The Workshop on
Glaciers, Snow Melt and Runoff in the Himalayas
February 6 – 7, 2012, Kathmandu, Nepal

Pradeep Mool, ICIMOD
Hotspot for climate change: vital resources and growing vulnerabilities

The third pole on earth - an area of extraordinary beauty and a world heritage site for biodiversity

Himalayan glaciers are sources of freshwater reserves providing headwaters for 10 major river systems in Asia - a lifeline for almost one third of humanity

Ecological buffer between the Tibetan Plateau and South Asia
Changing Glacier Environment

“ISRO: 75% of Himalayan glaciers retreating” (Tol, 16 May 2011)

Fast retreating Gangapurna glacier at the northern slope of Annapurna Range, Manang Lake and Manang Village, Nepal
Imja Glacier – Repeat Photography

1956 photograph of Imja glacier (Photo: Fritz Muller; courtesy of Jack Ives)

2006 photograph of Imja glacier (Photo: Giovanni Kappenberger courtesy of Alton C Byers)
Imja Growth

- Imja developed as supra ponds in late ‘50s.
- The seven supra ponds existed on the glacier surface in late ‘50s (Snider Map based on photos of 1957-58).
- Before ‘80s was amalgamation phase - merging of supra ponds.
- Late ‘80s are rapid expansion period towards the glacier terminus.
- The lake is still expanding.

Expansion of Imja, Oct 2010
Growth of Lakes (Tsho Rolpa, Imja &Thulagi)

Lakes Expansion Rate per Year

<table>
<thead>
<tr>
<th>Lakes</th>
<th>Length (m)</th>
<th>Area (sq km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imja</td>
<td>42-47</td>
<td>0.0266</td>
</tr>
<tr>
<td>Tsho Rolpa</td>
<td>17-20</td>
<td>0.0129</td>
</tr>
<tr>
<td>Thulagi</td>
<td>35-41</td>
<td>0.0115</td>
</tr>
</tbody>
</table>
Glacial Lake Outburst Floods (GLOFs)

- Impact of climate change is well observed in the Himalaya
- Several studies show that most of glaciers in Himalaya are shrinking at accelerated rates in recent decades
- Glacial lakes formed by rapid retreat of glaciers
- Water volume increase in these lakes from the glacier melt
- Lakes retained by unconsolidated moraine dams and ice core
- Moraine failure due to piping and overtopping
- Triggered by many factors
- Damaging impact downstream
- Common in Nepal, Tibet/China, Bhutan and other parts of HKH
Inventory of glacial lakes of the HKH region

Regional glacial lakes database in ICIMOD Geo-portal
(http://118.91.160.238/glacierlakes/index.html#)

There are 20482 lakes with area of 4320sq.km above 2500m asl
Physical and socioeconomic criteria used for ranking critical lakes
Mapping and monitoring using RS technique and ground based studies in Imja glacial lake
Field investigations activities for GLOF Risk Assessment
The field investigation include the following 5 major components:

1. Assessment of the stability of the natural moraine dams

2. Estimation of the lake storage volume

3. Potential external GLOF triggering factors

4. Hydro-meteorological data analysis

5. Dam Break Modelling and Down Stream Vulnerability assessment
Past GLOF events in HKH region

About 56 past GLOF events in the HKH Region (Bhutan - 4, China - 29, Nepal - 14, Pakistan - 9) recorded with about 10 of them of trans-boundary nature.
## GLOF events from Tibet/China affecting also inside Nepal in downstream area

