Third International Conference on Mountain Hydrology and Meteorology for the Sustainable Development

10-11 April 2017
Kathmandu, Nepal

PROCEEDING

Organized by
Society of Hydrologists and Meteorologists-Nepal
In Association with
Department of Hydrology and Meteorology

Supported by

CONFERENCE PROCEEDINGS

Third International Conference on

Mountain Hydrology and Meteorology for the Sustainable Development

10-11 April 2017
Radisson Hotel, Kathmandu, Nepal



Organized by:
Society of Hydrologists and Meteorologists-Nepal (SOHAM-Nepal)

In Association with:
Department of Hydrology and Meteorology (DHM), Government of Nepal (GoN)

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Conference Summary

This summary captures a two-day program of presentations, discussions and interactive dialogue at the **International Conference on Mountain Hydrology and Meteorology for the Sustainable Development**, which took place from on 10 and 11 April 2017 at Radisson Hotel, Lazimpat, Kathmandu, Nepal. The conference was organized by the *Society of Hydrologists and Meteorologists Nepal (SOHAM-Nepal) in association with Department of Hydrology and Meteorology (DHM), Government of Nepal. The supporting partners were Central Department of Hydrology and Meteorology (CDHM), Tribhuvan University (TU), Himalayan Cryosphere, Climate and Disaster Research Center, Kathmandu University (KU), International Centre for Integrated Mountain Development (ICIMOD), Kathmandu Centre for Research and Education, Chinese Academy of Sciences-Tribhuvan University (KCRE, CAS-TU), Nepal Academy of Science and Technology (NAST), OJERI and BK21Plus ELEC of Korea University, Seoul, South Korea, Real Times Solutions (RTS) Pvt. Ltd., Nepal and United Nation Educational, Scientific and Cultural Organization, International Hydrological Programme Nepal (UNESCO IHP-Nepal).*

The conference commenced with the inaugural ceremony lighting the 'Panas' by Rt. Hon'ble Vice President of Nepal Nanda Bahadur who graced the opening ceremony as the Chief Guest. The conference was chaired by Dr. Jagat Kumar Bhusal, Chairperson, Electricity Tariff Fixation Commission, GoN and SOHAM-Nepal. The technical session continued with invited speeches, interactive presentations, discussions, and briefings on topics of interest to the research scientists and young scholars. It concluded with Kathmandu Declaration 2017 followed by the closing ceremony. The event brought together more than 175 professional scientists, young researchers, students, and key officials from 15 countries to discuss and share ideas on latest research findings and to address current and future climate change challenges on water resource and cryosphere particularly in mountainous regions. Several invited speeches were delivered by distinguished scientists from renowned universities and institutions on pertinent issues. The invited speakers were **Dr. Fraser Sugden**, Nepal Country Representative and Senior Researcher, International Water Management Institute; **Dr. Richard L. Armstrong**, Senior Research Scientist, Cooperative Institute for Research in Environment Sciences, University of Colorado, Boulder, USA; **Prof. Dr. Ramesh Kumar Maskey**, Associate Dean, Kathmandu University,

Nepal; **Prof. Fan Zhang**, Key Laboratory of Tibetan Environment Changes and Land Surface Processes, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China; **Prof. Woo-Kyun Lee**, Korea University, Seoul, South Korea and **Prof. Hiroji Fushimi**, Kathmandu University, Nepal. Their talks were focused on water resource management, cryospheric changes and its impacts on water resource, climate variability and changes, mountain hydrology and hydrological modeling, mountain meteorology and climate, water-food-ecosystem resilience in mid-latitude zone and disaster risk reduction. This conference provided a valuable networking opportunity and set the stage for further cooperation among government and non-governmental organizations in Nepal and beyond, including developed and developing countries for sustainable water resource management and collaborate to understand climate change impacts on mountain hydrology.

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Introduction and Aim of Conference

Hydrology and meteorology of mountain is very crucial components for the development of mountainous countries of the world. The importance of mountain hydrology and meteorology has increased significantly nowadays due to change in world climate. Its importance in the Hindu-Kush-Karakorum-Himalayan region is much more due to the presence of snow and glacier ice in those mountain ranges which is very sensitive to changing climate. Water is one of vital natural resources required for sustainable development and environmental integrity. Hence, scientific discussion and knowledge sharing on the mountain hydrology and meteorology is essential in order to understand its complex nature so that a sustainable development can be achieved.

In order to address the issues of mountain hydrology and meteorology for the sustainable development, ***The Third International Conference on Mountain Hydrology and Meteorology for the Sustainable Development*** was organized in Kathmandu, Nepal on 10 and 11 April 2017. The Conference was organized by the Society of Hydrologists and Meteorologists-Nepal (SOHAM-Nepal) in association with the Department of Hydrology and Meteorology (DHM), Government of Nepal (GoN). The supporting partners were Central Department of Hydrology and Meteorology (CDHM), Tribhuvan University (TU), Himalayan Cryosphere, Climate and Disaster Research Center, Kathmandu University (KU), International Centre for Integrated Mountain Development (ICIMOD), Kathmandu Centre for Research and Education, Chinese Academy of Sciences-Tribhuvan University (KCRE, CAS-TU), Nepal Academy of Science and Technology (NAST), OJERI and BK21Plus ELEC of Korea University, Seoul, South Korea, Real Times Solutions (RTS) and United Nation Educational, Scientific and Cultural Organization, International Hydrological Programme Nepal (UNESCO IHP-Nepal).

The conference aims was to invite researchers, scientists, engineers, planners, development workers as well as experts on related fields and to provide platforms for presenting their research activities along with discussion on observations, findings and innovative ideas. Invited speakers were invited to deliver presentations on specific burning issues. More than 175 participants actively participated in the conference. There were 59 oral and 13 poster presentations along with 6 invited lectures from eminent professionals. The conference also included an exhibition

stall from Real Time Solutions (RTS), Pvt. Ltd., Nepal and a travel desk from Raya Tours and Travels Pvt. Ltd., Nepal for post conference excursion.

Conference Topics

The conference covered a wide range of topics concerning mountain hydro-meteorology, its links to sustainable development and other related issues. The conference was dedicated to following topics but not limited to:

- Mountain hydrology and hydrological modeling
- Water resources management
- Isotope hydrology
- Trans-boundary issues of water resources
- Cryospheric changes and its impacts on water resources
- Watershed management
- Mountain ecosystem services
- Mountain meteorology and climate
- Paleoclimate
- Climate variability and changes
- Monsoon
- Extreme weather events
- Climate change and cryosphere
- Disaster risk reduction

Inaugural Session Highlights

The inaugural session was started on Monday, 10 April 2017 from 9 am (Annex I). The conference was inaugurated by Rt. Hon'ble Vice President Mr. Nanda Bahadur Pun by lighting the 'Panas'. Rt. Hon'ble Vice President Mr. Nanda Bahadur Pun highlighted the importance of Hydrology and Meteorology for the sustainable development of the country in his inaugural remarks. Dr. Rijan Bhakta Kayastha, Chairperson of the Organizing Committee and Vice-Chairperson, SOHAM-Nepal gave warm welcome and highlighted the program. Hon'ble Jay Dev Joshi, Minister, Ministry of Population and Environment, Prof. Dr. Jiba Raj Pokharel, Vice-Chancellor, Nepal Academy of Science and Technology, Dr. Bishwa Nath Oli, Secretary, Ministry of Population and Environment also spoke during inaugural session. SOHAM-Nepal Executive Committee/life and general members, distinguished guest from various national and international organizations participants and media persons were also present on this occasion. The program was chaired by Dr. Jagat Kumar Bhusal, chairperson, SOHAM-Nepal.

Opening Speeches

Inaugural Speech by

Rt. Hon'ble Vice-President Mr. Nanda Bahadur Pun

Government of Nepal

Chairperson of this Inaugural Session
Hon'ble Minister
Ladies and Gentlemen



It is my great pleasure to inaugurate this international conference in the beautiful city of Kathmandu, this morning, to discuss remedial measures of the burning problems faced by the mountainous countries.

Furthermore, I would like to express my sincere thanks to the organizers and other contributors for organizing such an important event in Nepal, which is a country facing problems related to global warming and environmental changes along with the global communities.

Nature is not only our common resource but also a lifeline of the Earth, since the existence of human beings solely depends on conducive environment provided by nature as there is an intimate relationship between man and nature.

Development and implementation of appropriate and useful technologies for accelerated physical prosperity are the goals of all countries these days. In this context, human beings have been successful to reap the benefit of innumerable natural resources and natural gifts. On the contrary, the exploitation of nature has also caused negative impacts imposing climatic and environmental challenges faced by the world.

You belong to the scientific communities that have amply clarified the facts that climate change, loss of biodiversity, soil loss and ever increasing magnitude of water induced disasters are

causing negative impacts on living beings and plants on the Earth. Existence of life and vegetation are in peril in the absence of timely mitigative measures.

Climate change as a result of environmental imbalance may cause accelerated snowmelt glacial lake outburst floods, avalanche, landslides and soil erosion. In addition, loss in agricultural productivity and appearance of new diseases have been anticipated in the scenarios of increasing floods, intense precipitation, isolated precipitation, droughts and extreme temperatures.

Negative impacts are of greater concern particularly for mountainous countries like Nepal where adverse impacts are not limited to environmental imbalance but extend to agriculture productivity, economic development and other developmental activities. In this regards, it is the primary duty of all of us to contribute to maintain the balance of environment and development.

The resources provided by nature are adequate to meet human needs. However, it is of utmost importance for all of us to understand that human's desire has led to a situation that the environment can hardly cope. In this context, we need to stop over exploiting the nature considering our dependence on environment. In addition, it is extremely important for us to concentrate on the establishment of effective policies, planning and implementing effective activities targeting towards environmental safeguard.

Climate change is considered to be the result of excessive greenhouse gas emission. Nepal is not at all responsible but is forced to bear its negative impacts. Nepal has already initiated programs targeted to the adaptation and resilience development in this regard. I believe the outcome of the conference will provide recommendations and upgraded knowledge base useful to tackle negative impacts faced by countries like Nepal.

We have endorsed and implemented several activities related to the major international conventions, accords, agreements and treaties established to address climate change, water resources management and disasters. I understand this conference is one more activity in this regards. I feel, our efforts to draw attention of industrialized countries should be continued for mitigating the negative impacts of climate change.

Nepal has made some progress in the management of climate change impacts. Nepal has already implemented Climate Change Policy 2011. Despite limited resources, Nepal has paid adequate attention in the areas of climate, water resources and disasters.

These days, Nepal is implementing climate change adaptation activities supported by the Climate Investment Fund. Nepal is presently at the early stage of drafting constitution. I believe, the new constitution will also address issues related to the environment, climate change impact mitigation, adaptation and the development of resilience.

Private sectors, civil societies, non-governmental organizations, stakeholders and general public have important roles to play in climate change adaptation and impact mitigation. If all of us adopt activities that contribute to climate change adaptation and disaster mitigation in our life style, habits and dealings, we can ensure our livings in healthy, clean and safe environment.

*To end, I wish all the best for successful deliberations in the conference and believe that the outcomes of the conf*erence *will be fruitful in promoting environment conservation.*

Thank you.

Opening Remarks by

Hon'ble Minister Mr. Jay Dev Joshi

Ministry of Population and Environment, Government of Nepal



His Excellency Chief Guest Vice President,

Chairperson,

Distinguished guests in the dash,

International participants, Nepalese participants, Guests, ladies and gentlemen,

First and foremost, let me take this opportunity to express my gratitude to the organizer for organizing this international conference on ***"Mountain Hydrology and Meteorology for the Sustainable Development"*** *in Nepal. Let me also register my gratitude to the organizing Committee for inviting me to officiate on this important conference.*

*Today I am very much pleased to find me amongst scientists, and experts working on hydrology, meteorology and related fields. The streams and rivers originating from the Himalayas provide sufficient fresh water in Nepal. Global warming has been enhancing ice-melting processes, and so the perennial nature of these resources is altered and threatened by the resulting disasters. This is one of the new challenges added by climate changes to the economic development of the countries. Therefore, this "****International Conference"*** *and its themes are pertinent and timely. The Himalayas is also called the third pole. The countries lying at the sea level are concerned from sea level rise due to melting of polar ice. Similarly, Nepal, a country in mountainous areas is concerned about the dangers of changing of year round snow-covered mountains to the bare rocky mountains due to increase in global warming. Nepal like other countries is also concerned to the threat of excessive rainfall and drought and it's the consequences to water resources, agriculture and other life cycles due to increase of greenhouse emissions globally. In the 19th century, research in the Polar Regions was initiated with the launch of the first International Polar Year. In Nepal, data collection and research on hydrology and water resources started institutionally only after 1960 A.D. It is also crucial that the findings of researches on climate*

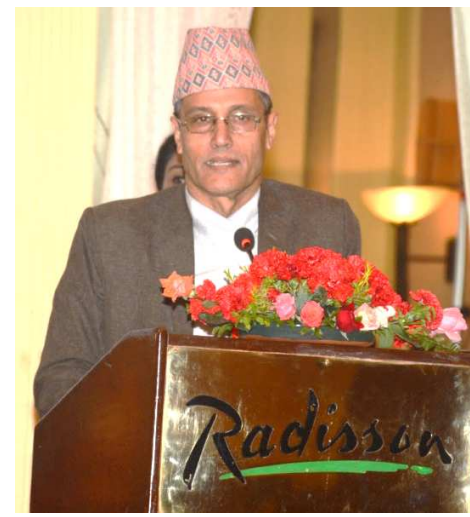
change, hydrology and meteorology and knowhow of adaptation measures need to be reached to the community level as well. I hope conferences like this will provide encouragement and create opportunities for Nepali scientists and professionals to share knowledge and conduct collaborative research with international scientists and experts. Nepal had ratified the Kyoto Protocol and had also prepared National Communication Report under the UNFCCC. The Ministry for Environment, Science and Technology has prepared policy regarding the climate change. As the government of Nepal has many other priority areas, especially the poverty alleviation and so the government might not be able to provide sufficient resources to the research on climate change. However, the government will always encourage and support your efforts to tape international resources. The floods in Nepal and its surrounding areas are causing substantial adverse impacts. Even after almost half a century after the institutionalization of research on hydrology, expected progress has not been made in the area of flood forecasting and warning. The discussion on "Floods in Nepal" in one of the sessions in this conference has a great relevance. The special session in conservation programs for the rivers in the cities to be implemented is also timely. I am hopeful that concrete suggestion and recommendations will be gathered that would be helpful to the government to formulate policies and to implement programs for the benefit of the country and the region. Finally I would like to wish our international participants an enjoyable stay and thank the organizers and supporters of the conferences.

Thank you.

Opening Remarks by

Respected Vice-Chancellor Prof. Dr. Jiba Raj Pokharel
Nepal Academy of Science and Technology

The Chair of this session, Rt Honourable Vice President of Nepal, the Chief Guest of this session, other dignitaries seated on the Dias and participating ladies and gentlemen



We are present in the inaugural session of a two day international conference on Mountain Hydrology and Meteorology for Sustainable Development. I am immensely pleased to speak a few words in this opening session of a two day International Seminar for several reasons.

Firstly, it is addressing a very important topic of sustainable development which has been a core issue in the development of all the countries round the globe. It has in a way dominated international as well as national scene after its predecessor Million Development Goals that came to an end in 2015. Secondly, it is dealing with important subjects such as Hydrology and Meteorology which have a unique attributes in Nepal. Thirdly, it is being debated, deliberated and discussed amongst luminary scientists of several countries of the world. Fourthly, several institutions national and international have worked hand in glove for the organization of this conference.

It is a welcome development that several seminars are conducted in Nepal these days. Barely a week passes without the organization of an international conference on one theme or the other. Very good resolutions are also passed as a part of such seminars. But they are not very seriously followed up to see whether or not they are really implemented by the concerned agencies. In fact, such resolutions should lead to some concrete Projects no matter even if they are small which should be implemented so that the implementation of such Projects can be projected as the achievement in the forthcoming conference. Nepal Academy of Science and Technology would be very happy to help in the execution of such Projects if they are related to research aspects.

I like to thank the Organizers for giving me this opportunity to speak a few words in such an important conference. I wish the participants specially the foreigners for their comfortable stay in Nepal during this two day conference. I hope you will get an opportunity to see the plurality of languages, religion and culture of Nepal during your brief stay. At the end I wish for a successful organization of this Conference.

With these few words I like to bring my remarks to a close.

Thanking you.

Opening Remarks by

Secretary Dr. Bishwa Nath Oli

Ministry of Population and Environment, Government of Nepal



His Excellency Chief Guest Vice President

Hon'ble Minister Jaye Dev Joshi, Ministry of Science Technology and Environment,

Respected Experts and representatives from various organizations and countries

Ladies and Gentlemen

The role and importance of climate and hydrology for the existence of life in this planet cannot be ignored. Any change in the climate will have corresponding impact in the hydrological cycle. So, we must be careful with what we do with the climate. We have two options: improve it for better living or destroy it. Naturally then, you will agree with me in opting for better living not only for the present, but also for betterment for the future generations. If so, then we must do something for improving the climatic conditions of this planet, which has been tampered with towards global warming through the increase in greenhouse gases like CO_2, CH_4, N_2O, and others because of uncontrolled human activities.

As is evident, the climate change scenario will have a major impact especially on regional water resources. Hence, we need to understand and materialize the concept of integrated water resources management in the present context of climate change. We need to understand the effects of climate change on the hydrological regimes. Then we need to understand the inevitable role of both mitigation and adaptation measures. Whatever the measures are taken, we must understand that they are achievable. The sharing of knowledge and expertise is very much needed. In Nepal, based on the data from the Department of Hydrology and Meteorology, during the 32 year long period from 1975 to 2006, there has been an increase of 1.8^{o} C that means 0.056^{o}C increase per year. Number of days with precipitation of 100 mm or more is increasing. Even changes in the time and period of precipitation are being noticed. According to the climate

change study that was started from 1994 in Nepal, a shift in the peak discharge was noticed from August to July. Due to warming effect, snow and glacier melt is taking place, thereby increasing the sizes of glacier lakes, thus increasing the possible dangers of glacier lake outburst floods known as GLOFs. Thus, the adverse effects of climate change are being noticed in Nepal as well. Hence, preventive measures need to be taken through timely monitoring and reporting and other mitigation measures along with other corrective measures including management and adaptation. Moreover, collaboration and cooperation are needed among all countries both in sharing knowledge and implementing suitable practices. In the context of Nepal, the mountainous areas are vulnerable to the climate change impacts. I hope the present conference would address these problems of vulnerability to climate change so as to enable the countries concerned to take up the appropriate preventive/mitigation and adaptation measures.

I believe that your active participation and deliberation will make this international conference successful in achieving its goal; and I am confident that we can come up with some fruitful summaries and constructive output in the matters of climate change issues in relation to the water resources and disasters in the most fragile mountainous areas. I wish you a grand success in this conference, and wish our international participants and presenters an enjoyable stay in Nepal!

Thank you.

Welcome Speech by

Director General Dr. Rishi Ram Sharma

Department of Hydrology and Meteorology (DHM), Government of Nepal



His Excellency Chief Guest Vice President
Hon'ble Minister
Chairperson
Distinguished guests in the dash
International participants, Nepalese participants,
Guests, ladies and gentlemen,
Very Good morning and Namaste all of you

First of all I would like to welcome you all in this international conference on Mountain Hydrology and Meteorology for the Sustainable Development.

Ladies and Gentlemen, I want to highlight a few about the conference. Some of the hydro-meteorological phenomenon like Climate variability and climate change, Floods and droughts are the concern for all the levels of society including the organizations and individuals involved in planning and policy formulation.

Developing countries are more vulnerable to climate change because of their inadequate capacity and resources to cope its adverse effects. Scientific discussions and knowledge sharing on different aspects of climate change are essential to understand its complex nature. Water is one of the vital resources required for sustainable development, environmental integrity and the eradication of poverty and hunger. Changes in climate have been adversely affecting various water bodies including surface water and groundwater. Changes in hydrological regimes and natural ecosystems have become global concerns. The situations are more alarming in mountainous areas. In order to address the issues of climate change in mountainous regions, this International Conference on Climate Change, Water Resources and Disasters in Mountainous Regions: Building Resilience to Changing Climate is organized. This Conference is jointly organized by the Society of Hydrologists and Meteorologists-Nepal (SOHAM-Nepal),

Department of Hydrology and Meteorology (DHM), Government of Nepal (GoN), and supported by many other stakeholders.

This conference aimed to invite scientists, engineers, planners, development workers as well as experts on related fields providing a platform for presenting their research outcomes, on observations, findings and innovative ideas. Invited speakers are called to deliver presentations on specific burning issues. Selected peer reviewed papers will be published in the Journal of Hydrology and Meteorology published by SOHAM-Nepal.

In this regard, I welcome all of you again. We organizer are very much happy to see this big volume of national and international participants. We really appreciate your keen interest to devote your life in climate and water sciences.

Thank you.

Welcome Address and Program Highlights by

Dr. Rijan Bhakta Kayastha
Chairperson of the Organizing Committee and Vice-Chairperson, SOHAM-Nepal

Dear Chairperson of the inaugural session,

On behalf of Organizing Committee of this international conference and all members of Society of Hydrologists and Meteorologist – Nepal (SOHAM-Nepal) first of all I would like to warm welcome our today's Chief Guest, Rt. Hon'ble Vice President, Mr. Nanda Bahadur Pun. We would like to thank for his gracious presence in this inaugural session and for his very keen interest on the theme of the 3rd International Conference on Mountain Hydrology and Meteorology for Sustainable Development organized by SOHAM-Nepal in association with the Department of Hydrology and Meteorology, Ministry of Population and Environment, Government of Nepal and six other supporting national and international institutions of this International Conference. Also I would like to welcome Hon'ble Minster for Population and Env., Mr. Jay Dev Joshi, Secretary of the ministry, Dr. Biswa Nath Oli, Director General of Department of Hydrology and Meteorology (DHM), Gov. of Nepal, Dr. Rishi Ram Sharma, Vice Chancellor of Nepal Academy of Science and Technology, Prof. Jiba Raj Pokharel. I would like to thanks for your valuable time and kind support to this conference and continuous support to SOHAM-Nepal.



Also I would like to welcome all participants of this international conference which includes 59 international participants from 15 countries and more than 105 Nepali participants. I would like to welcome all our invitees from different government agencies, academic and research institutions, private, media persons and all well-wishers of SOHAM-Nepal to this conference,

There are major two groups of International Scientists participating this Int. Conference. They are from the Contribution of High Asia Runoff from Ice and Snow (CHARIS) Project of the

University of Colorado, Boulder, USA supported by USAID and Expert's Group under the Korea University, Seoul, South Korea working on the Water-Food-Ecosystem Resilience in Mid-Latitude Zone.

Now I would like to briefly explain about the SOHAM-Nepal and this conference.

The Society of Hydrologists and Meteorologists - Nepal (SOHAM-Nepal) is a professional organization working in the field of hydrology, meteorology, climatology and related fields. The main aims of SOHAM-Nepal are to promote studies and researches in the field of hydrology and meteorology in Nepal, to promote involvement of national professionals of hydrology and meteorology towards overall development of the country, to promote contacts, solidarity and professional ethics among hydrologists and meteorologists nationally and internationally. In line with these objectives, we are organizing this third international conference to interact among researchers, scientists, engineers, planners, development workers as well as experts on related fields and to provide platforms for presenting their research findings along with discussion on observations, findings and innovative ideas so that we can move towards sustainable development.

The conference is attending by more than 175 participants. There will be total 65 oral presentations (6 invited talks) and 13 poster presentation during the two days conference. There will be total 14 technical sessions (13 oral and 1 poster) under the following 9 topics:

1. Water Resource Management

2. Cryospheric Changes and its Impacts on Water Resource

3. Climate Change and Cryosphere

4. Mountain Hydrology and Hydrological Modeling

5. Mountain Meteorology and Climate

6. Water-Food-Ecosystem Resilience in Mid-Latitude Zone

7. Climate Variability and Climate Change

8. Hydro-geochemistry

9. Disaster Risk Reduction

With these wide ranges of topics which are very much relevant now a days due to changing climate and its impacts on different field of national development and sustainable development, I hope the presentations and interactions among scientists will help definitely a lot to overcome negative impacts. With this short introduction of SOHAM-Nepal and conference, I would like to welcome you all once again.

Thank you!

Closing Remarks and Vote of Thanks in the Inaugural Session by

Dr. Jagat Kumar Bhusal
Director General Electricity Tariff Fixation Commission, Government of Nepal
Chairperson, SOHAM-Nepal



Chief Guest of the Inaugural Ceremony, Rt. Hon'ble Vice-president Mr. Nanda Bahadur Pun,

Hon'ble Minister, Jay Dev Joshi, *Ministry of Population and Environment, GoN*

Prof. Dr. Jiba Raj Pokharel, *Vice-Chancellor, Nepal Academy of Science and Technology*

Dr. Biswa Nath Oli, *Secretary,* *Ministry of Population and Environment, GoN*

Dr. Rishi Ram Sharma*, Director General, Department of Hydrology and Meteorology, GoN*

Distinguished guests, national and international participants, representatives from different organizations, Media persons, Ladies and Gentlemen

Namaste and Good Morning

It is my immense pleasure to get this opportunity to chair the opening ceremony of the Third International conference on ***Mountain Hydrology and Meteorology for the Sustainable Development*** *and to offer vote of thanks. The first conference was organized in 2008 on* ***Hydrology and Climate Change in Mountainous region*** *and second was held in 2013 on* ***Climate Change, Water Resources and Disasters in Mountainous Regions: Building Resilience to Changing Climate****.*

To begin my remarks*, I would like to mention the hydrological cycle which has made the lives on Earth possible. The* ***sun energy and the gravity*** *are driving forces of the* ***hydrological cycle****. Water vaporizes and appears as clouds, moves, thunders, also touches to mountains; cools and falls as the rain, hail, and snow; infiltrates and runs in surface, floods and swells in rivers and*

finally reaches back to the sea. Looking to past, the underline philosophy of hydrological cycle is documented in the 19th hymn of Atharva Veda, in about 2500 B.C ago.

*As mentioned before, hydrological and meteorological science deals with water, wind and temperature etc. Mountains influence the meteorological and hydrological processes and also contribute to the livelihood and ecosystem. We all are also aware that "**too much water also cause disasters",** and "**too less water also cause drought & famine**". Thus, understanding of mountain hydrology and meteorology is very much necessary for sustainable development in the mountain environment and to sustain the ecosystems. We, scientists, engineers, planners, development practitioners and experts on various fields, are gathered here with a common aim to share our respective research outcomes, observations, findings and innovative ideas, and in conclusion to come with lessons. Lectures, presentations, discussions, interactions and; recommendations to be made at the end of this conference will be valuable inputs in addressing the issues of mountainous regions.*

Now, I would like to offer vote of thanks

Right Hon'ble Vice President of Nepal is genius personality. In fact, he has a very busy schedule to be attended to, but he has graciously consented to inaugural the conference. I am deeply grateful to him. On behalf of organizing committee, associating partners and supporting organizations as well as participating institutions, I would like to express gratitude to him for his remarkable opening speech and for inaugurating the conference. Similarly, I would like to thank Hon'ble Minister who, in spite of his very busy schedule, kindly managed time to grace the opening ceremony and deliver valuable remarks to this session. None the less, I would like to thank Prof. Dr. Jiba Raj Pokhrel, Vice-Chancellor, Nepal Academy of Science and Technology. Dr. Biswa Nath Oli, Secretary, Ministry of Population and Environment, GoN, and Dr. Rishi Ram Sharma, Director General, Department of Hydrology and Meteorology for their valuable remarks.

Appreciation goes to Dr. Rijan Kayastha, vice chair of SOHAM Nepal and his team, who worked day and night, without their efforts, this conference would not have been happened. Thanks to him for his welcome address and highlighting objectives and programs of the conference as well.

I would also like to thank to Chair and Co-Chair of Scientific Committee and their teams; SOHAM EC members for their remarkable contributions and; advisory committee members for their encouraging supports.

Finally, I would like to thank to all foreign delegates who accepted our invitation, travelled a long distance to participate and to share their research findings. I wish a pleasure and comfortable stay in Nepal. Thanks to all national participants, invitees to this opening session, colleagues, media persons, security persons, hotel managements and; to all who directly and indirectly have been supporting the conference.

With this, I would like to declare this opening session closed, but also would like to inform you that technical sessions are followed after this opening session.

Thank you very much.

Highlights of Technical Session

The technical sessions comprised of total 13 sessions and a poster session (Annex II). A total of 59 scientific papers were presented by the research scientists, professors and young researchers. There were 6 invited talks from eminent research scientist, professors and professionals working in sector of water resource management and related fields.

DAY 1: Monday, 10 April 2017

A total of 6 sessions and a poster session were conducted on Monday, 10 April. These sessions particularly focused on water resource management, cryospheric changes impact on water resource and use of hydrological models to better understand mountain hydrology. Three sessions were about Cryospheric changes and its impact on water resource which was mainly based on CHARIS (Contribution of High Asia Runoff from Ice and Snow) project. CHARIS project assess the role that glaciers and seasonal snow play in the fresh water resources of High Asia which will be useful to forecast the future water availability and vulnerability of the water resource.

Session I: ***Water Resource Management***

The first session on *Water Resource Management* was chaired by **Dr. Mandira Singh Shrestha**, Program Coordinator-HYCOS Initiative, International Centre for Integrated Mountain Development (ICIMOD), Nepal. This session consisted of an invited talk and 6 oral presentations. **Dr. Fraser Sugden**, Nepal Country Representative and Senior Researcher from International Water Management Institute delivered the Invited Talk on "Water availability versus access in the sub-Himalayan lowlands: The case for an interdisciplinary approach". His talk highlighted the climate change vulnerability in the eastern Terai belt of Nepal.

