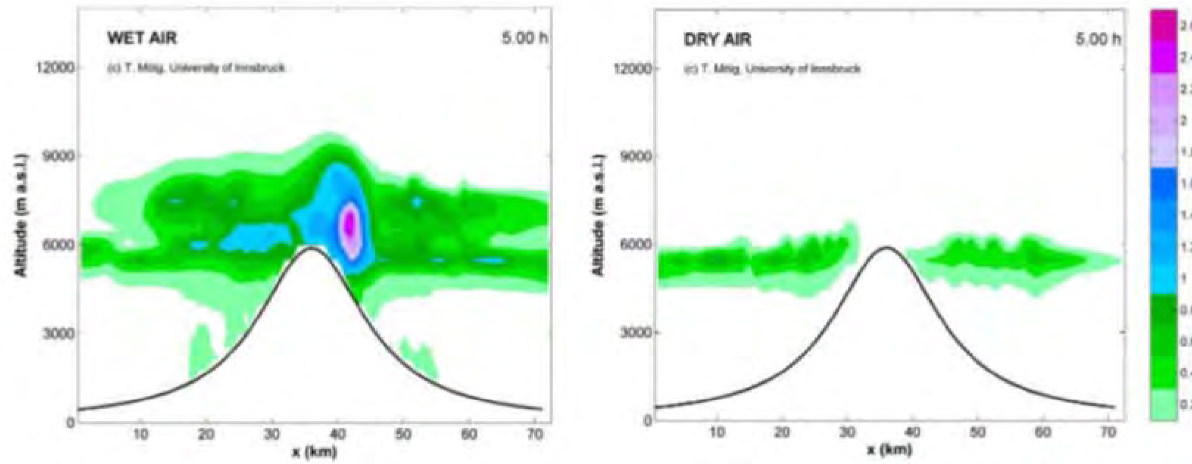


A new Intermediate Complexity Atmospheric Research Model (ICAR) developed at NCAR shows promise at realistic precipitation downscaling at modest computation cost (Ethan Gutmann, NCAR)



