

INARCH: International Network for Alpine Research Catchment Hydrology

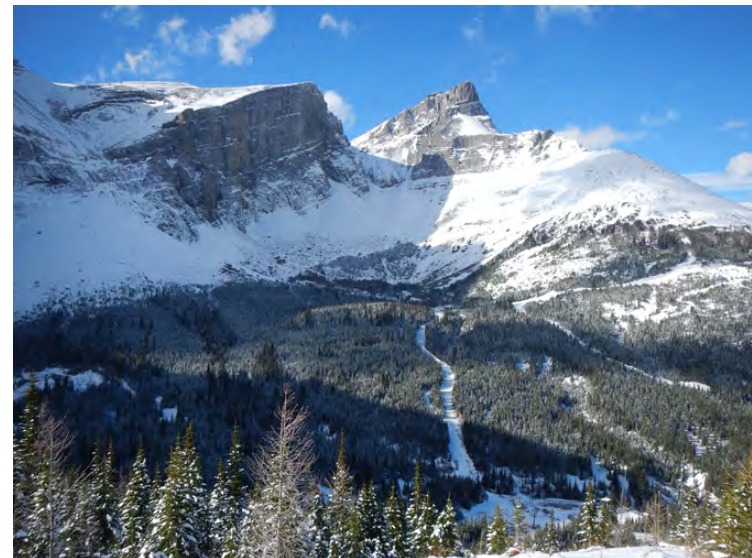
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Urgency

- 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.

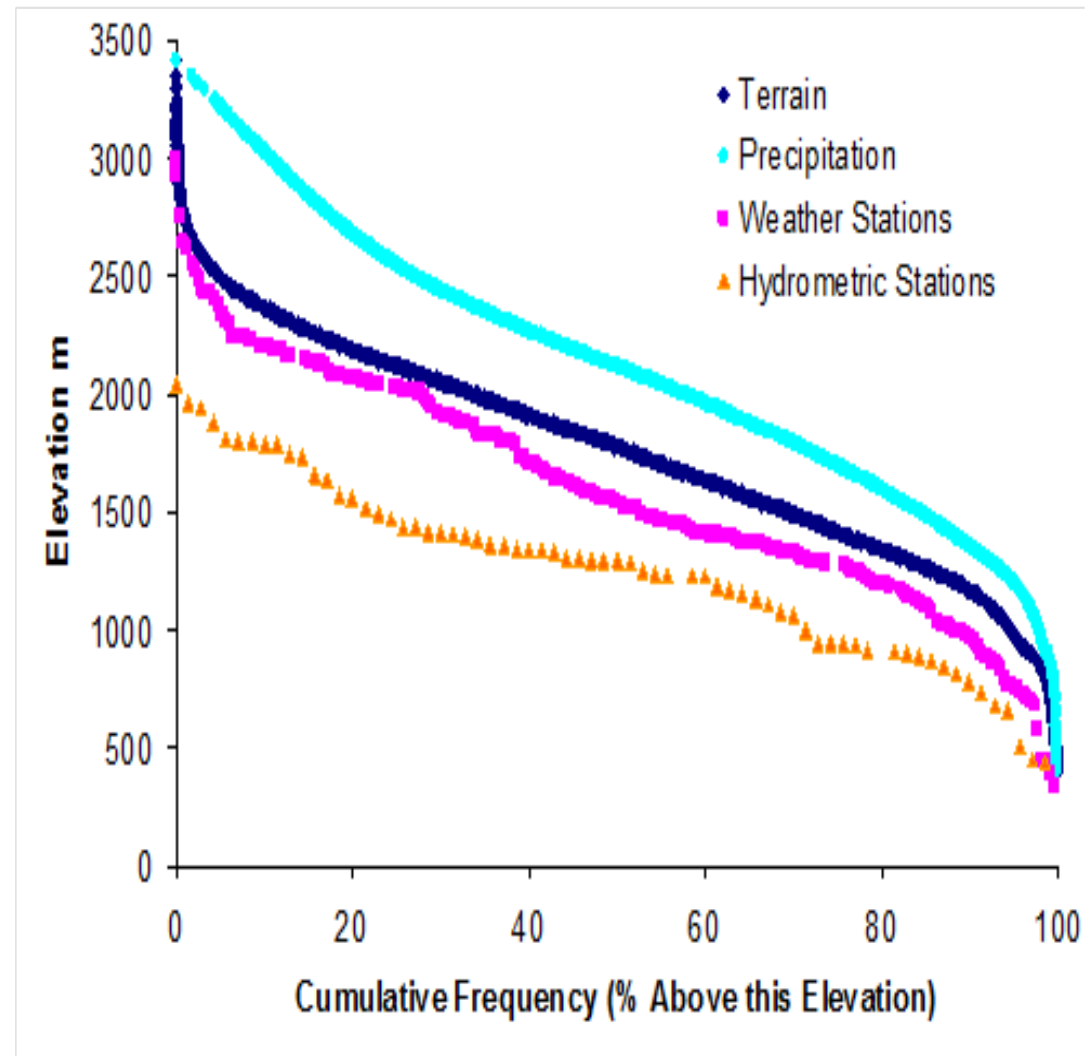
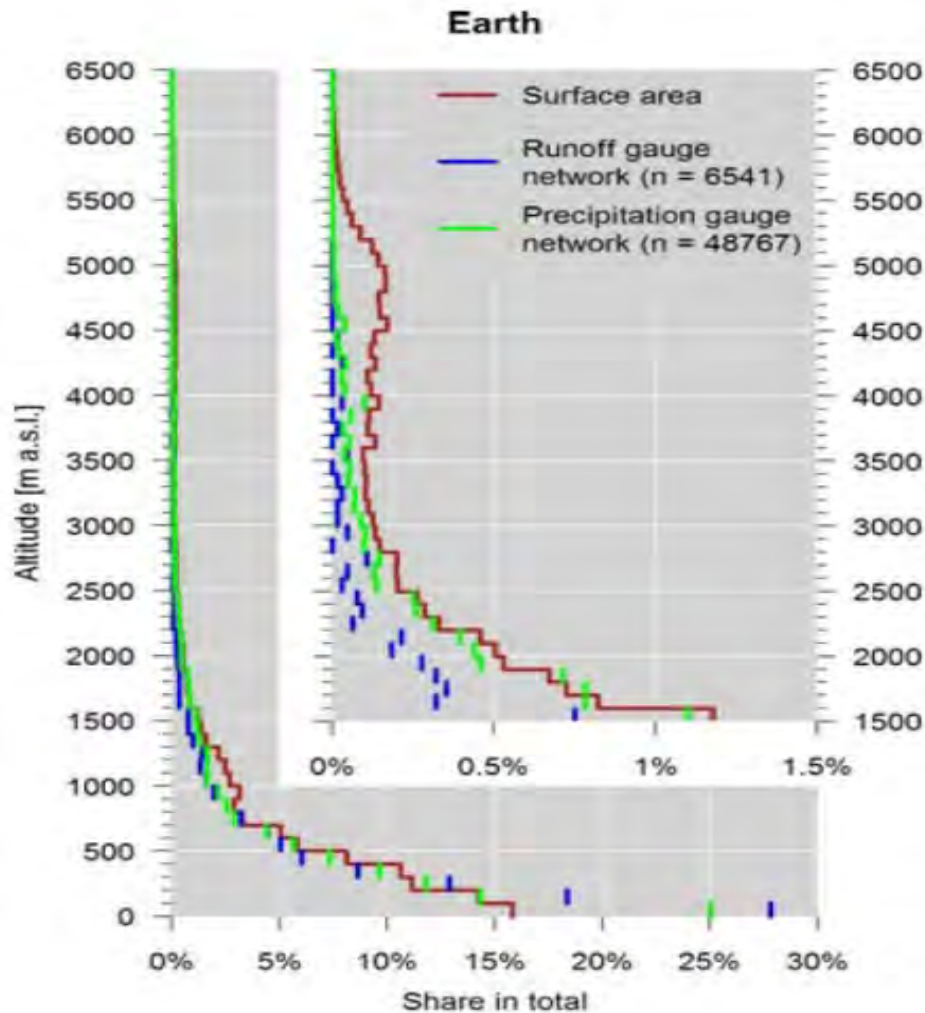