Dr. Jagat Kumar Bhusal, Society of Hydrologists and Meteorologists- Nepal, presented a case of irrigation system from Mustang, climate change induced risk. He talked about the water disputes, water sharing and control in Mustang, Upper Kaligandaki basin. His research identified the citizen science practice in watering forms used by locals in Mustang with updated water governance system with science. **Mrs. Nandini Thakur**, Department of Environment Studies, Punjab University, India gave presentation on spring water quality assessment in Upper Beas Basin of Kullu valley, Himachal Himalayas. Her research focused on water quality parameters to

categorize the quality of water. She talked about her findings of water quality index that about 10% of her samples were of poor water quality. She concluded that the increased urban activity, population and land-use change will alter the spring water quality in long run. **Mrs. Shova Kumari Yadav**, Institute for Social and Environmental Transition Nepal – (ISET-N) presented her talk about hydrological variability and its implication for local management in Nepal. Her talk was about how the extreme rainfall events of Nepal and variability of hydrological system with uncertainties of climate change impacts creates huge knowledge gap for water resource planning and management. **Associate Professor Dr. Prem Sagar Chapagain**, Central Department of Geography, Tribhuvan University, Nepal gave oral presentation on his research about the role traditional institutions form Upper Mustang in ecosystem service management. He talked about how the people of Mustang are managing the scarce water with traditional practice of *Mukhiya* system, a strong institutional local mechanism. He also highlighted the water rights of families of local people called *Dhongba* which had been practiced form generations for effective water resource management. **Ms. Reshu Bashyal** from Central Department of Environmental Science, Tibhuvan University Nepal, presented her research on climate change impact and adaptation practices in water resource. She presented her a case of Salyantar form Central Nepal which had increasing trend of temperature and decreasing precipitation. Her finding was that the water coverage in the region was decreasing 29.93% to 6.47%. The last presenter of this session, **Mrs. Praju Gurung**, Society of Hydrologists and Meteorologists Nepal, gave her presentation about the understanding of migration and its impact on livelihood. She gave the examples of Dhakarjhong and Phalyak villages of Upper Kaligandaki basin. She explained that the area being rain shadow region received low rainfall thus increased migration of locals seasonally to India for trade or wage work.

Session II: ***Cryospheric changes and its Impact on Water Resource, CHARIS-I***

The parallel session on *Cryospheric changes and its Impact on Water Resource, CHARIS-I*, was chaired by **Dr. Madan Lall Shrestha**, Academician at Nepal Academy of Science and Technology (NAST). This session was the special session of the CHARIS project (Contribution of High Asia Runoff from Ice and Snow). The session consisted of an invited talk and 6 other oral presentations. The invited speaker, **Dr. Richard L. Armstrong,** Senior Research Scientist, Cooperative Institute for Research in Environment Sciences, University of Colorado highlighted

about the CHARIS projects' collaborative effort in assessing the role of glaciers and seasonal snow cover in the hydrology of the Mountains of high Asia. He talked about the aim of the project and its partnership with 11 institutions form 8 countries to benefit regional research capabilities through capacity building and data sharing. He talked about project study region to be the 5 Asian basins (Brahmaputra, Ganges, Indus, Syr and Amu Darya) where contributions form snow and glacier melt from these basins was studied using melt model. He concluded that there were large variations in the contribution of snow and glacier melt in the basins along with the variation due to elevation within the basin.

Ms. Mary J. Brodzik, University of Colorado, Boulder presented her research about a global historical passive microwave record and its applications to estimate melt onset. She talked about the microwave radiations captured by the microwave sensors of satellite to have a meaning climate record for studying mountain hydrology. She explained the limitations of the use of this data. She said that the historical gridded data was reprocessed to increase image spatial resolution and thus improved the results of melt detection and melt onset variability in the Hunza basin of the Upper Indus. **Professor Mohammad Naim Eqrar**, Kabul University, Afghanistan gave presentation about the water resources of Afghanistan and its climate change impacts. He talked about how the river basins in Afghanistan are suffering from localized water scarcity. His talked about the droughts occurrences which has affected the Afghans' livelihood. He also discussed other water related issues in Afghanistan and water scarcity challenges with several downstream riparian countries. **Professor Dr. A.L. Ramanathan** from School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India gave presentation about the relationship between pro-glacial stream discharge and meteorology in Chhota Shigri glacier catchment of Indian Himalaya. He concluded that the Chhota Shigri glacier was possibly wasting away to reach equilibrium to the changed climatic conditions, however he stressed his results to be corroborated with runoff modeling. **Dr. Bruce Raup**, National Snow and Ice Data Centre, University of Colorado Boulder, USA gave his presentations about GLIMS, RGI and other glacier databases. He talked about updated survey of glacier databases available, their use cases, strengths and weakness. He inferred that the Global Land Ice Measurements form Space (GLIMS) to be the only complete and multi-temporal glacier database capable of tacking glacier changes. **Mr. Vassiliy Kapitsa**, Institute of Geography, Almaty, Kazakhstan presented his

research on the assessment of evolution of Mountain lakes and risks of Glacier Lake Outbursts in the Djungarskiy Alatau, Central Asia using Landsat Imagery and Glacier Bed Topography (Glab Top2) Model. His concluded that 21% of lakes had increased and 13% of lakes declined with contact lakes having largest growth out of which 50 lakes were identified as potential danger of outburst. **Ms. Shruti Singh**, Department of Environmental Sciences, Sharda University, Uttar Pradesh, India gave presentation about the emerging challenge of climate change induced hazard and gave a case from Himachal Pradesh. She talked about the increase of glacial lakes from 38 (1993-94) to 390 (2015). Also she said that Chenab basin which originated form Himachal Himalaya had also increased number of glacier lakes i.e. form 116 in 2013 to 192 in 2015. She concluded that the considerable increase in the number of lakes in the Himachal Himalaya with lakes with area >10 hectare and with 5-10 hectare to be the potential vulnerable site of glacial lake outburst flood (GLOF).

Session III: *Climate Change and Cryosphere*

The session on *Climate Change and Cryosphere* was chaired by **Associate Professor Dr. Rijan Bhakta Kayastha**, Department of Environmental Science and Engineering School of Science Kathmandu University, Nepal. This session consisted of 3 oral presentations. **Dr. Michel Esteves**, University of Grenoble Alpes, France gave his presentation on the contrasted surface mass balance of debris-free glaciers observed between the southern and the inner parts of the Everest region (2007-2015). He talked about the contrasted mass balances of Mera Glacier, Pokalde and white Changri Nup glaciers. He concluded that the contrasted mass balance was due to the low elevation of Pokalde and white Changri Nup glaciers and to the steeper vertical gradient of mass balance for glaciers located in the inner arid part. **Associate Professor, Dr. Sudeep Thakuri**, Central Department of Environmental Sciences, Tribhuvan University, Nepal gave presentation about the Himalayan ponds being the indicators of glacier melting and precipitation trends. He talked about the glacial lake evolution and surface area variation to be visible signal of impact of climate change in higher ecosystems. He stressed about the unconnected glaciers ponds in the Everest region in his talk which can be used as a proxy for detecting past changes in the main hydrological components of water balance. He concluded in general that the unconnected ponds to have decreased significantly in terms of surface area over the last 50 years in the Everest region. **Mr. Sabin Maharjan**, Sanima Hydro and Engineering P.

Ltd., Kathmandu, Nepal presented about improved glacier melt model in SWAT. He talked about the Soil and Water Assessment Tool used for modeling catchments. He delivered his research about the proposed algorithm for glacier melt and glacier mass balance implemented in the SWAT model. He told that model applied in the Melamchi catchment with and without glacier model. He concluded with the remarks that the model performance was improved with glacier model with reduced glacier area and volume during simulation period.

Session IV: ***Cryospheric changes and its Impact on Water Resource, CHARIS-II***

The session on *Cryospheric changes and its Impact on Water Resource, CHARIS-II*, was chaired by **Dr. Bruce Raup**, National Snow and Ice Data Centre, University of Colorado Boulder, USA. This session consisted of 4 oral presentations. **Professor Dr. Haleem Zaman Magsi**, Department of Earth Sciences, Karakoram International University, Gilgit, Pakistan presented on the permafrost zone thaw at high altitude above glacier's accumulation zone in Gilgit, Baltistan. He mentioned that the unique behavior of the permafrost zone was a result of accumulation of the internal energy of the earth's crust at permafrost basal interface. He concluded that the internal energy of the less seismically active zone transfers to surface and traps at ice-basal interface and permafrost-basal interface that influenced the dynamics of permafrost and glaciers. **Professor Dr. Rajesh Kumar**, Department of Environmental Sciences, Sharda University, India, gave presentation on the glacio-hydrological processes in Shaune Garang basin, Western Himalaya. He told that the temperature index based glacio-hydrological model gave very good model performance during validation period. He concluded that the simulated discharge in the basin showed decreasing trend and the simulated mass balance showed loss of mass by glaciers in the basin except for two years. **Mr. Parviz Noramtov**, Tajik National University, Tajikistan, presented on the hydrology and hydrochemistry of the Vakhsh River and its tributaries. He talked about the nature of inter annual distribution of the runoff in Vakhsh River. He reported that the runoff of the river was increasing though the precipitation showed decreasing trend. He concluded his talk with the note that the melting of small glaciers increased water volume of river and the river had no source of pollution. **Mr. Arindan Mandal**, School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India, gave presentation on micro-meteorological variability in different elevation zones of Chhota Shigri Glacier, India by analyzing three in situ stations during summer season 2015. He concluded that the diurnal cycles

of the vertical temperature and vapor pressure gradients during the peak melting period highlighted the importance of in-situ measurements for glacier mass-balance and glacio-hydrological modeling.

Session V: *Mountain Hydrology and Hydrological Modeling*

The session on *Mountain Hydrology and Hydrological Modeling* was chaired by **Dr. Dilip Kumar Gautam**, Senior DDR Consultant, Practical Action Consulting South Asia, Kathmandu Nepal. The session consisted of an invited talk and 3 oral presentations. **Prof. Dr. Ramesh Kumar Maskey**, Associate Dean, Kathmandu University, Nepal, delivered his invited talk on the "A novel approach for determining environmental flow: the case of Gandak River basin, Nepal". He explained the importance of environmental flow to river health, economic development and poverty alleviation. He stated that the E-flow assessment done at Gandaki basin was the first attempt in Nepal. His research proved that the building block methodology (BBM) used to determine the needed flow without degrading to be most flexible methodology. He said that the use of UAV with TS shortened the field work and CaSiMir could be used to validate findings. He also reported that the research outcomes were the first baseline information on the structure and composition of benthic micro-invertebrates for Gandak River basin for pre-monsoon and post-monsoon season. He concluded the study suggested the natural river discharge could satisfy the environmental flow whole year.

Dr. Francios Delclaux, UMR HydroSciences Montpellier, Montpellier University, France, gave presentation on the water balance estimation of a large mountain lake with a coupled model which was applied to Issyk Kul Lake, Kyrgyzstan, Central Asia. He stated that the reanalysis data to be very useful for generating long-time series data especially for atmospheric variables. The lake water budget was done using two step approach with the use of distributed HDSM model. He said that water balance of Chon Kyzyl Suu was studied at local scale and Issyk Kul lake was studied for regional scale. He concluded that at local scale the water deficit was found where factors like ice contribution and evapotranspiration needed to be compared. However at regional scale he stated that water volume was good but may not be well distributed and the groundwater fluxes and irrigation withdrawals were the two major variables for great sensitivity. **Dr. Santosh Nepal**, Water and Climate Specialist, International Centre for Integrated Mountain Development (ICIMOD), Nepal, presented his paper about the water balance assessment of the

Gandaki river basin by applying the J2000 hydrological model. He reported that there was high spatial variability in precipitation distribution in the basin. His findings showed that J2000 hydrological model was able to represent the hydrological dynamics for different percentile values. He concluded that the glacial contribution to the total discharge was 13 % although pre-monsoon contribution was significant (7-28%). **Dr. Michel Esteves**, University of Grenoble Alpes, France, presented about the assessment of hydrologic components of a high altitude glacierized catchment in Nepalese Himalaya. His research was focused on partly glacierized Khumbu river catchment. He reported that there was large temporal variability in climate forcing and higher contribution of glacierized areas and snowmelt to runoff. He stated that temperature gradients were not observed between Pheriche and Pyramid, and temperature to be main controlling factor the type of precipitation in the region. He concluded with the note that there is enough water for tourism and local domestic needs at the moment in the study region.

Session VI: ***Cryospheric changes and its Impact on Water Resource, CHARIS-III***

The session on *Cryospheric changes and its Impact on Water Resource, CHARIS-III*, was chaired by **Associate Professor Dr. Rijan Bhakta Kayastha**, Department of Environmental Science and Engineering School of Science Kathmandu University, Nepal. This session consisted of 3 oral presentations. **Mr. Milan Waqar Ali Shah**, Glacier Monitoring Research Center, Pakistan Water and Power Development Authority, Lahore, Pakistan, presented about the hydrological similarity framework based on Budyko theory for applications in China. He explained the use of climatic dryness index to hydro-climatic classification. **Mr. Parviz Noramtov**, Tajik National University, Tajikistan, presented about the monitoring of meteorological conditions of the formation area of the Transboundary Pyanj River. He stated that the importance and role of the Pyanj River was not only in neighboring countries of Tajikistan and Afghanistan, but also for the countries of the downstream of the transboundary Amu Darya Rivers. He reported the increasing trend of temperature in all parts of the Pamir for the period 1934-1994. And the individuality of each Pamir zone was reflected in a significant difference between the values of precipitation in these areas and in the absence of a single expression in depending of the amount of precipitation from the height of the terrain. **Ms. Larissa Kogutenko**, Nanjing University of Information Science and Technology, Nanjing, China, gave presentation on the glacial components in the rivers runoff of Balkhash-Alakol basin. She

reported that the runoff from ice melt in the not a large factor in annual river runoff. She stated that the stability of average river flows and inter-annual variability during glacier reduction suggested the presence of some compensating process. According to her estimation, increasing share of flow from the melting of underground ice is a possible compensating process and stressed that the estimation of the amount of underground ice (buried ice, rock glaciers and permafrost) is an important task for the near future.

Poster Session

There were 13 poster presentations. These posters comprised of wide themes which included researches on climate variability and climate change, cryospheric changes and its impacts on water resource, hydro-geochemistry and mountain hydrology and meteorology. This session was highly interactive with discussions and series of questions to the poster presenters. A poster by **Associate Professor, Dr. Sudeep Thakuri**, Central Department of Environmental Sciences, Tribhuvan University was about morphological factors controlling changes in mass balance, surface area, terminus, and snow line altitude of Himalayan glaciers. A poster by **Mr. Sahadeep Thapa**, University of Chinese Academy of Sciences, Beijing, China was about snow: An important component of cryosphere in the Tibetan Plateau. A poster by **Dr. Alexander Yegorov**, Institute of Geography, Almaty, Kazakhstan was about the features of changes of air temperature in the geo unit plains-mountains in central Asia. A poster by **Ms. Larissa Kogutenko**, Nanjing University of Information Science and Technology, Nanjing, China was about glacier degradation in Chinese Tien-Shan Mountains for the last half century on the example of Koksu and Kunes rivers. **Mr. Dendup Tshering**, Department of Environmental Science, Sherubtse College, Royal University of Bhutan presented a poster about water stable isotopes in the lower Chamkhar Chhu (River) basin of the central Bhutan, Eastern Himalaya. **Ms. Alice Hill**, University of Colorado-Boulder, Boulder, USA presented poster about using hydrochemistry and isotopic tracers to clarify meltwater influence to water supplies at a basin scale: techniques and challenges. A poster by **Mr. Sudish Lal Maskey**, Senior Engineer, Hydro Venture Pvt. Ltd., Kathmandu Nepal was about revised estimate of sediment yield of the upper Koshi Basin in Nepal. A poster by **Mrs. Sumitra K.C**., Asian Institute of Technology, Thailand was about stream discharge response to climate change and land use change in Tamor Basin, Nepal. A poster by **Mr. Santosh Regmi**, Society of Hydrologists and Meteorologists-Nepal was about

adaptive governance of mountain ecosystem services through citizen Science: A case of participatory monitoring of water resources in Mustang district, Nepal. **Mr. Sagar Shiwakoti**, Hydroelectricity Investment and Development Company Limited, Kathmandu Nepal presented a poster about hydrological modeling and climate change impact assessment using HBV-Light Model: A case study of Karnali River basin of Nepal. **Ms. Minami Masuda**, Graduate School of Science and Technology, Hirosaki University, Japan presented a poster about daily adjustment for the wind-induced precipitation under catch of daily gridded precipitation in Japan. **Mr. Sunil Acharya**, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China presented a poster about stable isotopic composition in precipitation in eastern Nepal.

DAY 2: Tuesday, 11 April 2017

A total of 7 sessions were conducted on Tuesday, 11 April. These sessions particularly focused on water and climate change, water-food-ecosystem resilience in mid-latitude zone, climate variability and climate change, mountain meteorology and climate, hydrogeo-chemistry and disaster risk reduction. There was a session on water and climate by Kathmandu Centre for Research and Education (KCRE), Chinese Academy of Sciences, Tribhuvan University (CAS-TU) and two mid-latitude sessions on water-food-ecosystem resilience in mid-latitude zone by Korea University. KCRE was established in Nepal under CAS-TU to strengthen the scientific and education cooperation between China and south Asian countries which tends to further study the third pole evolution and its impacts on Asia and the northern hemisphere. Mid-latitude session is of expert's group and young scholars under the Korea University, Seoul, South Korea working on the Water-Food-Ecosystem Resilience in Mid-Latitude Zone.

Session VII: ***Water and Climate Change-KCRE, CAS-TU***

The session on *Water and Climate Change-KCRE, CAS-TU* was chaired by **Professor Fan Zhang**, Key Laboratory of Tibetan Environment Changes and Land Surface Processes, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China. There were 5 oral presentations. **Professor Fan Zhang**, gave presentation on the research and activities of Kathmandu Centre for Research and Education, Chinese Academy of Sciences, Tribhuvan University. She highlighted the goal of KCRE to integrate research with education, and to strengthen cooperation between China and south Asian countries such as Nepal, India, Pakistan

and Bhutan in resources, environment and ecology. She talked about the establishment of KCRE in March 2016, and its progresses till date which included KCRE lab construction, establishment of satellite monitoring system, equipment for atmospheric and environmental research, homepage and database management, trainings to young scientists with TWAS, UCAS and Chinese governmental scholarships. She concluded with the remarks that the KCRE project aimed to assess the environmental changes of the Third Pole region and serve for regional development.

Ms. Smrita Acharya, Central Department of Environmental Sciences, Tribhuvan University, Nepal, gave her presentation on estimation of discharge using temperature index melt model in Modi River basin, Kaski, Nepal. She talked about the widely used temperature index melt model in data scare Himalayan region. She reported that the average discharge of the basin from 2016-2050 for RCP 4.5 and RCP 8.5 scenario was in decreasing trend with low relative contribution of snow and ice melt. She concluded that the modeling approach and emission scenarios gave insights to the future water resource availability of the basin. **Ms. Anita Tuitui**, Central Department of Hydrology and Meteorology, Tribhuvan University presented about the impact of climate change on snowmelt in Marshyangdi River basin of Nepal. She told that the J2000 hydrological model was able to represent the hydrological dynamics of the basin. She reported that the increasing temperature trend results to high contribution of snowmelt to the stream flow. She concluded that the overland flow in RCP 4.5 and RCP 8.5 emission scenarios may cause flooding events during monsoon season in future in the basin where climate change has high effects in its discharge. **Mr. Bikas Nepal**, Department of Hydrology and Meteorology, Government of Nepal gave his presentation on the evaluation of GPM satellite rainfall estimation over Nepal. He talked about the comparative analysis of the half hourly final run of Integrated Multi-satellite-Retrievals (IMERG) for GPM and daily gauge data of Department of Hydrology and Meteorology, Nepal. He concluded that the IMERG performed better in the mid-mountain and low-altitude areas and it had to be specially improved for the high mountain region before use. **Ms. Pratikshya Chalise**, Central Department of Botany, Tribhuvan University, Nepal, presented about the distribution of vascular plants along the subalpine-alpine gradient in Manang and their fate against climate change. She reported that vascular plants species exhibited a hump-shaped pattern with elevation (3700m to 4600m asl). She stated that the narrow elevation

amplitude was most vulnerable to climate change and species needed to adapt to range shift to compensate the future rise in temperature. She concluded that the upslope migration would affect the other alpines species which are used for food, fodder or traditional medicine.

Session VIII: ***Mid-Latitude Session on "Water-Food-Ecosystem Resilience in Mid-Latitude Zone" (Expert Committee)***

The *Mid-Latitude Session on "Water-Food-Ecosystem Resilience in Mid-Latitude Zone" (Expert Committee)* was chaired by **Professor Dr. Sonam Wang**, Bhutan Institute for Himalayan Studies, Bhutan. This session consisted of an invited talk and 3 oral presentations. **Professor Woo-Kyun Lee**, Korea University, Seoul, South Korea gave his invited talk about different ecosystem services on land degradation-restoration-sustainability in mid-latitude ecotone. He highlighted the land use issues in the densely populated mid-latitude zone. He suggested that appropriate land cover and land use management plans for solving the problems. He reported classification of developed and developing countries based on degradation stage of forest resources for better understanding. He stated that nation with enough restoration capacity and increasing forest was used as the case of sustainability. He concluded that the differentiation of forest ecosystem services from vegetated area by each land stage in the mid-latitude zone would aid the decision makers for environmental planning and solving local issues of climate change and water management.

Professor Dr. Sonam Wangyel Wang, Korea University, Seoul, South Korea gave his presentation on building climate resilience of urban systems through ecosystem based adaptation (EbA) in high altitude city of Thimphu Bhutan. He underlined the need to crucially understand how vulnerable or resilient Thimphu city was in terms of impacts on people, infrastructure, public health, economy and climate change or climate variability. He stated that the population increase coupled with poor infrastructure and unemployment causes social problems and degradation of ecosystem services. He concluded that the quality of poor urban housing was least resistant to extreme weather events and stated the need in city to implement EbA interventions (quick fix and long term) improving urban resilience and for sustainable development. **Professor Dr. Yowhan Son**, Korea University, Seoul, South Korea, presented about the forest and watershed management projects with enhanced food security under the forest and landscape restoration mechanism in the mid-latitude region. He talked about the status of Mongolia and

Uzbekistan and suggested projects for improvement of forest, watershed management and food security in context of climate change in forest and landscape restoration mechanism. He suggested preserving permafrost forest layer by planting trees in the degraded coniferous forests northern part of Mongolia, improving sustainable livelihood management in southern part of Mongolia and enhancing food security in Uzbekistan. **Associate Professor Dr. Rijan Bhakta Kayastha**, Department of Environmental Science and Engineering School of Science, Kathmandu University, Nepal presented about determining environmental flows of the Gandaki river basin, Nepal: a hydrological aspect. He talked about the use of glacio-hydrological model to determine snow and ice melt contribution and future discharge prediction to evaluate the required flow for ensuring the presence of fish habitat in the river system. He stated that the MPDDM simulated good hydrological regime and the e-flow of the basin was also fair enough to sustain fish habitat.

Session IX: ***Mountain Meteorology and Climate I***

The session on Mountain Meteorology and Climate I was chaired by **Professor Dr. Lochan Prasad Devkota**, Central Department of Hydrology and Meteorology, Tribhuvan University, Nepal. In this session there was an invited talk and 4 oral presentations. **Professor Fan Zhang**, Key Laboratory of Tibetan Environment Changes and Land Surface Processes, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China, gave her invited speech about the air temperature estimation using MODIS LST for snowmelt modeling in the Tibetan Plateau. She stated that the proposed air temperature estimation method could reduce the cloud blockage dramatically by integrating all the available MODIS LST at four pass times and in the meantime keep relatively high estimating accuracies. She reported although no significant changing trend was detected for annual snowmelt in the whole TP, the amounts and changing trends of snowmelts vary greatly among different sub-regions. She concluded that the interacting impacts of temperature and precipitation introduced increasing snowmelt in northern TP but decreasing snowmelt in southeast part.

Dr. Francios Delclaux, UMR HydroSciences Montpellier, Montpellier University, gave presentation on characterizing hydro-climatic systems at the local scale to reduce uncertainties, application to the Dudh Koshi River basin, Nepal. He talked about physical modeling approach that was applied in two representative basins of middle and high mountains. He reported

uncertainties orographic effects on precipitation. He stressed on the need of additional validation criteria for improving precipitation maps i.e. snow variables and existing models. **Ms. Bibhuti Pokhrel**, Meteorological Forecasting Division, Department of Hydrology and Meteorology, Tribhuvan International Airport, Nepal, presented about the synoptic study of Hudhud cyclone in Nepal. She talked about the impacts of the cyclone and loss of lives and property. She described the three dimensional structure of atmosphere in relation to Hudhud cyclone. She stated that the copulation of westerly trough moving from west in the upper troposphere with low pressure area at the lower troposphere was responsible for diverting cyclone trajectory to central Nepal. She concluded that Himalayas facilitated the orographic lifting of abundant moisture supply and caused heavy snowfall over Nepal. **Professor Dr. Md. Abdullah Elias Akhter**, Department of Physics, Khulna University of Engineering and Technology, Bangladesh, gave his presentation on the estimation of the error track of the tropical cyclones of the Bay of Bengal using high resolution ARW model. He reported that the model had difficulties to predict recurving of tropical cyclone because large scale steering could play principle role in deciding storm track, especially in the case recurving tropical cyclone. He suggested that assimilation of satellite derived sea surface wind could improve the forecasting of recurving of tropical cyclone. He concluded with remarks that the errors obtained for different categories of 16 cyclones studied were comparable and WRF model could be used to forecast track positions of tropical cyclone of Bay of Bengal. **Mr. Dambaru Ballab Kattel**, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China, gave his presentation on the variation in temperature lapse rate in the past 20 years on the southern slopes of southern Himalayas. He reported that the changing of mean temperature lapse rate is positively related with the changing OLR. He stated that the highest negative TLR trends during winter indicated increasing inversion and moist adiabatic conditions while the positive trend indicated the decreasing moisture enhancing dry adiabatic conditions.

Session X: ***Mid-Latitude Session on "Water-Food-Ecosystem Resilience in Mid-Latitude Zone" (Young Scholars Committee)***

The *Mid-Latitude Session on "Water-Food-Ecosystem Resilience in Mid-Latitude Zone" (Young Scholars Committee)* was chaired by **Professor Dr. Sonam Wangyel Wang** and **Professor Dr. Yowhan Son**, Korea University, Seoul, South Korea. This session consisted of 6 oral

presentations. **Ms. Wona Lee**, Korea University, Seoul, South Korea, gave her presentation about the expert group meeting on achieving the sustainable development goals with water-food-ecosystem resilience in mid-latitude region. She highlighted about need to better understanding of interdependence of water-food-ecosystem from scientific perspective. She talked about the expert group meeting focused to achieve the sustainable development goals which required the integrated approach to promote synergies and to address common challenges such as growing climate related stresses. **Mr. Gang Sun Kim**, Korea University, Seoul, South Korea presented about the case from Republic of Korea on the impact of reforestation on soil erosion in mountain region. He talked about use of GIS and SWAT model to determine each factor of MUSLE. He reported that in the MUSLE, only C and P factors can be controlled by human, but the P factor in the area where people can not intervene cannot be controlled. He concluded that afforestation to be the most effective way to control the C factor directly and decreasing productivity, desertification, landslide caused by soil erosion could only be prevented by national scale reforestation. **Ms. Soo Jeong Lee**, Korea University, Seoul, South Korea, gave his presentation about the evaluation of spatial distribution of water yield service based on precipitation and population in South Korea. His study found that the value of NF was spatially, randomly distributed according to the forest condition, while the values of ES and ESS were higher in urban areas where industrial and human activities occur. He concluded that with an understanding of the differences among the NF, ES, and ESS concepts, decision makers could be equipped with more efficient and effective tools for the management of ecosystem services. **Mr. Aniket Gupta**, Himalayan Cryosphere and Disaster Research Center, Department of Environmental Science and Engineering, School of Science, Kathmandu University, Nepal, gave his presentation about comparison of hydrological regime in Marshyangdi river basin, Nepal and Chandra river basin, India using modified positive degree day model. He concluded that the model gave fair results in both the basins. **Mr. Nim Dorji**, Bhutan Institute of Himalayan Studies, Thimphu, Bhutan, gave presentation about piloting the FBSC model to estimate forest carbon dynamics in Bhutan. He reported highly varied forest carbon dynamics by forest age and carbon pool. He concluded that the results showed a possibility for reporting annual forest C inventory in Bhutan with reliable modeling method. **Mr. Ajit Sapkota**, Himalayan Cryosphere and Disaster Research Center, Department of Environmental Science and Engineering, School of Science, Kathmandu University, Nepal, presented about the geomorphological mapping of the

lower part of Ponkar glacier and sediment load study of the Dudh Khola, Manang, Nepal. He stated that Bhimthang valley was developed by glacial erosion, transportation and deposition. He concluded that sediment load of Dudh Khola showed seasonal effect on sediment content and discharge.