WCRP Grand Challenges

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

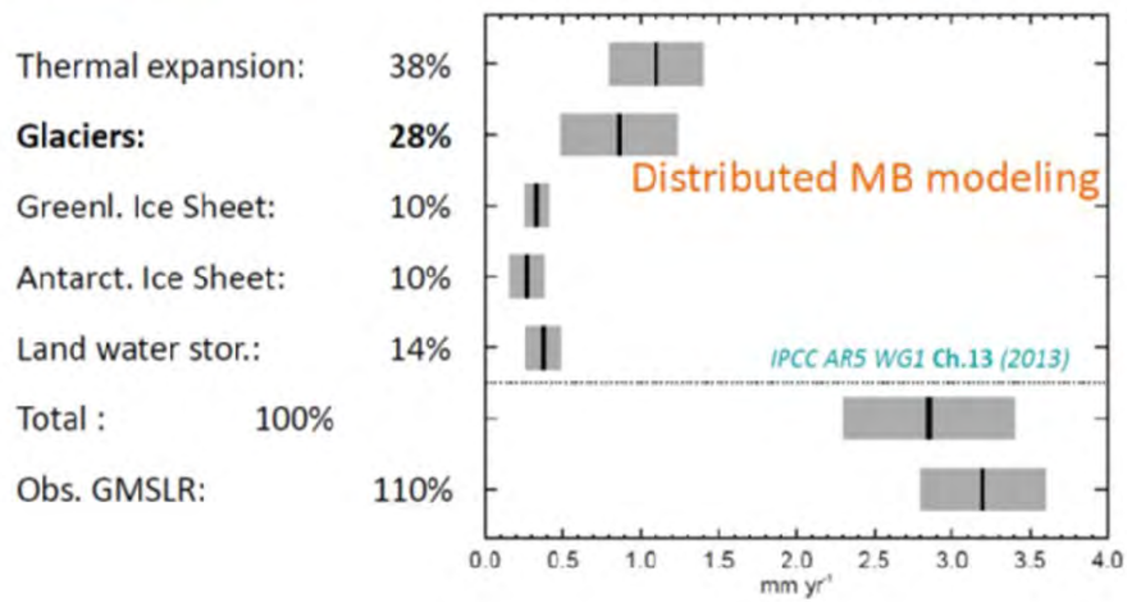


Mölg et al., **QJRMS** *(2009)*

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

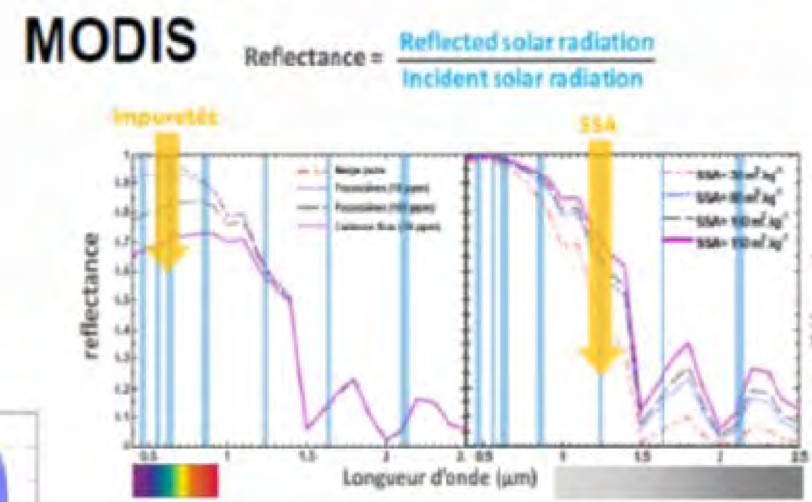
(Georg Kaser)

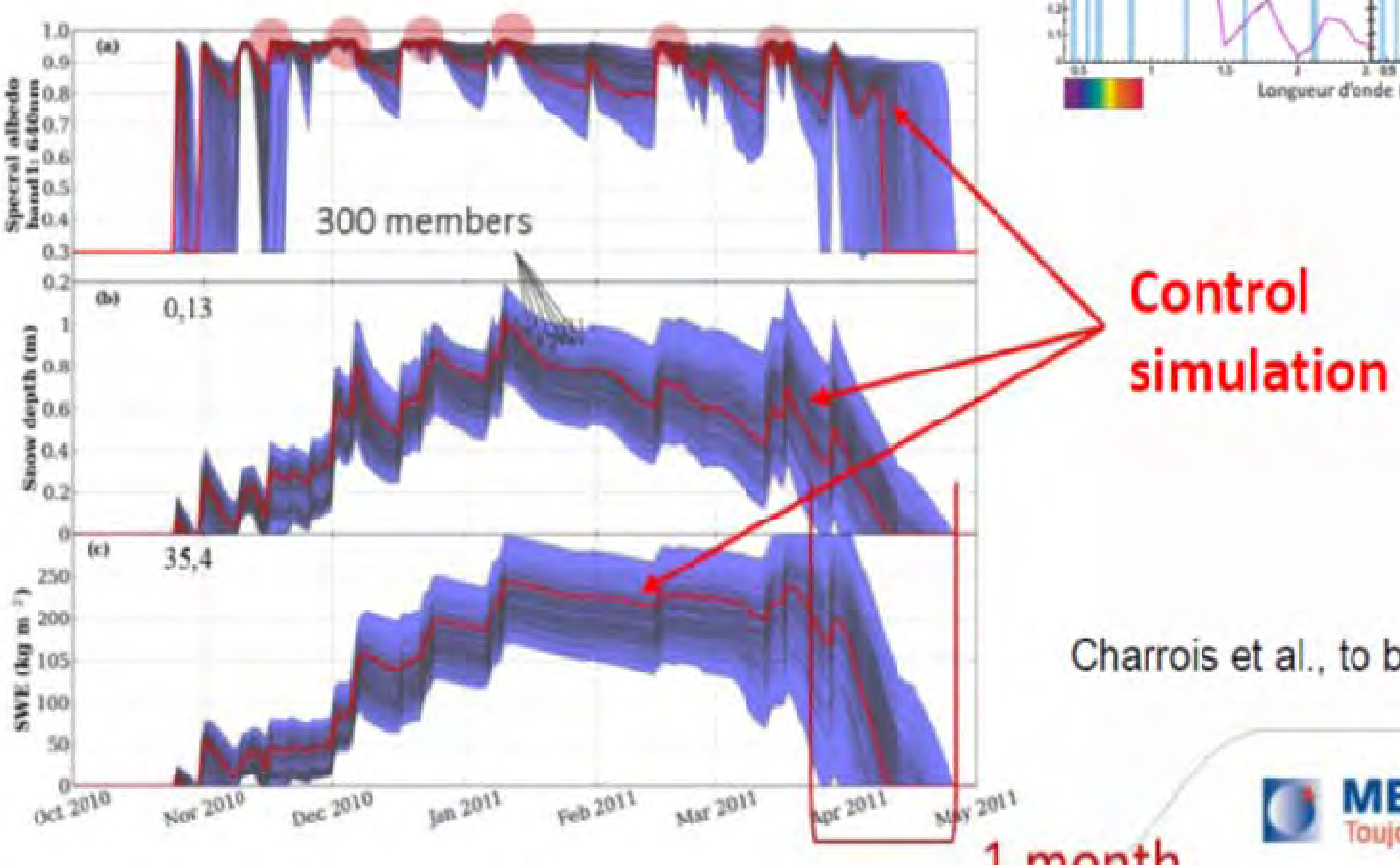
Observes sea level rise 1993-2010:
3.2 mm/year