Significance

- 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.



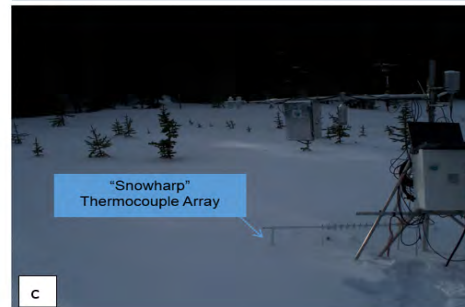
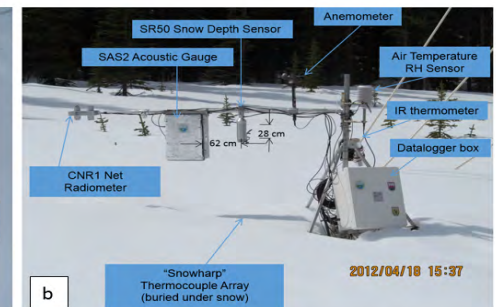
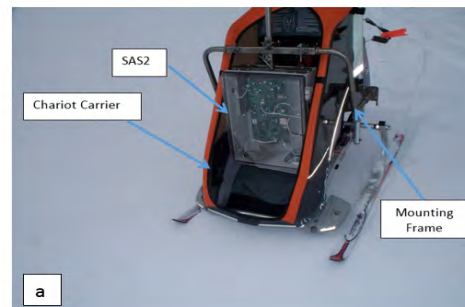
Sub-Objectives

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
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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

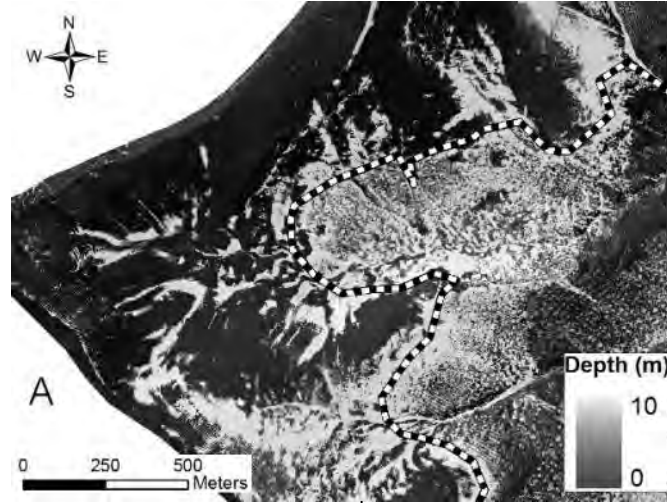
S. Morin¹, Y. Lejeune¹, B. Lesaffre¹, J.-M. Panel¹, D. Poncet¹, P. David^{1,†}, and M. Sudul^{1,†}
¹Météo-France – CNRS, CNRM-GAME, URA1357, CEN, Grenoble, France
[†]deceased

