

Integrating Precipitation Forecasts and Climate Prediction with Basin-Scale Hydroclimatic Modelling in the Himalayas

Report of Scientific Workshop, May 2018

June 2019



INDIA-UK
Water Centre
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जल केन्द्र

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The India-UK Water Centre promotes cooperation and collaboration between the complementary priorities of NERC-MoES water security research.

भारत-ब्रिटेन जल के द्र एमओईएस-एनईसीआरसी(यूके) जल सुरक्षा अनुसंधान के पूरक प्राथमिकताओं के बीच सहयोग और सहयोग को बढ़ावा देने के लिए करना है

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Executive Summary

This report represents an overview of the participation, activities and conclusions at a Science Workshop held at the Wildlife Institute of India, Dehradun, Uttarakhand, India, between the 2nd and 4th of May 2018. It was convened by the India UK Water Centre and led by Dr Martin Widmann of the University of Birmingham, UK and Dr Shresth Tayal of The Energy and Resource Institute (TERI), India.

This inter-disciplinary workshop aimed to foster the integration of weather forecast and climate models with glacio-hydrological models for the Himalayas, which is crucial for the improvement of short-, medium-, and long-term hydrological predictions for Himalayan basins. By bringing together scientist from India and the UK it led to a detailed understanding of the key challenges related to data scarcity, process understanding, development and validation of meteorological and hydrological models, and to downscaling and bias adjustment methods. Based on this, a number of specific steps forward were suggested, which partly can be implemented in the near future using inter-disciplinary and inter-institutional synergies, and partly require additional resources and longer implementation periods.

The report is intended for the workshop participants, IUKWC Open Network members and stakeholders.



Figure 1: The workshop delegates at the Wildlife Institute in Dehradun

1. Workshop Conveners

The workshop was convened by the India-UK Water Centre (IUKWC) and led by:

Dr. Martin Widmann

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Dr. Shresth Tayal

The Energy and Resource Institute

India Habitat Centre Complex, Lodhi Road, New Delhi 110003

India

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The workshop was held at the Wildlife Institute of India, Dehradun, Uttarakhand, India, from 2th - 4th May 2018

2. Workshop Aims

The IUKWC is based around five key cross-sectoral themes and aims to deliver a portfolio of activities across these themes. This activity focused on the theme ‘Developing hydro-climate services to support water security’.

The workshop aimed to foster the development of short-, medium-, and long-term hydrological predictions for Himalayan basins. A key challenge for this is the integration of weather forecast and climate models with glacio-hydrological models. Integrated forecast systems for the Himalayas are still in a pioneering phase and are not operationally available. A major problem is precipitation biases in weather and climate models, which in turn lead to biases in the output of glacio-hydrological models. Moreover, not all important processes, basin properties and water use aspects are incorporated in glacio-hydrological models, partly due to scarce observations.

The specific workshop objectives were to:

- Discuss solutions for key scientific problems that hamper integrated modelling, such as precipitation biases and choice of suitable statistical post-processing correction methods, or availability of observations for model evaluation and for defining initial conditions.
- Assess the current state of meteorological and glacio-hydrological modelling capabilities and identify gaps and ways forward, including how to gain synergies by increasing cross-institutional collaboration.
- Increase the collaboration between the meteorological and hydrological communities.

This workshop developed out of a project led by Dr. Widmann that looked at the current opportunities and challenges in developing hydro-climatic services in the Himalayas (for more information see Widmann *et al.*, 2018, at <https://iukwc.org/water-briefs> Water brief 04).

3. Workshop Participants

An open call for the workshop was placed on the IUKWC website and 87 applications were received. A selection panel consisting of one member of the IUKWC office in India, one member of the office in the UK, and the two workshop leads allocated scores for the applications. These were based on the relevance of the applicant’s research to the workshop, the motivation for attending, the expected contribution to the workshop aims, and the expected benefit for the applicant.

