# Project Report for the 2016 GEWEX GHP Meeting

Cross-cut Project Name: International Network for Alpine Research Catchment Hydrology (INARCH) Reporting Period: November 2015 – October 2016 Starting date: January 2015 End date: January 2020 URL: <u>www.usask.ca/inarch</u> Chair(s) and term dates: John Pomeroy, University of Saskatchewan. 2015-

## 1) Project activities over the last year

#### Science Highlights

INARCH developed specialised science on downscaling atmospheric models in mountain regions through the activities of a working group on the subject. The working group implemented and tested the new ICAR intermediate complexity atmospheric research model at high resolution at various mountain locations and also raised the need for "snow drift resolving" atmospheric models in mountains that made a series of presentations to CORDEX 2016 base. INARCH developed a mountain snow hydrology sensitivity intercomparison project and has conducted intercomparison of Mediterranean climate (Spain, Morocco, California, Chile) snow hydrology around the world that is being compiled into a multi-authored publication. INARCH developed a continental climate mountain snow hydrology sensitivity intercomparison that is being published in a series of multi-authored papers.

INARCH was well represented at the 6<sup>th</sup> **Third Pole Environment** Workshop, held at Ohio State University in Columbus, USA, from the 16th to the 18th of May, 2016.

- Dr Anil Mishra of UNESCO-IHP gave an opening address, mentioning INARCH and IHP. IHP was a major sponsor of the workshop.
- Dr Joseph Shea (Nepal), Dr Walter Immerzeel (Netherlands), Dr Maxime Litt (Nepal) and colleagues from ICIMOD (Nepal) gave important scientific talks at the workshop.
- Dr Peter van Oevelen of GEWEX gave a talk on how TPE might link to GEWEX and WCRP.
- Dr John Pomeroy presented on INARCH to the TPE group, strengthening links to this important initiative.

More information about the workshop is available here.

#### Science Issues

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. Besides contributing to GEWEX, INARCH provides mountain snow and ice water security information for UNESCO's International Hydrological Programme Water Security Project.

Dr. John Pomeroy, Dr. Danny Marks (USA) and Dr. Tobias Jonas (Switzerland) are guest-editing an INARCH special issue of <u>Earth System Science Data</u>, covering **Hydrometeorological data from mountain and alpine research catchments**. The aims of the issue are to respond to an international need to improve the understanding and modelling of mountain snow and ice hydrological processes. Data sets contributed to the special issue will 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. Contributors and researchers will use this mountain hydrology data publication special issue for the benefit of global alpine hydrological research. More detail on the submission process is available <u>here</u>. The final deadline is 30 September 2017.

## New projects/activities put in place last year

Downscaling atmospheric models to mountain catchments. INARCH developed a working group on downscaling atmospheric models in mountain regions. To present this science INARCH was well represented at WCRP's International Conference on Regional Climate – CORDEX 2016 in Stockholm over 17-20 May 2016, by Richard Essery (UK), Ethan Gutmann (USA) and Kabir Rasouli (Canada). An overall INARCH presentation by Richard Essery and co-authored by J Pomeroy (Canada), E Gutmann (USA), V. Vionnet (France) and A Winstral (Switzerland) reviewed current thinking on observations and downscaling for alpine hydrological modelling. The presentation is available as a <u>PDF (2.5 Mb)</u>.

## Workshops and meetings held

INARCH organised and chaired an oral session and a poster session on understanding and prediction of mountain hydrology at the 2015 Fall American Geophysical Meeting in San Francisco.

#### AGU Session on Improved Understanding and Prediction of Mountain Hydrology through Alpine Research Catchments

<u>Session C43F (oral presentations)</u>: 13:40 - 15:40, Thursday, 17 December 2015: Moscone W. - 3005 <u>Session C33A (posters)</u>: 13:40 - 18:00, Wednesday, 16 December 2015: Moscone S. - Poster Hall **Conveners**: John Pomeroy and Danny Marks

Mountains receive and produce a disproportionately large fraction of global precipitation and streamflow, including contributions to floods and essential water supplies for at least half of humanity. However, research in alpine catchments is complicated by the data scarcity of mountainous areas and that only a few well equipped alpine research catchments are available around the world. These sessions will address the following questions: How can snow and ice hydrology best be measured in various alpine regions? How do land surface energy and water exchanges differ in various high mountain regions of the Earth? What improvements to high mountain hydrological predictability are possible in various alpine regions through improved process physics, representation of spatial variability and incorporation of ground and remote observations? Intercomparisons of alpine hydrology and development of measurement and modelling methods that can have international applicability are especially encouraged. These sessions formed a contribution to GEWEX's INARCH project.

