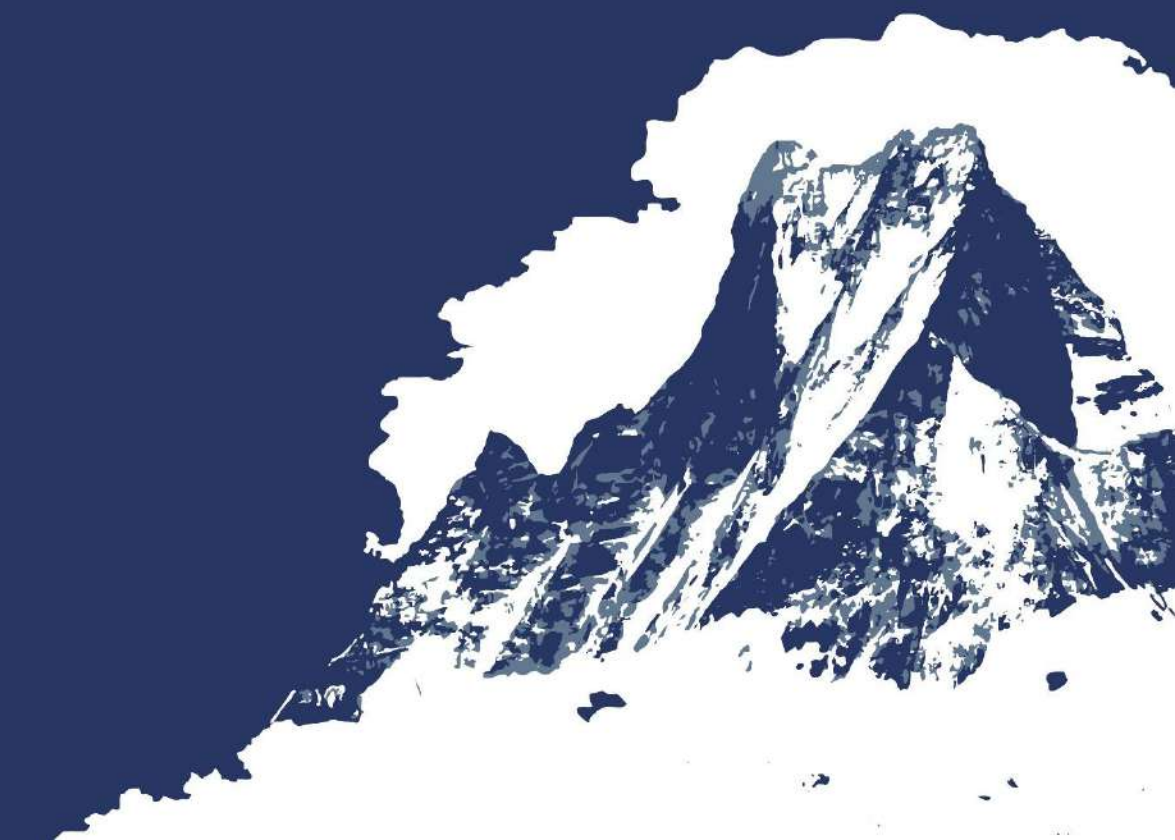
Climate Change in the Hindu Kush Himalaya: Impacts on Water and Air

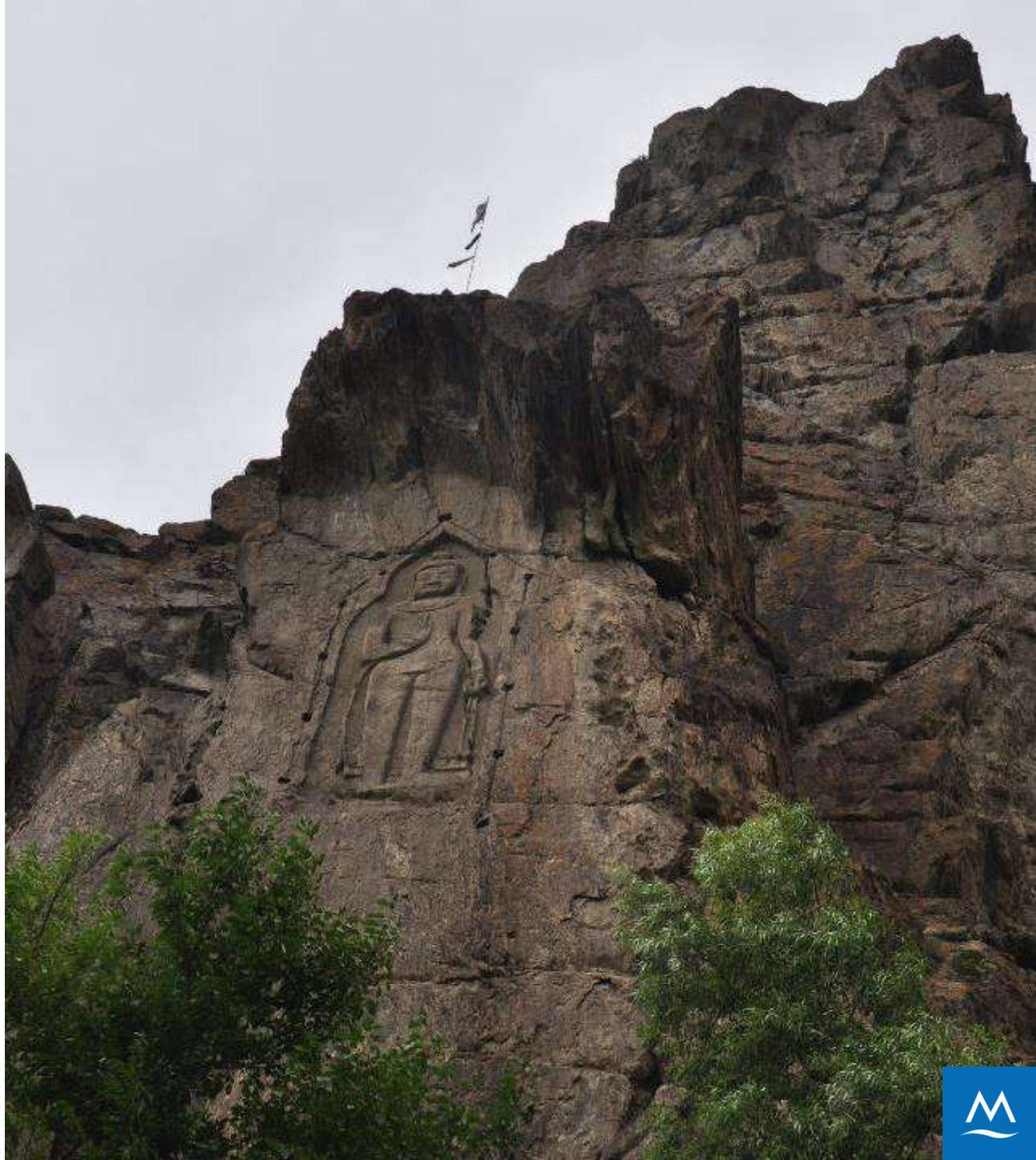


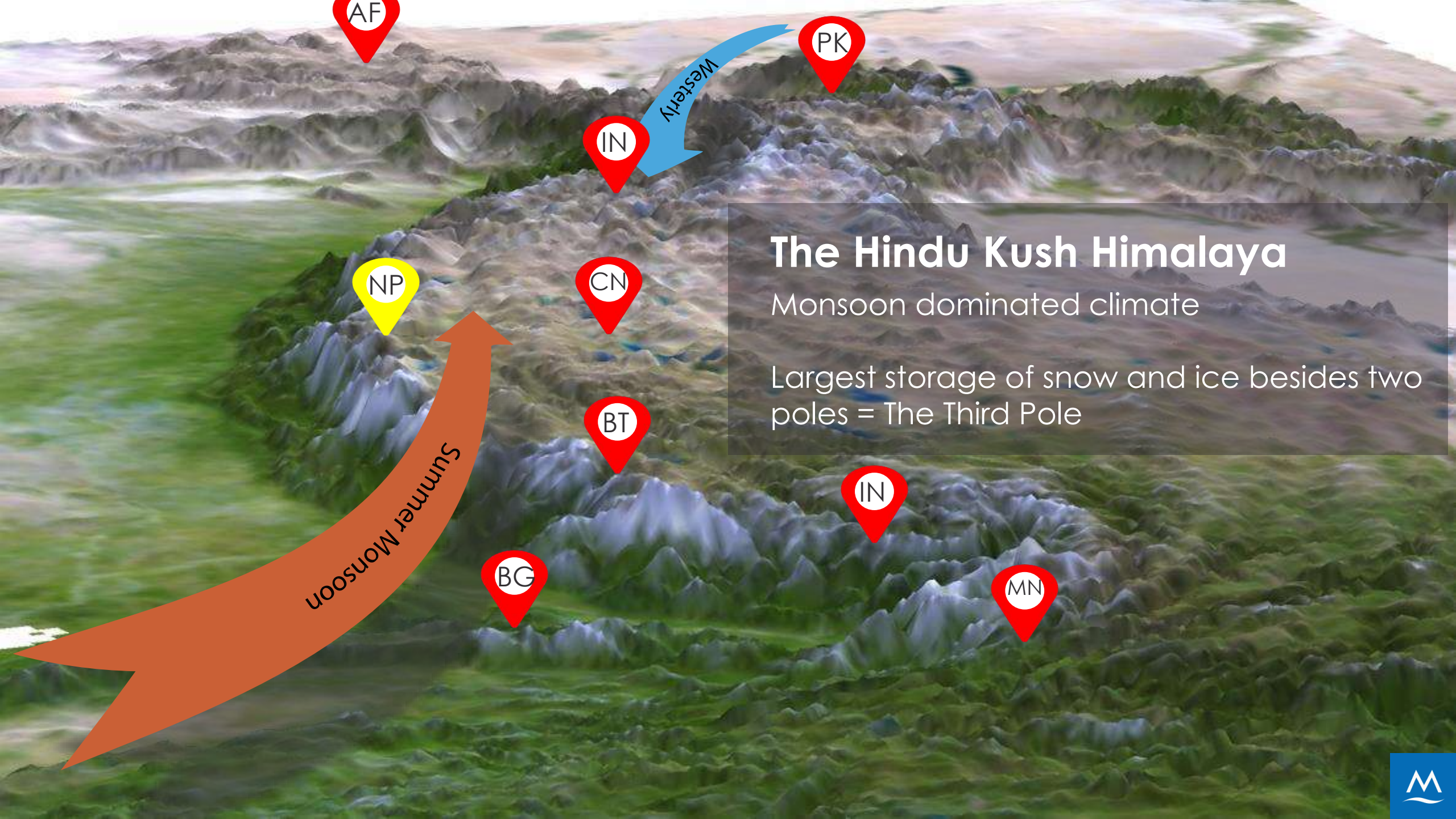
Arun B Shrestha
Senior Advisor – Climate and Environmental Risks, ICIMOD

11-04-2025, Nepal Engineers' Association

This talk

- Hindu Kush Himalaya (HKH)
- Climate change in HKH and Nepal
- Impacts of climate change
  - Impacts on cryosphere
  - Impacts on water resources
  - Impacts on extreme events
- Climate-air quality-cryosphere nexus
- Key messages