Because the workshop was held in India, the number of places for participants from India was higher than for those from the UK, and 22 participants from India and 11 from the UK were selected, with an additional twelve spaces reserved for invited speakers from the Wildlife Institute of India, who acted as hosts for the workshop. The delegates provided a broad range of expertise in hydrology, meteorology and climate science, covering observations, process understanding, modelling, and applications. The participants represented a large number of leading Indian and UK universities and research centres (Table 1). There was a good balance of gender (33 male and 15 female) and of different career stages, with about nine early career researchers in attendance.

Table 1: List of delegates

	Name	Institution
UK		
1	Dr. Alexandre Gagnon	University of the West of Scotland
2	Dr. Andrew Ross	University of Leeds
3	Dr. Andrew Orr	British Antarctic Survey
4	Dr. Jonathan Eden	Centre for Agroecology, Water and Resilience (CAWR), Coventry University
5	Mr. Jamie Hannaford	Centre for Ecology & Hydrology
6	Dr. Calum Baugh	European Centre for Medium Range Weather Forecasts
7	Miss. Anya Schlich-Davies	University of Leeds
8	Dr. Andrea Momblanch	Cranfield Water Science Institute, Cranfield University
9	Dr. Alan Gadian	National Centre for Atmospheric Sciences, University of Leeds
10	Ms. Emily Potter	British Antarctic Survey
11	Dr. Indrani Roy	University of Exeter
12	Dr. Martin Widmann	University of Birmingham (UK Lead)
13	Dr. Rhiannon Blake	University of Birmingham (UK Co-Lead)
14	Dr. Harry Dixon	Centre for Ecology & Hydrology (IUKWC UK Coordinator)
15	Mr. Chris Bell	Centre for Ecology & Hydrology (IUKWC UK Secretariat)
India		
16	Dr. Ramarao MVS	Indian Institute of Tropical Meteorology
17	Dr. Basudev Biswal	India Institute of Technology Bombay
18	Dr. Kasiviswanathan KS	Indian Institute of Technology Mandi
19	Dr. Saravanan K	Vellore Institute of Technology Chennai
20	Mr. Saquib Saharwardi	Indian Institute of Science Education and Research Bhopal
21	Mr. Javed Akhter	Jadavpur University
22	Ms. Akanksha Patel	Indian Institute of Technology Roorkee
23	Mr. Dinesh Kumar Singh	Tata Consultancy Services Ltd
24	Dr. Aditi Bhadra	North Eastern Regional Institute of Science and Technology
25	Dr. Sneha Joshi	National Centre for Medium Range Weather Forecasting
26	Dr. Asha Rajvanshi	Wildlife Institute of India
27	Dr. K. Sivakumar	Wildlife Institute of India
28	Dr. G. S. Rawat	Wildlife Institute of India
29	Dr. Sathyakumar	Wildlife Institute of India
30	Mr. Arun Kumar	Wildlife Institute of India
31	Ms. Sujata Upgupta	Wildlife Institute of India

32	Dr. Vineet K Dubey	Wildlife Institute of India
33	Ms. Aashna Sharma	Wildlife Institute of India
34	Ms. Tanvi Gaur	Wildlife Institute of India
35	Dr. Gautam Talukdar	Wildlife Institute of India
36	Ms. Chaitra Arakesha	Indian Institute of Science
37	Prof. Lalu Das	Bidhan Chandra Krishi Viswavidyalaya
38	Dr. Milind Mujumdar	Indian Institute of Tropical Meteorology
39	Dr. Akhilesh Mishra	Amity Interdisciplinary Center for Climate Research and Policy, Amity University
40	Dr. Ashis Mitra	National Centre for Medium Range Weather Forecasting
41	Dr. Pankaj Kumar	Indian Institute of Science Education and Research Bhopal
42	Dr. Riddhi Singh	Indian Institute of Technology Hyderabad
43	Dr. Indu J	Indian Institute of Technology Bombay
44	Prof. Ghulam Jeelani	University of Kashmir
45	Mr. Sandeep Shukla	Indian Institute of Technology Roorkee
46	Mr. Jaydeo Dharpure	National Institute of Technology Roorkee
47	Dr. Manohar Arora	National Institute of Hydrology
48	Dr. Shresth Tayal	The Energy Research Institute (India Lead)
49	Dr. Atul K Sahai	Indian Institute of Tropical Meteorology (IUKWC India Coordinator)
50	Mr Ajith Prasad	Indian Institute of Tropical Meteorology
51	Ms. Priya Joshi	Indian Institute of Tropical Meteorology (IUKWC India Secretariat)
52	Mr. Anil K Pandey	Indian Institute of Tropical Meteorology (IUKWC India Secretariat)