WCRP Grand Challenges

Understanding and predicting weather and climate extremes





Charrois et al., to be submitted

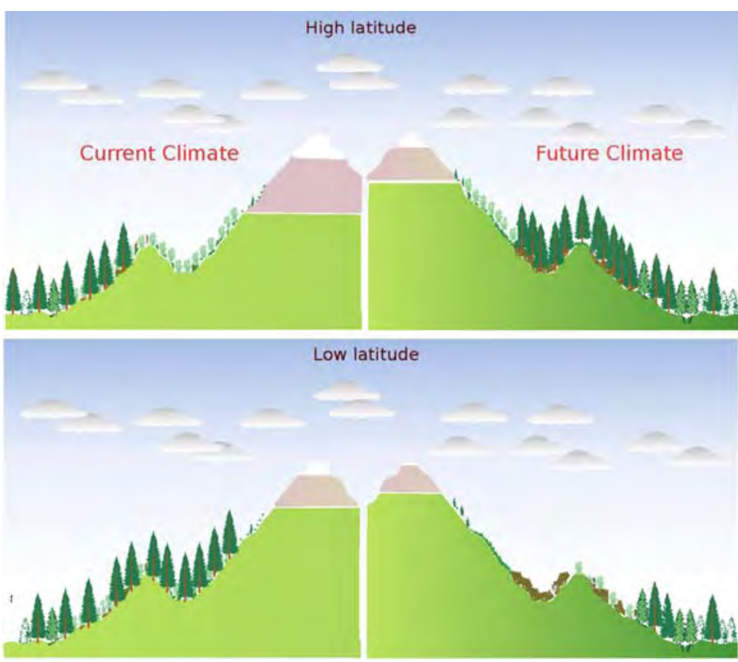
METEO FRANCE
Toujours un temps d'avance

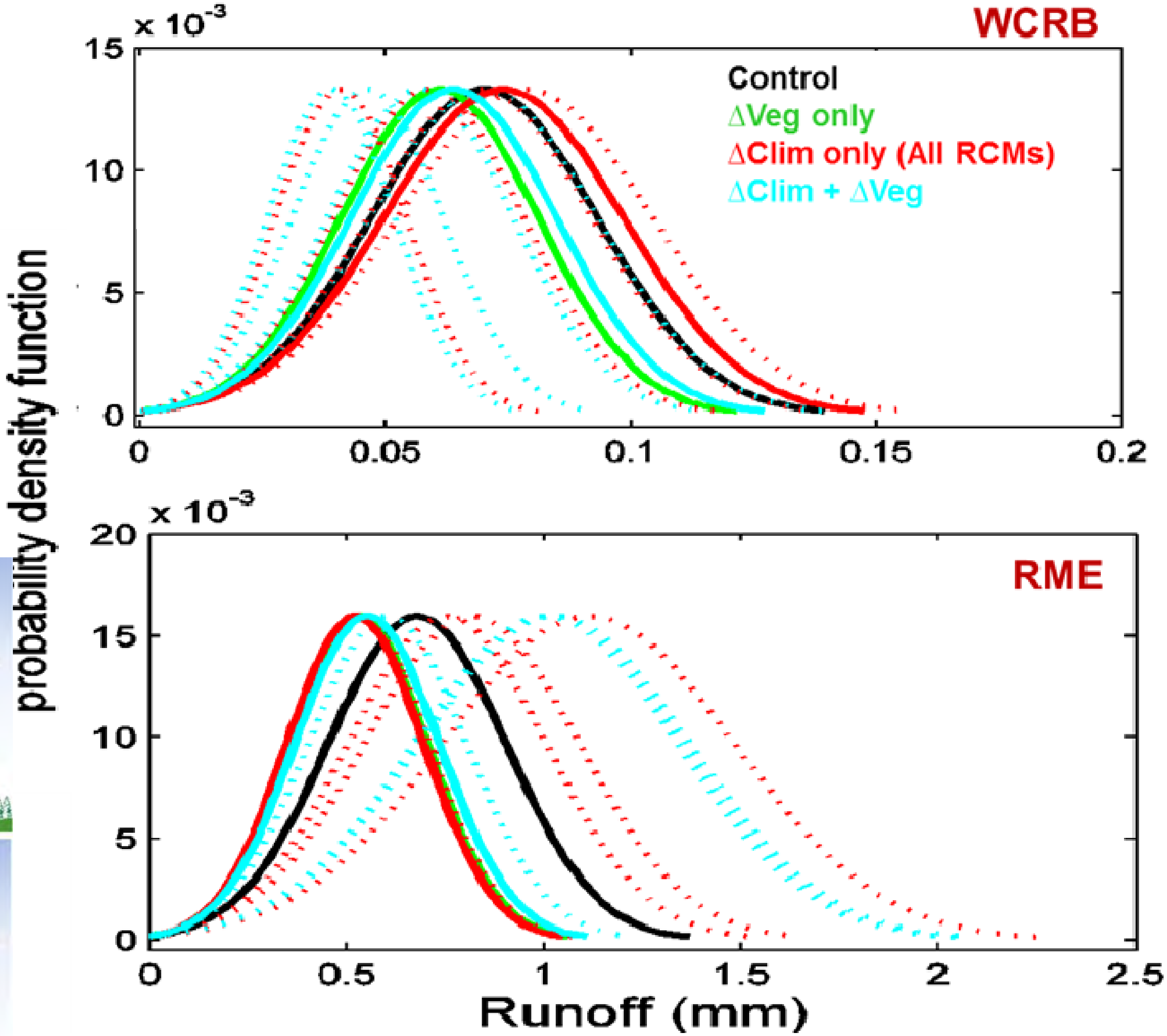
WCRP Grand Challenges

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)





INARCH Workshop 2015
Observations and Data

- Observations – INARCH recognises the value of existing mountain observation stations and encourages increased numbers and improved quality of stations on high mountains to provide understanding and warning of the impacts of climate on downstream water resources. INARCH recognises the urgent need to reduce measurement uncertainty – it will contribute to WMO's SPICE and CRYONET and then implement SPICE and future CRYONET findings in correcting observations at INARCH observatories.
- Data – INARCH supports documentation of metadata on observatories and publication of specialised observational data. Our webpage will point where to find specialized data and metadata for sites and include the originator's assessment of the fitness use of the data. INARCH will organize a mountain data publication special issue.
- *In order to provide warning of the impacts of climate on downstream water resources, INARCH finds an urgent need for enhanced mountain hydrometeorological and cryospheric observations with open availability of data, and reduced measurement uncertainty. INARCH has identified a series of mountain hydrometeorological observatories around the world that address this need, and will promote enhanced mountain observations, and data publication for these observatories.*

INARCH Workshop 2015
Uncertainty and Models

- Uncertainty – INARCH notes that uncertainty derives from measurements, scaling and models, and that model uncertainty includes structural, parameterisation and parameter facets. Uncertainty can be identified and reduced via catchment classification, improved physics, appropriate model complexity, model comparisons. Model comparisons need to be informative, multi-year, multi-climate and multi-site and should be expanded to include forests, slopes, glaciers, the alpine basin scale and include ice, streamflow and subsurface processes.
- Downscaling & Assimilation. Downscaling atmospheric models appropriately is difficult yet crucial in mountains. INARCH will develop a “mountain downscaling toolbox” of various methods that can be applied in mountains. Comparisons of downscaling methods are needed. New satellite, drone-based and ground-based data assimilation methods need to be evaluated.