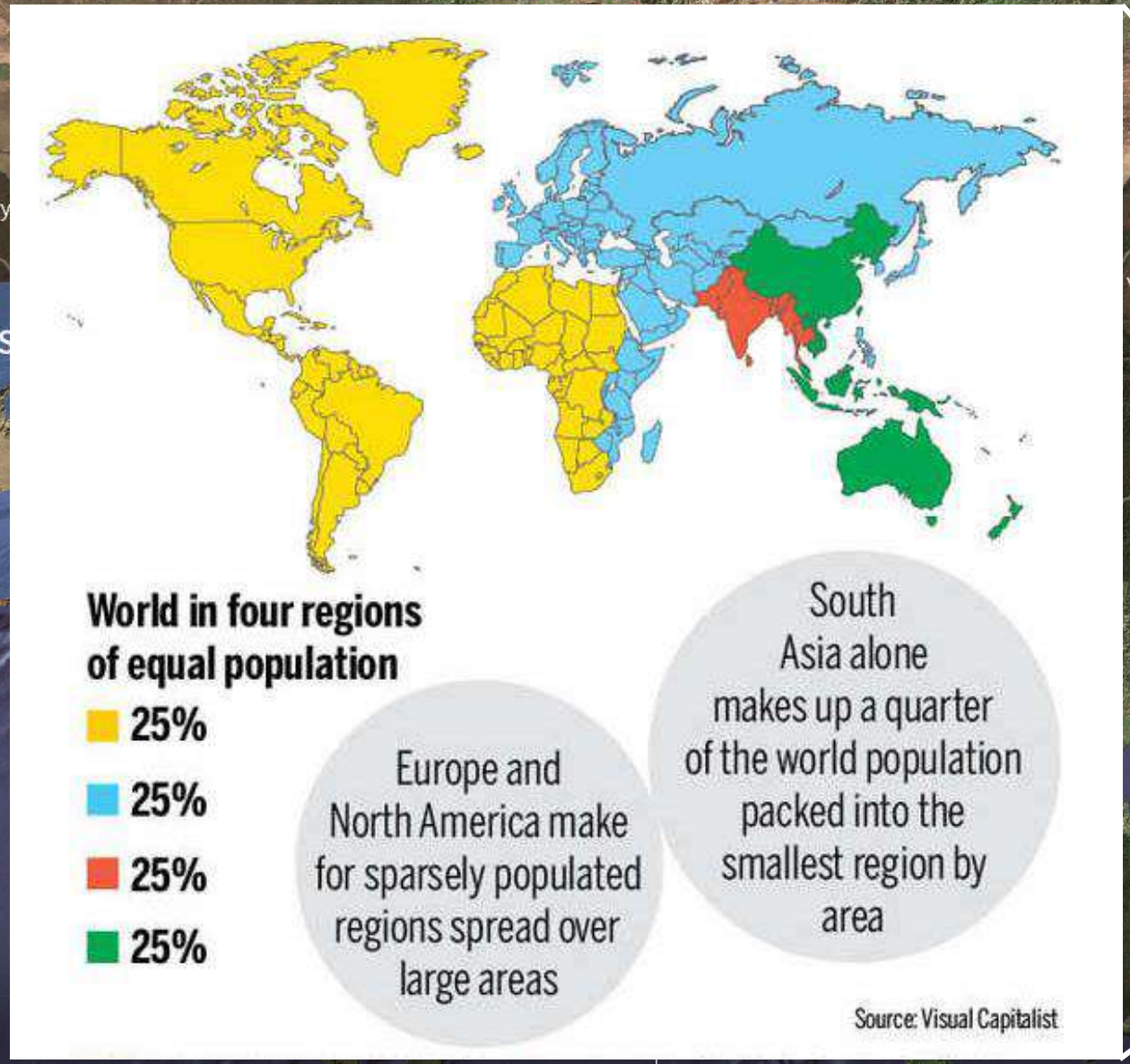




The Hindu Kush Himalaya

Monsoon dominated climate

Largest storage of snow and ice besides two poles = The Third Pole



Hindu Kush Himalaya
Major river basins
Major rivers

8 countries

>1000 languages are spoken across the region

10 major Asian river systems

1.9 billion people in the HKH mountains and hills and river basins downstream

4 of 36 global biodiversity hotspots and 330 Important Bird and Biodiversity Areas

Triple planetary crisis

In the Third Pole

Rapid warming (0.28° C/ decade) comparable or higher than global average warming

Precipitation extremes increasing- extreme and erratic rainfall

Both warming and precipitation extremes to increase in the future

Cryosphere decline

Changing hydrological regime and extremes

Biodiversity loss

Environmental pollution

Climate change in HKH and Nepal

Climate change

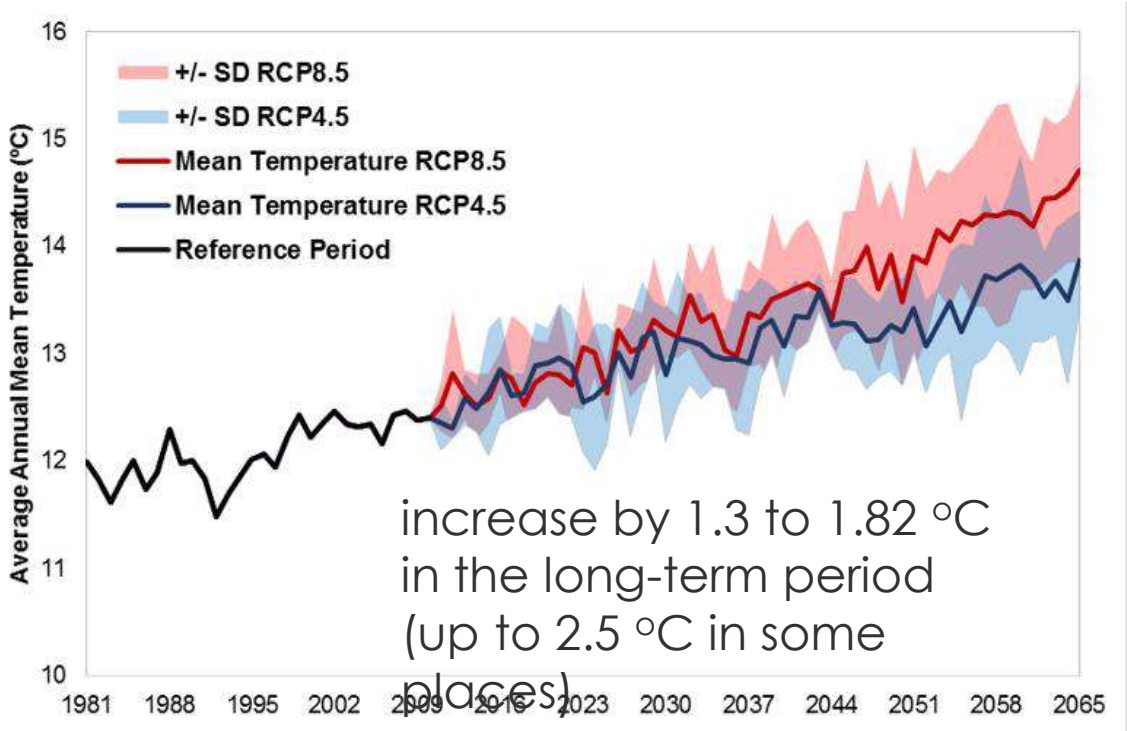
Temperature

Warming rate in the HKH: 0.28 °C/decade

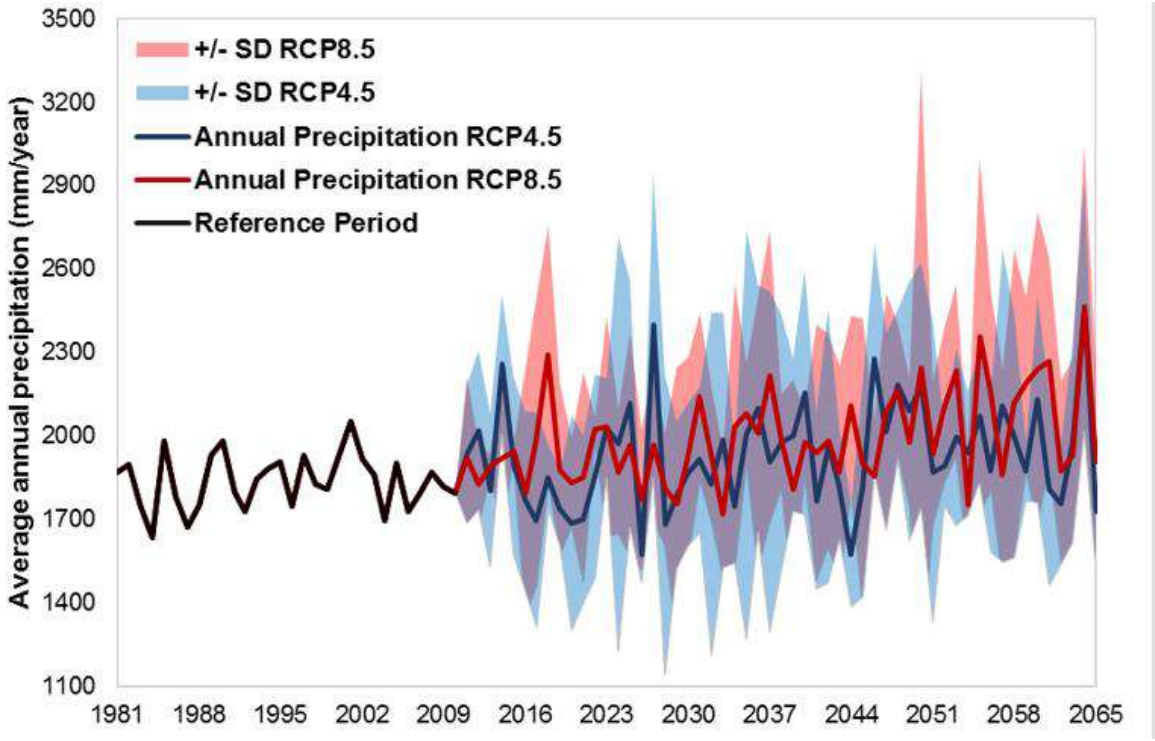
Maximum temperature increased at the rate of 0.06°C/year (1977-1994) (Shrestha et. al. 1999)

All Nepal annual maximum temperature trend is significantly positive (0.056 °C/yr). (DHM, 2017)

Elevation dependent warming: Mountains are warming more than the Plains



Precipitation (rainfall) past and future



8-12% increase, more in western regions

In HKH and Nepal no clear trend in the past

Extremes increasing (e.g. Karki et al. 2017)

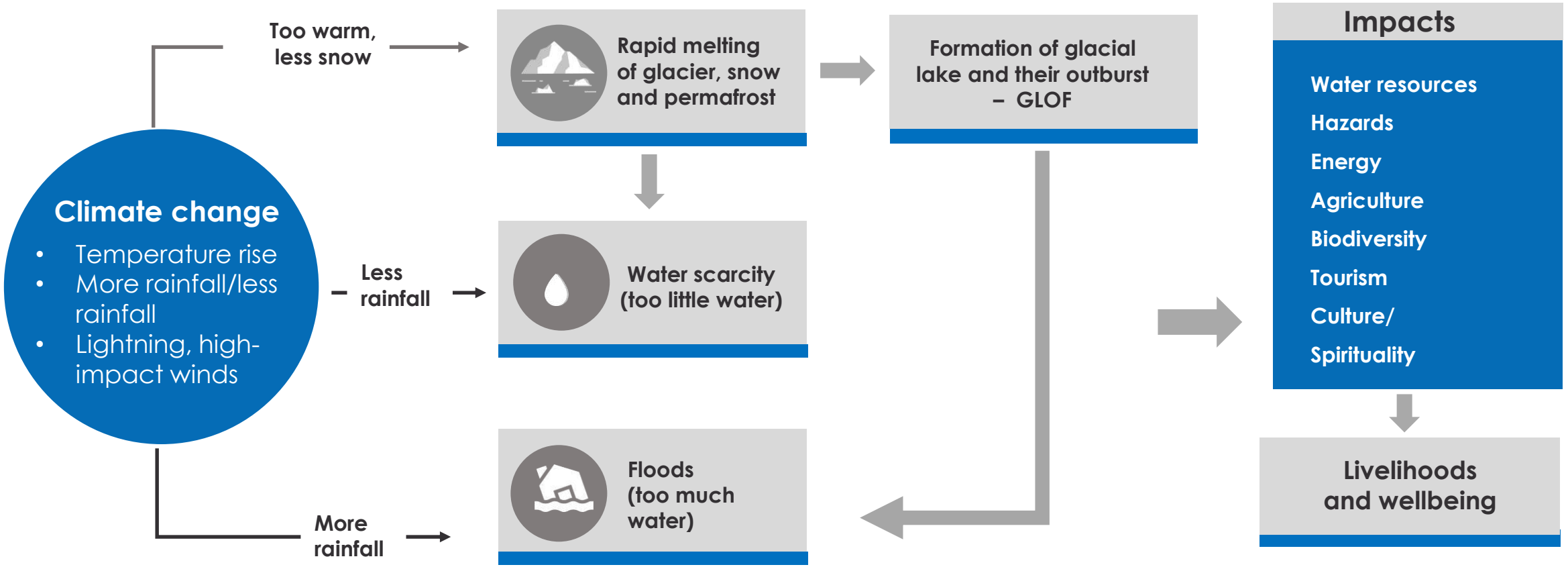
In the future 8-12% increase in Nepal and 4-12% in HKH

