

Building integrated high-mountain observations and modelling capacity in the Nepal Himalaya: HiM-DATA & Preliminary CRHM applications

(Observation to Modelling)

Dhiraj Pradhananga, Nepal

Kumar Aryal, Tribhuvan University

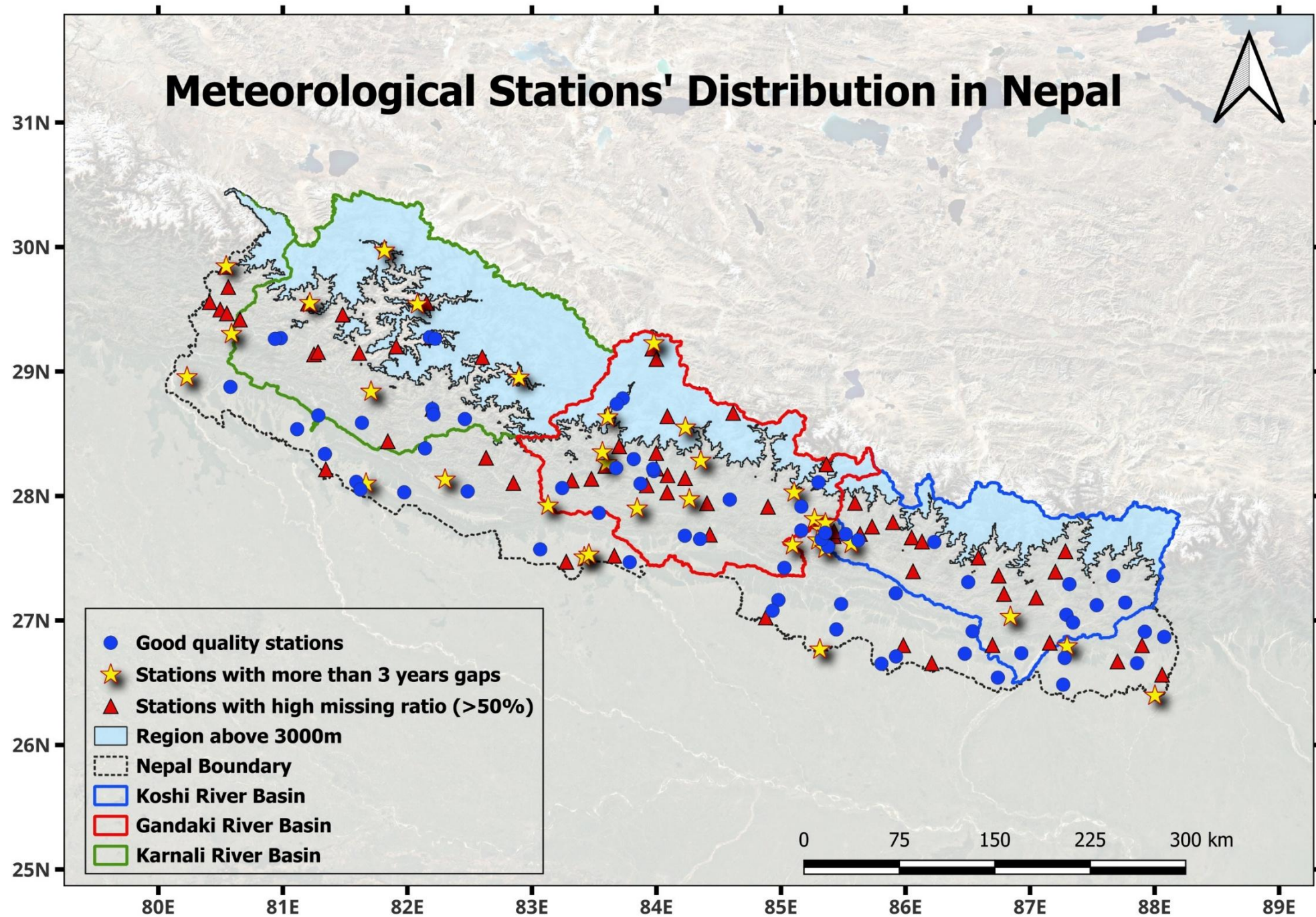
Susa Manandhar, The Small Earth Nepal

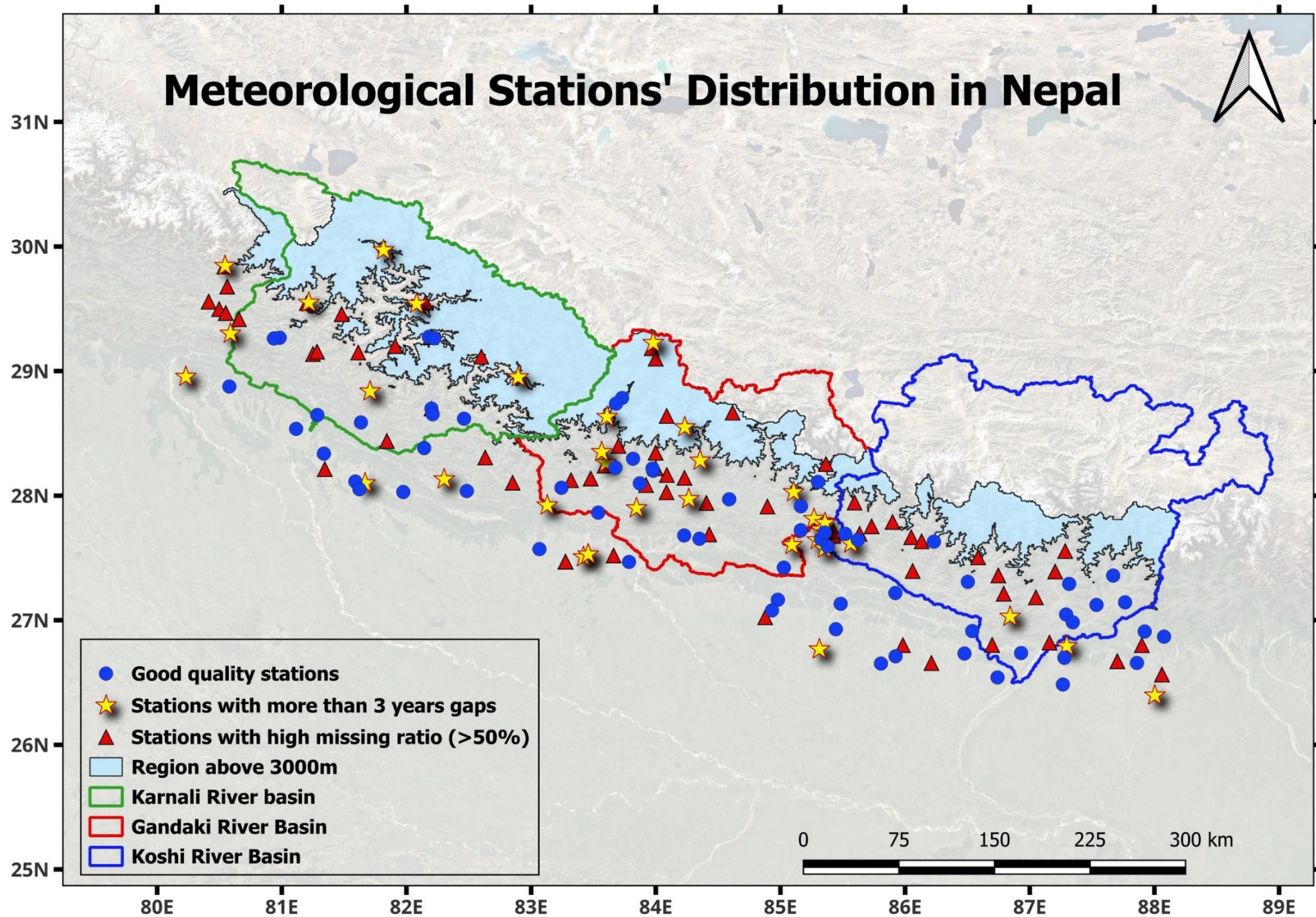
8 Sept 2026

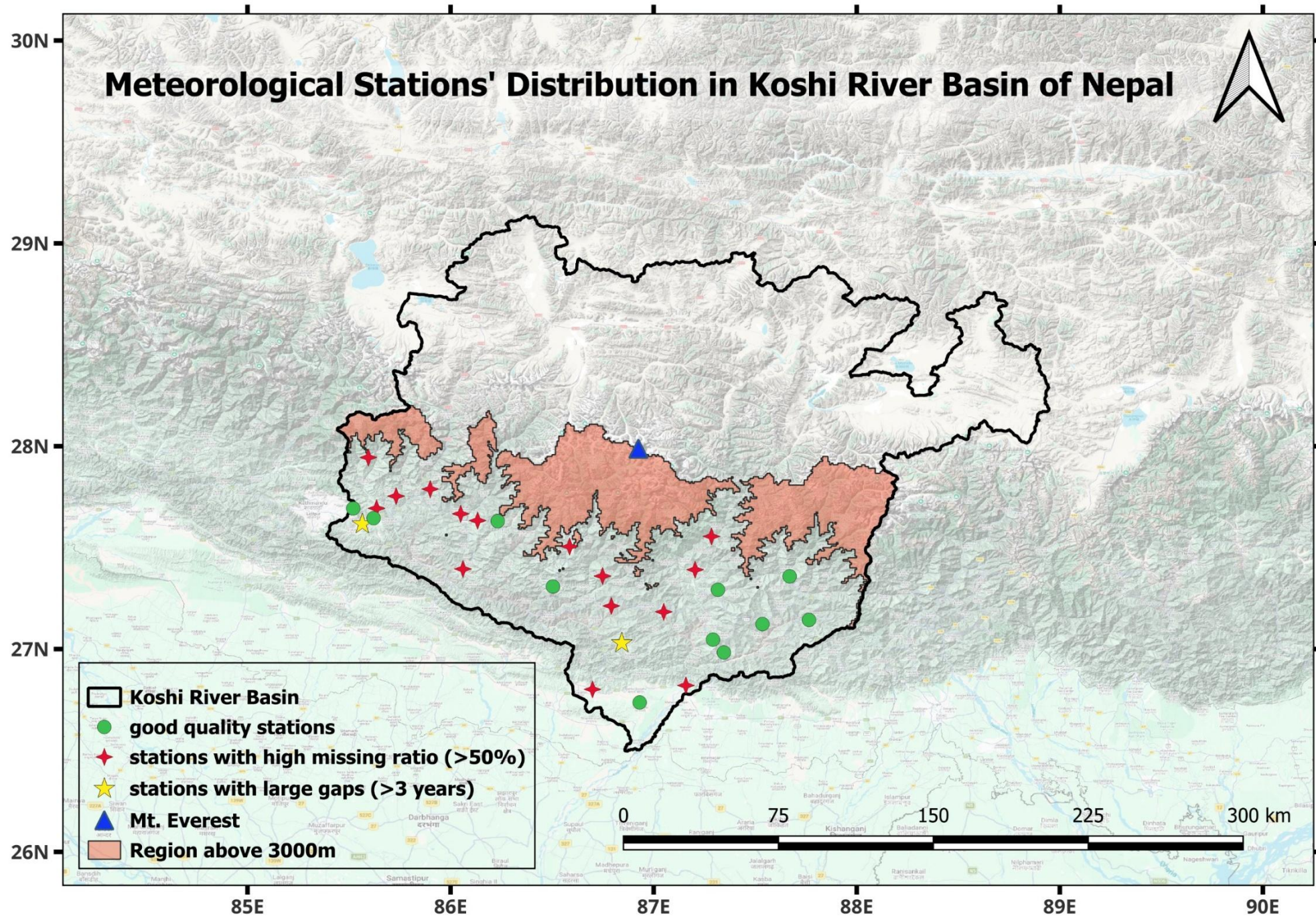
INARCH 2026, Kananaskis, Alberta, Canada

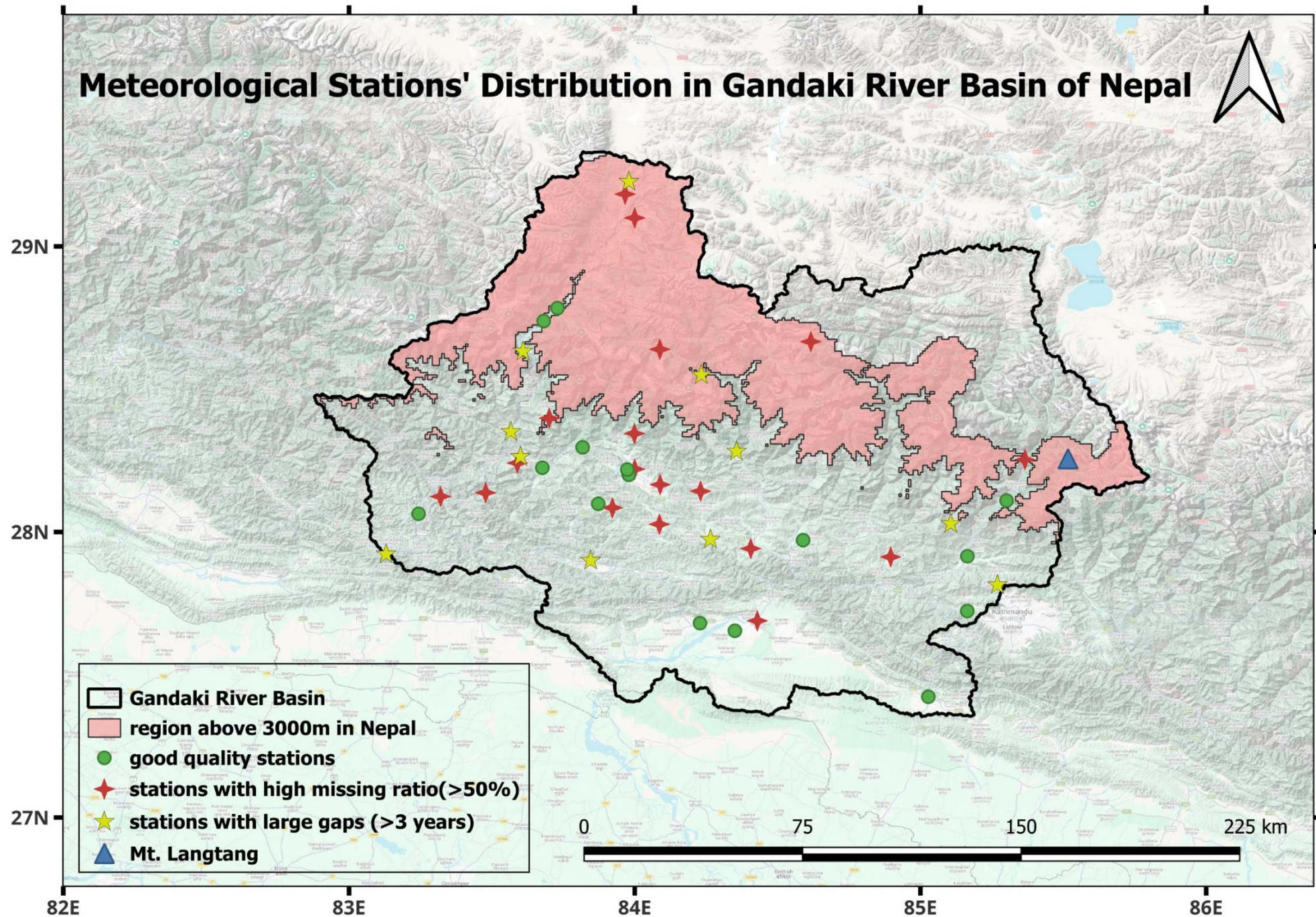
Background

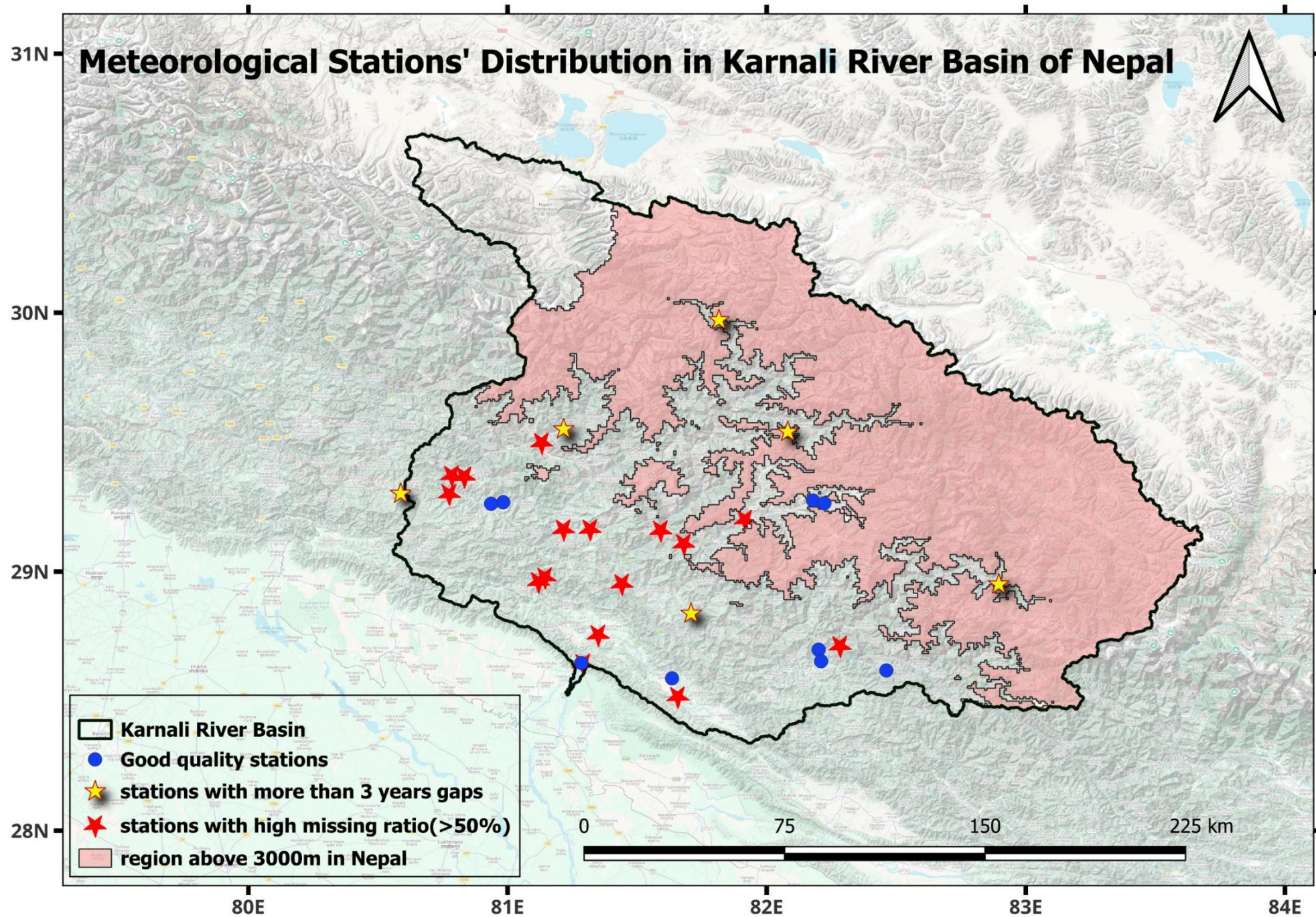
- Need for high-elevation hydroclimatic data in the Himalayas
- Bridge local observations with advanced hydrological modelling
- Extreme topographic gradients
- Sparse high-elevation meteorological stations and vulnerabilities to cryospheric change (glacial retreat, snow cover shifts, extreme precipitation)
- Standard networks don't capture high-altitude processes
- Need for innovative observation strategies
- Not many glacio-hydrologists (female hydrologists?)