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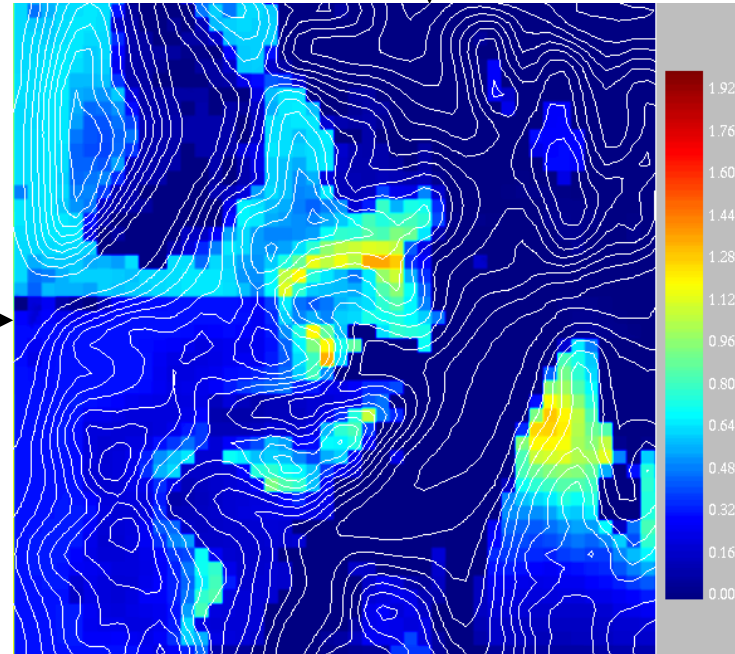
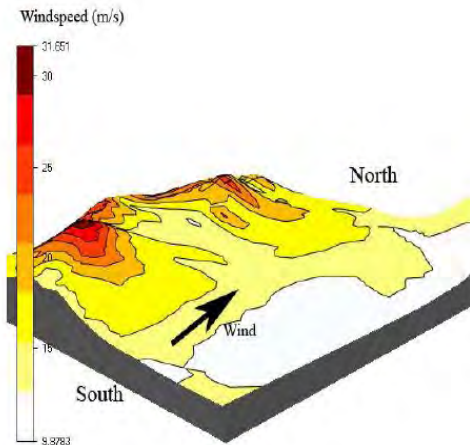
Received: 16 January 2012 – Published in Earth Syst. Sci. Data Discuss.: 6 February 2012
Revised: 31 May 2012 – Accepted: 9 June 2012 – Published: 6 July 2012



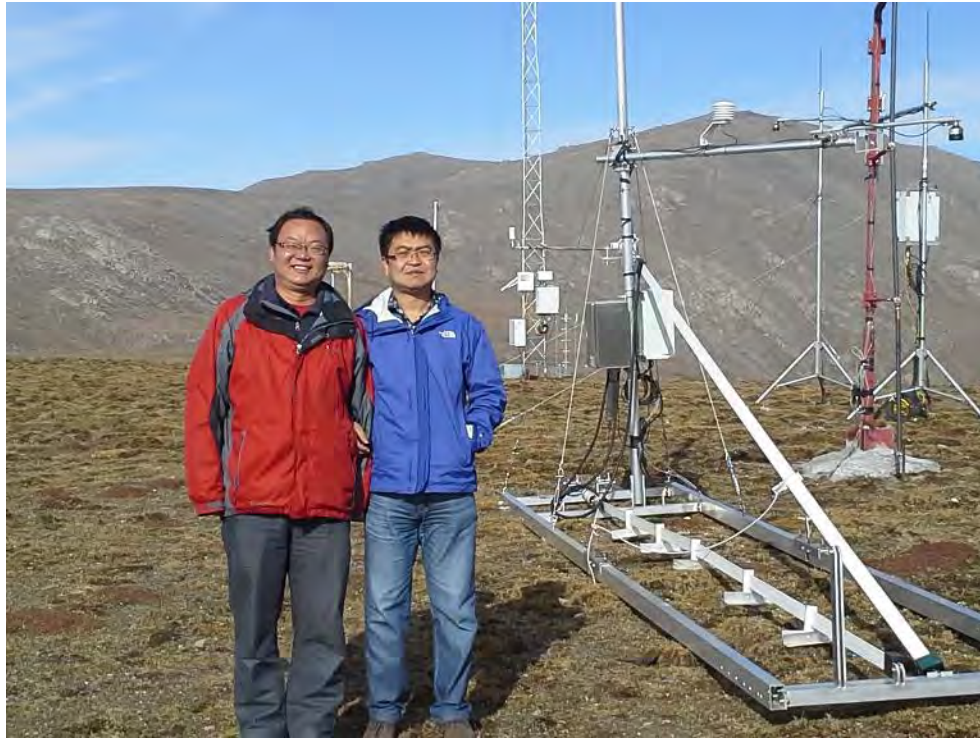
Integrated Alpine Observing & Predicting Systems - IAOPS



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
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- Vincent Vionnet (Meteo-France, France)



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- 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;