Extremes (wet and dry) are likely to increase in the future

Source: Krishnan et al., 2019; MoFE, 2018

Impacts of climate change

Climate-cryosphere-water-society nexus

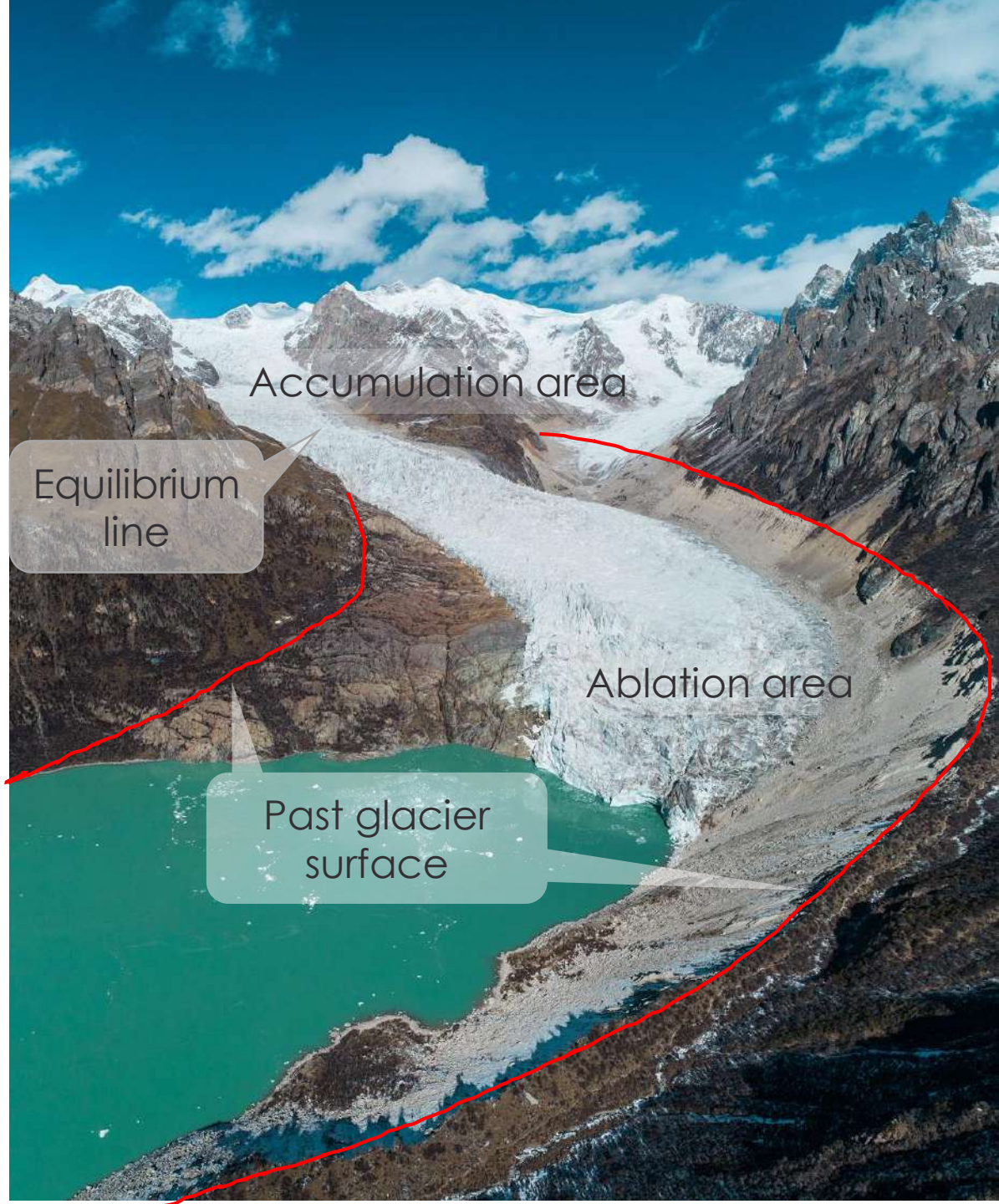


Understanding a glacier

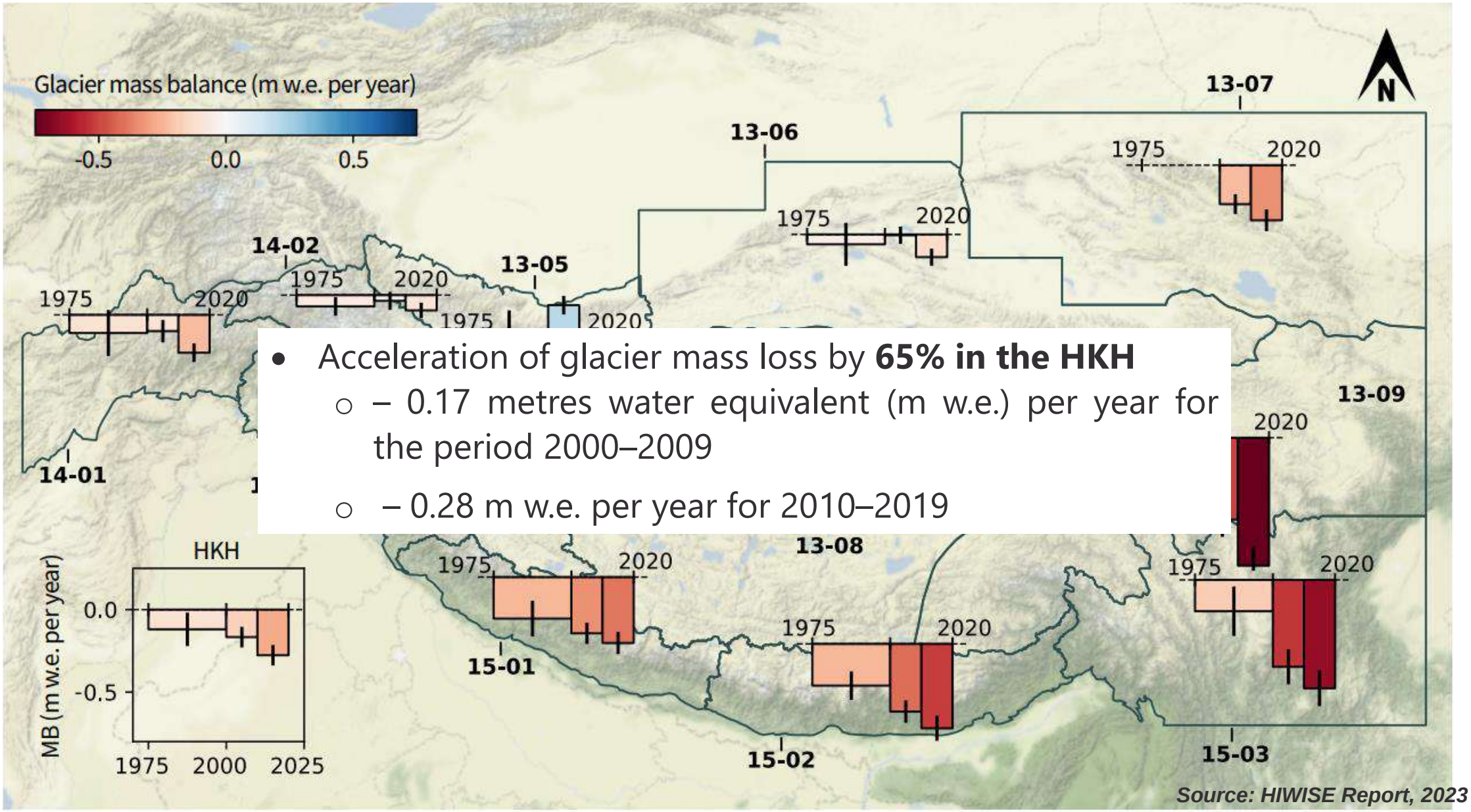
The HKH region has the highest snow and glaciers concentration outside the polar region

- ~ 54,000 glaciers (60,000 km^2)
- ~3,250 glaciers in Nepal (5,320 km^2)

(Bajracharya et al., 2015; Bajracharya et al., 2020; Bolch et al., 2019)



Glacier mass balance



- Acceleration of glacier mass loss by **65% in the HKH**
  - – 0.17 metres water equivalent (m w.e.) per year for the period 2000–2009
  - – 0.28 m w.e. per year for 2010–2019

Source: HIWISE Report, 2023

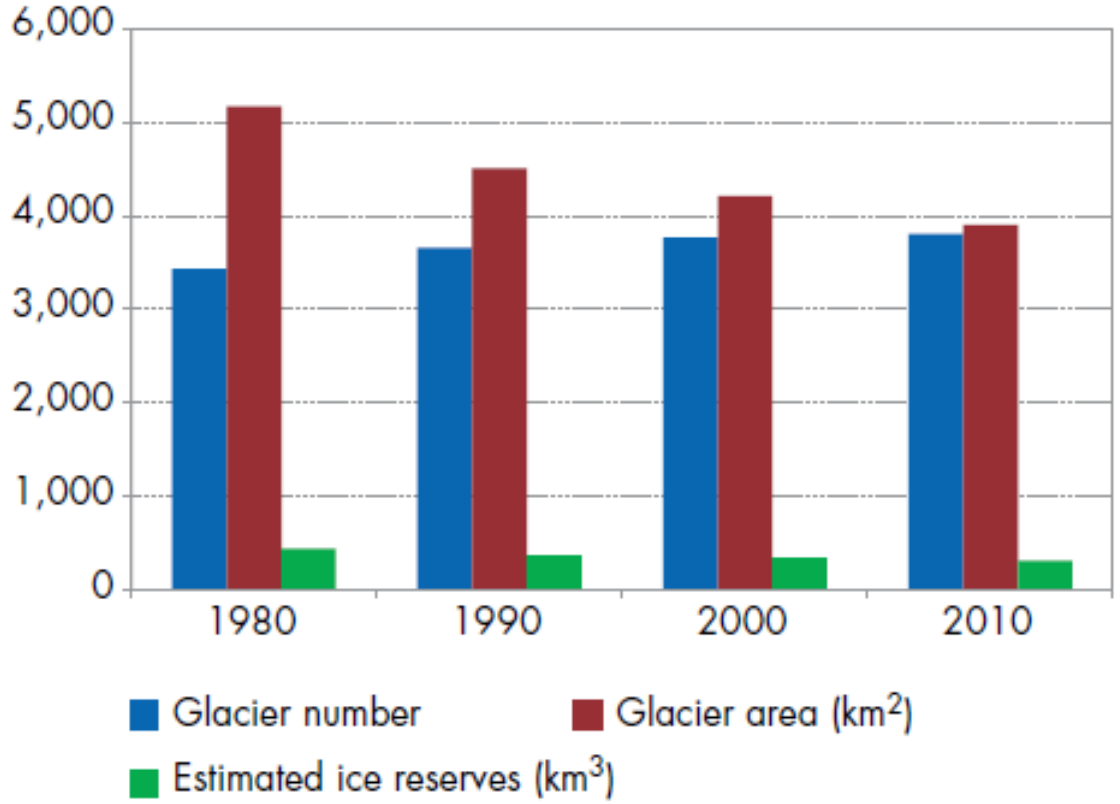
Glacier change in Nepal

Glacier area decreased from

- 1980: 5168 km^2
- 2010: 3902 (25%)

Glacier number increased from

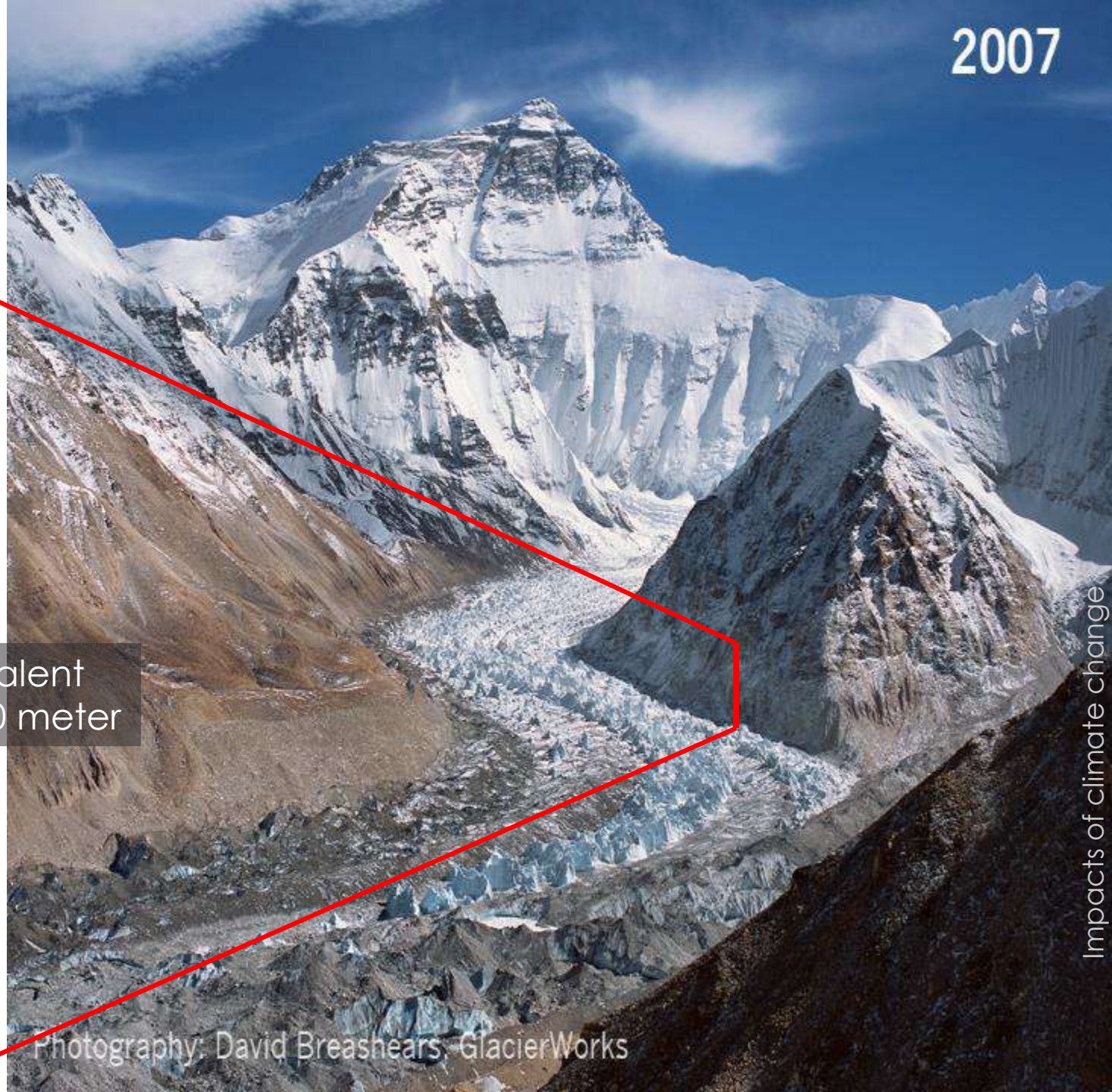
- 1980: 3430
- 2010: 3808 (11%)