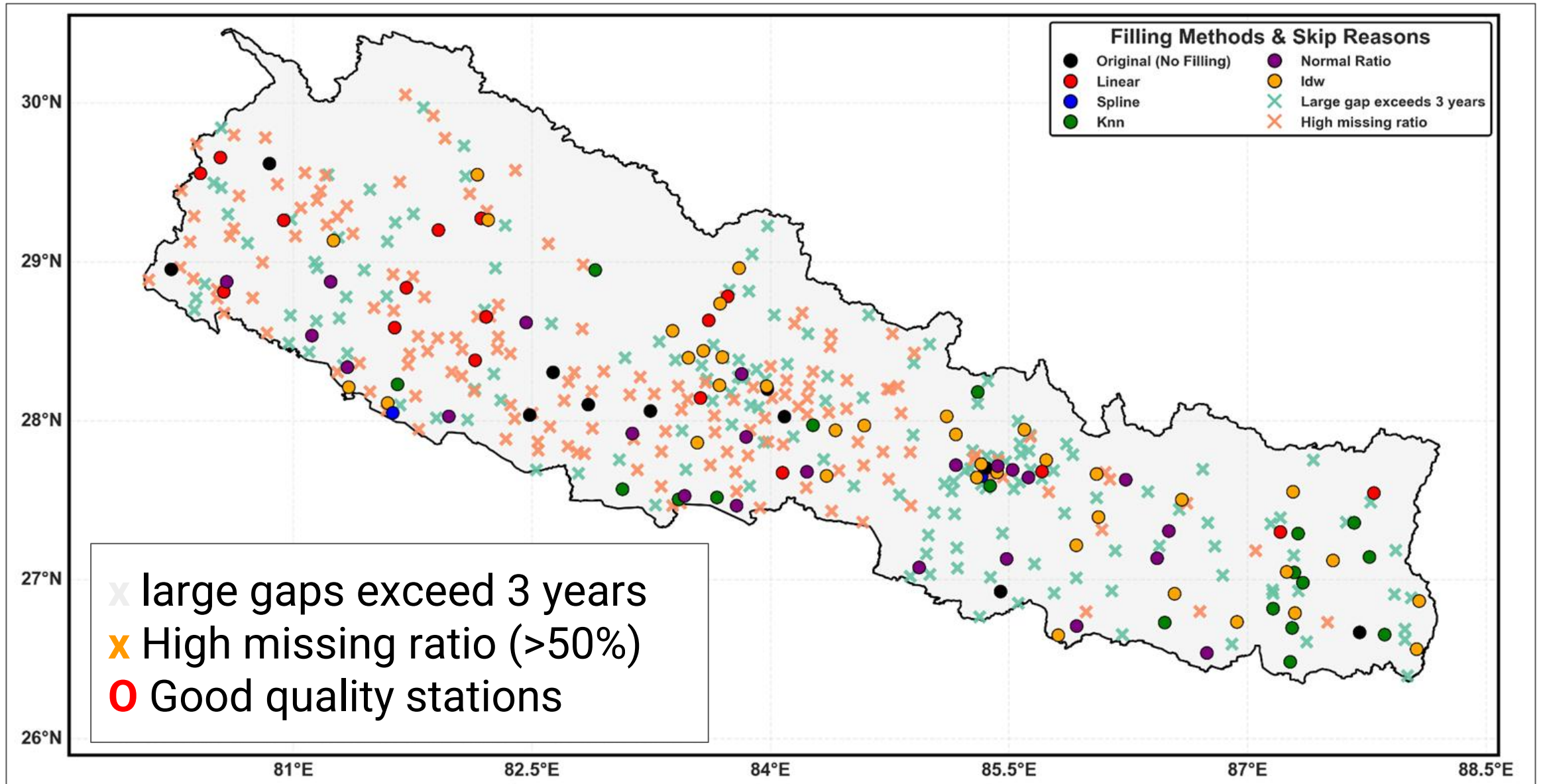






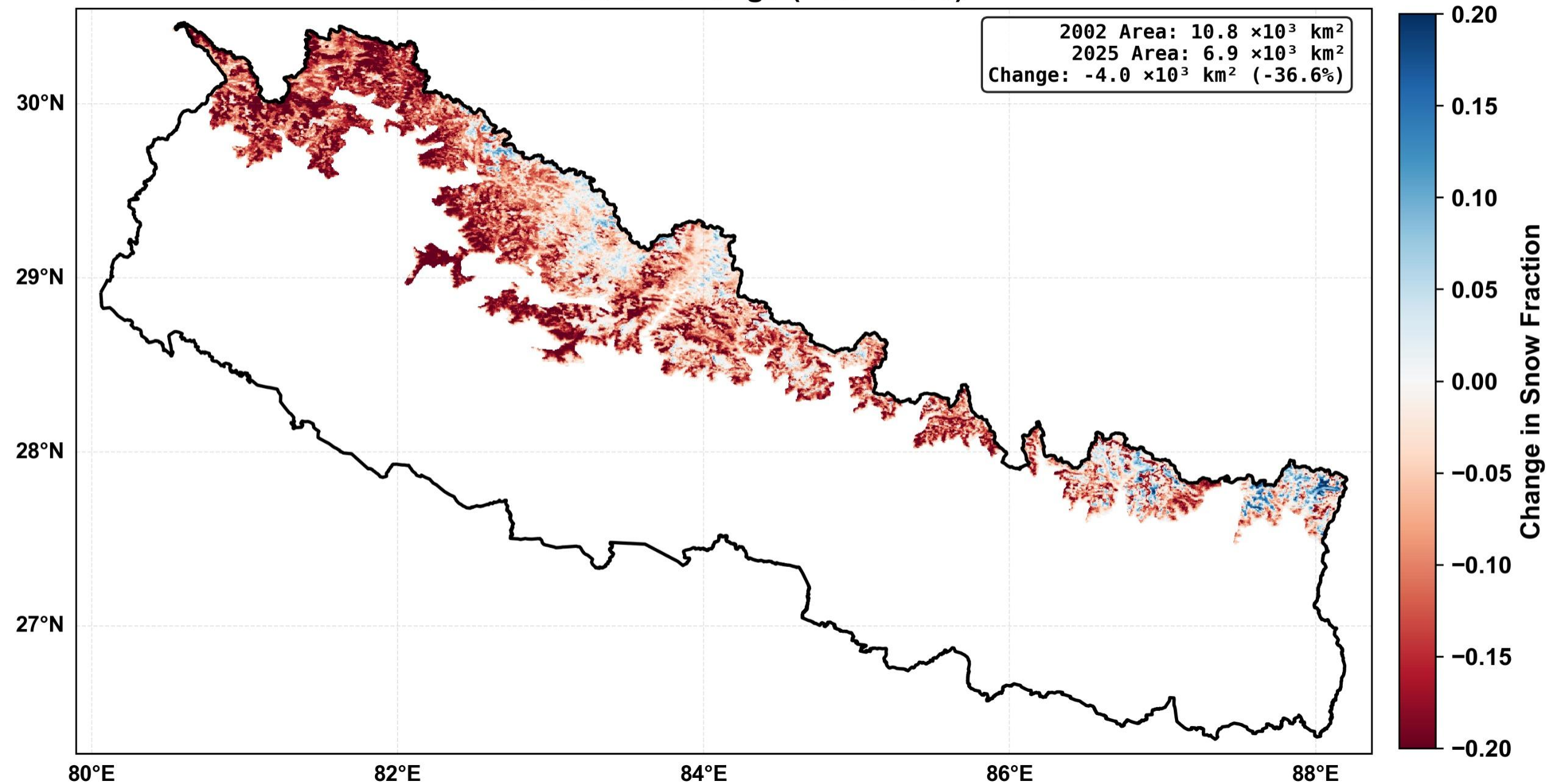


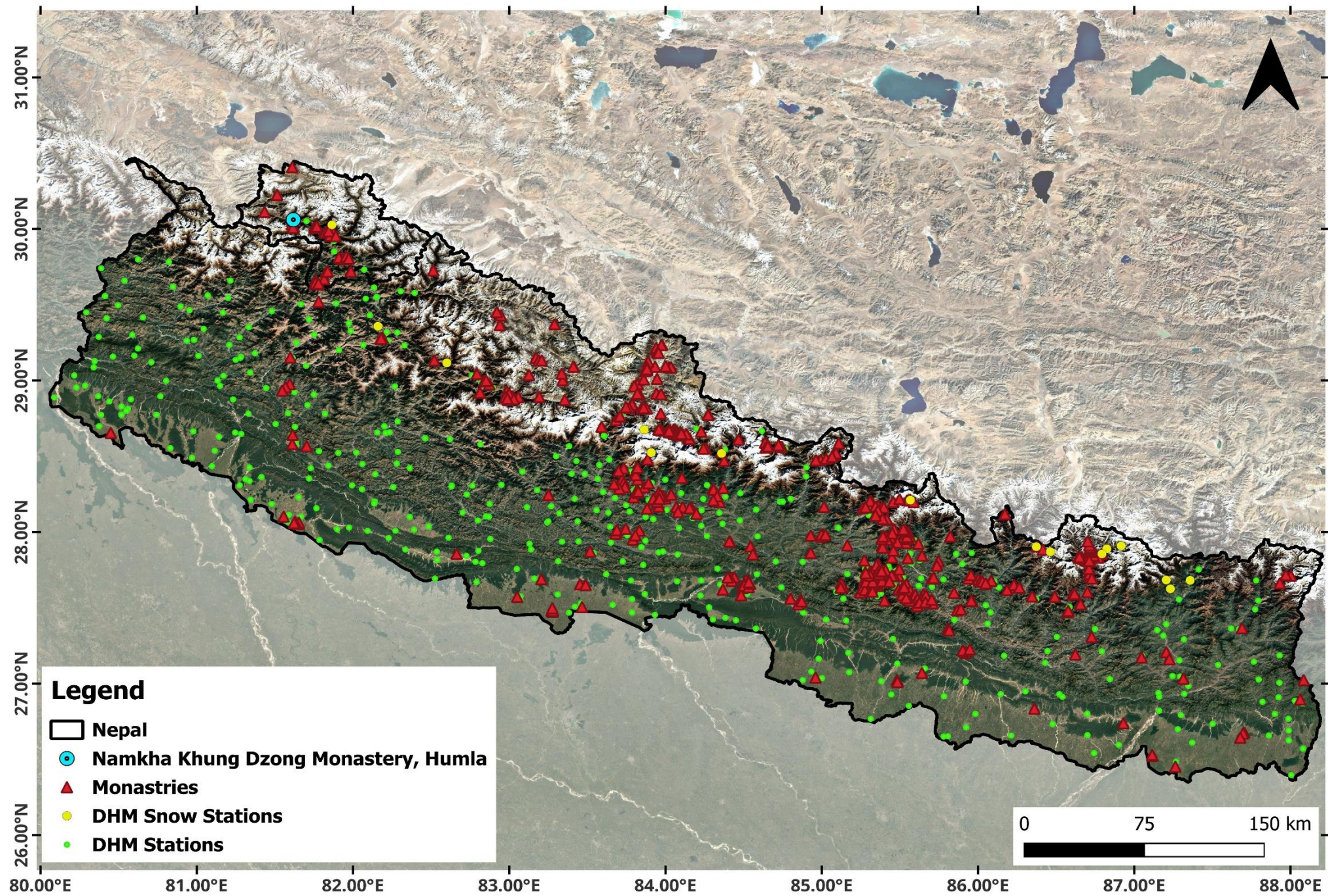
Meteorological Stations Distributions and Quality Challenges

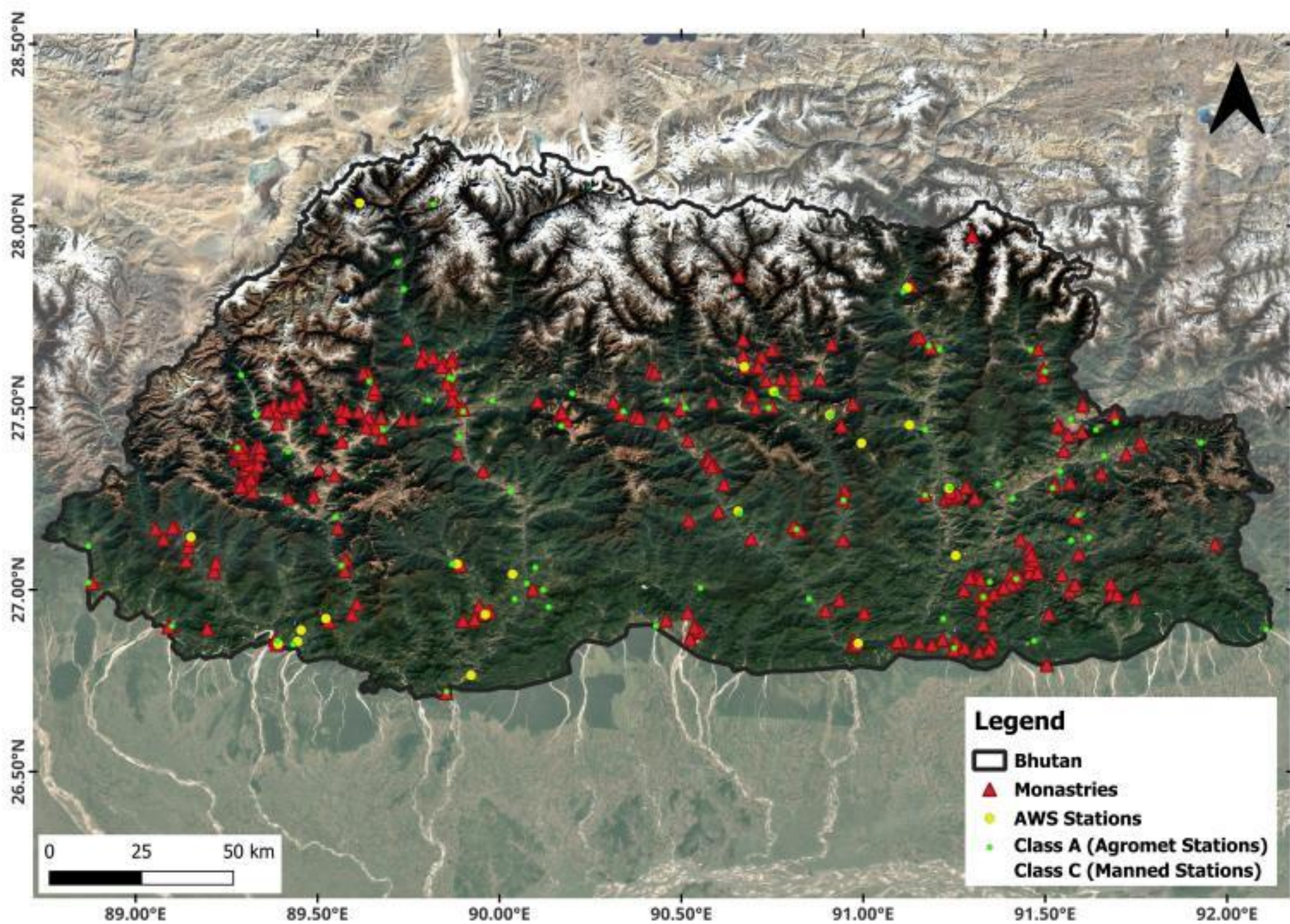


Snow Cover Change (2002–2025)

2002 Area: $10.8 \times 10^3 \text{ km}^2$
2025 Area: $6.9 \times 10^3 \text{ km}^2$
Change: $-4.0 \times 10^3 \text{ km}^2$ (-36.6%)







HiM-DATA (High-Altitude Monasteries for Data Acquisition, Tracking and Awareness)

- Remote high-elevation monasteries serve as ideal, inhabited sites year-round for continuous data collection, community engagement, and environmental tracking.
- Community-led data collection and research
- Local stewardship (local government, monastery, school)
- Monasteries bridge indigenous knowledge with scientific instrumentation and processes

- Strategic locations near snow and glacier zones
- Year-round presence in remote high-altitude regions (?)
- Security and protection from theft and vandalism
- On-site support by the monks in the maintenance of the stations
- Strong community trust, enabling knowledge dissemination
- Educational function, allowing monks and students to act as climate ambassadors
- Knowledge hub and dissemination place





World Meteorological Organization

157,900 followers

2w • 🌐

+ Follow

Around 90% of essential weather observations are still missing in Least Developed Countries and Small Island States. Inspiring community-driven projects like HiM-DATA help close this gap by strengthening local observation and open data in hard-to-reach regions like the high Himalaya.



The Small Earth Nepal

2,885 followers

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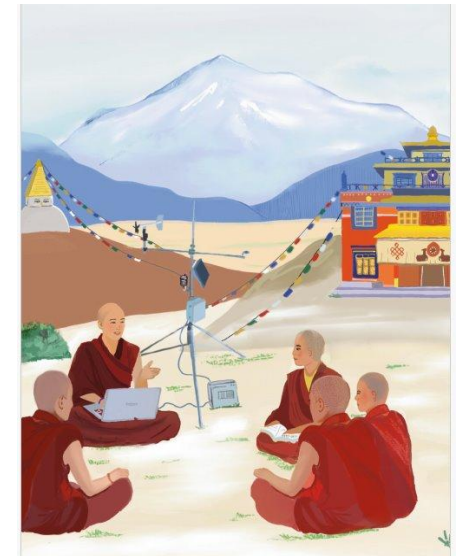
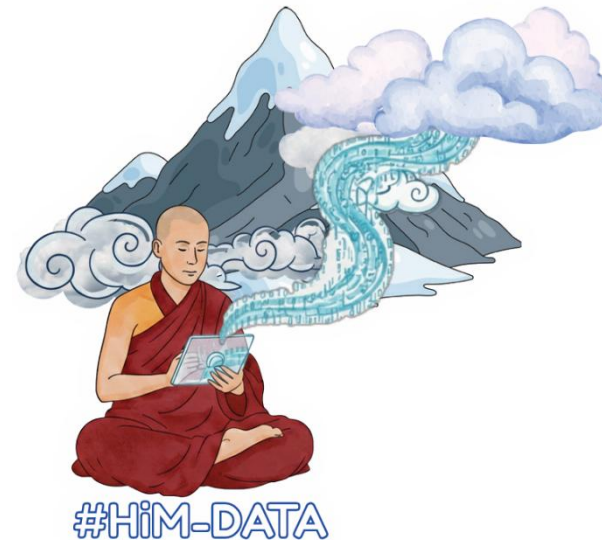
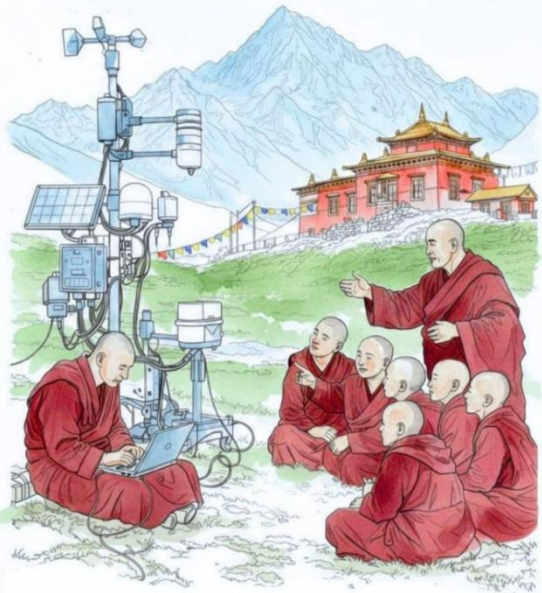
Introducing **HiM-DATA**!

A community-driven initiative uniting science and monastic partners to strengthen climate observation in the high Himalaya. 🏔️ Together, we're expanding weather monitoring and advancing open data and open science for all. HiM-DATA is about **co-creation**: empowering local mountain custodians, keeping Himalayan data open and accessible, and turning knowledge into climate action.

#HiM-DATA

High-altitude Monasteries for Data Acquisition, Tracking & Awareness

- *a community-based initiative*
- *pairs scientific research with monastic communities to improve climate observation*





Monks engaged in a roundtable group discussion and presentation.



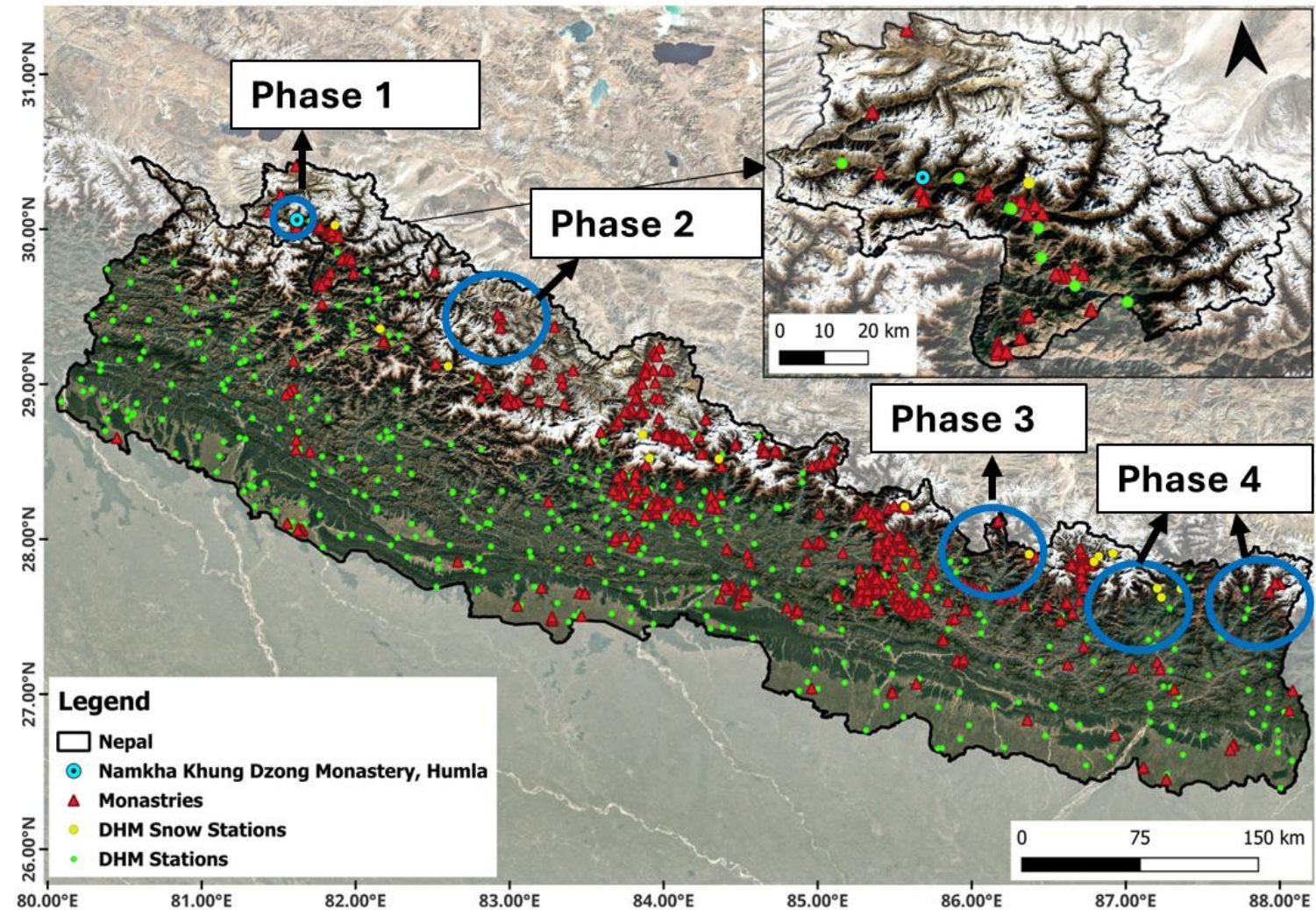
Signing of MOU

Workshop glimpses:

Gap Analysis:

Lack of long-term high-altitude monitoring (3000+) remains a critical challenge

- **Phase 1:** Implementation of Pilot Station (Humla) (2026-27)
- **Phase 2:** Planning, consultation and installation of additional Stations (Dolpo, Manang) (2026-27)
- **Phase 3:** Planning, consultation and installation of additional stations (Dolkha)
- **Phase 4:** Planning, consultation in further regional gaps (i.e., eastern Nepal) (2027-2028)



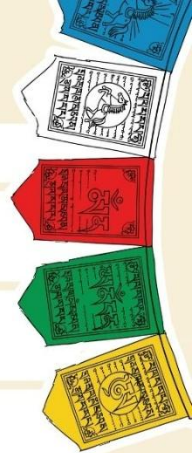
Pre-Pilot Station in Manang, Nepal



Mr. Jamie Smith at the Monastery



A vertical string of five colorful prayer flags (yellow, green, red, white, and blue) with Tibetan script and symbols. The flags are arranged vertically, with the yellow flag at the top and the blue flag at the bottom. Each flag features different Tibetan script and symbols, including a central circular emblem on the white flag. The flags are tied together by a string at the top.



