

INARCH: International Network for Alpine Research Catchment Hydrology 2018 Meeting

John Pomeroy
Centre for Hydrology
University of Saskatchewan,
Saskatoon and Canmore, Canada

www.usask.ca/inarch



3rd Annual INARCH Workshop, Zugspitze, Germany, 8 Feb 2018

Urgency

- 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 snow/ice accumulation or melt potential*
- Snow, ice, and phase change domination of alpine hydrology means that it is especially sensitive to temperature change.



Significance



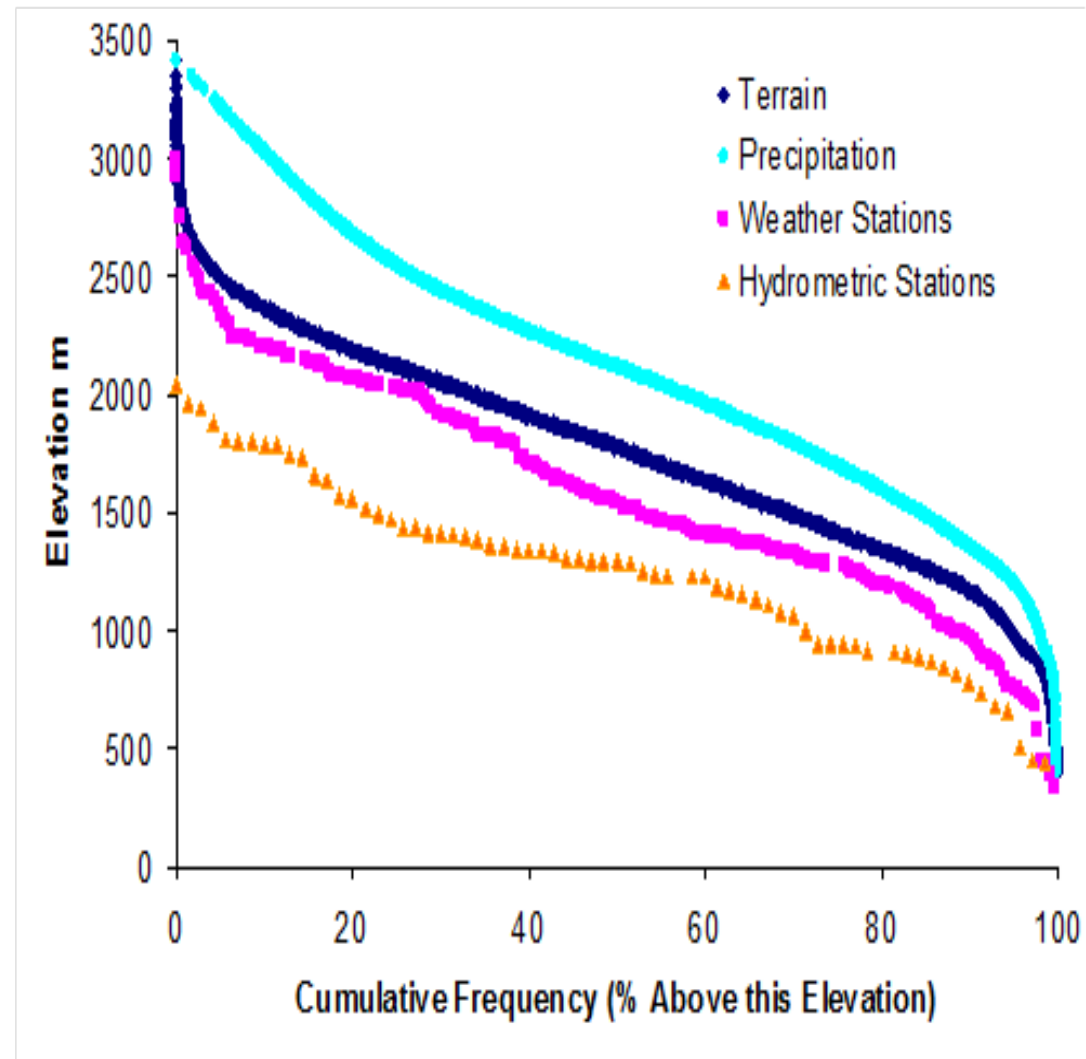
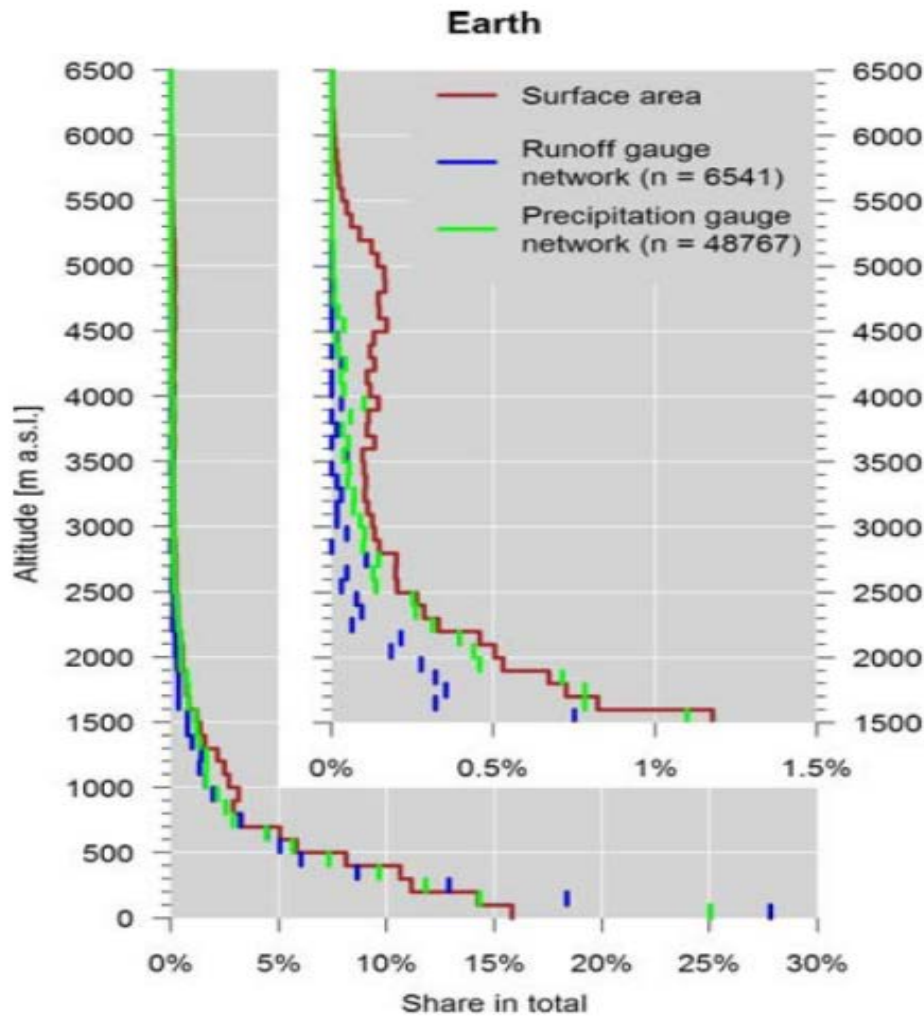
Ongoing change in climate has already resulted in

- 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 or persistent downstream water shortages.



Alpine Regions are Data Scarce



Left Side: (Viviroli et al. 2011).

Right Side: (Pomeroy, Sinclair, Marshall).