<table>
<thead>
<tr>
<th>Date</th>
<th>River basin</th>
<th>Lake</th>
<th>Source</th>
<th>Cause of GLOF</th>
<th>Losses</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 Aug-35</td>
<td>Sun Koshi</td>
<td>Tara-Cho</td>
<td>Tibet (China)</td>
<td>Piping</td>
<td>66,700 m² of wheat field, livestock etc</td>
<td>28° 17’ 00”</td>
<td>86° 08’ 00”</td>
</tr>
<tr>
<td>1621-Sep-64</td>
<td>Arun</td>
<td>Gelhaipco</td>
<td>Tibet (China)</td>
<td>Glacier surge</td>
<td>Highway and 12 trucks</td>
<td>27° 58’ 00”</td>
<td>87° 49’ 00”</td>
</tr>
<tr>
<td>17 1964</td>
<td>Sun Koshi</td>
<td>Zhangzangbo</td>
<td>Tibet (China)</td>
<td>Piping</td>
<td>No remarkable damage</td>
<td>28° 04’ 01”</td>
<td>86° 03’ 45”</td>
</tr>
<tr>
<td>1825-Aug-64</td>
<td>Trisuli</td>
<td>Longda</td>
<td>Tibet (China)</td>
<td>Not known</td>
<td>Not known</td>
<td>28° 37’ 01”</td>
<td>85° 20’ 58”</td>
</tr>
<tr>
<td>19 1968</td>
<td>Arun</td>
<td>Ayaco</td>
<td>Tibet (China)</td>
<td>Not known</td>
<td>Road, bridges etc</td>
<td>28° 01’ 00”</td>
<td>86° 29’ 00”</td>
</tr>
<tr>
<td>20 1969</td>
<td>Arun</td>
<td>Ayaco</td>
<td>Tibet (China)</td>
<td>Not known</td>
<td>Not known</td>
<td>28° 01’ 00”</td>
<td>86° 29’ 00”</td>
</tr>
<tr>
<td>21 1970</td>
<td>Arun</td>
<td>Ayaco</td>
<td>Tibet (China)</td>
<td>Not known</td>
<td>Not known</td>
<td>28° 01’ 00”</td>
<td>86° 29’ 00”</td>
</tr>
<tr>
<td>22 11-Jul-81</td>
<td>Sun Koshi</td>
<td>Zhangzangbo</td>
<td>Tibet (China)</td>
<td>Glacier surge</td>
<td>Hydropower station</td>
<td>28° 04’ 01”</td>
<td>86° 03’ 45”</td>
</tr>
<tr>
<td>23 27-Aug-82</td>
<td>Arun</td>
<td>Jinco</td>
<td>Tibet (China)</td>
<td>Glacier surge</td>
<td>Livestock, farmland</td>
<td>28° 00’ 35”</td>
<td>87° 09’ 39”</td>
</tr>
<tr>
<td>24 6-Jun-95</td>
<td>Trisuli</td>
<td>Zanaco</td>
<td>Tibet (China)</td>
<td>Glacier surge</td>
<td></td>
<td>28° 39’ 44”</td>
<td>85° 22’ 19”</td>
</tr>
</tbody>
</table>
Extreme rainfall events - Nepal

- Less rainy days
- More intense rainfall events

(Adopted from Baidya and Regmi, 2007)
Spatial distribution of temperature trends in the HKH region (deg C/year; data source: New et al. 2002)
Under-representation of meteorological observation in the high Himalayas

![Graph showing the distribution of meteorological stations by elevation.](attachment:image.png)

952 met. stations

Station Types:
- Synoptic
- Aeronautical
- Agrometeorology
- Climatology
- Precipitation
- Snow
- Unknown
- HKH Region

