Project proposal form

Project title: Projecting hydroclimatic extremes in the Himalayas for the 21st century
Project code:
Host institution: School of Geography, Earth and Environmental Sciences, University of Birmingham
Theme:
Key words: climate change, hydrological extremes, Himalayas
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Project Highlights

- **Investigating hydroclimatic extremes affecting over 1 bn people in vulnerable regions;**
- **Use of cutting-edge climate and hydrological models;**
- **Working in an international and interdisciplinary research environment.**

Overview

The livelihoods of over 1 bn people inhabiting the Himalayan region_and_the downstream river basins are heavily dependent on agriculture, making them highly vulnerable to water shortages and flood events. In addition, hydropower is a major contribution to energy production. Mitigation against climate- and hydrology-related risks caused by climate change and exploitation of potential benefits of hydrological changes requires comprehensive climate and glacio-hydrological predictions for the region.

Figure 1: *Glacierised river basin in the Himalayas.*

Coupling climate and hydrological models is still a challenge, partly due to systematic biases in the output of global and regional climate models, which in turn can lead to unrealistic hydrological projections. Current projections for precipitation changes in the Himalayan region during the 21st century show a large spread over some areas, encompassing wetter and drier conditions. Although some of this spread may reflect fundamental and non-reducible uncertainties caused by random, natural climate variability, a large part of it may be due to differing sytematic errors in the climate models, which in principle can be reduced.

The aim of this project is to reduce the uncertainty in hydroclimatic projections for the Himalayan region by only using models that represent the key large-scale mechanisms well, rather than using a skill-independent full ensemble approach. The specific objectives needed to implement this 'emeregent constraints' approach are:

- to identify the specific aspects of large- and meso-scale processes such as Indian Summer Monsoon and wintertime westerly disturbances that are driving regional precipitation variability, with a focus on extremes;
- to define suitable performance measures for these aspects to evaluate climate models against observations;
- to drive glacio-hydrological models with the full ensemble of climate simulations, as well as with the well-perfomring subset, and thus understand the nature of the spread in hydroclimatic predictions and reduce it.

Methodology

Global General Circulation Models (GCMs) from the CMIP5/CMIP6 ensembles will be evaluated with respect to i) characteristics of the Indian Summer Monsoon (e.g. onset and withdrawal dates, distribution of active and break periods); ii) location, frequency and intensity of wintertime westerly disturbances; and iii) large-scale atmospheric and sea surface temperature anomalies that influence the Himalayan climate (e.g. Indian Ocean sea surface temperatures, ENSO, Northern Annular Mode). Model evaluation will be against surface and satellite observations, and atmospheric reanalyses (ERA-Interim, ERA20C).

Regional Climate Model (RCM) simulations driven by CMIP5 are available from the CORDEX-South Asia archive, and CMIP6-driven RCM simulations are ongoing. A representative selection will be used in combination with bias correction to drive glacio-hydrological models, with some simulation conducted by the student and others by project partners. The sensitivity of precipitation runoff, glacier melt, river flow to the GCM-selection will be analysed, in particular for floods and droughts.

Training and skills

The project enables to work on cutting-edge problems in hydrology and climate modelling using supercomputers and state-of-the-art models. Training in climate and hydrological modelling and analysis will be provided at the University of Birmingham. There is the opportunity to attend related lectures on the MSc program 'Applied Meteorology and Climatology'.

Co-supervision by Indian collaborators will ensure direct involvement with experts on Himalayan climate and hydrology. Funding for visits of UK junior researchers to India is expected to become available. The supervisors also have many well-established international and international links, which will help the student to build a research network.

CENTA students are required to complete 45 days training throughout their PhD including a 10 day placement. In the first year, students will be trained as a single cohort on environmental science, research methods and core skills. Throughout the PhD, training will progress from core skills sets to master classes specific to the student's projects and themes.