Session XI: *Mountain Meteorology and Climate II and Hydro-geochemistry*

The session on *Mountain Meteorology and Climate II and Hydro-geochemistry* was chaired by **Mr. Mani Ratna Shakya**, ex-DDG, Department of Hydrology and Meteorology, Government of Nepal. This session consisted of 4 oral presentations on *Mountain Meteorology and Climate* and 1 oral presentation on *Hydro-geochemistry*. **Dr. Mandira Singh Shrestha**, International Centre for Integrated Mountain Development (ICIMOD), Nepal, gave her presentation on the accuracy of satellite-based rainfall estimates in Khudi Khola mountain catchment of Nepal. She talked about compared results of gauge observed rainfall with NOAA CPC_RFE2.0 estimates and TRMM 3B42 V 7. She stated that the increase in bias and drop in correlation at catchment scale indicated a drop in performance for finer scale applications in the mountain catchments. **Mr. Shiva Gopal Shrestha**, Nepal Development Research Institute (NDRI), Nepal, presented about the runoff response to climate change. He talked about the physically based SWAT model that was applied in Jammu sub-basin of Karnali basin. He reported that the catchment elevation was a key variable in defining the runoff response to climate change. He stated that the historical data analysis showed that the change in future precipitation would affect the monsoon flows more than dry seasonal flows. He concluded that more than 80% of CMIP5 model agree on increment of average annual flow. **Mr. Lohit Jain**, Indian Institute of Technology, Delhi, India, presented about the field investigation on the role of slope on infiltration over pasture surface with temperature variation. He talked about the infiltration technique for hill slope modeling based on different surface inclinations along with their validation with experimental data. **Mr. Dibesh Shrestha**, Nepal Development Research Institute (NDRI), Nepal, presented on the current climate trends and future climate of Nepal. He reported that there were no distinct changes of observed precipitation while temperature showed increasing trend. He stated that all the GCM models predicted that the future temperature would be warmer than present. He concluded that there would be increase in precipitation extremes in future in Nepal.

Professor Dr. Jitendra Pandey, Centre of Advanced Study in Botany, Institute of Science, Banaras Hindu University, India, gave his presentation on atmospheric deposition of nitrogen and phosphorous in Ganges basin, India. He reported a marked spatial and temporal variability in atmospheric depositions inputs indicating the influence of anthropogenic drivers and regional climate variables. He suggested the watershed managers to consider large scale inter-regional time series data on changing state of atmospheric-land-water transfer of carbon and nutrients.

Session XII: *Climate Variability and Climate Change*

The session on *Climate Variability and Climate Change* was chaired by **Professor Rupak Rajbhandari**, Tri-Chandra Multiple Campus, Tribhuvan University. This session consisted of 5 oral presentations. **Professor Dr. Vishwambhar Prasad Sati**, Department of Geography and Resource Management, Mizoram University, India, presented on analysis of climate variability and change in Liangshan mountain region, southwest China. He reported decrease in annual average rainfall and increase in annual average temperature during past 63 years in the study area. He stated that the household surveyed also responded to have observed climate variability and caused decline in traditional crops like paddy, maize and tobacco. **Associate Professor Tirtha Raj Adhikari**, Central Department of Hydrology and Meteorology, Tribhuvan University, Nepal, gave his presentation about recent temperature trends analysis in Nepal. He told that analysis of temperature of 67 different stations showed annual mean maximum temperature in all physiographic regions to be increasing trend. He concluded that the annual mean minimum temperature trend in Siwalik and middle Mountain region to be increasing among five regions in recent decade but winter annual mean minimum temperature trend were decreasing in all physiographic regions of Nepal. **Mr. Devesh Koirala**, Nepal Academy of Science and Technology, Kathmandu, presented on the assessment of precipitation trend over Nepal using gauge-based high-resolution gridded rainfall data. He told that APHORDITE data was of 64 years was used for precipitation analysis. He reported the precipitation showed increasing trend in the months of February, April and May except in high Himalayas. He concluded that the on seasonal basis whole Nepal showed strong increasing trend in pre-monsoon except for high Himalaya which showed decreasing trend in monsoon. **Dr. Madan Sigdel**, Central Department of Hydrology and Meteorology, Tribhuvan University, Nepal, gave presentation on the variability and trends in daily precipitation extremes on the northern and

southern slopes of the central Himalaya. He stated that there was increase in precipitation accompanied by increasing frequency of extremes over southern central Himalaya. He concluded that precipitation extreme indices and circulation indices for higher altitudes could not be established. **Mr. Kabi Raj Khatiwada**, Central Department of Environmental Science, Tribhuvan University, Kathmandu, gave his presentation on the understanding of climate variability and its impact in hydrology of Karnali river basin, using J2000 hydrological model. He reported that the average annual precipitation in the basin was increasing in mountain and decreasing in other regions of basin. He also reported maximum temperature increasing at faster rate than minimum temperature with significantly higher in high elevation and pre-monsoon. He stated that the glacier melt contribution 12.6% and snowmelt contribution 13% of the total discharge. He concluded that the rise in temperature and change in precipitation pattern to further increase the vulnerability of the basin.

Session XIII: *Disaster Risk Reduction*

The session on Disaster Risk Reduction was chaired by **Dr. Janak Lal Nayava**, ex-chairman, Society of Hydrologists and Meteorologists-Nepal. This session consisted of an invited talk and 3 oral presentations. **Professor Hiroji Fushimi**, Kathmandu University, Nepal, gave his invited talk on GLOF characteristics of the Nepal Himalaya. He talked about the GLOF events that have occurred in Nepal since 1970's. He explained the history of glacial environment and mountain people. He expressed that mountain people are very much affected by the environmental changes and had to cross the Himalayas as their way of migration. He concluded that the all the reported GLOFs occurrences in Nepal Himalaya were smaller glacier lakes and no larger glacial lakes such as glaciers Thulagi and Imja showed any GLOF phenomenon. He stressed on careful consideration for smaller lakes to mitigate the GLOF risks.

Dr. Dilip Kumar Gautam, Practical Action Consulting South Asia, Kathmandu, Nepal gave his presentation on improving performance of flood forecasting model using complementary error model. He talked about the conceptual rainfall-runoff model, TUW model and gave case of improving TUW model forecast for Karnali basin using error model. He stated that models were prone to errors and analysis of errors could reveal important information. He concluded that flood forecasts could be significantly improved by integrating error forecasts in conceptual hydrological model forecasts. **Mr. Binod Parajuli**, Department of Hydrology and Meteorology,

Government of Nepal, gave his presentation on the development of flood forecasting model for Narayani River basin, Nepal. He developed the flood forecasting model on the HEC-HMS in combination with HEC-Geo HMS for the studied basin. He used HEC-RAS for inundation mapping of the basin. He stated that rainfall bias correction and model error correction significantly improved the HEC-HMS model results and suggested real time data would give more accurate forecast. He reported that the inundation mapping showed the existing warning and danger level in the river to be quite less then what actually would be while some of the areas seemed to be inundated even in normal flood situation. He recommended that field survey and vulnerability assessment would give clearer picture on the potential risks from the flood models.

Mr. Binaya Kumar Mishra, United Nations University, Institute for the Advanced Study of Sustainability, Tokyo, Japan gave his presentation on assessment of alternative storm water capture measures for managing urban runoff in changing climate of Yato watershed in Japan. He reported that the storage facility alone was not adequate to reduce the future peak discharge and additional infiltration facilities were required in Yato Watershed to control the peak discharge. He stated that the climate scenario revealed significant change in rainfall magnitude and intensity for a range of durations and return periods. He concluded stating that alternative approach is effective, sustainable and flexible for disaster control accompanying with co-benefits from restored water-cycle.

Closing Session Highlights

The two day conference was concluded with a closing session on Tuesday, 11 April (Annex III). Dr. Rijan Bhakta Kayastha, Chairperson of the Organizing Committee and Vice-Chairperson, SOHAM-Nepal chaired the closing session. Dr. Rishi Ram Sharma, Director General, Department of Hydrology and Meteorology (DHM) announced the **Kathmandu Declaration 2017 on Mountain Hydrology and Meteorology for the Sustainable Development**. On behalf of participants, two representatives from national and international participants shared their experiences and feedbacks. Mr. Suman Kumar Regmi, General Secretary, SOHAM-Nepal gave vote of thanks. At the end, Dr. Rijan Bhakta Kayastha, Chairperson of the closing session highlighted the presentations of technical sessions of the two days international conference and concluded the conference with closing remarks.



Vote of Thanks

Mr. Suman Kumar Regmi

Member Secretary, Organizing committee and General Secretary, SOHAM-Nepal



Respected Chairperson, Dr. Rijan Bhakta Kayastha, Chairperson organizing committee and vice chairperson of SOHAM-Nepal,

Dr. Rishi Ram Sharma, Director General, Department of Hydrology and Meteorology, Scientists, Scholars, Researchers, students and SOHAM family.

It has been a great pleasure to host Third International Conference on Mountain Hydrology and Meteorology for the Sustainable Development on 10 and 11 April, 2017 in Kathmandu, Nepal.

The conference has come to this stage after the months of rigorous works from different committees such as organizing, advisory and scientific committees, sharing and coordinating with different collaborative partners, supporting agencies and paper contributors, presenters, invited speakers, chief guests, guests, session chairs, participants, media, volunteers, rapporteurs and management of the hotel.

On behalf of organizing committee, associating partner and supporting organizations as well as participating institutions, I would like to express gratitude for the kind presence of chief guest, guests and all participants to make the conference more successful.

We are very grateful to our Vice President Rt. Honorable Mr. Nanda Bahadur Pun, for gracing the inaugural session as a chief guest of the opening session and also for inaugurating the conference despite his busy schedule. I would like to thank Honorable Minister Jay Dev Joshi, Ministry of Population and Environment, Prof. Dr. Jiba Raj Pokharel, Vice Chancellor, Nepal Academy of Science and Technology, Dr. Bishwa Nath Oli, Secretary, Population and Environment for their kind presence and remarkable speech during Inaugural Session.

Our sincere thanks also goes to Dr. Rishi Ram Sharma, Director General of the Department of Hydrology and Meteorology for his remarkable speech in the opening session and also for delivering Kathmandu declaration in this closing session.

I take this opportunity to thank associate partner Department of Hydrology and Meteorology in joining hand in organizing this conference and commitment to provide financial support substantially. I would also like to thank to all the following supporters to organize this conference successfully.

- *Central Department of Hydrology and Meteorology (CDHM), Tribhuvan University (TU)*
- *Himalayan Cryosphere, Climate and Disaster Research Center, Kathmandu University (KU)*
- *International Centre for Integrated Mountain Development (ICIMOD)*
- *International Water Management Institute (IWMI)*
- *Kathmandu Centre for Research and Education, Chinese Academy of Sciences-Tribhuvan University (KCRE, CAS-TU)*
- *Nepal Academy of Science and Technology (NAST)*
- *OJERI and BK21Plus ELEC of Korea University, Seoul, South Korea*
- *Real Times Solutions (RTS) Pvt. Ltd., Nepal*
- *UNESCO International Hydrological Programme Nepal (UNESCO IHP-Nepal)*

Our special thanks goes to international guests and national participants for their presence and actively participation in the conference. We are also equally thankful to all session chairs and rapporteurs for their time and cooperation in running parallel sessions smoothly and effectively. In addition to this, we are thankful to chairs, co-chairs, contributors and editors of the scientific committee, whose substantial contribution assisted us to shape the conference abstract. We also thank to all the chairs, co-chairs and members of advisory committee for their significant suggestion and inputs from the stage of initiation to this stage. We thank our volunteers, media persons, hotel staff and those who directly and indirectly helped us to bring the conference at this stage. I, personally, as a General Secretary of SOHAM, would like to thank my colleague from SOHAM family including Executive Committee and life members of the society and conference secretariat staffs for their continuous efforts.

Last but not the least; once again, we are grateful to you all for being with us from beginning to the end of the conference.

Thank you very much! Namaste!

The Kathmandu Declaration 2017

Third International Conference on Mountain Hydrology and Meteorology for the Sustainable Development

The third International Conference on "Mountain Hydrology and Meteorology for the sustainable development" was held on 10 and 11 April 2017 in Kathmandu, Nepal. More than 175 participants from 15 countries including representatives from international organizations attended and effectively contributed to the conference. The participants of the conference unanimously adopted the "The Kathmandu Declaration 2017".

Reaffirming the importance of Hydrology and Meteorology for the sustainable development of the mountain region; the basic rights of people living in mountainous regions to water, food and energy; the prosperity of the people with socio-economic transformations and; the challenges of building societies adaptive and resilient to climate change under uncertainties;

Recognize the need for a sound scientific and indigenous knowledge base and the human resources to resolve sustainably the existing and future challenges of water resources development and their impacts on the Cryosphere, especially in the context of the changing climate in mountainous regions.

Note the importance of creating, sustaining, improving and transferring knowledge and the knowledge base of Hydrology, Meteorology and Cryosphere, to deal with the uncertainties that cloud the mountainous region.

Recognize that the Cryosphere is poorly understood, which confirms that a comprehensive approach to improve the hydrological and meteorological sciences is essential to achieve a sustainable development in the mountainous region.

With the above, we therefore call on relevant government authorities, multi/bilateral agencies and non-government organizations to:

Hold an international conference to advance the science of Hydrology, Meteorology and Cryosphere and to promote citizen science for making resilient people in the mountainous region.

Reenergize and strengthen the networks of Hydrologists, Meteorologists and other interdisciplinary scientists with the goal of promoting information and knowledge exchange, enhancing public awareness, influencing policies and contributing to capacity building for sustainable development, taking into consideration the ongoing national, regional and international level programs.

Realize the institutional and human resources capacity with regard to water resource management and development in the mountainous countries.

Establish a Regional Centre of Excellence on Climate Change and Cryospheric Research in the Himalayan Region in Nepal.

Make available sufficient funds to do scientific research using the latest equipment on mountain hydrology and meteorology including the Himalayan glaciers, to overcome the negative impacts of climate change on water resources, providing a mechanism for disseminating research findings down to the community level, conduct training/workshops, contribute to policy development incorporating climate change issues, and coordinate with relevant global and regional institutions; and

We call upon, with a sense of urgency, all international and national institutions, including NGOs and private sector, who are committed to and have been mandated for sustainable mountain development in general and sustainable development of the Himalayas in particular to contribute to and participate in implementing the Kathmandu Declaration.

We congratulate the organizers of the 2017 Conference on **"Mountain Hydrology and Meteorology for the Sustainable Development",** particularly SOHAM- Nepal and the Department of Hydrology and Meteorology (DHM) in successfully completing the conference.

We express our gratitude to Rt. Honorable Nanda Bahadur Pun, Vice President of Nepal and Honorable Jayadev Joshi, Minister for Population and Environment, for providing their patronage to the conference.

Annexes

Annex I: Inaugural Session Schedule

Venue: Hotel Radisson, Lazimpat, Kathmandu

Inaugural Session Schedule (Room: Nepa Dhuku)

Date: 10 April 2017 (Monday)

08:00 - 08:30	**Registration**
08:30-08:45	**All Participants to be seated** **Guests and Dignitaries on the dais** **Badge Distribution**
Inaugural Session	**Chief Guest: Rt. Hon'ble Vice President Nanda Bahadur Pun** **Chairperson: Dr. Jagat Kumar Bhusal**, *Chairperson, Electricity Tariff Fixation Commission, GoN/SOHAM-Nepal*
09:00 – 09:15	**Arrival of Chief Guest Rt. Hon'ble Vice President** **National Anthem** **Inauguration by Lighting the "Panas"**
09:15 – 09:20	**Welcome Address and Program Highlights: Dr. Rijan Bhakta Kayastha**, *Vice-Chairperson*, SOHAM-Nepal
09:20 – 09:23	**Remarks by: Dr. Rishi Ram Sharma**, *Director General, Department of Hydrology and Meteorology (DHM), Government of Nepal*
09:23 – 09:26	**Remarks by: Dr. Bishwa Nath Oli,** *Secretary, Ministry of Population and Environment*
09:26 – 09:29	**Remarks by: Prof. Dr. Jiba Raj Pokharel,** *Vice-Chancellor, Nepal Academy of Science and Technology*
09:29 – 09:32	**Remarks by: Hon'ble Jay Dev Joshi,** *Minister, Ministry of Population and Environment*
09:32 – 09:47	**Inaugural speech by Chief Guest Rt. Hon'ble Vice President Nanda Bahadur Pun**
09:47 – 09:52	**Remarks and closing of the inaugural session** **Dr. Jagat Kumar Bhusal**, *Electricity Tariff Fixation Commission, GoN/SOHAM-Nepal*
09:52- 09:57	**Photo Session**
10:00 - 10:30	**Tea/coffee**

Master of ceremony: Ms. Priyasha Maharjan

Annex II: Technical Program Schedule

Day 1: 10 April 2017, Monday	**TECHNICAL SESSION**
Session I: *Water Resource Management*	**Room 1: Nepa**

Chair: Dr. Mandira Shrestha		
10:35-10:55	**Invited Speaker: Dr. Fraser Sugden** *Nepal Country Representative and Senior Researcher, International Water Management Institute* Title " Water 'availability' versus 'access' in the sub-Himalayan lowlands: the case for an interdisciplinary approach"	
Time	**Abstract ID: Title**	**Presenter/Country**
10:55- 11:10	**Wm01:** Climate change induced risk on water availability: A case of an irrigation system of Mustang in Nepal	Jagat K. Bhusal Nepal
11:10- 11:25	**Wm02:** Spring water quality assessment in pursuance of water resource management in upper Beas basin of Kullu valley, Himachal Himalayas, India	Nandini Thakur India
11:25-11:40	**Wm03**: Hydrologic Variability: Implications for Local Management in Nepal	Shobha K. Yadav Nepal
11:40-11:55	**Wm04:** Role of Traditional Institutions in Ecosystem Service Management. A Study From Upper Mustang, Nepal	Prem S. Chapagain Nepal
11:55-12:10	**Wm05:** Understanding migration and its impact on livelihood of the households: Examples from Dhakarjhong and Phalyak Villages of Upper Kaligandaki Basin	Praju Gurung Nepal
12:10-12:25	**Wm06:** Climate Change Impacts and Adaptation Practices in Water Resources in Salyantar, Central Nepal	Reshu Bashyal Nepal
12:25-12:30	Concluding Remarks by Session Chair	
12:30-13:30 **LUNCH BREAK**		
13:30-14:30 **POSTER SESSION**		
Session III: ***Climate Change and Cryosphere***		
Chair: Dr. Rijan Bhakta Kayastha		
Time	**Abstract ID: Title**	**Presenter/Country**
14:30-14:45	**Cc01:** Contrasted surface mass balances of debris-free glaciers observed between the southern and the inner parts of the Everest region (2007-2015)	Michel Esteves France
14:45-15:00	**Cc02:** Himalayan ponds: Indicators of glacier melting and precipitation trends	Sudeep Thakuri Nepal
15:00-15:15	**Cc03:** Improved glacier melt model in SWAT	Sabin Maharjan Nepal
15:30-15:35	Closing Remarks by Session Chair	
15:35– 16:00 **TEA BREAK**		
Session V: ***Mountain Hydrology and Hydrological Modeling***		
Chair: Dr. Dilip Kumar Gautam		
16:00-16:15	**Invited Speaker: Prof. Dr. Ramesh Kumar Maskey** *Associate Dean, Kathmandu University, Nepal* Title "A Novel Approach for Determining Environmental Flow: The Case of Gandaki River Basin in Nepal"	
Time	**Abstract ID: Title**	**Presenter/Country**
16:15-16:30	**Mh01:** Water balance estimation of a large mountain lake with a coupled model: application to Issyk Kul Lake (Kyrgyzstan, Central Asia)	Francois Delclaux France
16:30-16:45	**Mh02:** Water balance assessment of the Gandaki river basin by applying the J2000 hydrological model	Santosh Nepal Nepal
16:45-17:00	**Mh03:** Assessment of hydrologic components of a high altitude glacierized catchment in the Nepalese Himalaya	Michel Esteves France
17:30-17:35	Concluding Remarks by Session Chair	
18:00-20:00 **DINNER**		

Day 1: 10 April 2017, Monday		**PARALLEL SESSION**
Session II: ***Cryospheric Changes and its Impacts on Water Resource, CHARIS I***		**Room 2:Dhukhu**
Chair: Dr. Madan Lall Shrestha		
10:35-10:55	**Invited Speaker: Dr. Richard L. Armstrong** *Senior Research Scientist, Cooperative Institute for Research in Environment Sciences, University of Colorado* Title "The CHARIS Project-A Collaborative Effort to Assess the Role of Glaciers and Seasonal Snow Cover in the Hydrology of the Mountains of High Asia"	
Time	**Abstract ID: Title**	**Presenter/Country**
10:55-11:10	**Ch01:** Enhancing spatial resolution with image reconstruction: a newly-reprocessed, global historical passive microwave record and preliminary applications to estimate melt onset	Mary J. Brodzik USA
11:10-11:25	**Ch02:** Water Resources of Afghanistan and it's climate change impact	Md. N. Eqrar Afghanistan
11:25-11:40	**Ch03:** Relationship between proglacial stream discharge and meteorology in Chhota Shigri Glacier catchment, Indian Himalaya	AL. Ramanathan India
11:40-11:55	**Ch04:** Glacier Data: GLIMS, RGI, and other databases	Bruce Raup USA
11:55-12:10	**Ch05:** Assessment of Evolution of Mountain Lakes and Risks of Glacier Lake Outbursts in the Djungarskiy Alatau, Central Asia, using Landsat Imagery and Glacier Bed Topography (GlabTop2) Model	Vassiliy Kapitsa Kazakhstan
12:10-12:25	**Ch06:** Climate Change Induced Hazards: An emerging challenge in the Mountain Ecosystem-A case study of Himachal Pradesh, NW Himalaya, India	Shruti Singh India
12:25-12:30	Concluding Remarks by Session Chair	
12:30-13:30 **LUNCH BREAK**		
13:30-14:30: **POSTER SESSION**		
Session IV: ***Cryospheric changes and its Impact on Water Resource, CHARIS-II***		
Chair: Dr. Bruce Raup		
Time	**Abstract ID: Title**	**Presenter/Country**
14:30-14:45	**Ch07:**Question of permafrost zone thaw at high altitude above glacier's accumulation zone in Gilgit Baltistan	Haleem Z. Magsi Pakistan
14:45-15:00	**Ch08:** Glacio-hydrological processes in Shaune Garang basin, Western Himalaya	Rajesh Kumar India
15:00-15:15	**Ch09:** Hydrology and hydrochemistry of the Vakhsh River and its tributaries	Parviz Normatov Tajikistan
15:15-15:30	**Ch10:** Micro-meteorological variability in different elevation zones of Chhota Shigri Glacier, India: an analysis of three in situ stations during the summer season 2015	Arindan Mandal India
15:30-15:35	Concluding Remarks by Session Chair	
15:35 – 16: 00 **TEA BREAK**		
Session VI: ***Cryospheric changes and its Impact on Water Resource, CHARIS-III***		
Chair: Dr. Rijan Bhakta Kayastha		
Time	**Abstract ID: Title**	**Presenter/Country**
16:00-16:15	**Ch11:** An Artificial Intelligence Approach for Flow Volume Modeling of Indus River at Tarbela Reservoir	Mian W. A. Shah Pakistan
16:15-16:30	**Ch12:** The monitoring of meteorological conditions of the formation area of the Transboundary Pyanj River	Parviz Normatov Tajikistan
16:30-16:45	**Ch13:** Glacial component in the rivers runoff of Balkhash–Alakol basin	Larissa Kogutenko Kazakhastan
16:45-16:50	Concluding Remarks by Session Chair	
18:00-20:00 **DINNER**		

Day 1: 10 April 2017, Monday		**POSTER SESSION**
S.N.	**Abstract ID: Title**	**Presenter/Country**
1	**P-Cc05:** Morphological factors controlling changes in mass balance, surface area, terminus, and snow line altitude of Himalayan glaciers	Sudeep Thakuri Nepal
2	**P-Cc06:** Snow: An important component of cryosphere in the Tibetan Plateau	Sahadeep Thapa Nepal
3	**P-Ch14:** The features of changes of air temperature in the geo unit plains-mountains in Central Asia	Alexander Yegorov Kazakhstan
4	**P-Ch15:** Glacier degradation in Chinese Tien-Shan Mountains for the last half century on the example of Koksu and Kunes rivers	Larissa Kogutenko China
5	**P-Ch16:** Glacier degradation in the Pskem and Chatkal river basins (Western Tien-Shan)	Alexander Yegorov Kazakhstan
6	**P-Ch17:** Water stable isotopes in the lower Chamkhar Chhu (River) basin of the central Bhutan, Eastern Himalaya	Dendup Tsering Bhutan
7	**P-Ch18:** Using hydrochemistry and isotopic tracers to clarify meltwater influence to water supplies at a basin scale: techniques and challenges	Alice Hill USA
8	**P-Hg05:** Revised estimate of sediment yield of the upper Koshi Basin in Nepal	Sudish L. Maskey Nepal
9	**P-Mh07:** Stream Discharge Response to Climate Change and Land Use Change in Tamor Basin, Nepal	Sumitra K.C. Nepal
10	**P- Wm07:** Adaptive governance of mountain ecosystem services through citizen Science: A case of participatory monitoring of water resources in Mustang District, Nepal	Santosh Regmi Nepal
11	**P-Mh06:** Hydrological Modeling and Climate Change Impact Assessment using HBV-Light Model: A Case Study of Karnali River Basin of Nepal	Sagar Shiwakoti Nepal
12	**P-Mc09:** Daily adjustment for the wind-induced precipitation under catch of daily gridded precipitation in Japan	Minami Masuda Japan
13	**P-Mc10:** Stable isotopic composition in precipitation in Eastern Nepal	Sunil Acharya Nepal

Day 2: 11 April 2017, Tuesday		**TECHNICAL SESSION**
Session VII: ***Water and Climate Change-KCRE,CAS-TU***		**Room 1: Nepa**
Chair: Prof. Fan Zhang		
Time	**Abstract ID: Title**	**Presenter/Country**
9:00- 9:15	**Kc01:** Kathmandu Centre for Research and Education, Chinese Academy of Science-TU: Research and Activities in Nepal	Fan Zhang China
9:15- 9:30	**Kc02:** Estimation of discharge using temperature index melt model in Modi River basin, Kaski, Nepal	Smrita Acharya Nepal
9:30-9:45	**Kc03:** Impact of Climate Change on Snow melt in Marshyangdi River Basin of Nepal	Anita Tuitui Nepal
9:45-10:00	**Kc04:** Evaluation of GPM/TRMM satellite rainfall estimates over Nepal	Bikas Nepal Nepal
10:00-10:15	**Kc05:** Distribution of Vascular Plants along Subalpine-Alpine Gradient in Manang, Central Nepal and their Fate against Climate Change	Pratikshya Chalise Nepal
10:15-10:20	Concluding Remarks by Session Chair	
10:20-11:00 **TEA BREAK**		
Session IX: ***Mountain Meteorology and Climate I***		
Chair: Prof. Dr. Lochan Prasad Devkota		
11:00-11:20	**Invited Speaker: Prof. Fan Zhang** *Professor, Key Laboratory of Tibetan Environment Changes and Land Surface Processes, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China* Title "Air temperature estimation using MODIS LST for snowmelt modeling in the Tibetan Plateau"	
11:20-11:35	**Mc01:** Characterizing hydro-climatic systems at the local scale to reduce uncertainties. Application to the Dudh Koshi River basin, Nepal	Francois Delclaux France
11:35-11:50	**Mc02:** Synoptic study of tropical cyclone: a case study of Hudhud cyclone in Nepal	Bibhuti Pokhrel Nepal
11:50-12:05	**Mc03:** Estimation of the error of track of the tropical cyclones of the Bay of Bengal using high resolution ARW model	Md. A E Akhter Bangladesh
12:05-12:20	**Mc04:** Variation in Temperature Lapse Rate in the past 20 years on the Southern Slopes of the Central Himalayas, Nepal	D. B. Kattel Nepal
12:20-12:25	Concluding Remarks by Session Chair	
12:40-13:30 **LUNCH BREAK**		
Session XI: ***Mountain Meteorology and Climate II and Hydro-geochemistry***		
Chair: Mani Ratna Shakya		
Time	**Abstract ID: Title**	**Presenter/Country**
13:30-13:45	**Mc05:** Accuracy of Satellite-based Rainfall Estimates in Small Mountain Catchments: Case Study in Khudi Khola, Nepal	Mandira S. Shrestha Nepal
13:45-14:00	**Mc06:** Runoff response to climate change	Shiva G. Shrestha Nepal
14:00-14:15	**Mc07:** Field investigation on the role of slope on infiltration over pasture surface with temperature variation	Lohit Jain India
14:15-14:30	**Mc08:** Current climate trends and future climate of Nepal	Dibesh Shrestha Nepal
14:30-14:45	**Hg02:** Atmospheric Deposition of Nitrogen and Phosphorus in Ganges Basin (India): Integrating Atmosphere-Land-Water Components to Uncover Cross-Domain Carbon Linkages in Ganga River	Jitendra Pandey India
14:45-14:50	Concluding Remarks by Session Chair	
14:50 -15:15 TEA BREAK		
Session XIII: ***Disaster Risk Reduction***		**Room: Nepa Dhuku**
Chair: Janak Lal Nayava		
15:15-15:35	**Invited Speaker: Prof. Hiroji Fushimi** *Professor, Kathmandu University, Nepal*	

	Title "GLOF characteristics of Nepal Himalaya"	
Time	**Abstract ID: Title**	**Presenter/Country**
15:35-15:50	**Dr01:** Improving Performance of Flood Forecasting Model Using Complementary Error Model	Dilip K. Gautam Nepal
15:50-16:05	**Dr02:** Development of Flood Forecasting Model for Narayani River Basin, Nepal	Binod Parajuli Nepal
16:05-16:20	**Dr03:** Assessment of alternative storm water capture measures for managing urban runoff in changing climate	Binaya K. Mishra Nepal
16:35-16:40	Concluding Remarks by Session Chair	
16:40-17:30	**CLOSING SESSION**	**Room: Nepa Dhuku**

