INARCH:
International Network for Alpine Research Catchment Hydrology
2018-19 Meeting Closing

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4th Annual INARCH Workshop, Portillo, Chile 24-26 Oct 2018

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.

INARCH Workshop Statement 2017-18

- INARCH's global mountain observatories are providing a unique set of published, archived, high quality, surface, model and remote sensing datasets that will be made available to WMO-GCW and other global initiatives including remote sensing.
- INARCH encourages process validation and description to inform large scale and operational model advances, acknowledging the need to demonstrate improved predictions of the water security impacts of global change in mountain regions.
- INARCH is implementing hybrid downscaling with moderate (km) scale dynamical downscaling from atmospheric models followed by fine (<100s m) scale downscaling (dynamical, empirical) to *snowdrift resolving* scales for improved snow and ice hydrology prediction in support of mountain climate change policy runs.
- INARCH will use these model runs to predict the response of mountain snow, ice and hydrology to climate change, taking into account transient vegetation cover, basin geometry and hydrological and cryospheric storage.

INARCH Workshop Statement 2018-19

- INARCH has identified the importance of the changing High Mountain Water Cycle to global initiatives such as GEWEX, ANDEX, GWF, TPE and is contributing to a WMO High Mountain Summit and initiative. INARCH supports the idea of an International Year of Snow and Ice and also a year devoted to Mountain Prediction.
- INARCH has published invaluable mountain catchment hydrometeorological datasets from around the world through a special issue of Earth System Science Data with 19 articles. It has expanded to 28 catchments with contributions from 45 scientists based around the world.
- INARCH has identified dramatic snowpack decline and glacial retreat in the Andes and Patagonia as issues of global concern with some of the highest rates of glacial ablation in the world, due to both sublimation and melt. Global warming has included mountain mega-droughts in South America, causing hydrological shortages downstream. Complications in glacial modelling due to high sublimation rates, debris cover and the occurrence of penitent surfaces require physically based energy balance techniques for glacier hydrology in the Andes. Mining impacts on some of these glaciers are further accelerating ablation through direct disturbance and dust. An increasing number of glaciers are now debris-covered and so techniques to calculate icemelt under debris are needed in hydrological models. International and national mountain hydrology research programmes should prioritize research in the Andes to address these problems.
- The advent of large area, high resolution atmospheric models at 4 km or less, now permits more confident meteorological drivers for advanced snow and glacier hydrology models in complex mountain terrain. The performance of these high resolution atmospheric models needs to be assessed at point and areal scales and spatial datasets for such assessments and for bias-correction need to be assembled. Global application of these products to mountains is needed. High resolution snow and ice hydrology models, including hillslope hydrology processes need development to take advantage of the more accurate alpine precipitation products that will result.
- There is tremendous potential to assimilate high resolution remote sensing products such as snow depth from airborne LiDAR, albedo, grain size and impurities from hyperspectral sensors and visible snowcovered area from multiple platforms into advanced snow hydrology prediction models and some examples of this are occurring. Efforts are needed to demonstrate how more mountain ranges around the world can be measured by these products and how the outputs can be used together to improve snow prediction models.
- INARCH has quantified the sensitivity of mountain snow hydrology regimes around the world using cold regions hydrological models of virtual alpine basins, driven by reanalysis data, and has shown that decoupling of the snow and hydrological regime with warming is most severe for temperate winter climates with winter precipitation maxima as typified by Mediterranean alpine environments. The results show the controls of both temperature and vapour pressure in determining the sensitivity of mountain snow hydrology to warming. This approach should be extended to examine the sensitivity of mountain glacier hydrology to global warming.
- INARCH continues to examine the performance of alpine snow models in simple alpine environments by comparison of model outputs to diagnostic measurements in INARCH catchments. The next step should be to examine model performance in extreme alpine environments that are more typical of alpine landscapes.

Next Steps

- Finalized Special Issue of *Earth System Science Data.*
- Mountain downscaling toolbox portal completion and posting to INARCH website
- LSS-H Model comparison and development – ongoing project linked to GEWEX-GLASS with publication imminent (Essery)
- Multiscale climate change vulnerability analysis of alpine hydroglaciological systems, use CRHM at INARCH basins
- Pre-assessment articles from INARCH for IPCC mountain report Jan 2019
- GEWEX RHPs – US Water for Foodbaskets, GWF, ANDEX
- Next Meetings
    - WMO High Mountain Summit Oct 2019
    - Bangalore India Future Earth - Water Futures: Mountain & Climate Change Session

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