Modelling Langtang River Basin with Future Climates

Application of Cold Region Hydrological Modelling (CRHM) platform, a physically based glacio-hydrological model in the HIMALAYAS

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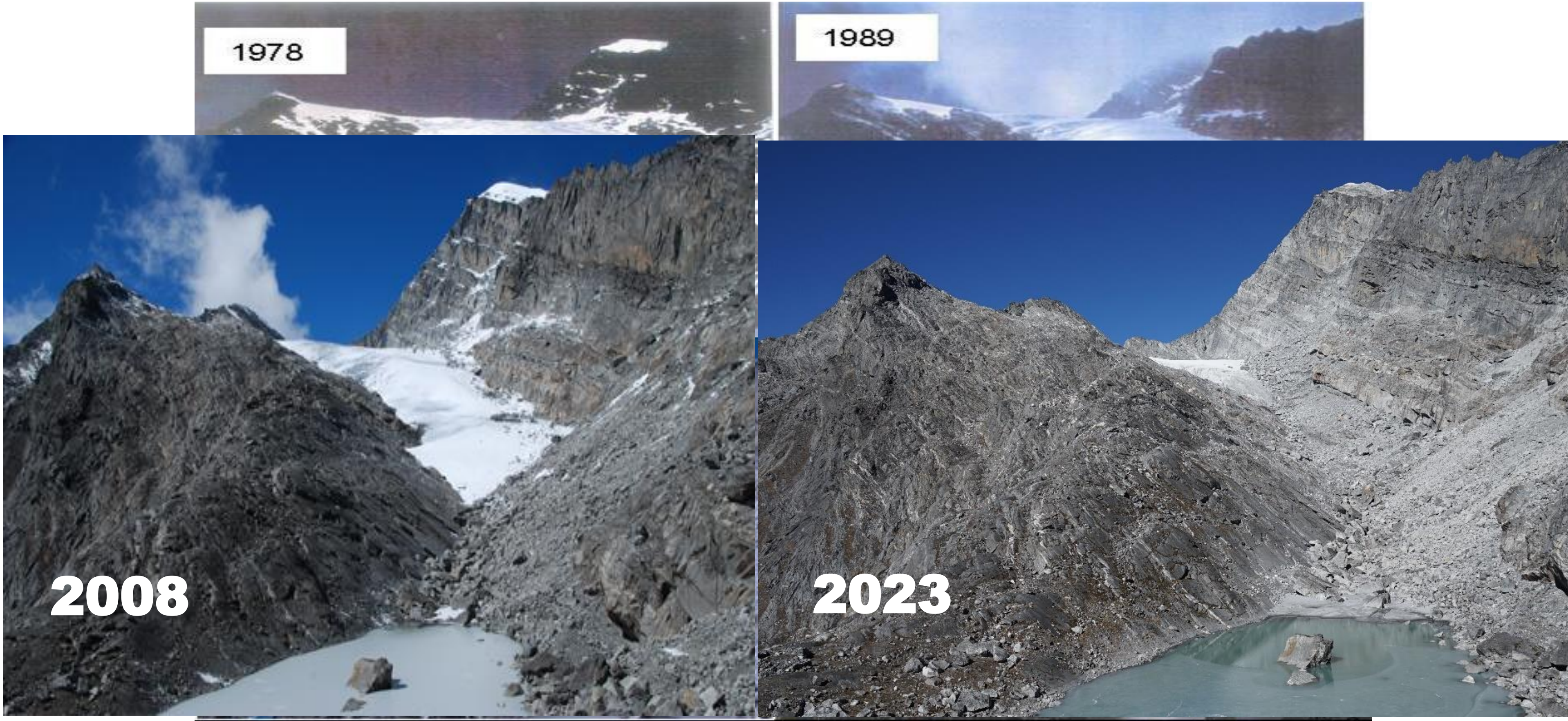
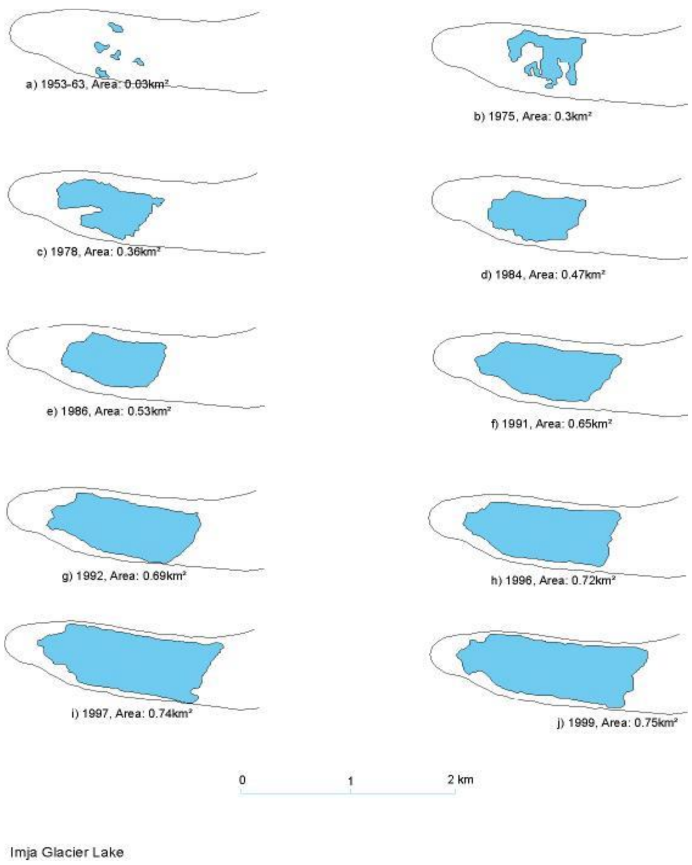
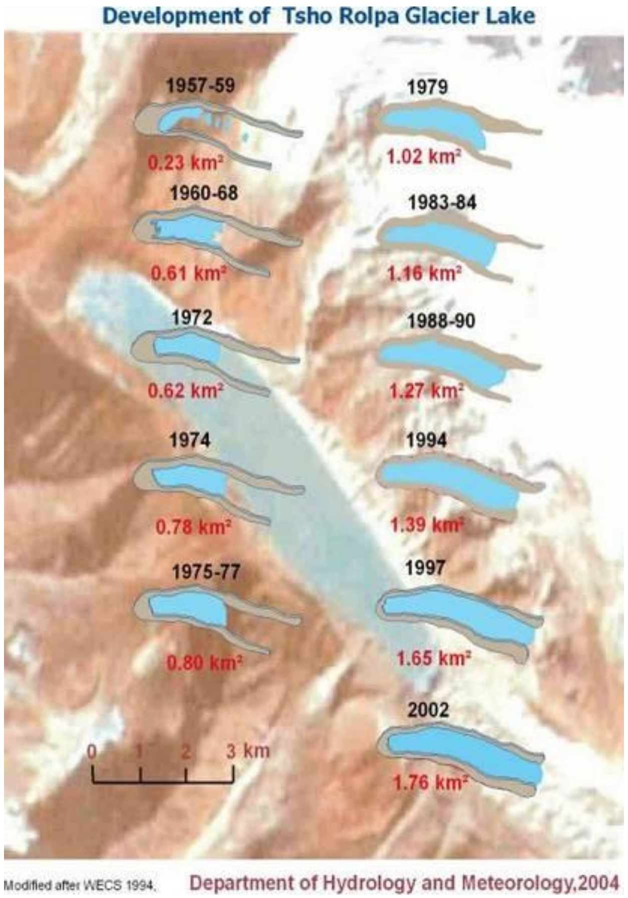
X010 Glacier retreating at the rate of 10 meter per year (Sources: GEN/DHM; R.B. Kayastha)



Imja Glacier Lake



Tsho Rolpa Glacier Lake



(Source: DHM)

DHM (Govt of Nepal) lowered 2 of the potentially dangerous - Tsho Rolpa and Imja Lakes

Imja Glacial Lake

Tsho Rolpa Glacial Lake

(Photo source: Gyawali, WECS)

Sikkim Flash Floods Highlights: Death toll rises to 18, nearly 100 people remain missing

1 min read . Updated: 06 Oct 2023, 08:02 AM IST

Livemint

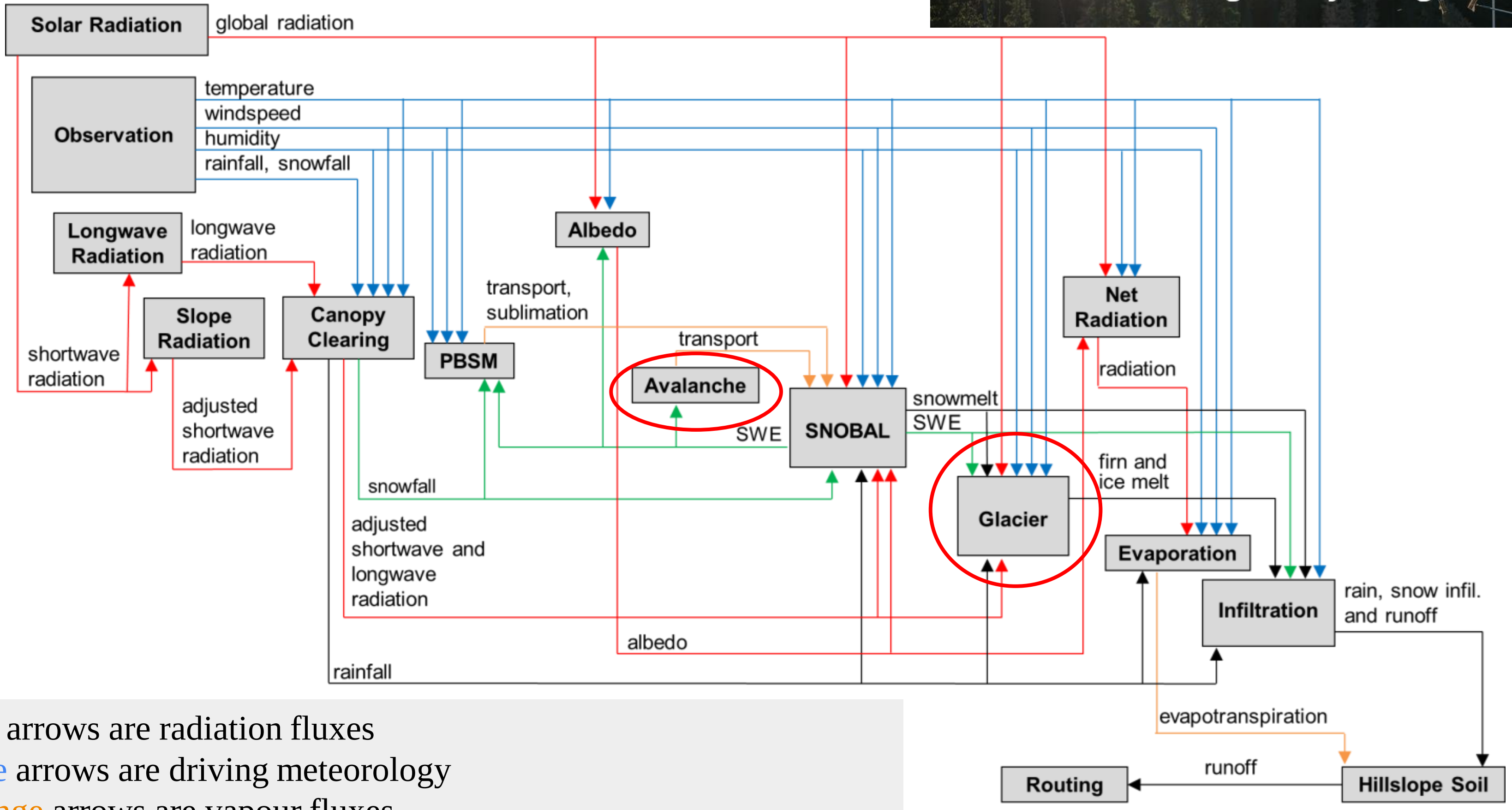
Sikkim Flash Floods Live Updates: At least 18 people were killed and 102 are missing after heavy rains caused a glacial lake in Sikkim to burst its banks.