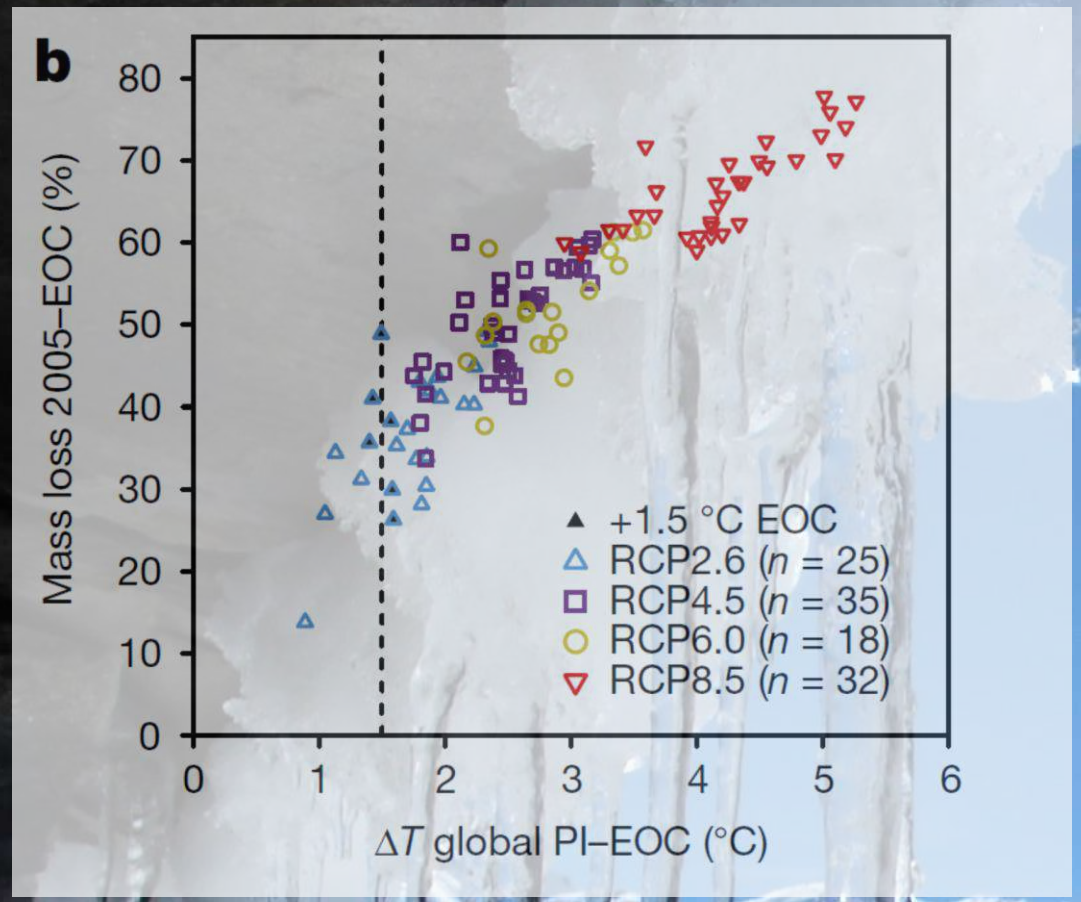


Bajracharya et al. 2014, ICIMOD

Changes in glaciers

Equivalent
to 100 meter





In a **1.5˚ to 2.0°C** world, glaciers in the HKH will lose **30 - 50%** volume by 2100 relative to 2015

A **+3˚ to +4⁰ C** global warming scenario implies **55- 75%** loss of ice volume

Every increment of warming matters and strongly influences glacier volume left in 2100!

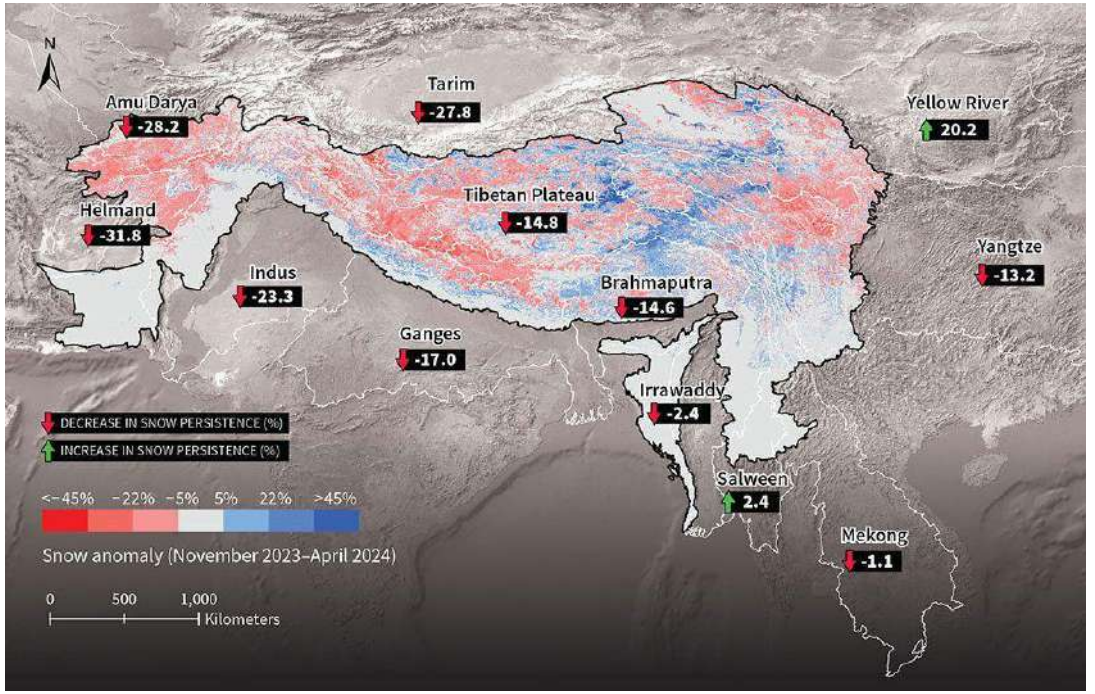
Source: HIMAP climate change chapter and Kraaijenbrink et al. 2017, *Nature*

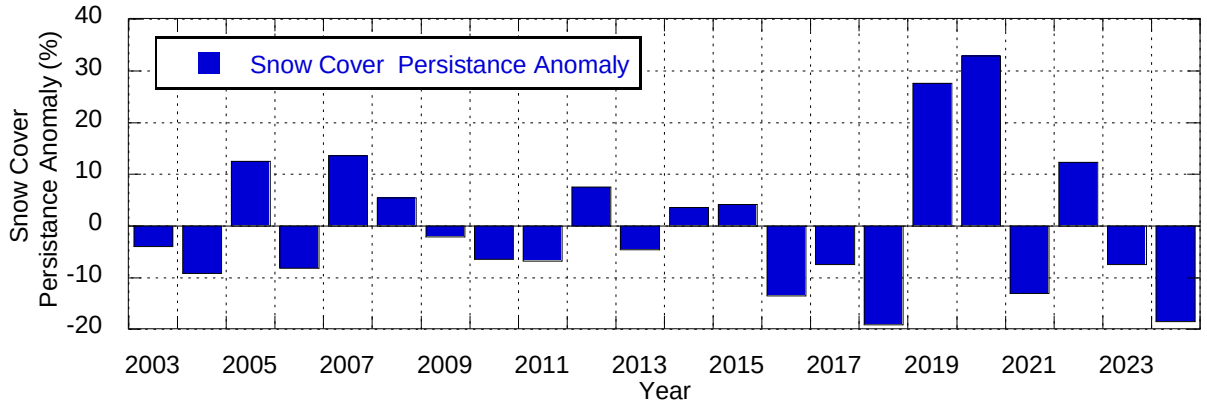
Snow Cover

Snow cover extent has shown a clearly negative trend generally

Declined at an average rate of 5 snow cover days per decade

2024 - a "below normal snow year"





https://lib.icimod.org/record/36512

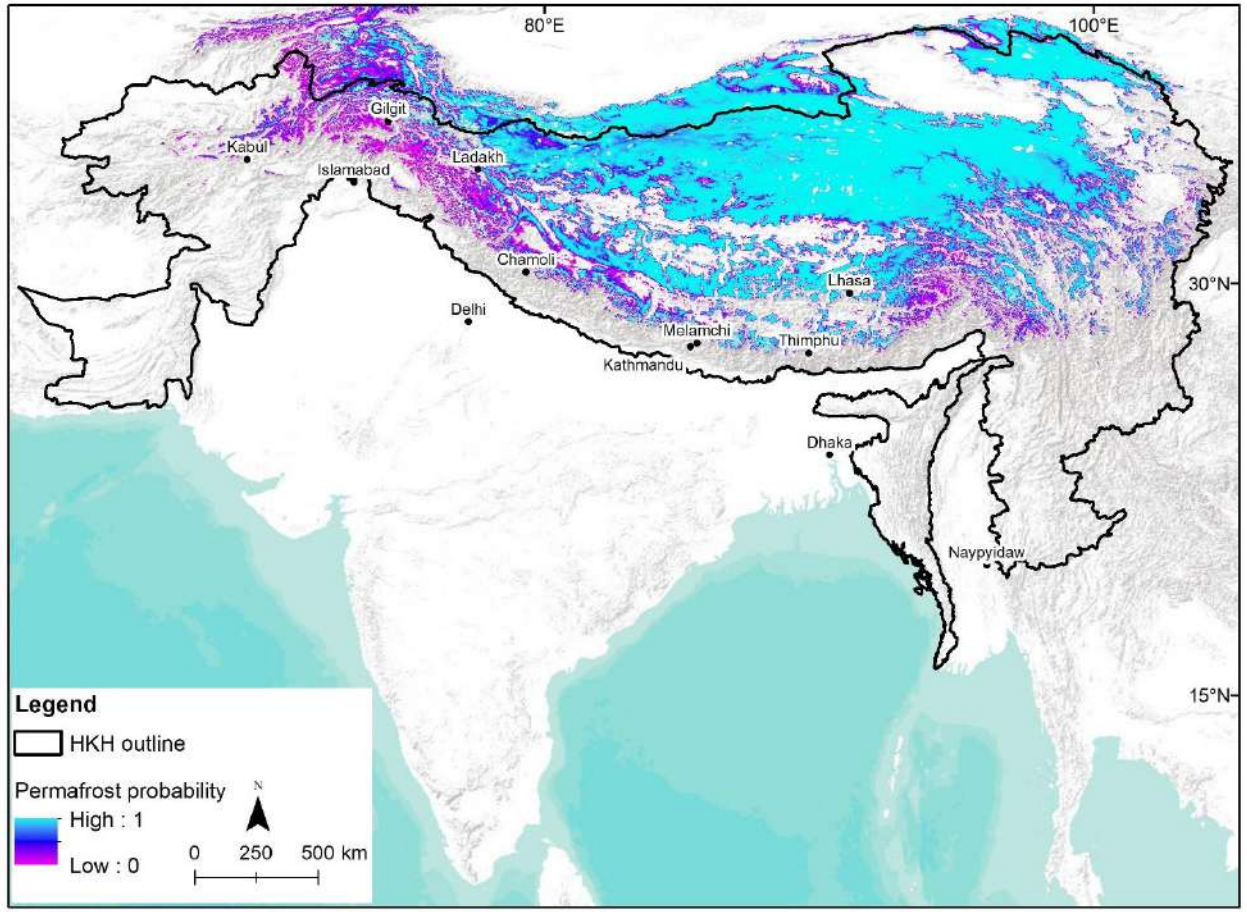
Permafrost

Ground that remains frozen for at least two consecutive years, found in high-altitude regions of the Hindu Kush Himalaya (HKH) above 4,000 meters.

Least studied component. Estimated that in HKH it covers 2 mil km^2

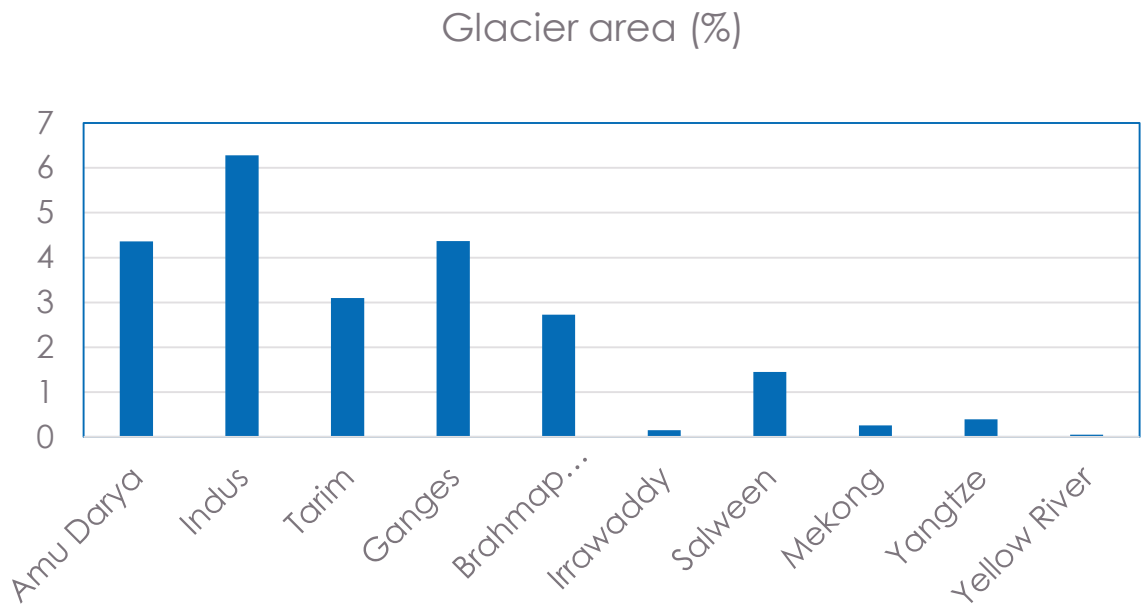
It stabilizes landscapes, prevents erosion and landslides, and acts as a major carbon store by trapping organic material for thousands of years.

