The changing Himalayan Cryosphere and likely consequences: an overview (GFCS)

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HKH Cryosphere Component

Snow

- SWE, depth, extent, state, density, snowfall, solid precipitation, albedo
- in-situ climate & synoptic (manual, auto), weather radar, remote sensing

Lake and River

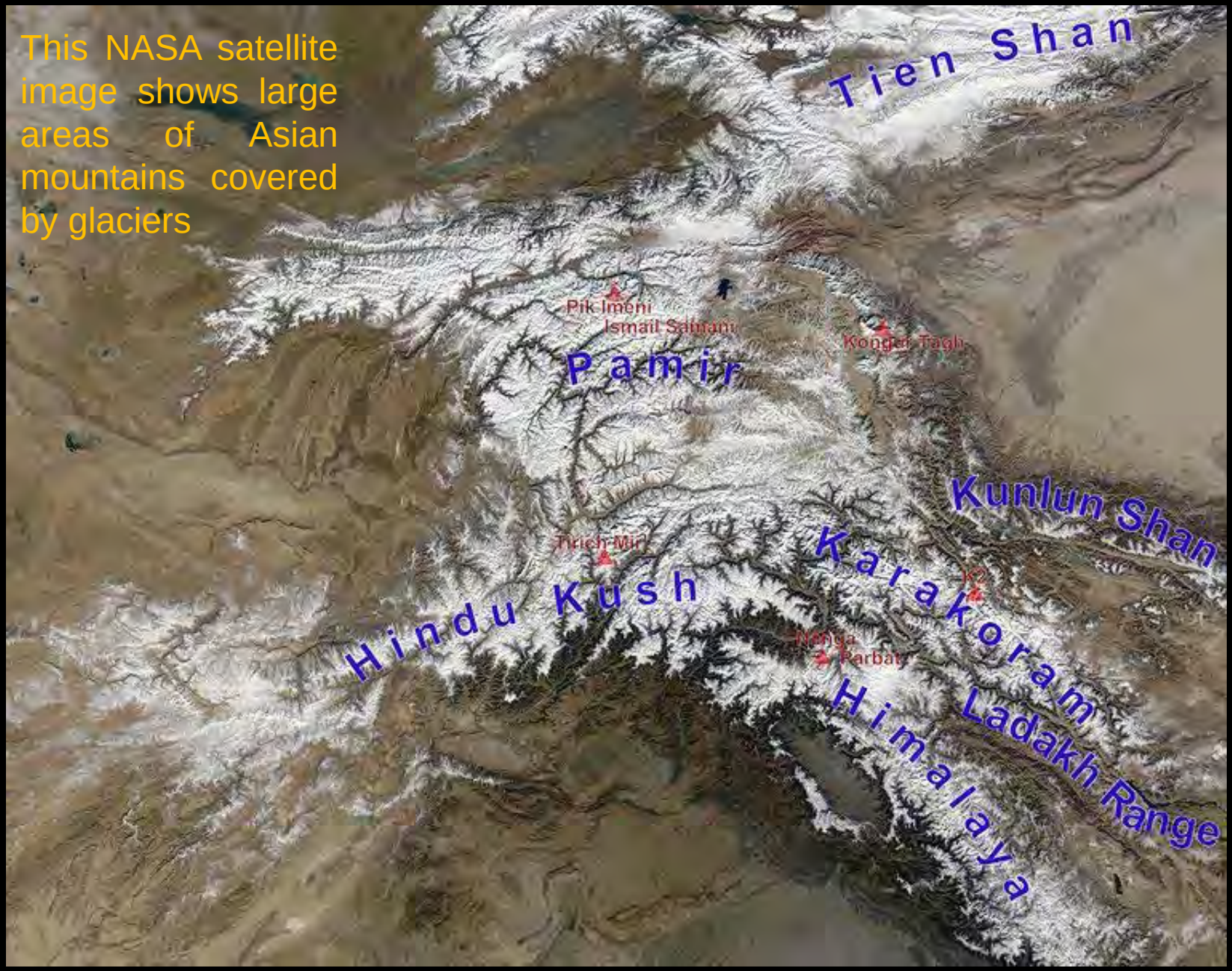
- *Reservoirs, Discharge, snow/ice melt contribution, GLOF*
- in-situ , remote sensing

Glaciers

- mass balance (accumulation/ablation), thickness, area, length (geometry), firn temperature, snowline/equilibrium line, snow on ice
- ground-based (in-situ), remote sensing

Frozen Ground/Permafrost

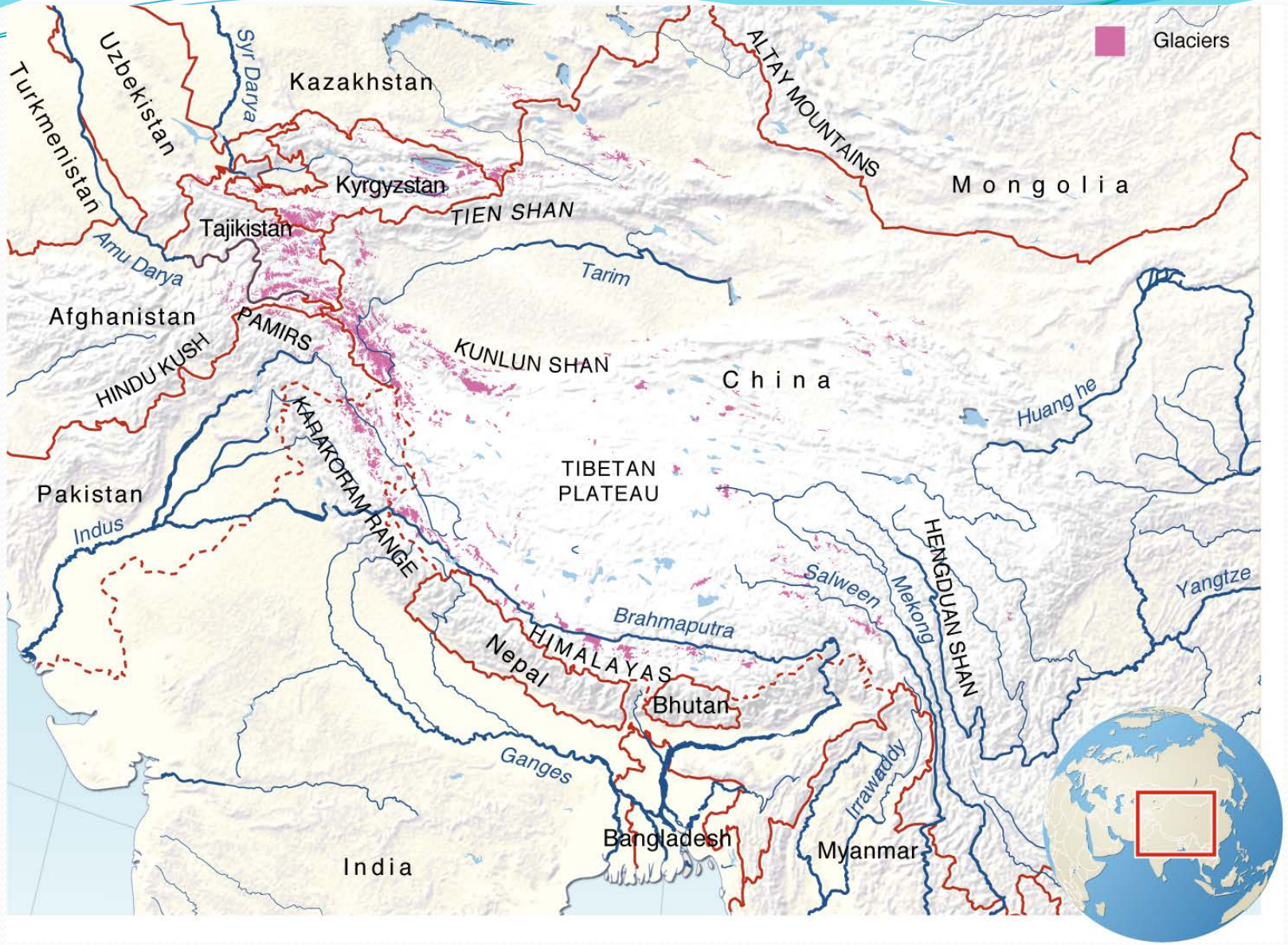
- soil temperature/thermal state, active layer thickness, borehole temperature, extent, snow cover
- in-situ (manual, auto), remote sensing (new)



http://commons.wikimedia.org/wiki/File:High_Asia_Mountain_Ranges.jpg?uselang=en-gb NASA/Rupert Pupkin