Day 2: Tuesday, 11 April 2017		**PARALLEL SESSION**
Session VIII: Mid-Latitude Session on *"Water-Food-Ecosystem Resilience in Mid-Latitude Zone"* (Expert Committee)		**Room 2: Dhuku**
Chair: Dr. Sonam Wang, Bhutan Institute for Himalayan Studies		
9:00-9:20	**Invited Speaker: Prof. Woo-Kyun Lee** *Professor, Korea University, Korea* Title "Different Ecosystem services on Land Degradation-Restoration-Sustainability in Mid-Latitude Ecotone"	
Time	**Abstract ID: Title**	**Presenter/Country**
9:20- 9:40	**Ml01:** Building Climate Resilience of Urban Systems through Ecosystem Based Adaptation (EbA) in high altitude city of Thimphu Bhutan: An assessment of vulnerabilities/impacts and needs	Sonam W. Wang Bhutan
9:40- 10:00	**Ml02:** Forest and Watershed Management Projects with Enhanced Food Security under the Forest and Landscape Restoration Mechanism in the Mid-Latitude Region	Yowhan SON Korea
10:00-10:20	**Ml03:** Determining environmental flows of the Gandaki River basin, Nepal: hydrological aspect	Rijan B. Kayastha Nepal
10:20-10:25	Concluding Remarks by Session Chair	
10:25-11:00 **TEA BREAK**		
Session X: Mid-Latitude Session *on "Water-Food-Ecosystem Resilience in Mid-Latitude Zone"* (Young Scholars Committee)		
Chair: Prof. Yowhan SON, Korea University, Dr. Sonam Wang, Korea University		
Time	**Abstract ID: Title**	**Presenter/Country**
11:00-11:15	**Ml04:** Expert Group Meeting on Achieving the Sustainable Development Goals with Water-Food-Ecosystem Resilience in the Mid-Latitude Region (MLR)	Wona Lee Korea
11:15-11:30	**Ml05:** Impact of Reforestation on Soil Erosion in Mountain Regions – Case Study from Republic of Korea	Gang Sun Kim Korea
11:30-11:45	**Ml06:** Evaluation of Spatial Distribution of Water Yield Service based on Precipitation and Population in South Korea	Soo Jeong Lee Korea
11:45-12:00	**Ml07:** Comparison of hydrological regime in Marsyangdi River basin, Nepal and Chandra River basin, India using Modified Positive Degree Day Model	Aniket Gupta India
12:00-12:15	**Ml08:** Piloting the FBDC Model to Estimate Forest Carbon Dynamics in Bhutan	Nim Dorji Bhutan
12:15-12:30	**Ml09:** Geomorphological mapping of the lower part of Ponkar Glacier and sediment load study of the Dudh Khola, Manang, Nepal	Ajit Sapkota Nepal
12:30-12:35	Concluding Remarks by Session Chair	
12:35-13:30 **LUNCH BREAK**		
Session XII: *Climate Variability and Climate Change*		
Chair: Prof. Rupak Rajbhandari		
Time	**Abstract ID: Title**	**Presenter/Country**
13:30-13:45	**Cc01:** An Analysis of Climate Variability and Change in Liangshan Mountain	Vishwambhar P. Sati

	Region, Southwest China	India
13:45-14:00	**Cc02:** Recent temperature trends analysis of Nepal	Tirtha R. Adhikari Nepal
14:00-14:15	**Cc03:** Assessment of precipitation trend over Nepal using gauge-based high-resolution gridded rainfall data	Devesh Koirala Nepal
14:15-14:30	**Cc04:** Variability and trends in daily precipitation extremes on the northern and southern slopes of the central Himalaya	Madan Sigdel Nepal
14:30-14:45	**Cc05:** Understanding climatic variability and its impact on hydrology of Karnali river basin, Nepal Himalaya using J2000 hydrological model	Kabi R. Khatiwada Nepal
14:45-14:50	Concluding Remarks by Session Chair	
14:50– 15:15 **TEA BREAK**		
Session XIII: *Disaster Risk Reduction*		**Room: Nepa Dhuku**
Chair: Janak Lal Nayava		
15:15-15:35	**Invited Speaker: Prof. Hiroji Fushimi** *Professor, Kathmandu University, Nepal* Title "GLOF characteristics of Nepal Himalaya"	
Time	**Abstract ID: Title**	**Presenter/Country**
15:35-15:50	**Dr01:** Improving Performance of Flood Forecasting Model Using Complementary Error Model	Dilip K. Gautam Nepal
15:50-16:05	**Dr02:** Development of Flood Forecasting Model for Narayani River Basin, Nepal	Binod Parajuli Nepal
16:05-16:20	**Dr03:** Assessment of alternative storm water capture measures for managing urban runoff in changing climate	Binaya K. Mishra Nepal
16:35-16:40	Concluding Remarks by Session Chair	
16:40-17:30	**CLOSING SESSION**	**Room: Nepa Dhuku**

Annex III: Closing Session Schedule

Venue: Hotel Radisson, Lazimpat, Kathmandu

Closing Session Schedule (Room: Nepa Dhuku)

Date: 11 April 2017 (Tuesday)

	Chairperson: Dr. Rijan Bhakta Kayastha, *Chairperson, Organizing Committee and Vice-Chairperson, SOHAM-Nepal*
16:50 – 16:55	**Announcement of the Kathmandu Declaration 2017: Dr. Rishi Ram Sharma**, *Director General of Department of Hydrology and Meteorology, Government of Nepal*
16:55– 17:00	**Remarks: Representative from National Participant**
17:00– 17:05	**Remarks: Representative from International Participant**
17:05 – 17:10	**Vote of Thanks: Mr. Suman Kumar Regmi,** *Member Secretary, Organizing committee and General Secretary, SOHAM-Nepal*
17:10 - 17:15	**Highlights of Technical Presentation and Closing Remarks: Dr. Rijan Bhakta Kayastha,** *Chairperson, Organizing Committee and Vice-Chairperson, SOHAM-Nepal*

Master of ceremony: Ms. Priyasha Maharjan

Annex V: Selected Photographs






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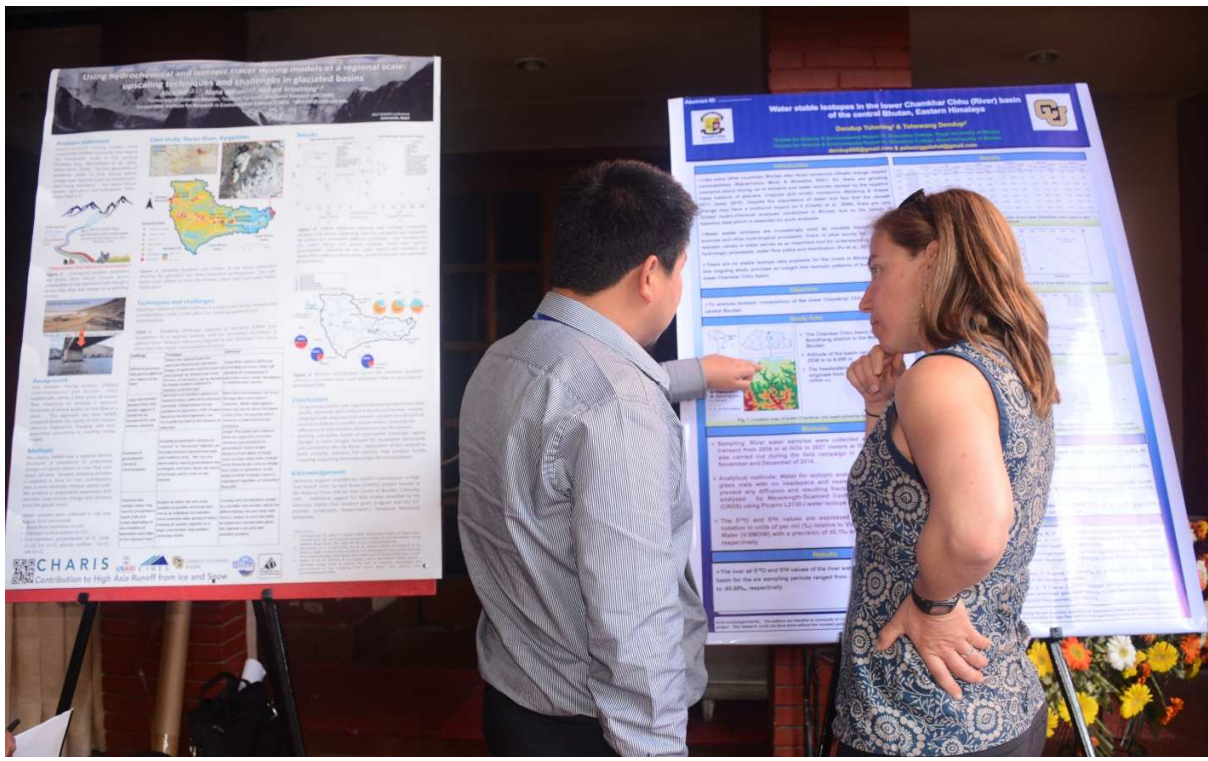





EXIT






Water stable isotopes in the lower Chamkhar Chhu (Rivor) basin of the central Bhutan, Eastern Himalaya
CHARIS
Contribution to High Asia Runoff from Ice and Snow






EXIT




Third International Conference on
Mountain Hydrology and Meteorology for the Sustainable Development
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Third International Conference on
Mountain Hydrology and Meteorology for the Sustainable Development
10-11 April 2017, Kathmandu, Nepal
Organized by
Society of Hydrologists and Meteorologists-Nepal (SOHAM-Nepal)
In Association with

ABSTRACT

Third International Conference on

Mountain Hydrology and Meteorology for The Sustainable Development

10-11 April 2017

Radisson Hotel, Kathmandu, Nepal

Organized by

Society of Hydrologists and Meteorologists-Nepal (SOHAM-Nepal)

In Association with

Department of Hydrology and Meteorology (DHM), Government of Nepal (GoN)

Supported by

Central Department of Hydrology and Meteorology (CDHM), Tribhuvan University (TU)

Himalayan Cryosphere, Climate and Disaster Research Center, Kathmandu University (KU)

International Centre for Integrated Mountain Development (ICIMOD)

International Water Management Institute, Nepal (IWMI)

Kathmandu Centre for Research and Education, Chinese Academy of Sciences-Tribhuvan University (KCRE, CAS-TU)

Nepal Academy of Science and Technology, (NAST)

OJERI and BK21Plus ELEC of Korea University, Seoul, South Korea

Real Times Solutions (RTS)

United Nation Educational, Scientific and Cultural Organization, International Hydrological Programme Nepal (UNESCO IHP-Nepal)

ABSTRACTS

Third International Conference on
Mountain Hydrology and Meteorology for the Sustainable Development
10-11 April 2017
Kathmandu, Nepal

Organized by

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Third International Conference on Mountain Hydrology and Meteorology for the Sustainable Development

10-11 April 2017, Kathmandu, Nepal

Introduction

Hydrology and meteorology of mountain is very crucial components in the development of many mountainous countries of the world. The importance of mountain hydrology and meteorology has increased significantly nowadays due to change in world climate. Its importance in the Hindu-Kush-Karakorum-Himalayan region is much more due to the presence of snow and glacier ice in those mountain ranges which is very sensitive to changing climate. Water is one of vital natural resources required for sustainable development and environmental integrity. Hence, scientific discussion and knowledge sharing on the mountain hydrology and meteorology is very much essential to understand its complex nature so that a sustainable development can be achieved.

In order to address the issues of mountain hydrology and meteorology for sustainable development, an International Conference on Mountain Hydrology and Meteorology for the Sustainable Development will be organized in Kathmandu, Nepal on 10 and 11 April 2017.

The Conference will be jointly organized by Society of Hydrologists and Meteorologists-Nepal (SOHAM-Nepal), Department of Hydrology and Meteorology (DHM), Government of Nepal (GoN), United Nation Educational, Scientific and Cultural Organization, International Hydrological Programme Nepal (UNESCO IHP-Nepal), Nepal Academy of Science and Technology (NAST), Central Department of Hydrology and Meteorology (CDHM), Tribhuvan University (TU), Himalayan Cryosphere, Climate and Disaster Research Center, Kathmandu University (KU) and International Centre for Integrated Mountain Development (ICIMOD).

The conference aims to invite researchers, scientists, engineers, planners, development workers as well as experts on related fields and to provide platforms for presenting their research activities along with discussion on observations, findings and innovative ideas. Keynote speakers will be invited to deliver presentations on specific burning issues.

Selected peer reviewed papers will be published in the Journal of Hydrology and Meteorology published by SOHAM-Nepal.

Conference Topics

The conference will cover a wide range of topics concerning mountain hydro-meteorology, its links to sustainable development and other related issues. The meeting will be dedicated to the following topics but not limited to:

- Mountain hydrology and hydrological modeling
- Water resources management
- Isotope hydrology
- Trans-boundary issues of water resources
- Cryospheric changes and its impacts on water resources
- Watershed management
- Mountain ecosystem services
- Mountain meteorology and climate
- Paleoclimate
- Climate variability and changes
- Monsoon
- Extreme weather events
- Climate change and cryosphere
- Disaster risk reduction

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Third International Conference on "Mountain Hydrology and Meteorology for the Sustainable Development"

Water Resource Management

Invited Talk

Water 'availability' versus 'access' in the sub-Himalayan lowlands: The case for an interdisciplinary approach

Fraser Sugden*
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Nepal's eastern Tarai belt skirts the foot of the Himalayan foothills, and despite the fertile land and favorable terrain for cultivation, it is home to some of the most marginal farmers in the country. Increased climatic variability has made rainfed cultivation increasingly risky, although this paper notes that vulnerability is rooted not in climate stress per se, but in the regions deeply inequitable agrarian structure. Changes in rainfall are of limited concern to farmers who can tap the Tarai's vast, under-utilised groundwater reserves. However, marginal and tenant farmers who form the majority of the rural population face significant institutional, tenurial and economic constraints in accessing groundwater. Pump ownership and rental markets are monopolized by a small group of wealthy cultivators, while sharecropping and absentee landlordism discourage investment in irrigation infrastructure. The resulting out-migration and feminization of agriculture adds further pressures on farmers as women face a number of gendered barriers in accessing groundwater. This paper highlights the need to understand vulnerability to climate change through a socio-economic as well as purely biophysical lens.

Keywords: Terai, Himalayan foothills, agriculture, climate change

Climate change induced risk on water availability: A case of an irrigation system of Mustang in Nepal

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Bordered with Tibet autonomous region of China in the north, Mustang on Upper Kaligandaki basin is situated in the cold arid Trans-Himalayan region of Nepal. Water has been always contested between individuals, communities, and social groups. Dispute over water utilization, water use, water sharing and, the control of water sources have been commonly noticed since long back. Traditionally, farmland and cultivable lands are preserved. Tools used for the study included quantitative and qualitative approaches. Tools like questionnaire survey, key informant interview, focus group discussion and observation were used for assessing the situation analysis focused on irrigation water in the study communities. Hydro-meteorological data were further collected during study periods and, required long-term data were sourced from standard publications. The water availability situation, management practices, impact of climate change on water, river flows and suspended sedimentation load were studied in depth. Uniquely, peoples are using citizen science in watering their forms that are characterized for high porosity and very low moisture holding capacity. People developed idea in sharing, storing, and application of water and updated water governance system with time. Identified issues are livelihood vulnerability due to insufficient and unavailability water for basic needs and, not having the capacity to pay for water conservation, decrease in production from traditional farming system, bio-diversity diluted and, lives and environments threatened.

Keywords: Climate change, water availability, water disputes. citizen science, Mustang region

Spring water quality assessment in pursuance of water resource management in Upper Beas Basin of Kullu Valley, Himachal Himalayas, India

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In mountainous regions ground water in the form of springs has always played a vital role for the high altitude habitant. Analysis of the water resources is important in terms of quality and quantity as its demand is increasing exponentially throughout globe. The study area lies in the upper Beas basin of Kullu District in Himachal Pradesh, India, which is a part of NW Himalayas. The present study aimed at assessing the water quality of water resources in general and spring water resources in particular. This is determined by collecting samples and subjecting them to physicochemical analysis. Most of the parameters were well within the standard limit of BIS (2012) except TDS, K^+, $Mg^{2+,}$ NO_3^-, Fl^- were found to be above desirable limit in some samples. Water quality index was calculated for the parameters; pH, TDS, TH, Ca^{2+}, K^+, Mg^{2+}, Na^+, HCO_3^-, Cl^-, NO_3^-, SO_4^{2-}, and Fl^-. WQI can be categorized into five types "excellent water" to "water unsuitable for drinking. The computed WQI values ranges from 10.89 to 151.82. Value of WQI has been found to be high mainly because of the higher values of TDS, K^+, Mg^{2+}, NO_3^- and Fl^- in water samples. As per the water quality classification based on WQI value, 10% of the samples were in the category of poor water, 15% sample in the category of good water and rest 75% of samples were in the category of excellent water. Water quality issues can be related to insufficient decentralised STPs, increasing urban activity, proliferating population, tourism industry, change in landuse pattern and climate change. Sustainable water resource management is immediate need of the hour to maintain the intergenerational equity in a long run.

Keywords: Springs, water quality index, mountain habitant, NW-Himalayas

Hydrologic variability: Implications for local management in Nepal

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The changes in the water cycle at the global levels are expected to exacerbate the uncertain hydrological trends at local scale. Precipitation is expected to increase and intensify triggering faster surface water concentration to form flash floods or increase instances of low flows in rivers. Planning and management decisions require knowledge of hydrologic behaviour so that they can be incorporated in designs. Better designs allow improved ability to quantify the project details and thereby provide a basis for estimating benefits and associated risks. However, relations among projected hydrological changes, increasing uncertainties and water resources management approaches have not been extensively explored. This paper suggests that the extreme events have embedded uncertainty with implications for water management strategies. Climate change would introduce further uncertainties and the paper highlights some of the variability of hydrologic systems in Nepal as well as the uncertainty that underlies it. In doing so, the paper analyses the extreme rainfall events in Nepal and its impact on hydrological responses. It will identify gaps where knowledge needs to be further developed to improve efforts at better resource planning and water management.

Keywords: Hydrological variability, extreme events, precipitation, climate change

Role of traditional institutions in ecosystem service management: A study from Upper Mustang, Nepal

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Mountain remains an isolated place for a long time. The existing inaccessibility and marginality context constrained mobility of people and resources in the mountain and the people have been managing natural resources through traditional local institution. The study area, Upper Mustang, located in the north western part of Nepal is also characterised by inaccessibility and marginality. It is an isolated trans-Himalayas valley located in the north western part of Nepal and bordered with China in the north. The livelihood of the people living in this area depends primarily upon the available ecosystem services and these services are mainly governed by traditional local institutions. This paper discusses the management of ecosystem services by the traditional local institutions in the study area. The *Mukhiya* system is the strong informal institutions in the study area that has been playing crucial role in managing the livelihood and ecosystem services for generations. Water, agriculture and pasture land have always been the main resources there. After opening the Annapurna Trekking Circuit (ACT), tourism has appeared as a new opportunity. Water has been one of the scarcest resources as its availability for irrigation, and drinking depends upon the amount of snowfall in the high mountain area. The decreasing amount of snowfall has stressed the livelihood of local people and environment. It is found that the available water is shared between the two studied villages and among the farm households. Each family has certain water right what is called *Dhongba* continued till today and managed by the *Mukhiya* system for generations. The local people have strong faith and trust to the institution that facilitate for development activities and resolution of the conflicts related to various ecosystem services.

Keywords: Nepal Himalayas, Upper Mustang, ecosystem services, Mukhiya, Dhongba

Climate Change Impacts and Adaptation Practices in Water Resources in Salyantar, Central Nepal

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The impacts of climate change are being felt everywhere in a number of ways but the most critical are likely to be those affecting the water resources. This study has attempted to assess the extent of climate change impacts on water resources and explore the adaptation strategies of local communities in Salyantar Village, Dhading District of Central Nepal. With the view of assessing the impacts and identifying adaptation means, people's perception was studied through Participatory Rural Appraisal tools which were supplemented by scientific means, where appropriate. The meteorological data was analysed followed by the Mann-Kendall Test to assign the statistical significance to the trend. Present scenario of water resources was found by discharge and water level measurement along with the analysis of Landsat images of last three decades. The temperature vegetation dryness index and laboratory analysis of soil samples were used to identify soil moisture. The study showed the maximum temperature was increasing at the rate of 0.039 ^{0}C per year and annual precipitation was decreasing at the rate of 22.99 mm per year with statistically significant trend. The perception was fully justified by the analysis of Landsat images, discharge of Haping River, soil moisture calculation, and other scientific and field assessments. Water coverage is decreasing from 28.93% to 6.47% and TVDI range lying between 0.01-0.7 in the last three decades, were identified as the most sensitive parameters. The community had identified new sources and adaptation measures to cope with it. The study area, which is already stuck in the grip of water stress because of its plateau like location, is experiencing the problem unfavorably, mainly because of the effects of climate change.

Keywords: Adaptive capacity, climate change impacts, water resources

Understanding migration and its impact on livelihood of the households: Examples from Dhakarjhong and Phalyak Villages of Upper Kaligandaki Basin

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The livelihood of residents in Upper Kaligandaki Basin is primarily characterized by agro-pastoral economy where households carry out crop faming in the village and raise livestock up in the highland pastures. However, household's economy is also largely subsidized by remittances earned through migration. A number of household members are involved in both external and internal migration. While some members participate in seasonal migration within the country others are engaged in long-term foreign labor migration. This paper is an outcome of a research program entitled "Adaptive governance of mountain ecosystem services for poverty alleviation enabled by environmental virtual observatories." The paper analyzes the status of migration and its impact on the households of Upper Kaligandaki Basin. It also examines the migration patterns and reasons for both categories of migrants.. Furthermore, it analyses the impacts of migration on local livelihood. The findings are based on a long term study carried out at two settlements: Dhakarjong and Phalyak of Kagbeni VDC in Mustang district. In terms of geographic location, it is a rain shadow area of main Himalaya with very low annual rainfall. Findings suggest that seasonal migration for trade to India and more long-term external migration for wage work were common features of the households in this area. Migrants send and/or bring remittances and these remittances play a significant role in household economies. While the remittance flow has increased the cash flow and improved the living conditions of the household, it has also increased the dependency of households on external income and on readymade market goods. In the meantime, migration of household members outside the village has also reduced the local crop and livestock production by creating shortage of labor in agriculture. Absence of household members especially the male member has resulted into a change in the traditional gender division of labor with women shouldering much of their as well as their absentee members' workload in the household. A tendency of renting lands and houses of external migrants to non-locals has been observed and it has long-term consequences to the area as well as to the society.

Keywords: Upper Kaligandaki, migration, remittances, consequences, agriculture, livelihood, women



Third International Conference on "Mountain Hydrology and Meteorology for the Sustainable Development"

Climate change and Cryosphere

Contrasted surface mass balances of debris-free glaciers observed between the southern and the inner parts of the Everest region (2007-2015)

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Three debris-free glaciers with strongly differing annual glaciological glacier-wide mass balances (*Ba*) are monitored in the Everest region (central Himalaya, Nepal). Mera Glacier (5.1 km^2 in 2012), located in the southern part of this region, has been in steady state during 2007-2015, whereas Pokalde (0.1 km^2 in 2011) and white Changri Nup glaciers (0.9 km^2 in 2013), ~30 km further north in the drier inner part of the range, have been losing mass rapidly with a *Ba* of -0.69 ± 0.28 m w.e. a^{-1} (2009-2015) and -1.24 ± 0.27 m w.e. a^{-1} (2010-2015), respectively. An analysis of high-elevation meteorological variables reveals that these glaciers are sensitive to precipitation, and to occasional severe cyclonic storms originating from the Bay of Bengal. This contrasted mass balance pattern over rather short distances is related (i) to the low elevation of Pokalde and white Changri Nup glaciers, resulting in years where their accumulation area ratio is reduced to zero and (ii) to a steeper vertical gradient of mass balance for glaciers located in the inner arid part. This steeper gradient is likely related to the negative horizontal gradient of annual precipitation in South-to-North direction across the range (≤ -21 mm km^{-1}, i.e. -2% km^{-1}).

Keywords: Debris-free glaciers, surface mass balance, Khumbu region

Himalayan ponds: Indicators of glacier melting and precipitation trends

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High altitude environments are especially considered vulnerable to changing climate, however long-term measurement of climate data in high-elevation area of the Himalayan is extremely rare. Although glacier shrinkage is now sufficiently well described, the changes in precipitation and temperature at these elevations are less clear. Glacial lake evolution and their surface area variation are highly visible and easily measurable signal of the impact of climate change in such ecosystems. We show that the surface area variations of unconnected glacial ponds, i.e. ponds not directly connected to glacier ice, but that may have a glacier located in their hydrological basin, can be considered as suitable proxies for detecting past changes in the main hydrological components of the water balance. On the south side of the Mt Everest, glacier melt and precipitation have been found to be the main drivers of unconnected pond surface area changes. In general, unconnected ponds have decreased significantly by approximately 10 ± 5 % in terms of surface area over the last 50 years (1963–2013 period) in the study region. Here, an increase in precipitation occurred until the mid-1990s followed by a decrease until recent years. Until the 1990s, glacier melt was constant. An increase occurred in the early 2000s, while a declining trend in maximum temperature has caused a reduction in the glacier melt during recent years.

Keywords: Lake evolution, proxy, high altitude, climate, satellite imagery

Improved glacier melt model in SWAT

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The Soil and Water Assessment Tool (SWAT) has been widely used for modelling catchment processes (water quantity, quality and sediment). While it has extensive models for simulating hydrological processes including snow melt, it lacks an explicit model for glacier melt processes. In this study, we proposed an algorithm for glacier melt and glacier mass balance and implemented in the SWAT framework. The model was applied in the Melamchi catchment, a small mountainous catchment in Nepal located about 40 km North-East of the capital city, Kathmandu. The catchment area is about 113 km^2 with 6.4% glacier covered area. The model performance was evaluated for two cases: with and without the glacier model. Our results show that the SWAT without glacier model under predicts the spring flows. The overall model performance was improved with glacier model with a Nash-Sutcliff efficiency from 0.61 to 0.74 and a Coefficient of Determination from 0.75 to 0.78. Our results also show that the glacier volume and area in the catchment reduced by 4% and 6% respectively during the simulation period from 2000 to 2008.

Keywords: Glacier, Melamchi catchment, snow, SWAT



Third International Conference on "Mountain Hydrology and Meteorology for the Sustainable Development"

Mountain Hydrology and Hydrological Modeling

Invited Talk

A Novel Approach for Determining Environmental Flow: The Case of Gandak River Basin in Nepal

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WWF Nepal under Hariyo Ban program funded by USAID collaborates with Kathmandu University involving a group of seven specialists for determining the Environmental Flow (E-Flow) of Gandak River Basin (GRB) in Nepal. An E-flow is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated. E-Flow provides critical contributions to river health, economic development and poverty alleviation. The E-Flow Assessment (EFA) integrated multiple disciplines including hydrology, hydraulics, fluvial geomorphology, flora, macro-invertebrates, aquatic vertebrates (Fish), socio-cultural and Livelihood. The GRB supports not only a large human population in the mountains, mid-hills and Terai but also will affect the aquatic ecosystems and river biodiversity. Since many of the infrastructures for different purposes, such as power production and irrigation, cumulative effects of which could be significant, are still at the early planning stage, an E-Flow Assessment (EFA) will be very timely to demonstrate possible effects of such infrastructures under different scenarios. It can be used as a planning tool for integrated water resource management to cope with the adverse impact of climate change and infrastructure development in the GRB. The EFA for GRB was the first attempt to ensure the time-series natural flow for maintaining ecology and socio-cultural livelihood.

Given the geo-spatially vast territory of the GRB, the study was limited to cover only eight reference sites within three geo-ecological zones during Pre-monsoon, Monsoon and Post-monsoon. This includes four sites along the Kaligandaki River namely: Lete in Mustang (Tibetan-Tethys Himalayan Zone), Setibeni in Syangja (Higher Himalayan Zone), Ruru-Ridi in Gulmi (Higher Himalayan Zone) and Devghat in Tanahu (Lesser Himalaya Zone) as well as four sites along Narayani River from Devghat confluence to Rapti River confluence namely: Alamtari-Narayani Confluence in Nawalparasi (Sub-Himalaya Siwalik Zone) and Arun Khola-Rapti Confluence in Chitawan (Sub-Himalaya Siwalik Zone) and finally Gandak River up to Tribeni namely: Baguwan-Gandak Confluence in Nawalparasi (Sub-Himalaya Siwalik Zone) and Tribeni-Gandaki in Nawalparasi (Terai Gangetic Plain). The main objectives of this study are to provide a baseline data, to describe the process and methodology used for analysis and to present the outcome of time-series E-Flow in the above mentioned selected river stretches. Among the various methodologies available for assessing E-Flows for rivers, the study team has applied the Building Block Methodology a novel approach developed in South Africa and applied in Upper Ganga Basin in India, was used and

verified with the Computer Aided Simulation Model for In-stream Flow and Riparia (CASiMiR). The groups of experts made use of existing and historical information and databases, and supplemented the fieldwork by analyzing respective theme critically. The BBM proved to be the most flexible methodology to use and adapt in interdisciplinary work. This study suggests that the natural river discharge can satisfy the requirement of environmental flow whole year. The result indicate that the annual flow at Lete, Seti-Beni, Ridi and Dev-Ghat are 1745.37 Mm^3, 15091.55 Mm^3, 30433.67 Mm^3 and 45730.66 Mm^3 respectively while the required flow for the respective sites are 92.10 Mm^3, 214.80 Mm^3, 504.03 Mm^3 and 548.83 Mm^3, respectively.

