Impact of climate change on glacier dependent Himalayan river basins

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ICIMOD

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Outline

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How climate is changing in the HKH region?

Changes in glaciers

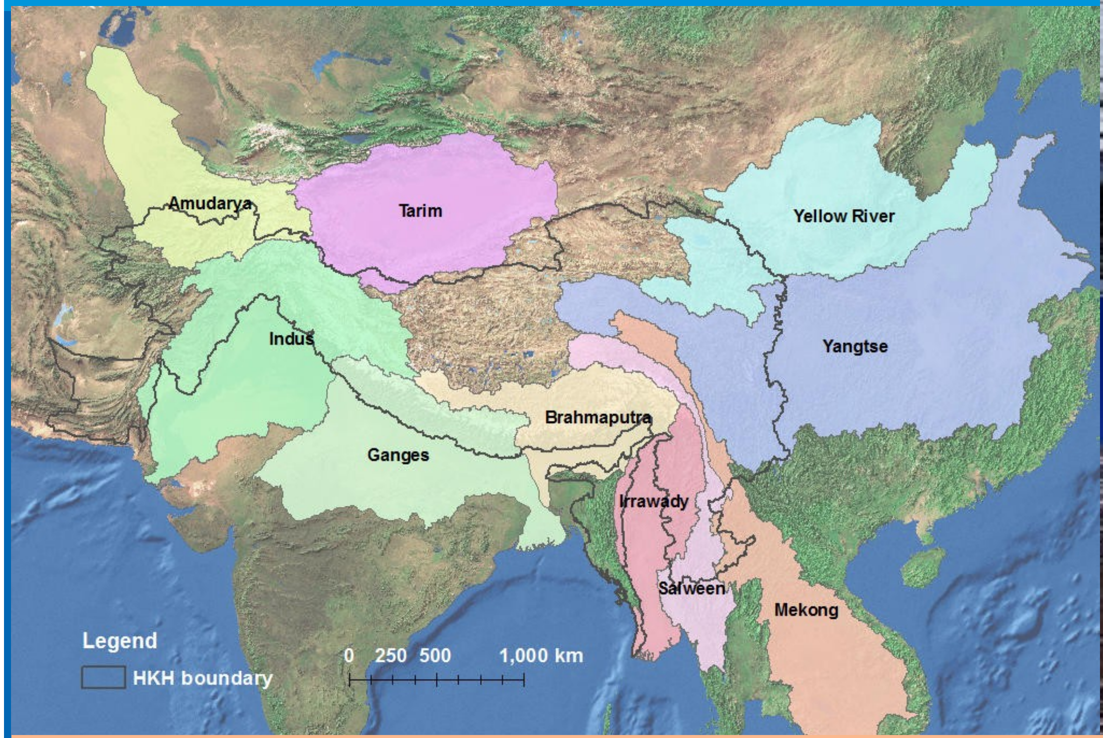
Present hydrology

Future Hydrology

Impact on hydrological regime

GLOF risk

Hindu Kush Himalayan region



The 10 river basins provide services to about 1.3 billion people

Widespread increasing temperature trend in the Himalayan region

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Indus Basin:

- Increase in winter mean and maximum (Fowler and Archer, 2005)
- Decrease in summer mean and minimum (Fowler and Archer, 2005)
- Increase in winter maximum (Khattak, 2011)
- Decrease in minimum temperature (khattak, 2011)

Nepal

- Maximum temperature trend of 0.06 ^{o}C/year in Nepal (Shrestha et al. 1999)
- Increasing maximum temperature of 0.058 oC/year trend in eastern Nepal (Nepal 2016)
- Increasing trend (Tmax and Tmin) in Western Nepal (Khatiwada, et al. 2016)
- Significant Tmax trend of 0.08 ^{o}C/year during pre-monsoon season (Khatiwada, et al. 2016)

Brahmaputra

- Increase in average annual temperature of 0.28^{o}C/decade (Flugel, 2008)
- Increase in temperature of 0.6 ^{o}C in last 100 years (Immerzeel, 2008)

Mountains are highly vulnerable

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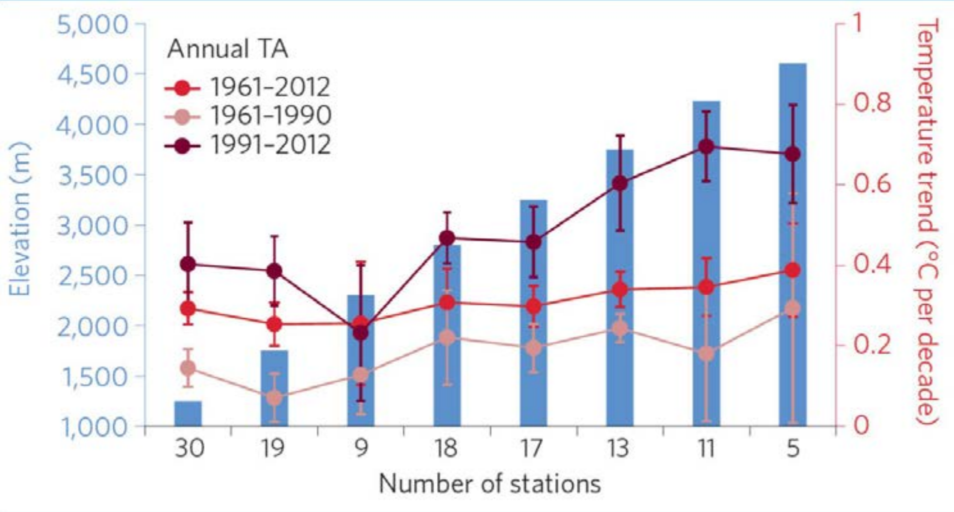
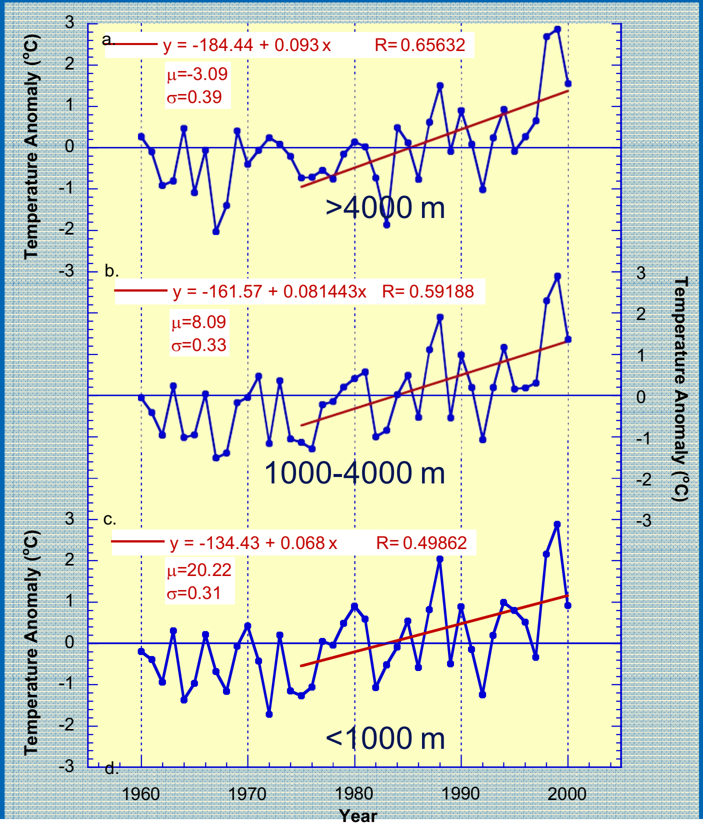
Elevation-dependent warming