Sikkim floods: Bridges of BRO's project 'Swastik' washed away by flood in Chungthang and Mangan area of North Sikkim on Thursday **(PTI)**

Cryospheric Sciences in the Himalayas

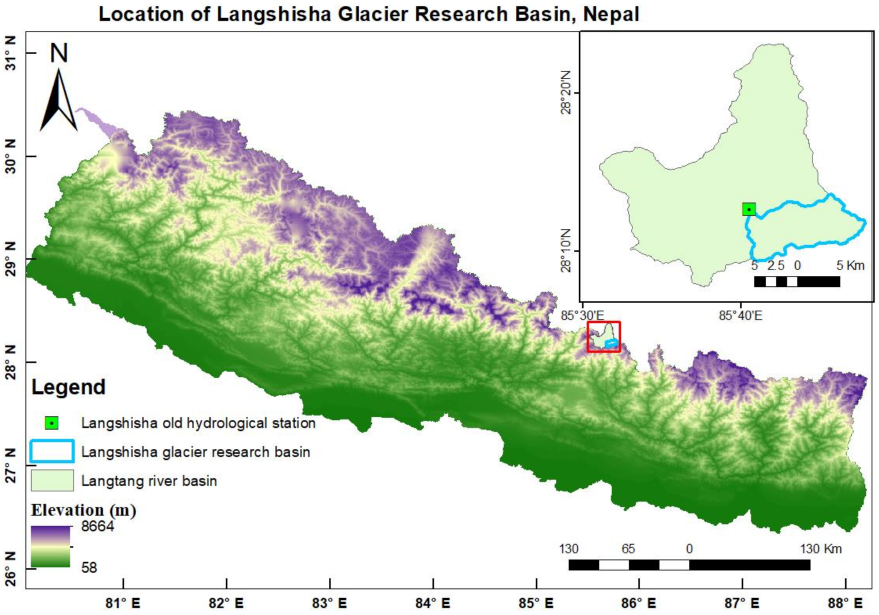
- Glaciers of the Himalayas are retreating.
  - Glacier lakes are forming and expanding
  - Higher chances of GLOF
- There are changes in the monsoon and winter climate.
- Hydro-climate processes of the high Himalayas are largely different from those of the lowlands.
- Cold Region Hydrological Modelling Platform (CRHM) in the Himalayas
  - Future Climates
  - Changes in Precipitation Phases
  - Black Carbon (BC)
- Cryosphere-induced Disasters
  - Birendra Lake Flood
  - Thame Flood

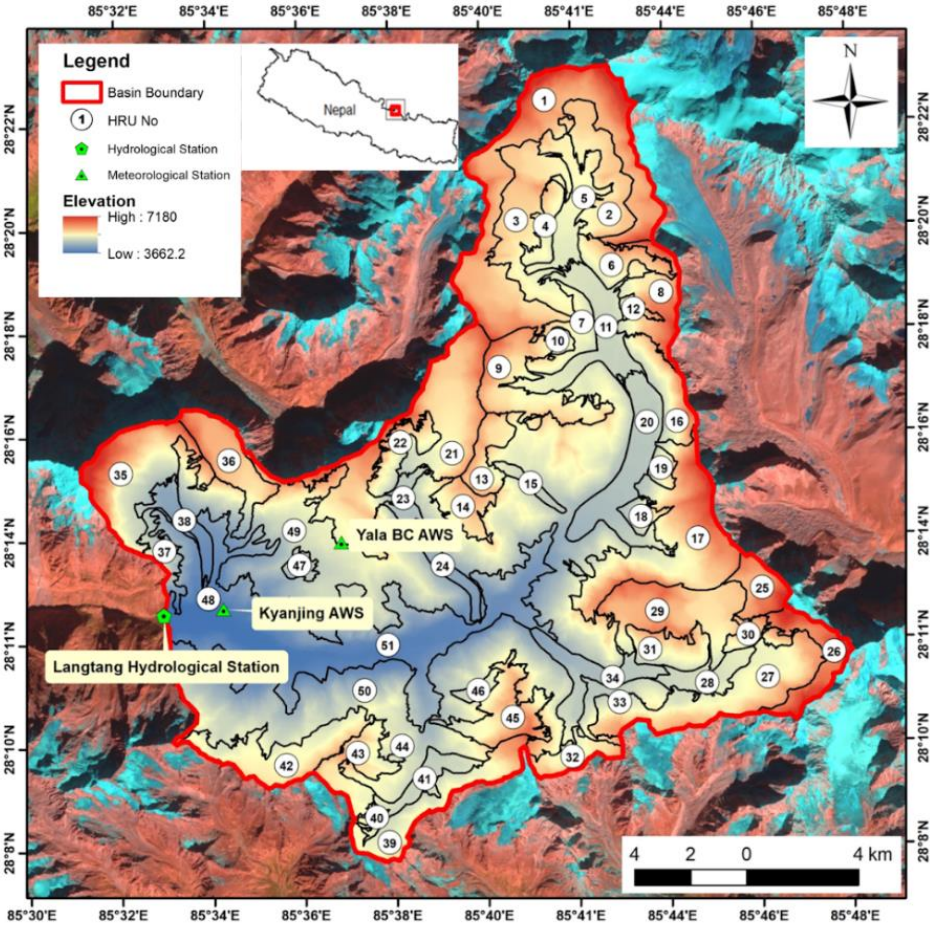
Modular Structure



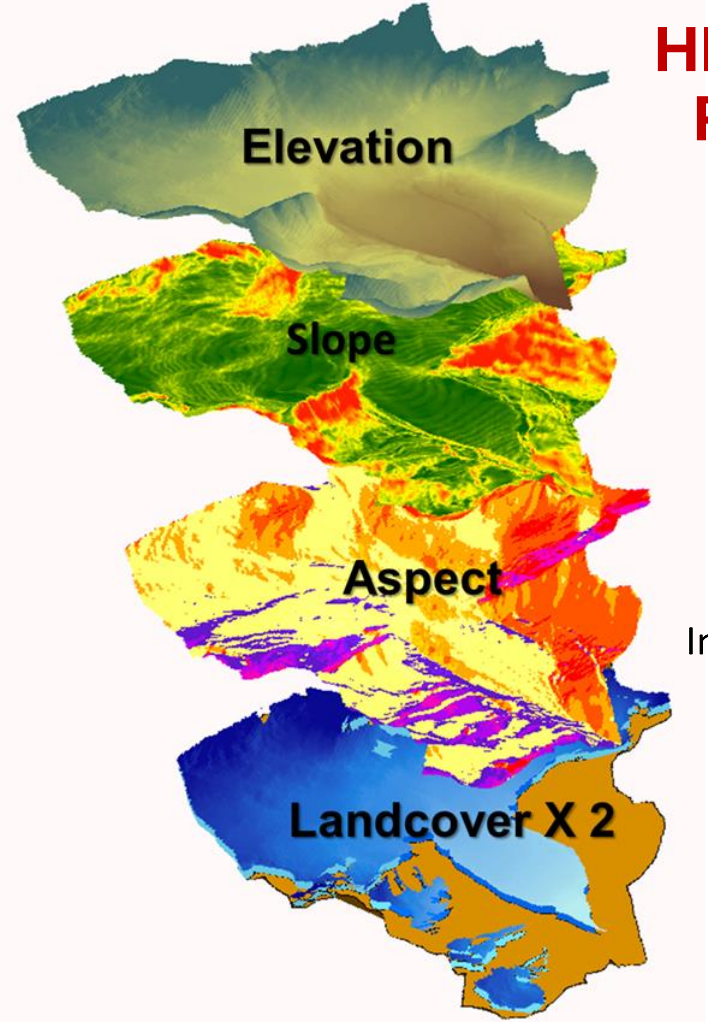
Red arrows are radiation fluxes
Blue arrows are driving meteorology
Orange arrows are vapour fluxes
Green and Black arrows are calculated solid and liquid mass fluxes.

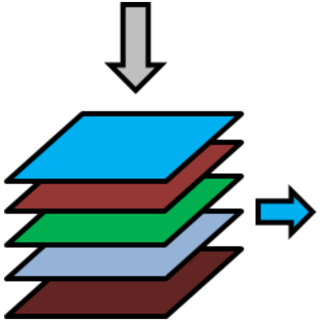
Langtang River Basin & Langshisha Sub-basin



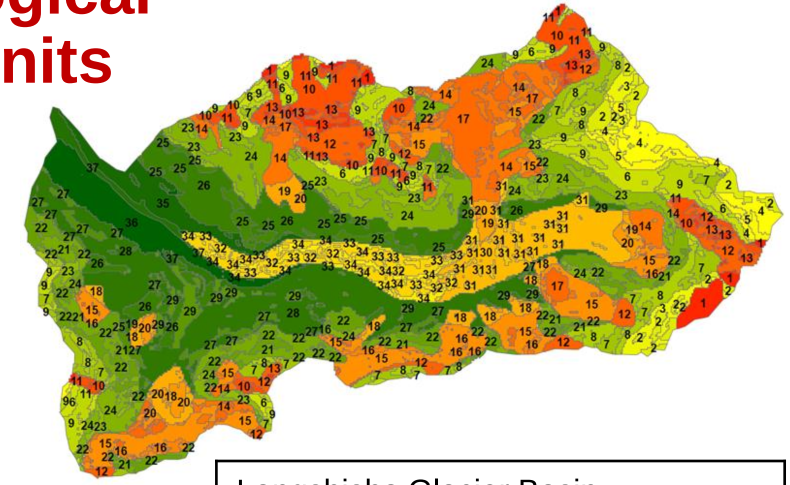


HRU, Hydrological Response Units



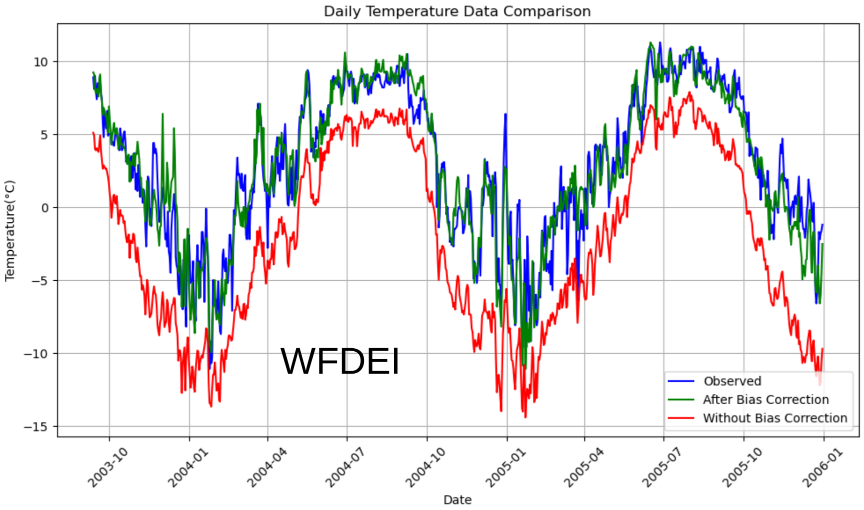


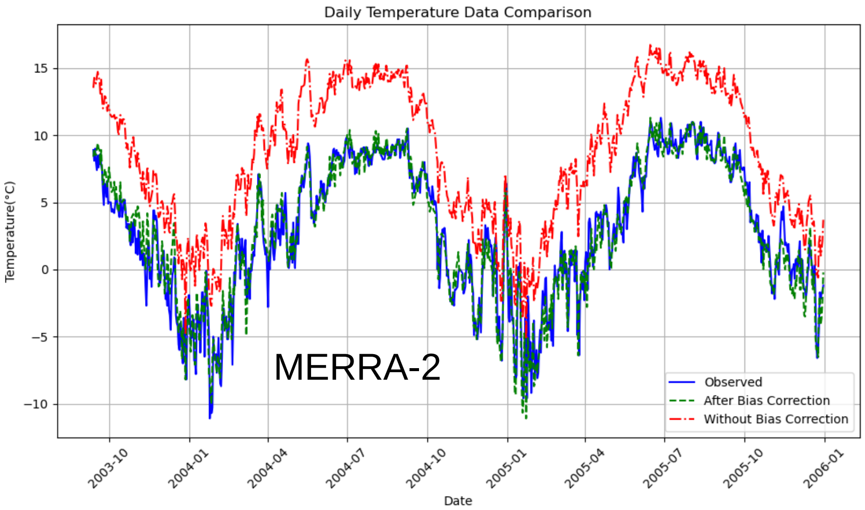
Intersect of 3+2 layers in ArcGIS interface