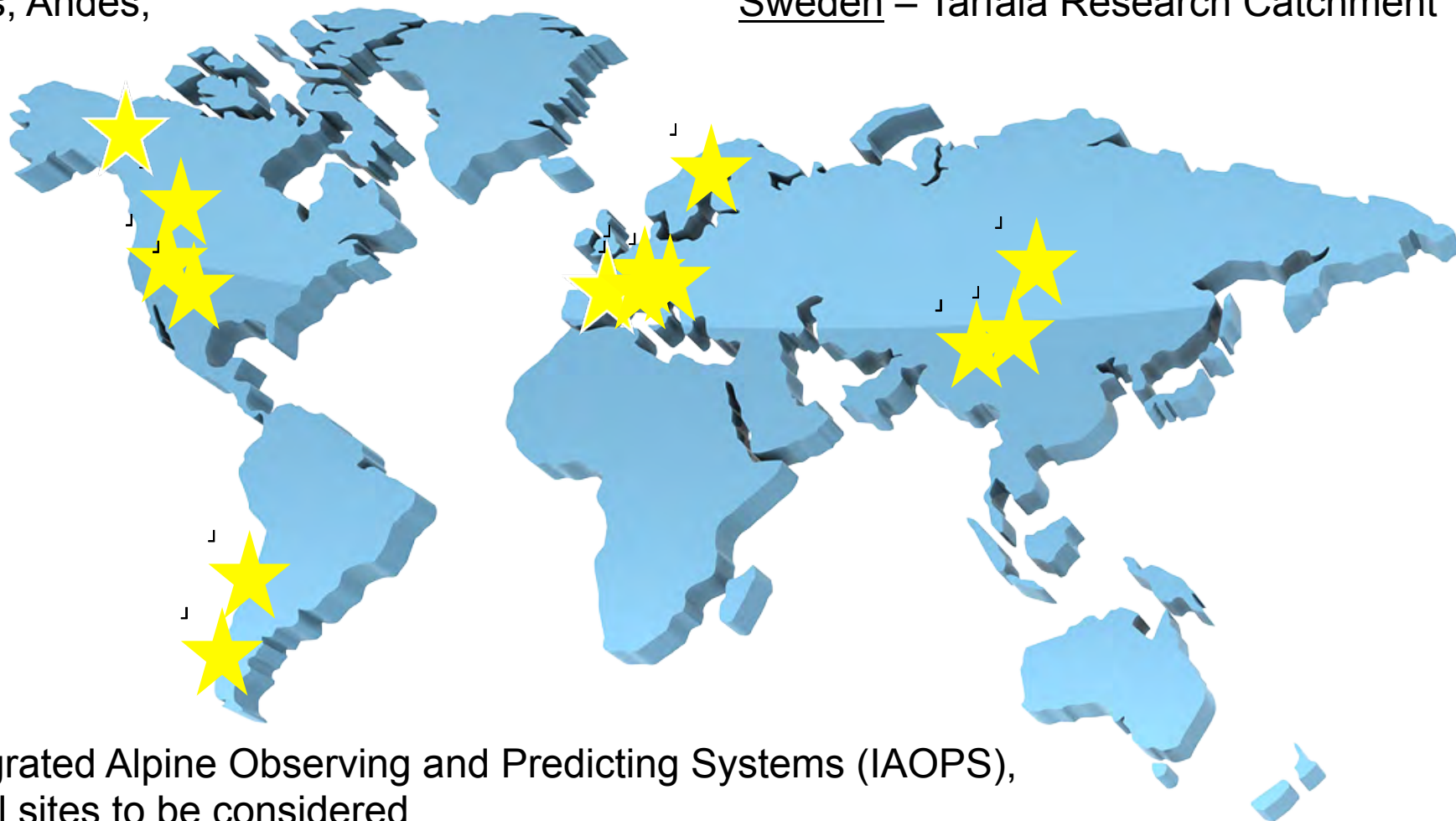
Austria - OpAL Open Air Laboratory, Rofental

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 Cryosphere 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>

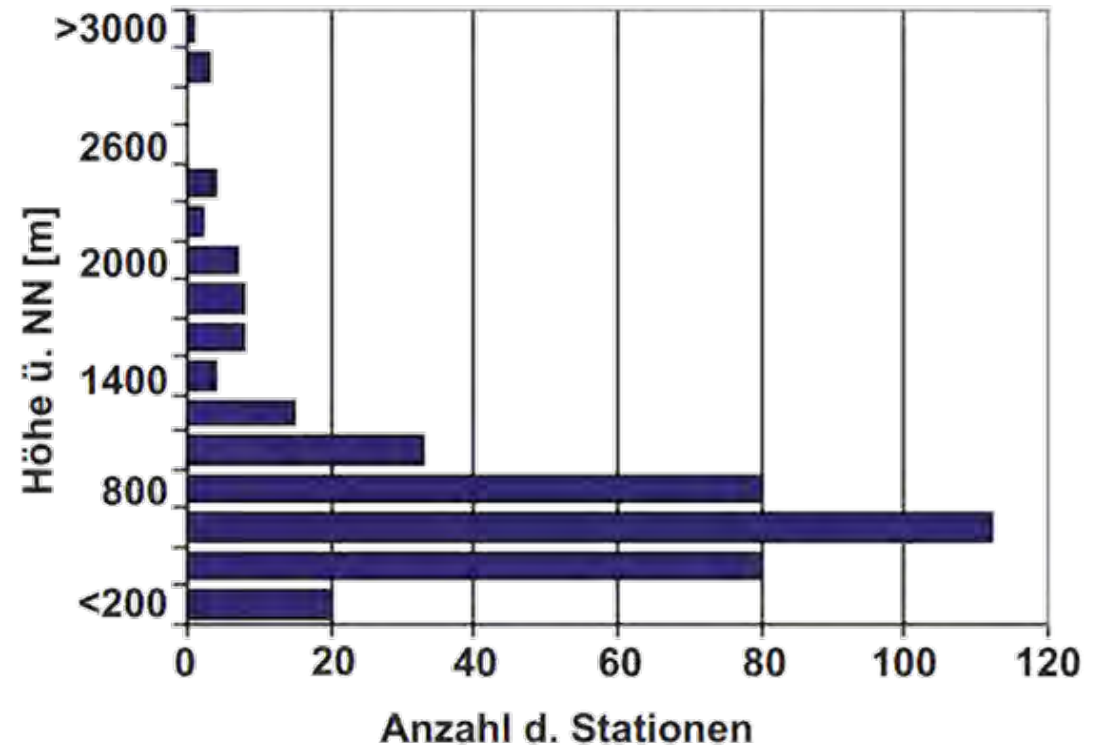
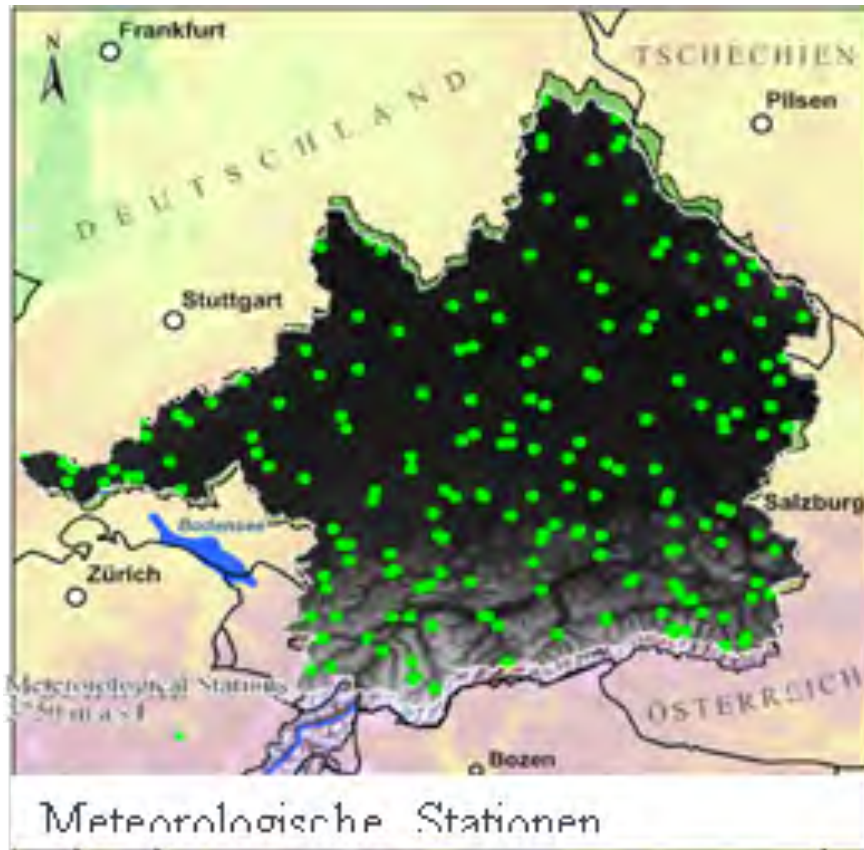
INARCH Workshop in Alberta, Canada Oct 2015