EDW Working Group, MRD (2015)

Tibetan Plateau

HKH



Shrestha et al. 2009

Climate Projections: 2021-2050

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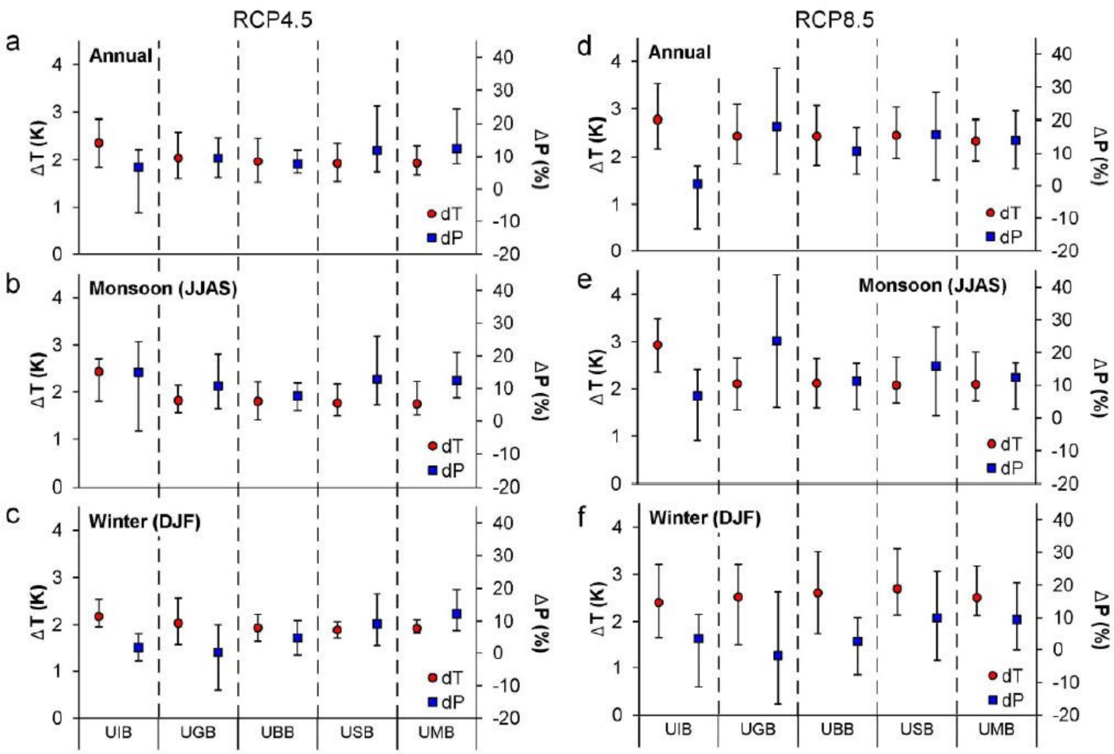
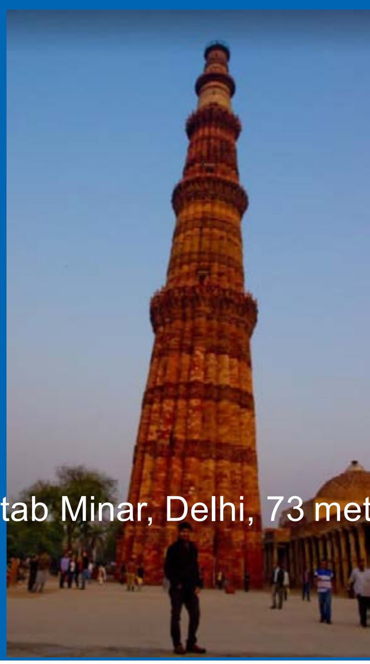


Projected changes in temperature (ΔT, red circles) and precipitation (ΔP, blue squares) for 2021-2050 with respect to 1961-1990 per basin for RCP4.5 (left panels) and RCP8.5 (right panels).