4. Workshop Structure

The Himalayan region and downstream areas are strongly affected by hydrological variability and thus there is a clear need for hydro-climatic predictions on all timescales. The current situation in India is characterised by the availability of state-of-the-art global and regional weather forecasting and climate models, as well as of glacio-hydrological models. However, integration of the different components is lacking, yet is crucially needed for hydrological predictions. This is one of the key findings of the IUKWC report on Challenges and Opportunities in Developing Hydro-Climatic Services for the Himalayas (Widmann *et al.*, 2018). The purpose of this workshop was to bring together a critical mass of researchers and practitioners that can advance integrated modelling to the next level.

The workshop was held over three full days (See Annex A for the Agenda). It started with an inaugural session with welcome addresses from the Indian and the UK IUKWC coordinators Dr. A.K. Sahai and Dr. H. Dixon, and the director of the hosting Wildlife Institute of India, Dr V.B. Mathur. There were five technical sessions. Four of them covered the modelling of the individual system components and the challenges of their integration. One session was dedicated to the

impacts of climate change to demonstrate the need for hydro-climatic predictions and to guide the development of user-oriented prediction systems. The session topics were:

- Glacio-hydrological modelling for the Himalayas;
- Weather forecasting and climate modelling for the Himalayas;
- Biases in simulated meteorological variables, bias correction and statistical downscaling methods;
- Impacts of climate change on socio-ecological systems in the Himalayas; and
- Modelling capacities and practical implementation of integrated prediction systems.

Each session comprised a series of oral presentations, usually 15 min in length with an additional 5 min for technical questions and specific discussions (Figure 2). Some topics were also presented and discussed in poster sessions on the first and second day (Figure 3). Presentations for which permission was granted for sharing can be accessed at <https://iukwc.org/workshop-presentations> by Open Network members, once they are logged in.

As the purpose of the workshop was not only to review current science but also to identify ways forward, a key element was allowing a generous amount of time for discussions (Figure 4). In addition to the discussions directly following the presentation there were, on each day, break-out groups or structured plenum discussions with the following cross-session topics:

- Model validation;
- Robustness of simulated climate change signals over the Himalayas;
- Dissemination of weather forecasts;
- Availability and quality of observational data;
- Main challenges and ways forward.



Figure 2: Technical sessions in progress



Figure 3: Discussions during the break and at the poster sessions

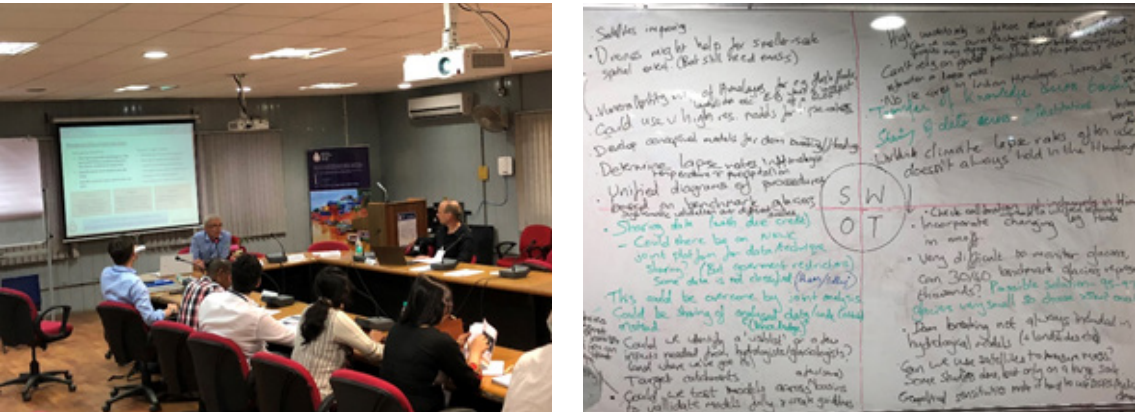


Figure 4: Breakout discussion session and the results of a wider SWOT analysis by the delegation