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



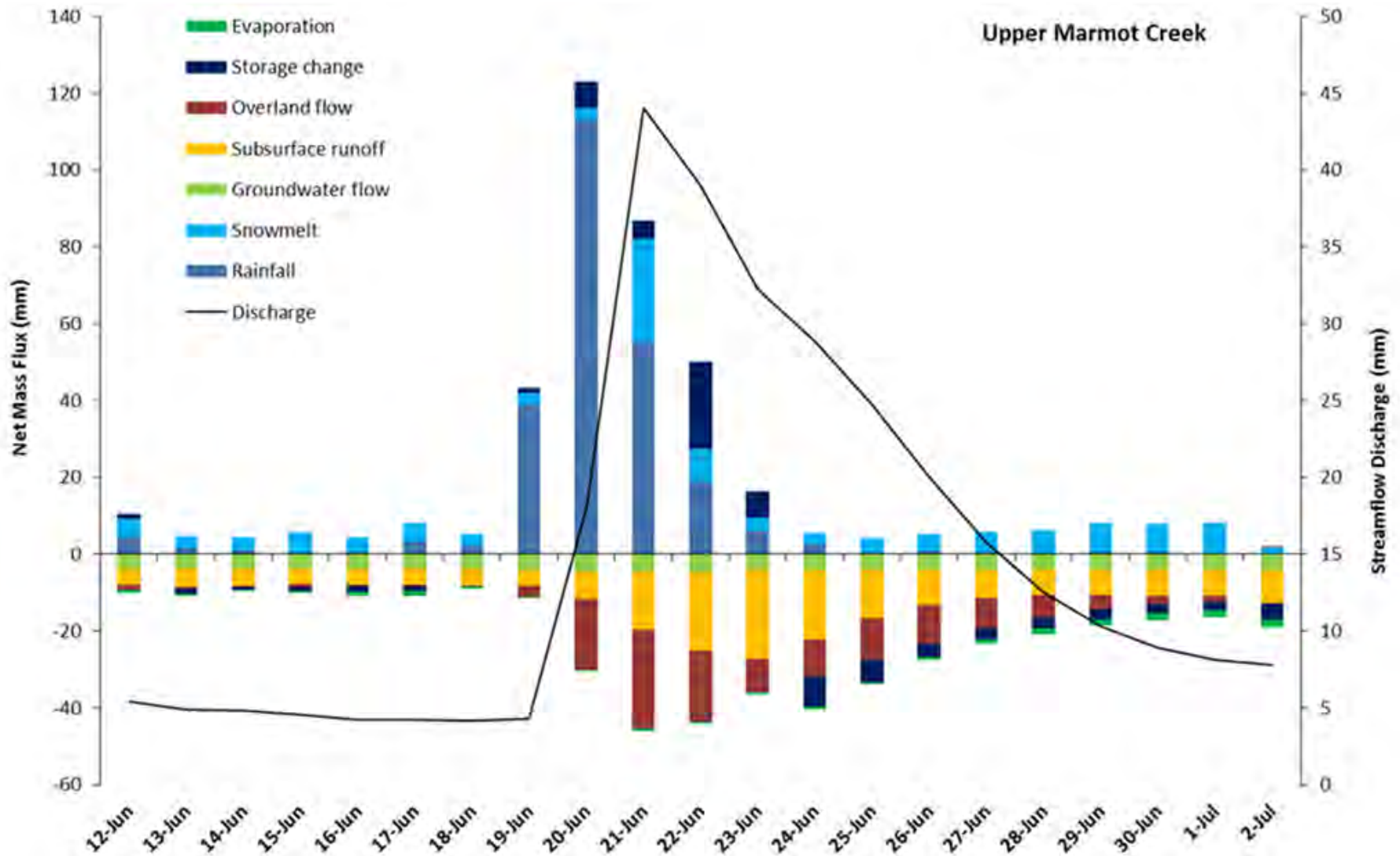
GSQ1: Observations and Predictions of Precipitation

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



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.