Lutz et al., 2014

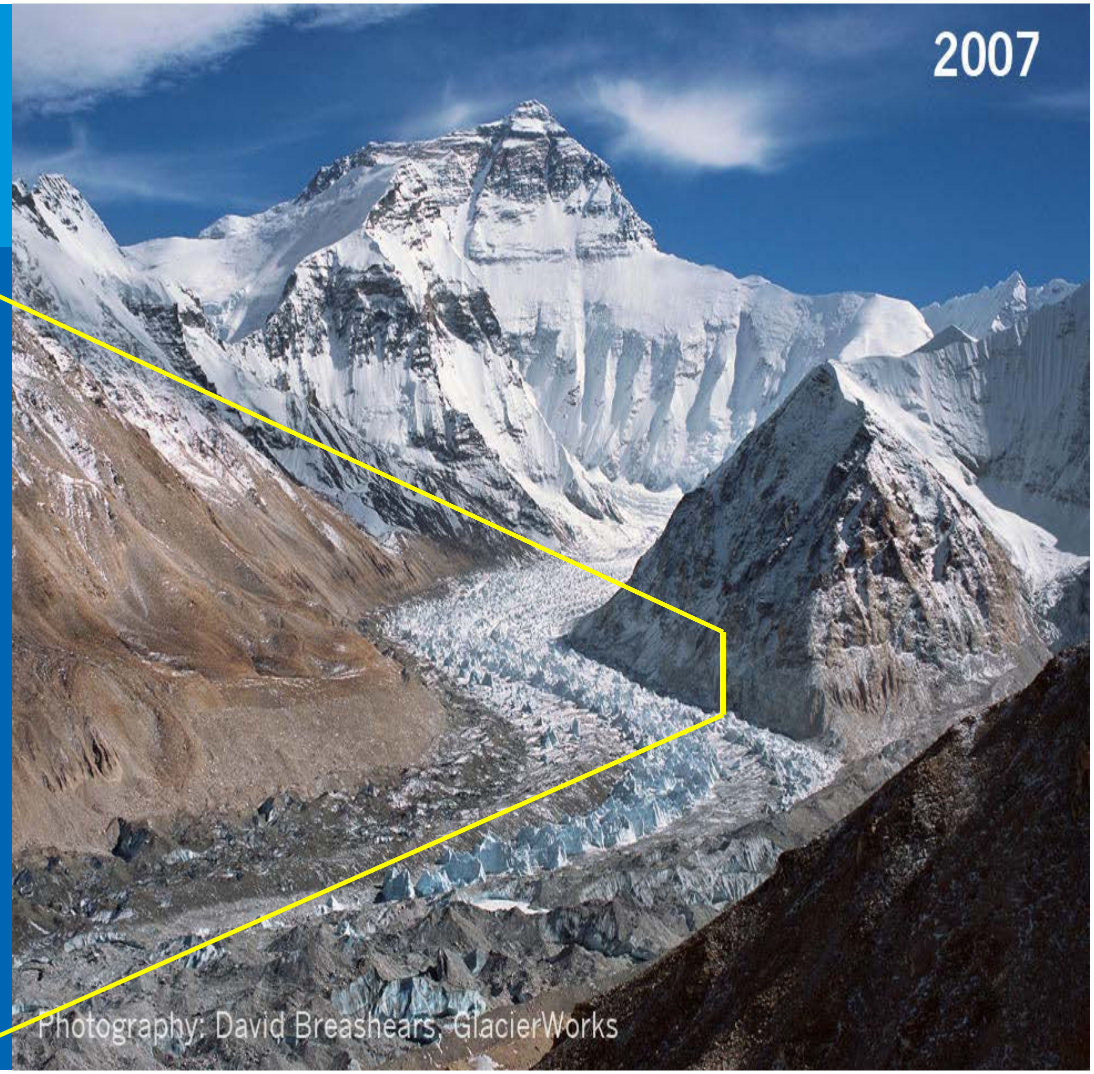
- Temperature:
  - Increase for all basins, all GCMs
- Precipitation:
  - Large uncertainty, increase for UGB, UBB, USB, UMB

Changes in glaciers



Qutab Minar, Delhi, 73 meter

Equivalent to 100 meter



Glaciers are shrinking

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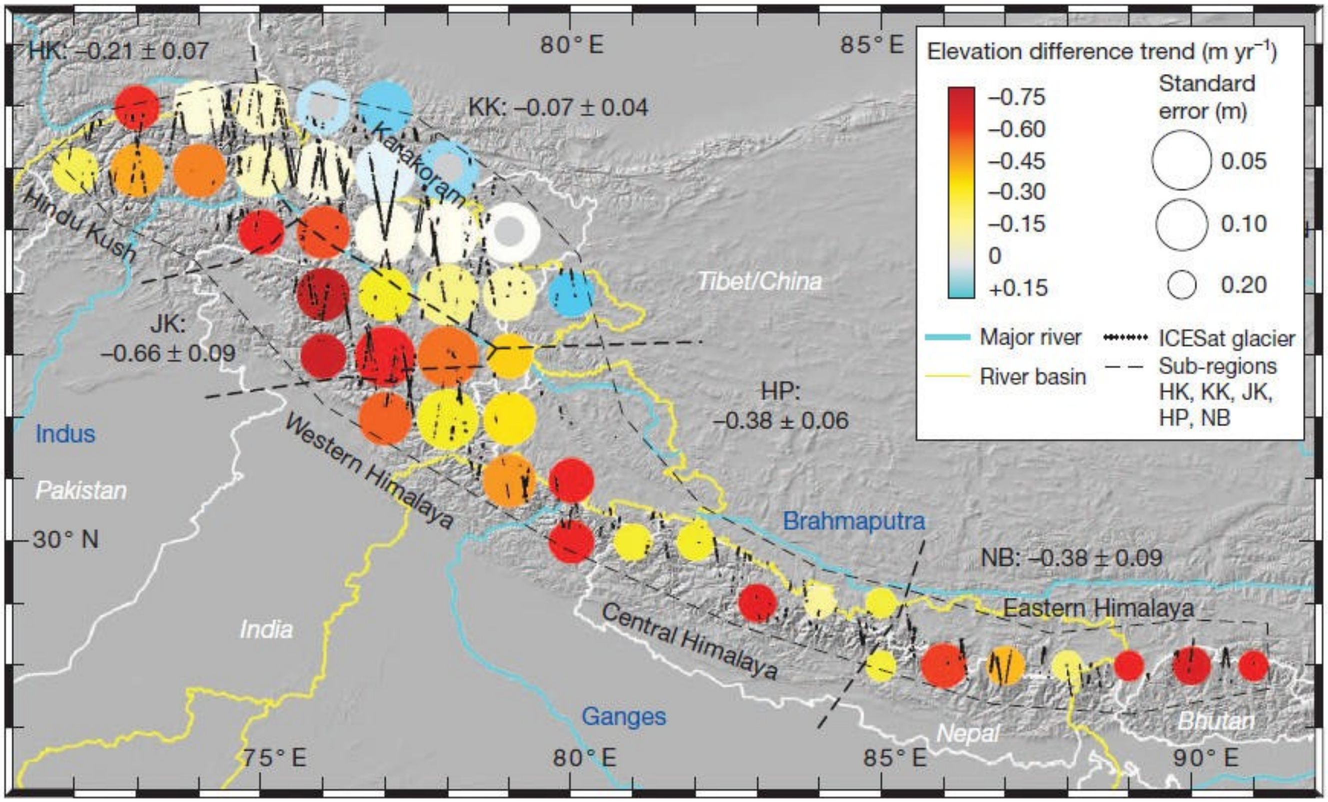
- The 2003–08 specific mass balance for the entire HKKH study region was -0.21 ± 0.05 m yr^{-1}
- Maximal regional thinning rates were 0.66 ± 0.09 metres per year in the Jammu–Kashmir region