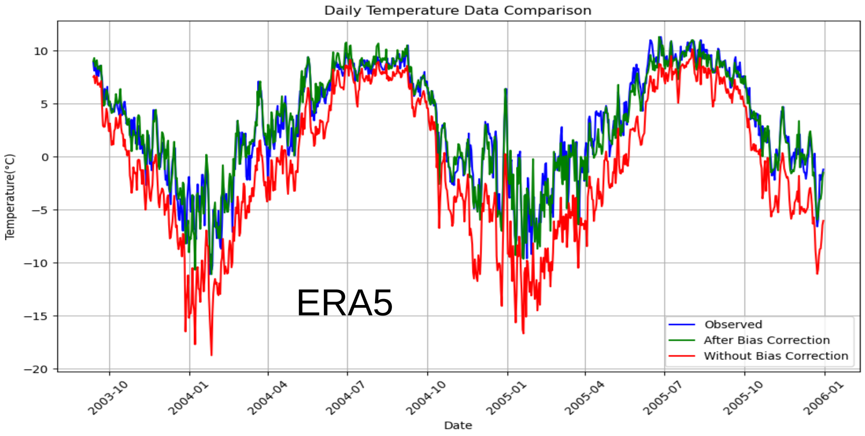


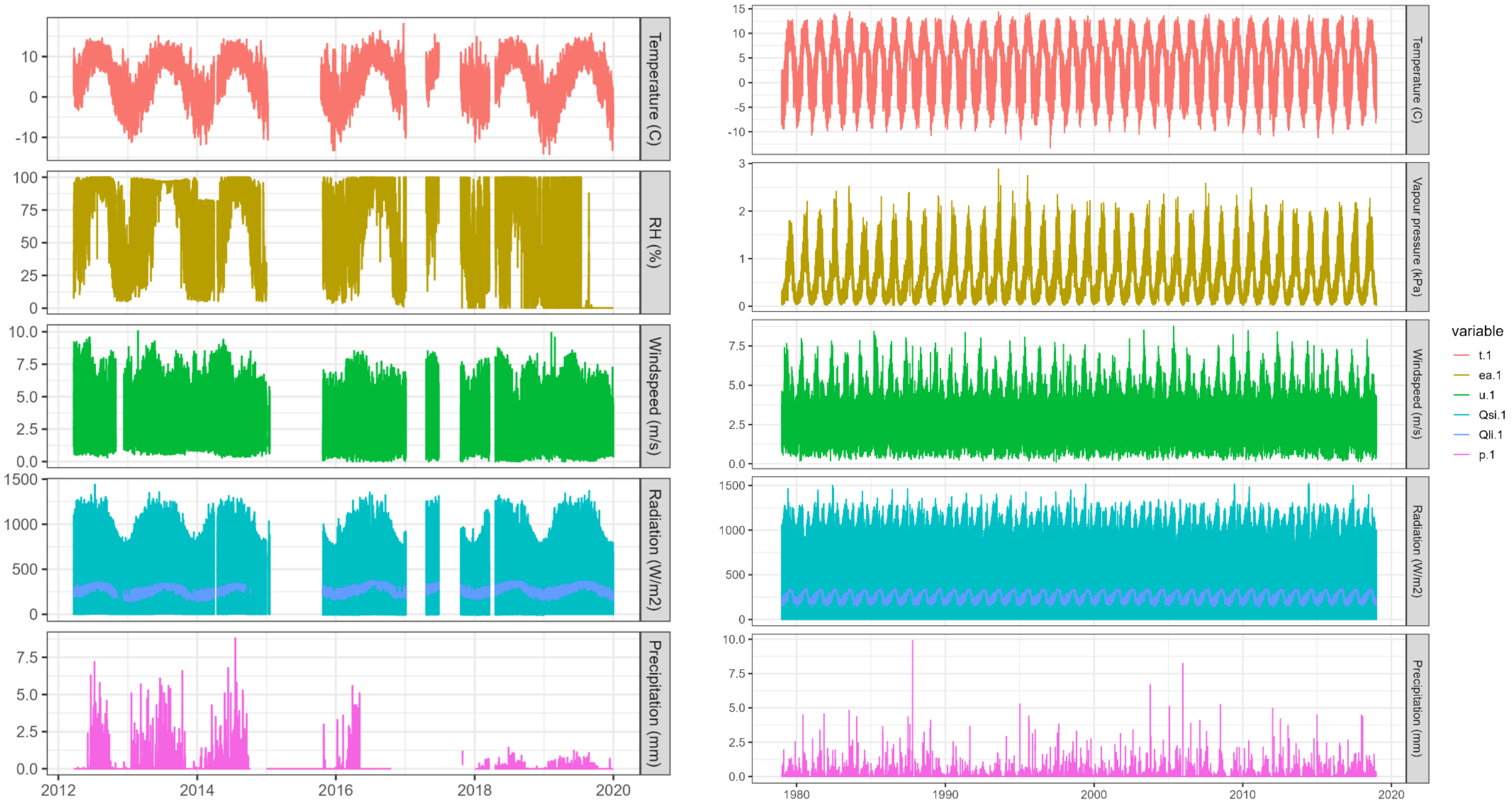
Langshisha Glacier Basin		
Land cover type	Area (Km^2)	% cover
Firn	12.0	22.0
Ice	3.7	6.7
Debris cover glacier	4.7	8.5
Pasture	13.9	25.4
Bare	20.5	37.4
Total	54.8	100.0

Bias-corrected Reanalysis Data



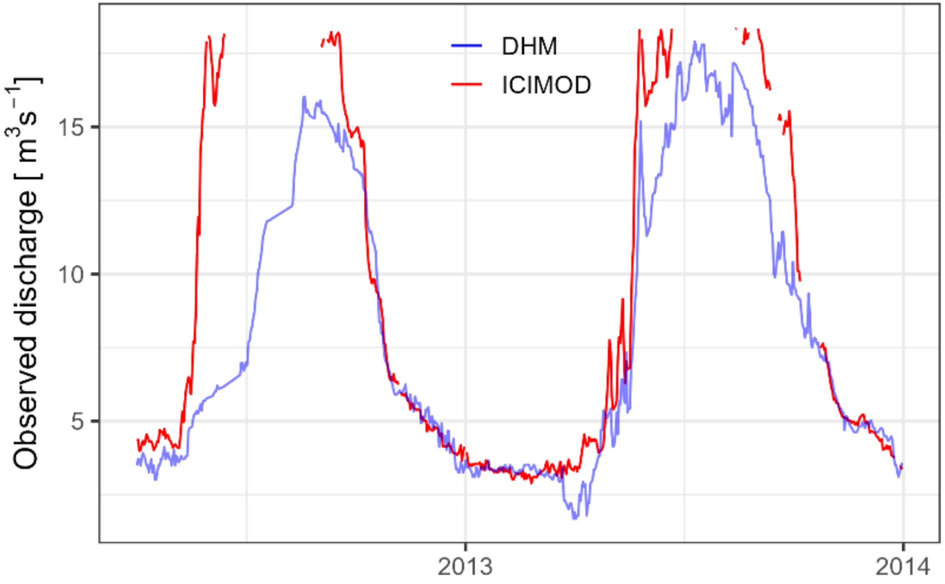






Temperature (C)
RH (%)
Windspeed (m/s)
Radiation (W/m2)
Precipitation (mm)
2012
2014
2016
2018
2020
Temperature (C)
Vapour pressure (kPa)
Windspeed (m/s)
Radiation (W/m2)
Precipitation (mm)
1980
1990
2000
2010
2020
variable
t.1
ea.1
u.1
Qsi.1
Qli.1
p.1

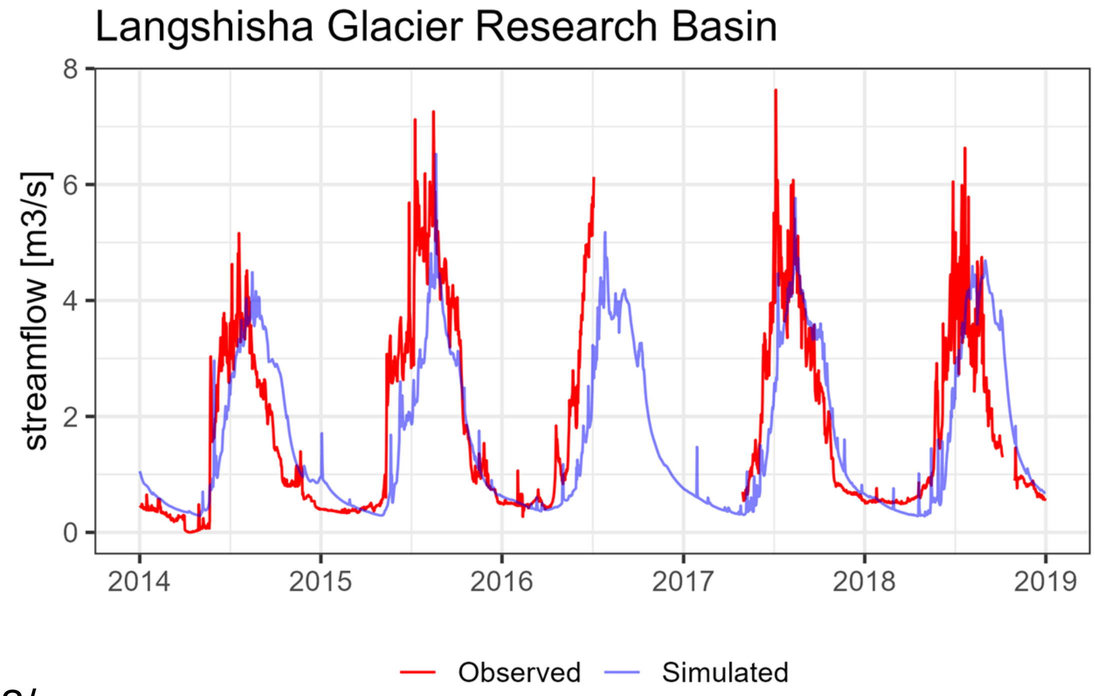
Discharge Data Challenge (Langtang River Basin)



DHM: Department of Hydrology and Meteorology, Govt. of Nepal
ICIMOD: International Centre for Integrated Mountain Development

Model Validation

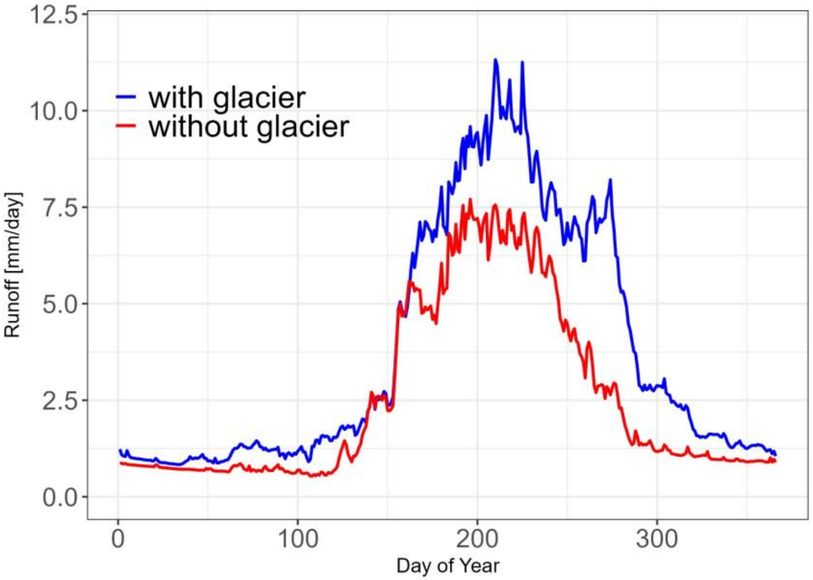
- The model could catch the overall hydrological pattern.
- Insufficient understanding of important hydrological processes (groundwater flow, routing)