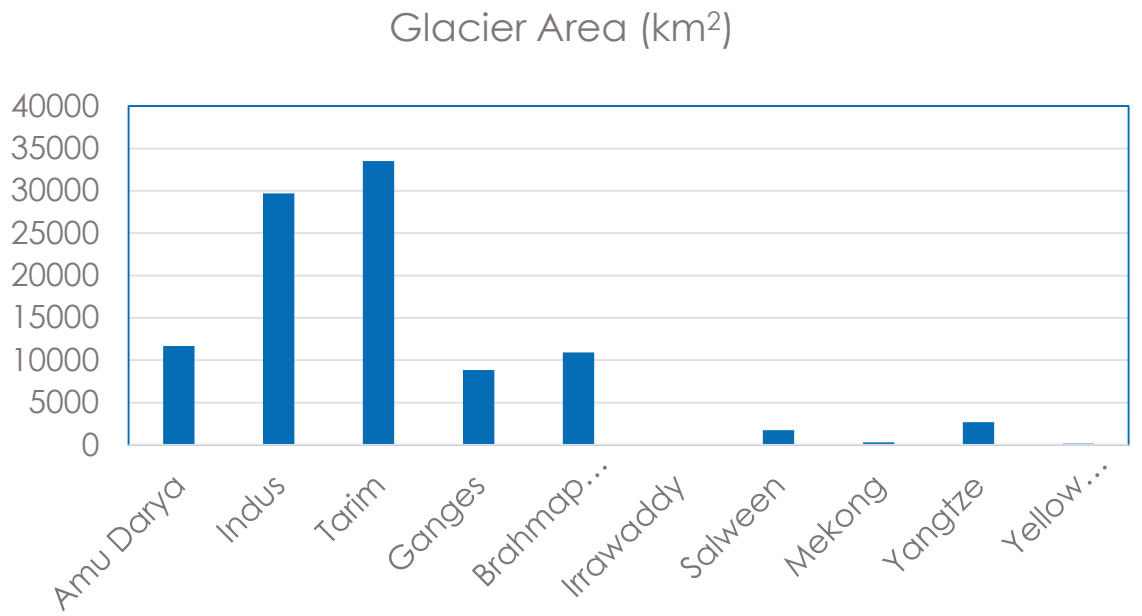
Thawing permafrost weakens slopes, increases landslide risks, and releases greenhouse gases (CO_2 and CH_4), further accelerating global warming.



Impacts of cryosphere loss

Cryosphere in HKH river basins

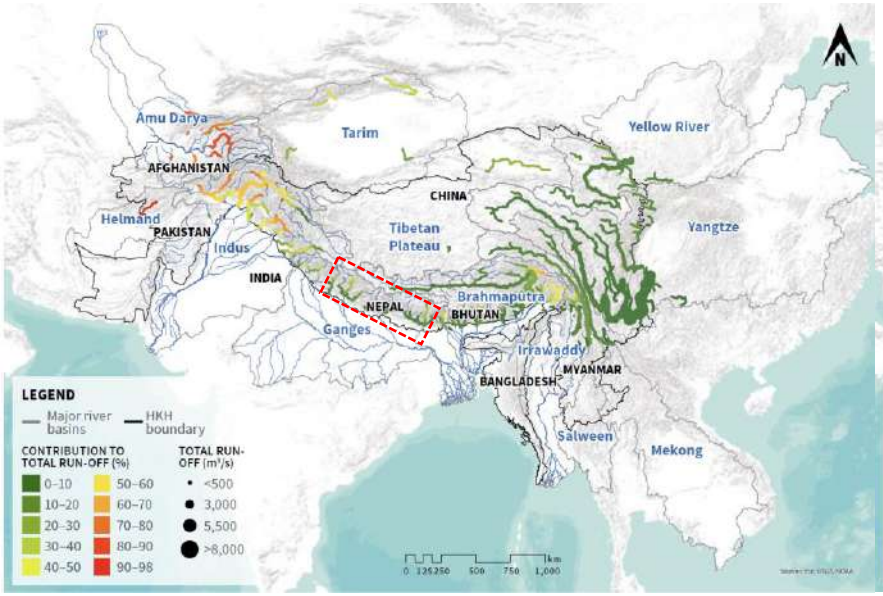




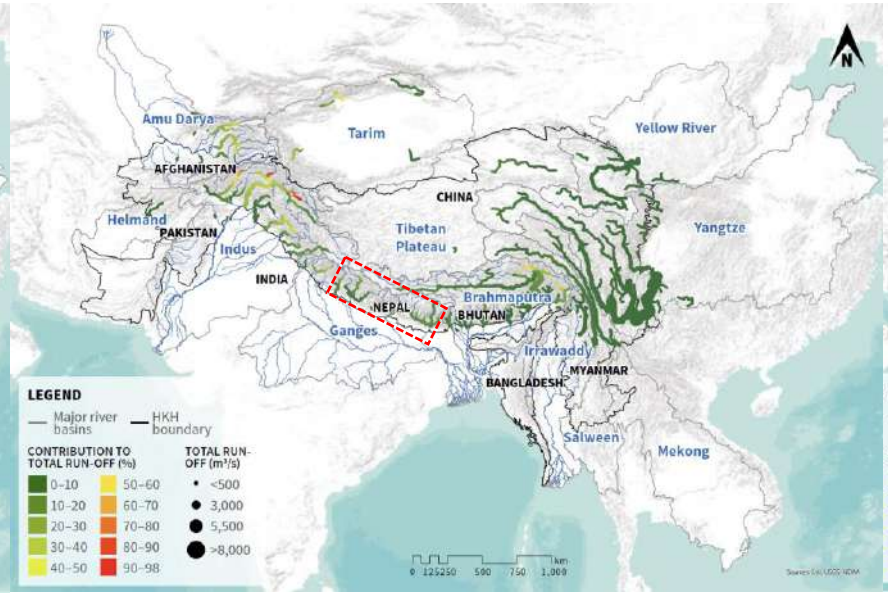
Source: HIWISE Report (2023)

Runoff components

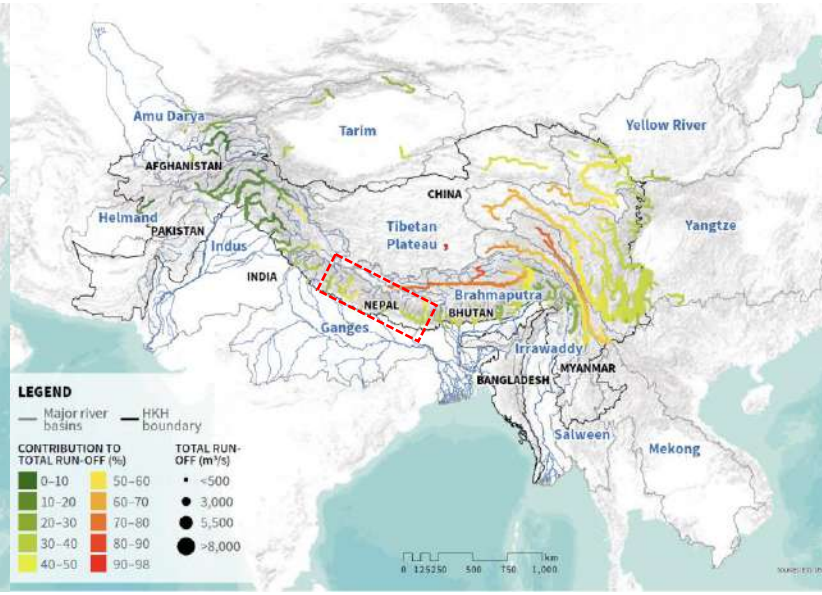
Snowmelt



Glacier melt



Baseflows



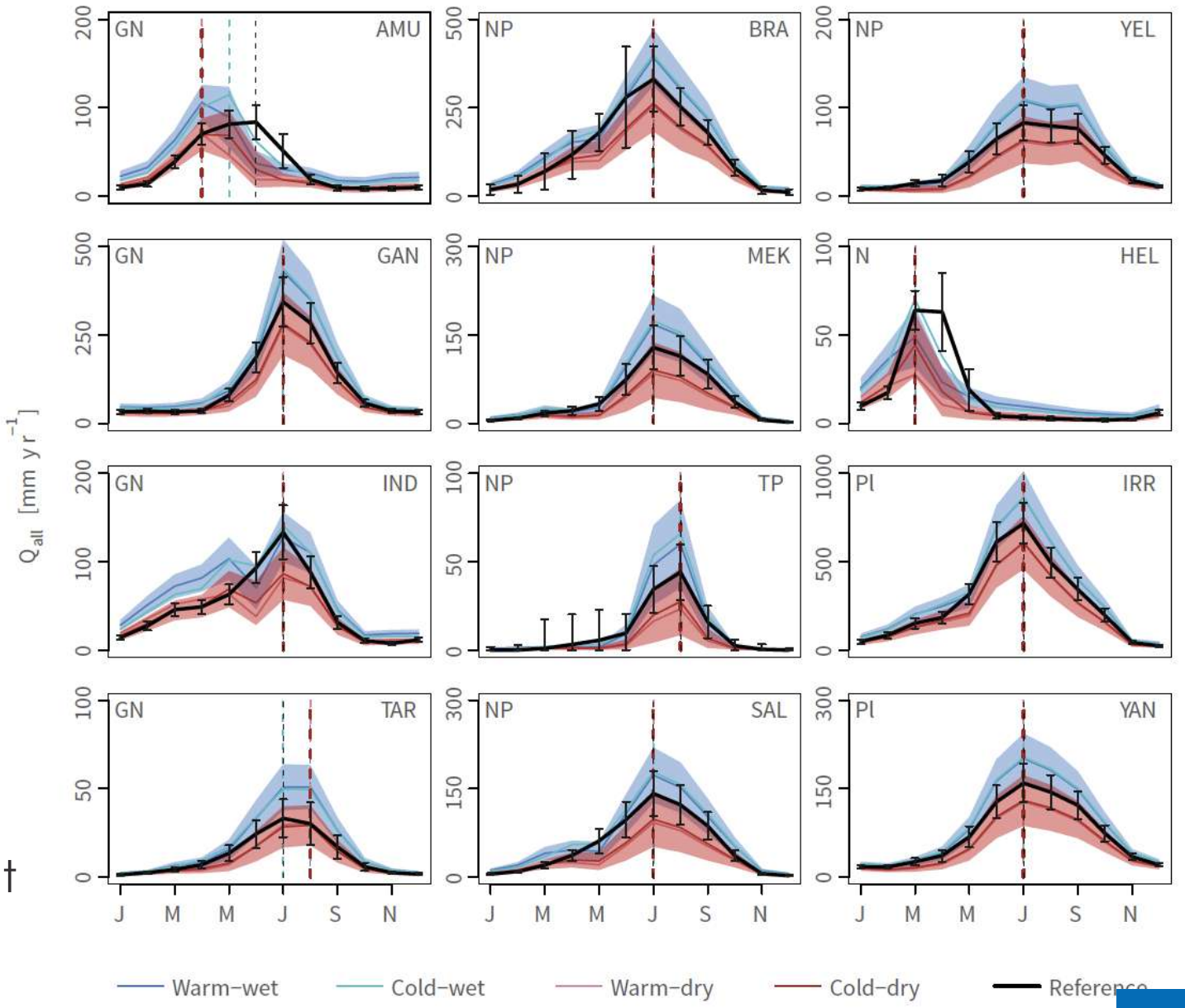
Source: HIWISE Report (2023)

Water availability

Under wet conditions, water availability is expected to increase, while under dry conditions, it will decrease (high uncertainty)

Snow/glacier melt regions: Increased flows in shoulder seasons, potential decline in peak flow. Rainfall-dominated regions: Changes driven by monsoon patterns.