Keywords: Gandak River Basin, environmental flow assessment, building block method, CASiMiR, climate change

Water balance estimation of a large mountain lake with a coupled model: Application to Issyk Kul Lake, Kyrgyzstan, Central Asia

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The Issyk-Kul Lake (Kyrgyzstan) is one of the largest altitude lakes in the world with an area of about 6000 km^2 at 1607 m a.s.l. in the Tian Shan Mountain. This lake, in a semi-arid environment, is an important resource for the country's economy based on agriculture and tourism. A preliminary evaluation of the lake water budget shows that if the rainfall and evaporation over the lake are relatively well known, river contributions and tributaries irrigation withdrawals involve poorly documented processes. Moreover, irrigation could be in a large part responsible of a decrease of about three meters of the lake water level as observed between 1927 and 1998. To quantify the lake water budget, a two-step modeling approach is applied, involving the distributed HDSM model. First a small basin (351 km^2) is considered, this basin including all the characteristics of the overall lake basin. In a second part, the model is applied on the total lake basin (21900 km^2) using the parameters calibrated on the small basin. Climatic ERA-Interim reanalysis data are considered for modeling historical lake behavior: air temperature at different pressure levels is interpolated according to DEM and corrected with observation; precipitation has been validated according to a double longitudinal-altitudinal gradient; reference evapotranspiration is calculated with Penman-Monteith formulae. Lake evaporation comes from a 1-D depth lake model (FLake) and water level is given by long-term observation coupled with remote-sensing altimetry (Hydroweb database). Finally, the groundwater input estimation to the lake comes from previous studies and irrigation withdrawals at the lake-basin scale are given by historical sources. As a result, on the small basin, calibration of snow melt parameters (degree-day model) is driven according to SCA issued from a gap filled MOD10A2 product, with a good efficiency (Nash ~ 0.78; Bias ~ 7%). For lake modeling, sensitivity analysis shows that the lake level variability is strongly influenced by two opposite key-factors, the groundwater contribution and the irrigation withdrawals.

Keywords: Tian Shan, Mountain Lake, cryosphere, irrigation, hydrological modeling

Water balance assessment of the Gandaki river basin by applying the J2000 hydrological model

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Understanding the hydrological aspects of the Himalayan Rivers is important for water resource planning and development. The transboundary Gandaki River originates from high altitude areas of Nepal (and few tributaries from China) and flows downstream to the Indo-Gangetic Plain before meeting with the mighty Ganges. The river basin contains too much water during the monsoon season and too little during non-monsoon months. In this study, a process oriented J2000 hydrological model is applied to the Gandaki river basin (31,776 km^2) to understand different water balance components. The J2000 model simulates the flow from glacier areas and can segregate seasonal snow melt and glacier ice melt. The catchment was distributed according to Hydrological Response Units (HRUs) by considering topography, elevation, soil, and land cover. We used data from 21 precipitation and 4 climate stations as input to the model. The model was run on a daily basis from 1998 to 2009 in which the calibration was from 1999 to 2004 and validation was from 2005-2009. The model results were compared with observed streamflow of various percentile values representing different parts of the hydrograph.

The best results were achieved while supplying 15% additional precipitation to observed stations during the monsoon season, suggesting underestimation of precipitation in measuring station. For the calibration period, the Nash Sutcliffe efficiency and co-efficient of determination (r^2) was 0.94 and 0.96, whereas it was 0.95 and 0.95 for the validation period. Overall, the model is able capture the hydrological dynamics of floods, high flow, mid-range flow and low flow very well.We looked at r^2 between simulated and observed flows for different percentile values representing different flow ranges. The coefficient of determination for Q90 (floods), Q90-Q75 (high flow), and Q75-Q50 (mid-range flow) and Q50 (low flow) is, respectively, 0.56, 0.50, 0.83, 0.63, which indicates the model's good ability to capture different dynamics of the hydrograph. The model has higher confidence in low flow conditions than in high flows. The glacier runoff contribution is about 13% (including 8% glacier ice) and snowmelt outside of glacier area contribution is around 9% of the total runoff. The overland flow contributed about 52% of the total runoff suggesting dominating processes of saturated and infiltration access runoff in the hillslope. The interflow and dry season flows contributed about 14% and 34% suggesting the significance of baseflow contribution to the basin. The evapotranspiration loss from the basin is nearly two thirds of the precipitation input. The study shows a successful application of the J2000 model in the macro scale catchment in the Himalayan region and the spatial distribution of water balance information is useful for water resources planning and management such as irrigation and hydropower.

Keywords: Hydrograph, percentile flows, water balance, snow and glacier melt, evapotranspiration

Assessment of hydrologic components of a high altitude glacierized catchment in the Nepalese Himalaya

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An assessment of water resource availability in the Upper Himalaya, where any dense hydrological network is lacking, is very challenging using classical water balance methods. Characterizing climate forcing and understanding hydro-meteorological processes in the high altitude and the glacierized catchments are key issues to estimate the water resource components in those regions. This requires reliable climate and hydrological data and improving knowledge on the water cycle. Here, we focus on the partly glaciated Khumbu River catchment (146 km^2; 4220-8848 m a.s.l), an Upper Dudh Koshi sub-catchment in Nepal. A dataset combining meteorological, glaciological, and hydrological records was collected during 6 years (2011-2016).We further use a distributed physically-based glacio-hydrological model (DHSVM-GDM, Distributed Hydrology Soil Vegetation Model - Glacier Dynamics Model) that includes snow cover and glacier dynamics. To simulate snow and glacier processes, the model uses an energy balance model with one ice and two snow layers. The model is forced with in-situ meteorological data to run simulations for a period of three years.

The observed time series were used to characterize both meteorological (rainfall, snowfall, air temperature, evapotranspiration) and runoff variability, and to identify the main contributions of rainfall, snowmelt, and glacier melt to streamflow. The availability of air temperature and precipitation observations at different elevations allows us to assess both vertical temperature and precipitation gradients. The hydrological regime of mountain catchments such as the Khumbu River, located in Nepalese Himalaya, strongly depends on high altitude diurnal and seasonal meteorological cycles. The hydrological regime of this catchment is mainly driven by glacier melt and by rainfall during the monsoon season from June to September. The combination of both in-situ data and modelling simulations allows us to estimate the hydrological budget and to assess the water resources availability.

Keywords: Mountain hydrology, glacierized catchment, glacio-hydrological modeling, Khumbu



Third International Conference on "Mountain Hydrology and Meteorology for the Sustainable Development"

Cryospheric Changes and its Impacts on Water Resource (CHARIS)

Invited Talk

The CHARIS Project- A Collaborative Effort to Assess the Role of Glaciers and Seasonal Snow Cover in the Hydrology of the Mountains of High Asia

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Realistic, accurate estimates of future availability and vulnerability of water resources across the High Asia region are not possible without a better understanding of the current hydrologic regime. In collaboration with Asian partners, the CHARIS project (nsidc.org/charis) is designed to develop a thorough and systematic regional scale assessment of the individual contributions of seasonal snow melt and glacier ice melt to water resources of High Asia. Partnerships have been established with 11 institutions in 8 countries (Bhutan, Nepal, India, Pakistan, Afghanistan, Kyrgyzstan, Tajikistan, Kazakhstan). These partnerships provide a two-fold benefit to regional research capabilities through capacity building and data sharing. A total of 9 training workshops for partners have been conducted over the past 5 years covering the topics of digital elevation models (DEMs), geographic information systems (GIS), satellite data applications, mountain hydrology, water chemistry, snow cover and glacier mapping and melt modeling. All partner nations have consistently participated in the training workshops. In addition, 12 students from partner institutions have participated in the graduate research program in glaciology at Kathmandu University with support from the CHARIS project.

The specific science goal of this collaborative effort is to develop a model to quantify the individual contributions of seasonal snow melt and glacier ice melt to downstream water resources. The amount, timing and spatial patterns of snow and ice melt play key roles in providing water for downstream irrigation, hydropower generation and general consumption. Researchers at the University of Colorado have completed the digital mapping of the major river discharge basins of the study region (Brahmaputra, Ganges, Indus, Syr and Amu Darya) using DEMs, and have systematically mapped the seasonal snow cover and glacier cover within these basins using satellite data. Melt model results are evaluated using discharge data from specific calibration basins. CHARIS models separately estimate the daily melt from snow on land, snow on glaciers and exposed glacier ice over the past 15 years across the CHARIS region. Results are presented that clearly demonstrate both the large variation in the contributions from melting snow and glacier ice across the region from the monsoon rainfall dominated south-east to the north-west where more precipitation falls as snow than rain, as well as the variation with elevation within the drainage basins.

Keywords: Mountain hydrology, snow cover and glacier ice mapping, snow and glacier ice melt modeling

Enhancing spatial resolution with image reconstruction: A newly-reprocessed, global historical passive microwave record and preliminary applications to estimate melt onset

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Operating since 1978, satellite passive microwave sensors observe microwave radiation travelling upward from the Earth. Collected globally both day and night and able to see through most clouds, passive microwave measurements are used to derive significant and meaningful climate records of interest to mountain hydrology studies, including snow water equivalent and snow and ice melt onset. However, the 25 km spatial resolution of historical products has been relatively coarse, compared to visible sensors like Landsat, at ~30 m. Currently available gridded passive microwave data sets do not meet many requirements of modern climate data records, most notably in the areas of inter-sensor calibration and consistent processing methods. Original gridding techniques for these data were relatively primitive and were produced on 25 km grids using the original EASE-Grid definition that is not easily accommodated in modern software packages. We are funded by NASA MEaSUREs to reprocess the historical gridded data sets as Earth System Data Records, using the most mature available Level 2 satellite passive microwave (SMMR, SSM/I-SSMIS, AMSR-E) records from 1978 to the present, and using state-of-the-art numerical methods to increase image spatial resolution. The new processing methods and improved spatial resolution, enhanced to ~3 km for the highest-frequency channels, enable hydrologists to better analyze trends in mountainous regions that had not been possible with previous releases of the data. We will summarize the image reconstruction methods used to improve spatial resolution and include examples of melt onset detection compared to discharge timing, as well as melt onset variability in the high-relief Hunza basin (area ~13,000 sq. km, at 36N, 74E) of the Upper Indus, using the enhanced-resolution brightness temperatures.

Keywords: Satellite passive microwave, EASE-Grid 2.0, brightness temperatures, image reconstruction, melt onset detection

Water resources of Afghanistan and its climate change impact

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Securing access for all to a critical resource such as water is one of the key human development challenges facing Afghanistan, considering the critical bearing that water has on many afghan livelihoods. Such vital task will essentially include managing and increasing scarcity (mainly fueled by a growing demand); ensuring protection against vulnerabilities associated with climate shocks and uncertainties in water flows; and safeguarding water resources quality. While confronting such challenge, Afghanistan cannot afford to ignore the regional dimensions of its water resources. At national level, Afghanistan could be labeled as water rich country. Yet, the perception as country level can be misleading. Indeed, the very high spatial variability at River Basin and sub-basin levels gives a different perspective and indicates that water scarcity (as defined per the Falkenmark indicator) is already serious in the Northern Basin. Other River Basins are already suffering from localized scarcity such as the Kabul-Indus or are under pressure. Predictions show that some River Basins such as the Helmand and Harirod will pass below the scarcity threshold within few decades if not years, while the Northern Basin will face absolute scarcity in the very near future. Dealing with this issue will involve improved water productivity via better efficiency of water use for food production but also, where possible, improved supply via storages and dams. Watershed rehabilitation and protection should also come as a long term but vital strategy. Such approach would in fact also contribute to being prepared for climate change impacts, which are inevitably going to add to the existing problem of scarcity and climate shocks.

Groundwater, which has traditionally been developed and utilized for irrigation purposes through the use of different water points should also be seriously, considered as a priority for development and protection. There is clearly a need to develop accurate estimates in the country to allow sustainable development of this resource. This effort should be combined with a water resource management approach in order to prevent over allocation and serious depletion of this resource on which millions of Afghans rely for domestic purposes.Afghanistan also faces strong challenges in terms of climate shocks. If droughts occur in Afghanistan as in any arid and semi-arid countries, the country is particularly sensitive to such shock. A strong dependence on the agriculture sector, a low level of infrastructure development and storage limitations are some of the factors which de-multiply the impacts of such climate shocks. Floods are another climate shock regularly affecting Afghans' livelihood. While Afghanistan increasingly needs to take initiatives in order to tackle its forthcoming water scarcity challenge, and to mitigate the devastating effects of droughts and floods, it cannot ignore the regional dimensions of its internal water management. As the majority of Afghan Rivers are shared with several downstream riparian countries, major development projects in Afghanistan's river basins will have to take into considerations the potential consequences for its neighbors. Engaging dialogue through appropriate institutional platforms should be encouraged to avoid unnecessary tensions. At the same time, the International Community needs to acknowledge Afghanistan's weak bargaining position (partly due to a lack of reliable data, expertise and relatively low diplomatic strength), and should commit to develop its capacity until it can be considered as an equally empowered stakeholder.

Keywords: Potential water resources, distribution of water, mismanagement, water scarcity and climate change impact on water resources of Afghanistan

Relationship between pro-glacial stream discharge and meteorology in Chhota Shigri Glacier catchment, Indian Himalaya

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It has been widely recognized that western Himalayan region depends heavily on glacier and snow melt for its water needs. This is true especially for the Chenab sub-basin and more generally for other sub-catchments of the mighty Indus catering to the water demands of millions of stake holders who depend on this water resource. However, there are very few studies available to understand high altitude glaciated catchments, the climatic controls over their flow regimes, and their dependency on glacier mass balances, mainly because of poor access. Hence, the pro-glacial stream discharges from Chhota Shigri Glacier, a representative glacier of western Himalayan region has been analyzed for understanding the impact of rising air temperatures and highly variable summer precipitation events on discharges that are sourced majorly from snow melt and glacier wastage. This study, for the first time attempts to understand the factors influencing the inter-annual, sub-seasonal, and the diurnal variability observed in this representative catchment over four ablation seasons (2010-2013), by monitoring solar radiation, air temperature, summer precipitation, albedo and transient snow cover. The pro-glacial discharge is governed by air temperatures and albedo-enhancing summer precipitation events, which also enhances transient snow cover. While, the positive mass balance years gave rise to lesser pro-glacial discharges in comparison to negative mass balance years, lesser winter accumulation was compensated by the lower ablation resulting summer snowfall events in some years. While rising summer air temperatures give rise to glacier wastage, the role of melting transient snow cover on stream discharge is highly significant, especially for positive mass balance years. The pronounced inter-annual variations and the decreased pro-glacial discharge in comparison to 1980s suggest that Chhota Shigri Glacier is possibly wasting its way to reach equilibrium to the changed climatic conditions of the 21st century; however these findings need to be corroborated with runoff modeling.

Keywords: Chhota Shigri Glacier, glacial runoff, western Himalaya, hydrology, climate change, meteorological parameters

Glacier data: GLIMS, RGI and other databases

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As glaciers around the world shrink in response to climatic warming, there is need to understand the nature of these changes and how they affect water availability, sea level, and hazards. Monitoring glacier extent, the state of associated ice-contact lakes, glacier velocities, and potential hazards from changes is essential for understanding these systems and avoiding loss of property and human life. In this contribution we will give an updated survey of glacier databases available, their use cases, strengths and weaknesses, recent improvements, differences in data models and capabilities, database specific tools, and plans for future growth. The glacier database of the Global Land Ice Measurements from Space (GLIMS) initiative has been online since 2005. The Randolph Glacier Inventory (RGI) built on GLIMS to fill gaps in geographic coverage, and achieved this goal in 2012. The RGI data set has been combined with additional metadata and incorporated into GLIMS. GLIMS is now the only globally complete and multi-temporal glacier database capable of tracking glacier changes and providing them to the scientific community and broader public.

Keywords: Glaciers, database, monitoring, lakes, velocities

Assessment of Evolution of Mountain Lakes and Risks of Glacier Lake Outbursts in the Djungarskiy Alatau, Central Asia, using Landsat Imagery and Glacier Bed Topography (GlabTop2) Model

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Changes in the abundance and area of mountain lakes in the Djungarskiy Alatau, south-eastern Kazakhstan between 2002 and 2014 were investigated with regard to various types, size classes of lakes and characteristics of the catchments using Landsat imagery. Four types of lakes were distinguished: contact, lakes forming on the young (20-21 Century) moraines, lakes forming on the Little Ice Age or older moraines and dammed lakes. In 2002 and 2014, 599 lakes with a combined area of 16.26±0.85 km^2 and 636 lakes with a combined area of 17.35±0.92 km^2 respectively were identified. Overall the number of lakes and their combined area increased by 6.2% and 6.6% representing growth rates of 0.51% a^{-1} and 0.55% a^{-1}. Areas of 21% of the lakes increased; areas of 13% of the lakes declined; changes in 66% of the lakes were within the uncertainty of measurements. Contact lakes exhibited the largest growth. Fifty lakes were identified as potentially in danger of outburst. GlabTop2 model was applied to simulate ice thickness and subglacial topography using glacier outlines for 2000 and ASTER GDEM as input data achieving realistic patterns of ice thickness. 513 overdeepening in the modelled glacier beds with individual areas in excess of 10,000 km^2 were identified with a combined area of 14.75 km^2. Positions of modelled overdeepenings in the areas deglaciated between 2000 and 2014 were compared to the positions of newly formed contact lakes showing robust results which are useful for the assessment of evolution of future lakes and management of dangerous lakes.

Keywords: Mountain lakes, GLOF, climate change

Climate change induced hazards: An emerging challenge in the mountain ecosystem - a case study of Himachal Pradesh, NW Himalaya, India

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Susceptibility of the State of Himachal Pradesh to vagaries of climate change has been well documented. Scientific insight gained from the analysis of Satellite images suggests that spatial extent of majority of glaciers is changing very fast leading to the formation of moraine dammed glacier lakes. Formation of such lakes is posing potential threat to the infrastructure and human life thriving in the downstream areas. Various studies have been carried out on this vital issue of climate change and reveals that there is an alarming increase in such potential lakes. The satellite data analysis of 1993-94 revealed the presence of 38 lakes out of which 14 lakes were part of the Himachal Himalaya and the remaining were in Tibetan Region. In another study of 2001 in Chenab Basin reveals the presence of 50 moraine dammed lakes and five supra-glacier lakes. Highlighting the case studies of two most devastating disasters i.e. 2000 Satluj Cloud burst floods in which 135 casualties occurred and loss to the Govt. exchequer by Rs.1466.26 Crores and in 2005 Parechu lake breach causing total loss to the Govt. exchequer by Rs.610 Crores. The present study attempts to delineate and assess the threat and risk posed by the potentiality dangerous lakes basin wise that have been identified as possible GLOF threat in Himachal Pradesh. As part of the disaster risk reduction mandate from the state's perspective, such lakes are being monitored regularly to avoid any situation like that of the Kedarnath tragedy of Uttrakhand Himalaya during 2013.

LISS III satellite data observation for the year 2013 and 2015 in the Satluj basin reveals the presence of total 390 lakes in 2013 and 2015, however, there is a large increase in the total number of lakes i.e.from 38 (1993-94) to 390(2015). The Chenab basin which mainly originates from the Himachal Himalaya reveals the presence of total 116 lakes in the year 2013, has now been increased to 192 in 2015, which is almost four times than the number of lakes identified in earlier study carried out during the year 2001. Likewise in the Beas basin, in 2015 there is 89 lakes which were 67 in 2013. The Ravi basin wherein a total of 22 lakes mapped in 2013 has now increased to 34 in 2015. The lakes have further been categorised in all the basins depending upon their aerial size like <5 ha, 5-10 ha and > 10 ha in each basin.

The present study concludes with the fact that there is considerable increase in the number of lakes in Himachal Himalaya. The lakes with area >10 hectare and with 5-10 hectare can be seen as the potential vulnerable sites with the possibilities of converting into glacial lake outburst flood (GLOF) and causing damage to downstream. Thus from the disaster risk reduction perspective considering climate induced hazards threat in Himachal Pradesh, these water bodies require proper monitoring in future.

Keywords: Disasters, climate induced hazards, moraine dammed lakes, Glacier Lake Outburst Floods (GLOFs)

Question of permafrost zone thaw at high altitude above glacier's accumulation zone in Gilgit, Baltistan

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The high altitude mountains Hindu Kush, Karakoram and Himalaya are result of intensive tectonic activity in the Gilgit Baltistan region. Thousands glaciers concentrate at high altitude above mentioned mountains. Researchers usually link dynamics of glaciers with climate change scenario. And consider permafrost fluctuation as indicator of climate change scenario. Despite significance of the permafrost fluctuation in glacier sciences, its observations have yet to receive adequate attention in Gilgit Baltistan. The field survey of glaciers gave opportunity to observe melting of permafrost zone above accumulation zone of glaciers in Hindu Kush and Nanga Parbat- Haramosh Massif.An attempt has been made to elaborate mystery of unique behaviour of the permafrost zone above accumulation at gateway of westerlies in Gilgit Baltistan. The strengthen of westerlies are sources of Karakoram Anomaly in Gilgit Baltistan.

In author's opinion the above mentioned unique behaviour of permafrost zone is result of accumulation of the internal energy of the earth's crust at permafrost-basal interface. Whereas, seismogeodynamic processes are the source of the internal energy which accumulates in blocks (seismotectonic Volume) and transfers to surface through highly deform blocks of earth's crust. The Ice-Basal Interface and Permafrost- Basal interface function as trap of internal energy. The increase of volume internal energy change temperature at permafrost –basal interface which force thawing of permafrost at high altitude above accumulation zones of glaciers in Gilgit Baltistan. The interpretation Landsat imageries allows to determine from less to highly deform blocks of earth's crust in Pakistan including Gilgit Baltistan region. The correlation of counter values intensity of deformation of earth's crust (-1 to +4) with seismicity illustrates that zones with value of -1 to +1 are highly seismically active and strong earthquakes occurs in these zones. However the zones with value more than +1 are less seismically active because of unfavourable condition of accumulation of internal energy. The internal energy of such zones transfers to surface and traps at ice-basal interface and permafrost-basal interface that influence on the dynamics of permafrost and glaciers. Whereas internal energy emission through faults and during glacio-quakes play role as an important factor of the climate change scenario in Gilgit Baltistan.

Keywords: Internal energy, permafrost zone, seismo-geodynamic, Earth's crust deformation, permafrost-basal interface, glacio-quake

Glacio-hydrological processes in Shaune Garang basin, Western Himalaya

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Himalaya has highest number of glaciers outside polar realm. These glaciers along with seasonal snow cover and permafrost gives rise to the major river basins which are the primary source of fresh water supply in the densely populated downstream areas. These glaciers are susceptible to even minute changes in temperature and precipitation due to their latitudinal and altitudinal position. Due to extreme weather condition and harsh weather condition, the observations made in the region regarding changing climate as well as changes in glaciers are scarce and fragmented. In this condition, the temperature index based glacio-hydrological serves as an important tool to get information about several glacio-hydrological parameters. In the present study we observed discharge and daily, seasonal and annual mass loss in Shaune Garang basin located in Western Himalaya. These observations coupled with satellite observations for changes in area covered by different land covers and meteorological parameters were used to develop and validate a glacio-hydrological model capable of estimating basin scale discharge and mass balance. The value of degree day factor varied between 2.6±0.4 $mm°C^{-1}day^{-1}$ to 9.3±0.3 $mm°C^{-1}day^{-1}$ depending on the land cover and altitude. The model showed very good performance during validation period with value of coefficient of determination (R^2) 0.9 and root mean square error (RMSE) 1.05 m^3sec^{-1}. The validated model was used to estimate long term monthly discharge (1985-2008) and annual specific mass balance (2001-2008) in the basin. The simulated discharge in the basin shows a decreasing trend for the simulation period. The simulated mass balance shows loss of mass by the glaciers in the basin except for two years. These results are in accordance to the observations made on other glaciers in the region. In addition, the comparison of simulated annual specific mass balance and melt season discharge shows weak positive correlation suggesting association of more positive mass balance with high discharge and vice-versa.

Keywords: Glacio-hydrological model, degree day factor, discharge, mass balance, climate change

Hydrology and hydrochemistry of the Vakhsh River and its tributaries

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Present the results of studies of the hydrological characteristics of the main tributaries of the Vakhsh River—Surkhob and Obikhingoy and meteorological conditions of the river basins. It was found that for the period 1932-2012 the water discharge dynamics in the main tributaries of the Vakhsh River have an increasing character. For the monitoring of the meteorological parameters of the river basins, data of the meteorological stations Lyakhsh, Tavildara and Garm for the period 1960-2012 was used. The trend of changes in the precipitation in the basins of tributaries of the Vakhsh River has the decreasing character at an increasing trend of average temperatures. A study of spatial-temporal regularities of runoff formations and the features of the hydrological regime of rivers allows for identifying the main relations between the elements of the water balance, particularly of underground and surface waters and the formation of their natural resources under existing and future climate conditions. The aim of this work was to identify the main trends in annual and low-flow runoff of the Vakhsh and the nature of intra-annual distribution of runoff. The increase of the water volume of the Vakhsh River and its tributaries-Surkhob and Obikhingou rivers is in tune with the statements that currently there is a reduction of the glaciation areas of Tajikistan, probably due to an increase in the overall temperature of the background in the region and changing precipitation patterns. In the Surkhob River basin, there are intensively melting small glaciers of the Northern slopes in the Western part of a ridge of Peter the Great. On the southern slopes of the Alay Ridge, glaciation decreases slower as there are larger glaciers. In the Obikhingou River basin, the largest glacier Garmo is intensively melting. During the XX century, it became shorter by almost 7 km having lost more than 6.0 km^2 in area. It is currently retreating at an average speed of 9 m/year and the surface settles due to the melting of up to 4 m/year. Another glacier in the same basin Skogach retreats annually at 11 m. A characteristic feature of changes of the Vakhsh River runoff for the period 1932-2012 his cyclicity.

By use of differential integral curves of average annual discharge were defined periods of high and low water availability of the Vakhsh River. It should be noted that the appearance of cyclicality in the water flow of rivers allows for predicting future scenarios of changes in the water flow of the river by 2030. Monitoring of water quality of Transboundary Rivers, identifying the sources of anthropogenic pressures and the adoption of adequate measures for their elimination through the development of modern techniques is a valid tool to regulate the relationship between the components of geoecosystem. It is an important element of geoecological analysis of the problems of Central Asia as a key link in the development of bases of rational use and protection of water ecosystems. The individuality of each tributary from the point of view of chemical composition perform by sampling of tributaries water up to the confluence with the main stream of the river and up to the junction with another tributary. We carried out chemical analysis of rivers water and groundwater of the rivers basin. The results of analysis of chemical elements indicate that they do not exceed established for their maximum allowable concentration. Thus, based on the conducted research to determine trends in temperature and precipitation for the period 1960-2012 observed that the water objects in the Vakhsh river basin is vulnerable to climate change. The increased water volume of the rivers, based on the data of Agency of Hydrometeorology of the Republic of Tajikistan on the reduction

of the area of glaciation in the basins of the Vakhsh River, is due to the melting of small glaciers. Using the cyclical change in volume of water of the Vakhsh River predicted its value by 2030. The basins of the investigated rivers there are no stationary sources of pollution and the formation of chemical composition of water is mainly due to the leaching of mineral rocks.

Keywords: Transboundary, Central Asia, Vakhsh River, tributary, pollution, cyclicality, runoff

Micro-meteorological variability in different elevation zones of Chhota Shigri Glacier, India: An analysis of three in situ stations during the summer season, 2015

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Chhota Shigri Glacier in the western Himalayas is one of the best studied glaciers in the Himalayas, but understanding of the interaction between near surface atmosphere and glacier surface processes has been hampered by a lack of *in-situ* (on-glacier) meteorological data sets. Monitoring stations and meteorological studies in high mountain catchments (>4000 m a.s.l.) related to glacier catchment hydrology and glacier mass balance-processes are strongly limited. Glacier mass balance and glacio-hydrolgoical models which simulate glacier change and catchment response to climate variability lack to a large degree on data necessary to force and validate these models. This study presents meteorological records between 1st June, 2015 and 30th September, 2015 at three stations on and close to Chhota Shigri glacier, ranging in elevation from 3844 to 4863 m a.s.l. Diurnal and monthly patterns of air temperature, relative humidity, short-wave incoming radiation, air pressure, vapor pressure, surface height change (ablation/accumulation) are compared between these three stations (together with one rain gauge close to one of the stations). Results show that incoming short-wave radiation plays the dominant role for daytime temperature. The summer season is relatively humid in the region of Chhota Shigri. The moisture advection and high temperatures in the peak monsoonal period (July-August) is responsible for higher values of vapor pressure at different locations on the glacier. A sudden drop of relative humidity at the end of September indicates the decay of the summer in the region of Chhota Shigri. The observed diurnal cycles of the vertical temperature and vapour pressure gradients during the peak melting period highlight the importance of *in-situ* measurements for glacier mass-balance and glacio-hydrolgoical modeling.