Kääb et al. 2012, Nature



23% loss of glacier area in Bhutan from 1980 to 2010

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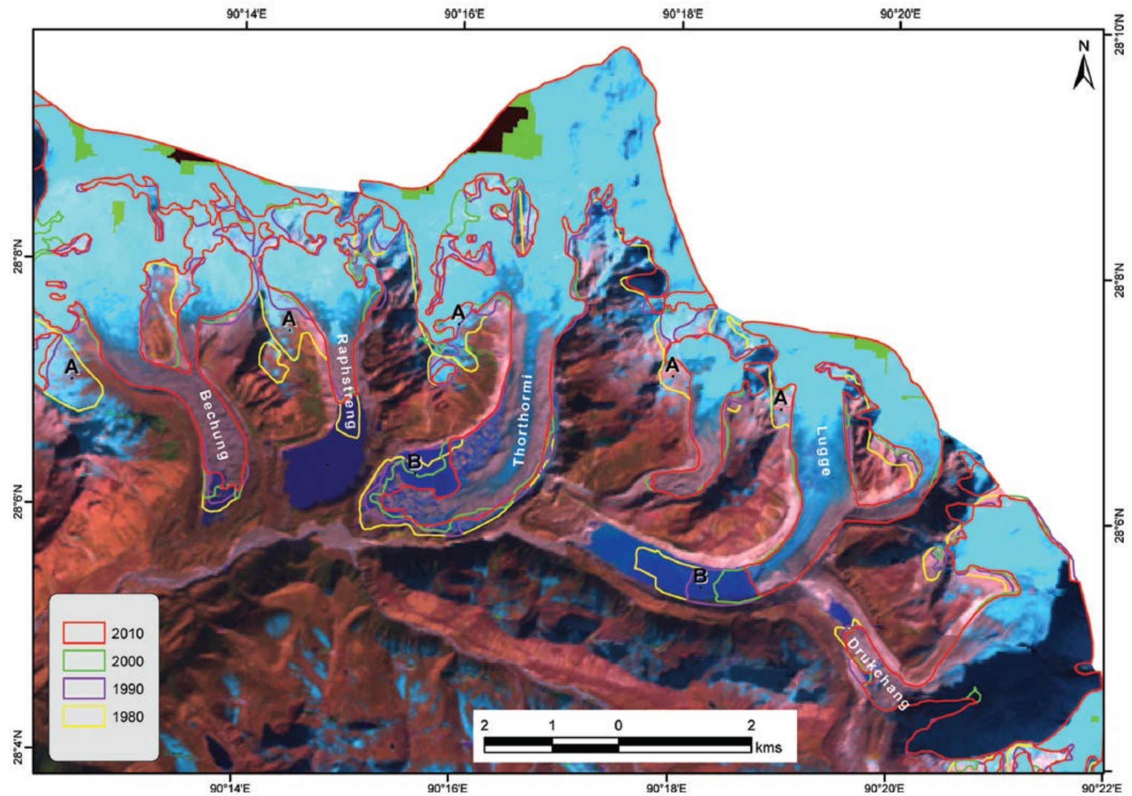

Glacier area decreased from 757 (in 1980) to 550 (in 2010) km^2

(Bajracharya et al. 2014, ICIMOD)

25% decrease in glacier area in Nepal

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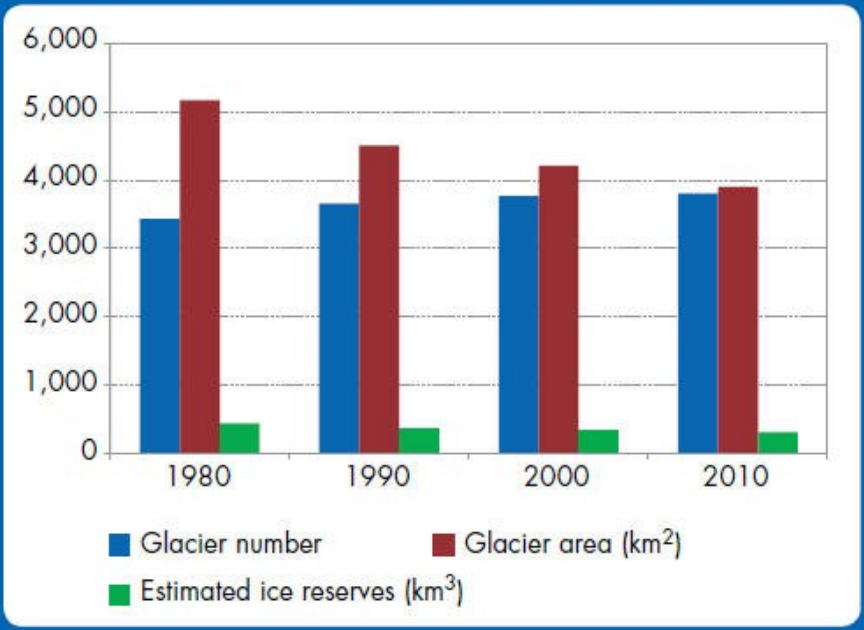
Figure 4.1: Glacier number, area, and estimated ice reserves in Nepal in ~1980, 1990, 2000, and 2010



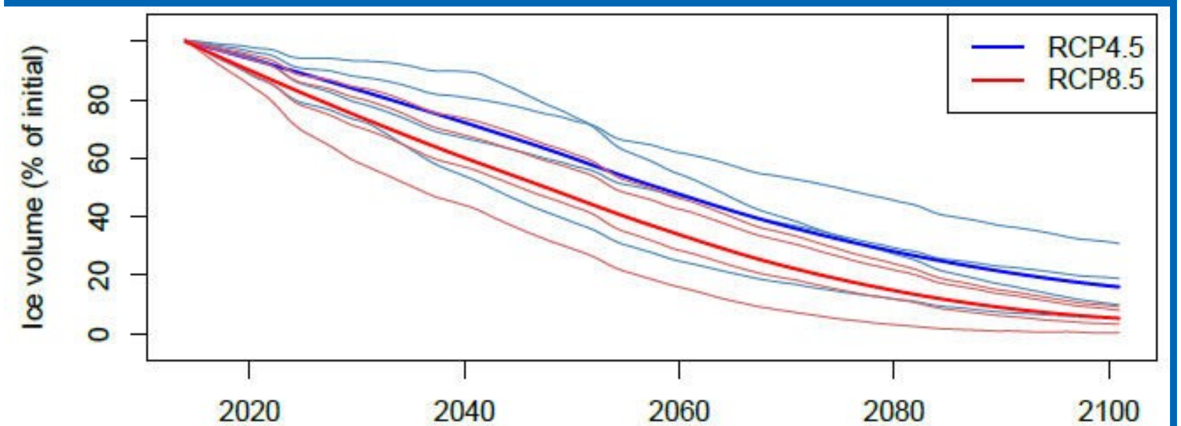
- Glacier area decreased from
  - ~1980: 5168 km^2
  - 2010: 3902 (25%)
- Glacier number increased from
  - ~1980: 3430
  - 2010: 3808 (11%)