Background

- The Hindu Kush Himalayan (HKH) region, often referred to as the Third Pole, contains the world's greatest areal extent and volume of permanent ice and permafrost outside the polar regions.
- The Hindu-Kush Karakoram Himalaya (HKH), covering a glacierized area of ◆40 000 km^2 (Bolch and others, 2012),
- This vast accumulation of snow and glaciers acts as a natural water reserve, which serves as a water source for approximately 2.0 billion inhabitants in the 10 major Asian river basins downstream.



Nearly all the great rivers of Asia begin in the High Mountain of Asia

Shares of national populations living in HKH region water basins

Country	Basin	Population in Basin[a]	National Population[b]	Share of National Population Living in Basins
Afghanistan	Indus	10,636,154	31,412,000	33.9%
Bangladesh	Gang/Brahm	103,326,928	148,692,000	69.5%
Bhutan	Gang/Brahm	699,847	726,000	96.4%
China	Gang/Brahm	1,712,145	1,348,932,000	0.13%
	Indus	35,585		
India	Gang/Brahm	466,738,395	1,224,614,000	38.1%
	Indus	36,074,708		
Nepal	Gang/Brahm	28,951,851	29,959,000	96.6%
Pakistan	Indus	148,104,460	173,593,000	85.3%

[a] Landscan (2010)
[b] United Nations (2011a)

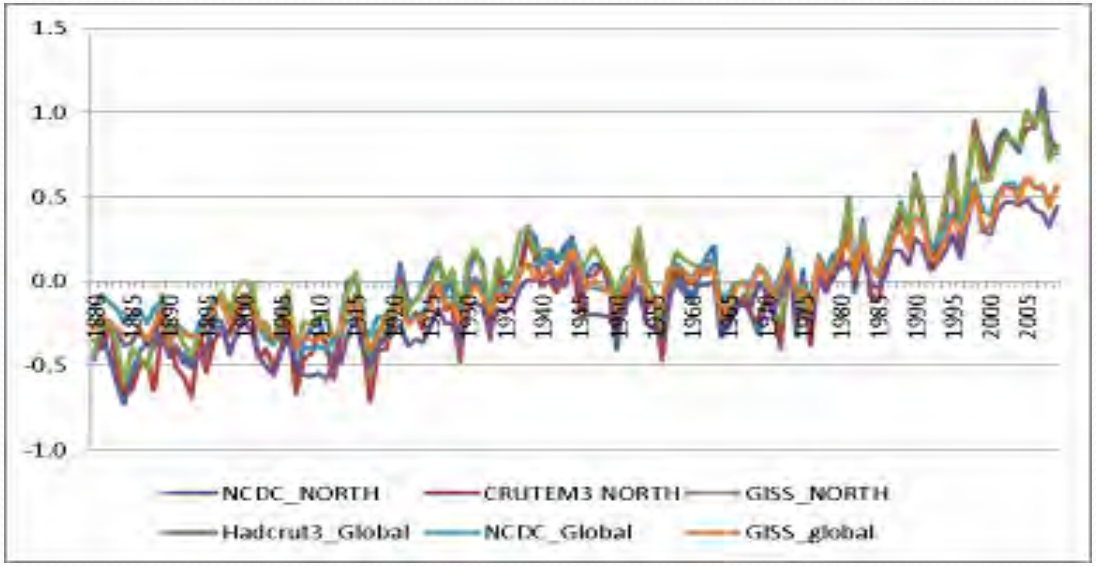
The Himalayan cryosphere is a critically important component of the earth system, affecting the energy balance, atmospheric circulation, freshwater storage, the storage, and release of large quantities of greenhouse gases, economy, infrastructure, health, and indigenous and non-indigenous livelihoods, culture and identity.

Following components of the Himalayan Cryosphere are subjected to dramatic change due to global warming:

- Climate
- Snow /Ice
- Water
- Permafrost

Change in Climate:

recent paleo-reconstructions show that current Himalayan summer temperatures are higher than at any time in the past 2000 years