Keywords: Micro-meteorology, glaciers, water resource management, summer-monsoon, western Himalaya, Chhota Shigri glacier

An Artificial Intelligence Approach for Flow Volume Modelling of Indus River at Tarbela Reservoir

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Hydrological modelling is a complex process and is influenced by various physical factors. Artificial Neural Networks (ANN) has the ability to relate inputs to outputs without considering the complex physics involved which makes it very suitable for streamflow forecasting and modelling. ANNs are considered as one of the robust techniques used for hydrological modelling as it is nonlinear and complex. A model was developed in this study using monthly Oceanic Nino Index (ONI) values and monthly flow volumes. The technique called Artificial Neural Networks (ANN) was used for the analysis to predict the monthly inflow volume at Tarbela Dam which is located on the Indus River. Indus River draws most of its flow from snow and glacier melt of the Upper Indus Basin. Inflow data of Tarbela Reservoir and ENSO variables from April 1961 to December 2015 in this study. Two-thirds of the data was used for training of the model and one-thirds was used for testing of the model. The R-Squared value of the model was 0.89 for training and 0.85 for testing. Various other parameters for model performance analysis such as Root Mean Square Error (RMSE), Mean Biased Error (MBE) and Nash-Sutcliffe Model Efficiency (NSME) were also checked. The results have shown that ANN could be a useful tool for flow prediction using ONI variables.

Keywords: Artificial neural networks, flow volume prediction, El Nino, La Nina, Tarbela

The monitoring of meteorological conditions of the formation area of the Transboundary Pyanj River

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The variety of the Central Asia climatic conditions, finding the change patterns in meteorological processes depending on the geographical and geoecological features of the region led to the need for the climatic zoning. The Mountain Pamir in the concept of climatic zoning is regarded as an area where there is a change of wet and cold Mediterranean precipitation to dry Central Asian. The main formation zone of the Pyanj River is located in the Pamir and the monitoring of meteorological conditions and dynamics of their changes in conditions of global warming is an urgent problem. In addition, the importance and the role of the Pyanj River water should be noted to the economy not only neighboring countries of Tajikistan and Afghanistan, but also for the countries of the downstream of the Transboundary Amu Darya rivers (Uzbekistan and Turkmenistan). For the hydrometeorological conditions monitoring of the respective zones the base stations are conditionally defined. For the Southern zone there is the meteorological station Parkhar located at an altitude of 448 m a. s. l. Climatic features of the Western, Central and Eastern Pamir are recorded at the stations Khorog (2075 m a.s.l., after name Gorbunov (Fedchenko glacier, 4169 m a. s. l.) and Murgab (3576 m a. s. l.).Present paper deals also the systematization of meteorological conditions the Southern, Western, Central and Eastern zones of the Pamirs and the dynamics change of temperature and precipitation for the period 1934-1994.

For this purpose the meteorological database stations of each zone were used, namely meteorological stations Parkhar, Khorog, Murgab and Gorbunov. Estimation of the temperature increase for the period 1934-1994 made to respect to the period 1960-1990 and by data from other meteorological stations. Data analysis shows that for the period 1934 -1994 the average temperature increased to 0.03°C for every 10 years. The trend change of precipitation determine by use of data from meteorological stations in four climatic zones of the Pyanj river basin. The trend of precipitation change shows the individuality of each Pamir climate zone cannot described by one equation. The comparison of precipitation data at four meteorological stations shows that their trend of change has no dependence on the altitude above sea level. The Murgab meteostation characterizes the climate of the Eastern Pamir. The average annual rainfall in the Eastern Pamir is small and ranges of 40-140 mm at the long-term average of about 76 mm. The deficit rainfall in the Eastern Pamir is characterized by a discharge of moist air with heavy rainfall on High Mountain (5000-6000 m a. s. l) in the Western Pamir, and the Western Pamirs air becomes dry.

Keywords: Pyanj River, Pamir, Transboundary, precipitation, trend

Glacial component in the rivers runoff of Balkhash–Alakol basin

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In our understanding glacial runoff is the runoff of melted water of snow, firn and ice as well as liquid precipitation flowing into the river network from the glacier surface. The glacial runoff from melting of the multiyear ice reserves was estimated as water equivalent of losses of the ice volume during the period between the previous and subsequent cataloging of the glaciers. The datasets of the unified glacier inventories of Ile Alatau and Kazakh Part of Zhetysu Alatau were used. Full glacier runoff was estimated based on the stable relation according to witch 30 % of the glacier runoff is the runoff from the melting of multiyear ice reserves and 70 % is the runoff from the all other components of the glaciers runoff. The part of the glacier runoff in the components of the 15 rivers of Ile and Zhetysu Alatau was determined by comparing of the volume of melting glacier water with volume of river flow measured in the 18 hydro-meteorological stations. The share of water from the melting of multi-year ice in the total annual runoff is comparable to the measurements inaccuracy of water discharge of the Mountain Rivers and could not have a significant impact to the hydrological mode and regional water resources. The value of that share is increasing in proportion to the coefficient of glaciations of basin K_{gl}. In Ile Alatau it was close to 20%, but only in the some basins at the outlet of the rivers from the mountains, accounting for the majority of the basins less than 10% of the total annual runoff.

The share of full glacial runoff in runoff of the Ile Alatau Rivers changed from 44% in 1955-1975 years to 13.9% in 1991-2008 years. In the average this proportion changed from 15 to 23% in basins with a minimum value of K_{gl} (Kishi Almaty, Turgen) and from 42 to 53% in basins with the highest values K_{gl} (Issyk, Talgar), with the average for all of the basins equal to 31%. The total glacial runoff in basins of Western Zhetysu Alatau was only around 10% from the total annual river runoff. In the much less snowy basins of the northern Zhetysu Alatau the share of the total glacial runoff was approaching 20% only in the period of the most intensive degradation of glaciers (1991- 2000 years). Much more significant role of melted glacier water in river runoff is observed during the vegetation period. In the annual of Ile Alatau rivers runoff the share of melted glacier waters changed from 60% at the beginning of the researched period to 40% on average for the 1955-2008 years, and in the rivers of the northern slope of Zhetysu Alatau from 40 to 20% on average for 1956-2011 time period.

After a short increase of the share of melted glacier water in river runoff, at the beginning of the period of intensive degradation of glaciers, it subsequently declined in the whole study area proportionally to the reduction of the area of glaciers.

Keywords: Glacier degradation, central Asia, runoff

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Water and Climate Change (KCRE, CAS-TU)

Estimation of discharge using temperature index melt model in Modi River Basin, Kaski, Nepal

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The hydrological dynamics of glacierized basins in Nepal are highly sensitive to climate change and likely to alter the water resource availability downstream. The relative contribution of various runoff components rain, snow and glacier melt to discharge is not well quantified for better understanding of implications of climate change on water resource. The main objective of this study was to estimate the present and future discharge with relative contribution of snow and ice melt to discharge of Modi River basin located in Kaski, Nepal using modified positive degree day model. The area of Modi River basin is 643.2 km^2 with 12.05 % glacier coverage. The model was calibrated for the period 1991-2000 and validated for the period 2001-2013. The model fairly simulated discharge during both calibration and validation years with Nash-Sutcliffe efficiency values of 0.75 and 0.76, and volume difference 1.23 % and -9.43 % respectively. The relative contribution of snow and ice melt during calibration and validation years were 5.29 % and 5.71 %, respectively. The daily bias corrected future temperature and precipitation data derived from Regional Climate Model-Weather Research and Forecasting from 2016-2050 under RCP4.5 and RCP8.5 emission scenarios were used for future discharge projection. During 2016-2050, the average discharge in basin is projected to be 54.86 m^3s^{-1} and 54.80 m^3s^{-1} for RCP4.5 and RCP8.5 scenarios, respectively which were not statistically significant. Under both emission scenarios, the discharge is projected to increase till 2020s and then gradually decrease with high and low fluctuations up to 2050. The relative contribution of snow and ice melt to future discharge was 5.92 % and 5.37 %, respectively for RCP4.5 and RCP8.5 scenarios. The decadal hydrographs under both scenarios showed slight earlier shifts in the monsoonal discharge peaks. The sensitivity analysis showed that the increase in 2 °C temperature and 20 % precipitation together caused highest change in discharge (increased by 20.56 %). The overall sensitivity analysis showed temperature to be the most influencing variable of the model and can be widely applied for data scare regions. Furthermore, the results provide vital information to planners and policy makers for effective water resource management and develop adaptive measures to combat climate change impacts on future water availability.

Keywords: Climate change, emission scenarios, snow and glacier melt, water availability

Impact of Climate Change on Snow melt in Marshyangdi River Basin of Nepal

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This study implemented the process-oriented distributed hydrological model J2000 to investigate the contribution of snow melt in Marshyangdi river basin station with area 4063 sq.km for 1987-2008 at Bimalnagar. In this studie the snow melt contribution is the main focused. The J2000 models able to distinguish different runoff components including snow and glacier melt contributions. The dynamically downscaled precipitation and temperature data were used for the future climate scenarios prediction for period of 2020-2050s, under the Representative Concentration Pathway's RCP4.5 and RCP8.5 scenarios. The downscaled RCPs data were used to run the distributed hydrological J2000 to study the climate change impacts on snowmelt of Marshyangdi River basin. The non-parametric Mann Kendall and Sen's slope estimator for the trend analysis of 1979-2012 showed warming of the basin. And precipitation trend at northern part of basin was decreasing whereas the southern part of basin showed increasing trend. The result of the model showed total 20% contribution of snow melt to stream flow which increased by 29% and 38% in RCP4.5 and RCP8.5 scenarios respectively which conclude the shifting of snowline to higher altitude in future due to the increase temperature. The study showed that 5.4% increase of precipitation increases 14% of discharge in RCP4.5 scenario and 3.9% increase of precipitation and 13% of discharge in RCP8.5 scenario. The analysis showed the discharge contribution of base flow and decreased, the overland flow by 30% and 23% in RCP4.5 and RCP8.5 respectively. Similarly actual evapo-transpiration of the basin will decrease by 21% and 19% in RCP4.5 and RCP8.5 respectively. With respect to the result of various runoff components, the overland flow (RD1) in future indicated the increased of flood event in future.

Keywords: Climate Change, J2000 hydrological model, Snow melt, Runoff component.

Evaluation of GPM satellite rainfall estimation over Nepal

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Uneven and poor rain gauge network across Himalayan mountain range of Nepal have greatly limited our understanding about spatio-temporal variations of precipitation and behaviour of hydrological system in the region. In this context, satellite estimated rainfall products are viable alternatives with a higher spatial and temporal coverage. In this study, half hourly final run of Integrated Multi-satellite Retrievals for the GPM (IMERG) is compared with daily gauge data obtained from Department of Hydrology and Meteorology (DHM) over Nepal and three physiographic regions for 2014 and 2015. In general, the results show that IMERG accords with spatial patterns of rainfall at daily, monthly and seasonal levels. However, there are region-specific biases. In daily scales, IMERG underestimates rainfall in all seasons except pre-monsoon. Verification of seasonal rainfall between the dataset reveals better performance of IMERG in the winter season (CC=0.55), but it had a high bias (RB=-13.8%). Overall, analysis show similar pattern of increasing correlation from pre-monsoon (MAM) to winter (DJF) (CC=0.31 to 0.70) but relative bias is found small in post-monsoon (0.7%) and high in pre-monsoon (-14.5%). Categorical verification against gauge-based observation shows that IMERG fairly able to detect precipitation during monsoon period with probability of detection (POD) 1 and threat score (TS) 0.98. In the mid mountain and low-altitude areas, IMERG performed far better (TS = 0.99 and 1) than that in high-mountain areas (TS 0.61). Hence, results from different statistical measure suggest that IMERG data needs to be improved specially for the high mountain region before any operational use.

Keywords: Gauge network, satellite estimated rainfall, APHRODITE, TRMM_2A25, IMERG, Himalayan Mountain

Distribution of vascular plants along subalpine-alpine gradient in Manang, Central Nepal and their fate against climate change

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A systematic investigation of vascular plant species distribution along a subalpine-alpine gradient of Manang, Central Nepal along an elevation gradient ranging from 3700 m to 4600 m asl was carried out. Study aimed at identifying the diversity and distribution of vascular plants, including different life forms and chorotypes along the gradient and predicting the climate change-led future distribution of vascular plants. Vascular plant species exhibited a hump-shaped pattern with elevation. Life form analysis revealed that majority of taxa were chamaephytes and hemicryptophytes indicating harsh climatic condition. Biogeographically, majority of taxa were Himalayan endemics followed by pan- Himalayan distribution. The proportion of Himalayan endemics increased with elevation, indicating the importance of endemics in shaping alpine vegetation. A total of 26.35% of total plant species (n=34) showed an increased upper elevation limit. About 9.03% species (n=12) of which showed narrow elevation amplitude (<1000 m asl) and these were projected to be the most sensitive to the rise of global temperature by 0.3- 4.8^{0}C at the end of 21st century under different emission scenarios by IPCC 2014. Out of these plant species with narrow elevation amplitude, 16.67% (n=2) were the most vulnerable (elevation amplitude <550 m asl) towards climate change under the RCP 6.0 and 66.67% (n=8) were the most vulnerable towards climate change under RCP 8.5 emission scenario. Majority of these taxa were chamaephytes and hemicryptophytes with biogeographical distribution restricted to the Himalaya. Such taxa with restricted geographical distribution and narrow elevation amplitude must adapt through range shift to compensate the future raise in temperature. This upslope migration will not only alter the alpine flora but also destruct the important harbors of traditional medicine, food, fodder, forage, fuel, etc. that sustain the lives of mountain dwellers since millennium. Thus, they seek greater scientific attention and proper understanding in order to counter climate change.

Keywords: Vascular, life forms, chorotypes, IPCC, range shift

Third International Conference on "Mountain Hydrology and Meteorology for the Sustainable Development"

Mountain Meteorology and Climate

Invited Talk

Air temperature estimation using MODIS LST for snowmelt modeling in the Tibetan Plateau

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Snow accumulation and melting are important hydrological processes in the Tibetan Plateau (TP). Accurate simulation of snow dynamics based on meteorological input of air temperature (T_{air}) etc is helpful for water resources management. Because of the sparseness of ground measurements, the remotely sensed land surface temperature (LST) data from Moderate Resolution Imaging Spectroradiometer (MODIS) have played a significant role in estimation of T_{air} in remote mountainous areas. MODIS LST over the Tibetan Plateau has a high cloud cover fraction of >45%. Therefore, this study firstly analyzed the effects of clouds on T_{air} estimation by LST which shows that the existence of clouds can affect both the accuracy of LST and the relationship between T_{air} and LST and thus impact the T_{air} estimation accuracies. Constraining all the four observations of MODIS per day to be non-cloudy is an efficient way to screen samples to build a good fit of T_{air} estimation using MODIS LST.

Secondly, an air temperature estimation method was proposed to develop a product of daily mean T_{air} in the TP that integrates MODIS LST and meteorological station observations, dramatically reduces the cloud blockage rate compared to that of MODIS LST data at four pass times, and keeps relatively high estimating accuracies compared to previous studies. Thirdly, snow accumulation and melting in the TP was simulated using a distributed degree-day model based on the T_{air} product through zonal calibration and validation of snow cover area (SCA). It was indicated that during 2005-2010, the interacting impacts of temperature and precipitation introduced increasing snowmelt in northern TP but decreasing snowmelt in southeast part.

Keywords: Snow dynamics, Land surface temperature (LST), MODIS, cloud cover, degree day model, Tibetan Plateau

Characterizing hydro-climatic systems at the local scale to reduce uncertainties: Application to the Dudh Koshi River basin, Nepal

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The central part of the Hindukush-Himalaya region in Eastern Nepal presents tremendous heterogeneity, in particular in terms of topography and climatology. At a large spatiotemporal scale, precipitation patterns over the Himalayan rangeare recognized to be strongly dependent on topography. However the spatial and temporal variability of the precipitation, largely due to orographic effects are roughly represented by the currently available products in this area. The objective of this study was to quantify the uncertainties stemming from the representation of the effect of altitude on precipitation extrapolated from ground-based measurements. A physical modeling approach, using the ISBA Soil-Vegetation-Atmosphere transfer scheme (Meteo France, CNRS) is applied to two small catchments selected in the Dudh Koshi River basin (Eastern Nepal), which represent high and middle mountain environments. During the last 3 years, 6 stations have been monitored for air temperature and precipitation measurement. Moreover, descriptions of the land cover, currently available at a large scale, were enhanced, based on field observations and local measurements of the soil properties. A weighted inverse distance method coupled with a multiplicative altitudinal factor was applied to spatially extrapolate measured precipitation. The altitudinal factor for the Dudh Koshi basin is shown to acceptably fit a piece-wise linear function of altitude, with significant seasonal variations.The result of the study shows that uncertainties associated with representation of the orographic effect account for up to 15 % for annual total precipitation, 29 %for annual simulated discharge and 15 % for annual simulated evapotranspiration. Although the quantification of uncertainties on simulated discharges strongly depends on model structure and parametrization, this method highlights quantitatively the significant role of uncertainties of spatialized precipitation grids on simulated discharges. Therefore, uncertainties, not only those associated with input data, but also those propagated to simulated variables, must be quantified in this sparsely instrumented region.

Keywords: Central Himalayas, precipitation, uncertainty analysis, hydrological modeling.

Synoptic study of tropical cyclone: A case study of Hudhud cyclone in Nepal

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The very severe cyclonic storm Hudhud caused extensive damage and loss of lives in Nepal and eastern India during October 6-7, 2014. A sudden plunge in the weather caused heavy snowfall in high-altitude districts of the central and western regions (Mustang, Manang, Rasuwa, Myagdi, Gorkha and most districts in Karnali Zone). Heavy rain and snowfall occurred mainly in the central regions of Nepal lead to the death of at least 43 people and rescued more than 500 people mostly foreign trekkers in and around mountain hills of Annapurna and Dhaulagiri Mountain. Manang, Mustang and Myagdi are the most affected districts in terms of human losses, wounded and rescued. On 6th October a low pressure area was formed over Bay of Bengal which intensified into the very severe cyclonic storm 'Hudhud' which reached its maximum intensity on 12th October 2014. Though Hudhud had already weakened into a low pressure area when it reached Nepal, its affect was tremendous. In and around the Annapurnan and Dhaulagiri Mountain, people trapped under the heavy rains accompanied by snowstorm from 13th Oct and thereafter. Many of the foreign trekkers were dead and severely injured by snow frosts and frost bites because of heavy avalanches and blizzard which swept across the mountain. This study revels three dimensional structure of the atmosphere in relation to the cyclonic system Hudhud with synoptic perspective. Weather chart/data and satellite imageries is envisaged in this study to diagnosis the event associated with cyclonic system. The study concludes that the copulation of westerly trough moving from the west in the upper troposphere with the low pressure area at the lower atmosphere is mainly responsible to divert its trajectory towards central Nepal. Abundant moisture supply and orographic lifting of the moist year due to presence of Himalayas in the north also facilitated to generate heavy snowfall over central Nepal.

Keywords: Annapurna, tropical cyclone, westerly trough, orographic lifting

Estimation of the error of track of the tropical cyclones of the Bay of Bengal using high resolution ARW model

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High resolution Advanced Research WRF (ARW) meso-scale model is used to study the track error of the tropical cyclones formed in the Bay of Bengal. WSM3 microphysics and Kain Fritisch's cumulus parameterization scheme has been used with Yonsei University planetary boundary layer. The model is run for 12, 24, 36, 48, 60, 72, 84 and 96 hours for 16 selected cyclones during 2008-2013 to obtain track position of the cyclone using 9 km horizontal grid size of the domain which cover the Bay of Bengal basin. The objective of the study is to calculate the error between model simulated track position and those obtained from Indian Meteorological Department (IMD). The cyclones are categories with respect to intensity (cyclonic storm, severe cyclonic storm and very severe cyclonic storm), movement (re-curving and straight moving) and seasons (pre-monsoon and post-monsoon) to calculate the track errors. Skill of gain and confidence interval of error of track positions are also calculated. The results indicate that the model-based errors of track position are less than that of the persistence-based errors.

Keyword: WRF model; tropical cyclone; track and landfall position error

Accuracy of Satellite-based Rainfall Estimates in Small Mountain Catchments: Case Study in Khudi Khola, Nepal

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The availability of satellite-based rainfall products provides an opportunity for estimating rainfall for water resources applications in areas in mountain regions that have a sparse network density. This paper presents an evaluation of the accuracy of satellite-based rainfall estimates in the Khudi basin (147 km^2), a tributary catchment of the Marshyangdi river in Nepal. Gauge-observed rainfall was compared with the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Centre's CPC_RFE2.0 estimates and Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) product TRMM 3B42 V 7, for the period 2002 to 2007. The daily CPC_RFE2.0 estimates showed a similar trend to daily gauge-observed rainfall but both products underestimated the precipitation amount. The correlation for CPC_RFE2.0 estimates was 0.49, the percentage error 44.7, daily bias -4.2 mm and POD 0.84. The correlation for TRMM estimates was 0.44, percentage error 32.0, daily bias -4.4 mm and POD 0.76. The annual error statistics for the same period using CPC_RFE2.0 for the whole of Nepal were better, with a correlation of 0.72, daily bias of -1.7 mm, multiplicative bias of 0.63 and POD of 0.80. The increase in bias and drop in correlation at catchment scale indicate a drop in performance for finer scale applications in mountain catchments.

Keywords: Accuracy evaluation, Nepal, satellite rainfall estimates, small mountain catchment

Runoff response to climate change

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The hydrological regime of the catchments in Nepal is highly influenced by the monsoon precipitation, complex topography and relief. While direct runoff response to monsoon rainfall is the major component of monsoon flow, dry season flows (winter and pre-monsoon months) are predominantly sustained baseflow and, for higher elevation catchments, snowmelt contribution is significant in pre-monsoon months. Hence, runoff response to changes in temperature and precipitation varies with the type of catchments, whether they are rain dominated, snow dominated or a mixture of both. Catchments with substantial snow contribution are the catchments with substantial areas above the approximate winter snow line elevation of 3000m and approximate permanent snowline elevation of 5000m.To better understand the runoff response to climate change (changes in P and T), a physically-based continuous-event hydrological model, SWAT (Soil Water Assessment Tool) has been used to simulate the rainfall runoff process in Jammu sub-basin of Bheri River in Karnali Basin.

Precipitation and temperature change can influence changes in hydrologic regime by affecting hydrological process through evapotranspiration, snow-rainfall ratio and melting time period and amount of snowmelt, and baseflow. Catchment elevation is a key variable in defining the runoff (hydrological) response to climate change. The case study of Jammu shows that for catchments with 100%, 83% and 51% catchment area above 3000 m and 40%, 10% and 5% above 5000m, the amount of snowfall is around 48%, 17% and 8% of annual precipitation in the current climate With rise in temperature, the average reduction in snow contribution per degree temperature change for the these catchment conditions are 8.6%, 9.3% and 9.7%, respectively and the average annual Evapo-transpiration(ET) increase is 10.0%, 4.2% and 2.1%, respectively. As for precipitation change, the snowfall and ET varies in the same direction. Historical data show coefficient of variation in monsoon flow is too high compared to dry season flow and the change in future precipitation would affect monsoon flows more than dry season flows. Referring to the ensemble of CMIP5 (*Coupled Model Intercomparison Project Phase 5*) models for 2050, the simulations show that the change in average annual flow could vary from -13% to 35% for RCP 4.5 (Representative Concentration Pathways) scenario and -21% to 36% for RCP 8.5 scenario. However, more than 80% of CMIP5 models agree on increment of average annual flow.

Keywords: Run-off, Climate change, CMIP5, RCP, SWAT

Field investigation on the role of slope on infiltration over pasture surface with temperature variation

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Knowledge of infiltration process and its controlling factors play significant role in investigation of runoff and subsurface flow during and after the rainfall event. Inclination of soil surface is the chief parameter which affects the infiltration rate and runoff volume. It is very rare to find horizontal surfaces as most of the soil layers and surfaces are inclined in nature, but infiltration modeling has been limited to horizontal plains and there are not enough studies to explain the effects of slope along with different land surfaces on the division of rainfall into surface flow and subsurface flow. Hillslope hydrology involves the interaction of inclined surface and precipitation and their effects on return flow, subsurface flow, runoff and ground water flow. It also involves the rising of ground water table which divides the hillslope into saturated and unsaturated area unlike plain surface. This study focuses on the infiltration technique for hillslope modeling based on different surface inclinations along with their validation with the experimental data. Single ring infiltrometer is used to estimate infiltration rate and observe the effect of slope under different temperature to estimate the effect of temperature variation and estimate evaporation in order to estimate net infiltered amount from the surface. The effect of pasture surface, its roughness and slope has been studied and model has been developed keeping them as main parameters. It involves the estimation of subsurface flow and relative comparison of infiltration rates on pasture area and plain surface area for different slopes.

Keywords: Hillslope, infiltration, double ring infiltrometer, temperature, pasture surface

Current climate trends and future climate of Nepal

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This paper explores current trends in precipitation and temperature and GCM models projections for changes in precipitation and temperature in future for Nepal. This paper presents these changes seasonally and annually by analyzing 23-GCM models projections for two Coupled Model Inter-comparison Project Phase 5 (CMIP5) Representative Concentration Pathways (RCPs) scenarios, namely RCP4.5 and RCP 8.5, for 2040-2059 compared to base period of 1960-1991. For the analysis, Nepal (with river basin areas in China and India) is divided into six regions based on elevation and precipitation pattern. These divisions also commensurate with the three major river basins in Nepal: Koshi River basin in Eastern Nepal, Gandaki River basin in Central Nepal and Karnali River Basin in Western Nepal. The analysis shows no distinct pattern of changes for observed precipitation while temperature shows increasing trend. Temperature is seen to increase at an annual rate of 0.01˚C to 0.04˚C though it varies across the country. All the GCM models agree that the future temperature will be warmer than the present. Magnitude of increases however varies spatially and temporally (seasonally); and they also vary among models. In general, they project temperature increase from 1.2˚C to 5.2˚C in the 2050s (2040 – 2059) from the historical period (1960-1991) in the monsoon and winter months. They project higher temperature increase in winter than in summer. Likewise, more than 17 out of 23 GCM models project wetter future with multi model mean increase in annual precipitation from 6 to 10% across Nepal. While about 80% of models projects an increase in monsoon precipitation, their magnitude varies from 6% decrease to 33% increase. Models are uncertain on winter precipitation, with half of the models projecting a decrease in winter precipitation. However, precipitation extremes (maximum 1-day precipitation and maximum 5-day precipitation) are projected to increase. Even though, precipitation extremes changes are from 8% decrease to 52% increase, majority of models agree on increase of extremes, on average, from 8 to 16% across Nepal.

Keywords: Current climate, climate change, temperature, precipitation, GCM models



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Hydro-geochemistry

Atmospheric Deposition of Nitrogen and Phosphorus in Ganges Basin (India): Integrating Atmosphere-Land-Water Components to Uncover Cross-Domain Carbon Linkages in Ganga River

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A connective organized framework to understand carbon budget is a big challenge the scientific communities are facing both on regional and on global scales. The atmosphere-land-water connectivity of dissolved organic carbon (DOC) is not fully accounted in the Ganges Basin despite recent researches highlighting its importance. We investigated the pattern of atmospheric deposition (AD) of reactive nitrogen (Nr; NO_3^- and NH_4^+) and soluble reactive phosphorus (SRP) and associated shift in runoff flushing of N, P and DOC in Ganga River for three consecutive years (November 2013 to October 2016) along a 518 km stretch of the river between Kanpur upstream (26°30′ N; 80°19′ E) and Varanasi downstream (25°19′ N; 83°01′ E). The AD-Nr and -SRP increased consistently over time and there was over 1.4 fold increase in AD- NO_3^- and over 1.6 fold increase in NH_4^+ and SRP over time. The results showed a marked spatial and temporal variability in AD inputs indicating the influence of anthropogenic drivers and regional climate variables. We found variable but strong linkage between AD inputs and hydrological controls of terrestrial carbon and nutrients into the river. The results showed significant positive relationships ($p<0.01$) between Nr and SRP added through atmospheric deposition and the concentrations of Nr, SRP and DOC in the runoff being flushed to the river. The coupled effect of increasing AD-input and runoff DOC favors DOC build-up in Ganga River in the study stretch. Our study suggests that the watershed managers should consider large scale inter-regional time series data on changing state of atmosphere-land-water transfer of carbon and nutrients and associated shift in carbon budget of major rivers for more accurately predicting regional climate change drivers and for designing strategies for integrated river basin management (IRBM).

Keywords: Atmospheric deposition, climate change drivers, dissolved organic carbon, Ganga River, nutrients, runoff

Third International Conference on "Mountain Hydrology and Meteorology for the Sustainable Development"

Mid-Latitude Session on *"Water-Food-Ecosystem Resilience in Mid-Latitude Zone"*

Invited Talk

Different ecosystem services on Land Degradation-Restoration-Sustainability in Mid-Latitude Ecotone

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In the Mid-Latitude zone, where can be broadly defined as part of the hemisphere between 30° - 60° latitude, approximately 50% of global population live and there appears land use problems. In relation to the climatic condition, there appears horizontal differences in land cover type. For instance, the area surrounded by sea is well vegetated, but inland area can be characterized as semi-arid or arid area which are facing problems such as drought and desertification. Therefore, appropriate land cover and land use management plans for solving the problems are required with growing understand of food-water-energy nexus in the Mid-Latitude. By adopting the standard from IMF or World Bank, developing and developed counties were classified. Based on the classification, this study suggested the land cover and use stages as degradation, restoration, and sustainability. As the degradation stage, the nations which had decreasing forest area with less environmental restoration capacity based on economic size were selected. As the restoration stage, the nation which had increasing forest area or restoration capacity were selected. In the case of the sustainability, the nation which had enough restoration capacity with increasing forest area or small ratio in forest area decreasing were selected. Because various land cover and use among the regions, form vegetated parts of East Asia and Mediterranean to deserted parts of Central Asia, the forest area was varied between countries. Thus, focal ecosystem services from vegetated area in Mid-Latitude are differentiated by each land stage. Based on these understanding, decision makers can suggest different environmental planning for enhancing ecosystem services step by step and solving local issues in terms of global carbon budget, water management and climate change.