Panel 1: Inside a monastery, a monk explains the importance of being on time to a young boy.

Panel 2: The monk shows the boy a digital watch.

Panel 3: The monk holds a water bottle in a courtyard.

Panel 4: The monk holds a rolled-up map.

Panel 5: The monk looks at a map in a snowy village, with a table for weather predictions.

Climate Disasters, Climate Vocabulary, Data Collection and Use, Weather Instruments, Data Presentation and Interpretation, Links between Indigenous Knowledge and Science, Learning Activities, Summary

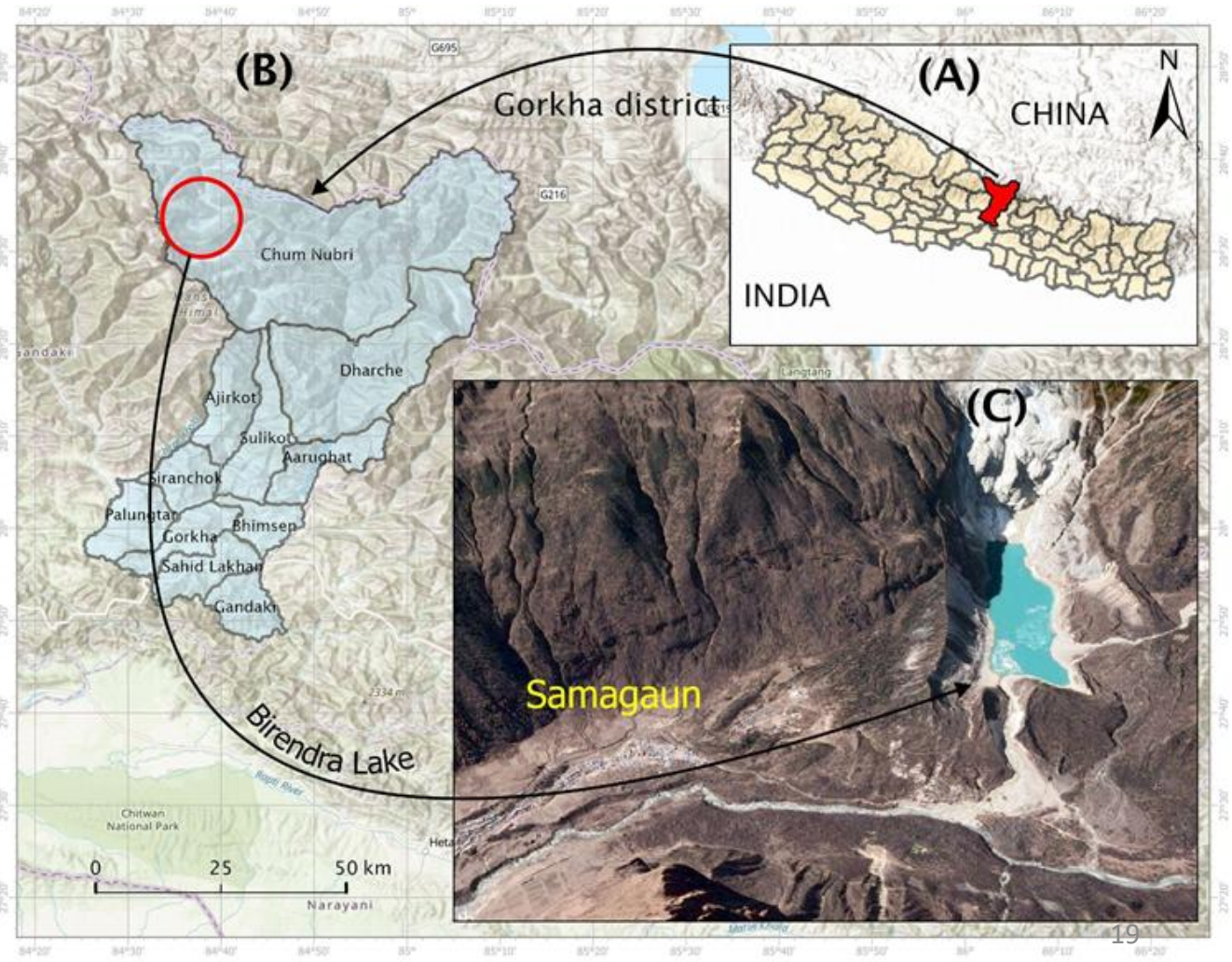
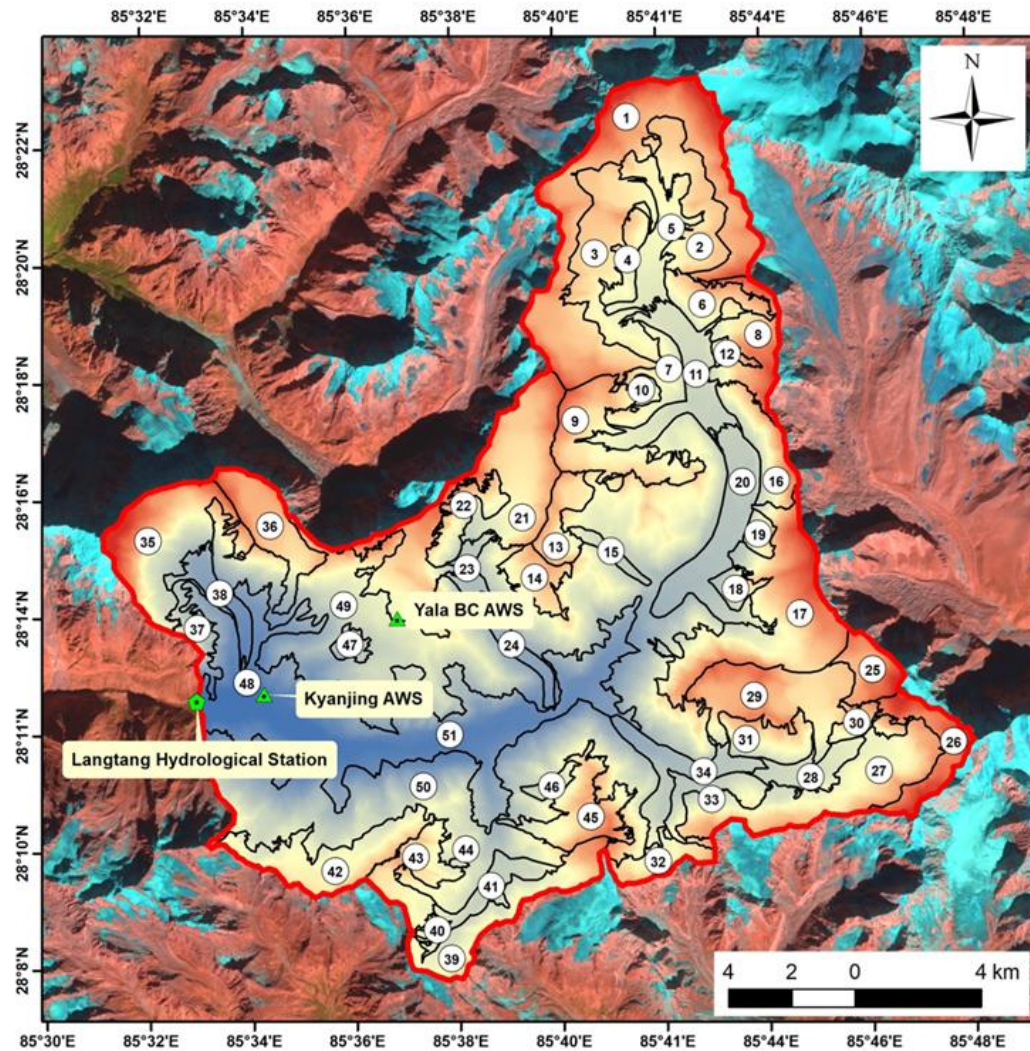


CRHM in The Small Earth Nepal (SEN)

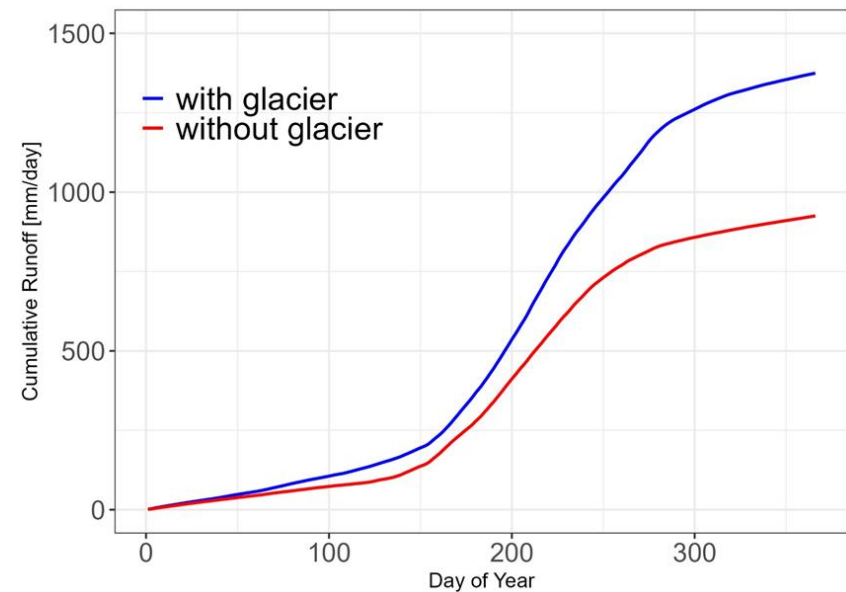
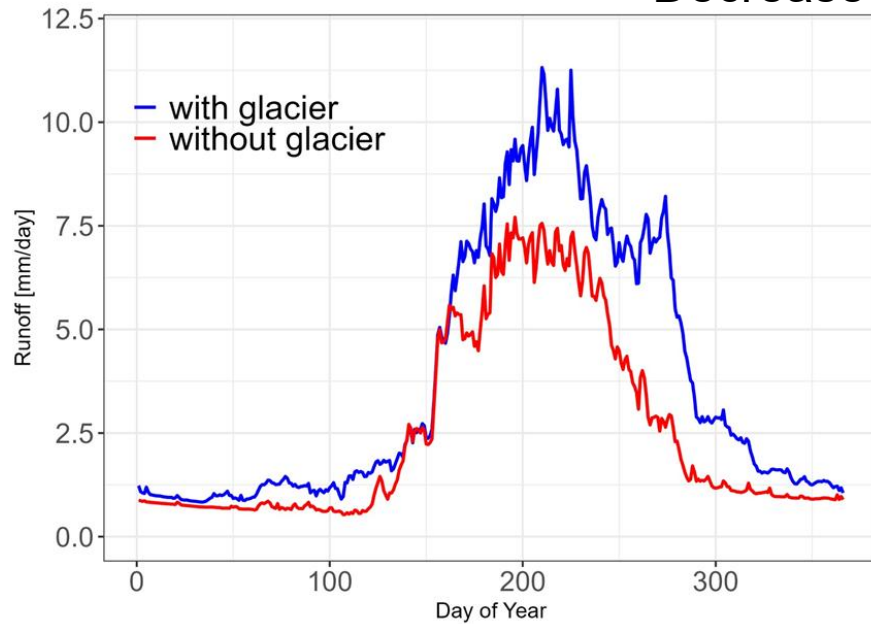


Research

Modelling CRHM: The Cold Regions Hydrological Model



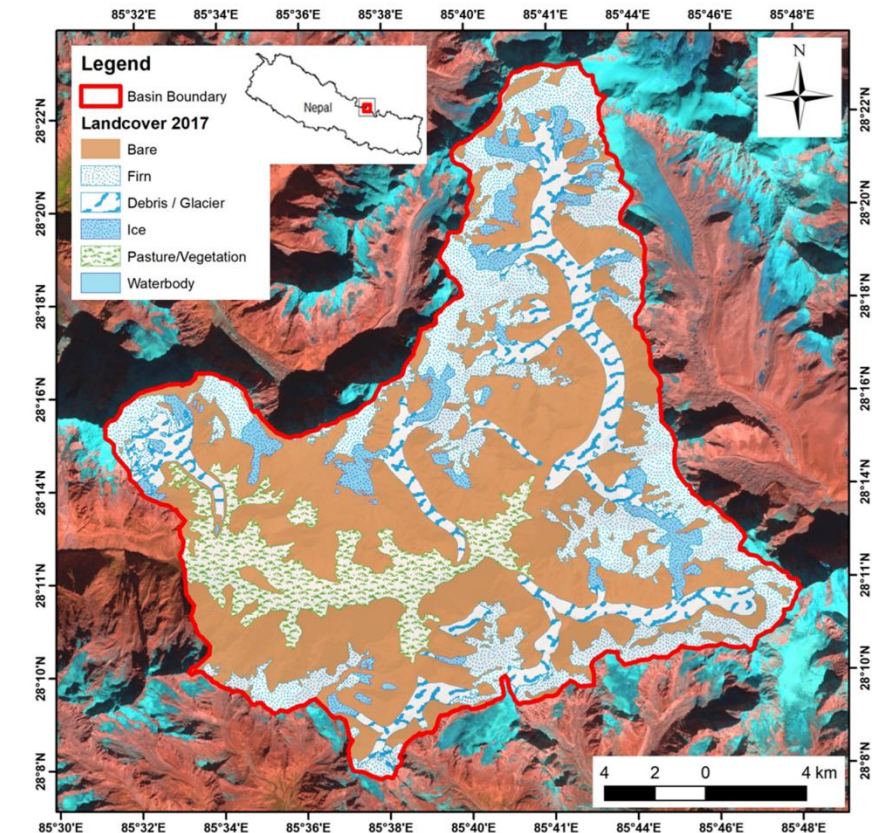
Decrease in runoff by 32%



Scenario	% Change in runoff
With Glacier	0%
Without Glacier	32%
(a) Increase in Temperature 1.5°C and Precipitation 5%	
With Glacier	+ 89%
Without Glacier	-7.6%
(b) Increase in Temperature 2°C and Precipitation 10%	
With Glacier	+112%
Without Glacier	-3.2%
(c) Increase in Temperature 4°C and Precipitation 20%	
With Glacier	+ 234%
Without Glacier	-27.6%

Modelling

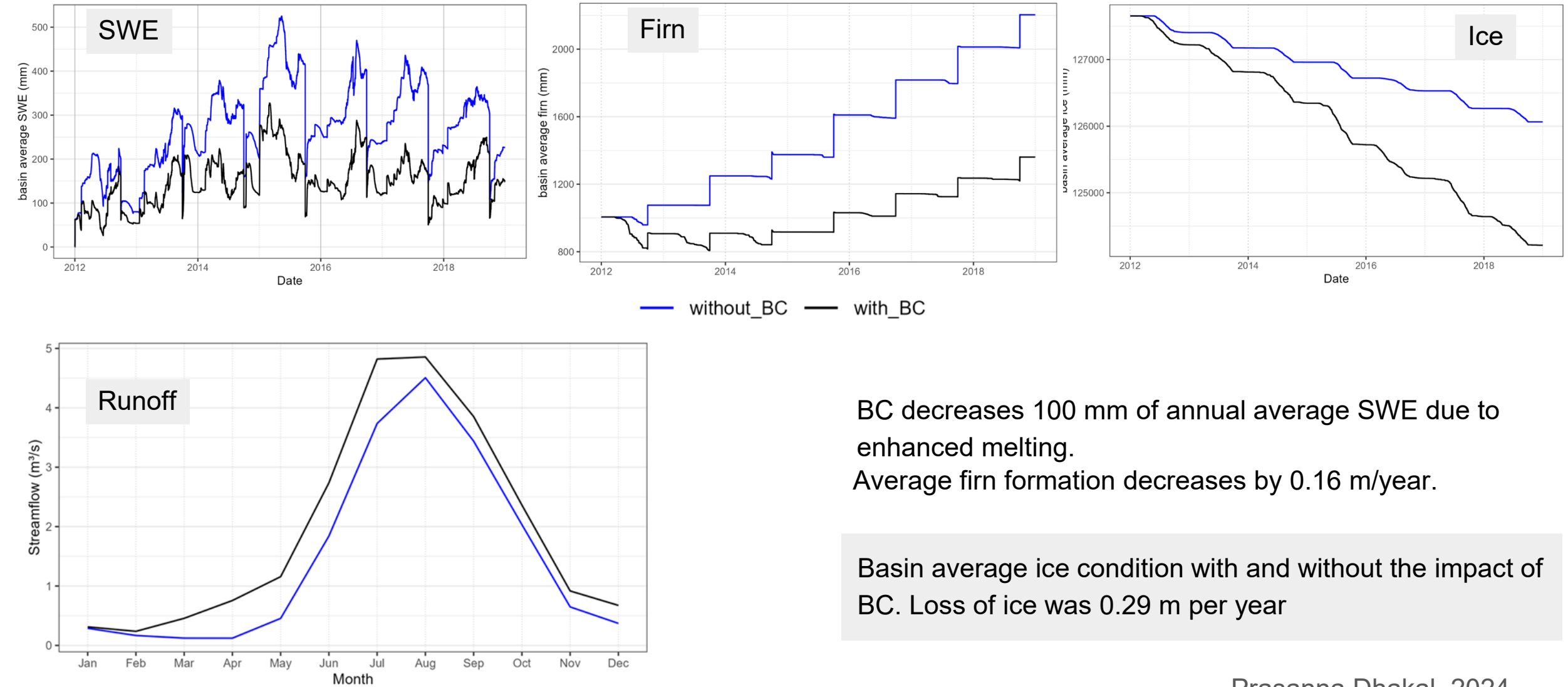
CRHM: The Cold Regions Hydrological Model



Langtang River Basin

Averaged streamflow from 2012 to 2018

Black Carbon (BC) Induced Changes in Langshisha

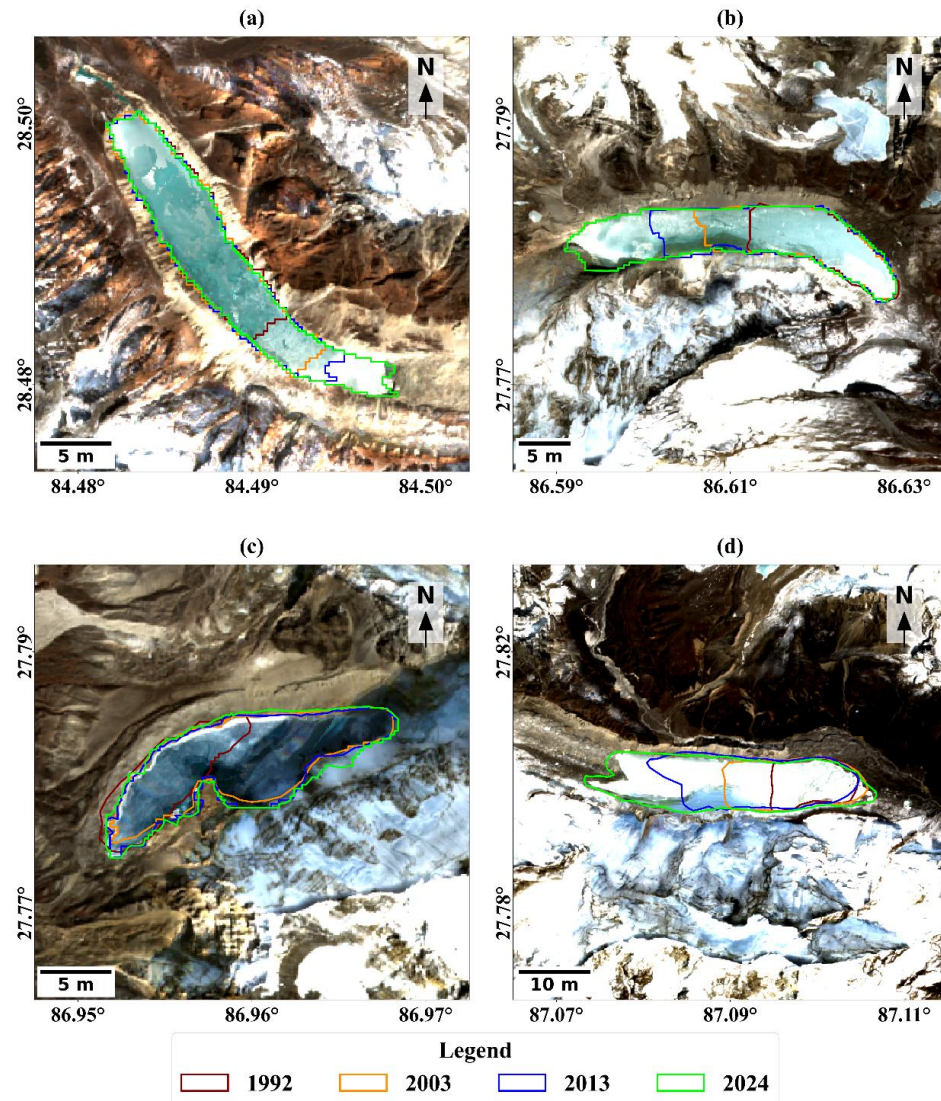


BC decreases 100 mm of annual average SWE due to enhanced melting.
Average firn formation decreases by 0.16 m/year.

Basin average ice condition with and without the impact of BC. Loss of ice was 0.29 m per year

Monthly averaged streamflow from 2012 to 2018.