Elevation Zone:
- 0 - 1000 m
- 1001 - 2000 m
- 2001 - 4000 m
- >4001 m

H - Meteorology station
<table>
<thead>
<tr>
<th>Glacier</th>
<th>z-max [m a.s.l.]</th>
<th>Area [km²]</th>
<th>Record years (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changmekhan (India)</td>
<td>5300</td>
<td>4.5</td>
<td>1981 – 1986 (6)</td>
</tr>
<tr>
<td>Dunagiri (India)</td>
<td>5150</td>
<td>2.56</td>
<td>1986 – 1990 (5)</td>
</tr>
<tr>
<td>Shaune Garang (India)</td>
<td>5360</td>
<td>4.94</td>
<td>1982 – 1990 (9)</td>
</tr>
<tr>
<td>Gor Garang (India)</td>
<td></td>
<td>2</td>
<td>1977 – 1984 (8)</td>
</tr>
<tr>
<td>Tipra Bank (India)</td>
<td>5730</td>
<td>7</td>
<td>1986 – 1988 (3)</td>
</tr>
<tr>
<td>Neh Nar (India)</td>
<td>4925</td>
<td>1.7</td>
<td>1980 – 1984 (5)</td>
</tr>
<tr>
<td>Kolahoi (India)</td>
<td>5000</td>
<td>11.9</td>
<td>1984 (1)</td>
</tr>
<tr>
<td>Shishram (India)</td>
<td>4900</td>
<td>9.9</td>
<td>1984 (1)</td>
</tr>
<tr>
<td>Dokriani Glacier (India)</td>
<td></td>
<td>7</td>
<td>1993 – 2000 (6)</td>
</tr>
<tr>
<td>Chhota Shigri (India)</td>
<td>6263</td>
<td>15.7</td>
<td>2003 – 2006 (4)</td>
</tr>
<tr>
<td>Langtang (Nepal)</td>
<td>7000</td>
<td>74.8</td>
<td>1987 – 1997 (11)</td>
</tr>
<tr>
<td>Rika Samba (Nepal)</td>
<td></td>
<td>1</td>
<td>1999 (1)</td>
</tr>
<tr>
<td>AX010 (Nepal)</td>
<td>5360</td>
<td>0.568</td>
<td>1996 – 1999 (4)</td>
</tr>
<tr>
<td>Meikuang (China)</td>
<td>5520</td>
<td>1.1</td>
<td>1989 – 1998 (9)</td>
</tr>
<tr>
<td>Chongce i.c. (China)</td>
<td>6374</td>
<td>16.4</td>
<td>1987 (1)</td>
</tr>
<tr>
<td>Xiaodongkemadi (China)</td>
<td>5926</td>
<td>1,767</td>
<td>1989 – 1998 (10)</td>
</tr>
</tbody>
</table>

Dyurgerov & Meier (2005) - INSTAAR 58; Wagnon et al. (2007) – J.Glac. 53(183)
Source: Kaser, G; Innsbruck University, Climate & Cryosphere; 2009 June 08 Tromso, Norway
Project title:
Monitoring and assessment of changes in glaciers, snow, and glacio-hydrology in the Hindu Kush - Himalayas with a special focus on strengthening the capacity of Nepalese organisations

Project goal:
Improve knowledge and understanding of the cryosphere in relation to climate change and impact on water resources in the HKH region and capacity building of Nepalese organisations.

Funding:
Ministry of Foreign Affairs, Government of Norway through the Royal Norwegian Embassy in Kathmandu

Project duration: Five years (November 2010 – November 2015)

Partners:
Water and Energy Commission Secretariat, Government of Nepal (WECS/GoN)
Department of Hydrology and Meteorology, Government of Nepal (DHM/GoN)
Tribhuvan University, Kathmandu (TU)
Kathmandu University, Kathmandu (KU)
The three pillars of the cryosphere monitoring are in-situ measurements, modelling and remote sensing, which are methods that complement each other for calibration and validation.
Cryosphere Monitoring Project

Hydro-Meteorological Observations
- Global
- HKH region
- Basin
- Sub-basin
- Glacier

Glacier Mass Balance Monitoring

Field Measurements

Remote sensing

Modelling

Regional Cryosphere Knowledge Hub

Capacity Development
# Cryosphere Monitoring Project

Monitoring and assessment of changes in Glaciers, Snow, and Glacio-hydrology in the Hindu Kush - Himalayas with a special focus on strengthening the capacity of Nepalese organizations

<table>
<thead>
<tr>
<th>Components</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Field based glacier mass balance measurements</td>
<td>Cryospheric data for water resources</td>
</tr>
<tr>
<td>2 Water resources assessment in glaciated catchments and sub-basin scale</td>
<td>Glacio-hydrological data for water availability scenario analysis</td>
</tr>
<tr>
<td>3 Remote Sensing based snow and glaciers monitoring</td>
<td>Fully operational remote sensing based snow and glaciers mapping</td>
</tr>
<tr>
<td>4 Cryosphere knowledge hub</td>
<td>ICIMOD as a Regional Cryosphere Knowledge Hub</td>
</tr>
<tr>
<td>5 Capacity building</td>
<td>Capacity development of Nepalese institutions in above components</td>
</tr>
</tbody>
</table>
### Glaciers in the HKH region