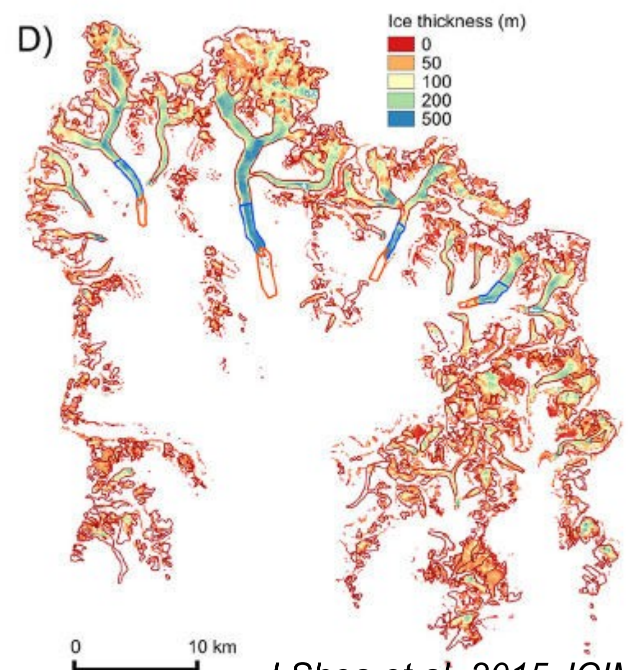
(Bajracharya et al. 2014, ICIMOD)

Changes in glacier ice volume in Everest region

- Glaciers in the region appear to be highly sensitive to changes in temperature
- Future climate scenarios result sustained mass loss from glaciers

What is the impact on flows downstream?





J Shea et al. 2015, ICIMOD

Glacial lakes in Nepal

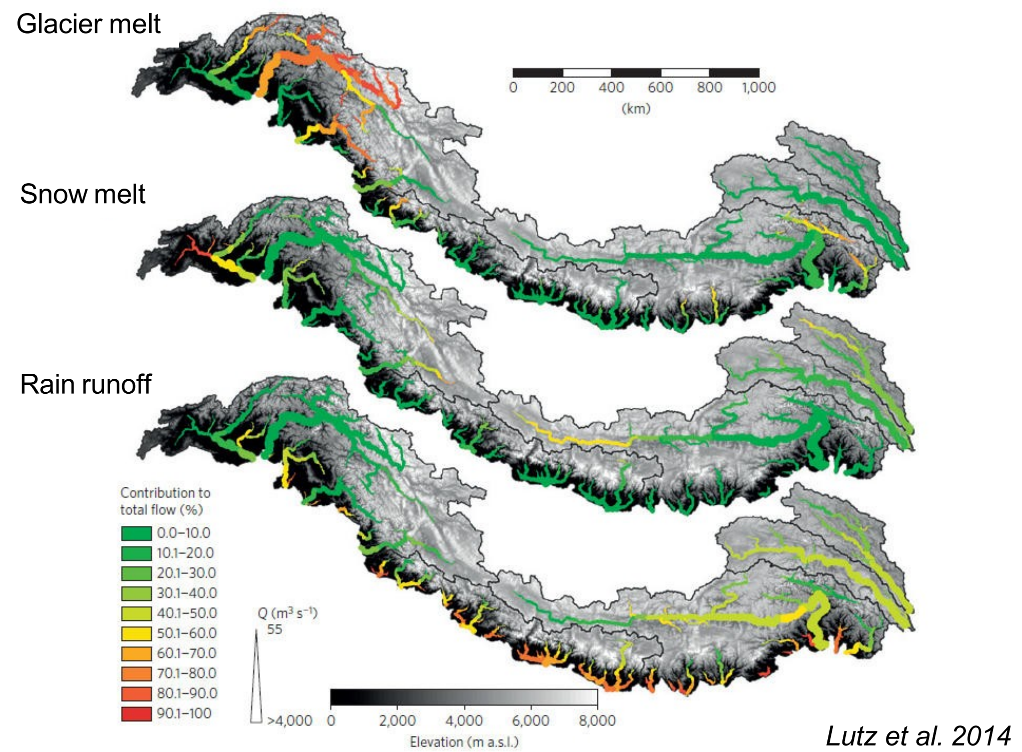
Glacial lake reduced from 2323 in 2001 to 1466 in 2009

- 37% reduction in number
- 14% reduction in area

21 potentially dangerous

ICIMOD, 2011

Present hydrology of the HKH rivers



Lutz et al. 2014

Figure 3 | Contribution to total flow by flow components in major streams. a–c, Contribution to total flow by glacier melt (**a**), snow melt (**b**) and rainfall runoff (**c**) for major streams during the reference period (1998–2007). Line thickness indicates the average discharge (Q) during the reference period.

Basin	Contribution to total runoff (%)			
	Glacier melt	Snow runoff	Rainfall- flow 41 22	Base melt 27
UIB		10		
UGB	12	9	66	13
UBB	16	10	59	15

- **Indus:** Glacier melt dominates including flow peak during the summer season
- **Brahamputra:** glacier melt is important for the most eastern tributaries
- **Ganges:** Rain runoff dominates the streamflow

Shrestha et al. 2015, ICIMOD

Present hydrology: seasonal melt contribution is important: Dudh Koshi river basin, eastern Nepal