- Models. INARCH supports the integration of atmospheric, cryospheric and hydrological models in mountains. The headwaters catchment should be recognised as the fundamental modelling unit within which are important horizontal and vertical mass and energy exchanges. Model structure, parameterisation, and parameter identification need multiple year data from a range of sites and environments.
- *INARCH notes that despite the substantial predictive skill shown, there is a need to identify and reduce uncertainty in application of mountain atmospheric, cryospheric and hydrological models. The understanding developed using mountain hydrometeorological observatories can help accomplish this by improving the capability and range of downscaling methods to drive models, improving exchange processes with frozen surfaces, and integrating atmospheric, cryospheric and hydrological components to consider impacts of dynamic climate and transient vegetation and hydrological and cryospheric storage at various scales.*

INARCH Workshop 2015
Climate Change

- Changing Mountain Hydrology – INARCH notes that mountain snow and ice resources are diminishing rapidly in most regions of the Earth due to rising temperature-driven energy and mass exchange processes including several positive feedback mechanisms such as dust and vegetation change. Streamflow and water storage are impacted by the changing cryosphere, but show a broader range of dampened or enhanced responses depending on the catchment topography, cryospheric state, vegetation and climate.
- *INARCH will observe and diagnose mountain climate, cryospheric and hydrological change and explore the changing prospects for mountain water resources through diagnostic modelling experiments using our instrumented catchments from around the world, paying particular attention to the impact of loss of snow and ice on hydrological cycling. This will help quantify and improve the prognostic potential of these models for predicting the water security impacts of global change in mountain regions.*

Next Steps

- Special Issue of *Earth System Science Data.*
- Mountain downscaling toolbox
- Synthesis paper on diagnosing the sensitivity of global alpine snow regimes to warming temperatures.
- Review paper on advances in alpine hydrology.

- Second workshop 2016 – Europe TBD – coincident with GHP?