Glacier Area in HKH: about 60,000Km²

Glacier Cover in HKH: 1.43%

<table>
<thead>
<tr>
<th>Basins</th>
<th>Number</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amu Darya</td>
<td>3,277</td>
<td>2,566</td>
</tr>
<tr>
<td>Indus</td>
<td>18,495</td>
<td>21,192</td>
</tr>
<tr>
<td>Ganga</td>
<td>7,961</td>
<td>8,981</td>
</tr>
<tr>
<td>Brahmaputra</td>
<td>11,497</td>
<td>14,019</td>
</tr>
<tr>
<td>Irrawaddy</td>
<td>133</td>
<td>35</td>
</tr>
<tr>
<td>Salween</td>
<td>2,113</td>
<td>1,351</td>
</tr>
<tr>
<td>Mekong</td>
<td>482</td>
<td>234</td>
</tr>
<tr>
<td>Yangtze</td>
<td>1,389</td>
<td>1,561</td>
</tr>
<tr>
<td>Yellow</td>
<td>189</td>
<td>137</td>
</tr>
<tr>
<td>Tarim</td>
<td>1,091</td>
<td>2,310</td>
</tr>
<tr>
<td>Interior</td>
<td>7,351</td>
<td>7,535</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>53,978</td>
<td>59,926</td>
</tr>
</tbody>
</table>
Results: HKH region

Temporal variation of snow cover area (SCA) of HKH

Snow cover variation over last decade (2002-2010) across the Himalaya based on linear equation.
### Snow cover trends

<table>
<thead>
<tr>
<th>Basin</th>
<th>Total land area (sq.km)</th>
<th>Average snow cover area</th>
<th>Mean elevation (masl)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(sq.km)</td>
<td>(sq.km)</td>
<td>(%)</td>
</tr>
<tr>
<td>Amu Darya</td>
<td>645,895</td>
<td>9,918</td>
<td>1.6</td>
</tr>
<tr>
<td>Brahmaputra</td>
<td>528,082</td>
<td>107,121</td>
<td>20.4</td>
</tr>
<tr>
<td>Ganges</td>
<td>1,001,087</td>
<td>47,742</td>
<td>4.8</td>
</tr>
<tr>
<td>Indus</td>
<td>1,116,347</td>
<td>167,992</td>
<td>16.7</td>
</tr>
<tr>
<td>Irrawaddy</td>
<td>426,393</td>
<td>9,511</td>
<td>2.4</td>
</tr>
<tr>
<td>Mekong</td>
<td>841,337</td>
<td>23,534</td>
<td>3.0</td>
</tr>
<tr>
<td>Salween</td>
<td>363,898</td>
<td>38,571</td>
<td>10.7</td>
</tr>
<tr>
<td>Tarim</td>
<td>929,254</td>
<td>167,061</td>
<td>15.9</td>
</tr>
<tr>
<td>Yangtze</td>
<td>2,066,050</td>
<td>193,304</td>
<td>9.4</td>
</tr>
<tr>
<td>Yellow River</td>
<td>1,073,443</td>
<td>95,193</td>
<td>9.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Season</th>
<th>HKH region</th>
<th>Western HKH</th>
<th>Central HKH</th>
<th>Eastern HKH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual</td>
<td>-0.05 ± 1.32 %</td>
<td>0.02 ± 1.36 %</td>
<td>-0.40 ± 1.86 %</td>
<td>0.03 ± 1.55 %</td>
</tr>
<tr>
<td>Summer</td>
<td>-0.01 ± 0.49 %</td>
<td>+0.16 ± 0.65 %</td>
<td>-0.20 ± 1.40 %</td>
<td>-0.04 ± 0.52 %</td>
</tr>
<tr>
<td>Autumn</td>
<td>+0.09 ± 3.97 %</td>
<td>-0.26 ± 2.81 %</td>
<td>+0.02 ± 5.74 %</td>
<td>+0.29 ± 5.32 %</td>
</tr>
<tr>
<td>Winter</td>
<td>-0.16 ± 2.23 %</td>
<td>-0.02 ± 2.80 %</td>
<td>-0.84 ± 2.63 %</td>
<td>-0.01 ± 2.47 %</td>
</tr>
<tr>
<td>Spring</td>
<td>-0.03 ± 1.28 %</td>
<td>+0.11 ± 1.83 %</td>
<td>-0.23 ± 2.46 %</td>
<td>-0.03 ± 1.06 %</td>
</tr>
</tbody>
</table>
Snow cover trend of HKH from 2002 to 2010