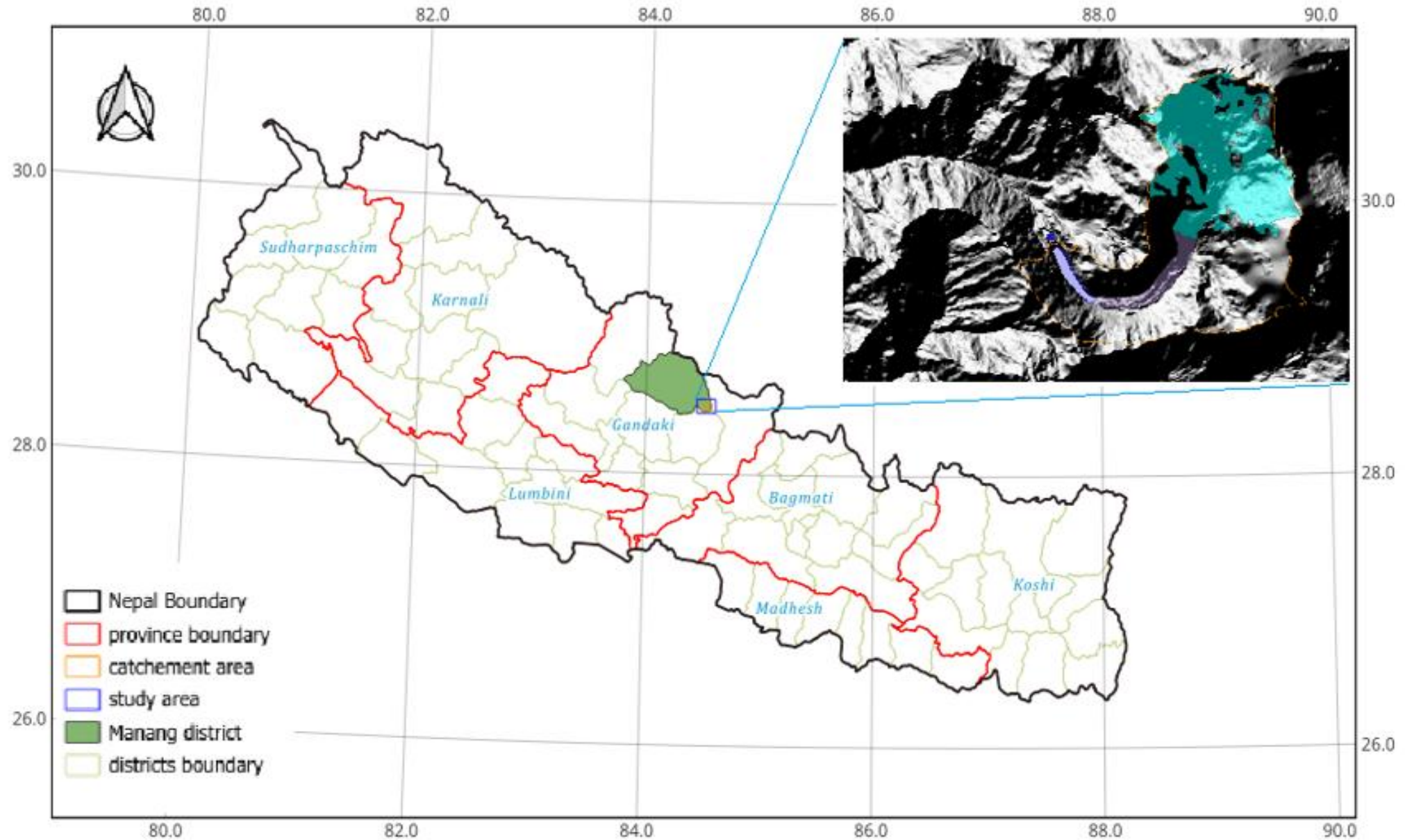
Potentially Dangerous Glacial Lakes



Multi-temporal lake boundaries (1992, 2000, 2010, 2024) overlaid on 2024 Sentinel-2 imagery for (a) Thulagi, (b) Lumding Tsho, (c) Hongu 2, and (d) Lower Barun

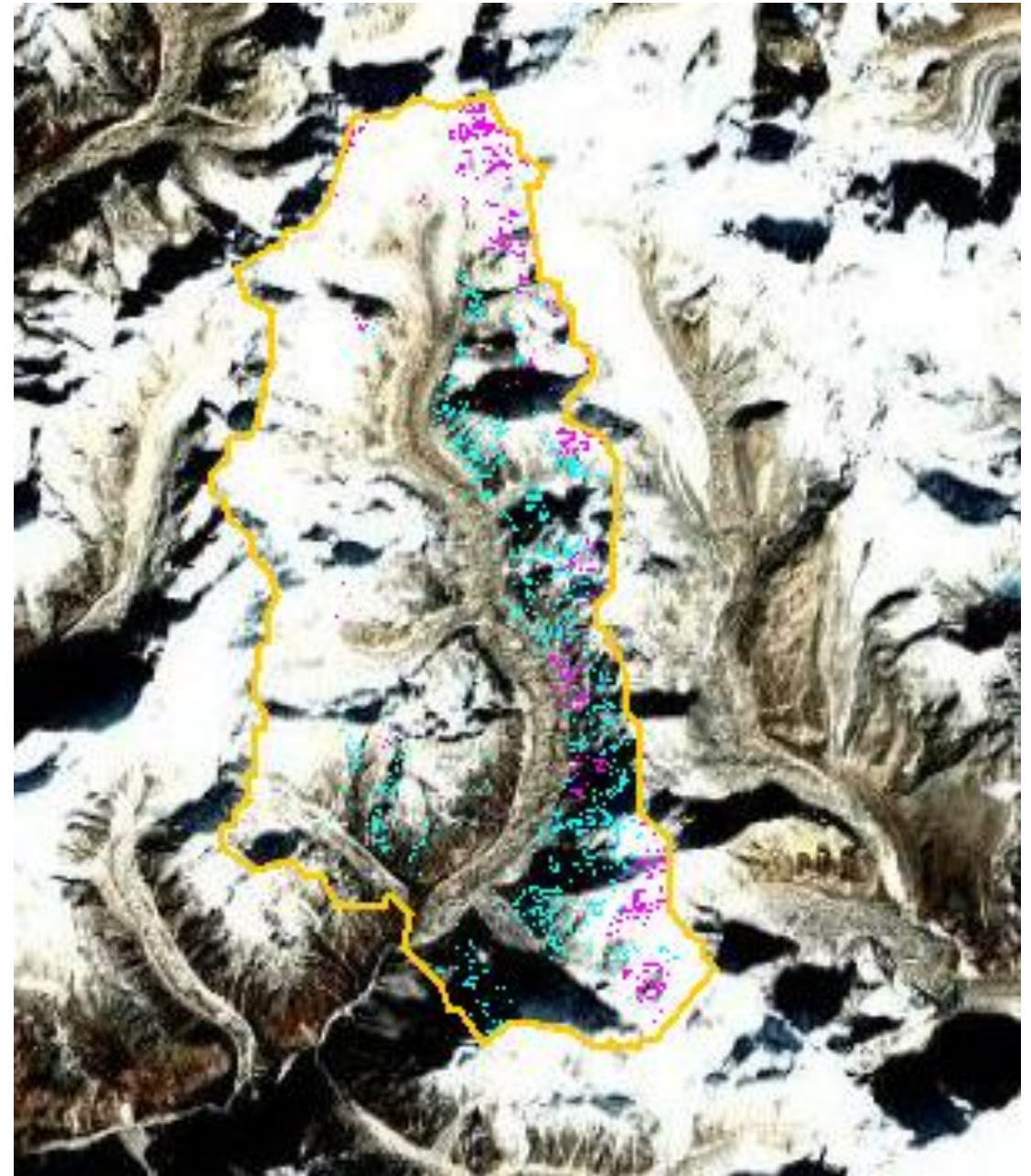
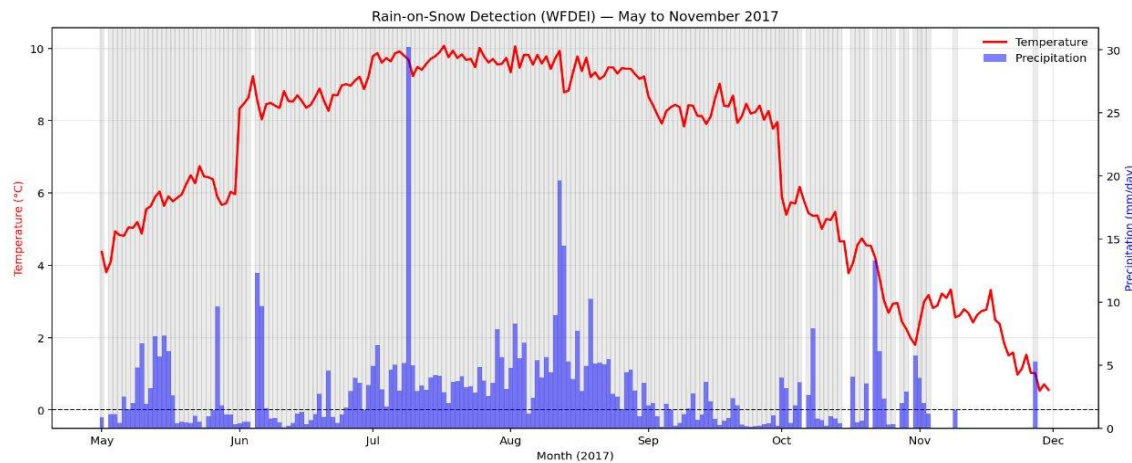
Lake	Area 1992 (km ² ± unc)	Area 2024 (km ² ± unc)	% Change
Thulagi	0.75 ± 0.009	0.97 ± 0.013	≈ 29.3%
Lumding Tsho	0.70 ± 0.007	1.53 ± 0.013	≈118.6%
Hongu 2	0.46 ± 0.05	1.09 ± 0.094	≈137%
Lower Barun	0.77 ± 0.053	2.76 ± 0.13	≈258%

Thulagi Glacier (Prabhat Rai)



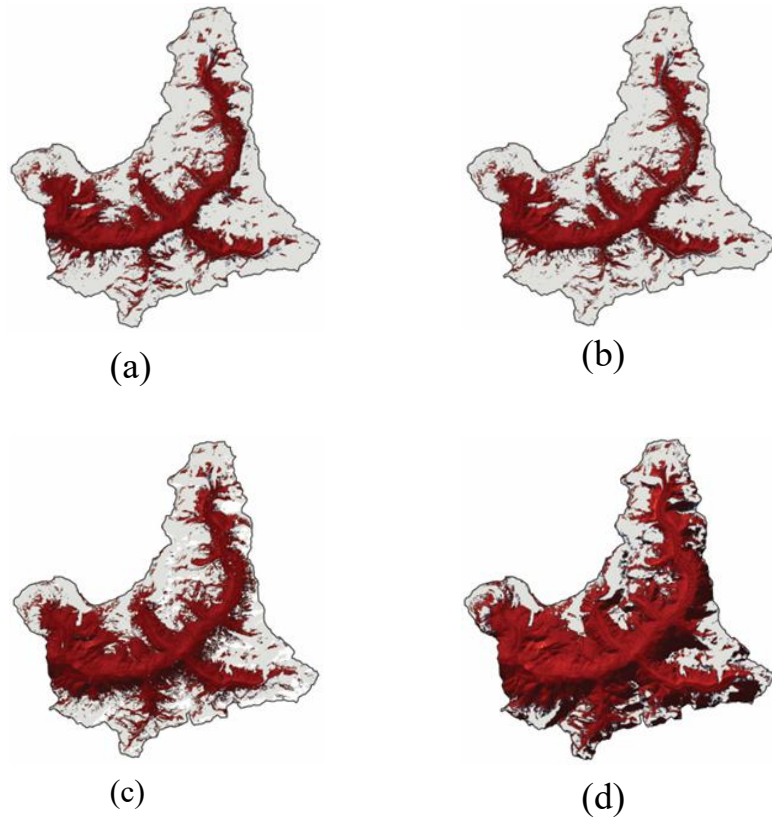
Spatial Mapping of Wet Snow (Bandana Koirala)

- 2.01 km² of wet snow detected during the August 2017 event
- Represents ~5.3% of pre-event snow cover (38.1 km²)
- Analysis scaled to the entire sub-basin (~354 km²)
- Comparison with CRHM runoff peaks

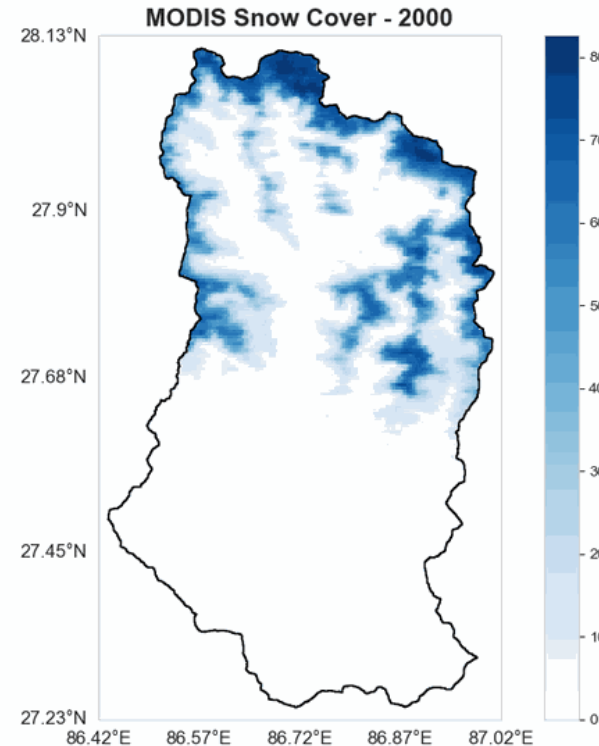


Cyan: Wet snow detected from Sentinel-1 backscatter anomaly
Magenta: Rain-on-snow overlap zone
Source: Sentinel-1 SAR, processed in GEE

Snow Covered Area (SCA) and Snowline Elevation at Langtang and Dudhkoshi Basin



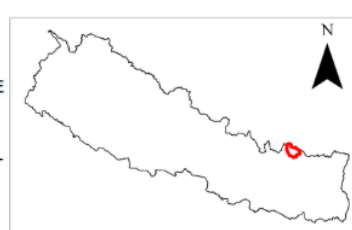
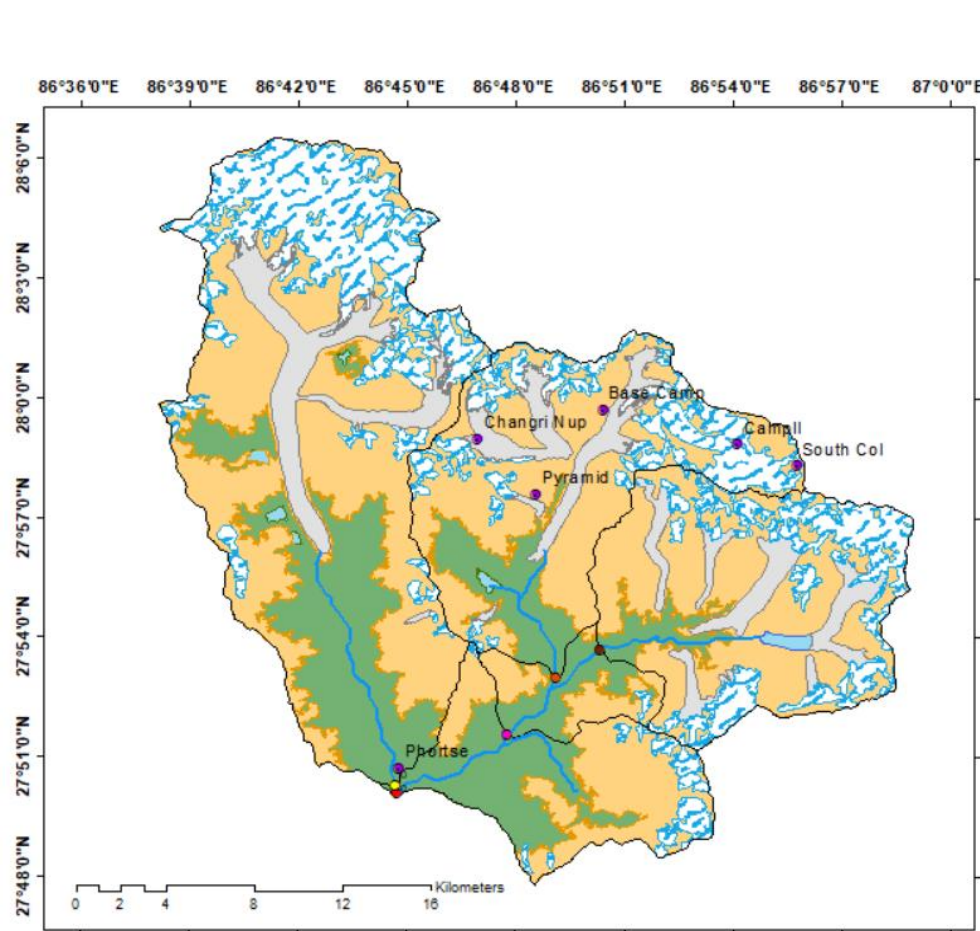
Decadal snow cover maps for Langtang basin using Landsat imagery for (a) 1988 -1996, (b) 1997 - 2005, (c) 2006 - 2015, & (d) 2016 - 2024.



Snow cover maps using MODIS imagery for Dudhkoshi basin

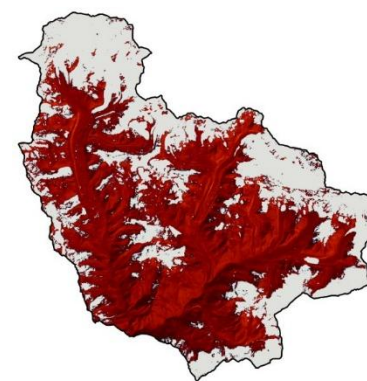
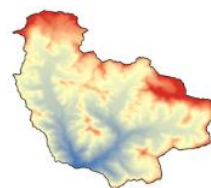
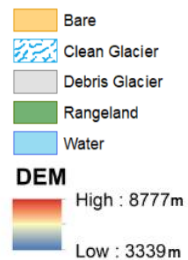
Parameters	Langtang Basin	Dudhkoshi Basin
Snowline Elevation	+2.24 m/year	+9.57 m/year
Snow Cover Area	-3.7 km ² /year	-1.84 km ² /year

Everest Region



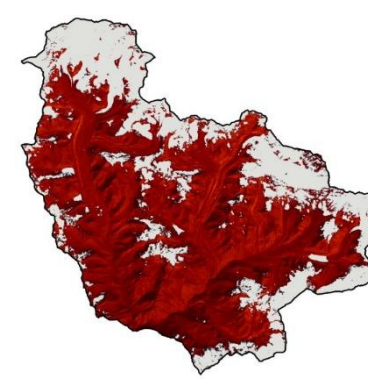
Legend

- Dingboche
- Meteorological Station
- Pangboche
- Lobuche
- Ngozumpa
- Watershed Outlet
- rivers



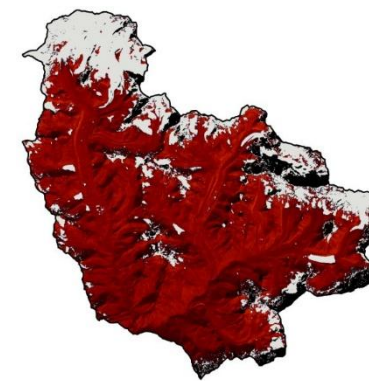
1991-2001

263.8 km²



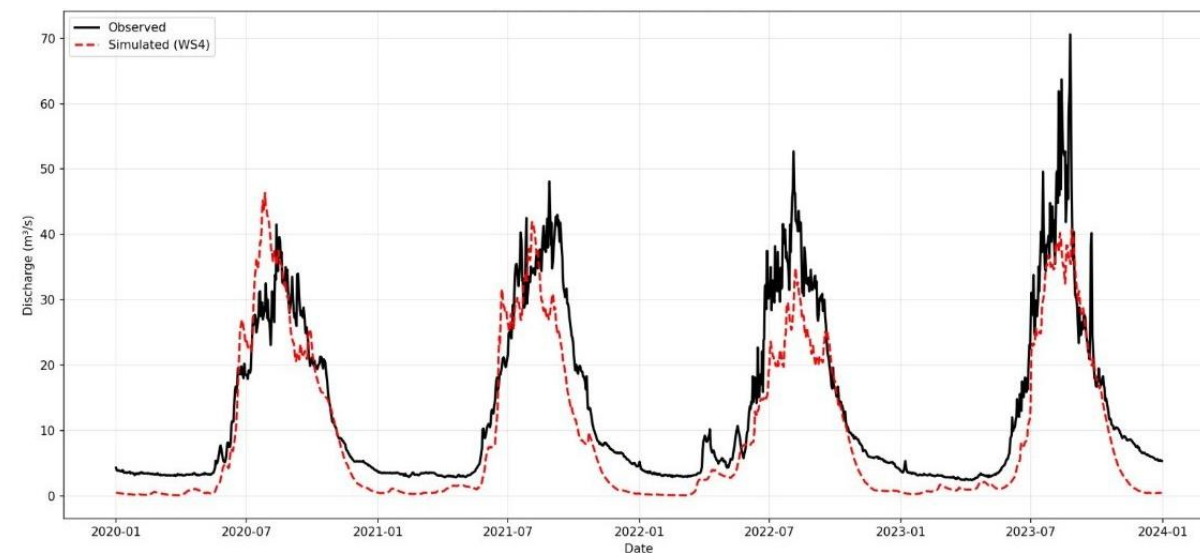
2001-2010

208.9 km²



2014-2024

140.8 km²

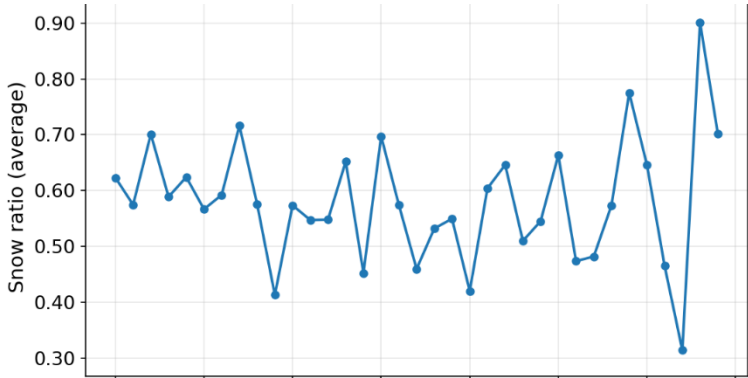


Nash-Sutcliffe Efficiency (NSE)