Indus: melting may start 1–2 months earlier, increasing spring/autumn flows but decreasing peak melt season flows



Source: HIWISE Report (2023)

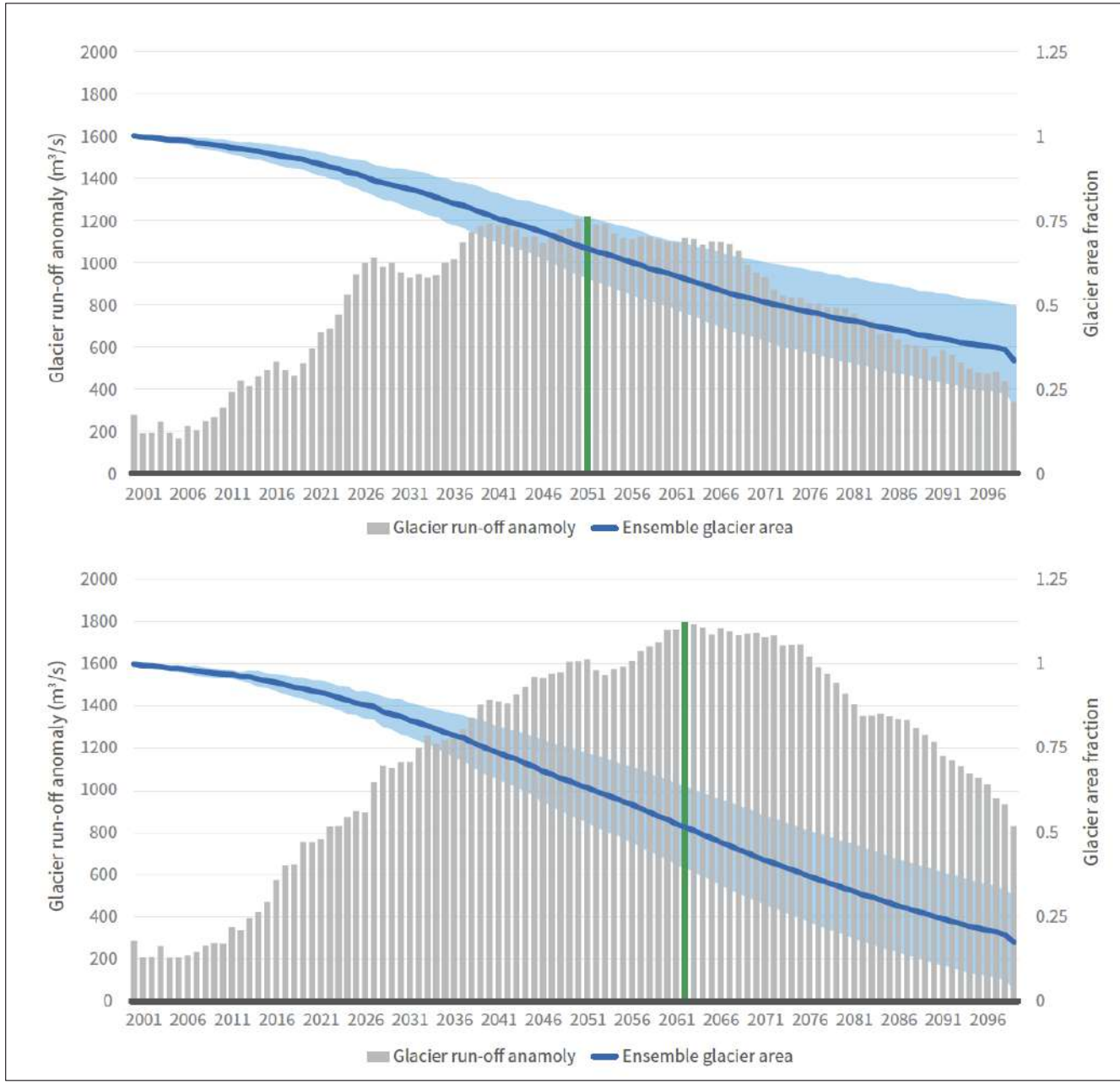
Peak meltwater

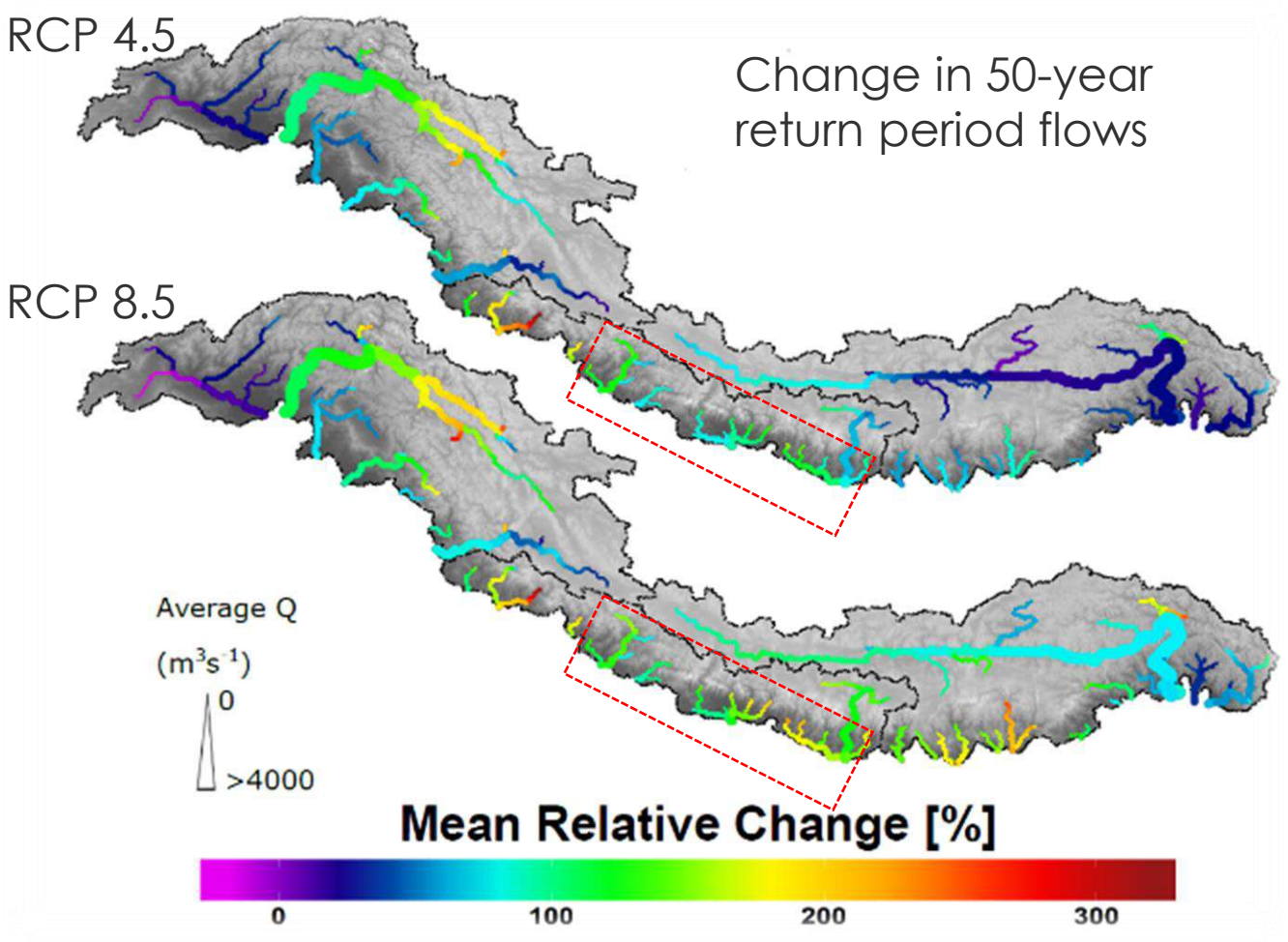
After this point, the flow of meltwater from glaciers will gradually decline as the glaciers lose mass

Projections suggest that peak meltwater may occur between 2030 and 2050, depending on local climate conditions, glacier characteristics, and future warming scenarios.

Source: HIWISE Report (2023)

Indus Basin





Changes in extreme flows

Extremes will increase strongly during the 21st century, almost doubling in magnitude by the end of the century

Source: Wingaard et al. 2017, PlosOne

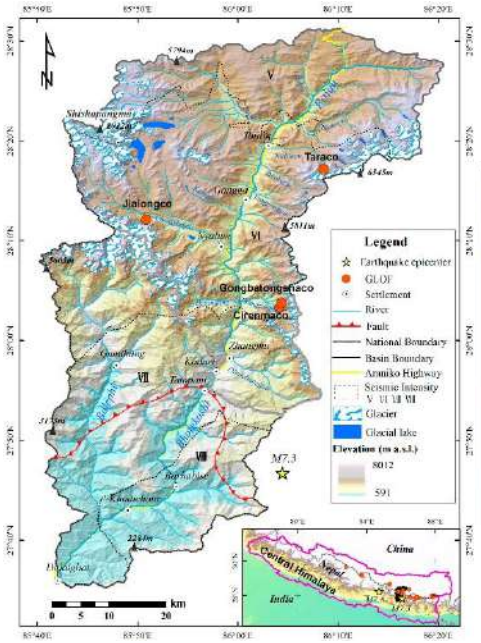
Too much water
Extremes are increasing

Extreme hazard events

- Glacier Lake Outburst Floods (GLOFs)
- Increasing seasonal floods /flashfloods
- Landslide/Landslide dam outburst flood (LDOF)

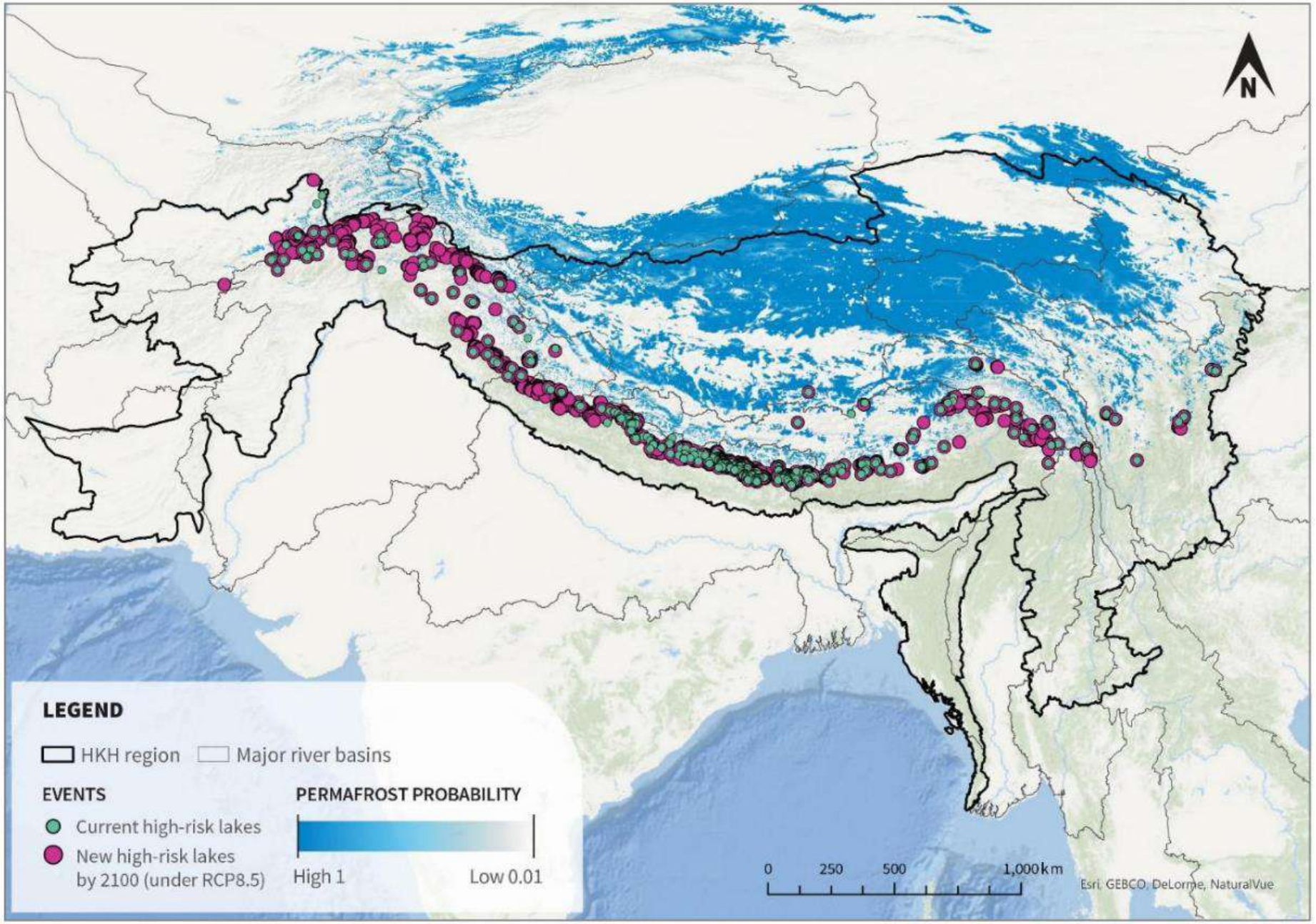
Changing characters

- **Cascading hazards** resulting from a **multi-hazard environment** are increasing
- Extreme precipitation in high altitude
- Permafrost related hazards



Bhote Koshi GLOF (2016) a transboundary disaster

Thame/Thanbo GLOF (16 August 2024)



Glacial lake outburst floods (GLOFs)