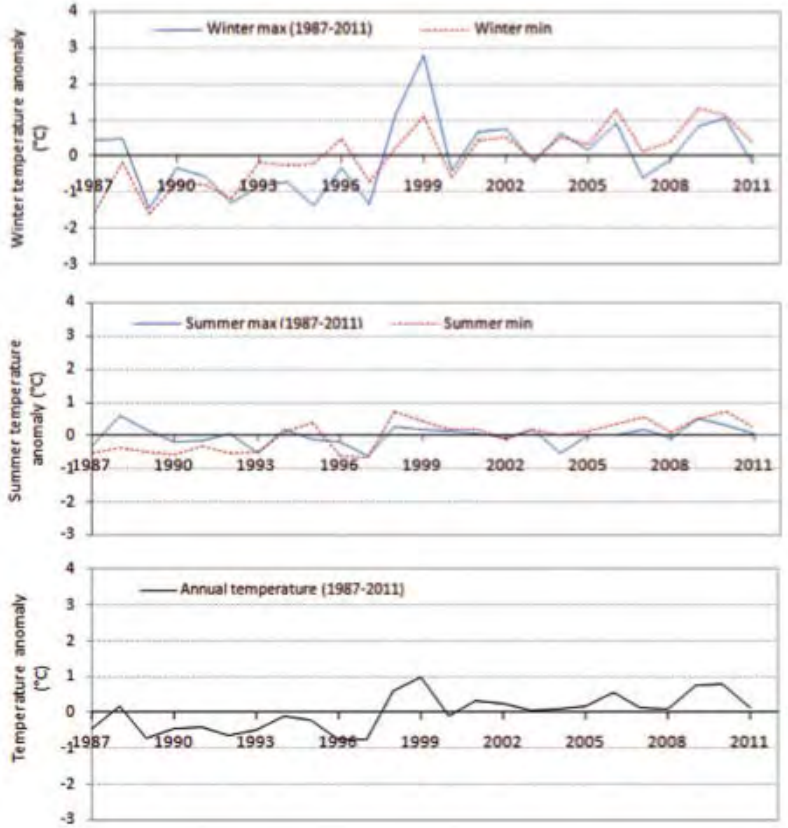


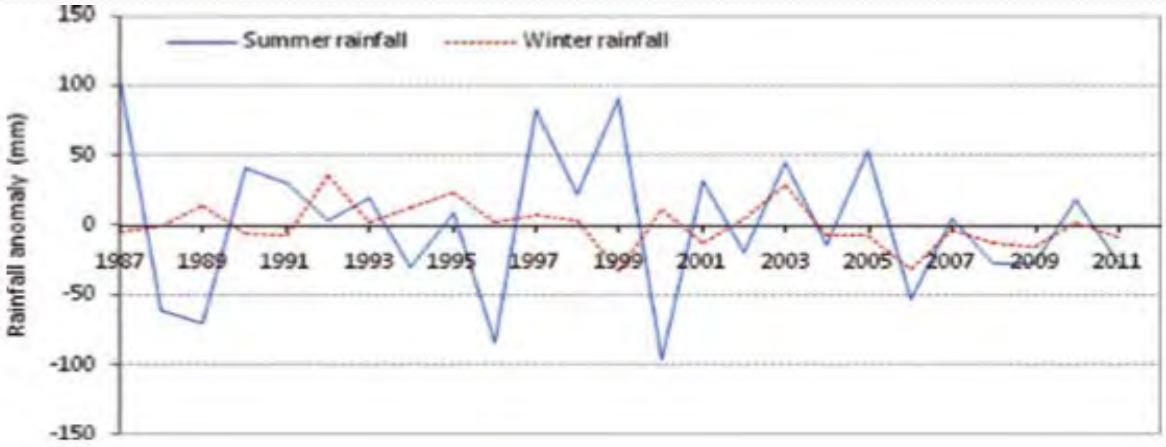
Temperature rise per decade (°C 10 y^{-1})		
	Global	**North**
since 1901	0.07	0.08
since1960	0.13	0.24
Absolute temperature rise (°C)		
	Global	**North**
since 1901	0.75	0.89
since1960	0.63	1.12

North Hemisphere warming is now 0.24 °C decade^{-1} since 1960, the double than the Global warming (0.13 °C decade^{-1}).

- Temperature and precipitation trends Himalaya during 1987-2011

- Summer and winter temperature have significantly increase during last few decades
- Reduction in summer and winter precipitation are not statistically significant however trend is negative



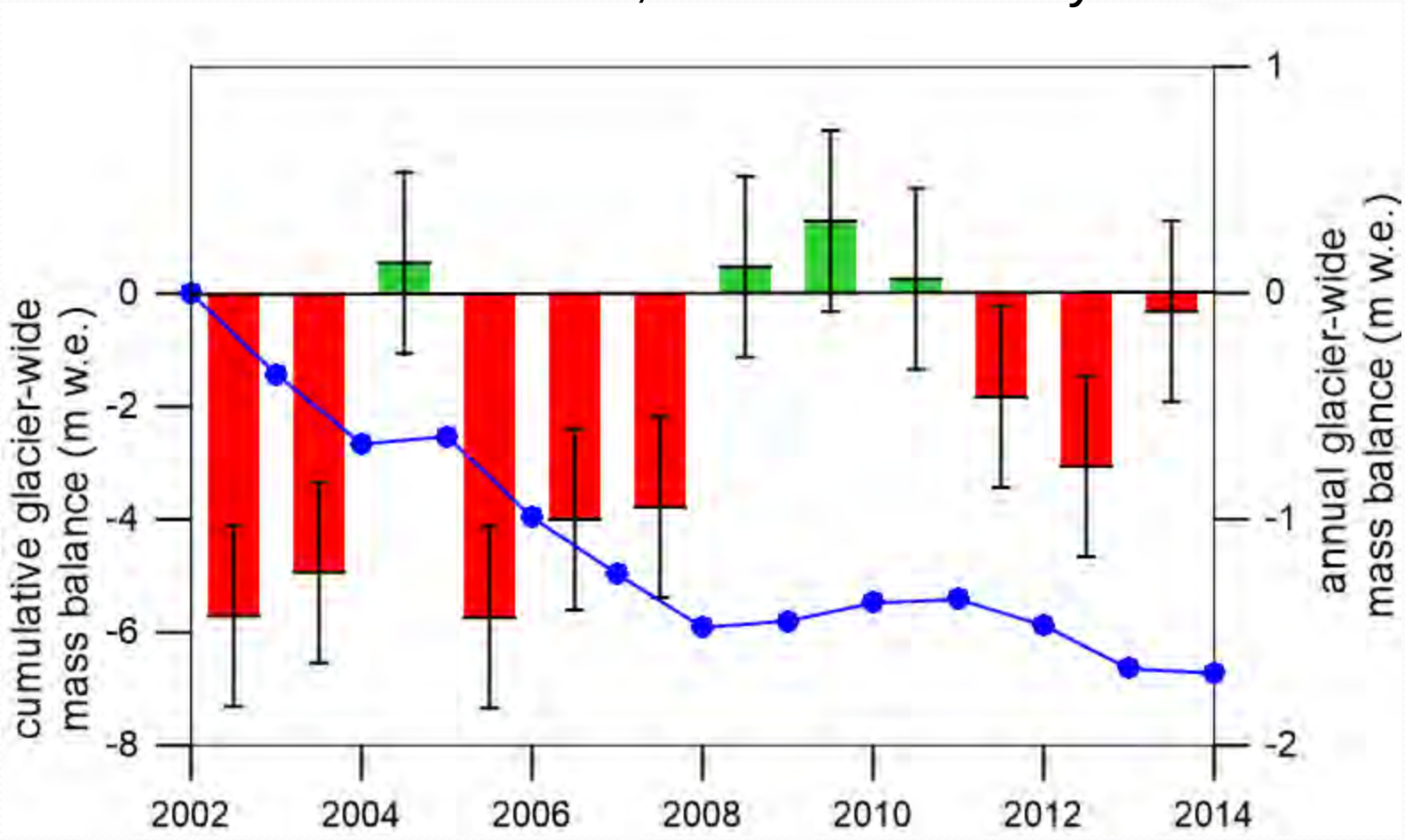


Rising temperatures, especially at higher altitudes, are playing a role in rapid glacier melt; Consequences results:

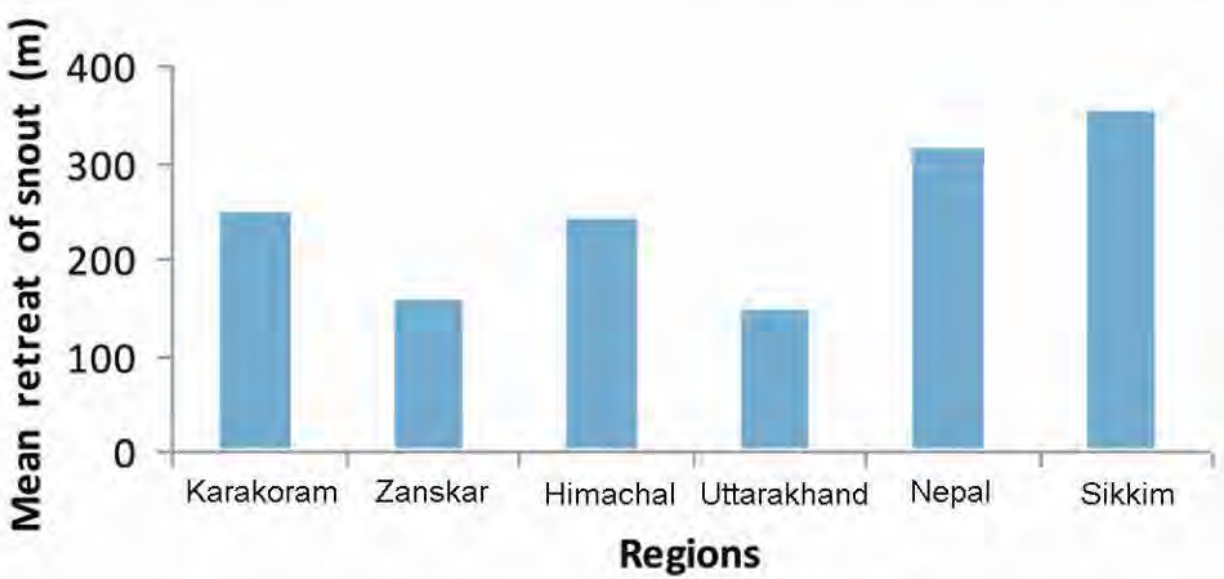
increased frequency and magnitude of associated extreme weather events, such as