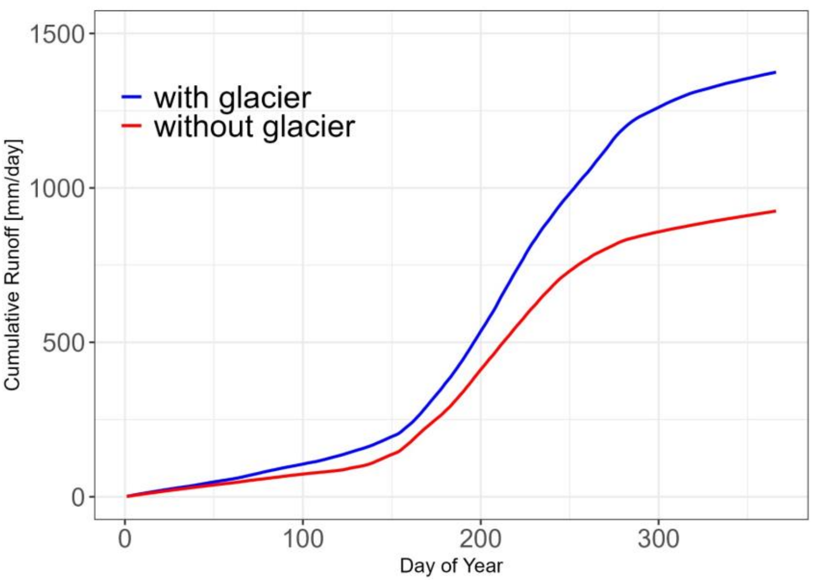


KGE: 0.71, NSE: 0.59
RMSE: 1.02 m3/s, MBE: -0.17 m3/s

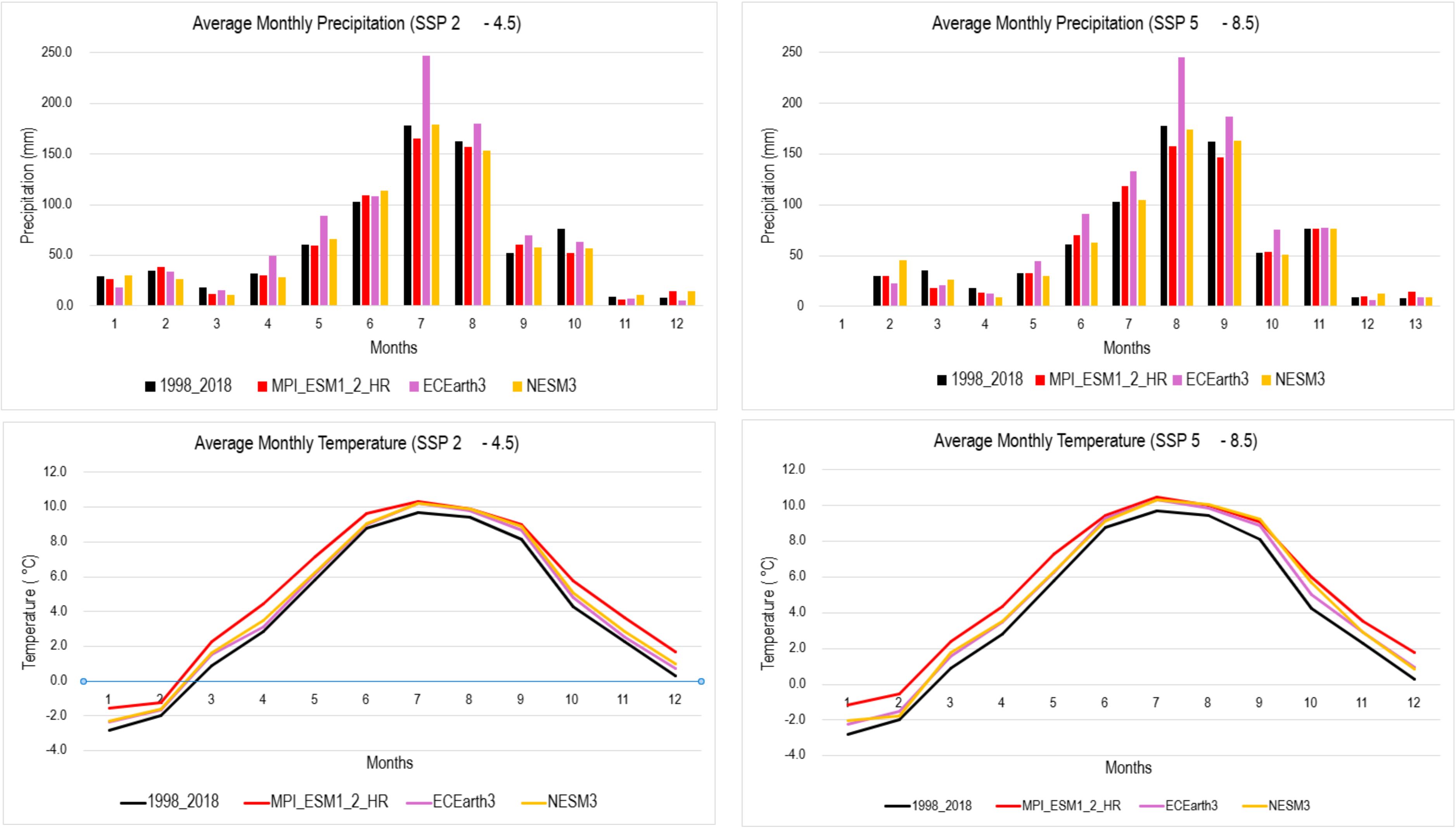
Langtang River Basin

Daily averaged streamflow from 2012 to 2018.



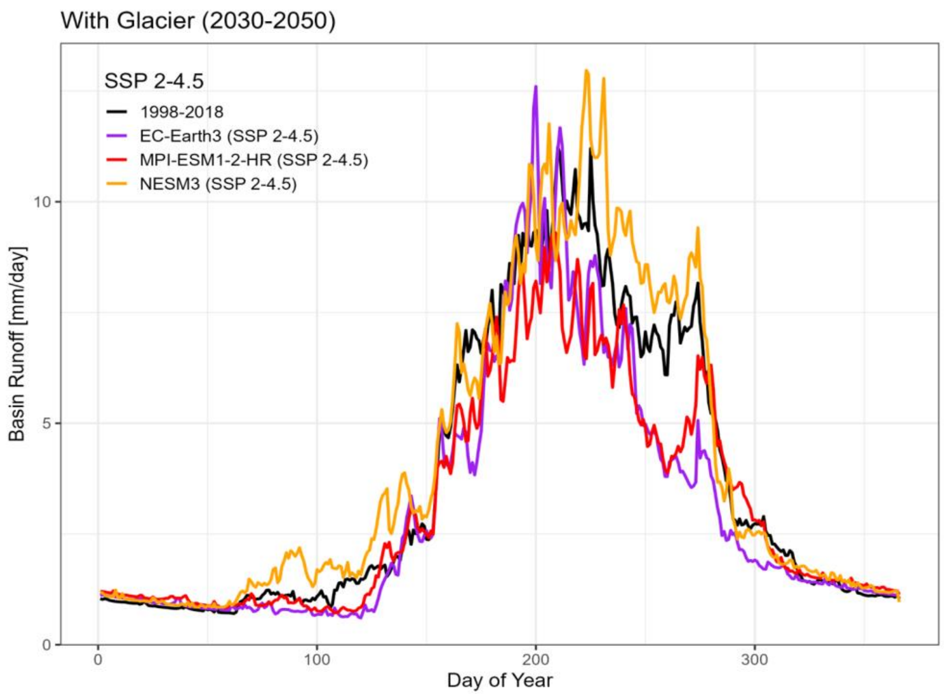


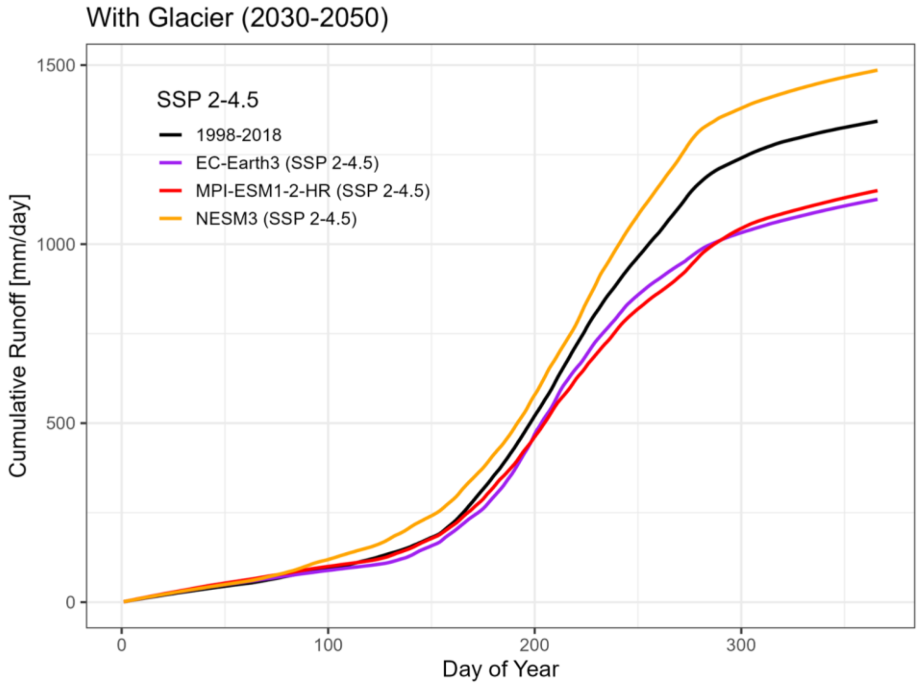
Decrease in runoff by 32%



Average Monthly Precipitation (SSP 2 - 4.5)
Precipitation (mm)
Months
1998_2018
MPI_ESM1_2_HR
ECEarth3
NESM3
Average Monthly Precipitation (SSP 5 - 8.5)
Precipitation (mm)
Months
1998_2018
MPI_ESM1_2_HR
ECEarth3
NESM3
Average Monthly Temperature (SSP 2 - 4.5)
Temperature (°C)
Months
1998_2018
MPI_ESM1_2_HR
ECEarth3
NESM3
Average Monthly Temperature (SSP 5 - 8.5)
Temperature (°C)
Months
1998_2018
MPI_ESM1_2_HR
ECEarth3
NESM3

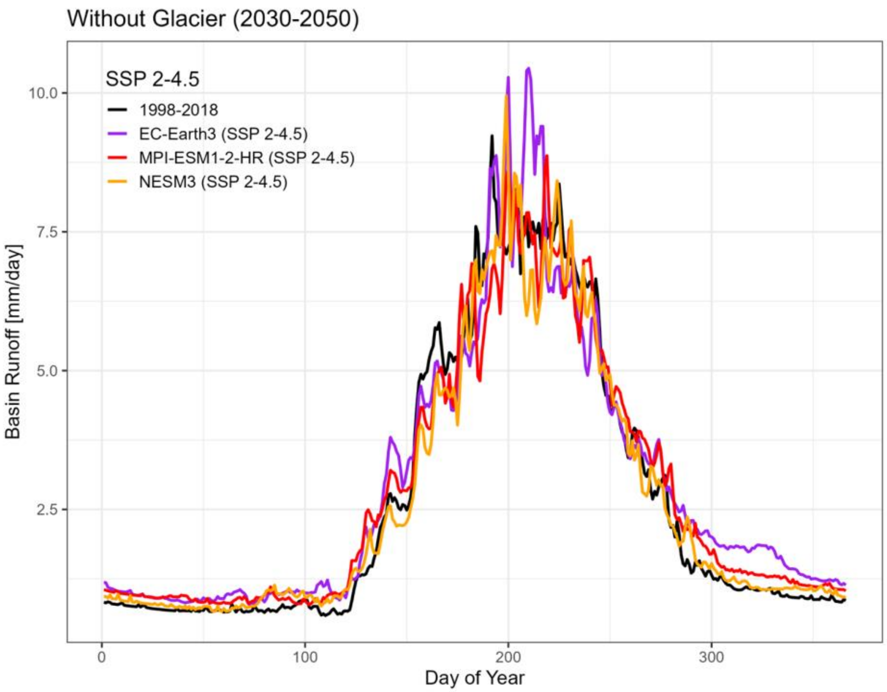
SSP 2-4.5

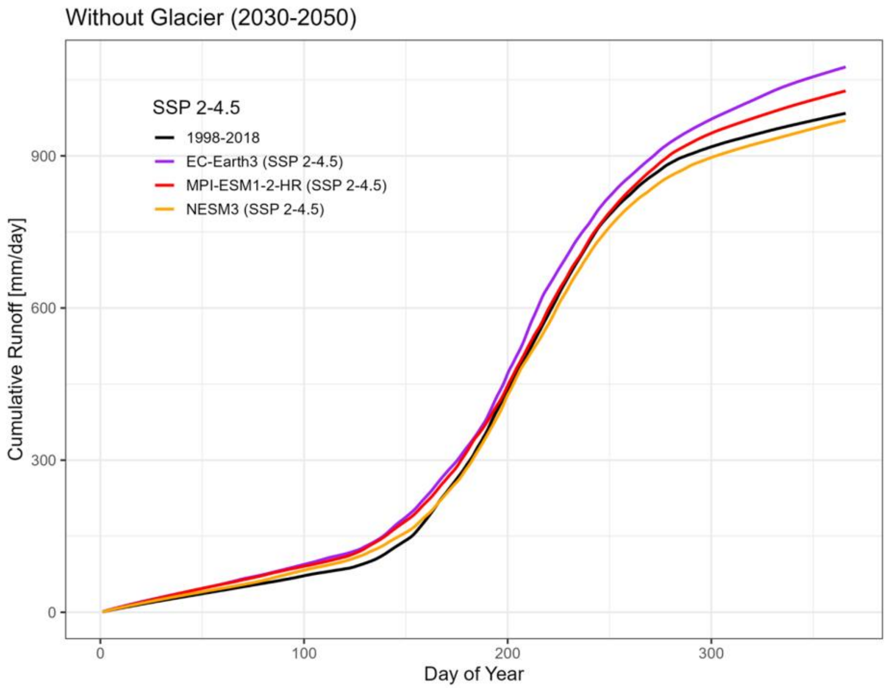




	1998-2018	EC Earth-3	MPI-ESM1-2-HR	NESM3
Cumulative Runoff (mm)	1343	1125	1150	1486
Percentage Change	–	-16.2%	-14.4%	10.7%