A **three-fold increase in GLOF risk** across HKH is projected by the end of the 21st century

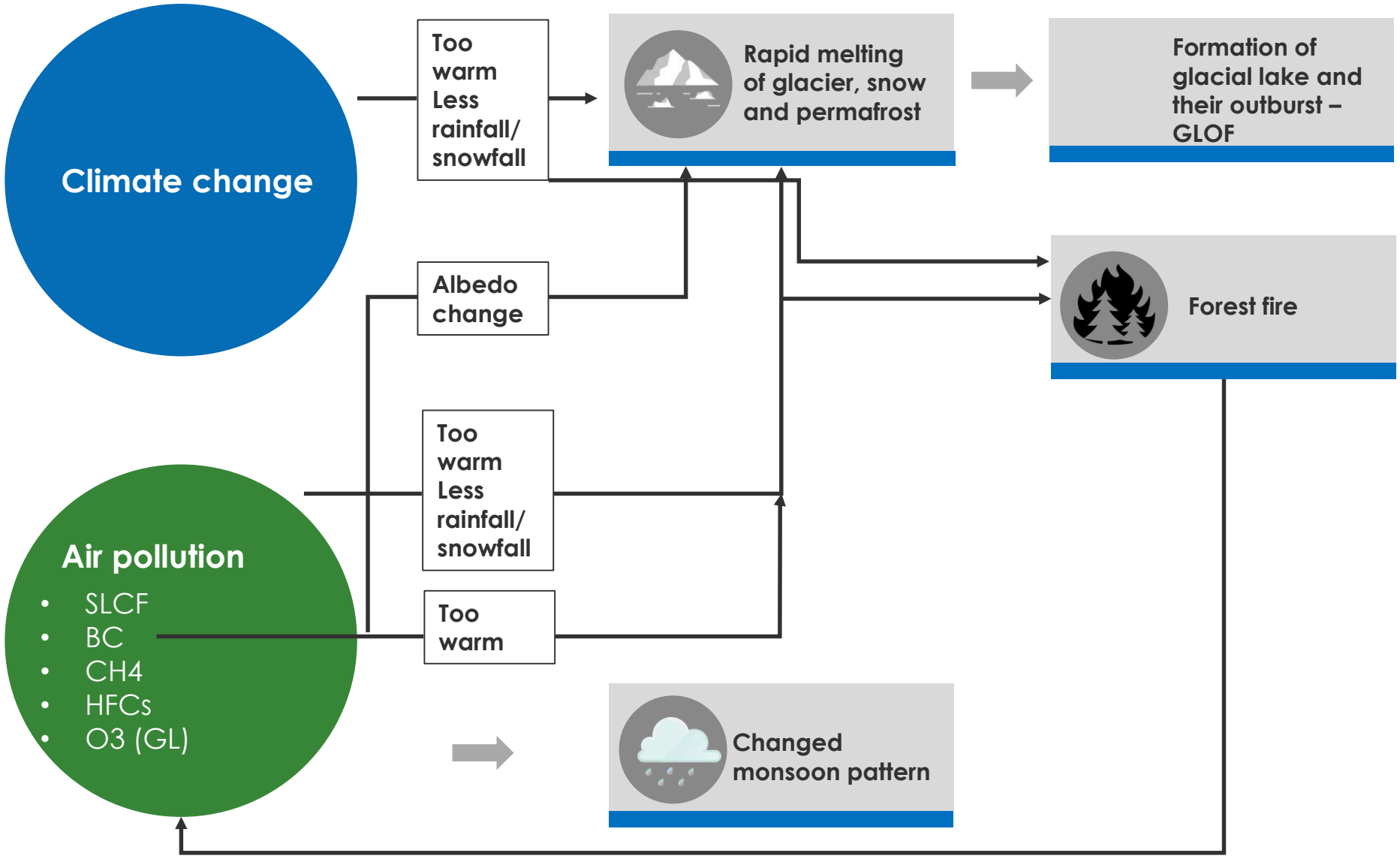
Populations in High Mountain Asia (HMA) are the **most exposed to GLOF risks** as they live closest to glacial lakes

Approx **1 million people living within 10 km** of a glacial lake

HIWISE Report (2023(based on Dbu (2021); Zheng, Allen, et al. (2021)

Climate-Air Quality-Cryosphere Nexus

The nexus diagram

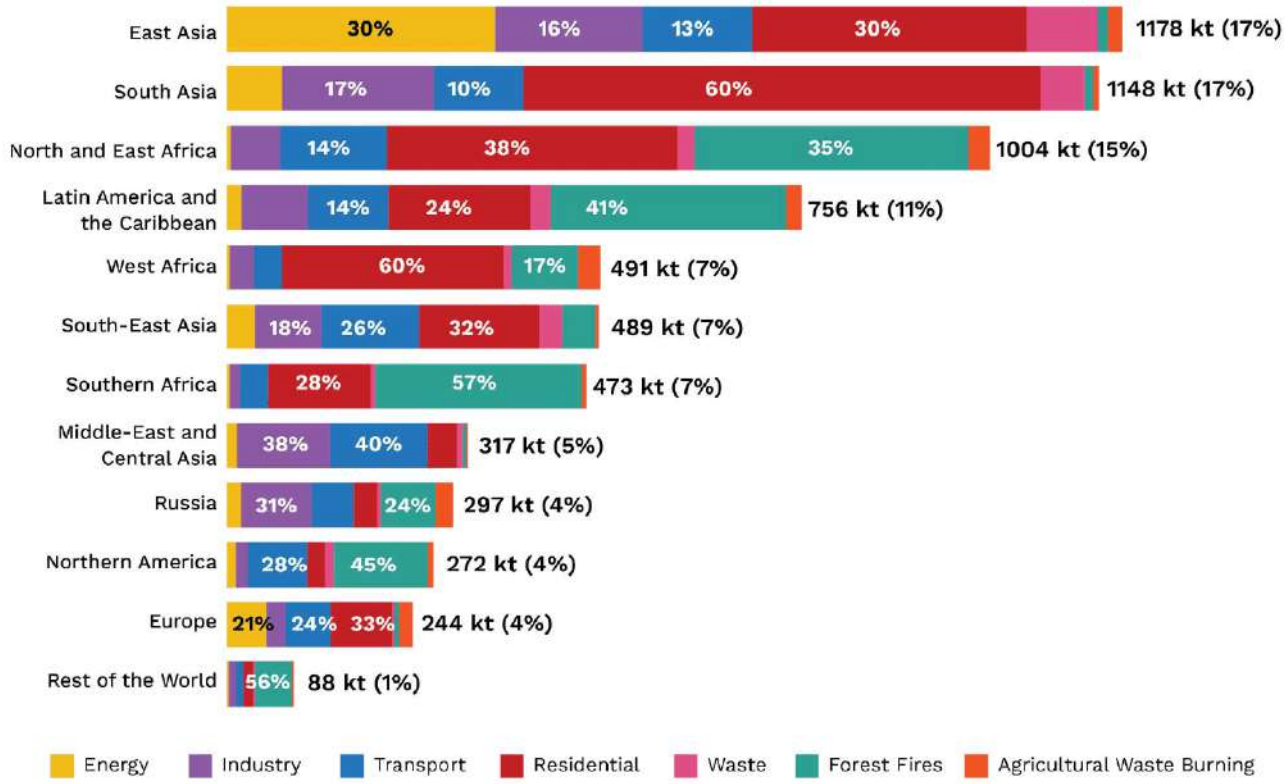


Black carbon – the super pollutant

BC warms the planet at a far more potent rate per tonne than CO_2

Black carbon accelerates ice melting in the Arctic and the glaciers, ice sheets, icebergs, and sea ice that make up the wider cryosphere.

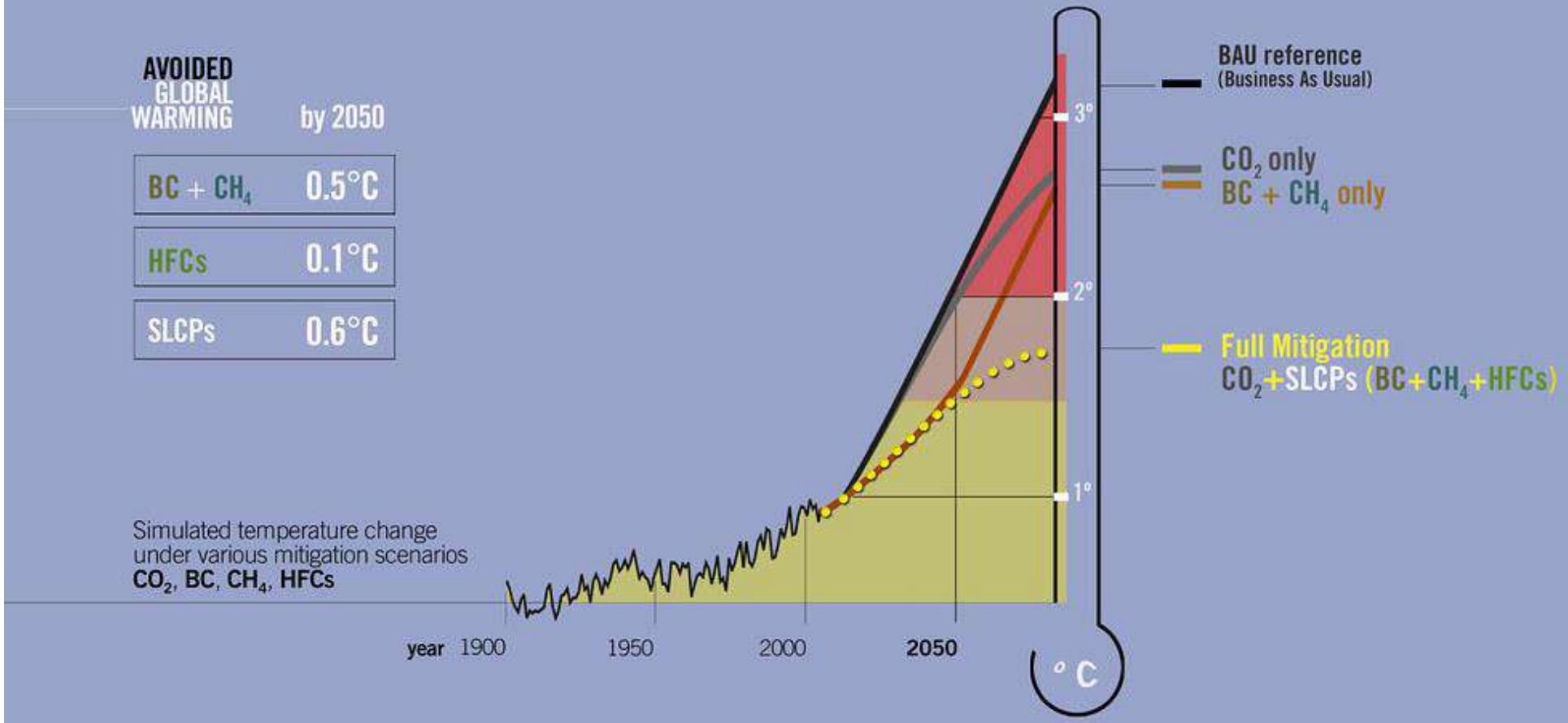
As a component of fine particulate matter (PM2.5), black carbon contributes to ill health and the >8 million premature deaths caused by air pollution each year.



SLCP Climate Benefits Avoided global warming

Rapid implementation of SLCP mitigation measures, together with measures to reduce CO_2 emissions, would greatly improve the chances of keeping the Earth's temperature increase to **less than 2°C** relative to pre-industrial levels.