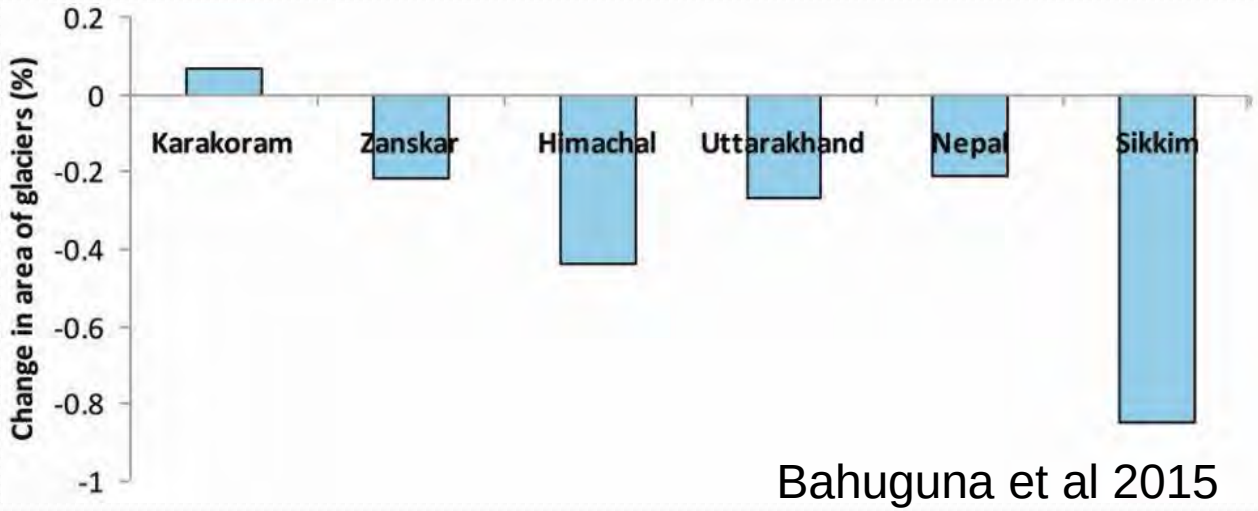
- Flash flood
- Glacier Lakes Outburst Flood(GLOF)
- shifts in monsoon patterns
- availability of water for agriculture, domestic needs, industry, and hydropower

Mass balance , Western Himalaya



HIMALAYA Glaciers Retreat 2001-2010





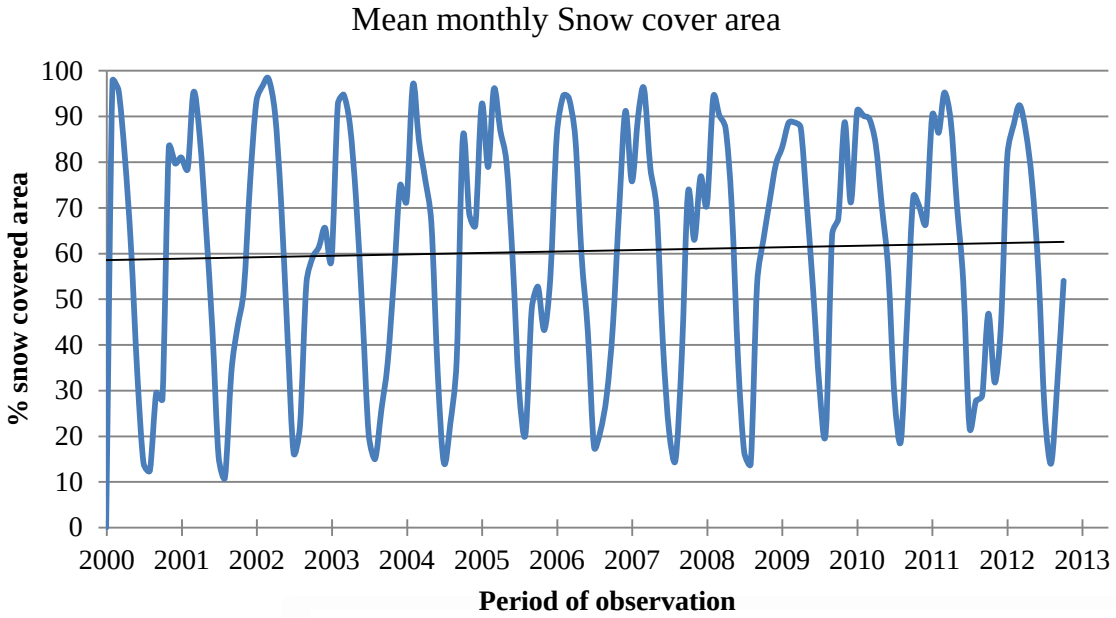
Bahuguna et al 2015

Indus basin Western Himalayas (Indian region) which contains 33,382 km^2 of glacierised area, and have 3398 number of Glaciers (GSI Report, 2009)

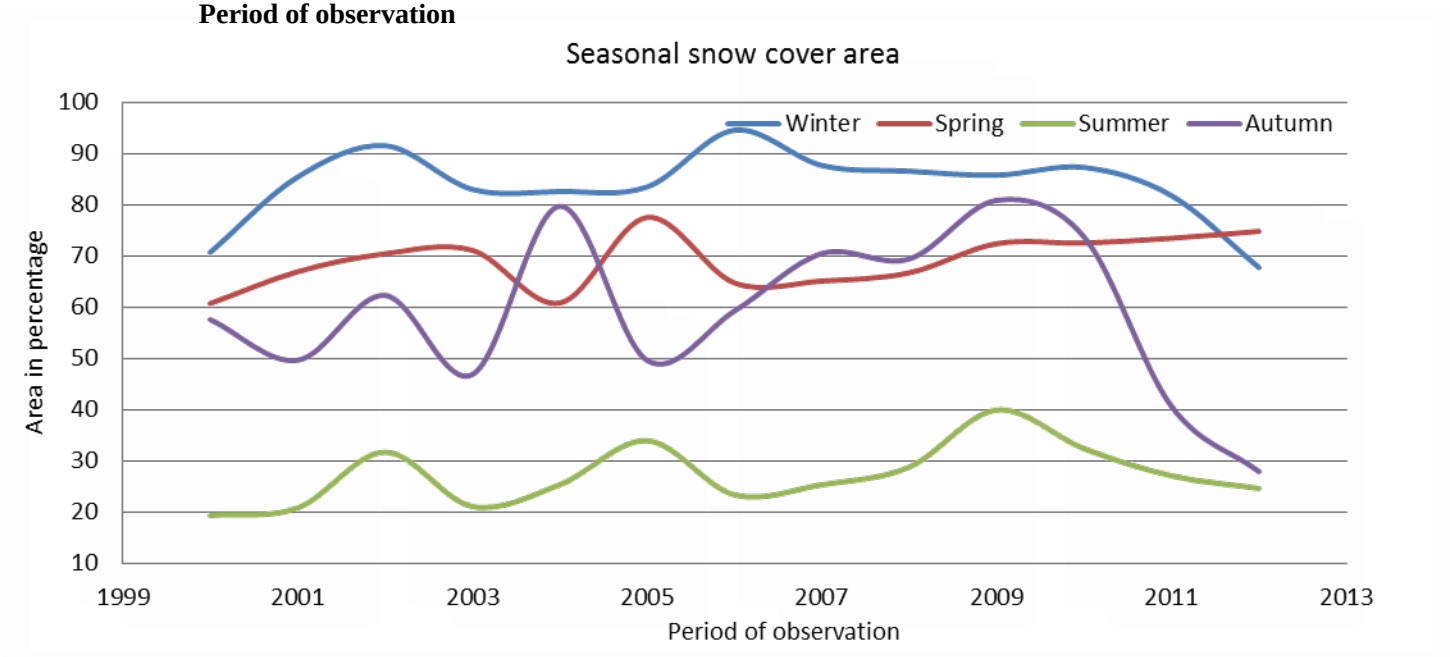
Basin	Number of Glaciers	Time period	Retreat (loss)
Chenab	359	1962-2004	21%
Parbati	88	1962-2004	22%
Baspa	19	1962-2004	19%
Ravi Basin	285	1971-2010/2013	4.7 ± 4.1 %
Beas	50	1972-2006	22.3%