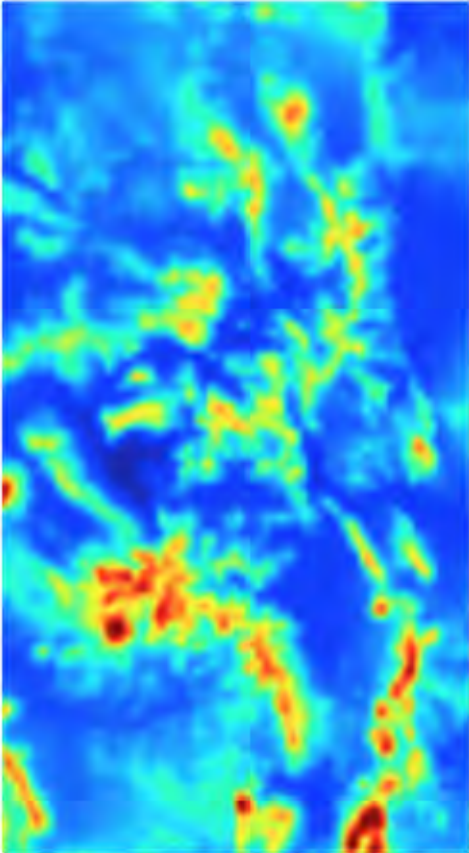
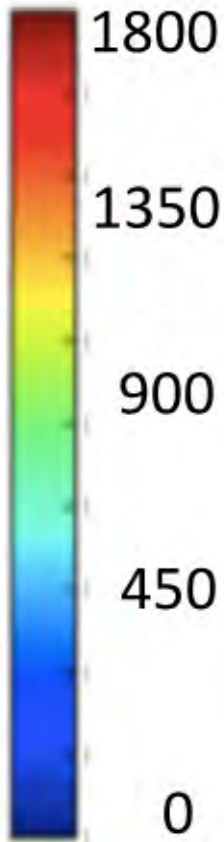
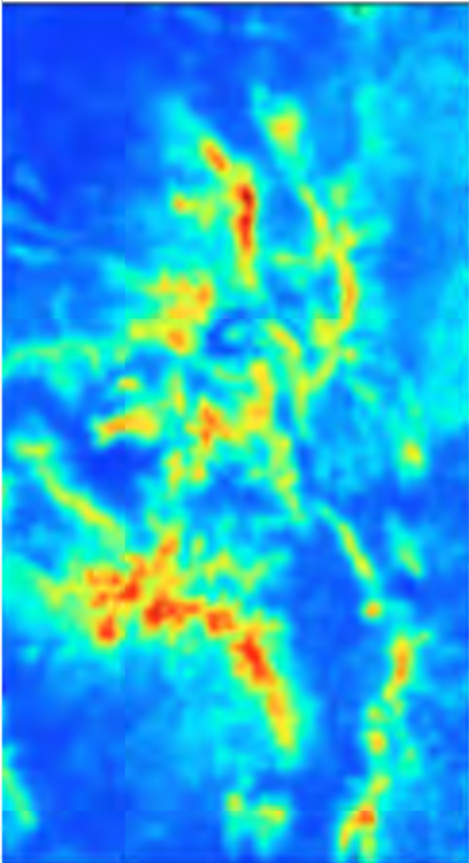


GSQ4: Water and energy cycles

WRF

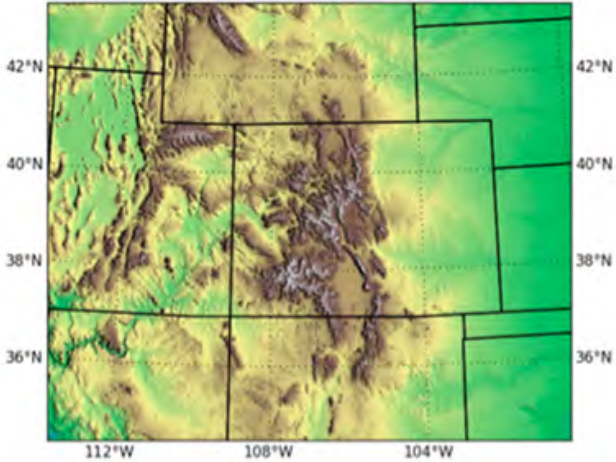
Annual
Precip. (mm)

ICAR



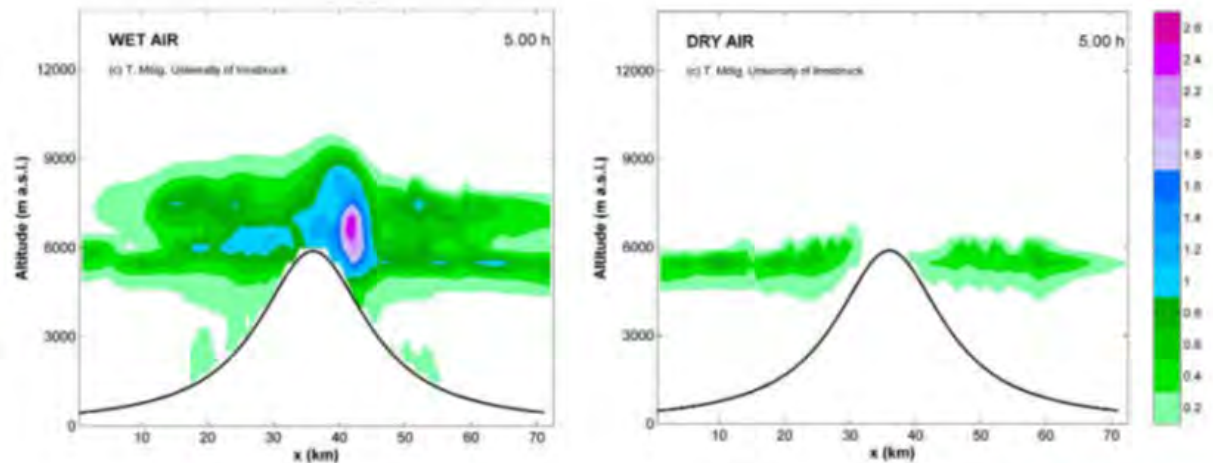
(pre-bias correction)

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)

