Addressing Water Security through Better Understanding and Predicting Mountain Snow Water Resources under Climate Change

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Global Water Security Challenges:

- unsustainable use of water food, energy, industry, drinking
- increasing competition for water resources transboundary issues
- degradation of water quality agricultural runoff, industry, sewage
- increasing risk from extreme events heavy rainfall and snowfalls
- unprecedented environmental change,
 - especially in high mountains rapidly glacier melt, declining snow, heavy rainfall



Water Security Impacts from Mountain Catchments

- Mountains provide water supply for over half of humanity.
 - Diminishing supplies due to climate change and consumption, both in mountains and downstream
- Recent mountain flood deaths and damage from unprecedented precipitation - examples
 - Pakistan, Afghanistan, Nepal, India since 2010 ~8225 deaths reported from heavy mountain rains.
 - Bosnia, Serbia May 2014, 62 deaths reported, 1.6 million affected
 - Western Canada June 2013, 4 deaths reported, \$6 billion in damages
 - Colorado, USA Sept 2013, 10 deaths, 2000 homes damaged





Urgency

- to 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 including contributions to floods and water supply and drought protection for vast downstream areas.
- Snow, ice, and precipitation phase change dominate the behaviour of alpine hydrology – therefore especially sensitive to climate warming.





Declining Spring Snowcovered Area



Ross Brown, Environment Canada

Significance

- Understanding the sensitivity of alpine hydrological processes to changing high elevation climate is of disproportionate importance to global water and energy exchange and downstream water resources.
- 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.





Alpine Regions are Data Scarce





Altitudinal distribution of global runoff stations represented in the GRDC archive and global precipitation station network represented in the GPCC archive compared to global hypsography of the land surface area (without Greenland and Antarctica). The inset shows a magnification for altitudes above 1500ma.s.l. (Viviroli et al. 2011).

Research Need

A concerted global effort is needed to address how changing high mountain hydrological processes will mediate the influence of atmospheric change in alpine catchments.





Objectives

Overall: to better understand alpine cold regions hydrological processes, improve their prediction and find consistent measurement strategies.

To achieve this objective it is necessary to develop transferable and validated hydrological model schemes of different complexity that can support research in data sparse mountain areas dominated by elements of snow, permafrost and glacier cover.



Integrated Alpine Observing & Predicting Systems



Instrumented alpine catchments with, remote sensing, modelling, downscaling, data assimilation in order to better evaluate mountain water and energy exchange.

International Collaboration through Field & Model Experiments





Upper Heihe River Basin, 4150 m China

Schneefernerhaus, Zugspitze, 2650 m Germany



Wolf Creek, Yukon, Canada Ecozone Effects



Wolf Creek, Yukon, Canada Streamflow Impact





INARCH: International Network for Alpine Research Catchment Hydrology

<u>Canada</u> – Canadian Rockies & Yukon; <u>USA</u> – Reynolds Creek, Idaho; Senator Beck Basin, Colorado.

<u>Chile</u> - Upper Maipo & Upper Diguillín River Basins, Andes, <u>Germany</u> – Schneefernerhaus & Zugspitze; <u>France</u> – Arve Catchement, Col de Porte & Col du Lac Blanc;

<u>Switzerland</u> – Dischma & Weissfluhjoch;

<u>Austria</u> - OpAL Open Air Laboratory, Rofental <u>Spain</u> – Izas, Pyrenees;

<u>China</u> – Upper Heihe River, Tibetan Plateau,

<u>Nepal</u> – Langtang Catchment, Himalayas

Integrated Alpine Observing and Predicting Systems (IAOPS), initial sites to be considered

INARCH Collaborators



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- INARCH accepted by GEWEX Hydrometeorology Panel as a "Project" in December 2014
- GEWEX = Global Energy and Water Exchanges project of World Climate Research Programme
- Core funding to INARCH is needed to facilitate collaboration and central project operation through:
- Travel funding support for workshops, scientific exchanges, joint field and modelling experiments,
- User support for and central modelling development of Modelling and Downscaling Toolboxes
- Data management of the data repository and model outputs for intercomparison experiments
- Outreach and training activities.

UNESCO and **INARCH**

Contribution to Water Security

► UN Year of Snow and Ice (?)

Conclusions

- Global need for improving predictive models and observations of mountain snow hydrology for water security assessments through collaboration
- Mountain snowpacks show extreme sensitivity to warming with important variations by region, altitude, ecosystem. This results in reduced streamflow volumes after snowmelt
- Increased frequency of mountain flooding has been concomitant with reduced warm-season streamflows