5. Workshop Conclusions and Outputs

The workshop brought together the different scientific communities that are needed to move forward with the integration of meteorological and hydrological predictions. The participants identified the key challenges and suggested ways forward. The activity strengthened existing links between Indian and UK scientists and fostered the development of new ones.

5.1. Key Challenges

The following key challenges were identified:

Category	Description
Data scarcity	Very limited availability of hydrological and meteorological in situ data, because of various challenges of working in the Himalayas. This strongly hampers: <ul style="list-style-type: none"> i) the development and validation of hydrological and meteorological models; ii) process understanding and model development; iii) the development and validation of downscaling and bias-adjustment methods; and iv) the development of gridded datasets. Satellite data such as precipitation estimates from microwaves have also substantial deficiencies over mountainous regions.
Process understanding	Poor understanding of important processes, such as convection, valley circulation, cloud-aerosol-precipitation interaction, atmosphere-land-cryosphere interaction, small-scale orography.
Model validation and selection	Need for more comprehensive and systematic validation frameworks for global and regional meteorological models, and for hydrological models over the Himalayas.
Downscaling and bias adjustment	Lack of clarity on what the best downscaling and bias adjustment methods are. This is due to scientific challenges, as well as to limited communication between downscalers and end users in hydrology.
Inter-disciplinary integration	There is a lack of this form of integration, which is vital to progress

5.2. Recommendations

The suggested short-term (S) and medium-term (M) ways forward identified are as follows:

5.2.1 Data scarcity

- Development of an inventory of agencies providing in-situ observations (S) and of an online platform for raw data or derived variables, and make these available on IUKWC website (S). Identification of catchments that are relatively well gauged (S).
- Development of a few test catchments with good hydrological and meteorological data coverage, including areas with different hydro-climatic characteristics (M).

- Development of an inventory of freely available remote sensing products (S) and creation of partnerships to improve data accessibility (M).
- Undertaking field campaigns to obtain targeted observations, potentially including deployment of drones (M).
- Exploration the potential of crowd-sourced hydro-meteorological observations (M).

5.2.2 Model validation, selection and development

- Documentation of various downscaling and bias adjustment methods, and regional meteorological models on IUKWC website (S).
- Application of meteorological models, downscaling and bias adjustment methods, and hydrological models in test catchments with relatively good data coverage (M).
- Use systematic model validation similar to the EU-COST action VALUE framework, including user-specific performance measures (M).
- Validation and intercomparison of CORDEX South Asia and other simulations over the Himalayan region (M).
- Quantification of different sources of uncertainty, including those from global and regional models, downscaling and bias-adjustment, and hydrological models (M).
- Development of hydrological models for ungauged catchments (M).

5.2.3 Forecasting, dissemination and decision making

- For longer-term hydrological forecasts the use of input from meteorological models is essential. Improvement of collaborations between meteorological and hydrological modellers is needed to tackle the substantial technical problems related to this (M).
- Understand the different types of forecast information required by different users and provide forecasts in a user-specific way, including advice on actions (S).
- Increase two-way communication between forecast providers and users, for instance by registering the users with the forecast providers, trusted intermediaries, direct engagement activities and workshops for specific users. Help users with the interpretation of probabilistic forecasts and of different forecast products.

5.2.4 Community and capacity building

- Develop knowledge centre for sharing information, including annual workshops, similar to ICIMOD or CORDEX structure (M).
- Inter-disciplinary training of early career researchers (M).
- Develop socio-economic inventory for stakeholder identification (S).
- Make scientific publications better available, e.g. by linking to university repositories (S).