![Graph showing snow cover area from 2001 to 2011, with peaks in 2005 and 2008, and a notable decrease in 2010.]}
Glaciers selected for monitoring

<table>
<thead>
<tr>
<th>Glacier name</th>
<th>Coordinates</th>
<th>Elevation (m asl)</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yala, Langtang Valley</td>
<td>28°15' N / 85°37' E</td>
<td>5174 – 5746 m</td>
<td>2.8 km²</td>
</tr>
<tr>
<td>Rikha Samba, Hidden Valley</td>
<td>28°50' N / 83°30' E</td>
<td>5250 – 5985 m</td>
<td>4.8 km²</td>
</tr>
</tbody>
</table>

Mass balance measurement training on Yala Glacier, November 2011

Discharge measurements at Langtang Khola, November 2011
Study of Black Soot in glaciers in Tibetan Plateau

Ice core record revealed that black soot concentration increased rapidly during the past 30 years in Southeast Tibetan Plateau.

Ice cores extracted sites:
1. Muztagh Ata
2. Tanggula
3. E. Rongbuk
4. Ningjingkangsang
5. Zuoqiupu

Source: Baiqing Xu et al., 26 October 2010, 2nd TPE Workshop, Kathmandu
International Symposium

Benefiting from Earth Observation

Bridging the Data Gap for Adaptation to Climate Change in the Hindu Kush-Himalayan Region

4 - 6 October 2010, Kathmandu, Nepal

Organised by
ICIMOD

Supported by
USAID, NASA, SERVIR, Sida, GTZ

Collaborating partners

UNEP, Swiss National Foundation, MOST, NDF, UNDP, SDF, UNWTO, UNESCO
Trans-Himalayan Transects and landscape approach
KSLI - Regional Programme with Conservation Focus

China
India
Nepal
River Basin - Emerging Regional Programme

Trans-boundary collaboration in scientific knowledge development and knowledge sharing to support knowledge development, and policy influence for better management of water resources to facilitate adaptation measure (Indus Basin, Koshi Basin)

Abu Dabi Dialogue and South Asia Water Initiative
Himalayan Climate Change Adaptation Programme (HICAP): Preparing Climate Resilient Communities

HICAP - Emerging Regional Programme on Adaptation

Proposed HICAP Working Areas in the HKH Region

Legend:
- Major river
- Upper Brahmaputra sub basin
- Mid Brahmaputra
- Kosi sub basin
- Mahakali-Karnali sub basin
- Mid Salween sub basin
- Upper Indus sub basin
- HKH boundary

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Basin Name</th>
<th>Area (Km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upper Brahmaputra</td>
<td>85,000.55</td>
</tr>
<tr>
<td>2</td>
<td>Mid Brahmaputra</td>
<td>23,070.94</td>
</tr>
<tr>
<td>3</td>
<td>Kosi</td>
<td>26,941.24</td>
</tr>
<tr>
<td>4</td>
<td>Mahakali-Karnali</td>
<td>45,500.13</td>
</tr>
<tr>
<td>5</td>
<td>Mid Salween</td>
<td>16,418.73</td>
</tr>
<tr>
<td>6</td>
<td>Upper Indus</td>
<td>56,762.24</td>
</tr>
</tbody>
</table>
Adaptation - Too Little Water Situation
Example Technological Innovations