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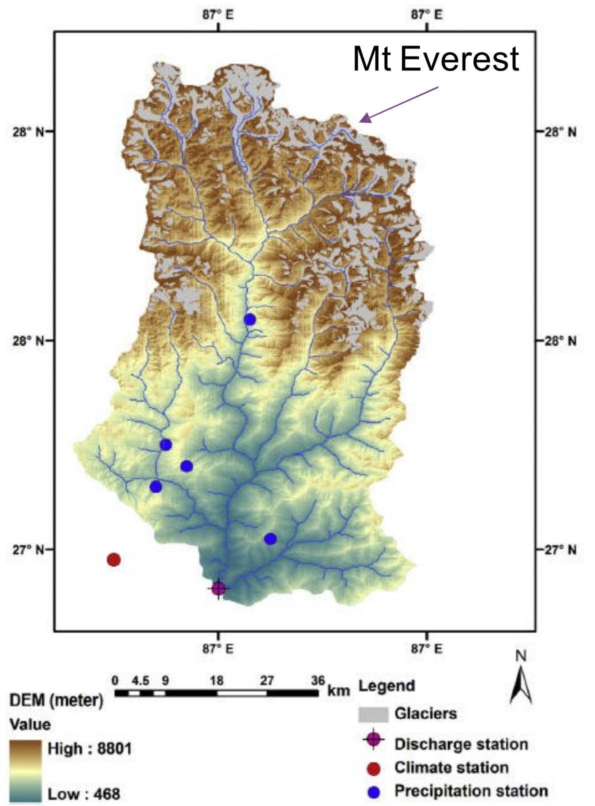
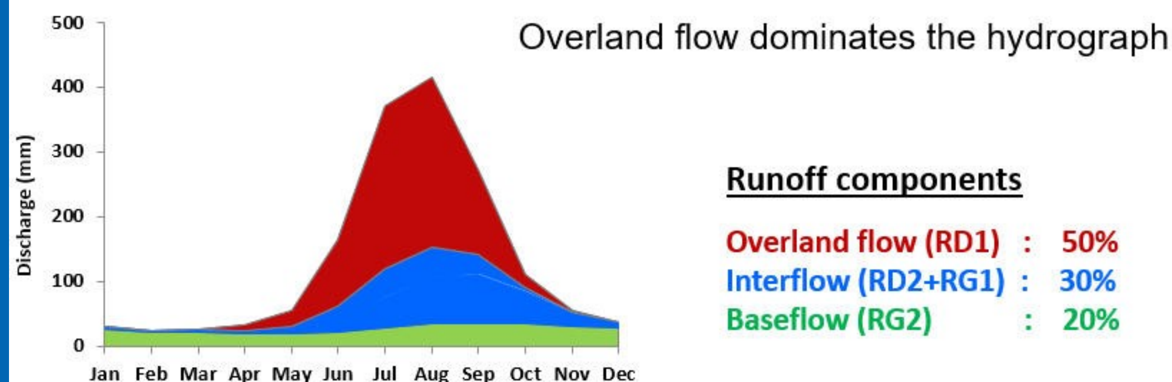
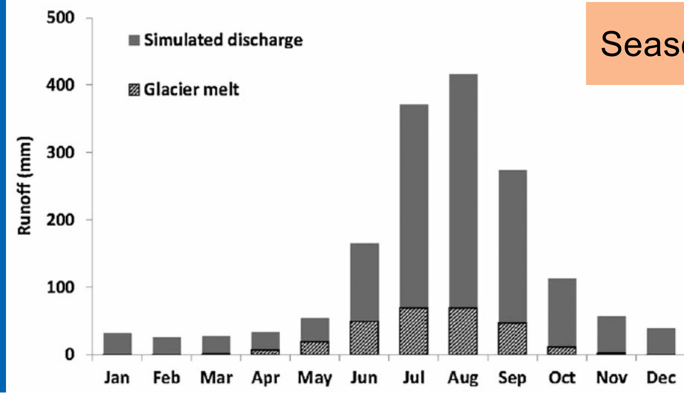




Runoff components

Overland flow (RD1) : 50%
Interflow (RD2+RG1) : 30%
Baseflow (RG2) : 20%



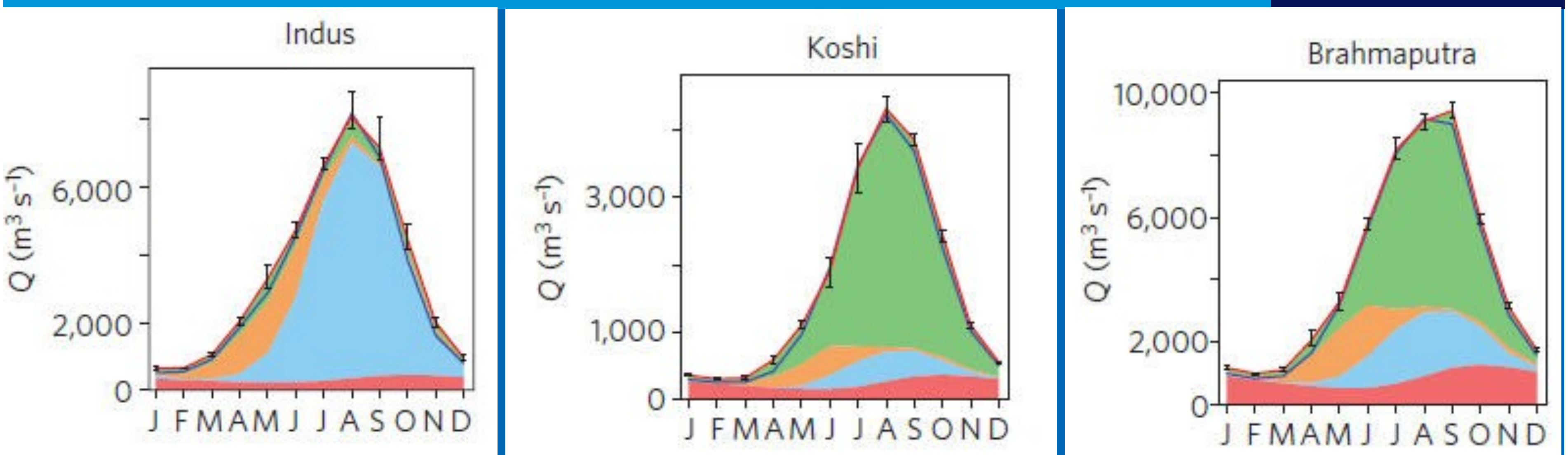
Seasonal contribution is important

Glacier melt contribution to total discharge 17%

- Snowmelt, Icemelt and rain-runoff

Nepal et al. 2014

Future hydrology



- Increase in runoff at least 2050
  - Due to increase in precipitation in UGB and UBB
  - Due to accelerated melt in UIB
- Large uncertainty in precipitation projection