GSI 2009; Kulkarni et al 2005; Kulkarni et al 2007

Spatio-temporal variations in snow cover area

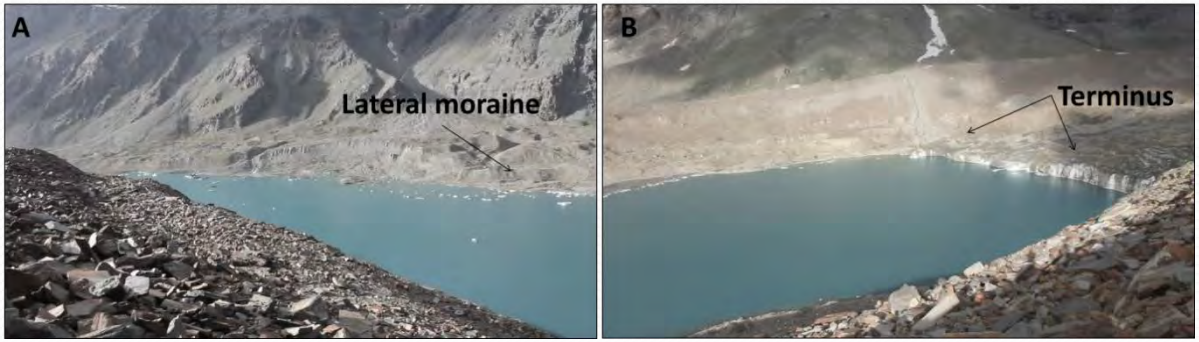


Observations	Period of observation	Trend
Maximum/ Highest snow cover area	March, 2005 & 2007	-n/a-
Trend	2001-2014	Increasing
Seasonal snow cover area	2001-2014	Increasing



There is also the risk of sudden flash floods as rapidly expanding glacial lakes burst through their natural dams.

There are more than 12000 glaciers in the Indian Himalaya including Nepalese Himalayas and more than 3000 of them contain glacial lakes. These lakes are quietly growing because of rising temperatures, but nobody knows how many are close to bursting, and there are no early warning systems for the villages downstream.



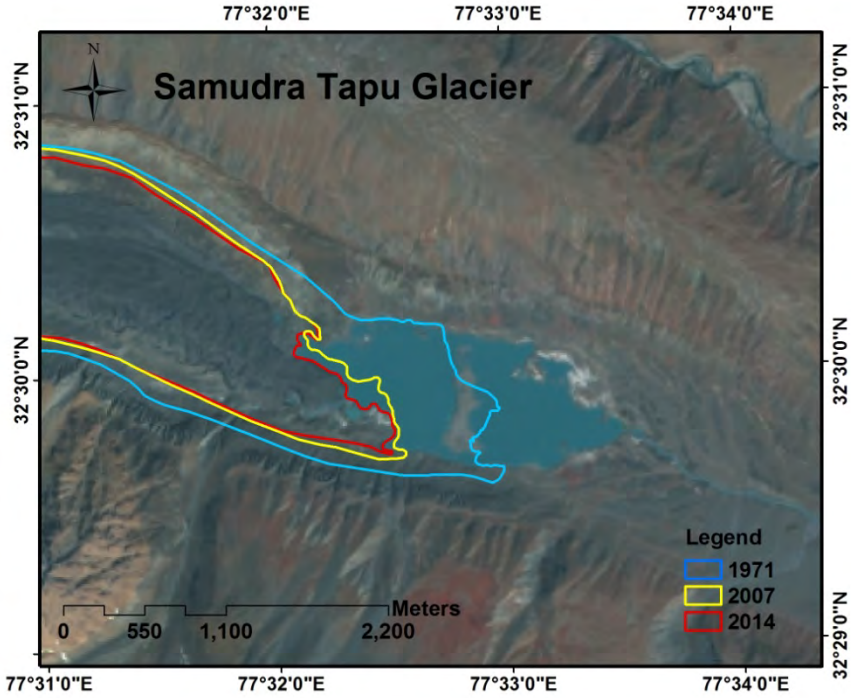
A glacier lake catastrophe happened once in a decade 50 years ago,' said UK geologist John Reynolds, whose company advises Nepal.

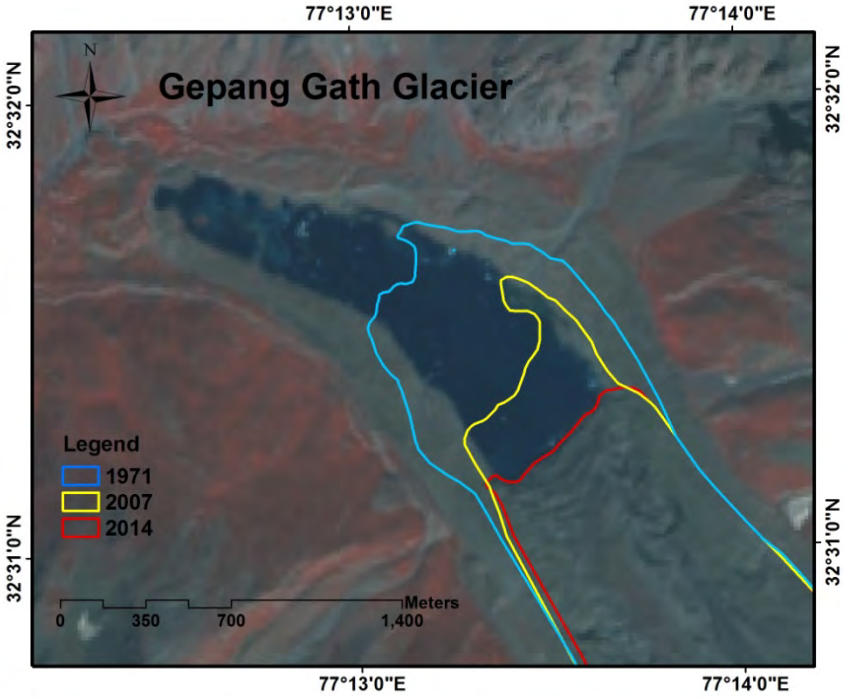
Now a nearby lake, below the Thorthormi glacier, is in imminent danger of bursting. That could release 50 million cubic meters of water, a flood reaching to northern India 150 miles downstream.