5.3. Conclusion

The workshop provided a valuable opportunity to refine the understanding of the challenges for integration of meteorological and hydrological modelling over the Himalayas. Based on this understanding the specific ways to move forward listed in section 5.2 were identified. Careful consideration will need to be given to which of these suggestions can be implemented by better use of existing resources, improved collaboration and using synergies, and which will require additional funding to tackle technically challenging problems.

5.4. Participant Feedback

At the conclusion of the Activity a feedback form was circulated to participants who were asked

to provide comment on:

- the Workshop content;
- the meeting venue and organisation; and
- networking opportunities.

The delegates were also requested to provide any further comments and an overall score out of 10 for the Workshop. This was a voluntary exercise and we received twenty one responses (61% of the delegation).

The respondents rated the workshop an 8 out of 10, with the overall planning and layout of the workshop considered well organised and diverse, but with a need to have smaller breakout groups, more time for the posters, and more information provided to delegates in advance of the workshop. These are all things that can be easily incorporated into future IUKWC events. Respondents also requested that outcomes of the workshop, in terms of new projects for example, should be shared through the IUKWC and that data sharing should also be made possible through IUKWC.

“Interdisciplinary nature and diversity of topics presented is much appreciated”

Participant feedback quote

A significant objective of the workshop, of increased interaction between the hydrological and meteorological communities, was achieved as all respondents said they had made new contacts, with the majority stating they are discussing future research project collaborations and are engaged in knowledge exchange.

6. Annexes

ANNEX A: Agenda

Day 1 – Wednesday 2nd May

Time	Agenda item
08:30 – 09:00	Arrival and Registration (WII) Refreshments - Tea / coffee
09:00 – 10:30	Inaugural session (WII, workshop Hall) <ul style="list-style-type: none"> Welcome and introduction to the IUKWC and its activities <i>Dr. Atul Sahai (IUKWC Coordinator, IITM) and Dr. Harry Dixon (IUKWC Coordinator, CEH)</i> Welcome and remarks from WII (Dr. V.B. Mathur, Director, WII) Overview by Martin Widmann (University of Birmingham) General Introduction by Participants Q&A
10:30 – 11:00	High Tea
Technical Session 1: Glacio-hydrological modelling for the Himalayas	
11:00 – 12:40 <i>15 min talks Plus 5 min discussions</i>	<ul style="list-style-type: none"> Impact of Climate Change on Himalayan Water Resources <i>Dr. Manohar Arora (National Institute of Hydrology)</i> Assessment of snow cover and climatic variability using MODIS data of Teesta river basin located in Sikkim, India <i>Mr. Jaydeo Dharpure (National Institute of Hydrology Roorkee)</i> Stream Flow Simulation of a Snow-Fed Mountainous Sub-basin in Western Himalaya <i>Mr. Sandeep Shukla (IIT Roorkee)</i> Contribution of glacier melt and snow melt to river flow in a mountainous catchment of western Himalayas using tracers <i>Prof. Ghulam Jeelani (University of Kashmir)</i> Land Data Assimilation in Hydrology <i>Dr. Indu J (Indian Institute of Technology Bombay)</i>
12:40 – 13:40	Lunch

13:40 – 15:00 15 min talks Plus 5 min questions	<ul style="list-style-type: none"> Is there a “universal”™ calibration-free continuous hydrological model? Testing a dynamic Budyko model in multiple continents <i>Dr. Basudev Biswal, Indian Institute of Technology Bombay</i> Modelling the Himalayan catchments Saltuj and Beas: hurdles and ways forward <i>Dr. Andrea Momblanch (Cranfield, Water Science Institute - Cranfield University)</i> Impact of river interlinking on vulnerability of catchments to climate change: lessons learnt from southern India <i>Dr. Riddhi Singh (Indian Institute of Technology, Hyderabad)</i> Glaciers Mass balance changes in the Karakoram: A dynamic regional coupled glacier-climate model assessment <i>Dr. Pankaj Kumar, IISER, Bhopal</i>
15:00 – 16:00	Poster Session with Tea
16:00 – 17:30	Moderated Discussion and wrap up of day 1
19:30	Dinner: Hotel Softel Plaza, Dehradun