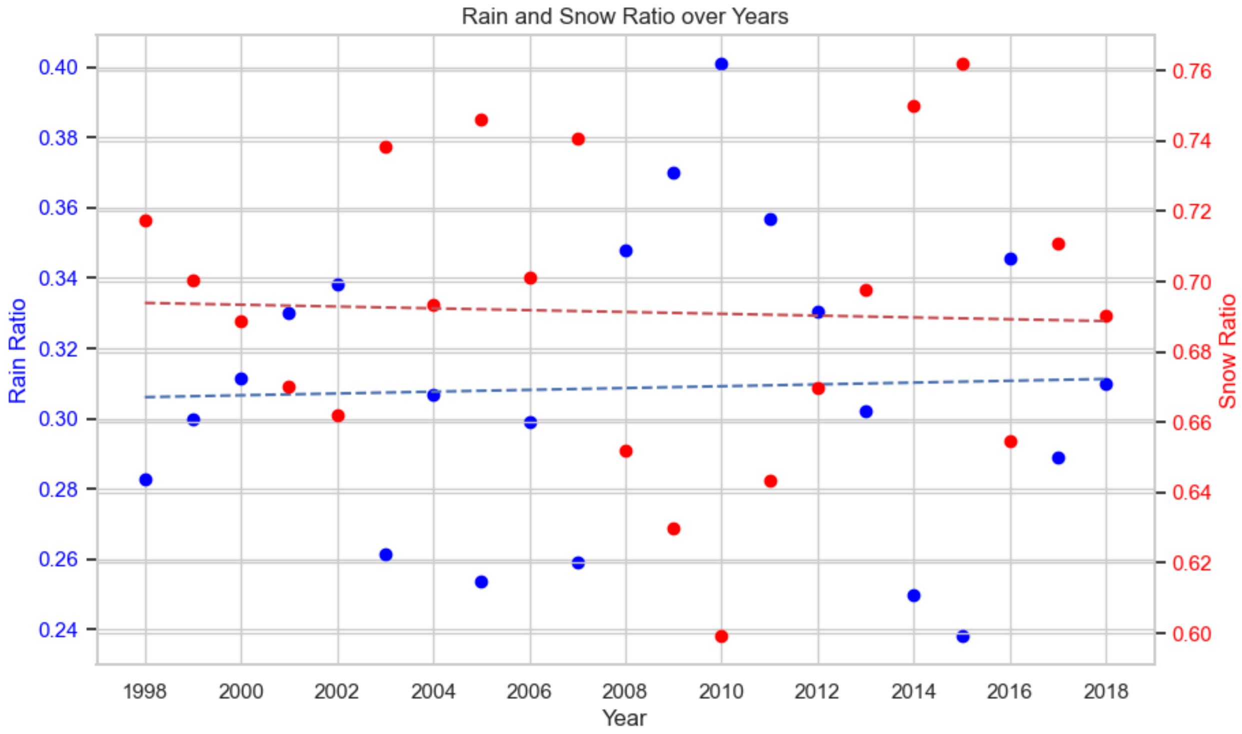
SSP 2-4.5





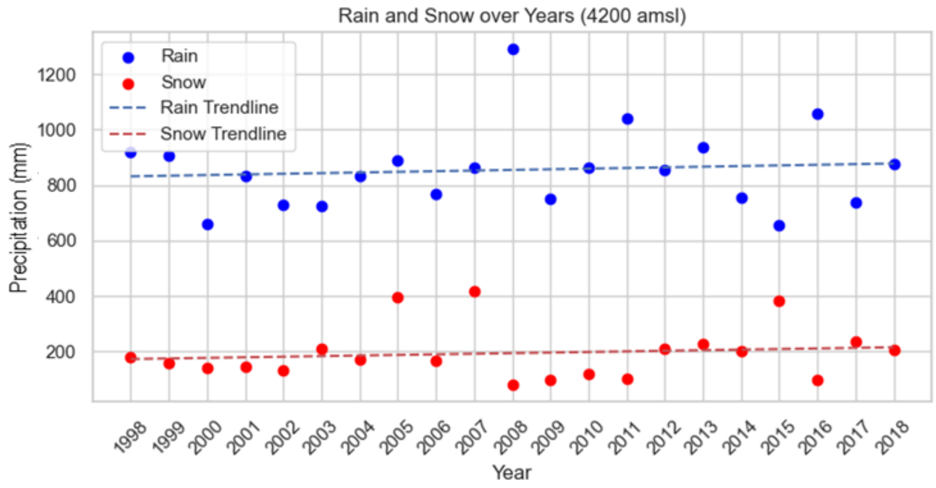
	1998-2018	EC Earth-3	MPI-ESM1-2-HR	NESM3
Cumulative Runoff (mm)	984	1075	1028	969
Percentage Change	–	9.2%	4.4%	-1.5%

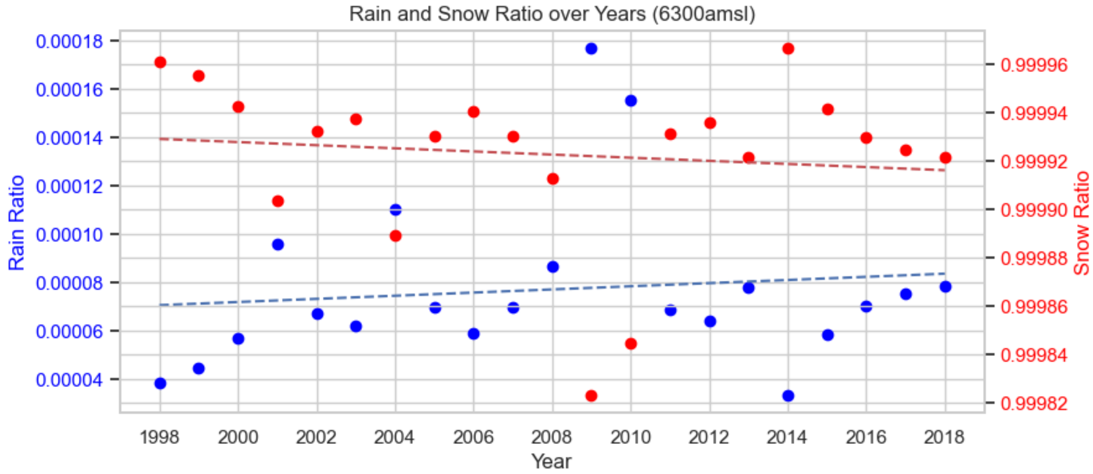
Precipitation Phase



- Precipitation is partitioned into rain and snow using a physically based psychrometric energy model (Harder and Pomeroy, 2013), integrated into CRHM.

Precipitation Phase





Black Carbon (BC) induced snow albedo change

Season	Atmospheric BC (ug/m^3)	Albedo reduction (%)
pre-monsoon	0.73	5.08
monsoon	0.23	1.6
post-monsoon	0.29	2.02
winter	0.46	3.2

- Gul et al. (2021) provided a 5.08% albedo change for 0.73 ug/m^3 atmospheric BC concentration during the pre-monsoon and provided atmospheric concentration for other seasons.
- Albedo change for other seasons was interpolated using the pre-monsoon albedo change and atmospheric BC concentration.
- This approach has limitations and the assumption that the atmospheric BC deposits on snow and affects the snow albedo similarly to all seasons.

BC-induced firn/ ice albedo change

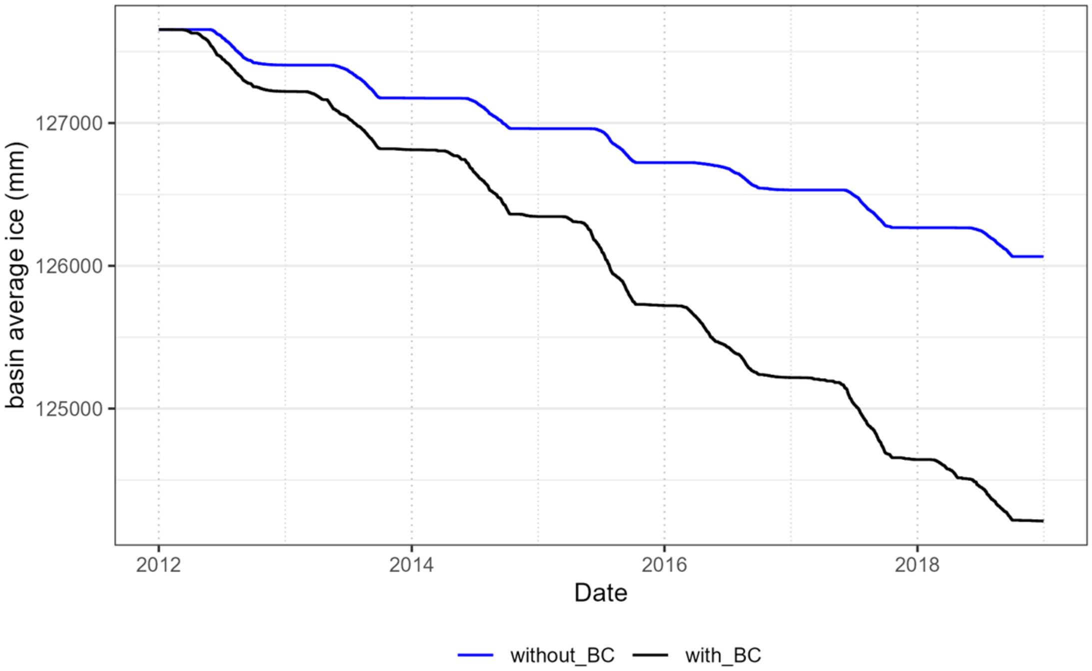
- The average BC deposition amount of 266 (μg/m²) for Yala Glacier measured by Gul et al. (2021)
- It was provided as input in the equation provided by Yasunari et al. (2010) to obtain the change in albedo due to BC concentration on firn and ice.

Firn				
BCD amount (μg/m²)	Firn density (kg/m³)	BC deposition snow depth (m)	BCC (μg/kg) (x)	Reduced albedo (%) (y)
266	450	0.02	29.56	8.0
266	780	0.02	17.05	5.3

Ice				
BCD amount (μg m⁻²)	Ice density (kg/m³)	BC deposition snow depth (m)	BCC (μg/kg) (x)	Reduced albedo (%) (y)
266	915	0.02	14.53	4.7

Regression equation to calculate albedo change due to BC concentration (Yasunari et al., 2010)
Eq. $y=2.20386E\text{-}01x+1.51181$; where, x = BC concentration (μg kg^{-1}) on snow/firn/ice; y = % of reduced albedo