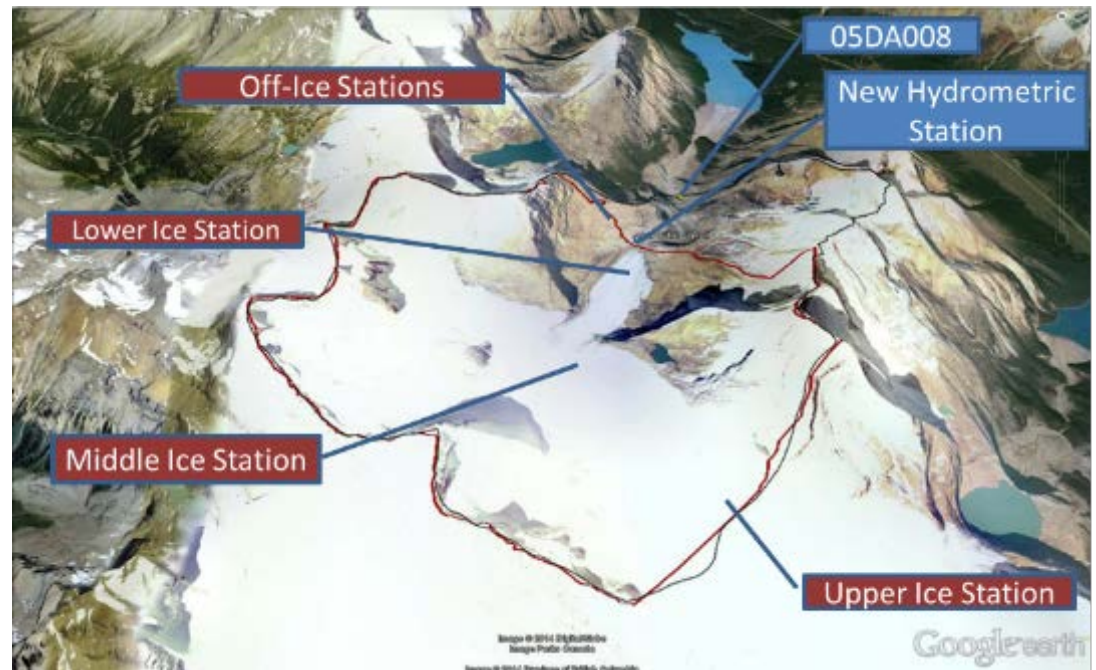
INARCH Objectives

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

Canada – Canadian Rockies, BC & Yukon;

USA – Reynolds Creek, ID; Dry 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