Day 2 – Thursday 3rd May

Time	Agenda item
07:00 – 08:00	Guided Tour to WII campus and forest (bring comfortable walking shoes)
Technical Session 2: Weather forecasting and climate modelling for the Himalayas	
09:00-10:40 15 min talks Plus 5 min questions	<ul style="list-style-type: none"> Forecasting at National Centre for Medium Range Weather Forecasting <i>Dr Ashis Mitra (NCMRF)</i> Influence of ENSO on summer monsoon precipitation in the Himalayan sector—Local Atmospheric Influences or Remote Influence from Pacific <i>Dr Indrani Roy (University of Exeter)</i> Dynamical Downscaling with and without active Ocean component Dr. Akhilesh Mishra (Amity Interdisciplinary Center for Climate Research and Policy, Amity University) Climate change consequences relevant to the extreme events over Himalayas <i>Dr. Milind Mujumdar (Indian Institute of Tropical Meteorology)</i> Future changes in summer wind and convective precipitation over the UK and Europe from a regional climate simulation <i>Dr. Alan Gadian (National Centre for Atmospheric Sciences, University of Leeds)</i>
10:40-11:00	Tea

11.00– 11.40	<ul style="list-style-type: none"> Mechanisms controlling wind and temperature in the Khumbu valley <i>Ms. Emily Potter (British Antarctic Survey)</i> An analysis of catchment-scale, high elevation meteorology in the Khumbu region of the Nepal Himalayas, 2009-2012 <i>Ms. Anya Schlich-Davies (University of Leeds)</i>
Technical Session 3: Biases in simulated meteorological variables, bias correction and statistical downscaling methods	
11:40-12:20 15 min talks Plus 5 min questions	<ul style="list-style-type: none"> Downscaled rainfall and temperature scenarios for all available station locations over Western Himalayan region of India <i>Prof. Lalu Das (Bidhan Chandra Krishi Viswavidyalaya)</i> Assessment of downscaled hindcast predictions of precipitation patterns for the Beas and Sutlej Basins, Indian Himalayas <i>Dr. Andrew Orr (British Antarctic Survey)</i>
12:20-13:30	Lunch
13:30 – 14:10	<ul style="list-style-type: none"> Inter-model uncertainty of CMIP5 model based precipitation projection over India: Effect of weighting and bias-correction <i>Mr. Javed Akhter (Jadavpur University)</i> The challenge of providing defensible regional climate projection <i>Dr. Martin Widmann (University of Birmingham)</i>
14:10-14:50	Moderated discussions
14:50-15:20	Poster session with Tea
Technical Session 4: Impact of Climate Change on Socio - Ecological Systems in the Himalayas	
15:20 - 17:00 15 min talks Plus 5 min questions	<ul style="list-style-type: none"> Impacts of climate change on forests in the Brahmaputra, Koshi and Upper Indus river basins <i>Ms. Chaitra Arakesha (Indian Institute of Science)</i> National Mission for Sustaining the Himalayan Ecosystem (NMSHE) Project - Overview <i>Dr. Sathyakumar (Wildlife Institute of India)</i> Impacts of Climate Change on Alpine Rangelands & Open Top Chamber Experiments <i>Dr. G. S. Rawat (Wildlife Institute of India)</i> Impacts of Climate Change on Aquatic Systems & E-Flow Requirements <i>Dr. K. Sivakumar (Wildlife Institute of India)</i> Cumulative Environmental Impact Assessment of Hydro Electric Power projects & Strategic Environmental Assessment Policy <i>Dr. Asha Rajvanshi (Wildlife Institute of India)</i>
17:00 – 19:30	Workshop activity outdoors

20:00	Workshop Dinner at WII
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Day 3 – Friday 4th May

