Updates on the International Network for Alpine Research Catchment Hydrology (INARCH) and its 2023 Annual Workshop

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Overview of INARCH

The International Network for Alpine Research Catchment Hydrology (INARCH, *https://inarch.usask.ca*) is a cross-cutting project of the GEWEX Hydroclimatology Panel (GHP) to better understand alpine cold regions hydrological processes, improve their prediction, diagnose their sensitivities to global change, and find consistent measurement strategies. At its core is a global network of highly-instrumented mountain observatories and experimental research sites, which are testbeds for detailed process studies on mountain hydrology and meteorology, developing and evaluating numerical simulation models, validating remotely sensed data, and observing, understanding, and predicting environmental change. There are now 38 research basins and sites in 18 countries and six continents, with more continuing to join the network. For a full description of INARCH and details on the research basins, participants, science questions, goals, and activities, visit our website and see the article in the February 2023 issue of *GEWEX Quarterly* (*https://www.gewex.org/resources/gewex-news/*).

Update on the Common Observing Period Experiment (COPE), 2022–2024

INARCH is conducting a Common Observing Period Experiment (COPE) over the period 2022–2024 as a focal network activity. The purpose of this is to collect high-quality measurements to the extent possible, along with supplementary observations and remote sensing campaigns, to produce a common, coherent, and well-documented and described data set of mountain meteorology and hydrology from INARCH basins over the two-year period at a minimum, and longer where possible. We plan to take different models, apply them across our basins, examine the impact of different forcing data and process representations and model structures, calculate snow and ice dynamics and hydrological responses, and look at these diagnostically using observations.

COPE is now well underway with intensive observation campaigns at most of our basins and frequent visits for fieldwork and site maintenance. We have developed detailed inventories of the sensors and instrumentation in place, the data being collected, and the models to be run and their input requirements and outputs. There is an ongoing effort to assemble the data and conduct basic quality assurance and control procedures and gap-filling for model input, as well as ensuring we have the proper variables for model testing and for further description of the hydrometeorology, where this is available. It is already clear that the period has covered a range of simultaneous and varying extremes—from extreme high snowpacks in the Sierra Nevada, USA, to devastatingly low snowpacks and snow-cover in the Alps in 2022–2023; from severe drought in many places such as the Canadian Rockies, the Andes, and Alps, interrupted by extreme rainstorms such as in central Chile in June 2023, to devastating floods such as in Sikkim, India, in October 2023; and with extreme heat causing extremely high melt of mountain glaciers.

The next steps will involve diagnostic model evaluations on INARCH basins—not the formal intercomparisons of snow water equivalent (SWE) simulation as has been done in the past, but evaluating the results of diagnostic modelling using field observations to better understand why models produce various behaviors and to see if models benchmark various known aspects and regimes of the coupled atmospheric-cryospheric-hydrological system. Model diagnostic evaluations will emphasize atmospheric, snow, glacier, and water processes in high mountain terrain and include sparse forest, non-needleleaf vegetation, glaciated, and alpine windblown sites. Other planned analyses include comparison of the responses and sensitivity of COPE basins to temperature and precipitation changes, comparing trends and change points in basin cryosphere and hydrology, and comparing ecological changes occurring (e.g., treeline, shrubs, wildfire) and their impacts on basins. COPE will have tremendous scientific value in reducing the uncertainty of our understanding and ability to predict global change and water cycling and contributes directly to GEWEX; the World Meteorological Organization (WMO); the United Nations Educational, Scientific and Cultural Organization (UNESCO); Future Earth, the United Nations Framework Convention on Climate Change (UNFCC); and other global programs. It will produce a valuable and unique set of observations, model simulations and intercomparisons, new process understanding and insights, and better prediction of the changing mountain water cycle in the headwaters of many of the world's major river basins.