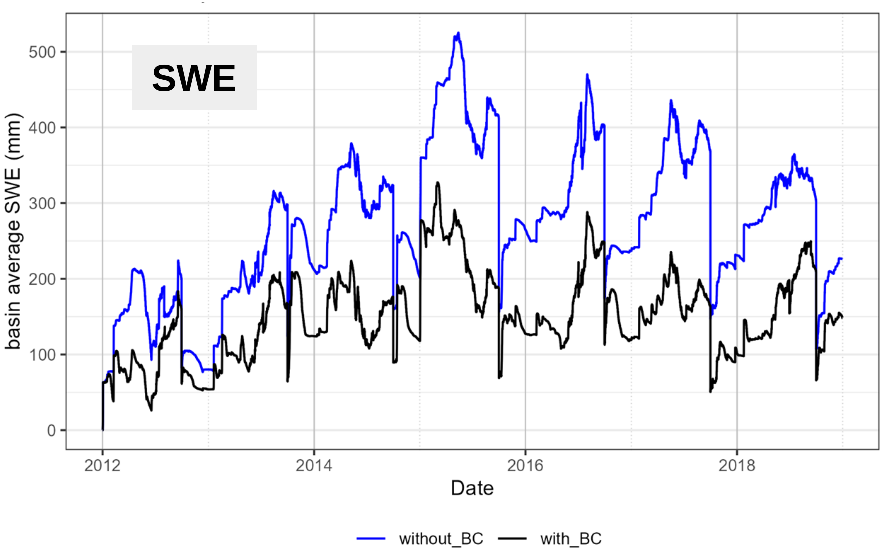
Glacier loss in Langshisha

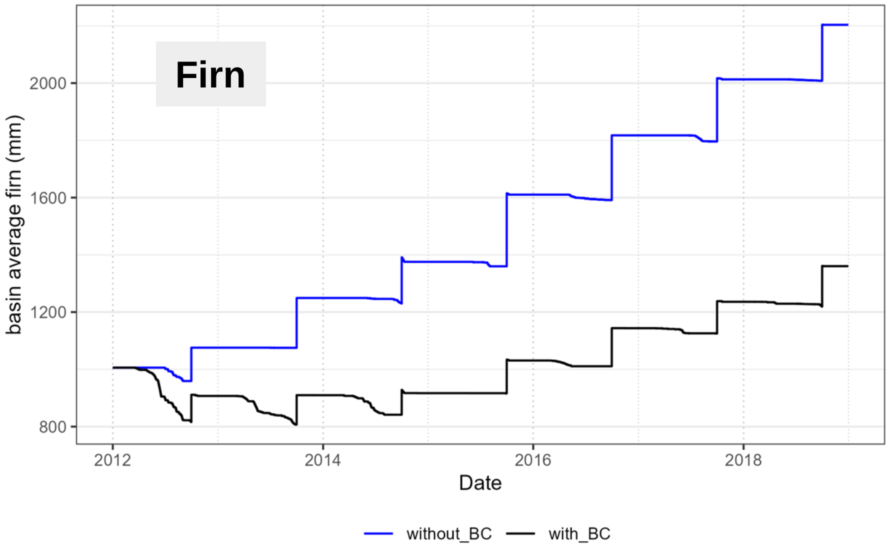


Basin average ice condition with and without the impact of BC. Loss of ice was 0.29 m per year

Snow/Firn Loss in Langshisha

Basin average conditions with and without the impact of BC

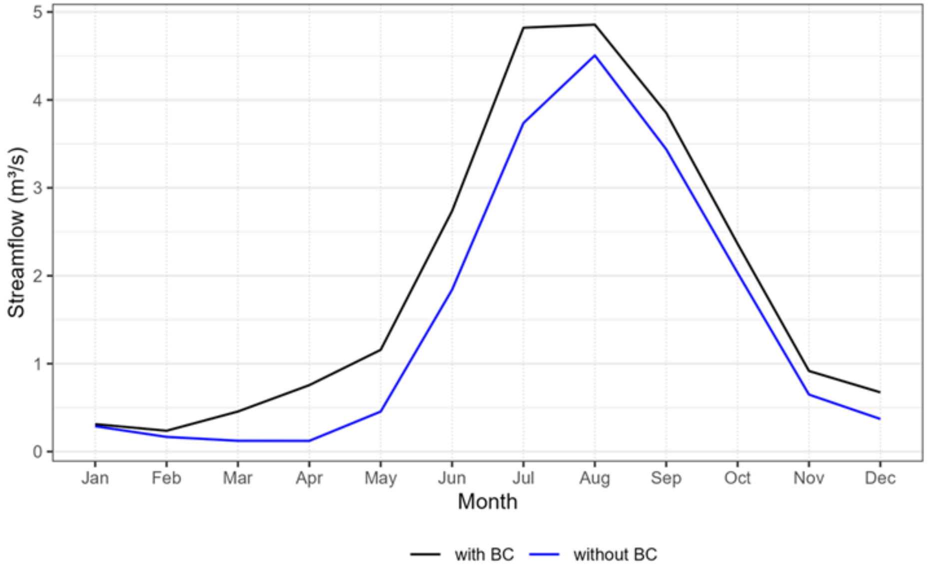


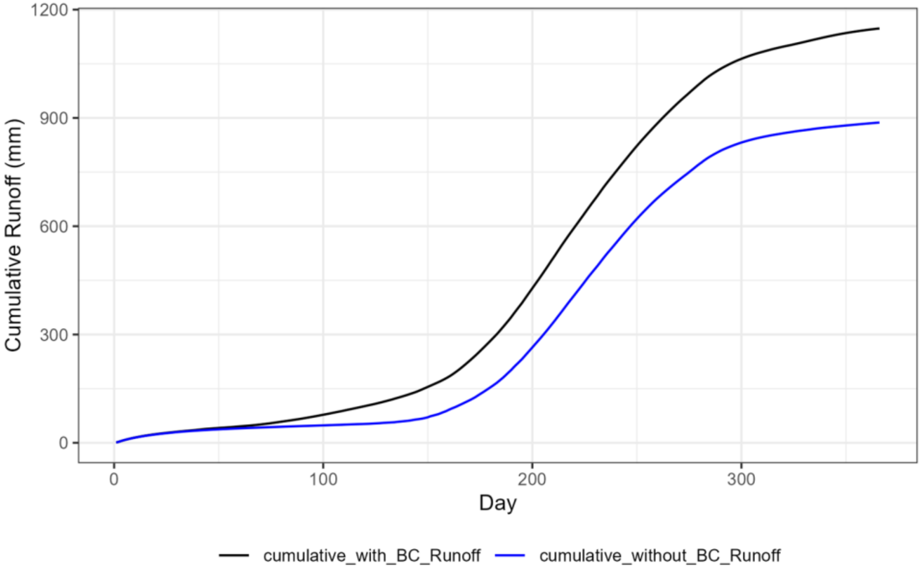


BC decreases 100 mm of annual average SWE due to enhanced melting.
Average firn formation decreases by 0.16 m/year.

Hydrological Response

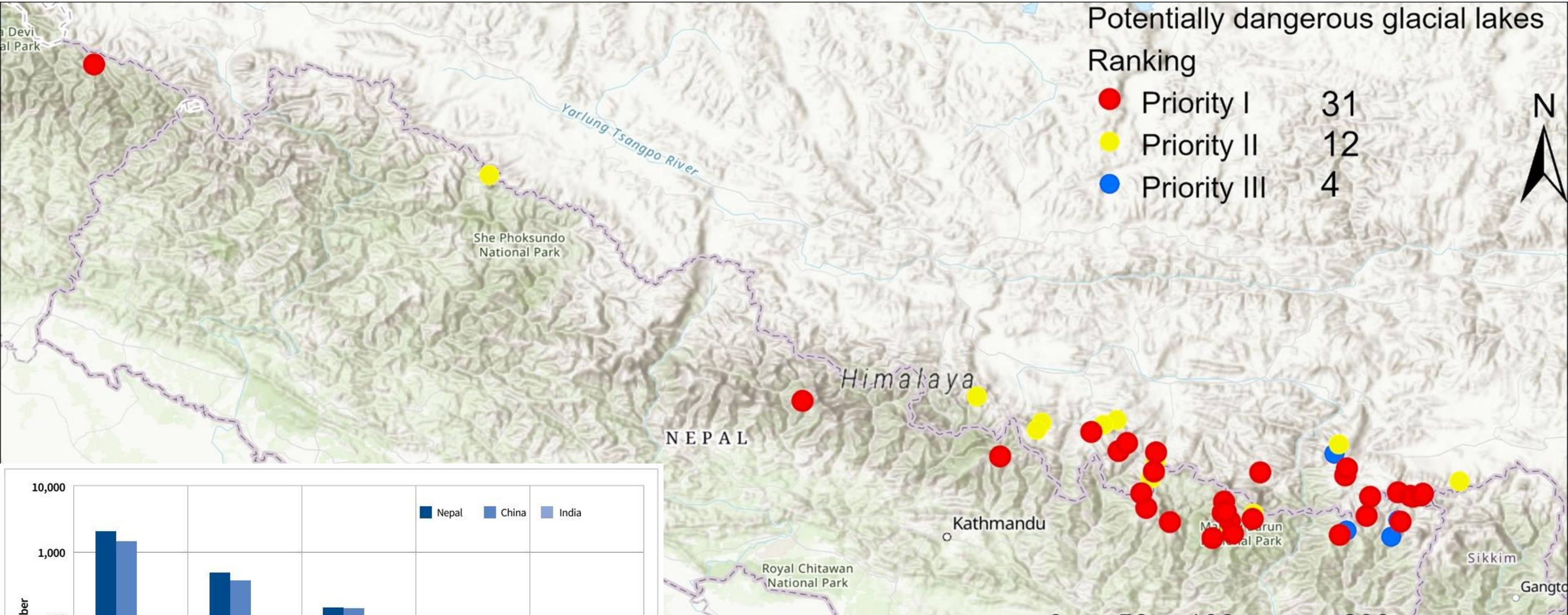
Monthly averaged streamflow from 2012 to 2018.

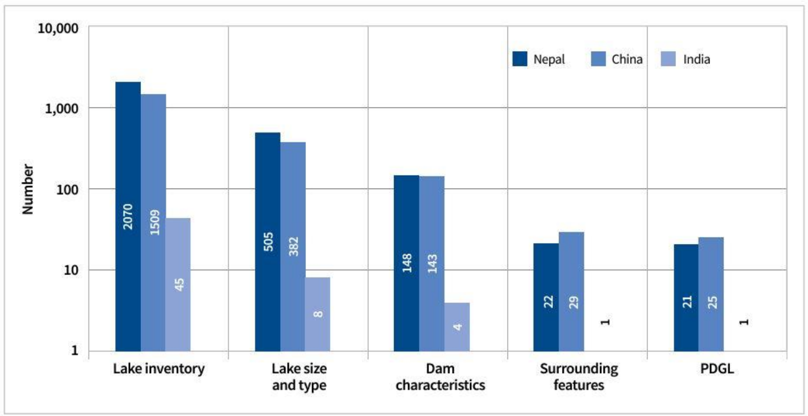




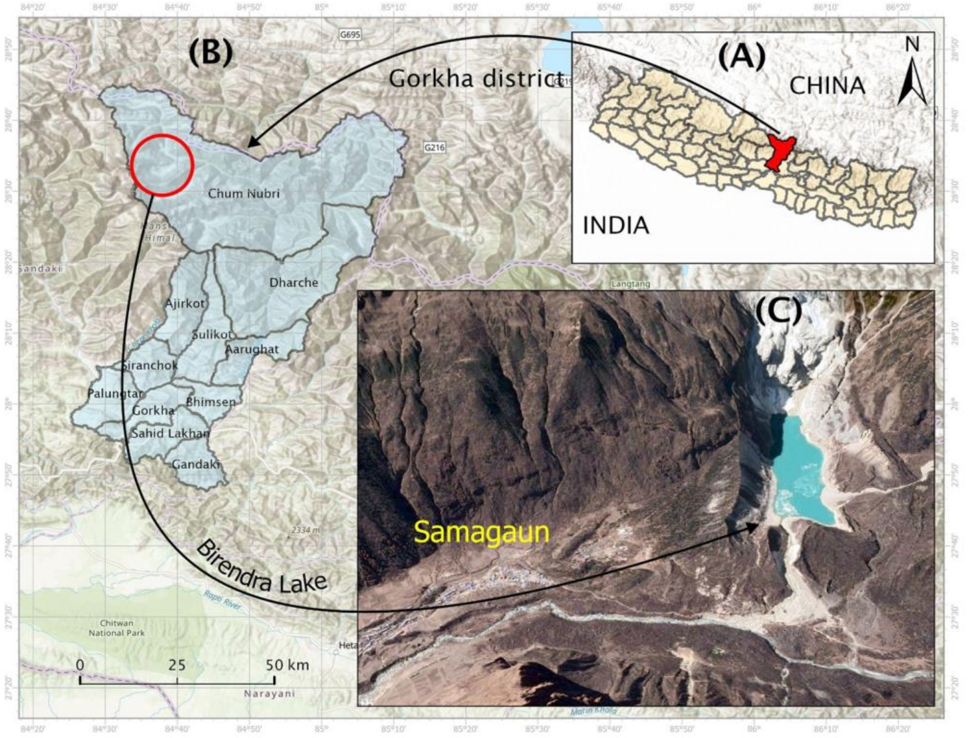
Increase in runoff by 0.29 m

PDGL = Potentially Dangerous Glacial Lakes (ICIMOD and UNDP, 2020)





Avalanche Hazards in the Nepal Himalayas: The April 2024 Birendra Lake Case Study



Birendra Lake in Gorkha district. A) Nepal with district boundaries with the location of Gorkha District, B) Local municipalities of Gorkha District with the location of Birendra Lake in Chum Nubri Rural Municipality, and C) Google Earth image of Birendra Lake.

