International Network for Alpine Research Catchment Hydrology

INARCH 2024 Closing

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https://inarch.usask.ca

INARCH Phase II Science Questions

1. How different are the **observation and measurement approaches** amongst INARCH basins and do we expect distinctive differences in our understanding of basin response and hydrological predictability because of the sampling schemes, and data quality and quantity?

2. How do the **predictability, uncertainty and sensitivity of energy and water exchanges** vary with changing atmospheric thermodynamics, ecosystem structure and water management in various high mountain regions of the Earth?

3. What improvements to high mountain **energy and water exchange predictability** are possible through improved physics in, coupling of, and downscaling of models in complex terrain, and improved and expanded approaches to data collection and assimilation?

4. To what extent do existing **model routines have global validity**, are transferable, and meaningful in different mountain environments for providing service to society?

5. Can mountain systems be **predicted and managed to find solutions** to help achieve water sustainability in river basins under climate change?

Eventually contribute to answering - How have mountain atmospheric-cryospheric-hydrological-ecosystem-human systems co-evolved to their current states and how will they respond to climate change over the next century?

INARCH Workshop Statement 2021

- We have <u>completed our Phase 1 Science Plan</u> and have a suite of well-instrumented research basins, high-resolution forcing meteorological datasets, and advanced snowdrift-permitting and glacier-resolving hydrological models that are exemplars of **Integrated High Mountain Observation and Prediction Systems (IHMOPS)**.

- We have used the <u>IHMOPS to improve our scientific understanding, and evaluate observed changes, data and models</u> around the world. The models are being used to estimate the sensitivity of the high mountain cryosphere and hydrology to climate change.

- We need to
  - provide common and archived observations for basin diagnosis and modelling through a Common Observation Period Experiment (COPE),
  - enhance basin observations with novel and more sensors,
  - Improve, downscale and correct atmospheric forcing datasets using basin observations,
  - develop, improve, compare, and apply multiscale high-fidelity cryosphere-hydrological-water management models to river basins originating in high mountains
  - work with communities to develop plans to predict future water scenarios, build capacity, enhance forecasting systems, answer questions on water futures and evaluate the sustainability of proposed water management solutions.

INARCH Statement 2022

We have

- begun Phase 2, started COPE,
- expanded investigators, observations, basins, mountain ranges, and models,
- implemented a data cataloguing system, snowdrift-resolving models continentally,
- explored new measurement techniques, data assimilation, parameter uncertainty and machine learning,
- started linking to ecosystems and downstream water resources;
- informed a proposed UN Year of Glacier Preservation and contributed to WMO, UNESCO, WCRP, UN Water Decade

We need to

- Develop detailed science investigations in COPE and ensure that it is used by other groups (WMO, intercomparison projects)
- Apply atmospheric/hydrological/other models to INARCH basins for the COPE period
- Co-develop plans to and share experiences on increase mountain community/regional science and decision making capacity

INARCH Statement 2023

- INARCH is helping to plan science for and contribute to the UN International Year for Glaciers' Preservation – 2025, including snow, mountain water and frozen ground.

- COPE is running successfully around the world, observations are being made and archived in a data management system and models are being identified and some prepared to analyse the data

- Climate change and extremes continue to strongly affect basin cryosphere and hydrology during the COPE period, including rapid glacier retreat, groundwater destabilisation, drought, fires, and floods.

- A greater appreciation of subsurface storage and flow pathways has emerged in INARCH which is improving the ability to predict and diagnose future hydrology as snow and glacier contributions decline.

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Summary of COPE Updates

- Compare elasticity of response of COPE basins to T and P changes
- Compare for trends and change points in basin cryosphere and hydrology
- Compare ecological changes occurring and their impact on basins – treeline, shrubs, wildfire
- Model intercomparisons should emphasize diagnosing processes in complex terrain and include sparse forests, non-needleleaf vegetation, glaciated and alpine windblown sites
- **Time to submit COPE data**.
- Models need to prepare for multi-basin runs to complete by spring.
- Special Issue of HESS, sessions at EGU and AGU
- Synthesis papers encouraged based on international collaborations.
- Continue ESSD data special issue.

INARCH Statement 2024

- INARCH met in Asia for the first time and engaged with many scholars and institutes who are contributing substantially to increasing the capacity and advances of high mountain hydrometeorology and cryospheric science

- Dramatic expansion of high quality observations in High Mountain Asia and use of this data with sophisticated models to diagnose changing cryosphere and hydrology

- Atmospheric forcing data including reanalysis continues to improve and refine resolution but needs bias correction in high mountains to be useable. INARCH to work with CliC.

- Risks and hazards in high mountains have been identified and there is a research need for observation, early warning and prediction systems.

- Sub-surface flow and ecological interactions are important areas for development in INARCH with some advances and more needed.

- Black carbon and dust impacts on albedo and melt are a source of uncertainty that needs more attention.

- International teams are testing and applying a suite of models in multiple INARCH basins and show transferability of approaches and algorithms

- INARCH should continue to develop collaborations with other groups and initiatives to enhance its capability and to build capacity.

- International Year for Glaciers Preservation and UN Decade of Action for the Cryospheric Sciences start in 2025 and INARCH is poised to deliver advances in monitoring, science and application to both initiatives. INARCH should continue.

INARCH 2025

- Meeting adjacent to the International Mountain Conference, Innsbruck, Austria in 13-19 September 2025
- Thank you Lindsey Nicholson, Uli Strasser and Rainer Princz for local organising.

Observe, Predict, Protect

Fortress mountain Gene 2019