Keywords: Mid-Latitude, ecosystem services, land cover, degradation, restoration

Building climate resilience of urban systems through Ecosystem Based Adaptation (EbA) in high altitude city of Thimphu Bhutan: An assessment of vulnerabilities/impacts and needs

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International Environment Development has classified Thimphu city as one of the 15 most vulnerable cities in the world. Like many major cities around the world, Thimphu, Bhutan's capital city is grappling with classic challenges of increasing population (urban population growth of 3.7%), lack of adequate infrastructure, unemployment and sprawling urban slums. These factors alone or combined has put excessive pressures on natural resources in and around the city thereby exposing the vulnerable groups to the impacts of climate change. However, for a variety of factors, there has been no modeling of future climatic conditions for Bhutan let alone Thimphu city. Through this study we attempt to assess vulnerability, impacts, and needs to identify ecosystem based adaptation approaches for improving urban ecosystem and social resilience. Climate induced natural disasters such as forest fires, landslides, flash floods, flooding of storm drains, and drying of water sources are becoming a familiar event in the city. For instance, the city experienced its heaviest rainfall in 2002 with Thimphu River rising 3 meters. Modeling exercise has identified areas along Norzin lam, Phenday lam, Doebum lam, Chang lam, lungtenzampa, Referral hospital, and vegetable market as most flood risk hotsots. Flooding has and is continuing to clog the existing storm and sewer drains thereby exposing residents to health risks. Storm drain areas prone to flooding has also been identified and mapped. Heavy rainfall coupled with steep slopes with scanty vegetation leads to frequent landslides in the city. The slides sometimes clog streams and gorges creating artificial dams which causes flooding during heavy rains. The urban poor who are particularly reliant on ecosystem services bear the brunt of these impacts. This is because these communities often lack access to basic services, such as clean water, sanitation, and electricity. For instance, drinking water is scarce even in the core of the city not to mention of those who live at the periphery. Water is highly rationed amongst the houses in Thimphu and as such most housing units have to use a water pump to get water into the tanks atop their buildings. Those who live in the marginal areas including slums have to fetch water from far off places and often stand in long queue. Inadequate infrastructure, limited resources and poverty further compound this problem.

Keywords: Thimphu, resilience, adaptation, ecosystem, urban, climate, poverty

Forest and Watershed Management Projects with Enhanced Food Security under the Forest and Landscape Restoration Mechanism in the Mid-Latitude Region

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Climate change directly affects forests by changing patterns of precipitation and temperature. Forest degradation reduces water availability and then influences food security. Forest and Landscape Restoration (FLR) is a driving approach that has the potential to deal with climate change by increasing productivity of landscapes, enhancing the resilience of forest ecosystems and landscapes, and reducing the vulnerability of forest-dependent communities. Developing countries in the mid-latitude region have been susceptible to continuous degradation due to human activities and climate change. People will continuously suffer from ongoing land degradation and deforestation with climate change in the region. These problems should be solved with interdisciplinary approaches in terms of climate and environmental changes. The current study focuses on Mongolia and Uzbekistan and suggests projects to improve forests, watershed management and food security in the context of climate change and FLR mechanism. Due to the severe water-shortage, numerous projects in Mongolia deal with afforestation to avoid further desertification. Awareness of watershed management is not common nor well organized at the country level. Further neglecting the issue of watershed management will accelerate the degradation of boreal forest communities in the northern part of Mongolia. If the forest continues to degrade, more permafrost will disappear eventually leading to wildfires in vulnerable regions. Therefore, government should focus on preserving the permafrost forest layer. Uzbekistan has concentrated its projects in the mountainous region, which is relatively more productive than the flat deserts. Planting pistachios elicited remarkable results for the economy, enhancing the life quality of local people compared with other economic activities. However, to improve the project several policy amendments are necessary. The challenges of both tenure and permission for cultivation discourage people from continuing the project. There needs to be a stable enabling environment as well as research on diversifying cash crops other than pistachios. The outcome of the project is expected to be enhanced forest management and food security by enlarging the cover of pistachio in the mountainous region.

Keywords: Food security, forest and landscape restoration mechanism, mid-latitude, Mongolia, Uzbekistan, watershed management

Determining environmental flows of the Gandaki River basin, Nepal: Hydrological aspect

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The E-flow analysis in Kaligandaki River including Gandak basin is performed taking some of its tributaries into account using a Habitat Simulation Model called Computer Aided Simulation Model for Instream Flow and Riparia (CASiMiR) Model based upon the provided data particularly in post-monsoon and pre-monsoon seasons. The sites with different geographical, geological, religious, environmental & demographical importance like Lete (Kalopani), Seti Beni, Ridi (Ruru Khola), Amaltarighat and Binaya Khola have been taken into account for the study. The main objective of the overall study is to evaluate the required flow to ensure the presence of the fish habitat in the river system. The hydrological aspect of the study deals with simulation of daily discharge of Kaligandaki River using a glacio-hydrological model, estimates the snow and ice melt contribution in the river discharge and predicts the future daily discharge (2020 – 2099) of the Kaligandaki River. The glacierized Kaligandaki River, sub river basin of Gandaki River basin is located in the Mustang district of western Nepal. The total area of Kaligandaki River sub basin is 4069.57 km^2 with the elevation ranging from 1300 m a.sl. at Tatopani to 7100 m a.s.l. based on the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) 2011. Out of the total area, 10 % (423.79 km^2) of the basin is covered by glaciers (debris covered and clean ice) and the remaining 90 % (3753.9 km^2) by rock and vegetation based on ICIMOD Glacier Inventory (2010). Landsat Thematic Mapper 5 (TM5) images from 23 January 2009 are used to delineate debris covered and clean glaciers from the total glacier area.

A glacio-hydrological model called Modified Positive Degree-Day Model (MPDDM) is used to simulate discharge at Tatopani hydrological station. The model is calibrated with the observed meteorological and hydrological discharge data from June to December in 2006 and 2007 and validated for the same period in 2008 to 2010. The simulated mean daily discharge is 87.93 m^3/s in calibration period and 88.13 m^3/s in validation period. The simulated daily discharge with Nash-Sutcliffe Efficiency is 0.6 in both calibration and validation period where as volume difference of 11.97 % and 17.58 %, respectively. The snow and ice melt contribution in discharge was 23.67 % and 20.62 % in calibration and validation years, respectively and remaining contributes by the rain and base flow. Future hydrological regime has been investigated by using two climatic scenarios, RCP 4.5 and RCP 8.5. The projected average discharge in both RCP projections are in increasing trend at all E-flow study sites in the Kaligandaki River basin. Overall analysis with the MPDDM concludes that model simulates the good hydrological regime and also estimates the contribution of snow and ice to total discharge of basin. These results are used to evaluate the required flow in the river for fish habitat.

Keywords: E-flow, Kaligandaki River, glacio-hydrological model, discharge

Expert group meeting on achieving the sustainable development goals with water-food-ecosystem resilience in the Mid-Latitude Region (MLR)

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UN Member States adopted the 2030 Agenda for Sustainable Development at the United Nations Sustainable Development Summit on 2015. The 17 Sustainable Development Goals (SDGs) and 169 targets were proposed and it was highlighted to promote efficiencies and synergies in achieving overall SDGs. Since water and food (agriculture) sectors are inextricably linked, the nexus of water and food has been globally recognized and the water-food nexus has been further expanded by incorporating other sectors such as ecosystem. While sustainable management of terrestrial ecosystems is essential to ensure water and food security, sustainable management of water resources and food production is significant to protect terrestrial ecosystems. The health of water-food-ecosystem is important to achieve the SDGs, which requires the integrated approach to promote synergies and to address common challenges such as growing climate-related stresses. The Mid-Latitude Region (MLR), where the water-food-ecosystem problems occurs, is required in-depth researches. Despite the socio-economic and cultural diversity, this region shares similar climate characteristics. Due to the continuous population growth and mobility, rapid urbanization, economic development and climate change, countries in the MLR are facing increased stresses for water and food as well as land degradation and desertification. These common challenges can be effectively addressed in water-food-ecosystem resilience. By bringing together experts from the regions with diverse knowledge and experience on water-food-ecosystem resilience, key discussion points were produced and disseminated for a wider knowledge basis on water-food-ecosystem resilience in the MLR. Ecosystem resilience in this region is a critical pre-requisite for sustaining water, food, energy and human wellbeing. Resource allocation must be prioritized for quick understanding of emerging environmental and social developmental issues in the MLR to guide adaptation and mitigation strategies. A cross-boundary approach in which to compare between west and east is important for addressing emerging challenges. The approach can be implemented through opportunities for joint achievement of SDGs – one SDG might offer an entry point. Water-Food-Ecosystem/Energy Resilience/Nexus can be an appropriate method for dealing with MLR problems and finding solutions which can be translated into policies.

Keywords: Sustainable development goals, reforestation, mid-latitude region, water-food-energy nexus, ecosystem, resilience

Impact of reforestation on soil erosion in mountain regions – case study from Republic of Korea

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When heavy rainfall happens, surface runoff occurs in watershed and it causes soil erosion. Because of soil erosion, carbon and nutrients in soil are lost and it have a bad effect to vegetation and ecosystem. Also, soil erosion can become landslide disaster if soil erosion in mountain becomes severe. Therefore, reducing soil erosion is important task for ecosystem and disaster prevention etc. The amount of soil erosion is decided by precipitation, soil property, land cover and slope. In case of land cover, the amount of soil erosion is reduced in forest area because of interaction and mechanism between vegetation and soil. Forest land cover is inhibitor for reducing soil erosion. Today 70% land area in Korea are mountains and the most of mountain's land cover is forest cover, because of national reforestation project since 1973. Last 40 years, Republic of Korea have successfully performed the reforestation project not only in Mid-Latitude but also in the world. Therefore, Republic of Korea is a good study area to test the change of soil erosion due to reforestation. It is hoped that this case study will be the cornerstone of next study on soil erosion and reforestation applied to other area in Mid-Latitude. To simulate soil erosion, MUSLE (Modified Universal Soil Loss Equation) is used in this study. MUSLE is modified version of USLE (Universal Soil Loss Equation), and both equation are the mostly used equations in the world for estimating soil erosion. Each Factor of MUSLE are prepared by performing GIS analysis and SWAT (Soil and Water Assessment Tool) model which is the semi-distributed hydrologic model.

Keywords: Soil erosion, reforestation, SWAT, MUSLE

Evaluation of Spatial Distribution of Water Yield Service based on Precipitation and Population in South Korea

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After Millennium Ecosystem Assessment (MA) and The Economics of Ecosystems and Biodiversity (TEEB), ecosystem services assessments have been actively researched and developed from regional and national bases. However, the assessments of ecosystem services in current studies, which simply multiply monetary value to estimated amount of ecosystem function, do not necessarily reflect the views of environmental factors and socioeconomic status for ecosystem service. Therefore, this study expands the previous Natural Function (NF), Environmental Service (ES), and Environmental Social Service (ESS) methodologies developed in Korea and tried to understand services corresponding water yield changes. The study assessed water yield function through the water yield model in InVEST Tool, and it evaluates the overall ecosystem service of water yield reflecting the amount of precipitation and population of the area. The result shows that a difference between spatial distributions of the ecosystem function of water yield that is derived from natural condition such as land cover and soil, and spatial distribution of the ecosystem service that takes account of climate and socioeconomic factors. The value of ecosystem service becomes larger for a higher-populated and lower-precipitated area in the condition of similar amount of water yield. Ecosystem service of water yield should be evaluated by climate and socioeconomic factors besides water yield function. This evaluation process is expected to be valuable for the evaluation of ecological service that is applicable in other sectors. When considering human needs and surrounding environmental conditions, the results suggest that decision makers should utilize the ES and ESS concepts, which reflect both population and pollutant density along with additional human-related factors.

Keywords: Water yield function, precipitation, population, ecosystem service

Comparison of hydrological regime in Marshyangdi River basin, Nepal and Chandra River basin, India using modified positive degree day model

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Many river basins in the Himalayan region cover by a large glaciated area. The glaciated area in Himalaya can be divided into two types; one is clean type glacier and the other one is debris covered glacier. Glacio-hydrological models are indispensable tool to study the catchment characteristics and its response to climate change. With the help of available glacio-hydrological model one can describe the hydrological processes of a river. Some of them require a large amount of field data as model input for simulations. For regions where there is a scarcity of field data we have to adopt a method which can be executed with least available data. The Modified Positive Degree Day Model (MPDDM) serves good for the glacierised basins and has already been applied in many basins of the central Himalaya. This study includes the comparison of hydrological regime in two basins i.e. Marshyangdi River basin in Nepal with an area of 3006.66 km^2, dominated by monsoonal precipitation through Indian summer monsoon and Chandra River basin in India with an area of 2466.63 km^2, dominated by westerlies precipitation through western disturbance. The prospect of the study is to accurately estimate the ice melt, snow melt and base flow contribution to river discharge by using the MPDDM. Daily air temperature, precipitation, discharge and base flow are input variables in the model while degree day factor, air temperature lapse rate, snow coefficient and rain coefficient, precipitation gradient are input parameters in the model. In both basins land cover is classified into bare ice, debris covered ice and rock/vegetation. Meteorological station data were used for input variable whereas the parameter values were entered through literature available on hydrological studies in the Himalaya. The model is calibrated and validated with the observed daily discharge data. The model is also used for future predictions of discharge in both river basins using different representative concentration pathways (RCPs).

Keywords: Himalaya, glacio-hydrological model, positive degree-day factor, discharge, RCP

Piloting the FBDC Model to estimate Forest Carbon Dynamics in Bhutan

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Bhutanese forest covers more than 70.5% of the total land surface and is net carbon (C) sinks (NSSC 2011). Government pledge to remain C neutral is one of the significant declarations for rest of the world to mitigate global climate change. For this reason, estimating forest C dynamics in Bhutan is essential for understanding the forest C sink. The study was designed to estimate C dynamics of Bhutanese forest using the simulation parameters of Forest Biomass and Dead Organic matter Carbon (FBDC) model of Korean forest carbon model. Accordingly, we tried to simulate Bhutanese forest C dynamics at 6 circular plots with FBDC model from Bumthang and Paro region where *Tsuga dumosa and Juniperus Spp.* was selected since they are major dominating species of the region. Tree data (species, diameter at breast height (DBH), tree height, and tree ring) were collected from 6 plots with 12.62 m radius (0.05 ha.). The mean air temperature, and annual precipitation data with recent figures were also used for the further simulation of the data. The FBDC model can simulate forest C cycle with small amount of input data. Parameterization of the FBDC model is essential to simulate forest C dynamics in Bhutan. Due to lack of allometry data in Bhutan, most of the parameterization data (of growth functions and model parameters) in the original FBDC model were used. The growth functions and parameters for Pinus densiflora and Chamaecyparis obtusa in Korea were used as those for Tsuga dumosa and Juniperus spp. in Bhutan, respectively, because they are included in the same genus and family. The growth functions of Juniperus spp. were newly developed because the FBDC model does not include those functions of Chamaecyparis obtuse. Bhutanese forests have been appropriately preserved and can sequester the atmospheric C. The study includes C stocks from biomass and dead organic matter estimated with reference to Carbon Dynamics of South Korean Forest from 1954 to 2012 and other related studies for further validation of study. We provided the C stocks and their changes in biomass, litter, dead wood and mineral soil through the parameterization of the parameters from the FBDC model. The forest C dynamics highly varied by the forest age and C pools. The simulation results showed, the total forest C stock ranged from 118.35 to 200.04 Mg C ha^{-1} with an average of 168.41 Mg C ha^{-1}. The C stocks in biomass, forest floor, dead wood, and mineral soil ranged from 3.40–88.13, 4.24–24.95, 1.99–20.31, 91.45–97.90 Mg C ha^{-1}, respectively. On average, the biomass, forest floor, dead wood, and mineral soil accounted for 36.0, 5.5, 2.5, and 56.0% of the total C stocks, respectively. Although our modeling approach was applied at a small pilot scale, it exhibited a potential to report Bhutanese forest C inventory with reliable methodology. The implication of the FBDC model was significant for estimating the forest C dynamics of Bhutan. We piloted the FBDC model with the limited data of Bhutanese forest. The simulation results showed empirical knowledge on forest C dynamics in Bhutan. It showed a possibility of annual Bhutanese Forest C inventory can be reported with modeling (Tier 3), which is one the most reliable reporting system in IPCC Good Practice Guidance.

Keywords: Bhutanese forest, forest carbon dynamics, carbon stock, atmospheric carbon, biomass

Geomorphological mapping of the lower part of Ponkar Glacier and sediment load study of the Dudh Khola, Manang, Nepal

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Geomorphological mapping of the lower part of Ponkar Glacier with respect of suspended sediment concentration of Dudh Khola is done to map different surface morphological features and structures developed in the glacier and its contribution to suspended sediment concentration of Dudh Khola, the outlet of Ponkar Glacier. Ponkar Glacier (84˚28'14" E, 28˚37'49"N) is a debris covered glacier located in Marsyangdi sub-basin of Gandaki River basin in Manang district, Nepal. It has an area of 28.509 km^2 with mean elevation of 5679 m a.s.l. Mapping is done in field in June 2016 using 1:50,000 scale topographic base map produced by the Department of Survey, Gov. of Nepal. Glacier moraine ridge, glacier boundary, ice cliffs, crevasses, Ponkar Lake, water bodies, vegetation, and supra-glacial ponds are mapped. Along with these major features landslides, debris deposits, alluvial deposits, lake deposits, outwash deposits, light band and drainage patterns are also mapped. Depositional landforms such as lateral moraines, outwash deposit, glacial lake deposit are also observed. Erosional landforms such as U-shaped valley, hanging valley, cirque are also marked on the map. There are two small moraine dammed lakes; Nyamlo Lake and Ponkar Lake. The length of Ponkar Lake is 1350 m and breadth 290 m. Comparison with topographic base map shows no significant change in water level of Ponkar Lake. Ice fall feature is developed at 2.6 km upstream from terminus of the Ponkar Glacier. Geologically, Bhimthang Valley comprises two major successions namely Higher Himalayan rocks and Tibetan Tethys rocks. Higher Himalayan Granite covers most part of the study area as bedrocks of surrounding hills whereas the north east peaks shows bands of sedimentary succession of Tibetan Tethys rocks. A mixture of these rocks is found as the debris constituent. More than 90 % of the debris consisting of granite with light minerals is mapped as light band whereas debris with dominant light to dark grey colored sedimentary rocks namely black shale, sandstone and gritty dolomite is mapped as dark band.Suspended sediment concentration of Dudh Khola is monitored between monsoon (July-Sept. 2016) and post monsoon seasons (Oct.-Nov. 2016) on daily basis using depth integration technique. Maximum concentration is found on 7 July 2016 (4859 mg/L) and minimum on 2 October 2016 (43 mg/L). About 70% of total high sediment concentration lies within monsoon season. Post monsoon season shows decreasing trend with decreasing discharge.

Keywords: Ponkar Glacier, geomorphological map, Ponkar Lake, debris constituent, suspended sediment concentration



Third International Conference on "Mountain Hydrology and Meteorology for the Sustainable Development"

Climate Variability and Changes

An Analysis of Climate Variability and Change in Liangshan Mountain Region, Southwest China

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Climate change and global warming has become a debatable issue worldwide during the past decades and it has been observed at local, regional and global scales. Evidences from the scientific studies show that increasing concentration of greenhouse gases will increase the global climate and will warm the planet earth. Global average temperature increased 0.75°C higher from the level of 1880. In China, annual average temperature has increased by about 0.5-0.8°C over 100 years. If this figure is true then climate change may be a potential threat to China and the rest of world in future. This study examines climate variability and change in the Liangshan Mountain region, southwest China. Climate data (1951-2013) were gathered from NOAA's National Centers for Environmental Information and analyzed using statistical methods. We averaged monthly, annually and decadal climate data and observed a decrease in annual average rainfall (0.5mm) and an increase in annual average temperature (0.8°C) during the past 63 years. Similarly, a substantial increase in mean maximum and minimum temperature and a decrease in mean maximum and minimum rainfall were observed during the period. We also interviewed 110 heads of households from seven villages to know whether they observed climate change. A number of heads (70%) responded that there has been high climate variability and change observed during the past and as a result, production of traditional crops such as paddy, maize and tobacco has declined.

Keywords: Climate variability, climate change, Liangshan Mountain

Recent temperature trends analysis of Nepal

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The analysis of observed monthly maximum and minimum temperature data from 1984 to 2013 (recent 30 years) of 67 different stations in Nepal utilizing the Mann-Kendall tests for statistical significance, it showed that the maximum temperatures of 42 stations are found significant (= 0.001 to 0.1) among the 67 station's data. Similarly, the minimum temperatures of 36 stations are found significance. These temperature trends analyses are done by the simple slope function method without interpolating missing data for the entire period of study. The annual mean maximum temperature warming trend of 0.047 ^{0}C/ year in the Terai, 0.077 in Siwalik, 0.208^0 C/year in Middle Mountain, 0.078 in Himalaya and 0.217 ^{0}C/year in High Himalaya region are found whereas the annual mean minimum temperature warming trend of 0.052 ^{0}C/year in Terai, 0.021^{0}C/year in Siwalik region, 0.104 ^{0}C/year in Middle Mountain, 0.033 ^{0}C/year in Himalaya and 0.372 ^{0}C/year in High Himalaya region are found. Under the five physiographic regions the annual, decadal and seasonal temperature trends with their spatial distribution are analyzed. The annual mean maximum temperatures of all regions are found to be increasing trends. Similarly, the annual mean minimum temperature trend in Siwalik region and Middle Mountain region is found to be increasing in (2004 to 2013) among five regions in the recent decade, whereas the winter annual mean minimum temperature trend are decreasing in all physiographic regions of Nepal.

Keywords: Trend, warming, physiographic regions

Assessment of precipitation trend over Nepal using gauge-based high-resolution gridded rainfall data

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A study of long term precipitation trend and its seasonal variability over Nepal at different physiographic regions has been carried out in this paper. Long term precipitation time series from 1951 to 2014 for gauge-based high resolution ($0.5^o \times 0.5^o$) gridded daily dataset of Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) was used for the study..Time series of precipitation of Nepal as a whole and four homogeneous regions, viz, High Himalayas (HH), High Mountains (HM), Middle Mountains (MM) and Tarai and Siwaliks (TaS) are considered to understand the nature, trends and change points in the dataset using sequential version of Mann-Kendall test statistic and Sen's Slope model are used to quantify the magnitude of change. This method is employed for monthly precipitation over the 64 years period of records for detection of abrupt change in the average precipitation for each of the months. The results indicate that the sequential version of Mann-Kendall test statistic values for months of February, April and May is significant at 99% confidence level ($p < 0.01$) with strong increasing trend for whole Nepal as well as all physiographic regions barring High Himalayas. On the seasonal basis, whole Nepal as well as all physiographical regions show a strong increasing trend in Pre-Monsoon rainfall significant at 99% confidence level ($p < 0.01$), except for HH where a decreasing trend in Monsoon is observed at 95% confidence level ($p < 0.05$).

Keywords: APHRODITE, Sequential Mann-Kendall test, gridded-data, trend, physiographic region

Variability and trends in daily precipitation extremes on the northern and southern slopes of the central Himalaya

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This study focuses on the precipitation extremes recorded on the northern and southern slopes of the central Himalaya, especially those documented at higher altitudes. Our study concentrated upon the central Himalaya, i.e., those mountains found in Nepal and adjacent areas of Tibet, China. Nine meteorological stations with relatively lengthy chronological records, i.e., six on the southern slopes of the central Himalaya (Nepal) and three on the northern slopes (Tibet), were used for data compilation. All stations are situated at altitudes higher than 2000 m above sea level. Daily precipitation data recorded over a 35-year period at nine meteorological stations in the region were studied. We used the precipitation extreme indices delineated by the Expert Team on Climate Change Detection and Indices (ETCCDI). The spatial and temporal variations in these precipitation extremes were calculated. When regional patterns were investigated to detect any anomalies, only 1 of the 10 precipitation extreme indices from the southern slopes of the central Himalaya showed a statistically significant trend; none from the northern slopes of the central Himalaya highlighted a statistically significant trend. On the southern slopes, all indices increased, apart from the maximum 1-day precipitation (RX1) and simple daily precipitation intensity (SDII) indices. Indices such as the consecutive dry days (CDDs) and RX1 exhibited similar increases on both the northern and southern slopes of the central Himalaya. These results suggest that increases in precipitation have been accompanied by an increasing frequency of extremes over the southern central Himalaya. Nonetheless, no relation could be established between the precipitation extreme indices and circulation indices for higher altitudes.

Keywords: Precipitation extreme, Trend, Himalaya

Understanding climatic variability and its impact on hydrology of Karnali river basin, Nepal Himalaya using J2000 hydrological model

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This research helps in understanding the fundamentals of hydrological dynamics for better management of river basin systems in the topographically challenging, comparatively remote and least explored Karnali River Basin of western Nepal Himalaya. This basin has area of 45,269 sq. km. with around 12% rocky bare land. Precipitation and temperature observations of past 32 years showed that the average annual precipitation is 1456 mm/year and is increasing in the mountains but decreasing in most of the other regions. In the basin, maximum temperature is increasing at faster rate than the minimum temperature with significantly higher in high elevation and pre-monsoon. A fully encapsulated, process-oriented, distributed J2000 hydrological model developed inside JAMS framework is used for further understanding of the basin. The calibrated and validated model results suggest that the J2000 model is able to represent the hydrographs fairly well with an efficiency result of Nash–Sutcliffe (0.90), logarithm Nash–Sutcliffe (0.91) and coefficient of determination (0.90) for the study period. 77% of rainfall occurs in monsoon and more than 10% of the annual precipitation is snowfall in the basin. The evapotranspiration is about 33% of the precipitation and discharge is about 66%. In total discharge, the glacier melt (from glacier areas) contributes 12.6% of the total discharge whereas snowmelt (from outside of glacier areas) contributes 13%. The different runoff components are overland flow (35%), subsurface flow (49%) and base flow (15%). General Likelihood Uncertainty Estimation method is used to understand the simulations and the range of uncertainty bands. Similarly, Regional Sensitivity Analysis in JAMS framework based on Monte Carlo Analysis (MCA) shows that that recession coefficient for overland flow is most sensitive parameter. The change in climatic elements shows that the further rise in temperature and change in the precipitation pattern will further increase vulnerability in the basin.

Keywords: Hydrological cycle, trend, evapotranspiration, glaciers, scenario



Third International Conference on "Mountain Hydrology and Meteorology for the Sustainable Development"

Disaster Risk Reduction

Invited Talk

GLOF characteristics of the Nepal Himalaya

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Since 1970's, many glaciers are receding and glacial lakes are expanding in the Khumbu region of east Nepal, and the (Nare) Mingbo GLOF (Glacial Lake Outburst Flood) occurred in 1977 (Fushimi et al,1985). After that, the (Digtso) Lagmoche GLOF in 1985 and the Saboi GLOF in 1998 occurred in the Khumbu region and nearby. The Tibetan GLOF occurred from a small glacial lake in the east of Langtang region was responsible for the destructive Bhotekoshi river flood of July 2016 (The Himalayan Times; 2017/01/23). The small glacial lake, Gaptse (the lowest glacial lake with altitude of 2,500 m a.s.l. in Nepal Himalaya) locates at the south side of Mt. Annapurna II and Lamjun Himal in the central Nepal Himalaya and caused frequent GLOFs at least in 2003, 2005 and 2009 along the Madi Khola, where is a quite large cliff which altitude difference is about 4000m in the upper part of the Gaptse glacial lake and huge avalanches create Tsunami to cause GLOF when they fall directly into the lake. All of the reported GLOFs observed are smaller glacial lakes which area are less than 1 km^2 and no larger glacial lakes showed any GLOF phenomena so far. The Tulagi glacial lake, one of the large glacial lakes, is located at the upper part of the Dana Khola, the Marshangdi's tributary in the west of Mt. Manaslu. The water level of Tulagi glacial lake has been lowered due to the outlet erosion at the end moraine since the 16^{th} century's glacial advance that indicates to lower continuously the lake level and consequently the GLOF risk. The large glacial lakes such as the Tulagi and the Imja in the Khumbu region are safe against the GLOF, as the ICIMOD (2011) already reported that "Imja Tso has less likelihood of outburst than Tulagi Lake". The end moraine structure of larger glacial lakes are strong enough to prevent the occurrence of the GLOF that is completely different from smaller glacial lakes with hanging glaciers at the upper part of the glacial lake producing avalanches with rock falls directly falling into the glacial lake causing Tsunami to destroy the fragile ice-cored end moraine and cause the GLOF, as it is found in the Mingbo (Nare) glacial lake. We must be very careful about smaller glacial lakes (not the larger glacial lakes), so smaller glacial lakes must be considered to mitigate the GLOF risks.