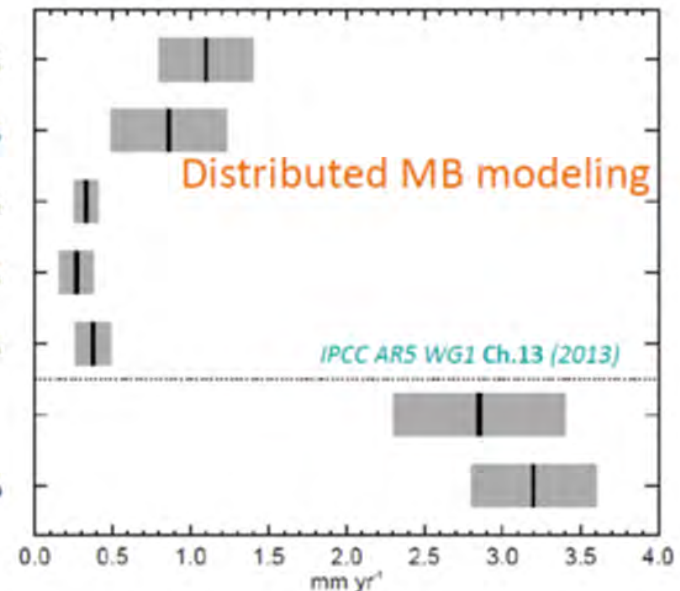
Melting ice and global consequences. The largest ice component is that by mountain glaciers (28% of sea level rise)

(Georg Kaser)

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



Thermal expansion:	38%
Glaciers:	28%
Greenl. Ice Sheet:	10%
Antarct. Ice Sheet:	10%
Land water stor.:	14%
Total :	100%
Obs. GMSLR:	110%

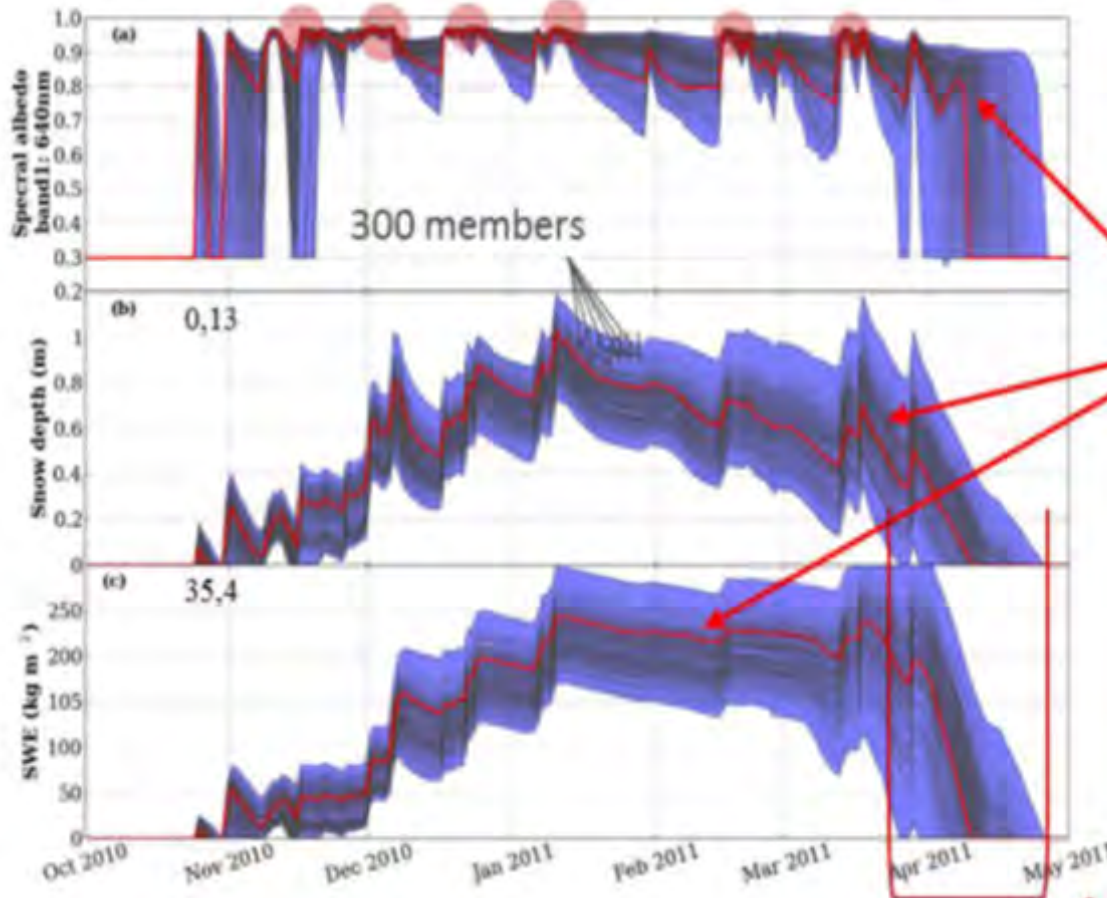
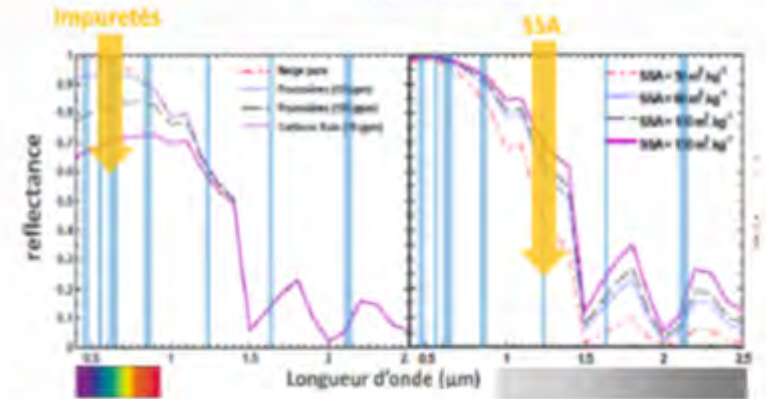


WCRP Grand Challenges

Understanding and predicting weather and climate extremes

MODIS

$$\text{Reflectance} = \frac{\text{Reflected solar radiation}}{\text{Incident solar radiation}}$$