Terminal retreat of Samudra Tapu and Gepang Gath glaciers from 1971-2014 (last 43 years)

- Samudra Tapu : lower terminal retreat 31.3 ma^{-1},
  : area loss 0.1 km^2a^{-1},
  : volumetric wastage 32.7 $x10^6$ m^3 a^{-1}

- Gepang Gath :lower terminal retreat 20.1 ma^{-1},
  : area loss 0.03 km^2a^{-1},
  : volumetric wastage 4.1 $x10^6$ m^3 a^{-1}





Catastrophic impact of GLOG (Chorabari glacier)

An example of the catastrophic impact by breaching the Chorabari lakes, Uttrakhand in India , which claimed more than 5000 loss of life during 2013

One more example sweeping Luggye Tsho, in Bhutan, which burst its banks in 1994, sweeping 10 million cubic meters of water down the mountain. It struck Panukha, 50 miles away, killing 21 people.

But in a few decades the glaciers will be largely gone and the water level in rivers will drastically decline, meaning massive eco and environmental problems for people in China, Nepal, India, and Bangladesh. Without the glaciers, drinking and irrigation water will be drastically reduced, especially during the dry season. Crops will die. Hundreds of millions of people will be affected.

These disruptions are quite likely to trigger major conflicts locally and internationally, as people clash over water and land. People will be forced to migrate away from their dry or flooded land. Governments will bicker over who will get the remaining water and who will pay the economic costs.

- Snowmelt and glacier melt increases linearly with temperature rise
- Snowmelt runoff, glacier melt runoff, and total streamflow increased 4-18%, 33-38%, and 6-12% respectively in +2°C scenario
- Higher streamflow in the spring
- Discharge increases by 150-170% before dropping by 33% and 4-18% in the Western and Eastern catchment respectively

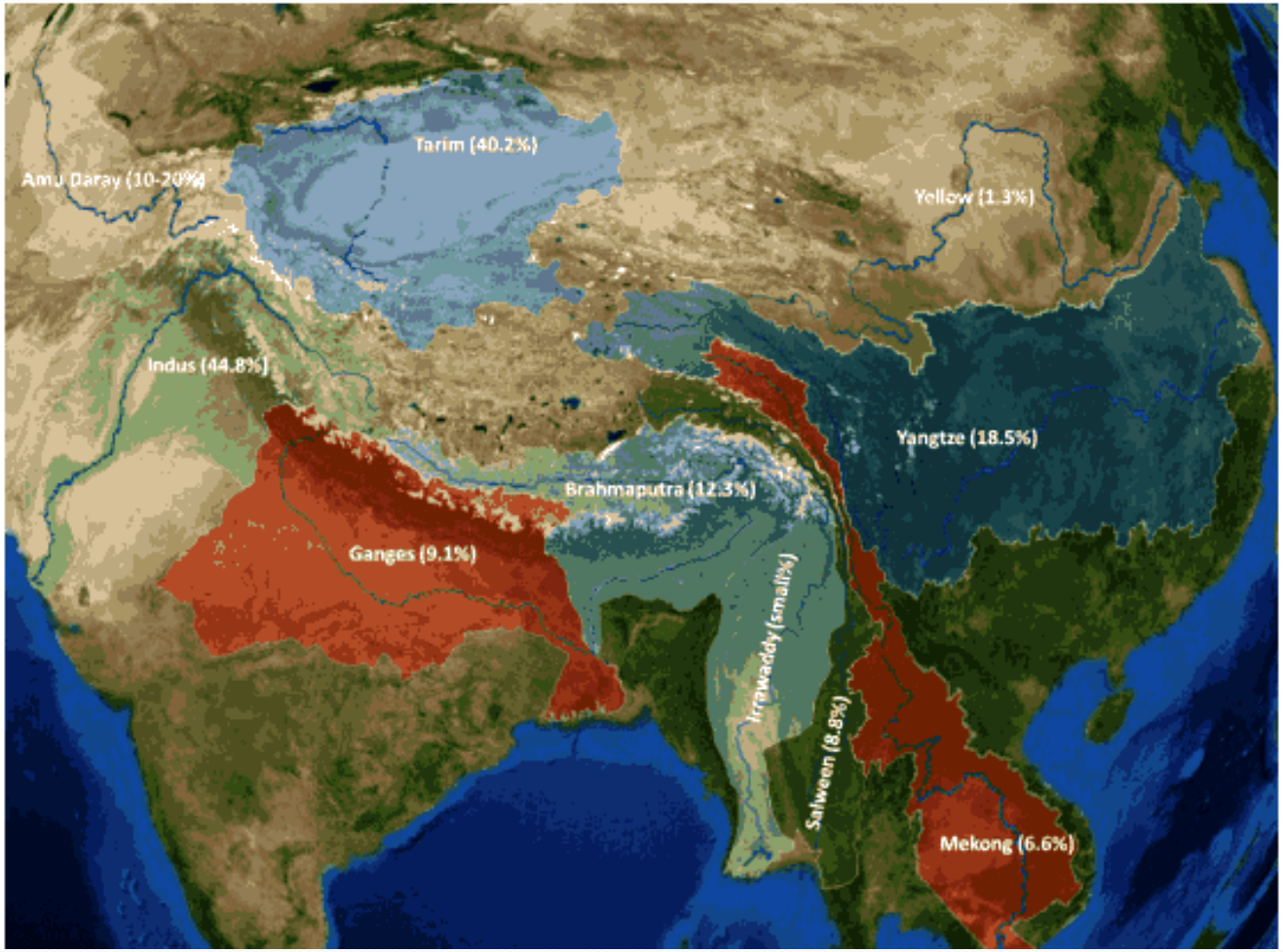
Short term

- Temperature rise causes streamflow to increase in spring and decrease in summer
- Water demand is highest during summer
- Reduced contribution of snowmelt from lower elevation is counteracted by increased glacier melt from higher elevation