AVOIDED GLOBAL WARMING	by 2050
BC + CH_4	0.5°C
HFCs	0.1°C
SLCPs	0.6°C



Simulated temperature change under various mitigation scenarios
CO_2, BC, CH_4, HFCs

CCAC

Not secure http://nepal.spatialapps.net/NepalForestFire/EN

Government of Nepal
Ministry of Forests and Environment
Department of Forests and Soil Conservation

Forest Fire Detection and Monitoring System in Nepal

Fire Incident | Fire Stats | ने | Login

Fire Incident Query

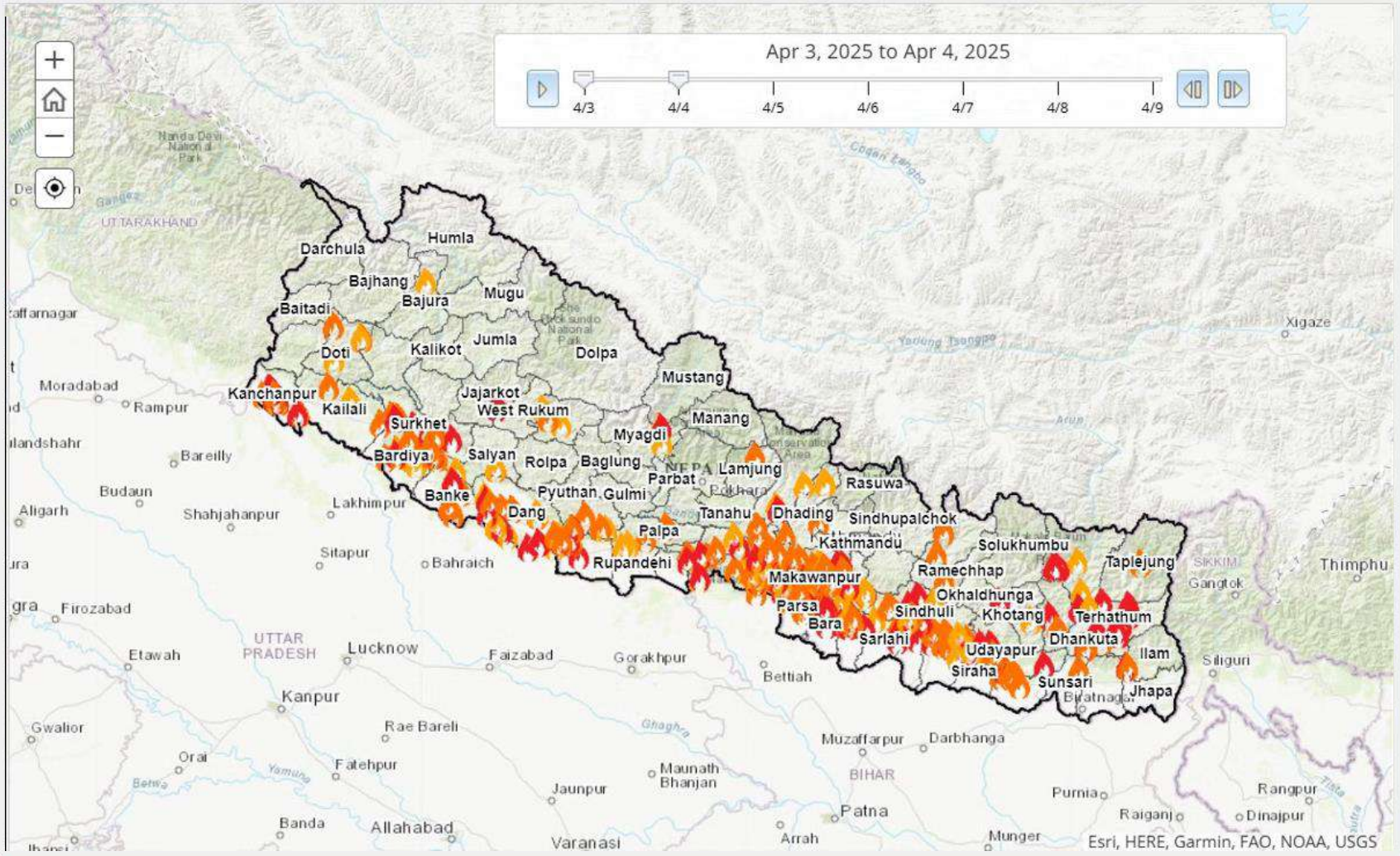
- Nepal
- Province: Koshi
- District: Achham
- Protected Area: All

Start Date: 4/3/2025
End Date: 4/9/2025

View on map
View on table
Subscribe email

Fire Statistics (MODIS) 691

District	Count
Achham	2
Arghakhanchi	7
Baitadi	4
Bajura	2
Banke	28
Bara	24

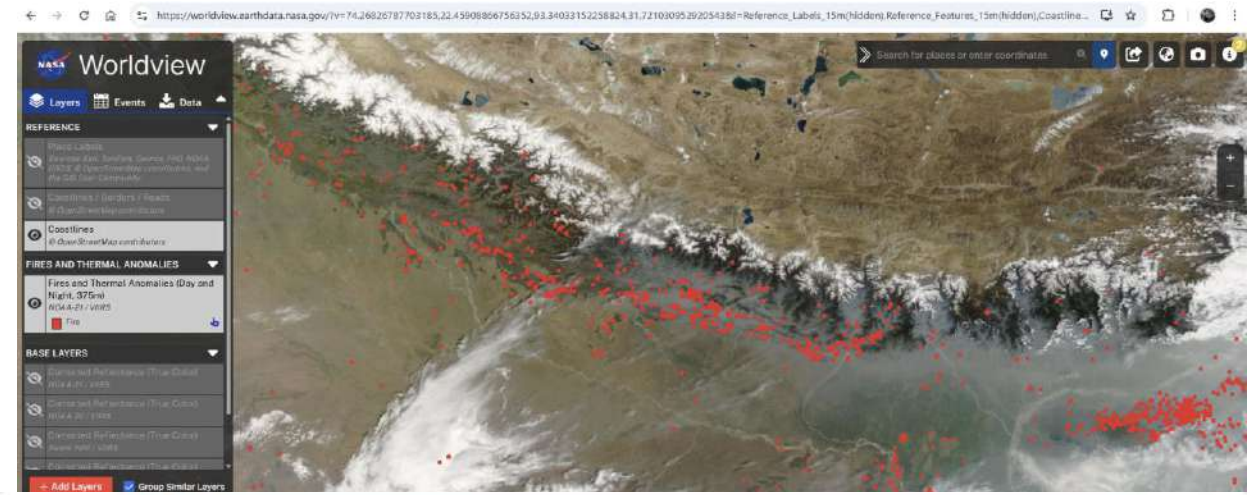


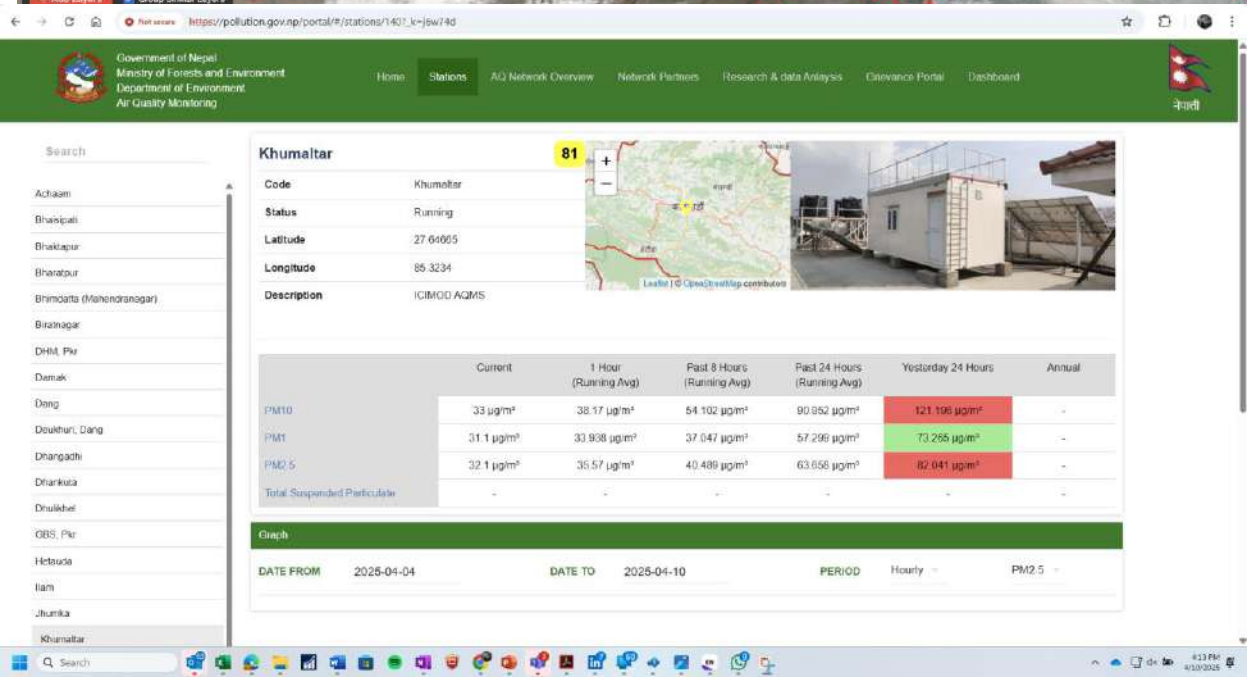
Layer | Legend | Basemap

- [x] Country outline
- [ ] Province
- [x] District
- [x] District labels
- [ ] Gaunpalika/Nagarpalika
- [ ] Protected area
- [ ] Protected area label
- [x] MODIS active fire
- [ ] VIIRS active fire
- [ ] MODIS fire outside forest
- [x] Reported forest fire

About

ICIMOD, in close collaboration with the Department of Forests and Soil Conservation (DoFSC), Ministry of Forests and Environment, Government of Nepal, has jointly developed this Forest Fire Detection and Monitoring System in Nepal.
The system provides information on historical and


Worldview
Layers
Events
Data
REFERENCE
Coastlines
FIRES AND THERMAL ANOMALIES
Fires and Thermal Anomalies (Day and Night, 375m)
Fire
BASE LAYERS
Add Layers
Group Similar Layers


Government of Nepal
Ministry of Forests and Environment
Department of Environment
Air Quality Monitoring
Home
Stations
AQ Network Overview
Network Partners
Research & data Analysis
Grievance Portal
Dashboard
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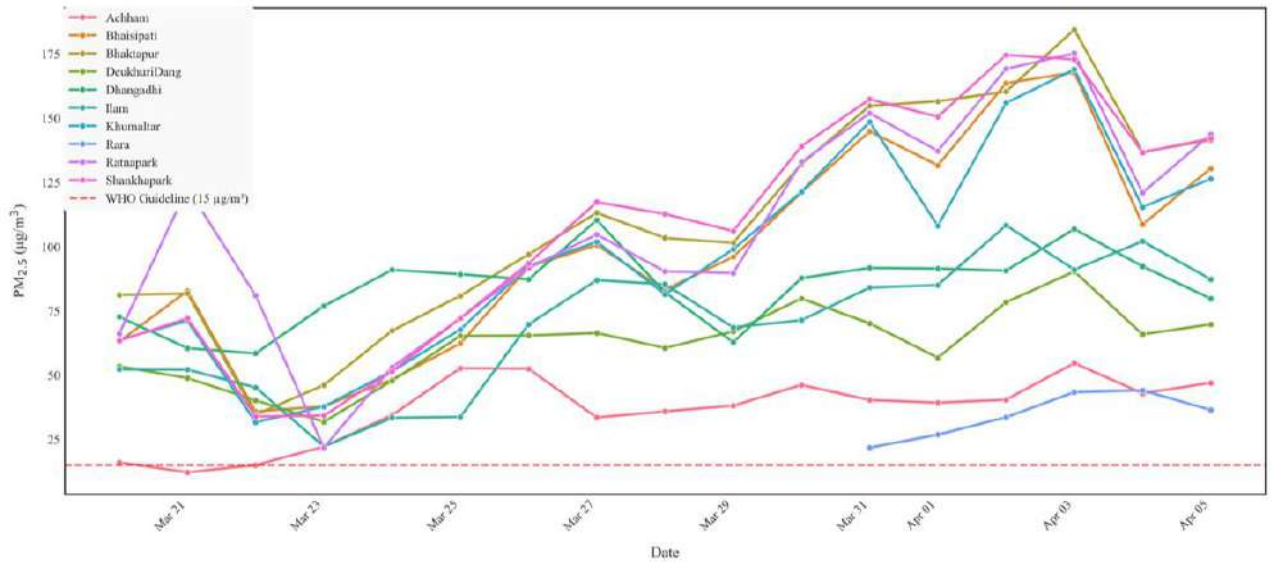
Bhaktapur
Bharatpur
Bhimdatta (Mahendranagar)
Biratnagar
DHM, Pkr
Damak
Dang
Deukhuri, Dang
Dhangadhi
Dhankuta
Dhulikhel
GBS, Pkr
Hetauda
Ilam
Jhumka
Khumaltar
Khumaltar
81
Code
Khumaltar
Status
Running
Latitude
27.64665
Longitude
85.3234
Description
ICIMOD AQMS
Current
1 Hour (Running Avg)
Past 8 Hours (Running Avg)
Past 24 Hours (Running Avg)
Yesterday 24 Hours
Annual
PM10
33 µg/m³
38.17 µg/m³
54.102 µg/m³
90.852 µg/m³
121.196 µg/m³
PM1
31.1 µg/m³
33.938 µg/m³
37.047 µg/m³
57.296 µg/m³
73.265 µg/m³
PM2.5
32.1 µg/m³
35.57 µg/m³
40.489 µg/m³
63.656 µg/m³
82.041 µg/m³
Total Suspended Particulate
Graph
DATE FROM
2025-04-04
DATE TO
2025-04-10
PERIOD
Hourly
PM2.5


Achham
Bhaisipati
Bhaktapur
DeukhuriDang
Dhangadhi
Ilam
Khumaltar
Rara
Ratnapark
Shankhapark
WHO Guideline (15 µg/m³)
PM2.5 (µg/m³)
175
150
125
100
75
50
25
Mar 21
Mar 23
Mar 25
Mar 27
Mar 29
Mar 31
Apr 01
Apr 03
Apr 05
Date

Key message

Crisis is happening now! It will only exacerbate in the future.

Disaster is becoming a regular phenomenon. Climatic **extreme, more frequent and severe impacts** in the coming days

More **cryospheric** hazards

Too much and too little water is the major challenge

Air quality is rapidly deteriorating on average reducing **5 years of life** of HKH population

There is a **strong link** between climate change and air pollution

Mitigation of climate change and air pollution have **co-benefits**


Thank You
Let's join hands before its too late!
1.5 DEGREES IS TOO HOT
#SaveOurSnow
www.icimod.org/saveoursnow