Keywords: GLOF (Glacial Lake Outburst Flood), avalanches, Tsunami, outlet erosion, end moraine structure, mitigation of GLOF risks

Improving performance of flood forecasting model using complementary error model

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A complementary error modeling framework presents an approach for improving real-time forecasting without needing to modify the pre-existing hydrological forecasting model, but instead formulating an independent additive or complementary model that captures the information the existing operational hydrological model may be missing. This paper presents the application of this principle for issuing improved daily flow forecasts for flood warning. The procedure presented comprises an error model added on top of an unalterable constant parameter conceptual rainfall-runoff model. The error model assimilates the latest observation and its corresponding prediction to inform the predictive distribution of the errors in future model predictions with respect to the observed data. It uses error time series to infer Auto-Regressive Integrated Moving Average (ARIMA) model if the errors are highly correlated. The structure of the error model is established based on attributes of the error time series from the conceptual hydrological model. The model is then utilized to forecast errors. Error forecasts are added to the model predictions to obtain corrected forecasts. This procedure is applied in the 42890 km^2 Karnali catchment in Western Nepal. A conceptual rainfall-runoff model TUW model has been developed to model the rainfall-runoff processes. The model accounts the snowmelt runoff, potential evapotranspiration, infiltration and base flow for runoff estimation at the outlet of the basin at Chisapani. The model has been calibrated for the period 2008 – 2011 with Nash-Sutcliffe Efficiency (NSE) 0.89 and percent bias (PBIAS) 2% and validated for the period 2012 - 2014 with Nash-Sutcliffe Efficiency (NSE) 0.85 and bias (PBIAS) -5.3% using the observed temperature, precipitation and discharge data. A complementary ARIMA error model has been developed from the error series for calibration set and the predicted discharges were corrected using the error predictions from error model. After error correction, NSE and PBIAS was 0.95 and 0.1% respectively for calibration set and 0.91 and 0% respectively for validation set showing significant improvement in the skill of forecasts.

Keywords: Flood forecasting, error modeling, flood warning, hydrological model, ARIMA

Development of flood forecasting model for Narayani River Basin, Nepal

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Hydrological models are commonly used to estimate the basin's hydrological response due to precipitation. They are important component of flood forecasting system. Provision of early flood warning is an important strategy in reducing flood damage and loss of life. To increase warning lead-time for preparedness and take immediate response more efficiently, flood forecasting models are increasingly becoming an essential component in the warning process. Advances in weather forecasting and near real time meteorological and hydrological data collection, and progress in hydrological and hydraulic models, are facilitating the development of advance flood forecasting system with longer lead time. In this study, we developed a flood forecasting model using HEC-HMS in combination with Geospatial Hydrologic Modeling Extension-HEC-Geo HMS for Narayani River Basin of Nepal. HEC-RAS has been used as the hydraulic model for inundation mapping. The HEC-HMS model was calibrated and validated using historical observed data obtained from Department of Hydrology and Meteorology (DHM) and the performance of the model was checked in forecasting mode for Weather Research and Forecasting (WRF) model's rainfall forecast for three days. Then Autoregressive Integrated Moving Average (ARIMA) model has been applied as a complementary model for error correction of the forecast.

Rainfall-runoff simulation was conducted using 6 years of (2008 – 2013) daily data. Out of these, 4years(2008-2011)have been selected for model calibration and 2 years (2012-2013) for model validation. The Nash- Sutcliffe efficiency for the Devghat Flood Forecasting Station is found to be 0. 892 for calibration set and 0.893 for the validation set for model without considering the snowmelt runoff. The result is similar with the inclusion of snowmelt component. After error correction using ARIMA model, the Nash-Sutcliffe efficiency increased to 0.97 for both calibration and validation periods. The calibrated model was tested with bias corrected WRF one-day precipitation forecast for the same periods. The bias correction scheme was computed and applied at the basin scale. When WRF precipitation was used as input to the HEC-HMS model the Nash-Sutcliffe was 0.33 for the calibration period and 0.66 for the validation period. However, the result improved significantly when the model error correction was applied again for the same, which resulted Nash-Sutcliffe 0.82 for calibration period and 0.87 for validation period indicating satisfactory performance of the model in forecasting mode. This indicates that the model can be used for one day flood forecasting. The flood inundation maps were prepared for the settlements along the Narayani/East Rapti rivers upto Indo-Nepal Border using HEC-RAS and Geographic Information System (GIS). The warning level of Narayani River was found at 2 years return period with estimated discharge of 8,898 m^3/s and the water level of 7.5 m from datum of the gauging station. The danger level was found at 5 years return period with the discharge of 10,769 m^3/s and the water level of 8.3 m. Similarly the warning level of East Rapti was found at 5 years return period with estimated discharge of 1,035 m^3/s and the water level of 3.0 m. The danger level is observed at 10 years return period flood with estimated discharge of 1,333 $m^3/s$and water level of 3.4m in the gauging station.

Keywords: Hydrological modeling, ARIMA, flood forecasting, inundation mapping

Assessment of alternative storm water capture measures for managing urban runoff in changing climate

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Increased rainfall intensities and prolonged dry spell are two of the most pressing problems associated with climate change. Climate change is attributed as one of the major reasons for the groundwater table depletion and increasing flood events, particularly in urban areas. It is necessary to improve existing water management systems for high-quality water and reduced hydro-meteorological disasters, while preserving our natural/pristine environment in a sustainable manner. This can be achieved through optimal collection, infiltration and storage of stormwater. Objective of this research is to understand the change in rainfall extremes and storm runoff due to climate change; and test environment-friendly stormwater capture measures for sustainable urban water environment. A case of Yato watershed, an urban area in Setagaya ward, Tokyo, Japan was considered to understand the climate change impacts and adaptation measures. Global Climate Model (GCM) precipitation output of GFDL-CM3 and MRI-CGCM3 were used for assessing the impact of climate change on extreme rainfall patterns over the Yato Watershed. Current and future climate were represented by the GCM data of 1976-2005 and 2071-2100 periods respectively. Observation and GCM data of current climate were compared for identifying and correcting any biases in the GCM output. Quantile-based bias correction technique was employed to correct the biases in GCM precipitation data. Comparison of rainfall intensity-duration-frequency values for current and future climate conditions indicated a significant increase (29%) in maximum rainfall intensities. In order to understand the change in urban runoff caused by climate change, HEC-HMS was utilized to simulate the rainfall – runoff. Simulations results indicated that there will be an increase of 11% to 20% in peak discharge at the outlet of Yato watershed around the end of this century. Combination of rainfall storage and infiltration measures was tested in developing a flood control plan to reduce the flood peak in future. The results of this study can be significant practical importance for stormwater management infrastructures under a changing climate scenario.

Keywords: Climate change, flood, GCM, rainfall, storm-water management



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Poster

Daily adjustment for the wind-induced precipitation undercatch of daily gridded precipitation in Japan

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To quantitatively evaluate precipitation over the northern land area of Japan, we adjust wind-induced precipitation for the Asian Precipitation Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) data set, which is a gauge-based high-resolution daily precipitation data set (with horizontal resolution of 0.05°) over Japan. An accurate estimation of precipitation in winter is required because of the importance of snowfall to water resources in northern Japan. Meanwhile, the use of rain gauges is quantitatively superior to other estimation methods (e.g. methods using satellite, or radar data) because it involves a direct observation, but the catch ratio is lower in the event of snowfall owing to the wind effect. Adjustment for the wind-induced precipitation undercatch is required to obtain the ground truth. The present study wind-induced undercatch of precipitation using daily precipitation, wind speed, temperature and snow depth data the Automated Meteorological Data Acquisition System (AMeDAS) and employing a general bias adjustment equation for AMeDAS. AMeDAS is an automatic observation meteorological system that has been developed over Japan at intervals of about 17km. We created daily gridded data that relate to the catch ratio (with horizontal resolution of 0.05°) using measuring wind measurements made at 900 stations. Additionally, daily gridded precipitation data are created using unadjusted rain gauge data and following previous studies. The adjusted precipitation is obtained by multiplying the gridded precipitation and correlation ratio.

As a result, the distribution of precipitation is changed temporally and spatially over the Tohoku region and the mean annual terrestrial precipitation over Japan increases by 22.2%.To validate this correction effect, the river inflows to nine dams in northern Japan are compared between grid unadjusted precipitation (P) and grid-adjusted precipitation (P_C) and it is verified that inflow in thespring snowmelt period is more than winter precipitation over the catchment (i.e., R>P). The value obtained by subtracting evaporation (E) obtained from the ECMWF's interim reanalysis from precipitation correspond to77% of inflow. Compared with previous studies that interpolated the monthly catch ratio to adjust monthly precipitation, the present detailed analysis using APHRO-JP evaluates more solid precipitation and decreases error in the evaluation of precipitation over northern Japan. Additionally, compared with unadjusted grid precipitation, the increase in precipitation tends to increase at the quantity snowfall and area of strong wind nearby Tsugaru Channel and northern Hokkaido. Adjustment of the APHRODITE data set over Japan using the daily gridded catch ratio provides quantitatively superior daily grid data.

Keywords: Bias adjustment, daily precipitation, APHRODITE, wind-induced undercatch

Morphological factors controlling changes in mass balance, surface area, terminus, and snow line altitude of Himalayan glaciers

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Which are the main morphological factors controlling the heterogeneous response of debris cover glaciers to climate change in southern central Himalaya? A debate is open on thinning rate of debris-covered glaciers than that of clean ones. So far, previous studies have adopted a deterministic approach, indispensable, but that made it possible that just few glaciers could be monitored. In this context, we proposed here, a statistical analysis based on a wider glacier population, not alternative, but complementary to these deterministic studies. We analyzed 28 glaciers lying on the southern slopes of Mt. Everest (central southern Himalaya) during the 1992-2008 period. Generally, the slope resulted the main morphological factor controlling the features and answers of glacier to climate change. In particular, the main key points emerged are (a) flatter glacier downstream slope is responsible of higher glacier elevation lowering, (b) the development of supraglacial ponds is a further control factor of the glacier elevation change, i.e., where supraglacial ponds are able to develop, glaciers register a further surface lowering; (c) whereas the debris coverage was not found significantly responsible neither about the development of supraglacial ponds nor the elevation change, nor the shift of snow line altitude (SLA). However, we pointed out that the limit of this analysis is to have considered, as morphological factor, only the surface coverage and not the thickness of the debris.

Keywords: Debris cover, glacier surface, elevation change, SLA, Mt. Everest

The features of changes of air temperature in the geo unit plains-mountains in Central Asia

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The results of the assessment of annual and seasonal air temperatures in the geo unit "plains-mountains" on the basis of the analysis of data of 170 climatological stations in Ili, Irtysh, Amudarya and Syrdarya river basins for the unified by duration period are presented. The positive trends of seasonal and annual air temperatures for the entire researched region are the evidence of the global climate warming. Annual and winter air temperature trends significantly change with altitude. Maximum trends values in the whole altitudinal range are chartered for the winter period (November-March) with feebly marked relationship with NOA index. Maximum of annual and winter trends of air temperature are observed in altitudinal range from 500 to 1000 m a.s.l., which is the most densely populated area of researched region with the most comfortable environment conditions. The air temperature trend of cold period is 0.048 °C/year which is 1.5 times higher than the corresponding trend of average annual air temperature trend. The trends of annual and winter air temperature at the altitude less than 500 m a.s.l. are significantly lower and equal to 0.028 and 0.046 °C/year respectively. This altitudinal range is characterized by a much more arid climate and less comfortable for the living conditions of the natural environment. The density of population there is incomparably lower and most of the settlements are small. Within the mountainous territory the value of the trend of temperature of the winter period is declining rapidly with increasing of altitude and at altitudes above 3,000 meters is equal to 0.0076 °C/year. The main reason of the observed changes in temperatures of the region in the considered geo unit "plains-mountains" is a distortion of the natural fields of climate characteristics by the warming effect of urbanized areas and anthropogenic-changed landscapes, accumulated over the time in the datasets of the majority of climate monitoring stations. In conditions of the researched region, these distortions are maximal in winter. These distortions are mostly expressed in the limits of the most densely populated piedmont plain (altitudinal range from 500 to 1000 m a.s.l.) and almost absent in the dataset of high-mountain stations, the majority of which are located outside of the settlements. This conclusion may be confirmed by the fact that the value of trend of winter temperature is linearly and closely connected to the duration of the heating season (correlation coefficient r = 0.87), and the values of trends of the vertical temperature gradient in the summer are almost not expressed, making in the average about 0,022 °C/year.The research results give a reason to believe that in the conditions of the researched region the data of the high-mountain weather station represent the natural course of changes of climatic characteristics and represent the most reliable base for the regional climate change researches. The data of many of plain and low mountain stations to some extent is distorted by the influence of urban areas and anthropogenic-changed landscapes and cannot be used for assessment of climate change without prior correction.

Keywords: temperature, Climate change, geo unit plains-mountains, heating seas

Glacier degradation in Chinese Tien-Shan Mountains for the last half century on the example of Koksu and Kunes rivers

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The analysis of the dynamics of glacier area changes in the Kuksu and Kunes river basin (Chinese Tien-Shan Mountains) were performed. The new inventories of glaciers for this region for 1990/93 and 2012 years were made. The new glacier inventories of Koksu and Kunes river basins were made on the basis of Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI satellite images. The glacier outlines and surrounding moraines were mapped manually using false-color composite bands on the Landsat images with 30/15 m resolution (30 m for the TM sensor and 15 m for the panchromatic band 8 of the ETM and OLI TIRS sensors). The reanalysis data the APHRODITE daily product version for the period 1961-2007 years were analyzed. Also the data of monthly air temperature and precipitation at the 9 weather stations were used. Analyzes of inter decadal variability of temperature and precipitation and linear regression analysis for the research territory of were made. According to our new inventories there were 648 glaciers in Koksu river basin in 1990 year including 54 unregistered before glaciers. The total glacier area was 376.808 km^2, and the average area of single glacier was 0.581 km^2. In Kunes river basin in 1993/94 years 240 glaciers were registered (including 7unregistered before small glaciers). The total area in this river basin was 81.511 km^2 while the average area of single glacier was 0.340 km^2. The glacier inventory for 2012 year showed that there were 638 glaciers in Koksu river basin. The total area of glaciers in that basin was 279.175 km^2. In Kunes river basin there were 193 glaciers with the total area 52.419 km^2. Using this data we characterized the spatial features of the glaciers. To estimate changes in a glacier area and ice volume we compared our results to the data from the First and Second Chinese glacier inventories as for 1962/63 and 2007/09 years. During the whole research period glacier area reduced by 37 % losing an average 0.8 % per year. The rate of the glacier retreat varies by sub-regions and time period. The biggest degradation rate was observed for the period 1990/93-2007/09. Glacier degradation rate is matching to the changing of air temperature in the region which is also increasing significantly during the last 20-30 years. Biggest glacier retreat were also observed for the small size glaciers (<1 km^2) and the glaciers which have low glacier minimum elevation and located lower than the average firn line in the region. The analysis showed that for last 40 years the increasing of the air temperature at the mountain area is equal to 0.3-0.4 ^oC $(10\ a)^{-1}$. There were not observed any significant changes in the annual sum of precipitation. All of these factors of increasing of temperature and deficiency of precipitation contribute towards negative influence of the glaciers and forcing its melting.

Keywords: Glacier degradation, Tien-Shan mountains, climate change

Glacier degradation in the Pskem and Chatkal river basins (Western Tien-Shan)

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The analysis of glacier degradation in the two neighboring basins Pskem and Chatkal (Syrdaria river tributaries) for the period from 1977 to 2014 years was made. These two small basins (9700 km^2) are located at the territory of three neighboring Central Asia countries Kazakhstan, Uzbekistan and Kyrgyzstan. The mapping of glaciers as for 1977, 1994 and 2014 years was made based on the satellite images from Landsat MSS/TM/OLI_TIRS. Manual and semiautomatic images processing methods were used. The total open glacier area in the Pskem river basin is 97 km^2 and in the Chatkal river basin is 28.4 km^2. Glaciation of these two basins is slightly different from each other in the sizes and morphological characteristics of glaciers. Glaciation of the basins is represented mainly by the small glaciers with the area of 0.5 km^2. The correspondence of the new data and the first USSR glacier inventory data as for the end of 1950 of this territory was analyzed. According to the results of our study it was found out that the data presented in the first catalog significantly underestimated the area of almost all the glaciers in the basin, and there was a large number of glaciers which had not been counted previously. It was also found out that for the whole research period from 1977 to 2014 years the open glacier area of the Pskem river basin decreased by 30 % of initial size and in the Chatkal river basin glacier area was reduced by 55 %. For the some sub-basins in the Chatkal river basin the comparison of the rates of glacier retreat for the two periods from 1977 to 1994 and from 1994 to 2014 was made. And the rate of reduction of glacier area of the second period was much higher than of the first period. Preliminary analysis of air temperature and precipitations on the nearest meteorological stations shows the positive trend of temperature (especially on the mountain stations) and no significant trend of precipitations. This research was made under the program of fundamental scientific research in the department of Glaciology of "Institute of geography" and CHARIS research project.

Keywords: Glaciers, degradation, central Asia, satellite images

Water stable isotopes in the lower Chamkhar Chhu (River) basin of the central Bhutan, Eastern Himalaya

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Despite the importance of water and profound climate change impact on it, there are very limited hydro-chemical analyses conducted in Bhutan. In fact, there is dearth of the baseline data available in the Eastern Himalayan regions especially Bhutanese rivers which are essential for such scientific studies. Hence, this study is intended to understand the isotopic composition of the lower Chamkhar *Chhu* (River) watershed of central Bhutan. River water samples were collected between 2538 and 3027 meters transect of the Chamkhar chhu. Synoptic sampling was carried out in March, June, July, August, October, November and December of 2016, for isotopic analysis of the surface water. Here, we present seasonal variability of $\delta^{18}O$ and $\delta^{2}H$ including d-excess values of the surface water in the lower Chamkhar Chhu basin. Our preliminary results demonstrate that the both $\delta^{18}O$ and $\delta^{2}H$ values were slightly more depleted in the winter and autumn as compared to spring and summer seasons. The $\delta^{18}O$ and $\delta^{2}H$ values also become more negative with increasing altitude.Similarly, d-excess values of the surface water showed seasonal variation.

Keywords: Stable isotopes, d-excess, seasonal variation, Chamkhar *chhu*,

Using hydrochemistry and isotopic tracers to clarify melt-water influence to water supplies at a basin scale: techniques and challenges

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Snow and ice in our mountain "water towers" are relied on to supply lower-lying valleys and plains with critical water supplies through dry seasons. Together with increasing downstream water demands, disproportionate climate change effects on frozen water resources may exacerbate water stress in mountain regions. To anticipate what climate change-induced snow and glacier trends will mean for the human and environmental systems that utilize melt-water resources we ask: how much water in any given river comes from melting snow, and how much from melting ice? Hydrochemistry and isotopic tracers, together with mixing model techniques, have been used in the eastern Himalaya to clarify the importance of meltwater to surface water flow at the headwater scale. Building from this work, we now investigate if these same techniques can be used to understand the role of melt-water at downstream locations – the places where most people, agriculture and hydropower use water – to anticipate the impact on water resource management practices and water resource vulnerabilities at the regional scale. While the premise of mixing model work remains intact, the extension of end member mixing model techniques to large scales (500 river km or more from the glacier snout) exacerbates uncertainties existing within models targeted at simpler, headwater hydrologic systems. For example, defining representative end members such as groundwater is problematic even at the small scale due to a spread in ion concentration data, but this challenge intensifies further downstream. At the regional scale, groundwater flow paths are even more diverse ranging from quick, shallow subsurface flow to deeper flow paths possibly affiliated with fracture networks surfacing hundreds of kilometers downstream. Additionally, because of the cumulative affect of flow generation, uncertainty in the headwaters is inherited and compounded at lower elevations. We address these challenges, among others, to derive accurate estimates of river source water separations at the basin scale. Using 520km of the Naryn River in Kyrgyzstan's Tien Shan as a case study, we utilize an isotopic and hydrochemical data set collected in July and August 2016 to evaluate the utility of mixing model approaches at these scales. Specifically we quantify the relative contribution of snow and ice melt water to river flow over the regional domain and aim to evaluate uncertainty in our results. We raise issues relating to the sustainability of surface flow in the context of cryospheric impacts in a warming climate, associated implications for water management and river development, and the potential for using similar techniques across High Mountain Asia.

Keywords: Source waters, end member mixing analysis, isotopes, hydrochemistry

Revised estimate of sediment yield of the upper Koshi Basin in Nepal

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The Koshi is the largest transboundary river of Nepal, with a drainage area expanding to China (Tibet) and India. The topography of the basin varies from high mountains, including Mount Everest, to plain lands. The favourable setting and hydrology make that the Koshi River and its tributaries are largely exploitable for hydropower production. For this, several multipurpose dams are currently planned or in construction. However, the Koshi is also one of the most sediment-laden rivers in the world. Sediment accumulation downstream of Chatara was the responsible for river avulsion and flooding in the past, whereas high sedimentation rates will affect the life span of the planned reservoirs in the future. Estimating the sediment yield of the basin is therefore important for the development of the area. Based on new data analysis and numerical modelling, this research estimated the sediment yield of the upper Koshi River at the sub-basin scale. The available data on precipitation, suspended sediment loads, bed material and river geometry, combined with the use of SWAT, a semi-distributed physics-based hydrological model integrating water and sediment, allowed quantifying the amounts of sediment that is transported by the river at Lamabagar and Chatara, among other locations. The results show that previous assessments, carried out in the nineteen-nineties, overestimated the average sediment load at Chatara by approximately 35%. The reason can be deduced from discharge and suspended solid concentration time-series, on which previous studies were based, showing higher amounts in the period 1985-1990.

Keywords: Koshi River, Chatara, sediment yield, sediment transport, SWAT

Stream discharge response to climate change and land use change in Tamor Basin, Nepal

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Climate change and land use change are two major issues that need to be addressed for sustainable land and water resource management. These are major factors influencing discharge in monsoon dominated basin. This study aims to quantitatively assess the impact of climate change and land use change on future discharge of the Tamor basin in Nepal using Arc SWAT. Result from the study indicated maximum temperature will reach to 40.63°C in 2030s, 40.63°C in 2060s and 45.95°C in 2090s which was 35°C in baseline period (1976-2005). Annual average precipitation was projected to change by 17.64% under RCP 4.5 and by 39.88% under RCP 8.5 till the end of the century as projected by HadGEM2. Since the basin is monsoon dominated, annual discharge was projected to increase by 12.25% under RCP 4.5 and by 32.67% under RCP 8.5 above baseline average till the end of the century. Result using HadGEM2 also shows that peak flows that used to occur in August in baseline period will shift to July except in 2030s under RCP 4.5. However, CSIRO-Mk3.6.0 projects decrease in annual precipitation and hence also discharge at the end of the century. Result from both Global Climate Models show that average monthly discharge due to climate change will change positively as well as negatively for both scenarios. Due to combined impact of land use change and climate change, annual discharge was projected to change by 16.53%, 21.28% and -4.39% under RCP 4.5 and by 38.29%, 45.64% and 13.06% under RCP 8.5 till the end of the century for conversion of forest into agricultural land, conversion of forest into barren land and conversion of barren land into forest respectively. Average annual discharge increased the most in case of conversion of forest into barren land and decreased or increased the least in case of conversion of barren land into forest. Unlike annual, seasonal response to combined impact was different. In monsoon and pre monsoon, discharge increased or decreased the least in case of conversion of forest into agricultural land and barren land while increased the least or decreased in case of conversion of barren land into forest. However, in post monsoon and winter, discharge decreased the least or increased the most in case of conversion of barren land into forest but discharge decreased the most or increased the least in case of conversion of forest into agricultural land and barren land.

Keywords: Climate change, Land use change, temperature, precipitation, discharge

Adaptive governance of mountain ecosystem services through citizen Science: A case of participatory monitoring of water resources in Mustang District, Nepal

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Agriculture and livestock are major activities dependent on natural ecosystem services, which support directly to the livelihood of local people in the Mustang district. Being placed in the cold-arid climatic region, Mustang has been facing the problem of water scarcity where annual precipitation is less than 300 mm. The situation is likely to be further stressed by climate change. As a result, optimizing water resources use through proper management is a paramount to increase production and thereby, reduce poverty due to worsening ecosystem services in Mustang. With the objective to support poverty alleviation, a programme named "adaptive governance of mountain ecosystem services enabled by environmental virtual observatories (MOUNTAIN-EVO)" was implemented in Nepal, Peru. Kyrgyzstan and Ethopia. One of the hypotheses of the work was that proper management of ecosystem services (ESS) can alleviate poverty if it is embedded in local processes of adaptive governance that relies on continuous monitoring and knowledge generation.

Upper Kaligandaki basin in Mustang district was chosen for the case study in Nepal. Situation on natural resources, ecosystem services, livelihoods support systems, institutions and governance was evaluated by researchers and experts through participatory mapping. Mountain EVO, a pilot study in Mustang has promoted the citizen science for better management of ecosystems to support in alleviating poverty. While promoting citizen science in support of the management of scarce water in irrigation and domestic uses, monitoring networks on stream flow and precipitation were established applying a participatory approach. This paper highlights some outputs of this programme and and the findings from the case study in Mustang. The activities of this program would enable local users to assess the water balance in the area, decrease the uncertainty associated with data-scarcity, generate useable information about water available for irrigation, livestock grazing, and domestic demand. An optimized water management strategy generated and shared through citizen science approach would contribute to the improvement of governance of mountain ecosystem services, to optimal use of water to support the livelihood, and to improve the economic condition of the local people.

Keywords: Ecosystem services, water balance, knowledge generation, participatory

Snow: An important component of cryosphere in the Tibetan Plateau

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The Tibetan Plateau is called the water tower of Asia. The perennial rivers, originating from the regions like Mekong, Yellow River, Karnali and Indus, sustain the life of many people living downstream in the region. These perennial rivers largely rely on the constant flux of the snow and glaciers. Modeling the timing and the magnitude of the snowpack depletion and runoff in the mountainous basins of the region is essential for forecasting the water supply for the irrigation, drinking, and industrial purposes. Snow cover dynamics and snowmelt are important hydrological processes and water resource for the drainage basins in this region. Snow has got considerable spatial and temporal variability which greatly governs the energy and water interactions between the atmosphere and land surface. Many approaches have been taken in developing the hydrological models which range from simplified temperature index models to physically-based models. Physically-based models accurately simulate the complex melt-refreeze snow physics and also show a better performance in capturing the diurnal freeze and thaw cycles. Snow measurements are largely hindered owing to the inhospitable terrain, hostile climate, poor accessibility etc. Satellite based snow cover data such as MODIS have been used for the calibration and validation of the simulated snow cover by the hydrological models. For accurate snow melt modeling, the effect of the wind on the snow distribution is important, but this remains unclear in this region. Studies have indicated that blowing snow sublimation and snow transport by wind are the key processes of the snow mass balance. Snow transported by the wind from the non glacierized area to the glacier surfaces may result in an increase of the winter mass balance of the glaciers. It is very important to account for the snow deposition patterns to model snow melt in a mountainous catchment.

Keywords: Snow cover dynamics, snow melt models, satellite data, snow mass balance

Hydrological modeling and climate change impact assessment using HBV-Light Model: A case study of Karnali River Basin of Nepal

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This study has been performed to predict the impacts of climate change on the runoff pattern of the snow-fed Karnali River Basin of Far-Western Nepal, which has a spatial coverage of 45,269 km2 from Dhaulagiri Mountain in the east to Nanda Devi Mountain in the west and elevation ranging from 140 m to 7498 m. Work has also been done to estimate snow melt contribution to streamflow and its variation in increased temperatures at the extreme outlet of the basin at Chisapani. The future climatic Had CM3 GCM (Hadley Center, General Circulation Model) scenario developed using the 'Providing Regional Climate for Impact Studies-Regional Climate Model' (PRECIS-RCM, a climate modeling system developed by the Hadley Centre, UK Met Office) has been forced into the Hydrologiska Byråns Vattenbalansavdelning (HBV) model to estimate future river discharge of the basin. HBV, developed by Dr. Sten Bergström at Swedish Meteorological and Hydrological Institute in the 1970s, is a conceptual precipitation-runoff model used to simulate runoff based on precipitation, air temperature and potential evapotranspiration data. Long term daily meteorological data has been obtained from the publications of the Department of Hydrology and Meteorology of the Government of Nepal. The PET has been calculated using the Penman-Monteith equation. The model has been extensively used for runoff modeling in many countries including Nepal. It estimates snow melt based on the degree-day method and computes snow accumulation, ground water storage and catchment runoff. Model calibration has been done by the Generalized Likelihood Uncertainty Estimation method by applying it to the basin with relevant ground information and refined hydro-meteorological data available from 1963 to 2008.

Analyzing the model performance indicates its suitability to simulate stream flow in the catchment with values of Nash Sutcliffe efficiency upto 0.85 during calibration and upto 0.87 during validation. Due to its structural complexity, the model shows difficulties in simultaneously modeling low and high flows accurately. Low flows are generally underestimated and peaks are correctly estimated except for some sharp peaks due to isolated precipitation events. Contribution of snow melt to annual flow has been estimated to be the highest (30%) at the beginning of May, as the accumulated snow begins to melt and lowest (2%) in January. Examination of this contribution under conditions of increased temperatures indicates that increase in average basin temperature due to global warming will significantly lead to higher snow melt contribution to runoff. Rise in temperature by 1.5°C causes increase in snow melt contribution from 22% to 30% at the basin outlet in summer and from 11% to 17% annually. Running the model with the HadCM3 GCM (A1B scenario) down scaled to the station level indicates significantly wetter months in the 2040s. It is observed that runoff will increase by 3% to 250% in various months as compared to the control period. The impact will be highly pronounced in the flooding season. Shift in hydrological regime is also indicated by the movement of peak flow. This may have consequence on water abstraction activities, leading to changes in cropping patterns, electricity production and supply of drinking water in the basin, which will have impacts on the economy of the region.

Keywords: HBV, climate change, hydrological modeling

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