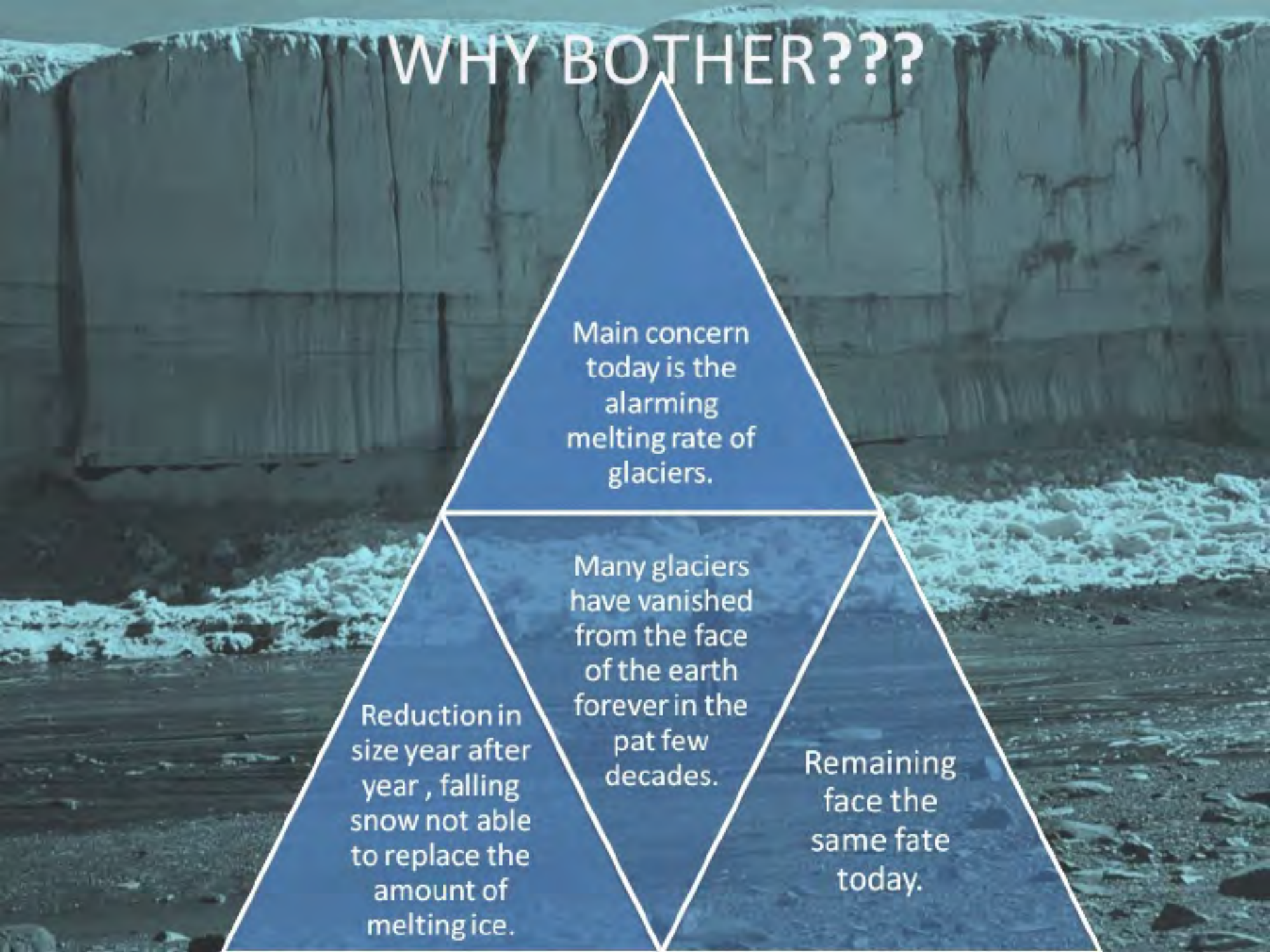
Long term

- Streamflow initially increases as glaciers melt, then decreases when glaciers are depleted

Snow/ice melt contribution to discharge



Source: UNEP- GRID 2012


WHY BOTHER???
Main concern today is the alarming melting rate of glaciers.
Many glaciers have vanished from the face of the earth forever in the pat few decades.
Reduction in size year after year , falling snow not able to replace the amount of melting ice.
Remaining face the same fate today.

ISSUES

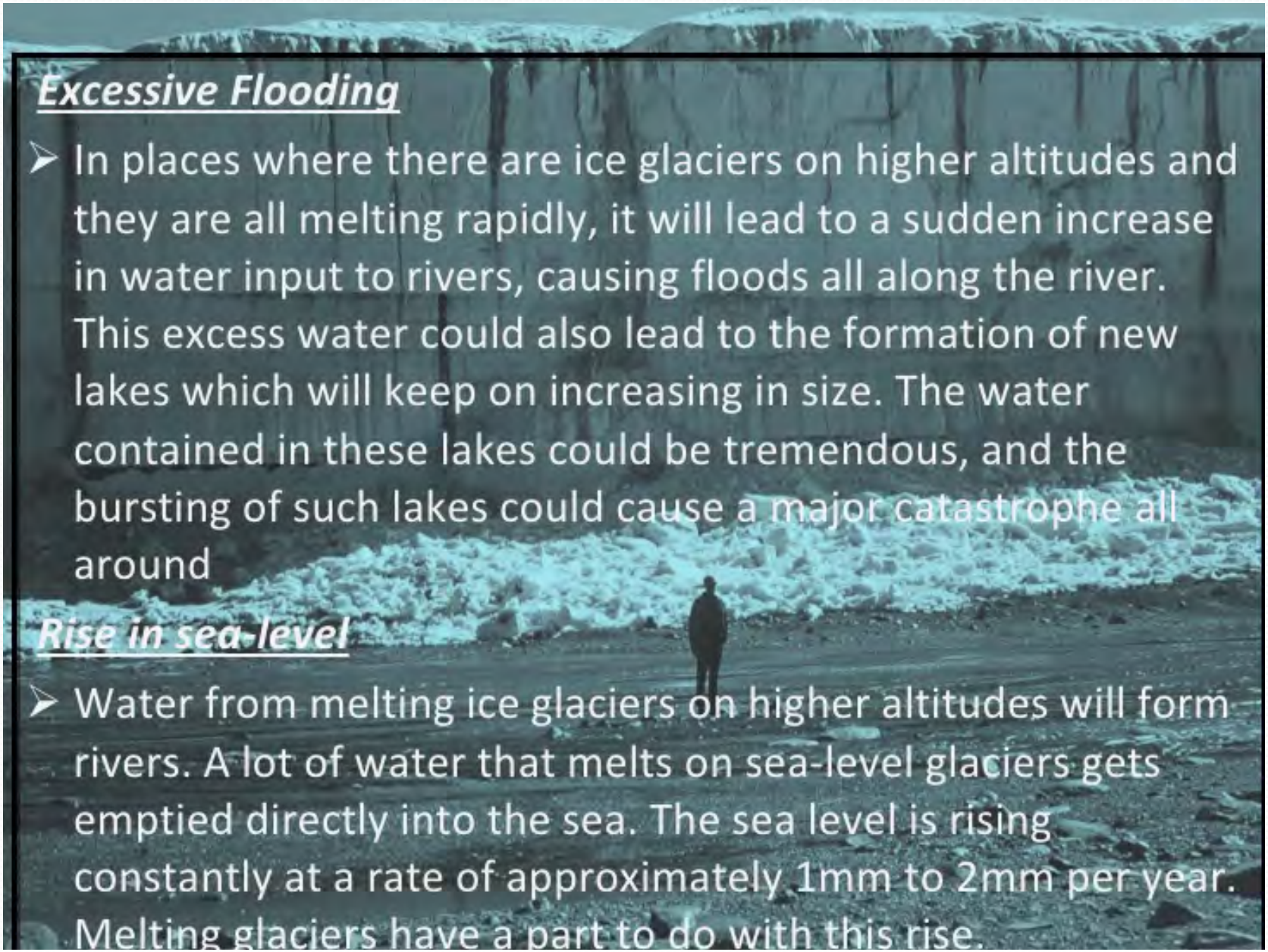
- Shortage of Fresh Water :The rapid melting of Himalayan glaciers will first increase the volume of water in rivers by 20-30 percent, causing widespread flooding. Hundreds of millions live on flood plains that are highly vulnerable to raised water levels.

Shortage of Electricity (Hydroelectricity)

- There are many places across the planet that depend solely on the constant flow of water from melting glaciers for the production of electricity. Once this flow of water is reduced or stops, the production of this clean electricity will stop too. Alternative means would in turn promote global warming.

Reduced Agricultural output

- Agriculture that depends solely on rain will be mostly unaffected by the effects of ice glaciers melting. Areas affected will be those that depend on water emanating from ice glaciers. During the dry seasons there will be a shortage of fresh water from ice glaciers, making the land dry and unsuitable for agriculture. Total agricultural output will reduce, leading to a shortage of food grains.