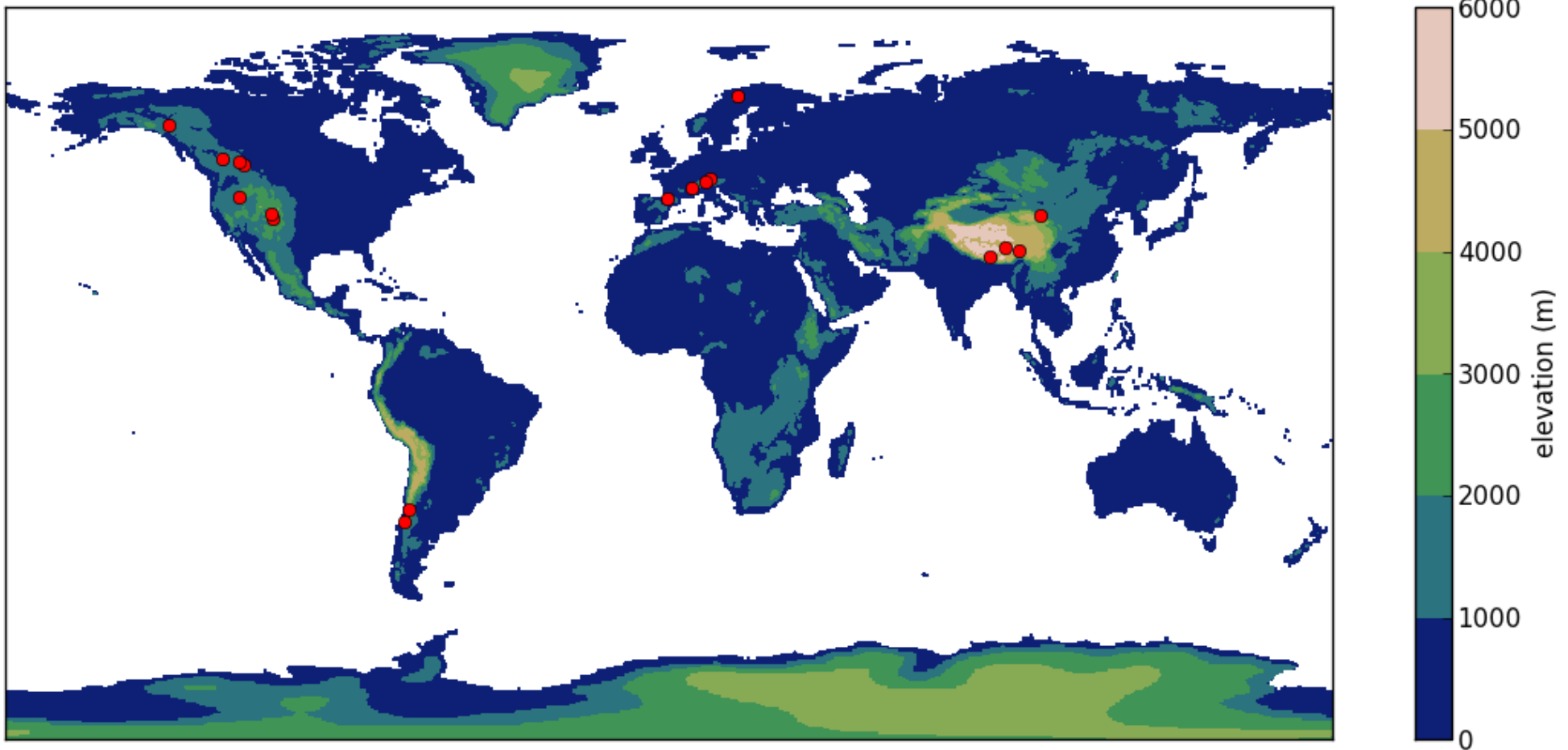
Spain – Izas, Pyrenees;

China – Upper Heihe River, Tibetan Plateau,

Nepal – Langtang Catchment, Himalayas

Sweden – Tarfala Research Catchment

Norway - Finse Alpine Research Centre



INARCH Linkages

- GEWEX GHP Projects
 - Precipitation phase
 - Mountain precipitation
 - Changing Cold Regions Network
 - Possible North America or South America??
- WMO Global Cryosphere Watch
- WMO-SPICE
- TPE (Third Pole Environment)
- 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 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.



2nd INARCH Workshop

- Held at the Institut des Géosciences de l'Environnement (IGE) in Grenoble, France, 17–19, October, 2016



CGCM

2nd INARCH Workshop

- Issues:
 - Atmospheric downscaling for mountain snow and ice hydrology modeling;
 - Availability and suitability of observations from mountain observatories and discussion of the INARCH special issue; and
 - Sensitivity of the cryospheric and hydrological response of mountain catchments to various representations of a changing climate

ICAR driven by WRFG-CGCM



2017 Report to GEWEX

- Further information and links to presentations:
http://www.usask.ca/inarch/wkshp2_report.php



2nd INARCH Workshop

17–19 October 2016
Grenoble, France

John Pomeroy¹, Vincent Vionnet² and INARCH Colleagues

¹Centre for Hydrology and Global Institute for Water Security, University of Saskatchewan, Canada; ²Snow Research Center, CNRM, Météo France/CNRS, Saint Martin d'Hères, France

The International Network for Alpine Research Catchment Hydrology (INARCH) is a crosscutting project of the GEWEX Hydroclimatology Panel (GHP) and its objectives are to better understand alpine cold regions hydrological processes, improve their prediction, diagnose their sensitivities to global change and find consistent measurement strategies. INARCH is formulated around addressing five core 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 global validity? (5) How do transient changes in perennial snowpacks, glaciers, ground frost, soil stability and vegetation impact alpine water and energy models?