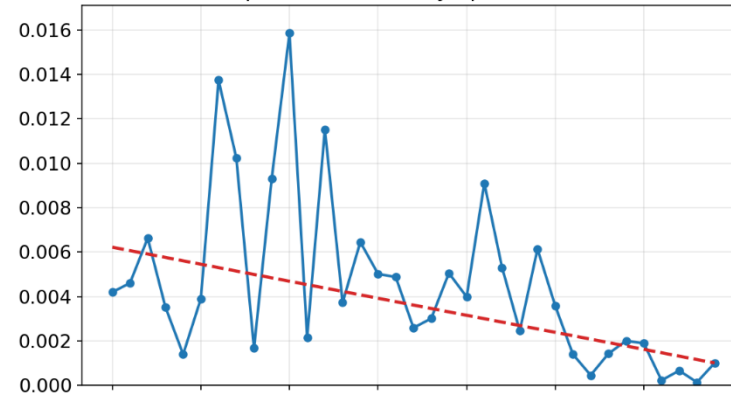
0.78

a. Elevation Band 4000 - 4500 m

Pre-monsoon



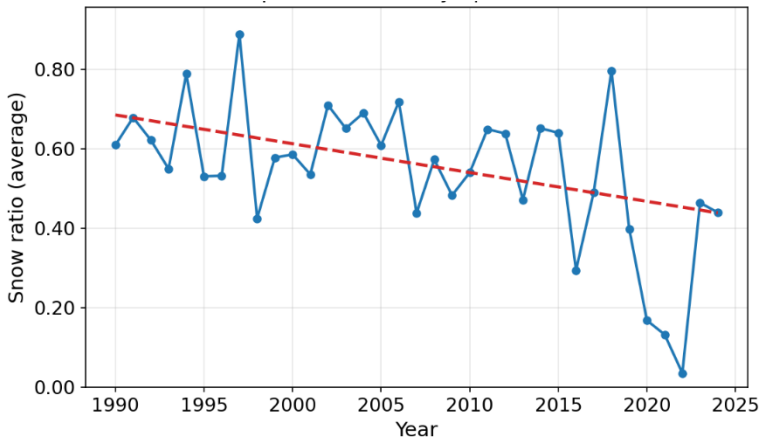
Monsoon



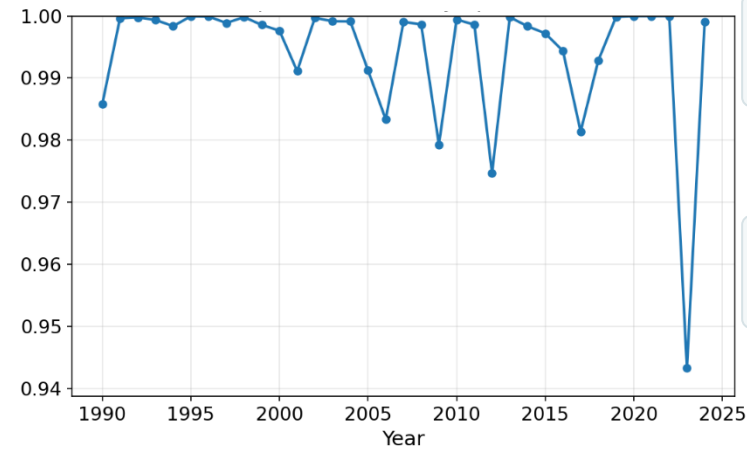
Pre-monsoon -0.0014/yr 0.514

Monsoon -0.0015/yr $p < 0.001^*$

Post-monsoon



Winter

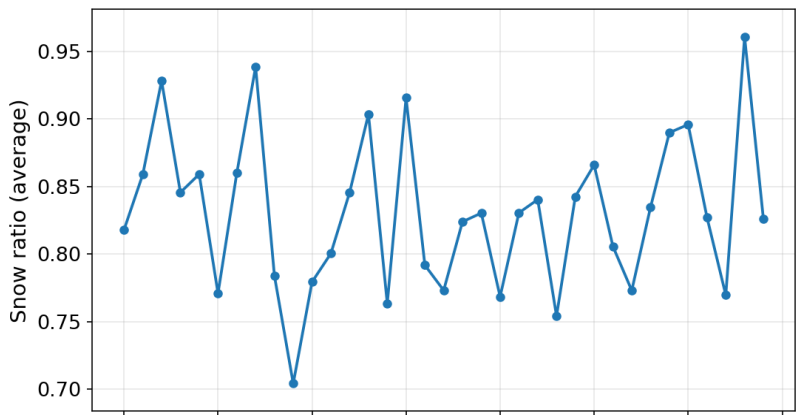


Post-monsoon -0.0073/yr $p = 0.007^*$

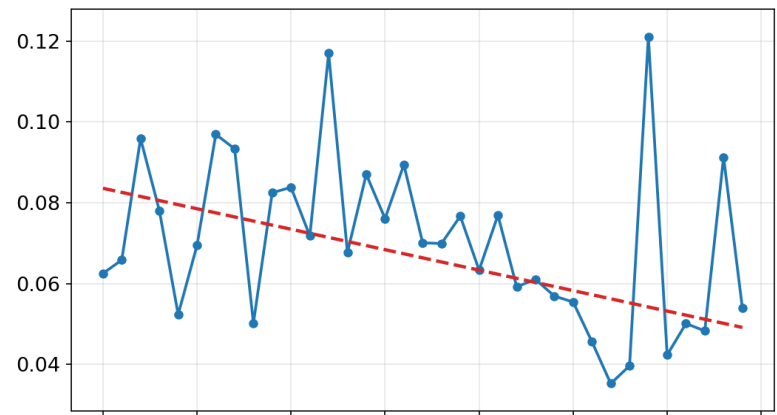
Winter ~0/yr (-ve) 0.478

b. Elevation Band 4500 - 5000 m

Pre-monsoon



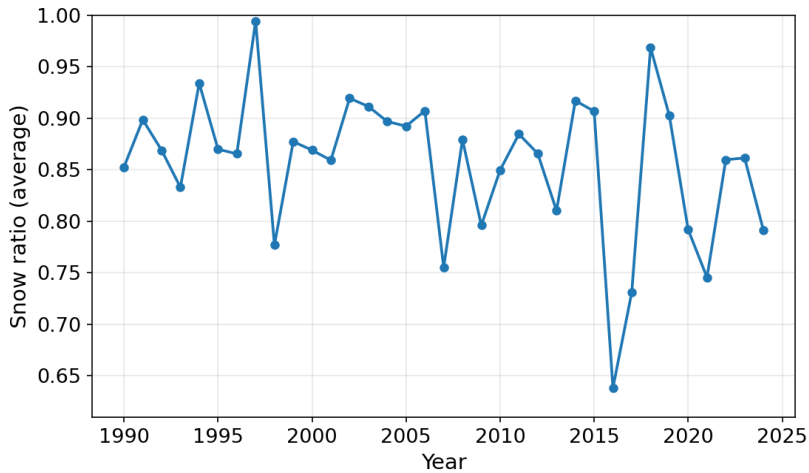
Monsoon



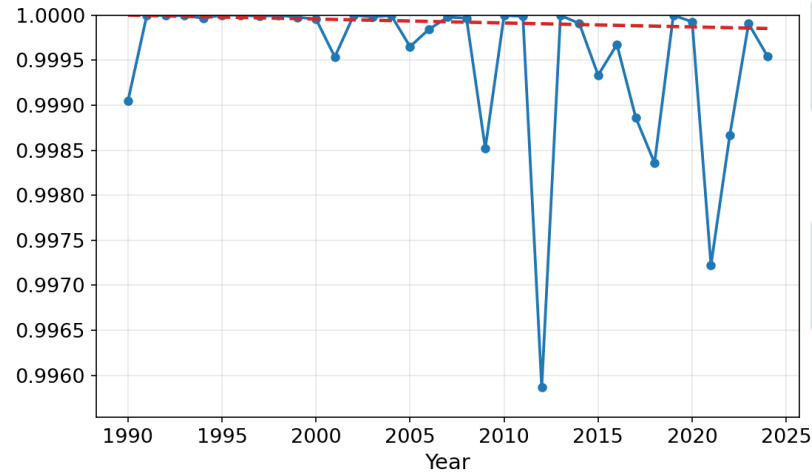
Pre-monsoon ~0/yr 0.9

Monsoon -0.0010/yr *p*=0.008*

Post-monsoon



Winter

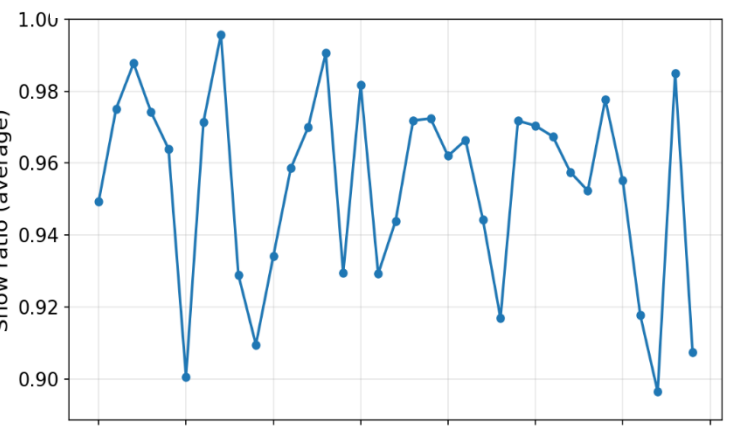


Post-monsoon -0.0014/yr 0.1

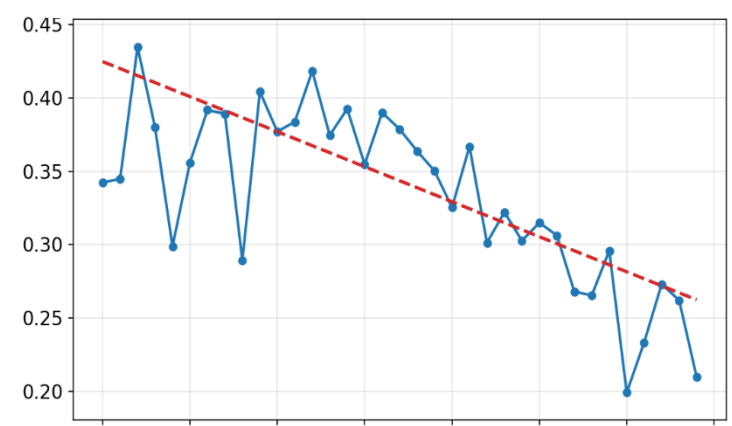
Winter ~0/yr (-ve) *p*=0.002*

c. Elevation Band 5,000 - 5,500 m

Pre-monsoon



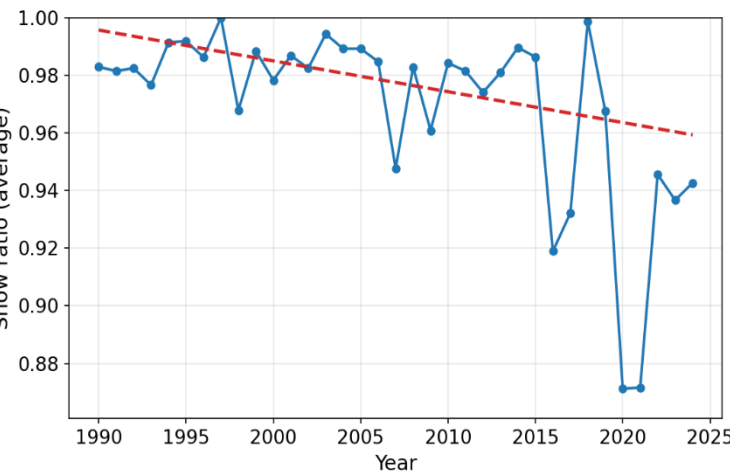
Monsoon



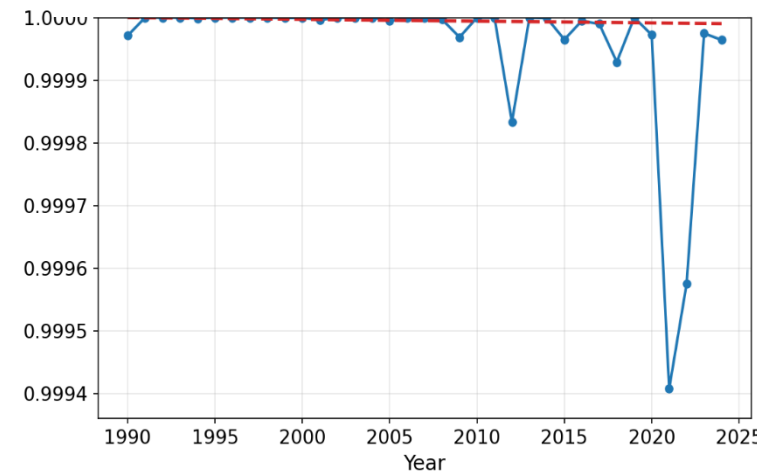
Pre-monsoon -0.0005/yr *n.s.*

Monsoon -0.0048/yr *p<0.001**

Post-monsoon



Winter

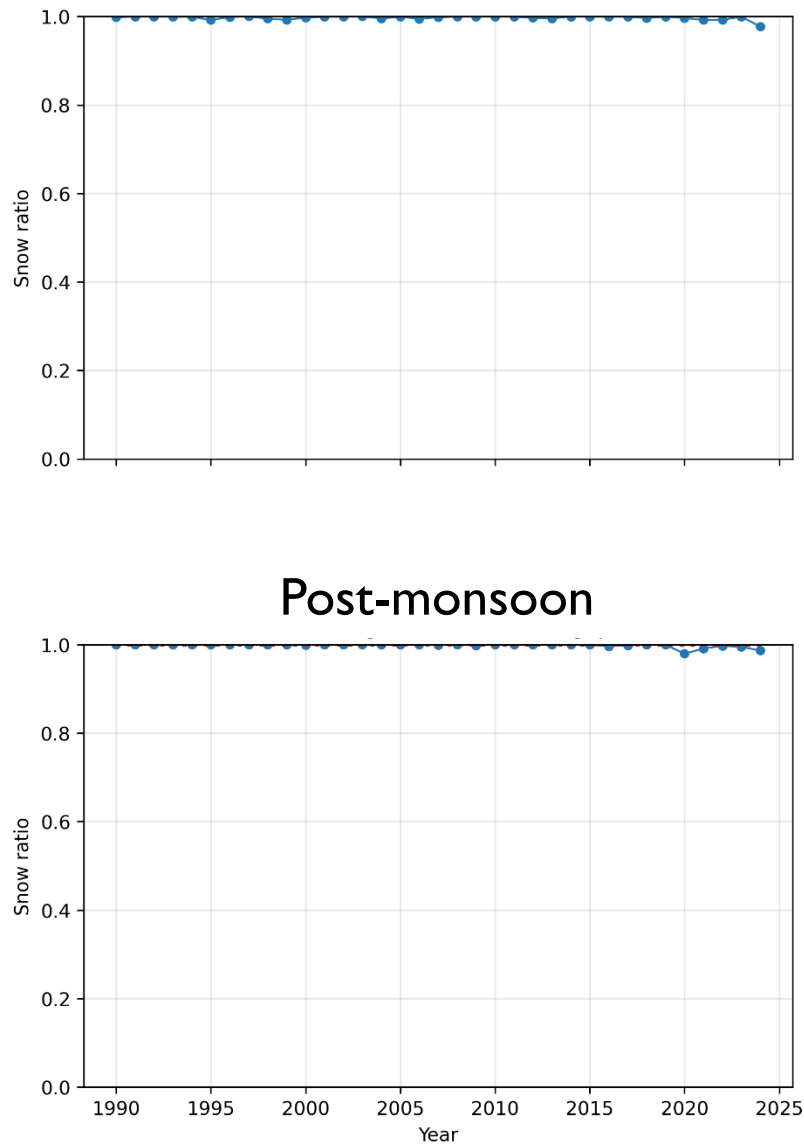


Post-monsoon -0.0011/yr *p=0.004**

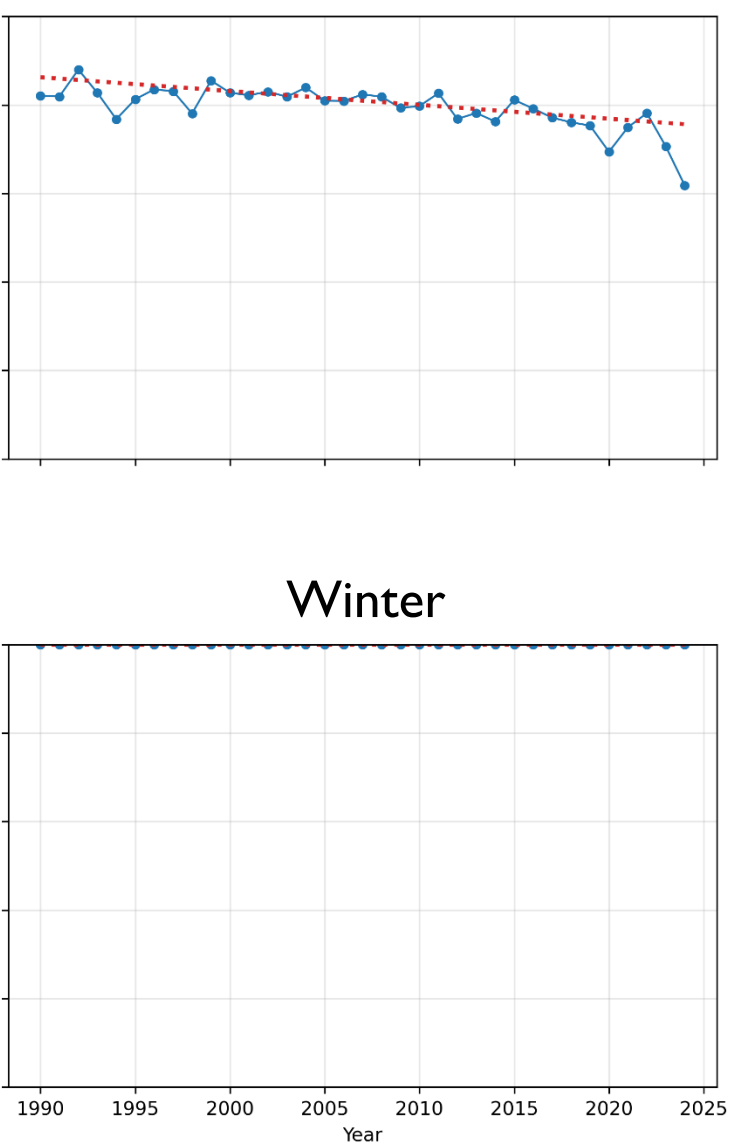
Winter ~0/yr (-ve) *p<0.001**

d. Elevation Band 5,500–6,000 m

Pre-monsoon



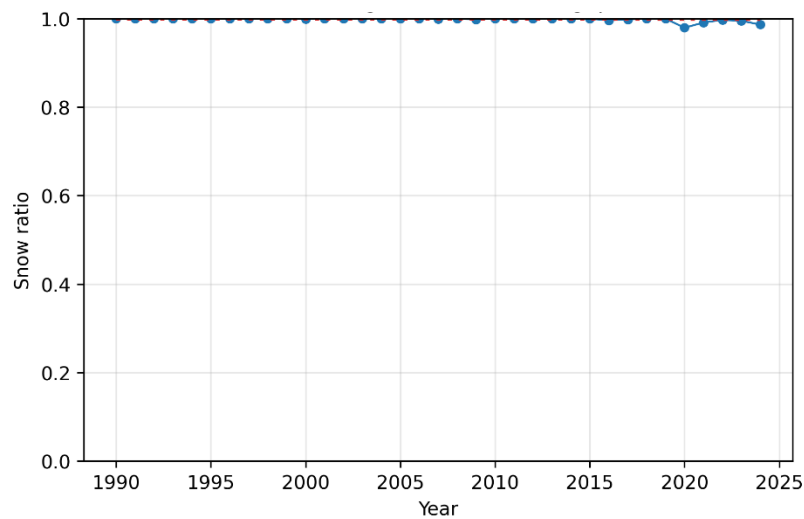
Monsoon



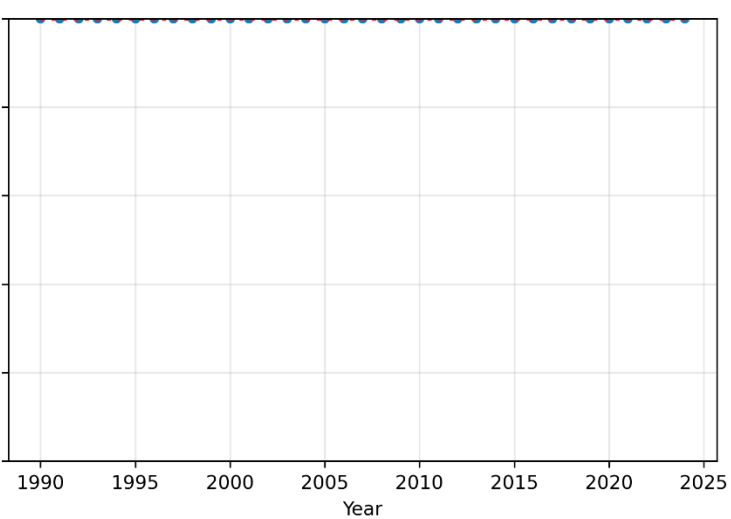
Pre-monsoon ~0/yr *n.s.*

Monsoon -0.0031/yr *p<0.001**

Post-monsoon



Winter

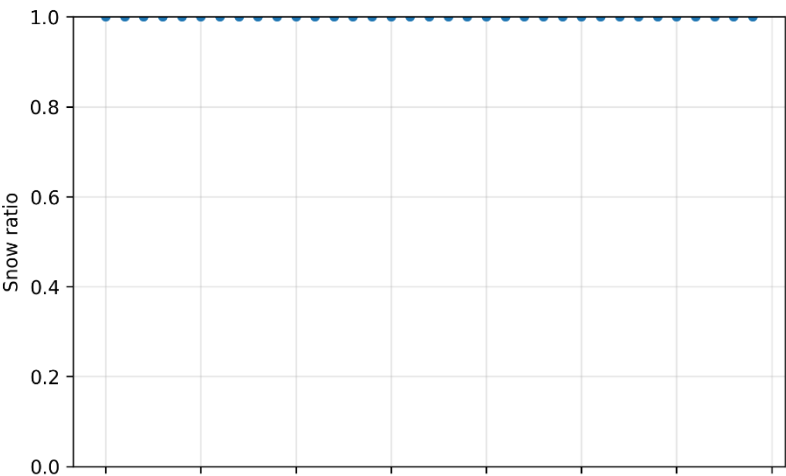


Post-monsoon ~0/yr (-ve) *p<0.001**

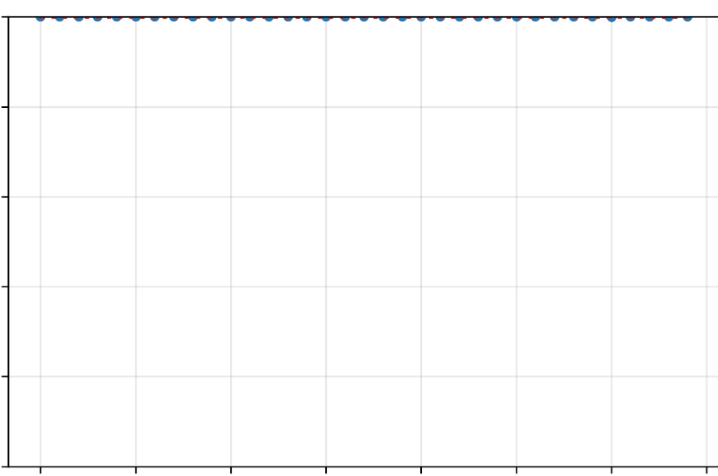
Winter ~0/yr (-ve) *p<0.001**

e. Elevation Band $\geq 6,000$ m

Pre-monsoon



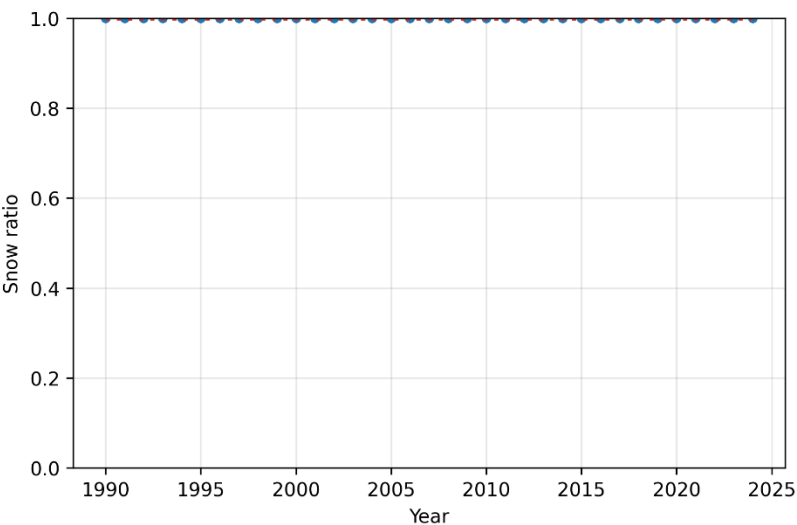
Monsoon



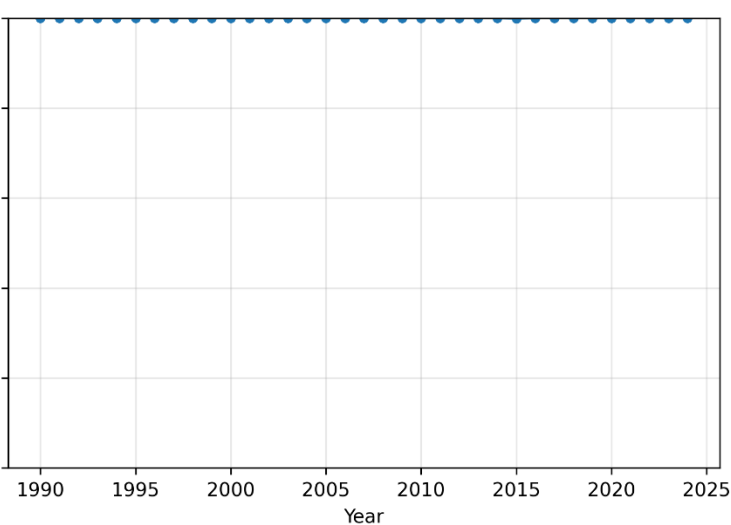
Pre-monsoon ≈ 0 *n/a*

Monsoon ≈ 0 *n/a*

Post-monsoon

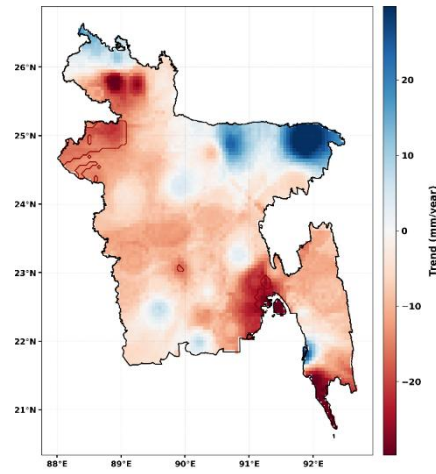


Winter



Post-monsoon ≈ 0 *n/a*

Winter ≈ 0 *n/a*



Precipitation Shifts and Impacts