- **Location:** Birendra Lake, Gorkha district, Nepal, underneath of Mt. Manaslu
- **Avalanche Event Date:** April 21, 2024
- **Impact:**

- Surge in Budhi Gandaki River (69 cm rise at Ghap station within 20 min)
- One of the huge events to the date according to local people

Transformation of Birendra Lake: Before and After the Avalanche Event

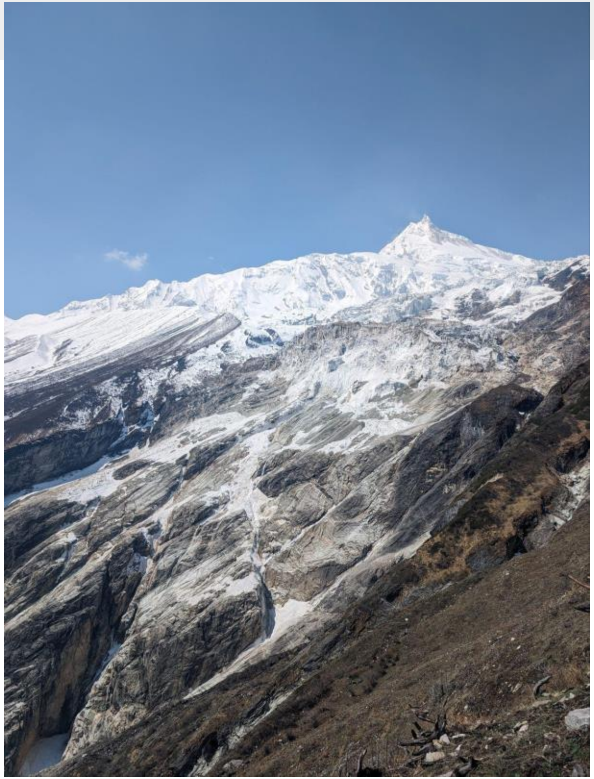
Before Event - 9/04/2023

Photo Credit: Nepal Tourism Hub

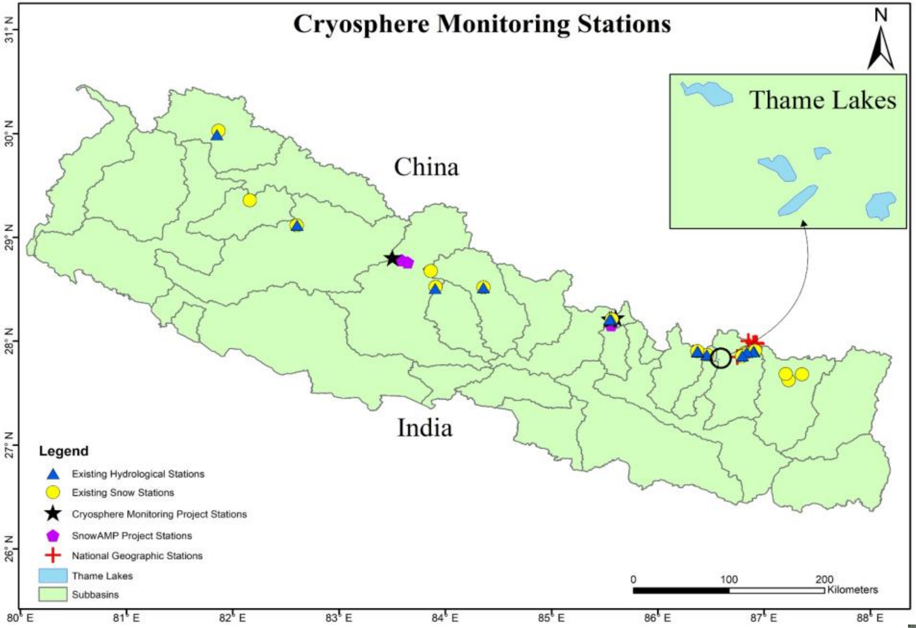
After Event - 25/04/2024

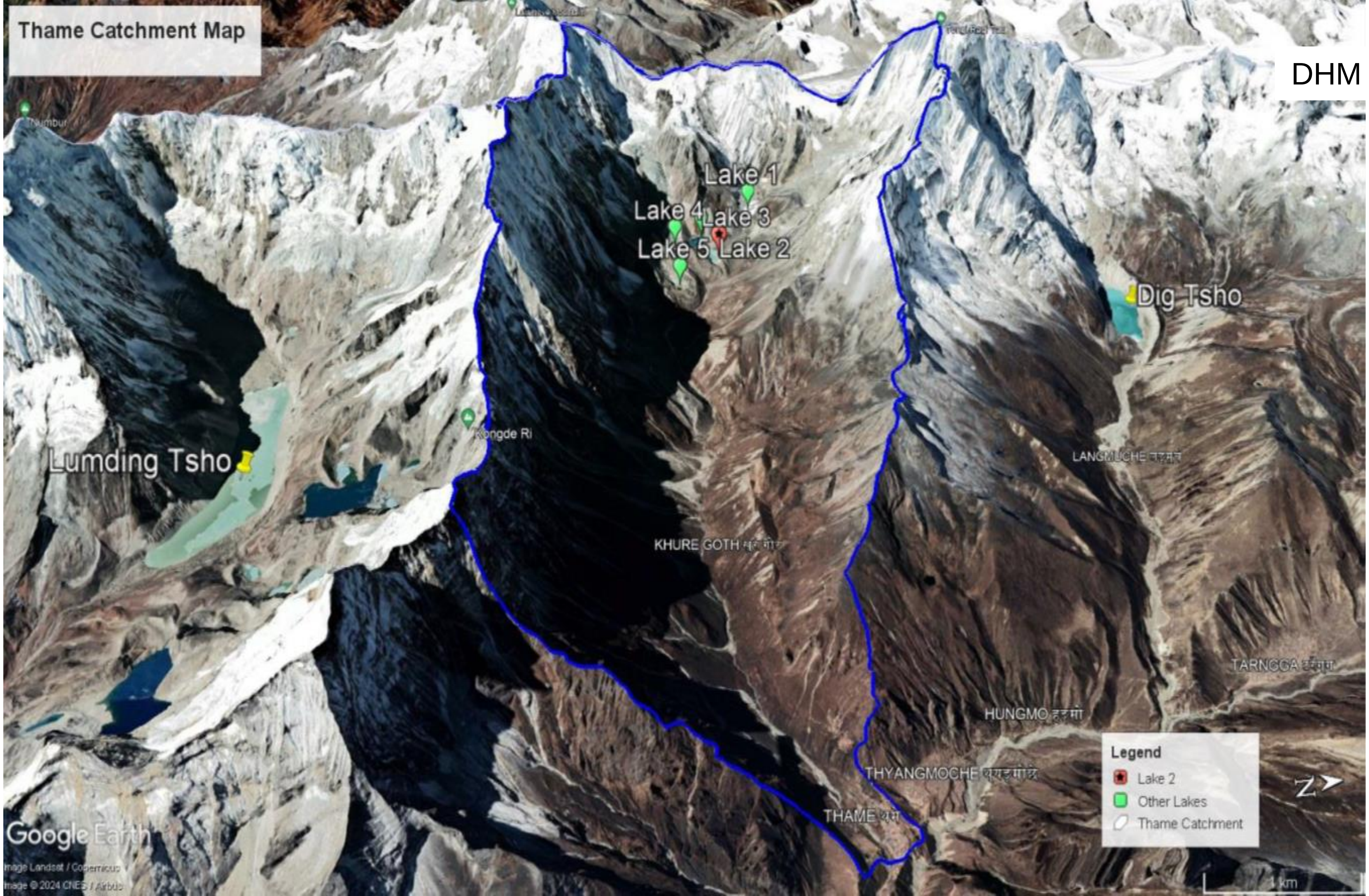
Photo Credit: Manavi Chaulagain


Ice debris floating on the lake's surface three days after the avalanche event


Mt. Manaslu Peak and glacier just above Birendra lake

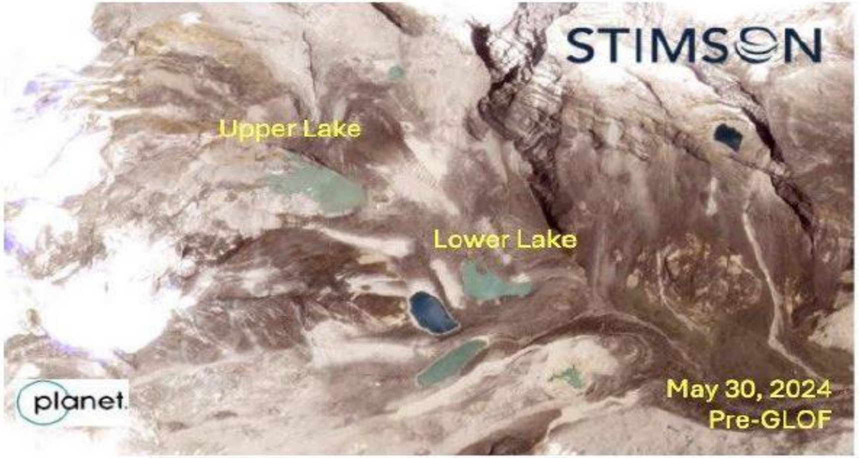
Thame GLOF, 16 August 2024

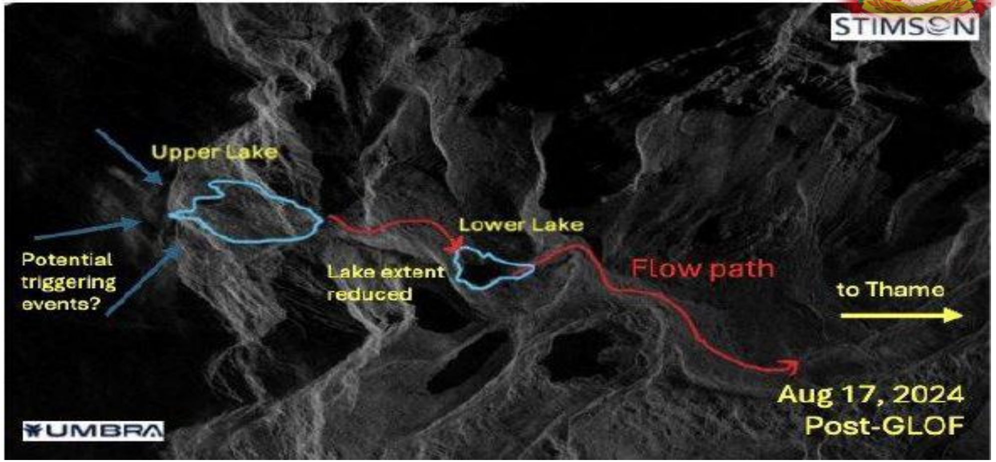


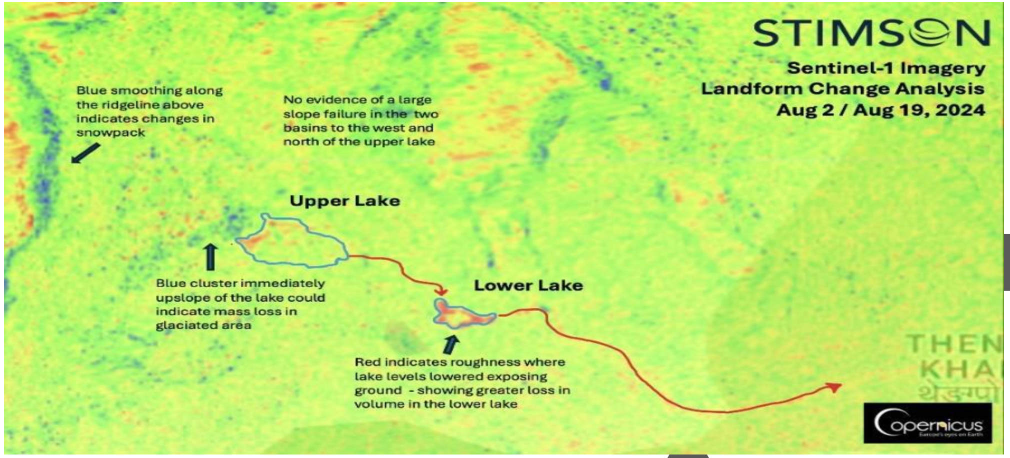

Thame Catchment Map
Lake 1
Lake 4
Lake 3
Lake 5
Lake 2
Dig Tsho
Lumding Tsho
Kongde Ri
LANGMUCHE
KHURE GOTH
TARNGGA
HUNGMO
THYANGMOCHE
THAME
Legend
Lake 2
Other Lakes
Thame Catchment
Google Earth
1 km