INARCH has a network of well-instrumented mountain research basins that INARCH members maintain. All of these research basins have hydrometeorological, cryospheric and hydrological observations at multiple scales over multiple years and some have snow, glacier, hydrological and atmospheric models run at various scales. Observations are embedded near the headwaters of larger river basins that supply water for vast downstream populations. The following figure shows a map of INARCH mountain research basins. Mount Lebanon has been proposed as a new research basin.

INARCH has linkages to GHP crosscutting projects on precipitation phases and mountain precipitation, as well as to the Changing Cold Regions Network (CCRN), a Regional Hydroclimate Project. INARCH is seeking stronger connections with the Global Cryosphere Watch and the World Meteorological Organization Solid Precipitation Intercomparison Experiment (WMO-SPICE) and the Third Pole Environment (TPE) initiative. INARCH contributes to the UNESCO-International Hydrological Programme (IHP) efforts to gauge climate change impacts on snow, glaciers and water resources within the framework of the IHP-VIII (2014-2021), and has linkages with

the International Commission for Snow and Ice Hydrology (IAHS-IUGG). INARCH also contributes to the Mountain Research Initiative led from Bern, Switzerland.

Over the last two years, INARCH has contributed to several conferences and workshops, such as the 2015 American Geophysical Union Fall Meeting, where INARCH organizers chaired an oral and poster session on Improved Understanding and Prediction of Mountain Hydrology through Alpine Research Catchments. INARCH also participated in the WCRP International Conference on Regional Climate, CORDEX 2016, with a presentation by Richard Essery (UK) on observations and downscaling for alpine hydrological modeling and through several other INARCH participants, including Ethan Guttman (USA), Kabir Rasouli (Canada) and Deborah Verfaillie (France). John Pomeroy gave a general presentation on INARCH at the 6th Third Pole Environment Workshop and Joseph Shea, Maxime Litt (Nepal) and Walter Immerzeel (The Netherlands) gave talks or poster presentations.

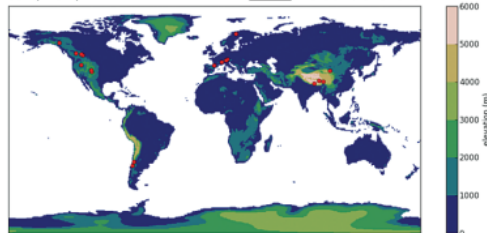
An INARCH special issue in *Journal of Earth System Science Data* is now open for submissions until 30 September 2017 on the topic of "hydrometeorological data from mountain and alpine research catchments." Contributions from openly available, detailed meteorological and hydrological observational archives from long-term research catchments at high temporal, well-instrumented mountain regions around the world are being prepared and at least 16 submissions are expected from the INARCH Project by the special issue co-editors, John Pomeroy (Canada) and Danny Marks (USA).

The 2nd INARCH Workshop was held at the Institut des Géosciences de l'Environnement (IGE) in Grenoble, France, and provided an opportunity for scientists to explore and discuss specific issues in mountain snow and ice hydrology

INARCH: International Network for Alpine Research Catchment Hydrology

Canada – Canadian Rockies, BC & Yukon;
USA – Reynolds Creek, ID; Dry Creek, ID;
Senator Beck, CO; Niwot Ridge, CO;
Chile – Upper Maipo & Upper Diguillin River Basins, Andes.