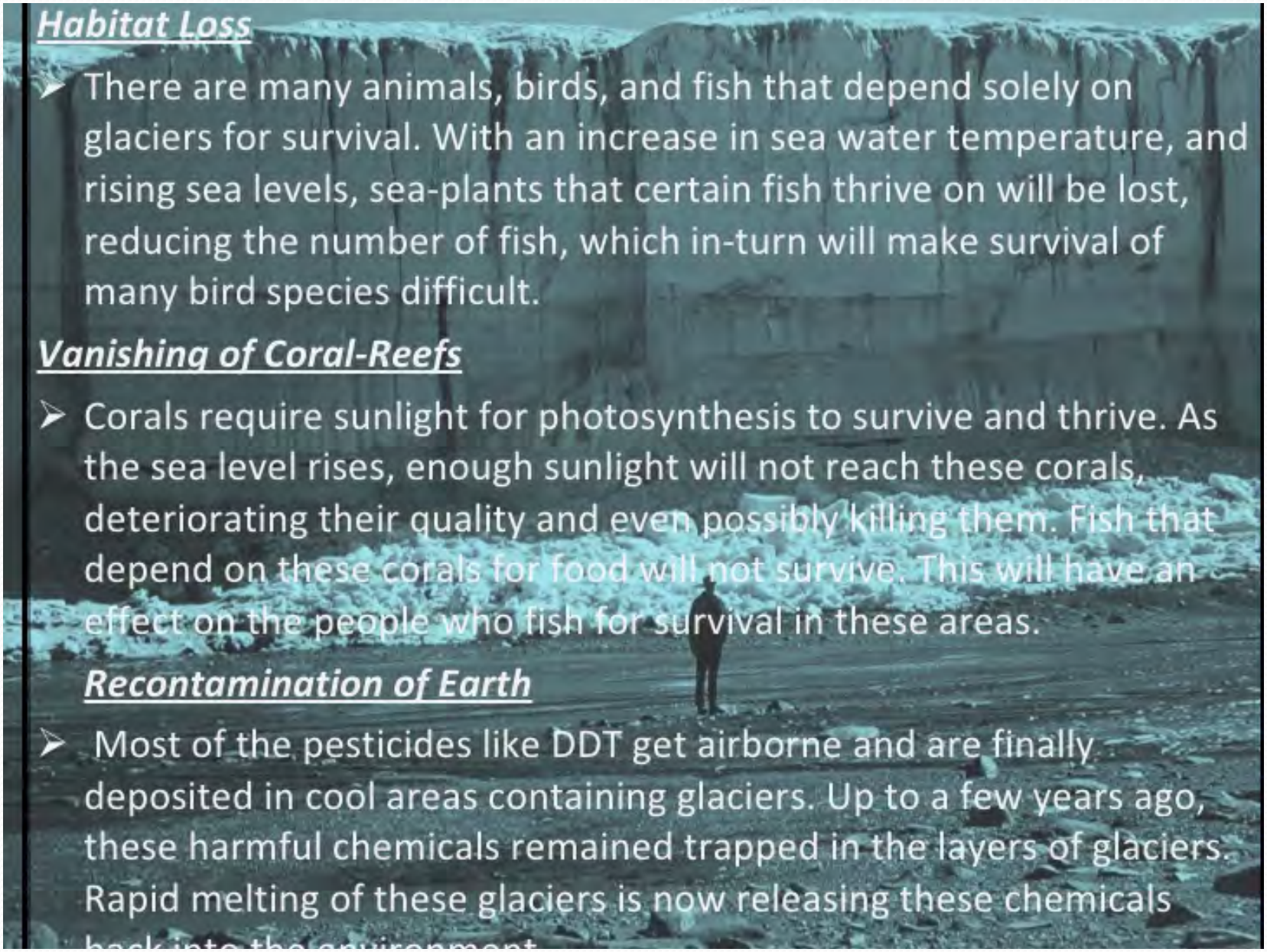


Excessive Flooding

- In places where there are ice glaciers on higher altitudes and they are all melting rapidly, it will lead to a sudden increase in water input to rivers, causing floods all along the river. This excess water could also lead to the formation of new lakes which will keep on increasing in size. The water contained in these lakes could be tremendous, and the bursting of such lakes could cause a major catastrophe all around

Rise in sea-level

- Water from melting ice glaciers on higher altitudes will form rivers. A lot of water that melts on sea-level glaciers gets emptied directly into the sea. The sea level is rising constantly at a rate of approximately 1mm to 2mm per year. Melting glaciers have a part to do with this rise.



Habitat Loss

- There are many animals, birds, and fish that depend solely on glaciers for survival. With an increase in sea water temperature, and rising sea levels, sea-plants that certain fish thrive on will be lost, reducing the number of fish, which in-turn will make survival of many bird species difficult.

Vanishing of Coral-Reefs

- Corals require sunlight for photosynthesis to survive and thrive. As the sea level rises, enough sunlight will not reach these corals, deteriorating their quality and even possibly killing them. Fish that depend on these corals for food will not survive. This will have an effect on the people who fish for survival in these areas.

Recontamination of Earth

- Most of the pesticides like DDT get airborne and are finally deposited in cool areas containing glaciers. Up to a few years ago, these harmful chemicals remained trapped in the layers of glaciers. Rapid melting of these glaciers is now releasing these chemicals back into the environment.

ACTION FOR CLIMATE SERVICES(Specific in high mountain region)

An operational User Interface Platform can promote engaging all stakeholders and ensure effective decision-making where it involves climate considerations.

Government-led organizational arrangements for implementation

At national level:

- **Coordination**:
- **Interaction**:
- **Technical**: Multi-sector integrated information sharing and interactive platform which provides climate service products to users including media

At local and community levels:

- **Full coverage:** Appropriate cooperation mechanisms of working and technical levels put in place at provincial, prefectural and county levels Mechanism building in progress at rural and urban community levels

Recommendations

1. Governments at all levels should play a leading role in promoting the implementation of GFCS, it's essential to ensure the operational and functional services in place, particularly for grass-root service delivery.

2. Communication and outreach is a key component of the partnership construction process. Dialogue on practical action at regional and national levels should be encouraged.

3. Improved services and benefits is the necessary condition for wide and effective engagement by various stakeholders. Climate service must be driven by user needs and sound science, and supported by practical participatory mechanism including that of investment.

Practice in priority areas

Case 1. Agriculture sectors:

◆ **Information service system to farming community**

-- Real-time service delivery system (grass-roots level service stations

-- Straight services to end users including farmer associations*, village leaders etc.)*

-- Experts alliance to enhance partnership and capacity development

Case 2. Disaster Risk Reduction:

◆**Climate prediction based flood/drought preparedness**

-- Task teams dispatched to prone areas

-- Structural measures taken in selected points

-- Materials reserved in selected zones, Shelters consolidated……

◆**Disaster risk warning based multi-sector coordinated response**

-- Risk census and Determine hazard thresholds in cooperation with partners

-- Combat disasters by governments and grassroots organizations with early warning, relief and resettlement measures including evacuation

Others cases: water, human health, urban planning……

a) Research Station at Sutri Dhaka Chandra basin

b) Automatic Weather Station at altitude of 5000m a[illegible] (Sutri Dhaka glacier)

c) Hydrological Station at altitude of 4200m (down stream of Sutri Dhaka glacier)

THANK YOU !