Asia-Pacific Network for Global Change Research

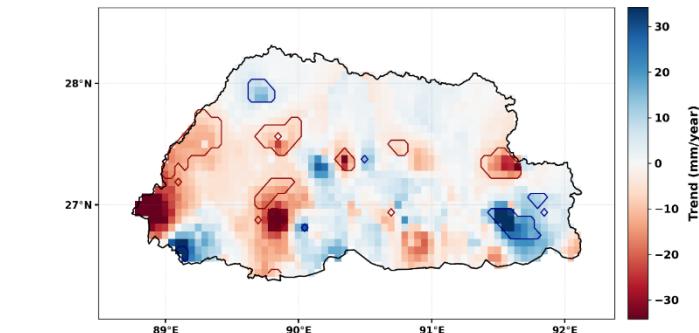
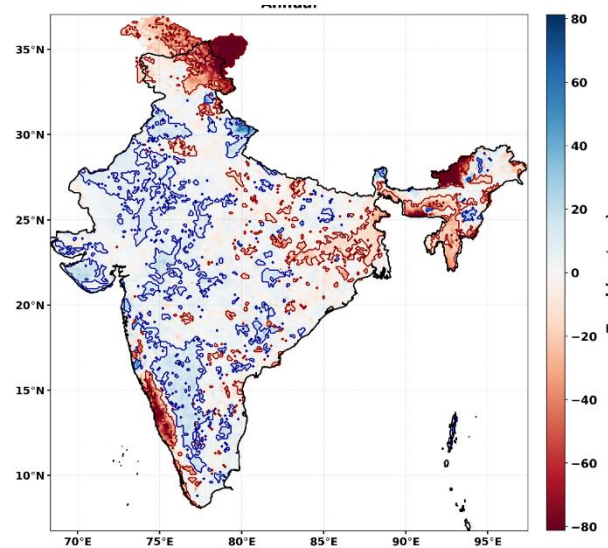
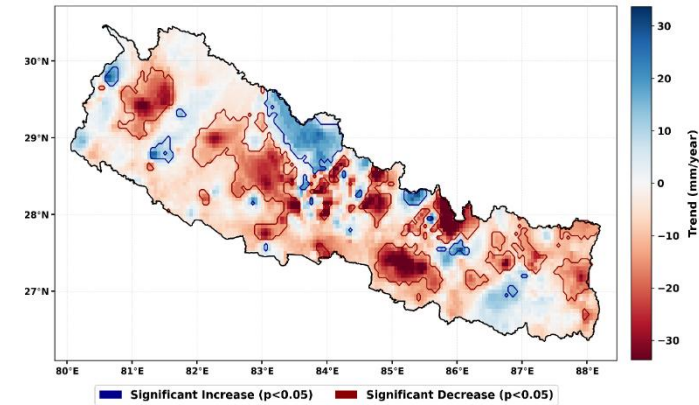
[Read our Science Bulletin](#)

Air, land, coasts and oceans Biodiversity and ecosystems Climate Food, water and energy Human dimensions Risk and resilience

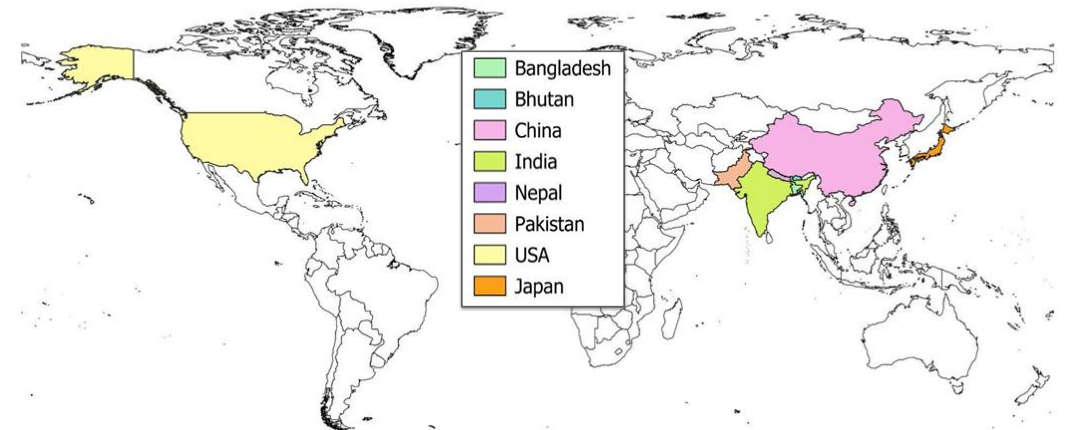
Core activities / Regional research

Project • CRRP2024-06MY-Pradhananga

Enhancing climate resilience in South Asia and China: Predicting precipitation shifts and their impacts for disaster risk reduction and resource security



Multi-country Annual Precipitation Trend (Spatial Analysis)



Primary Data Collection

- Conducted from 1-6 September at Varagung Muktichetra Rural Municipality, Mustang, Nepal
- Conducted 15 KII, 5 FGD, several questionnaires, and a stakeholder consultation workshop
- The Key informants were school's principal, co-chairperson, mukhiya (village leader), tourist guide, businessperson, ward chairperson, farmers, and ward representatives.



KII with principal



Interaction with local people³³

Fall School 2025

on 'Advanced Climate Data Analytics and Strategies'

- From 14-18 October (5 days)
- Participants: Early Career Researchers (ECRs) from Bangladesh, Bhutan, India, Nepal, and Pakistan
- Theory, hands-on, expert guidance, Climate Trivia
- Peer-learning approach



Participants of Fall school

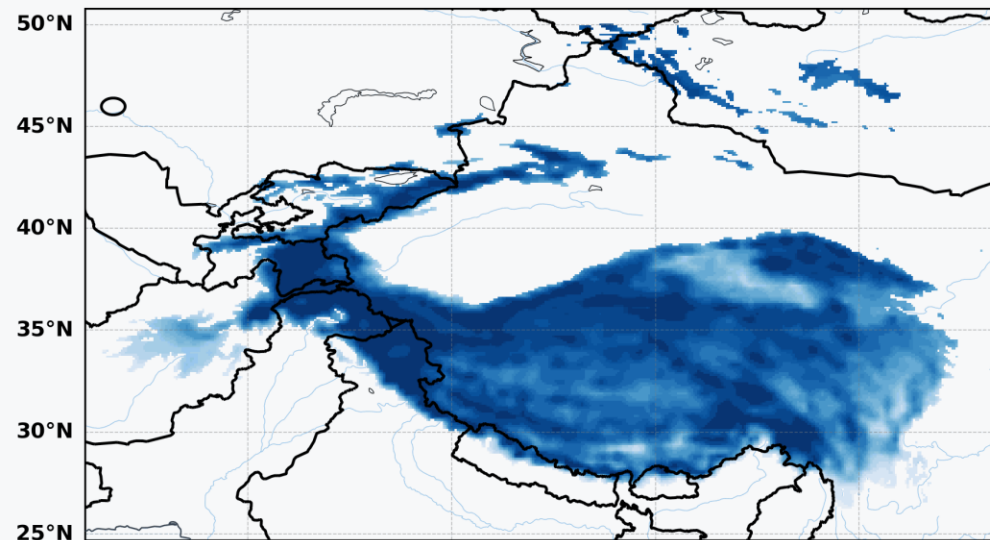


Remarks by Director
Toshiyuki Yamasaki, APN ³⁴

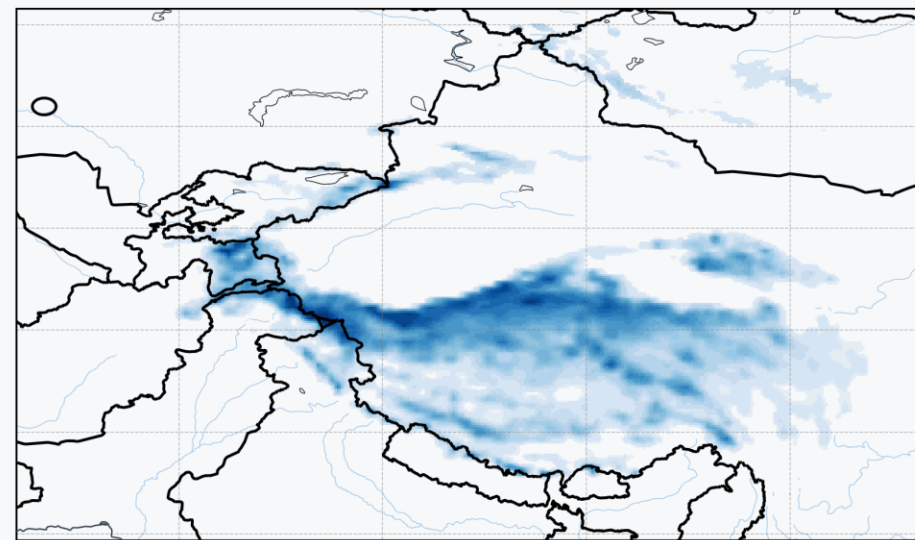


Seasonal Spatial Distribution of Snow Ratio (1980)

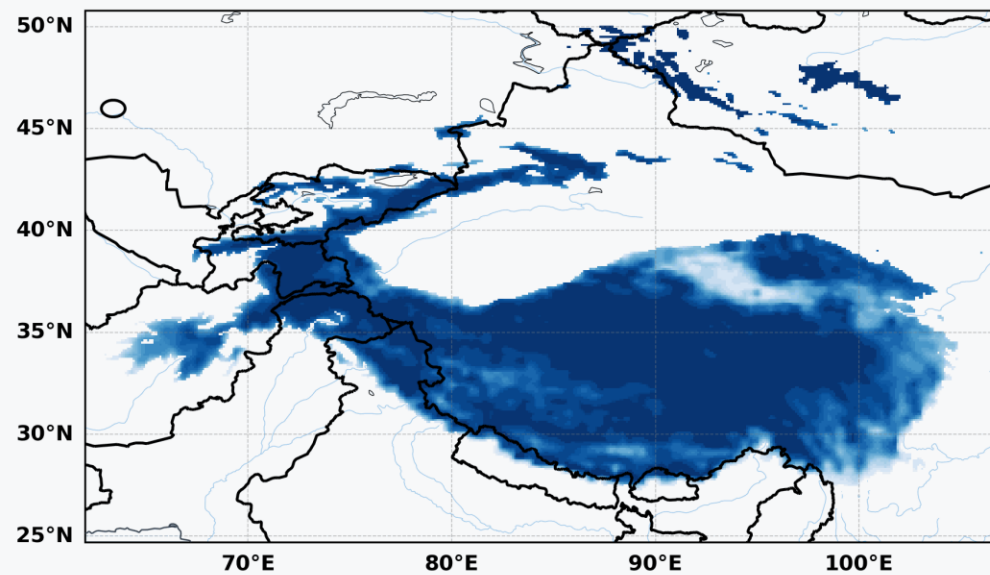
Premonsoon



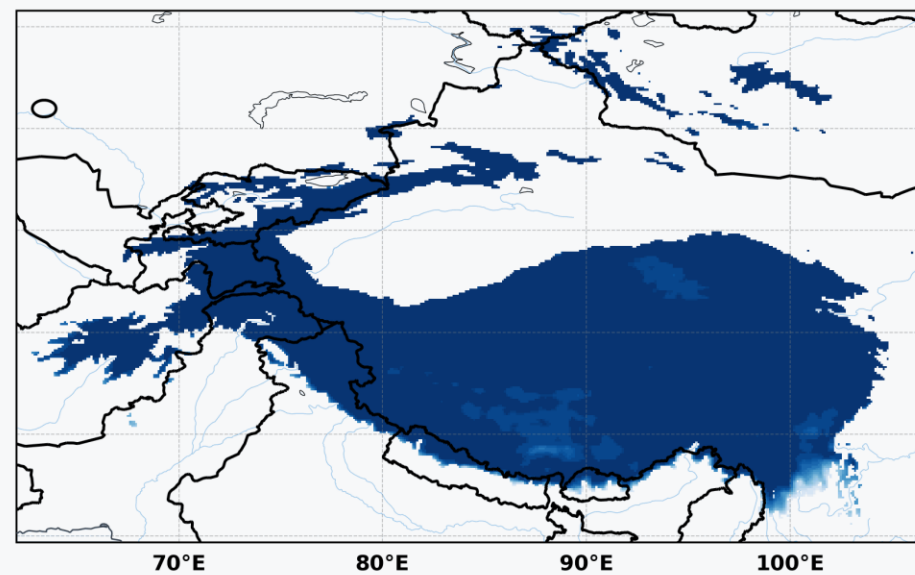
Monsoon



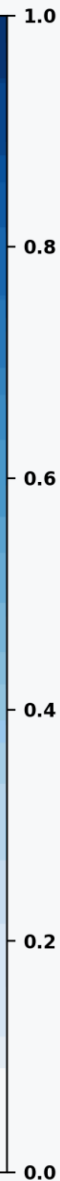
Post-monsoon



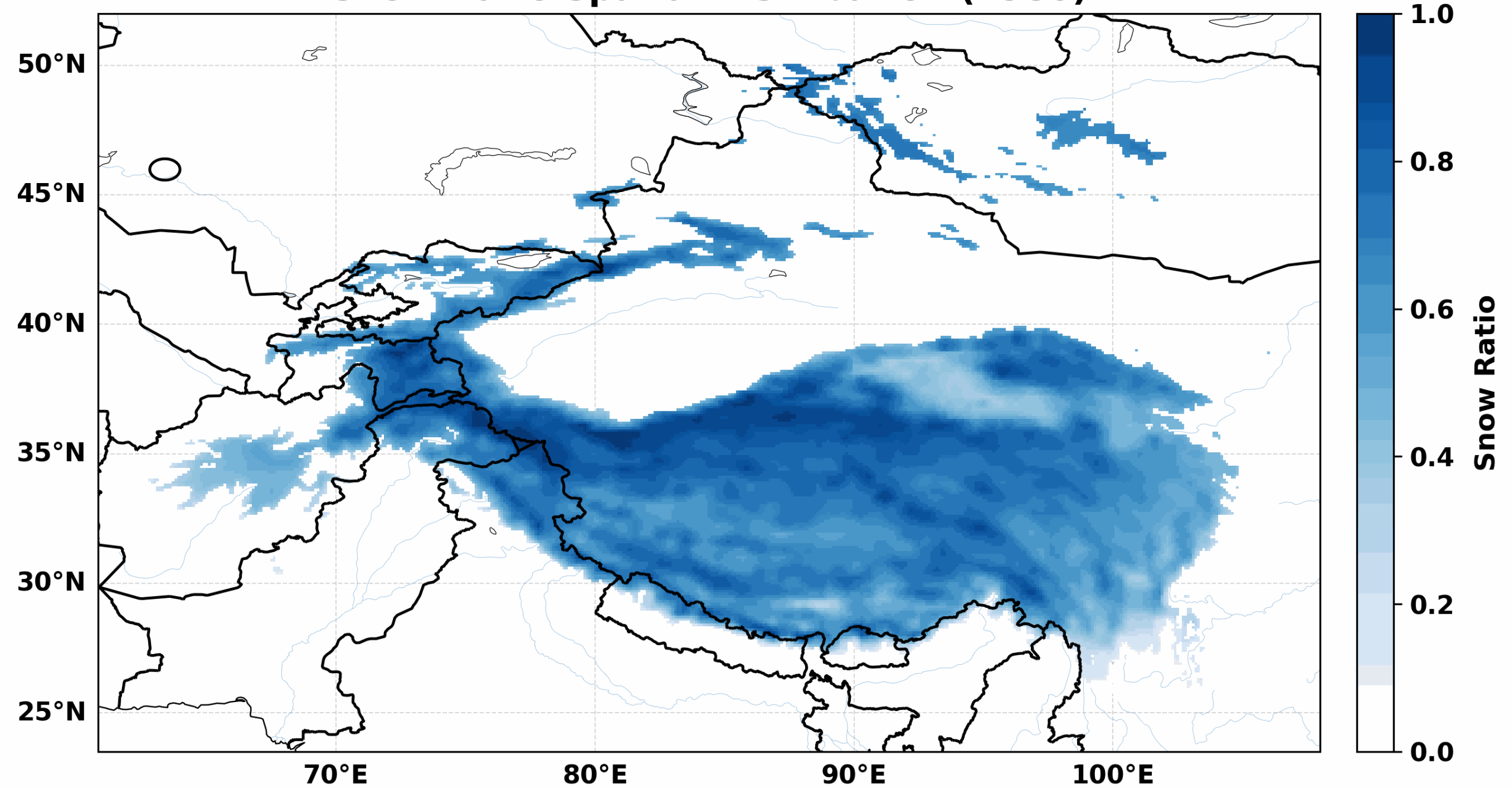
Winter



Snow Ratio



Snow Ratio Spatial Distribution (1980)