Germany – Schneefernerhaus & Zugspitze;
France – Arve Catchment, Col de Porte & Col du Lac Blanc;
Switzerland – Dischma & Weissfluhjoch;
Australia – Opal Open Air Laboratory, Rofental
Spain – Izas, Pyrenees;
China – Upper Heihe River, Tibetan Plateau,
Nepal – Langtang Catchment, Himalayas
Sweden – Tarfala Research Catchment



Current INARCH mountain research basins.

February 2017



highlighted in the first INARCH workshop held in October 2015. Sixty scientists from the USA, Canada, Chile, China, France, UK, Switzerland, Austria, Germany, Italy, Lebanon and Norway attended the workshop. The Local Organizing Committee of Vincent Vionnet [Météo France, Centre National de Recherches Météorologiques-Centre d'Etudes de la Neige (CNRM-CEN)], Isabella Zin (IGE), Jean-Emmanuel Sicart (IGE) and Delphine Six (IGE) arranged the workshop and a field tour to the nearby Mount Blanc area.

The workshop focused on the following topics: (i) atmospheric downscaling for mountain snow and ice hydrology modeling; (ii) availability and suitability of observations from mountain observatories and discussion of the INARCH special issue; and (iii) sensitivity of the cryospheric and hydrological response of mountain catchments to various representations of a changing climate.

The workshop fieldtrip visited research sites in the Aiguille du Midi (3842 m), near Chamonix. Christian Vincent (IGE) described the scientific activities of the CryObs-Clim Observing System, Thomas Condom (IGE) outlined the experimental rain gauge network and related scientific activities, and Florence Naaim Bouvet (IRSTEA) presented the Taconnaz avalanche path and associated protection. The group visited the Le Tour hydrometric station and learned about snow measurement techniques and hydrological issues in the Alps (Vincent Vionnet, Samuel Morin and Isabella Zin). At the confluence of the Arve and Arveyron d'Argentière, they were shown flood defenses, saw the sediment transport station at Pont des Favrans and heard about water quality issues.

The 2nd INARCH workshop had 42 oral and poster presentations covering high mountain environments from North and South America, Africa, Europe and Asia. The topics covered downscaling meteorological models for mountain snow and ice hydrology, modeling the cryospheric and hydrological response of mountain catchments under present and future climate and mountain observatories and links between INARCH and other research programs. Discussions on downscaling, observatories and future directions are summarized next.

Downscaling Discussion


The discussion focused on developing a toolbox or set of guidelines for downscaling. It was agreed that the product should be end user specific (e.g., operational forecasts, 1-3 month water supply forecasts and climate predictions) and the role of statistical versus dynamical methods for various end uses was discussed, including what tools are suitable for each use case. Reoccurring downscaling topics discussed include the following:

- Statistical downscaling of larger-scale regional climate models (RCMs) may be unsuitable for driving physically based snow models where co-occurrence of wind, humidity, temperature and radiation fields with precipitation events control snow regimes, precipitation phase, blowing snow and melt.
- Atmospheric model failure. INARCH recognizes the need for carefully applied bias corrections, but promotes the improved physical representation of atmospheric models in mountain environments. INARCH will interact with the atmospheric modeling community to make its members aware of performance issues in mountain environments. INARCH will promote the assimilation of mountain observations in atmospheric models and the use of mountain data sets in assessing model performance through multi-objective analysis.
- Physical models are never perfect. INARCH can quantify the impact of resolution increase on predicted surface variables (i.e., the diurnal temperature and precipitation cycle). The project will promote dynamical downscaling of atmospheric models but will assist in developing empirical, statistical or simpler dynamical downscaling at scales less than several kilometers.
- Ask questions that Global Climate Model (GCM) and RCM tools can answer. (Just because we want it doesn't mean we can have it.) What is the appropriate scale for evaluation of models given our catchment scales?



Participants at the 2nd INARCH Workshop.