**Control
simulation**

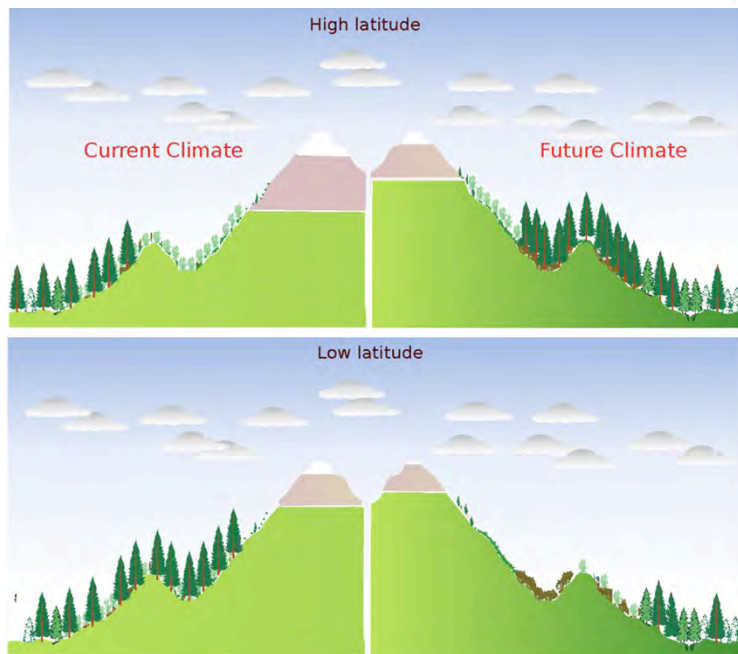
Charrois et al., to be submitted

1 month

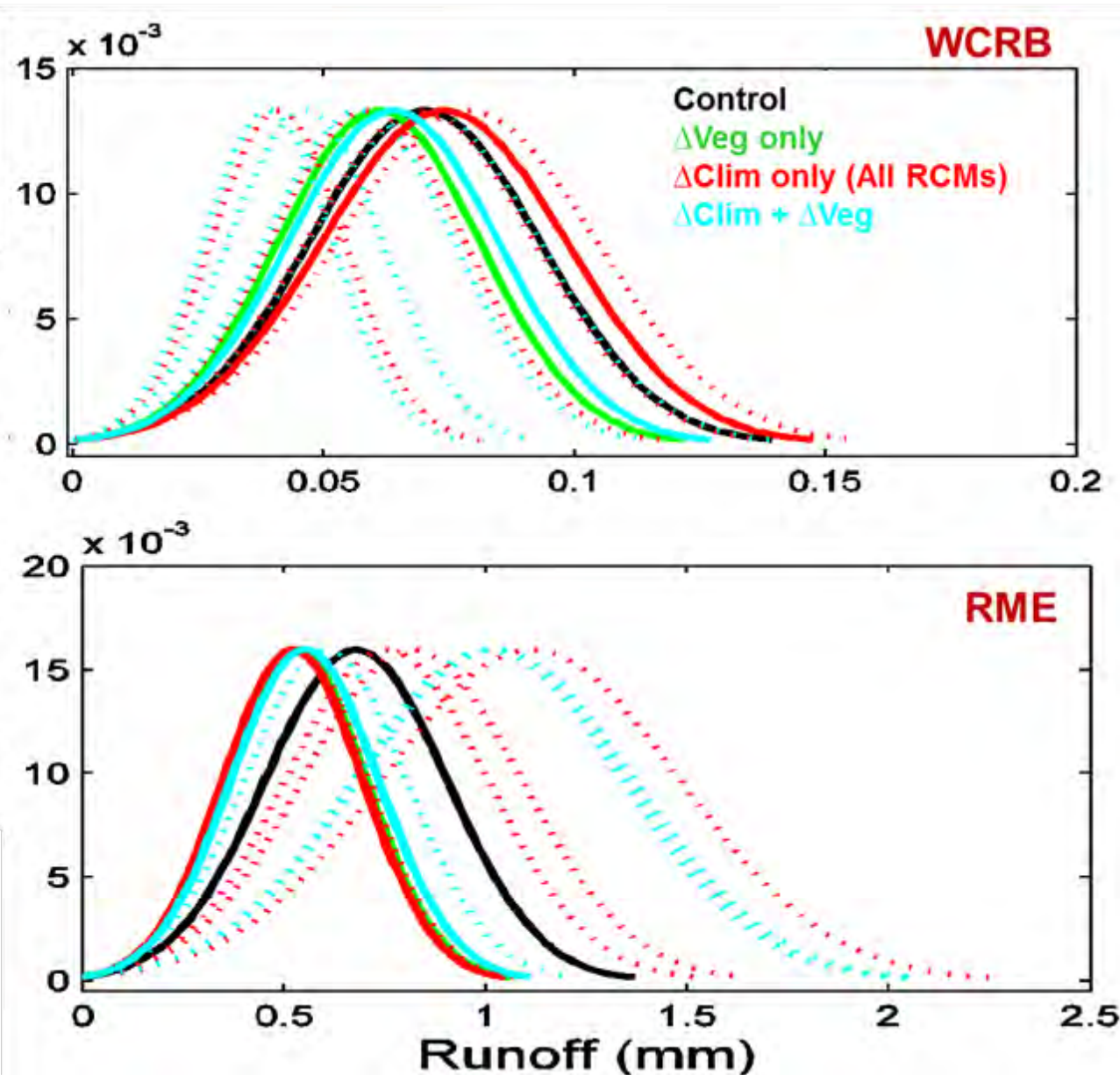
WCRP Grand Challenges

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)



probability density function





- 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 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 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 - CORDEX
- Synthesis paper on diagnosing the sensitivity of global alpine snow regimes to warming temperatures.
- Review paper on advances in alpine hydrology.
- Second workshop 2016 –coincident with GHP.