Summary of 2023 Workshop, Idaho, USA

INARCH's most recent annual workshop was held October 9–11, 2023 at the Mountain Village Resort in Stanley, Idaho, USA. Professor James McNamara and Dr. Ernesto Trujillo-Gomez of Boise State University (BSU), and Dr. Andrew Hedrick of the USDA Agricultural Research Service, were our 2023 workshop hosts, and there were 28 in-person attendees and 10 more online. Ahead of the workshop, participants visited the INARCH catchment at Dry Creek Experimental Watershed outside of Boise, with discussions of instrumentation, methodologies, goals, and scientific results, led by Jim McNamara, Ernesto Trujillo-Gomez, and Maggi Kraft. Following this, participants toured some of the cold laboratory facilities at BSU and then departed to Stanley in the Sawtooth Mountains.

The workshop included 1.5 days of presentations and discus-

Left: INARCH participants on October 11, 2023, outside of the Mountain Village Resort, Stanley, Idaho. **Middle**: *field tour at the Dry Creek Experimental Watershed.* **Right**: *field tour at the Reynolds Creek Experimental Watershed as part of the 2023 annual INARCH workshop.*

sion on topics including: Observatories and Measurement Techniques, Observations and Modelling, and COPE Updates, as well as one hybrid session to allow for updates via Zoom. The presentations showed tremendous scientific advancements and covered the wide range of field and modelling activities underway as part of the COPE. Presentations, workshop photographs, and summaries of the different sessions are available at *https://inarch.usask.ca/news-events/inarch-workshop-2023.php*.

After the workshop, participants visited the INARCH catchment at Reynolds Creek Experimental Watershed in the Owyhee Mountains, with discussions of instrumentation, methodologies, history, and findings led by Andrew Hedrick, Gerald Flerchinger, and other USDA Northwest Watershed Research Center staff. Throughout the workshop and field tours, our hosts at BSU and USDA provided excellent hospitality, organization, and arrangements.

INARCH Statement 2023

- INARCH is helping to plan science for and contribute to the UN International Year of 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, with some prepared to analyze the data.

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

We need to:

- Develop detailed science investigations in COPE and ensure that COPE data is used by other groups (WMO, intercomparison projects).

- Apply atmospheric/hydrological/other models to INARCH basins for the COPE period.

- Co-develop plans to share experiences on increasing mountain community/regional science and decision-making capacity.

Upcoming Activities and Events

A resolution (*https://digitallibrary.un.org/record/3994297?ln=en*) was passed by the UN General Assembly in December, 2022, which noted "shrinking of the cryosphere, with mass loss from ice sheets and glaciers and reductions in snow cover, which have decreased the stability of high mountain areas and change the amount and seasonality of runoff and water resources in snow-dominated and glacier-fed river basins" and declared 2025 as the International Year of Glaciers' Preservation and each March 21st as the World Day for Glaciers. The UN invited "activities aimed at raising awareness of the importance of glaciers, snow, and ice in the climate system and the hydrological cycle…and to share best practices and knowledge in this regard". INARCH is well-positioned to support this initiative and contribute to its scientific milestones on snow and ice observations systems, assessment and prediction of their contributions to freshwater supplies, and development of modelling and information systems for mountain basins and development of adaptations in downstream river basins. It can also contribute to sharing knowledge and building scientific capacity. The results of COPE will be available for release in 2025 and will be a contribution to this Year.

INARCH will hold the next Annual Workshop from October 14–19, 2024 in Lanzhou and Zhangye in central China. The workshop will be hosted by Dr. Tao Che and Dr. Xin Li of the Chinese Academy of Sciences and will involve examination of research catchments in the Qilian Mountains. As with past workshops, the plan will be to hold scientific sessions and discussions, updates on COPE, and to visit local research basins and experimental field sites. Further details will be available on our website.

We are excited about the ongoing work and looking forward to seeing it through to completion. INARCH welcomes new participants who wish to contribute to its goals and objectives, and to participate in the COPE initiative. Feel free to contact us or check our website for updates.