DHM 2024

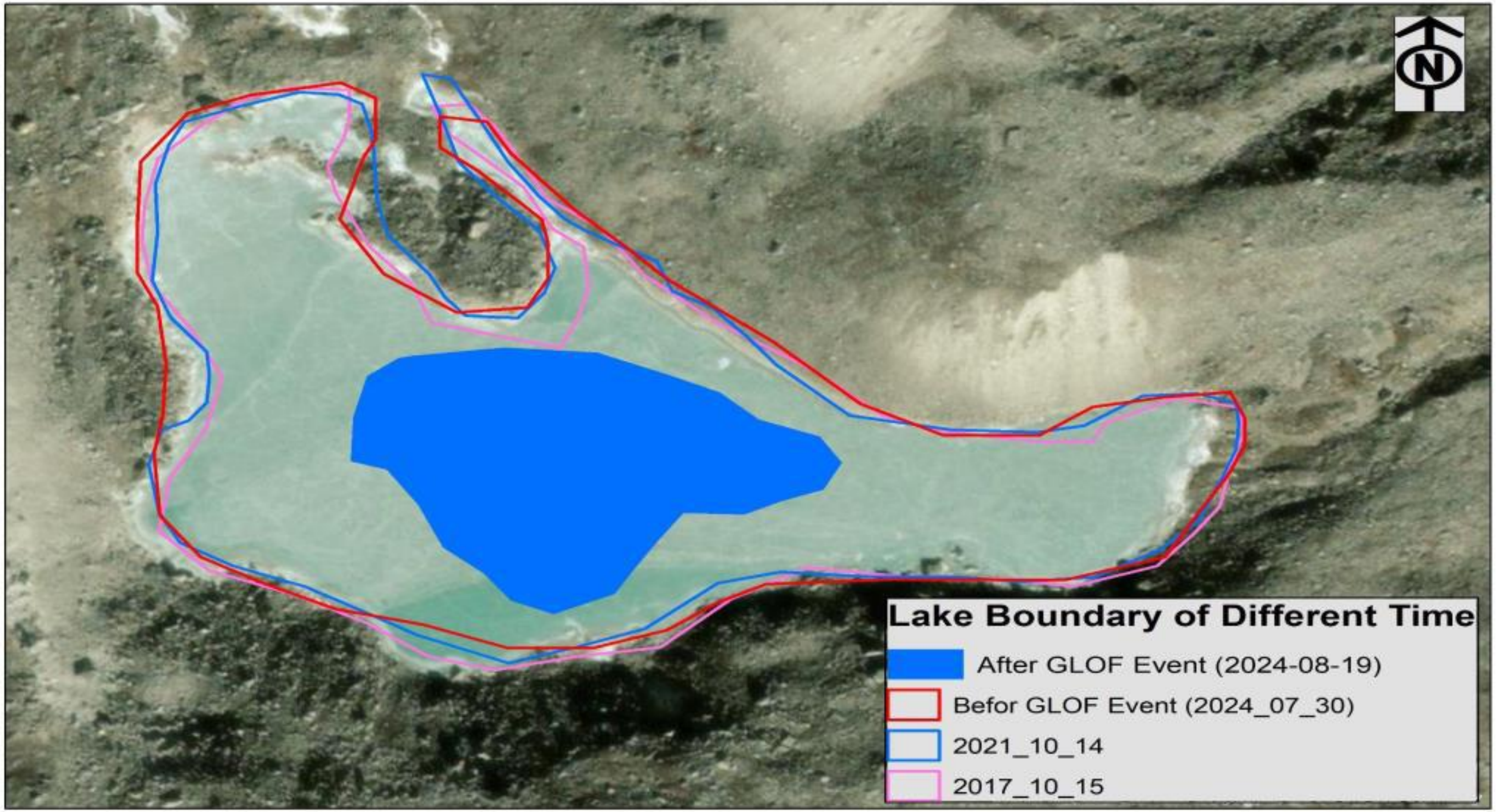
Stimson Centre

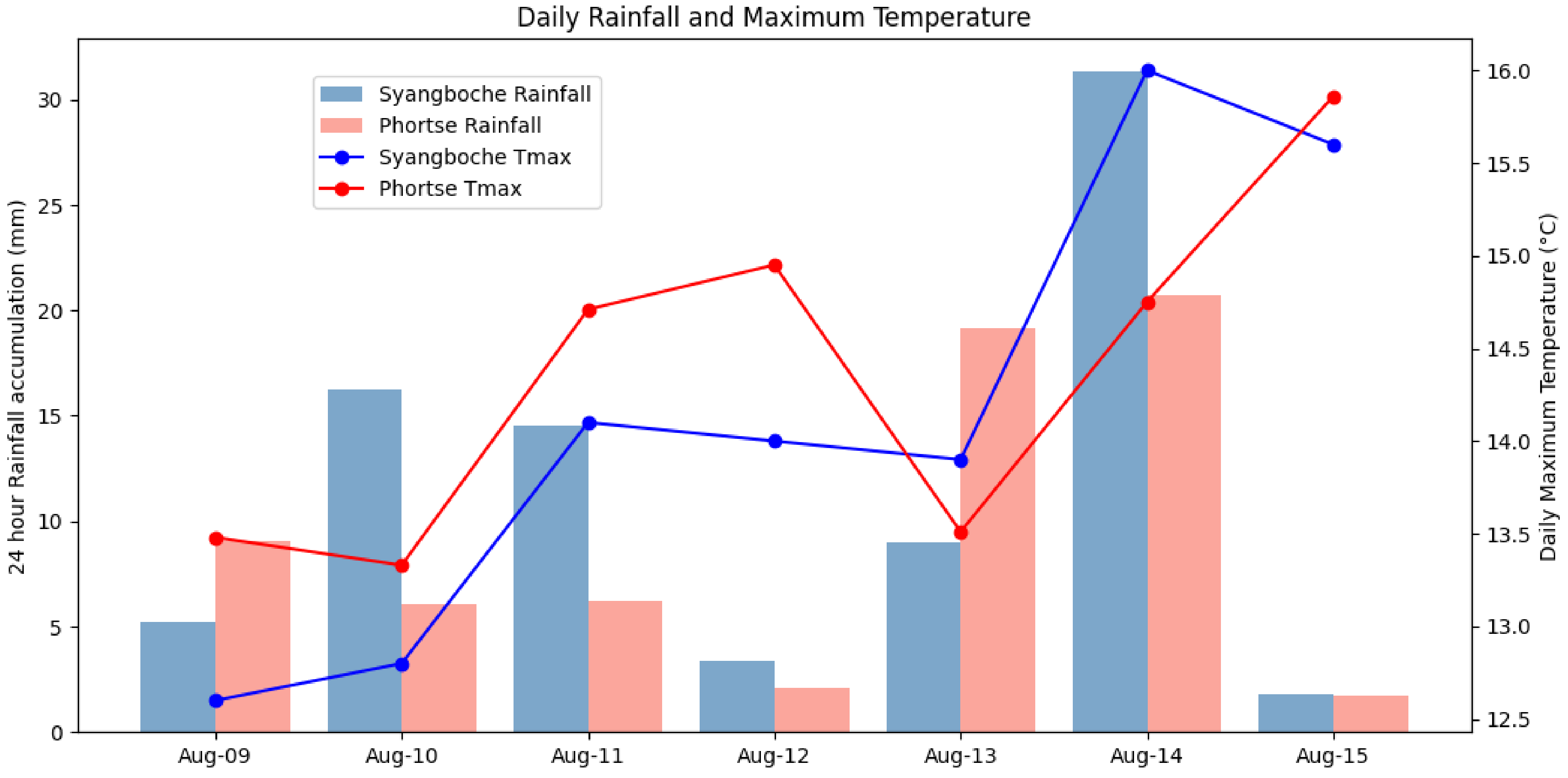




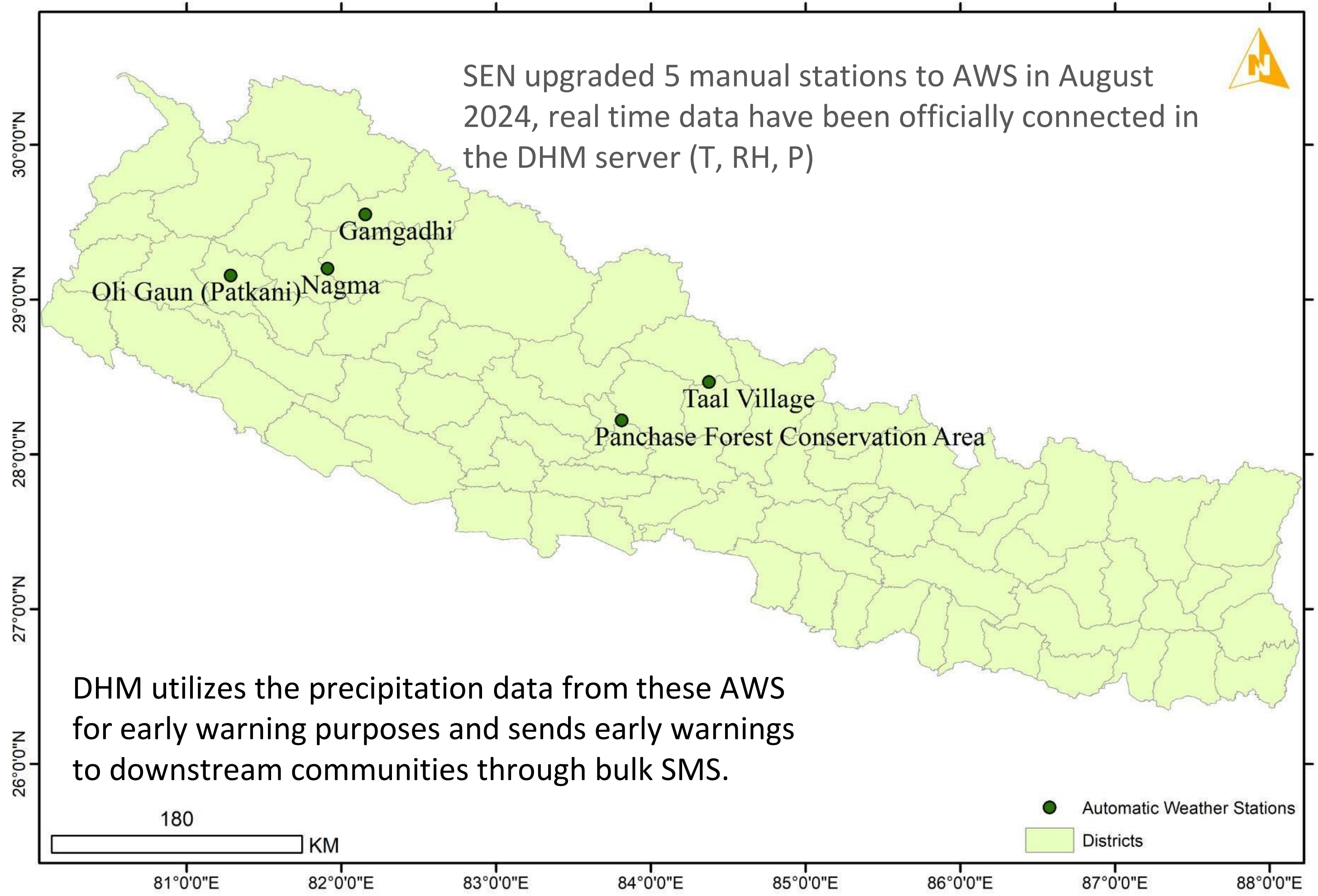


Evolution of Glacier Lake 2 over different time




Daily Rainfall and Maximum Temperature
Syangboche Rainfall
Phortse Rainfall
Syangboche Tmax
Phortse Tmax
24 hour Rainfall accumulation (mm)
Daily Maximum Temperature (°C)
0
5
10
15
20
25
30
12.5
13.0
13.5
14.0
14.5
15.0
15.5
16.0
Aug-09
Aug-10
Aug-11
Aug-12
Aug-13
Aug-14
Aug-15

SEN upgraded 5 manual stations to AWS in August 2024, real time data have been officially connected in the DHM server (T, RH, P)



DHM utilizes the precipitation data from these AWS for early warning purposes and sends early warnings to downstream communities through bulk SMS.

Conclusion

- Physically based models (e.g. CRHM) are useful for simulating future scenarios
- In recent years, South Asia and China have experienced frequent and intense droughts, floods, and landslides.
- There have also been instances where inadequate meteorological information for local communities has resulted in unfortunate loss and damages.
- Timely accurate forecast data are needed and more frequent monitoring and observations are to be expanded.
- Enhancing Climate Resilience in South Asia and China: Predicting Precipitation Shifts and Their Impacts for Disaster Risk Reduction and Resource Security

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