Partners and collaboration

The School of Geography, Earth and Environmental Sciences at the University of Birmingham includes strong groups in climate science, hydrology and glaciology, which makes it ideal to host this interdisciplinary project. In addition the student will benefit from links to international projects on regional climate change (EU COST Action VALUE, CORDEX South Asia), hydrological and glaciological processes (UNESCO-FRIEND, IAHS Panta Rhei), and hydroclimatic changes in India (India UK Water Centre). There are also well-established links with leading climate, hydrological and glaciological centres (UK Met Office, Max Planck Institute for Meteorology, British Antarctic Survey and universities of Freiburg, Zurich and Utrecht).

Possible timeline

Year 1:
Identify large- and mesoscale drivers for hydroclimatic extremes in the Himalayas. Define performance measures for their representation in GCMs and evaluate CMIP5/CMIP6 ensembles.

Year 2:
Conduct an ensemble of simulations with glacio-hydrological models driven by a representative subset of available GCM-RCM simulations.

Year 3:
Quantify changes in hydroclimatic extremes during the 21st century in the simulations, including uncertainties. Analyse the simulations based on the well-perfoming GCMs and on the full CMIP ensemble separately , and assess the reduction in uncertainty through model selection.

Further reading:

Widmann, M., R. Blake, K. P. Sooraj, A. Orr, J. Sanjay, A. Karumuri, A. Mitra, E.N Rajagopal, A.F. Van Loon, D.M. Hannah, N. Barrand,, R. Singh, V. Mishra, F. Sudgen, and D.S Arya, 2017: Current Opportunities and Challenges in Developing Hydro-Climatic Services in the Himalayas. IUKWC report. Available from http://www.iukwc.com.

Maraun and Widmann, 2018: Statistical downscaling and bias correction in climate research. *Cambridge University Press*, ISBN 1107066050.

Maraun, D, T. Shepherd, M. Widmann, G. Zappa , D. Walton, J. Gutierrez, S. Hagemann, I. Richter, P. Soares, A. Hall, and l. Mearns, 2017: Towards process-informed bias correction of

climate change simulations. *Nature Climate Change,* **7** (11), 764-773.

Garner, G, A.F. Van Loon, C.l Prudhomme, and D.M. Hannah, 2015: Hydroclimatology of extreme river flows. *Freshwater Biology*, **60** (12), 2461-2476.

Barrand, N.E. and T. Murray, T., 2006: Multivariate controls on the incidence of glacier surging in the Karakoram Himalaya. *Arctic, Antarctic and Alpine Research*, **38**(4), 489-498.

Krishnan, R., T. P. Sabin, R. Vellore, M. Mujumdar, J. Sanjay, B. N. Goswami, F. Hourdin, J.-L. Dufresne, P. Terray, 2016: Deciphering the desiccation trend of the South Asian monsoon hydroclimate in a warming world. *Climate Dynamics*, **47**, 1007-1027..

Mishra, V., D. Kumar, A. R. Ganguly, J. Sanjay, M. Mujumdar, R. Krishnan, and R. D. Shah, 2014: Reliability of regional and global climate models to simulate precipitation extremes over India, *J. Geophys. Res. Atmos.*, **119**, 9301–9323.

Singh, R., and Kumar, R., 2015: Vulnerability of water availability in India due to climate change: a bottom-up probabilistic Budyko analysis. *Geophysical Research Letters,* **42**, doi: 10.1002/2015GL066363.

Van Tiel, M., Teuling, A. J., Wanders, N., Vis, M. J. P., Stahl, K., and Van Loon, A. F., 2017: The role of glacier dynamics and threshold definition in the characterisation of future streamflow droughts in glacierised catchments, *Hydrol. Earth Syst. Sci. Discuss*., doi: 10.5194/hess-2017-119, in review.

Further details

Applicants should have a background in a related field such as climatology, meteorology, hydrology, geosciences, physics or mathematics. Good statistical analysis skills, as well as programming experience are essential. Working experience with UNIX and climate or hydrological models would be beneficial. For further details please contact M. Widmann (m.widmann@bham.ac.uk).