February 2017



8TH GEWEX SCIENCE CONFERENCE:
EXTREMES AND WATER ON THE EDGE

MAY 6 - 11, 2018 | CANMORE, ALBERTA, CANADA

INARCH session at 2018 GEWEX Open Science Conference

Canmore, AB, Canada

7–10 May, 2018

Title: The Mountain Water Cycle

Topic: Advances in remote sensing, big data techniques and process understanding that are often developed in instrumented alpine research catchments inform mountain water cycling predictions. This session welcomes papers that

- advance mountain water and energy cycle modelling techniques,
- process understanding,
- observations,
- downscaling methods, and
- predicting the impacts of a changing mountain cryosphere on water cycling.

Convenors: R. Rasmussen, J. Pomeroy, C. DeBeer,

INARCH Special Issue

Open Access
Earth System
Science
Data

Earth Syst. Sci. Data, 4, 13–21, 2012
www.earth-syst-sci-data.net/4/13/2012/
doi:10.5194/essd-4-13-2012
© Author(s) 2012. CC Attribution 3.0 License.



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

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

- Special Issue open in **Earth System Science Data (ESSD)**
- Editors: John Pomeroy, and Danny Marks
- **Topic:** Hydrometeorological data from mountain and alpine research catchments
- Contributions of openly available detailed meteorological and hydrological observational archives from long-term research catchments at high temporal in well-instrumented mountain regions around the world
- Submission possible until 6 April, 2018.

INARCH and UNESCO



Knowledge Forum on Water Security and Climate Change:
Innovative solutions for sustainable water resources management

18 – 20 October 2017
Room IX
UNESCO HQ, Paris, France

Session on “***Water Security and Climate Change Impacts in Mountains***”

INARCH Workshop Statement 2015

INARCH has identified a global set of mountain hydrometeorological observatories that address an urgent need for enhanced observations, and will promote the development of, and data publication for these observatories.

INARCH notes the need to identify and reduce uncertainty in application of mountain atmospheric, cryospheric and hydrological models. This can be accomplished by

- 1) improving the capability and range of downscaling methods to drive models,*
- 2) improving exchange processes with frozen surfaces, and*
- 3) integrating atmospheric, cryospheric and hydrological models to consider impacts of*

-dynamic climate

-transient vegetation and

-hydrological and cryospheric storage at multiple scales.

INARCH will conduct 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 in order to predict the water security impacts of global change in mountain regions.

INARCH Workshop Statement 2016



- INARCH has identified a series of observatories around the world that provide enhanced mountain hydrometeorological and cryospheric observations with open availability of data, and will promote publication of these observations.
- INARCH will help quantify and improve the diagnostic and prognostic potential of models for predicting the water security impacts of global change in mountain regions.
- INARCH will promote hybrid downscaling with moderate (km) scale dynamical downscaling followed by fine (10s m) scale empirical and other downscaling to snowdrift resolving scales.
- INARCH will calculate the sensitivity of mountain snow, ice and hydrology to climate change and resulting impacts, taking into account transient vegetation cover, and hydrological and cryospheric storage.

Next Steps from last meeting



- Complete Special Issue of *Earth System Science Data*.
- Mountain downscaling toolbox completion and posting to website
- LSS-H Model comparison and development – link to GLASS
- Multiscale climate change vulnerability analysis of alpine snow, ice and hydrological systems
 - Comparative analysis of alpine snow and ice hydrological sensitivity to warming – “Mediterranean Climate” and “Continental Climate”
- Link with Global Water Futures Program – international strategy



3rd INARCH Workshop

Zugspitze, Germany,
8–9 February, 2018



Topics:

- Snow Hydrology
 - Glacier Hydrology
 - Alpine Measurements including Remote Sensing
 - Climate Models and Downscaling for Mountains
- Each theme will be addressed by a keynote speaker and followed by a moderated discussion, and supplemented with topical poster sessions.
 - Progress on Comparative analysis of alpine snow and ice hydrological sensitivity to warming – “Mediterranean Climate” and “Continental Climate”



www.usask.ca/inarch