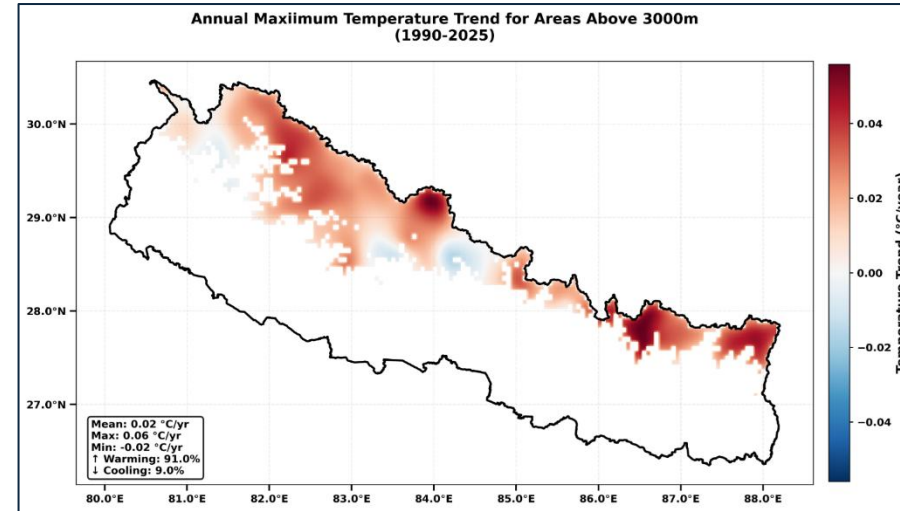
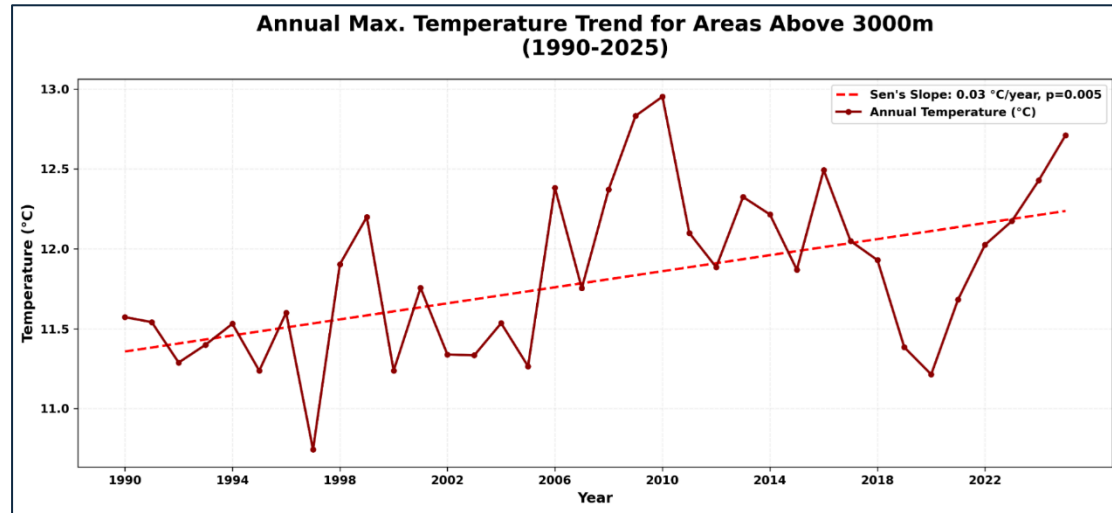


Data Interactive Platform and Monsoon Atlas

- A dummy demo of the data interactive platform and monsoon Atlas was presented
- Discussions on the requirements of the selection of parameters, strategies
- <https://suvekshya0.wixsite.com/climate-data-hub/home>

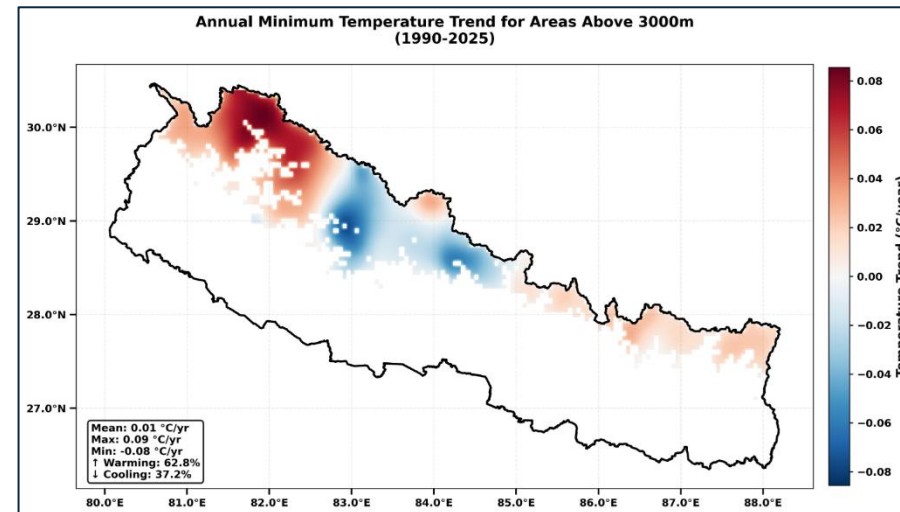
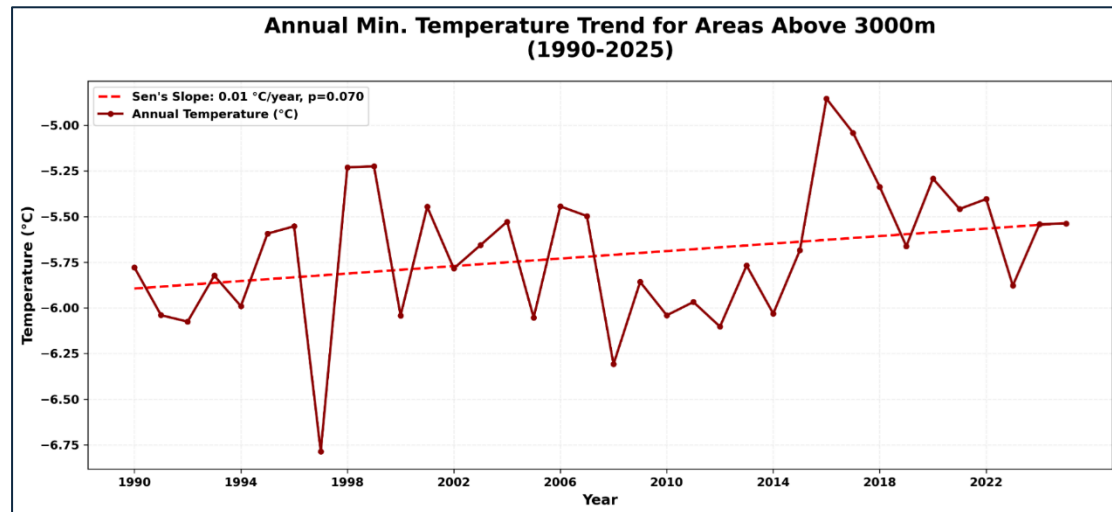


Temperature Trends Above 3000 m



Tmax

- Significant warming: **0.025 °C/year**
- Warming in **91%** of area

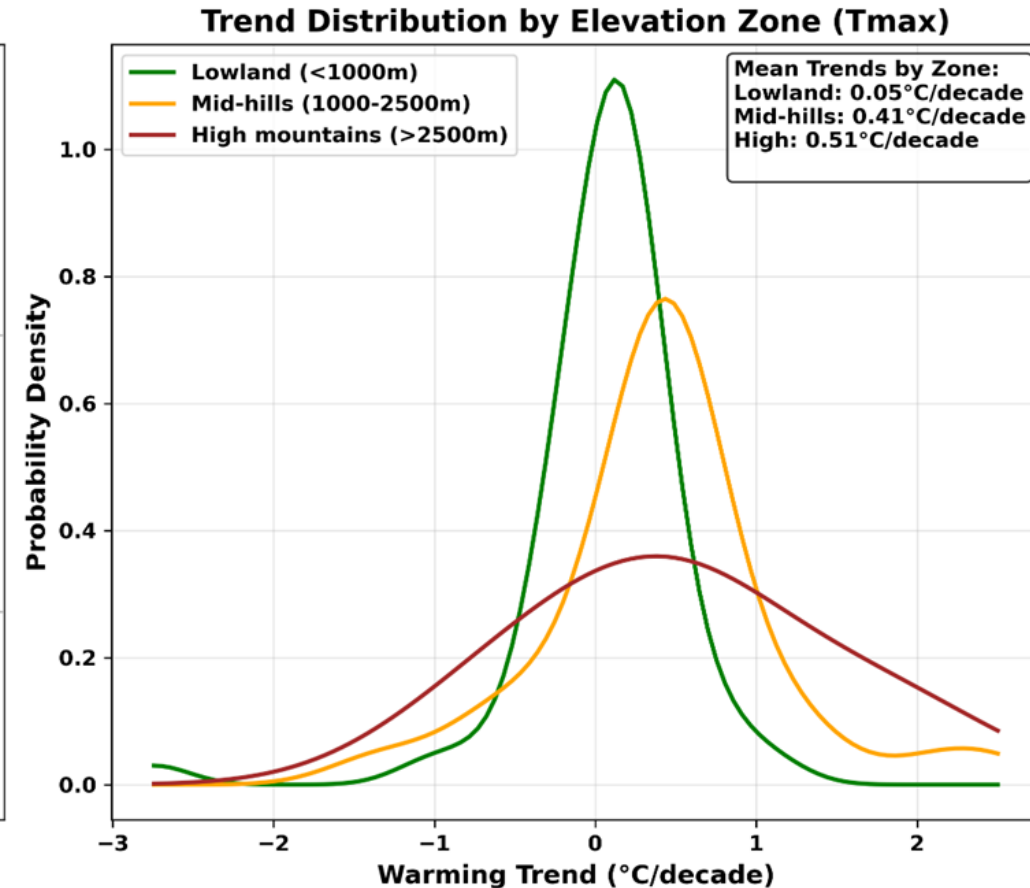
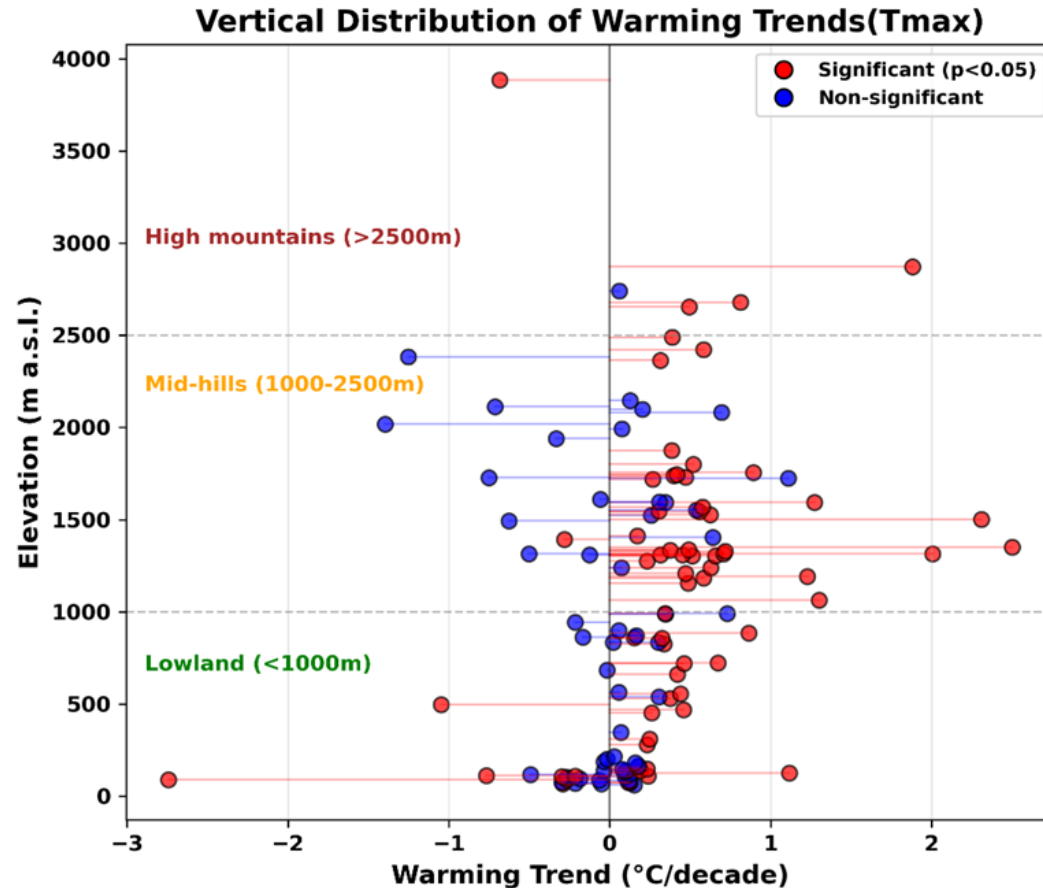


Tmin

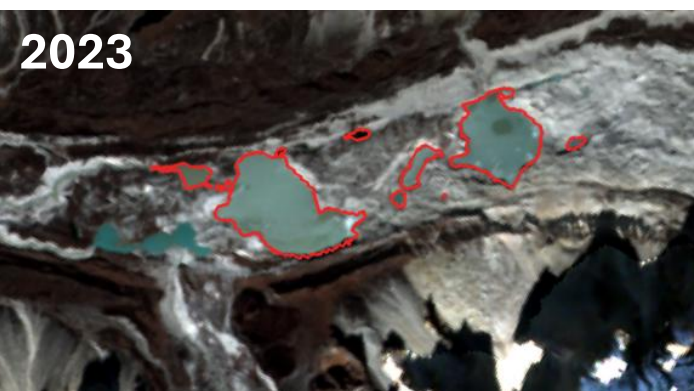
- Increasing tendency but weaker significance
- Warming in **63%** of area

Is warming altering snow-rain partitioning in high mountain regions?

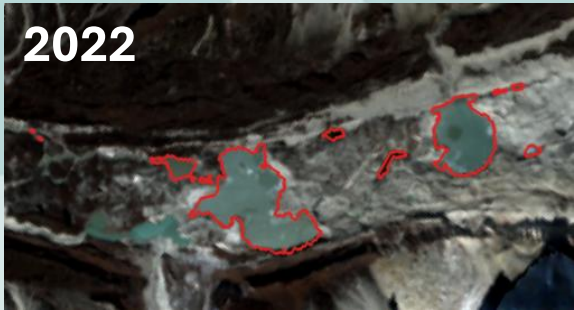
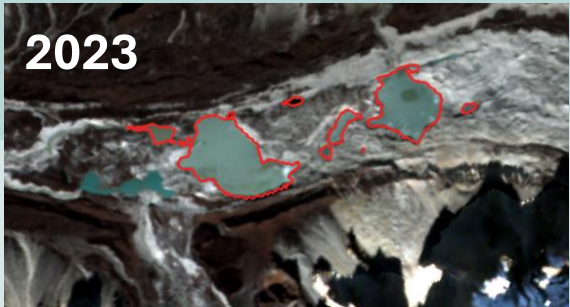
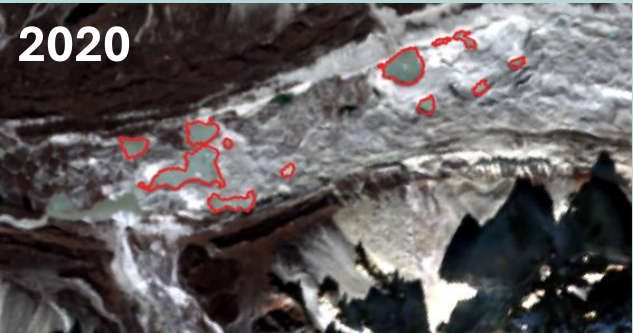
Distribution of Warming Trends Across Elevation Zones



- Analysis based on 120 stations (1990–2025)
- Regional (overall) warming trend: $0.020^{\circ}\text{C}/\text{year}$
- 56.7% of stations showed significant warming
- Warming magnitude increased with elevation
- High mountains ($>2500\text{ m}$) showed strongest warming trends ($0.51^{\circ}\text{C}/\text{decade}$)
- Significant EDW relationship observed ($p = 0.009$)



NO NAME LAKE

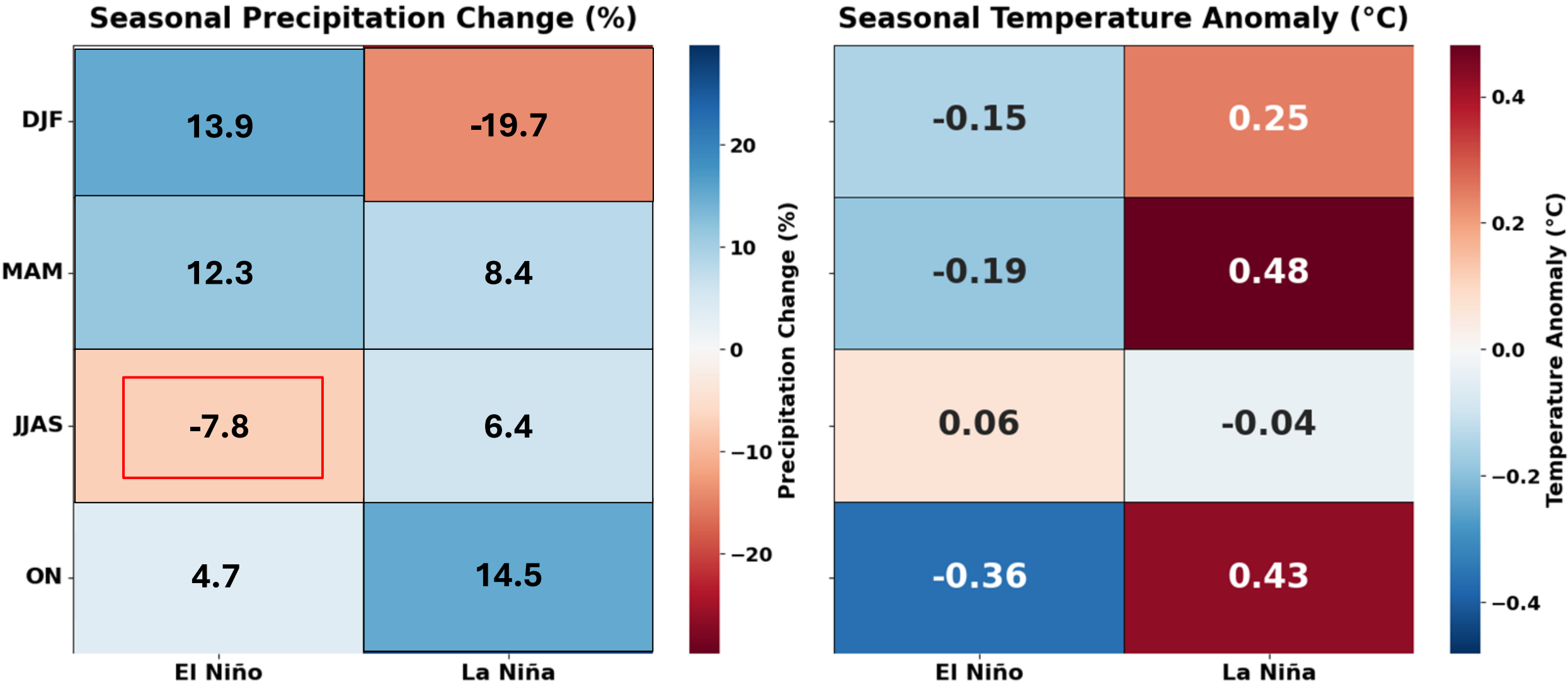


Year	Area (sq km)
2020	0.16
2021	0.23
2022	0.30
2023	0.36
2024	0.38
2025	0.43
2026	0.46



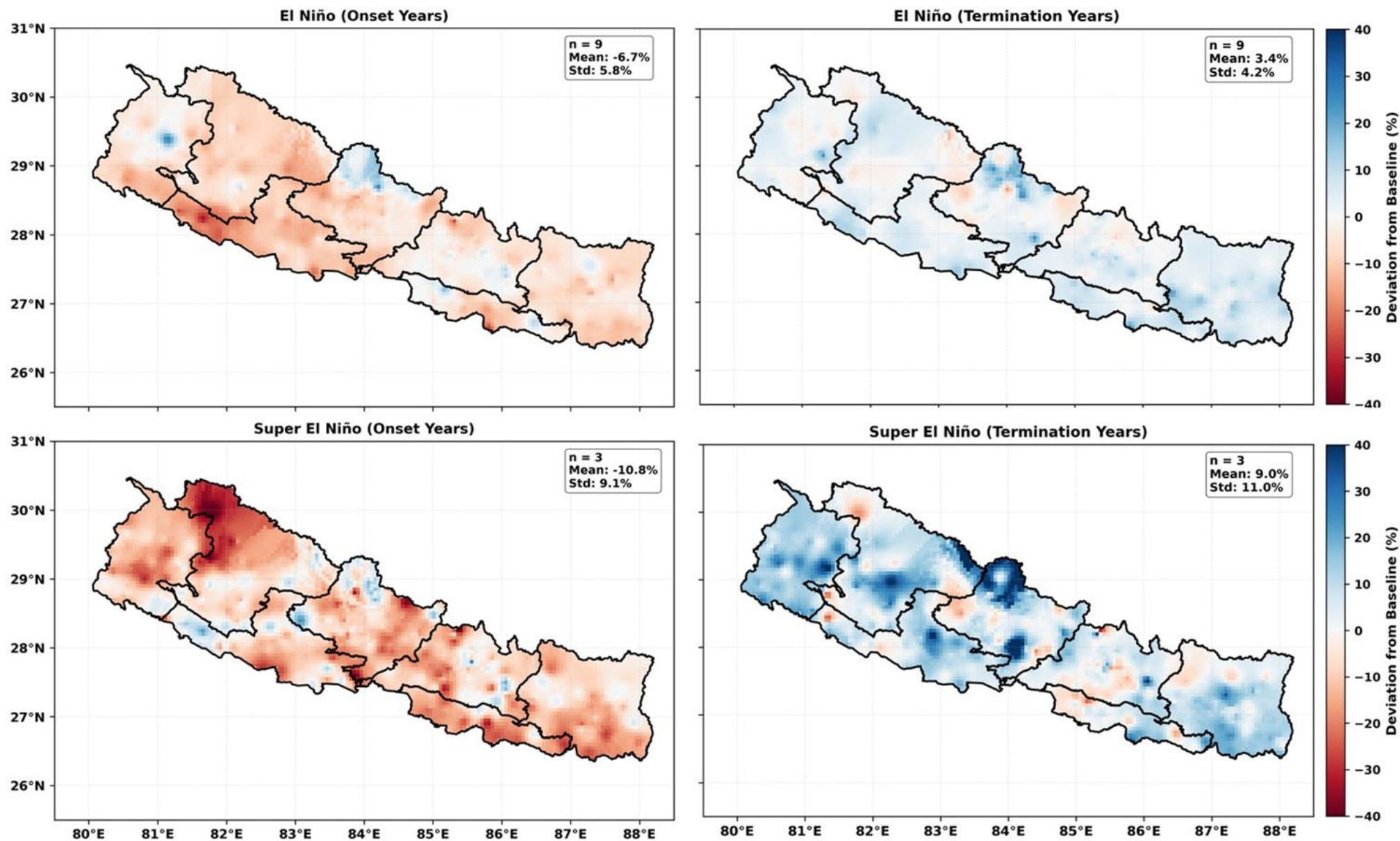
Impacts of ENSO on Nepal's Hydroclimatic Variability, Agriculture and Hydropower