# 2) Planned project activities for next year

## 2<sup>nd</sup> INARCH Workshop, Grenoble, France, Oct 17-19 2016.

This workshop <u>http://www.usask.ca/inarch/wkshp2\_Oct2016.php</u> will provide a venue to bring scientists together to explore and discuss specific issues in mountain snow and ice hydrology highlighted after the inaugural INARCH workshop in Kananaskis in October 2015. This will be a 3-day workshop, including 2 days of presentations/discussions and a 1-day field trip to the French Alps INARCH observatories. The meeting venue will be the Laboratory of Glaciology and Environmental Geophysics (Lliboutry Conference Room on the campus of University of Grenoble, Grenoble, France. Three main topics will be covered by the Workshop:

- Atmospheric downscaling for mountain snow and ice hydrology modelling
- Availability and suitability of surface observations and spatial observations from mountain observatories and discussion of the mountain observations journal special issue
- Climate sensitivity numerical experiments / results from numerical diagnostic experiments using the cryospheric and hydrological response of mountain catchments to various representations of a changing climate

<u>Participate in snow model comparisons</u> at sites where inputs can measured/defined through links with GLASS (Richard Essery).

<u>Reduce measurement uncertainty</u> by implementing WMO SPICE recommendations for solid precipitation measurements at all sites and making contact with Global Cryosphere Watch for how to further improve measurement quality

<u>Develop a downscaling toolbox</u> by examining various techniques for statistical, dynamical and medium complexity downscaling.

<u>Continue climate sensitivity comparative analysis</u> of various alpine basins using "standard virtual basin" modelling to compare the response of snowcover, snowpack, glaciers and hydrology to variations in temperature and precipitation in various climate regimes.

## 3) Contributions to the GEWEX Science Questions

• GSQ1: Observations and Predictions of Precipitation

Simulations of mountain precipitation with the Intermediate Complexity Atmospheric Research model (ICAR) for the ideal case are quite good when compared to WRF model simulations.



However, this ideal case is not representative of the real world. When ICAR is driven by ERA-Interim or WRFG-CGCM data in the Canadian Rockies, The lower resolution of the forcing products causes ICAR to miss convective precipitation outside of the mountains in nearby high plains and to misrepresent precipitation in the high mountains.



GSQ3 Changes in Extremes

INARCH contributes in studies of mountain flooding and drought. An example of analysis of the snowmelt and glacier melt dominated Athabasca River by Paul Whitfield looks for changes in extremes from this hydrograph over time and also changes to the timing of streamflow.



#### • GSQ4: Water and energy cycles

Water and energy cycles in mountain catchments are dominated by snow mass and energy exchange processes such as blowing snow, snow interception, sublimation, and melt. The following example provided by Kabir Rasouli shows how annual fluxes of these processes vary by ecozone in the Reynolds Creek Research Watershed, Reynolds Mountain East sub-basin operated by Dr. Danny Marks of USDA and how sensitive they are to perturbed climate. The four climate scenarios are a) control period of current climate, b) P=100%, T= +5 C, c) P=120%, T=+5C. d) P=80%, T=+5C



## 4) Activities contributing to the WCRP Grand Challenges as identified by the JSC

#### Melting ice and global consequences

Record ice ablation from global glaciers in 2015 were recorded and reported to the World Glacier Monitoring Service. Some of these glaciers were INARCH sites as shown in the record below for Peyto Glacier, Canada, provided by Michael Demuth (Canada).



#### Climate extremes and water availability

Analysis by Dhiraj Pradhananga (Canada) shows that the record ablation on the Peyto Glacier corresponds to a period of record warm spring temperatures. Analysis by Paul Whitfield shows that this extreme condition was also associated with hydrological drought in 2014-2015 in the nearby Bow River Basin, despite record glacier ice melt.







# 5) Cooperation with other GHP and WCRP projects (CLIVAR, CliC, SPARC), outside bodies (e,g. iLEAPS) and links to applications

• Collaboration with UNESCO IHP and information collaboration with SPICE and Global Cryosphere Watch (CliC).

## 6) List of key publications

- Pomeroy, J.W., Essery, R.L.H. and W.D. Helgason. 2016. Aerodynamic and radiative controls on the snow surface temperature. *Journal of Hydrometeorology*, DOI:10.1175/JHM-D-15-0226.1
- Weber, M., Bernhardt, M., Pomeroy, JW., Fang, X., Harer, S., and K. Shulz. 2016. Description of current and future snow processes in a small basin in the Bavarian Alps. *Environmental Earth Sciences*, 75(17), 1223. doi:10.1007/s12665-016-6027-1
- Pomeroy J.W., <u>Fang, X.</u> and Marks D. 2016. The Cold Rain-on-Snow Event of June 2013 in the Canadian Rockies – Characteristics and Diagnosis. *Hydrological Processes*. DOI:10.1002/hyp.10905.
- Fang X. and Pomeroy J. 2016. Impact of antecedent conditions on simulations of a flood in a mountain headwater basin. *Hydrological Processes*. DOI: 10.1002/hyp.10910.
- Liu A., Mooney C., Szeto K., Thériault J.M., Kochtubajda B., Stewart R.E., Boodoo S., Goodson R., Li Y., and Pomeroy J. 2016. The June 2013 Alberta Catastrophic Flooding Event: Part 1 – Climatological aspects and hydrometeorological features. *Hydrological Processes. DOI:* 10.1002/hyp.10906.
- Rothwell R., Hillman G., and Pomeroy J.W. 2016. Marmot Creek Experimental Watershed Study. *The Forestry Chronicle*, 92 (1): p. 32-36. DOI: 10.5558/tfc2016-010.