Time	Agenda item
Technical Session 5: Modelling capacities and practical implementation of integrated prediction systems	
09:20-11:00 15 min talks Plus 5 min questions	<ul style="list-style-type: none"> Rainfall runoff simulations of monsoon rainfall in a Himalayan river basin of India <i>Dr. Sneh Joshi (National Centre for Medium Range Weather Forecasting)</i> Assessment of future runoff from the Nuranang watershed, eastern Himalayan region, India under projected climatic scenarios <i>Dr. Aditi Bhadra (North Eastern Regional Institute of Science and Technology)</i> Role of mKRISHI Climate Change Adaptation (CCA) Services in enabling a Two-way Interactive Digital Extension services for farmers <i>Mr. Dinesh Kumar Singh (Tata Consultancy Services Ltd)</i> Medium and seasonal term hydrological forecasting with the Global Flood Awareness System (GloFAS) <i>Dr. Calum Baugh (European Centre for Medium Range Weather Forecasts)</i> The potential of multi-method seasonal hydrological monitoring and forecasting for addressing water resources challenges <i>Mr. Jamie Hannaford (Centre for Ecology and Hydrology)</i>
11:00-11:20	Tea
11:20-12:00 15 min talks Plus 5 min questions	<ul style="list-style-type: none"> High-resolution attribution of extreme hydrological events to climate change <i>Dr. Jonathan Eden (Centre for Agroecology, Water and Resilience (CAWR), Coventry University)</i> Sensitivity of runoff in an agricultural catchment to climate change scenarios. Assessing uncertainty to inform adaptation decision-making. <i>Dr. Alexandre Gagnon (University of the West of Scotland)</i>
12:00 – 13:15	Moderated Discussions for session 4 and 5
13:15 – 14:00	Lunch

14:00 – 15:30	Breakaway Group Discussions <ul style="list-style-type: none"> • Main challenges • Short-term ways forward • Medium-term ways forward • Capacity building • Training of early career researchers • Dialogue with stakeholder • India-UK and general international collaboration • Funding
15:30- 15:45	Closing remarks
15:45-16:00	High Tea
20:00	Dinner: Open

ANNEX B: List of Poster Presentations

Subject		Presenter	Organisation
Day 1: Hydrology & Glaciology			
1	Investigating the changes in land surface hydrology over India using high resolution climate simulations	Dr. Ramarao MVS	Indian Institute of Tropical Meteorology
2	Sensitivity of runoff in an agricultural catchment to climate change scenarios. Assessing uncertainty to inform adaptation decision-making.	Dr. Alexandre Gagnon	University of the West of Scotland
3	An integrated dynamic hydrological model for discharge prediction in large ungauged river basins	Dr. Basudev Biswal	Indian Institute of Technology Bombay
4	Spatial and temporal variability of Indian summer monsoon rainfall in major river basin: A probabilistic dependability analysis	Dr. Kasiviswanathan KS	IIT, Mandi
5	Water Balance Model for Chittar River Basin, Tirunelveli District, Tamilnadu	Dr. Saravanan K	VIT, Chennai
Day 2: Meteorology and Climate			
6	To understand the variability of precipitation over Himalayas using a high resolution Regional climate model (REMOnGlacier) with dynamic glacier scheme	Mr. Saquib Saharwardi	Indian Institute of Science Education and Research Bhopal
7	Future rainfall projection using bias-corrected CMIP5 simulations over North Mountainous India	Mr. Javed Akhter	Jadavpur University
8	Investigation of spatial distribution of rainfall over the Indian Himalayan region using satellite data	Ms. Akanksha Patel	IIT, Roorkee

9	An analysis of catchment-scale, high elevation meteorology in the Khumbu region of the Nepal Himalayas, 2009-2012 and implications for downscaling climate data.	Dr. Andrew Ross	University of Leeds
10	Sensitivity of simulated summer monsoonal Himalayan precipitation to cloud microphysics schemes in WRF	Dr. Andrew Orr	British Antarctic Survey
11	Empirical prediction of seasonal climate: evaluation and potential applications	Dr. Jonathan Eden	Centre for Agroecology, Water and Resilience (CAWR), Coventry University



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