**INCREASING AVAILABILITY**
- Increasing infiltration
- Water harvesting
- Drinking Water supply

**IMPROVING WATER USE EFFICIENCY**
- Irrigation methods
  - Drip irrigation
  - Sprinkler irrigation
  - Pitcher irrigation
  - SRI (System of Rice Intensification)
• Establishment of a Regional Flood Information System in the HKH (HKH-HYCOS)

• Climate Impacts on Snow, Glaciers and Hydrology in the Himalayan Region (HIMALA)

• Trans-boundary collaboration in scientific knowledge development and knowledge sharing to support knowledge development, and policy influence for better management of water resources to facilitate adaptation measure (Indus Basin, Koshi Basin)

• Regional Programme on Reducing the Impacts of Black Carbon and other Short-Lived Climate Forcers
Regional Cryosphere Knowledge Hub

International Conference on Cryosphere of the Hindu Kush-Himalayas: State of the Knowledge

14 – 16 May 2012
ICIMOD, Kathmandu

With the support of
Norwegian Ministry of Foreign Affairs through the Royal Norwegian Embassy in Kathmandu and
Regional Environment Office – South Asia, US Embassy in Kathmandu

Platform for exchange or sharing of knowledge on cryosphere monitoring from the region and beyond.
The conference will host scientists, policymakers, practitioners interested or working in cryospheric science such as glaciers mapping, glacier mass balance monitoring, remote sensing based observation system for snow and glaciers etc. as well as hydro-meteorology monitoring and modelling for assessment of current and future water resources in relation to cryospheric research.

It is anticipated that this event will contribute significantly in strengthening the exchange of knowledge, enhance the cooperation in cryosphere monitoring and modelling for assessment of current and future water resources in relation to cryospheric research.

It is anticipated that this event will contribute significantly in strengthening the exchange of knowledge, enhance the cooperation in cryosphere monitoring and promote the regional efforts to better understand the cryosphere of the HKH region.
INDIA
- Glacier Research Unit in Wadia Institute of Himalayan Geology and Environment, Dehradun
- Divecha Center for Climate Change, Centre for Atmospheric & Oceanic Sciences, Indian Institute of Science, Bangalore
- G.B.Pant Institute of Himalayan Environment and Development, Almora
- Glacier Division, Water Resources and Policy Management Division, The Energy and Resources Institute, New Delhi
- Sharda University, Greater Noida
- Jawaharlal Nehru University, New Delhi
- Snow and Avalanche Study Establishment, Chandigarh
- National Institute of Hydrology

PAKISTAN
- WAPDA
- Pakistan Meteorological Department
- Global Change Impact Studies Centre (GCISC)
- Center of Excellence Geology, Peshawar University

AFGHANISTAN
- Faculty of Geosciences, Kabul University

BHUTAN
- Department of Hydrology and Meteorology
- Department of Geology and Mines

CHINA
- Cold and Arid Regions Environmental and Engineering Research Institute, Lanzhou
- Institute of Tibetan Plateau Research, Beijing
- CMA, Beijing
- Institute of Mountain Hazards and Environment, Chengdu

MYANMAR
- Department of Meteorology and Hydrology, Ministry of Transport, Yangon, Myanmar

NEPAL
- DHM, TU, KU, WECS

Beyond ICIMOD Regional Member Countries
- North America, Europe, Japan, South America, ...
Hindu Kush - Himalayan Cryosphere Data Sharing Policy Workshop

17 - 18 May 2012

ICIMOD, Kathmandu
Regional training on glacier mass balance

Mountaineering safety and mass-balance (theoretical) training in Kathmandu, 26 – 28 April 2012

Glacier mass balance field training and glacio-hydrological short-term intensive field work in the Yala Glacier in Langtang Valley in Nepal, 29 April – 13 May 2012

(Afghanistan-1, Bhutan-2, China-2, India-2, Myanmar-1, Pakistan-2, (+4 MSc students from Nepal)
Glacio-hydrology Training Course for Nepalese organizations/institutes

15 May – 19 May 2012
Kathmandu
Thank you

www.icimod.org