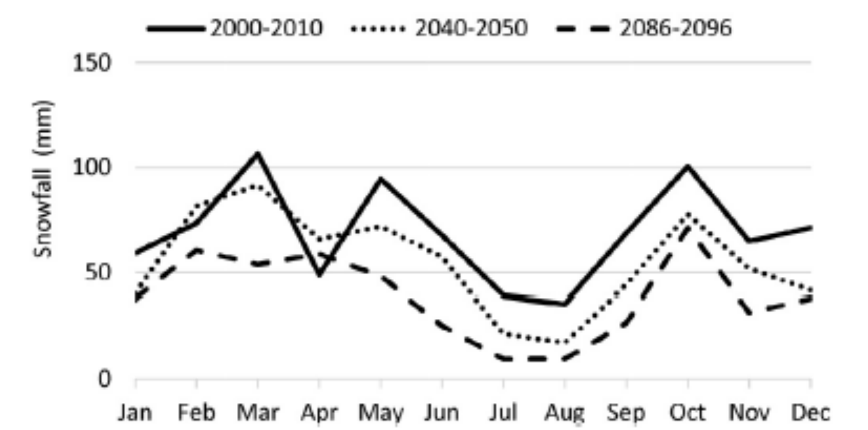
Average annual hydrographs for the future period (2041–2050, RCP4.5)

—Mean Q reference period (1998-2007)
—Mean Q 2041-2050 (mean of 4 GCMs)
Rainfall-runoff
Snow melt
Glacier melt
Base flow

Lutz et al. 2014

Impact on snowfall and snowmelt

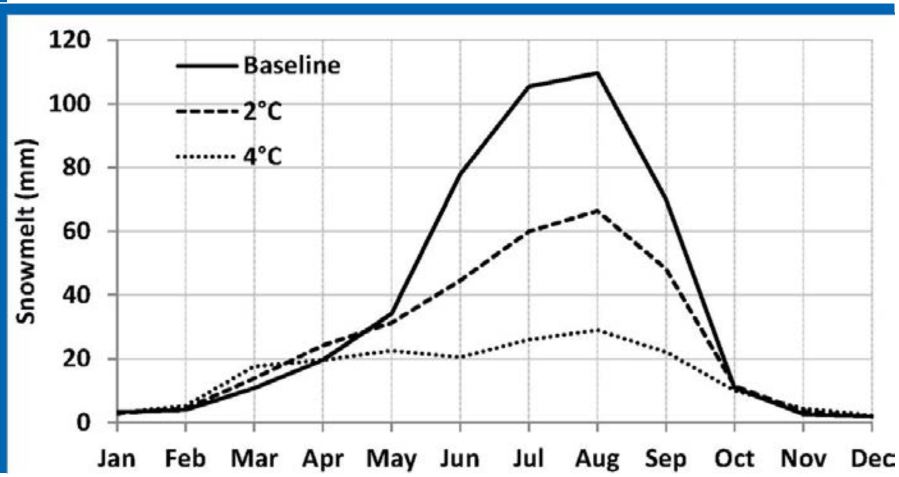
Dudh Koshi basin,



Snowfall pattern, results from PRECIS RCM

- Reduction in snowfall due to rise in temperature (~4°C by 2096)
- Snowfall is projected to decrease by 20
- and 43% in the mid- and late-century

Nepal, 2016, ICIMOD



Snowmelt pattern:

- Decrease in snowmelt by 31% (+2°C) and 60% (+4°C)
- Changing from a ‘melt-dominated river‘ to a ‘rain-dominated river‘

Nepal, et al. 2014, ICIMOD

Disaster risk increasing with more extreme events

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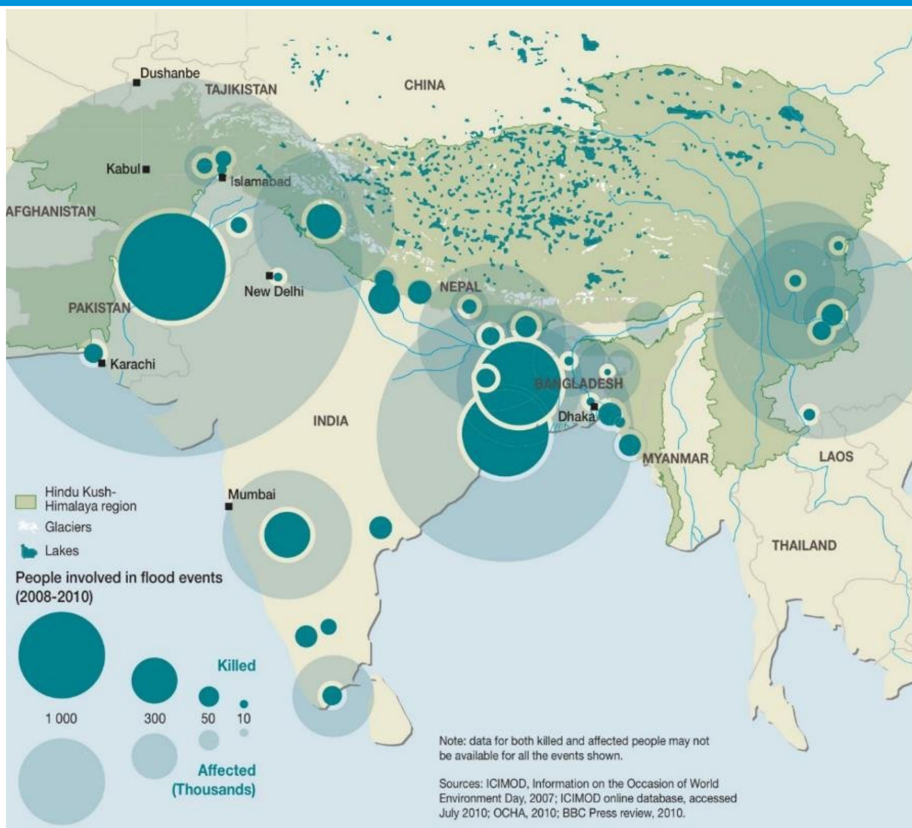

Big unknown: understanding hydrological extreme and seasonal shifts?