El Niño Impacts on Seasonal Climatology of Nepal (1980 - 2025)



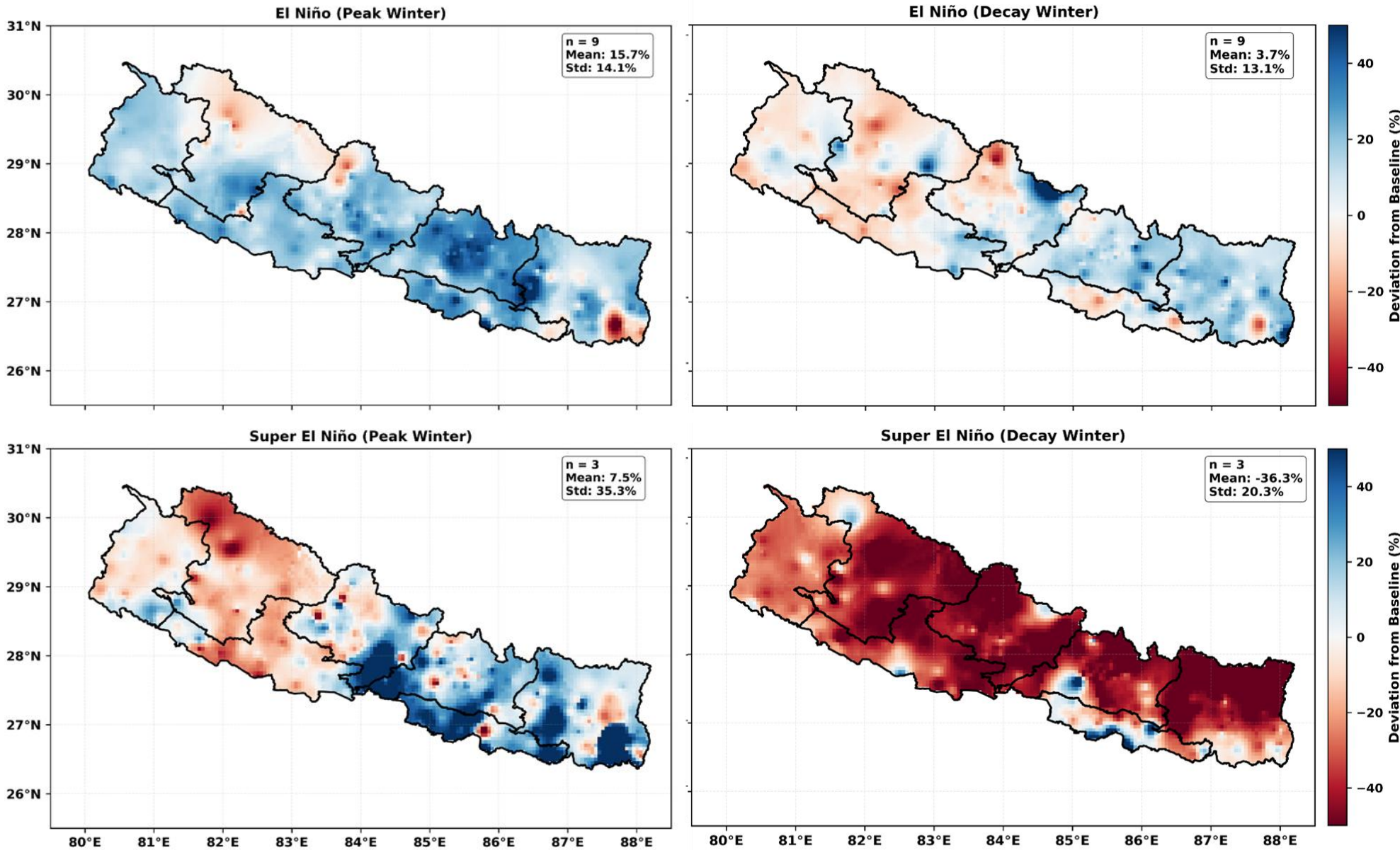
Climatological Base Period: 1991 - 2020

Monsoon Precipitation Anomaly (%) -1980 to 2025



Base period:
1991 - 2020

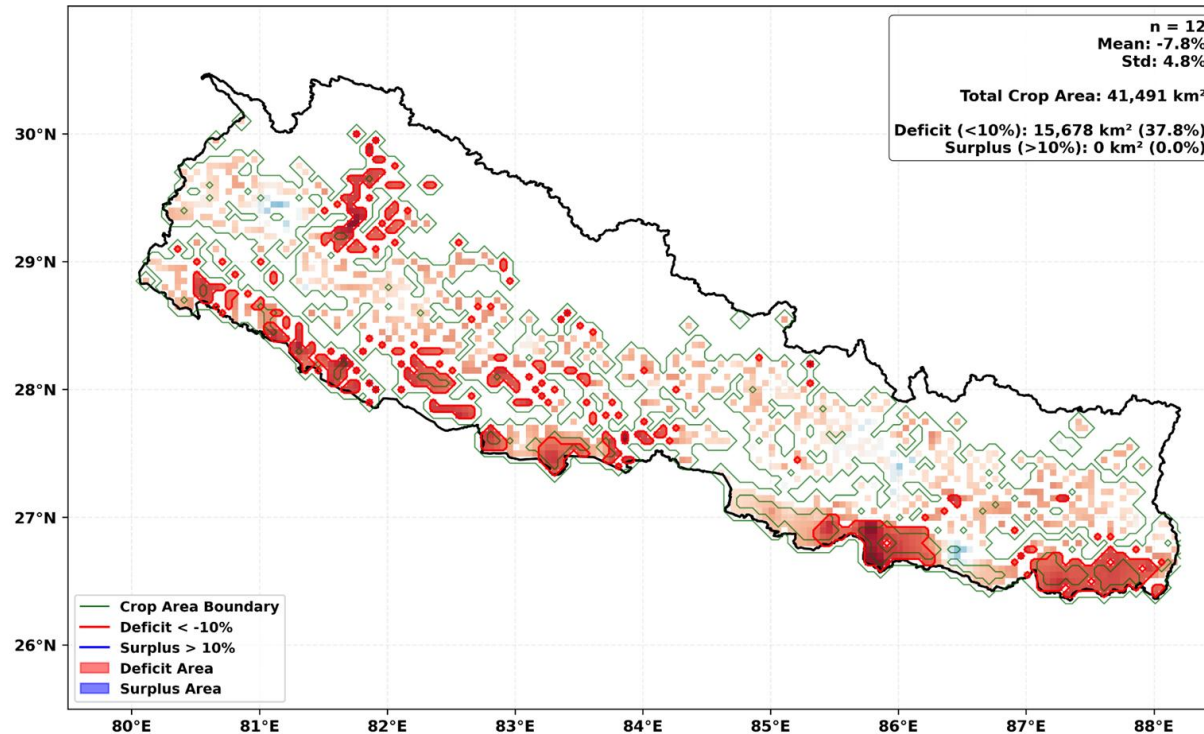
Winter Precipitation Anomaly (%) - 1980 to 2025



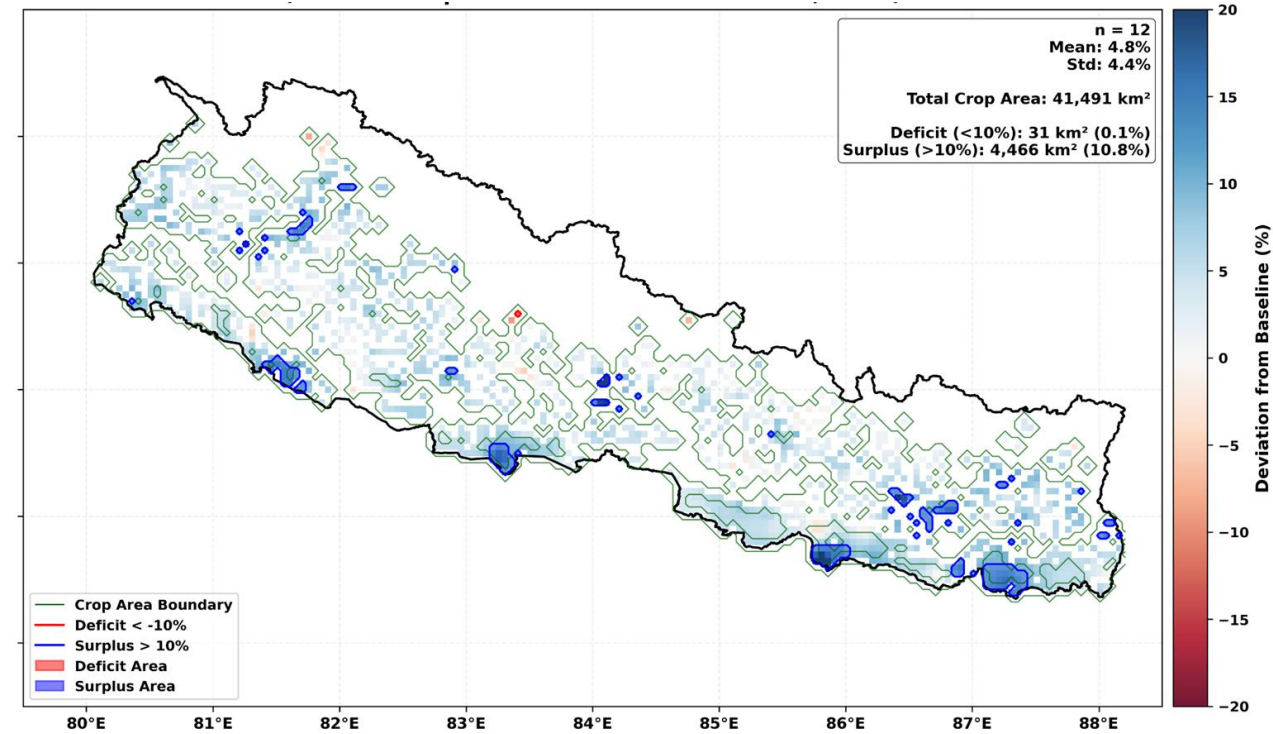
**Base period:
1991 - 2020**

Monsoon Precipitation Anomalies in Crop Area of Nepal (1980-2025)

Onset Years



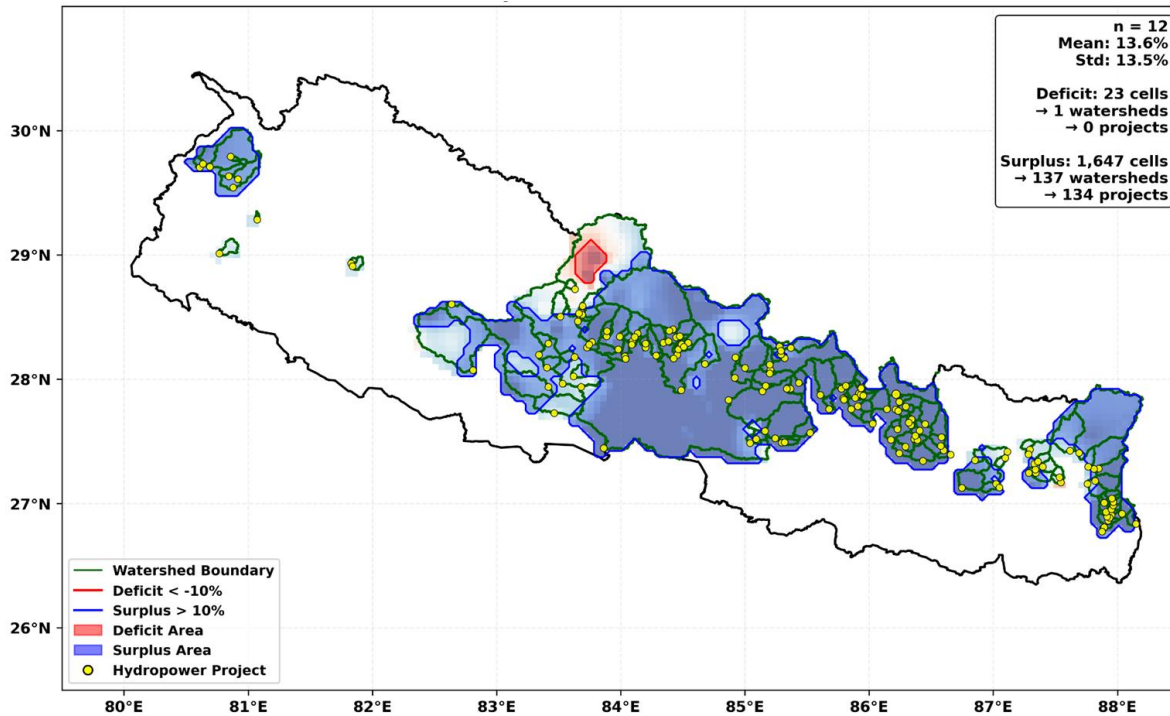
Termination Years



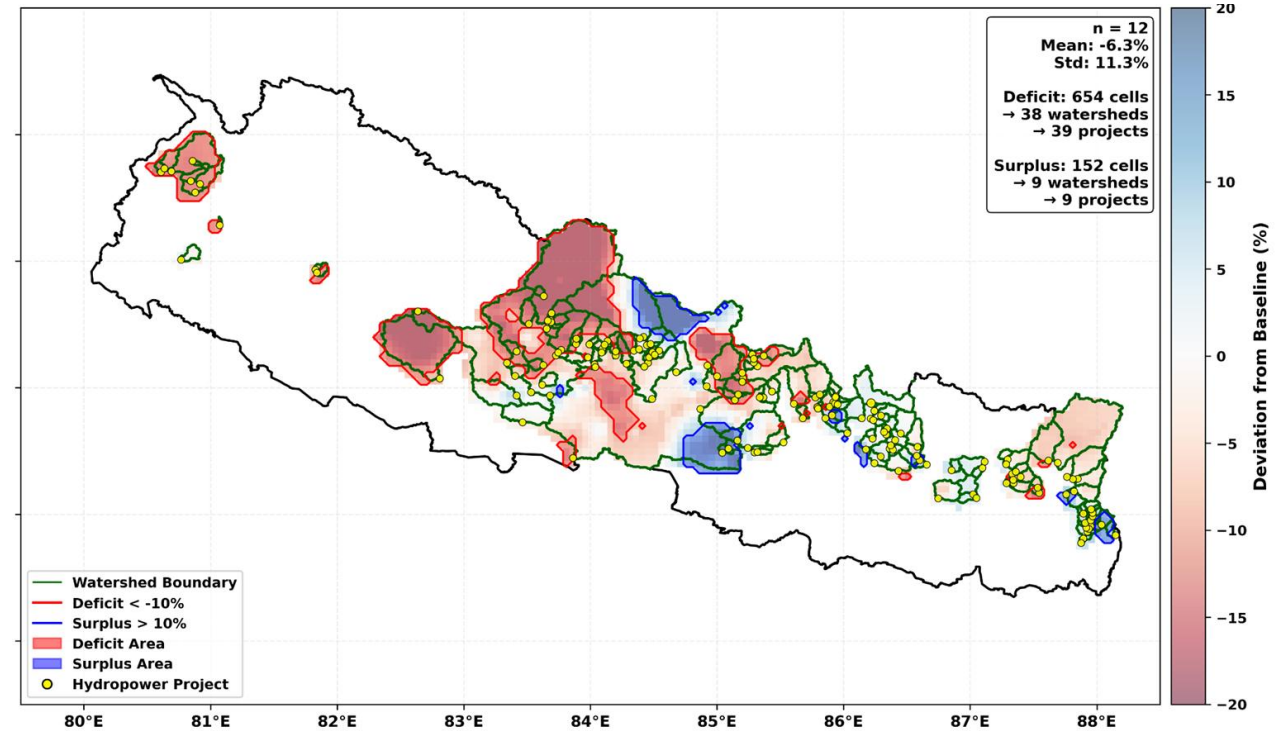
- **Onset:** Noticeable rainfall deficit in croplands (most critical in Eastern Terai during super El Niño).
- **Termination:** Full precipitation recovery across agricultural areas.
- **Key Contrast:** Acute drought stress shifts to sufficient crop water availability.

Winter Precipitation Anomalies in Hydropower Watersheds of Nepal (1980-2025)

Winter (Peak)



Winter (Decay)



Total 162 Hydropower projects (>1 Mw capacity)

- Winter (Peak) season shows good precipitation in most of the watersheds
 - Over 137 watersheds and 134 hydropower projects benefit
- Winter (Decay) season shows deficit in the precipitation over the hydropower watersheds
 - 39 hydropower projects are in <10% deficit area

Summary

- **DATA - still a major gap and data sharing is critical**

- There are significant changes in snow ice cover area in the high mountains.
- Need for understanding of the interaction between glacier, snow cover area and meteorological parameters, and the hydrological response to these changes.
- These changes could be diagnosed with physically based models, and it is possible to use such models in the mountains.
- Precipitation is important for people's lives directly and to biodiversity and water-induced disasters.
- Effect of El Nino is difficult to predict, summer monsoon is affected the most.
- Rice is the most impacted by El Nino. Hydropower sector is less affected.
- There is a need to link science with society and policy, and collaboration and networking are the keys.
- Sparse observational network above 3000 m elevation
- Complex topography strongly alters temperature and precipitation gradients
- Snowfall processes and rain–snow partitioning
- High uncertainty in hydrological modelling due to data scarcity

ICE 2 Water

The Glacial Lake Gallery



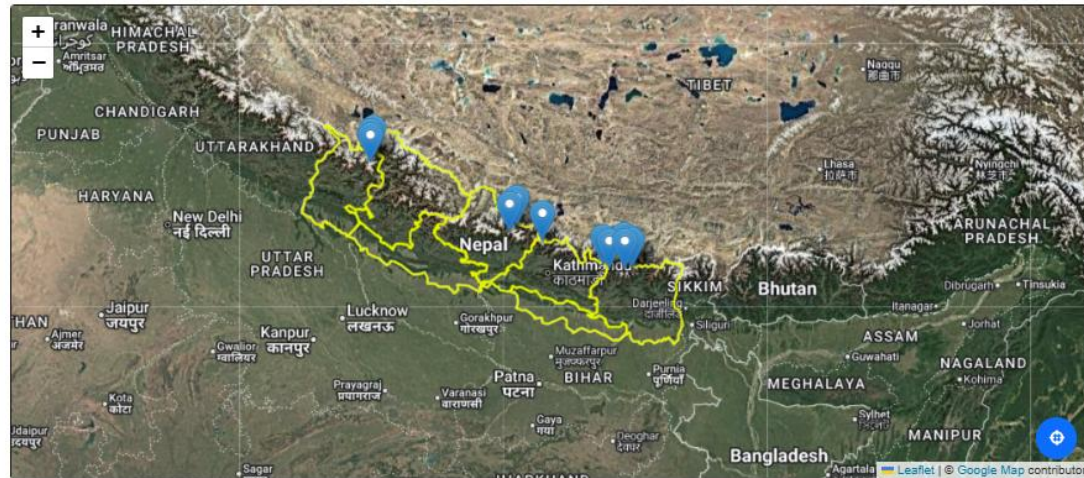
[Home](#) [Learn About Glacial Lakes](#) [Explore Glacial Lakes](#) [About Us](#) [Contact Us](#) [Source Code](#)

Welcome to Nepal's Glacial Lakes Monitoring Platform

Nepal's high mountain cryosphere is undergoing rapid transformation. Glacial retreat, proglacial lake expansion, and evolving hydrological regimes are redefining Himalayan landscapes and downstream risk systems. Nepal's Glacial Lakes Monitoring Platform is a dedicated, data-driven portal designed to systematically observe, analyze, and communicate these changes with scientific rigor and public accessibility.

This platform integrates multi-temporal satellite observations to provide a comprehensive view of glacial lake dynamics across the Nepal Himalaya. It enables users to visualize spatial extent changes, track temporal evolution, and understand emerging Glacial Lake Outburst Flood (GLOF) risks.

This platform bridges science and application — transforming satellite-derived datasets into actionable knowledge for researchers, planners, students, and policymakers.



Why This Platform Matters?

Glacial lakes are among the most visible indicators of climate change in high mountain environments. Their rapid growth increases the likelihood of catastrophic outburst floods, threatening downstream communities, infrastructure, and ecosystems. Reliable monitoring is therefore essential not only for scientific research, but also for early warning, climate adaptation, and sustainable water resource management.

What the Platform Offers

- Multi-Temporal Lake Monitoring:** Access comparative satellite imagery and delineated lake boundaries across different time periods. Evaluate surface area expansion, fragmentation, or drainage events through consistent, reproducible geospatial processing.
- Interactive Geospatial Interface:** Navigate basin-wise or lake-specific views through an intuitive interactive map. Click on individual lake markers to explore metadata, historical trends, and elevation context.