Impact of earthquake on hydropower

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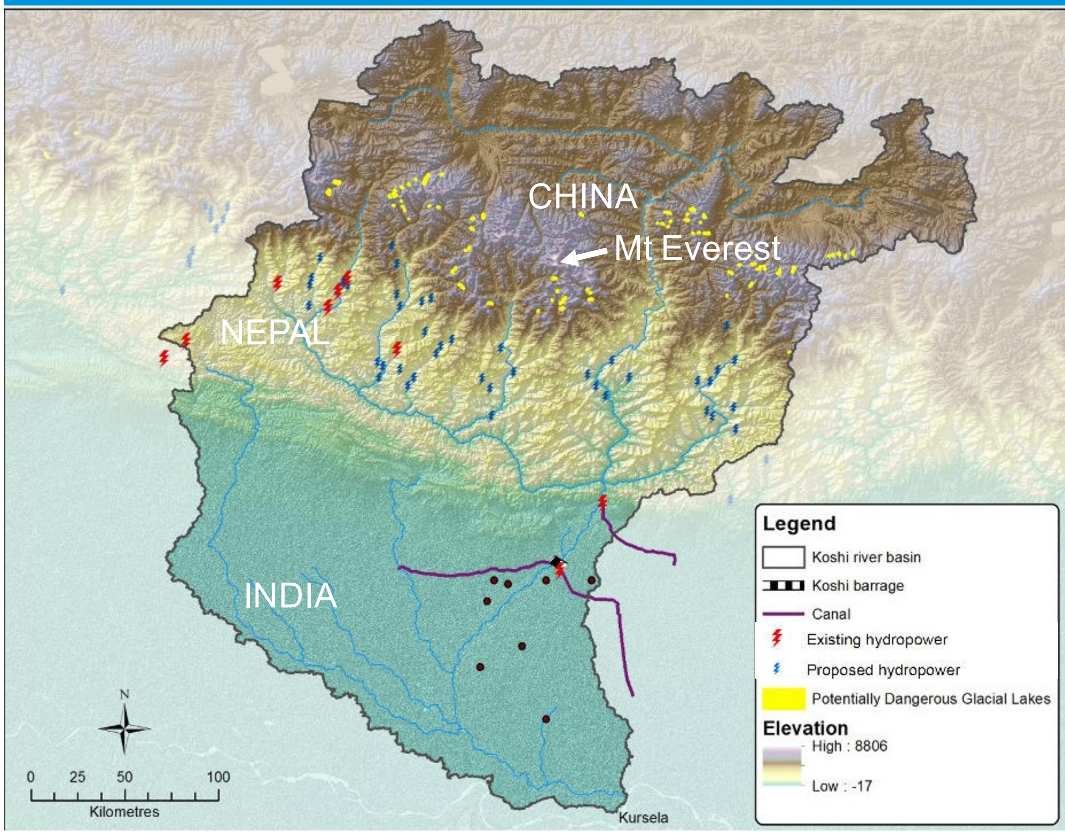
Nepal Earthquake Damages At Least 14 Hydropower Dams

May 5, 2015 / in Hydropower, South Asia, Water News / by Keith Schneider

Nation's power grid loses more than 30 percent of generating capacity.

www.circleofblue.org/2015/world/nepal-earthquake-damages-at-least-14-hydropower-dams/arly

Hydropower development in Koshi river basin



- Huge potential for hydropower in Koshi
- 214 MW from 7 hydropower (37% of total Nepal)
- 50 large hydropower projects have identified (JICA 1985)
- Potential risk from GLOF and climate change?

Data Source: Koshi Basin Information System, ICIMOD

GLOF poses risk to hydropower

Example: Tampokhari GLOF event in 1998

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Breached portion of moraine dam at Tam Pokhari glacial lake,
Source: Osti, et al. 2009

Existing and proposed hydropowers are at risk due to potential GLOF:

Other risk

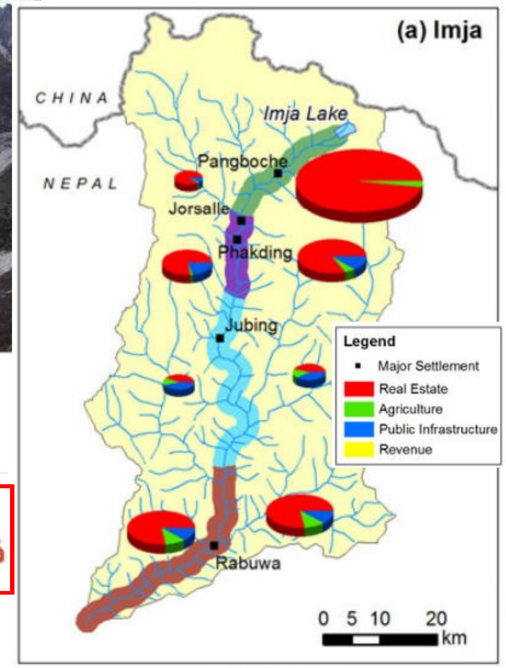
- Landslide and earthquake
- Floods and flash floods

Dudh Koshi (3 September, 1998 – Tam Pokhari Lake)

This GLOF was triggered when an ice avalanche hit the frontal lake and induced a surge wave which overtopped the end moraine dam. There is a brief report which indicates that lives were lost and that NRs 156 million in damage was incurred (about 2 million US$) (Dwivedi et al. 1999).

GLOF risk assessment

- Based on the study on four glacial lakes
  - People living in the downstream areas are at risk from GLOFs
  - Lives, property and infrastructure area at risk
  - Inaction or delay could result in huge loss of life, economic and environmental damage
  - Cost of Imja GLOF could be about 11.80 M USD



Estimated damage (US$)

11,894,000 — Imja Lake (Dudh Koshi B)

1,847,000 — Tsho Rolpa Lake (Tama Koshi B.)

Number of HH at risk

1,075 — Imja Lake (Dudh Koshi B)

422 — Tsho Rolpa Lake (Tama Koshi B.)

Number of Houses at risk

445 — Imja Lake (Dudh Koshi B)

145 — Tsho Rolpa Lake (Tama Koshi B.)

Khanal, 2015, ICIMOD

Summary

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Present understanding

- Glaciers are shrinking in general
- Glaciers play an important role in hydrology of the Himalayan river basin
- The seasonal contribution of melt runoff is more important
- Runoff is likely to increase at least until 2050 in major river basin
- Large uncertainty in precipitation projections
- GLOF poses threat to downstream communities (lives, agri, hydropower)

Major gaps to be address

- Understanding better roles of snow cover and permafrost
- High altitude precipitation, including estimation of future precipitation
- Uncertainty in climate projections
- Interlinkages between cryosphere – atmosphere – monsoon - hydrology
- Understanding the extremes and seasonal shift
- Adaptation under uncertainties

Thank you

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Photo: Santosh Nepal

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