# Himalayan Cryosphere in a changing climate

**M. Ravichandran**

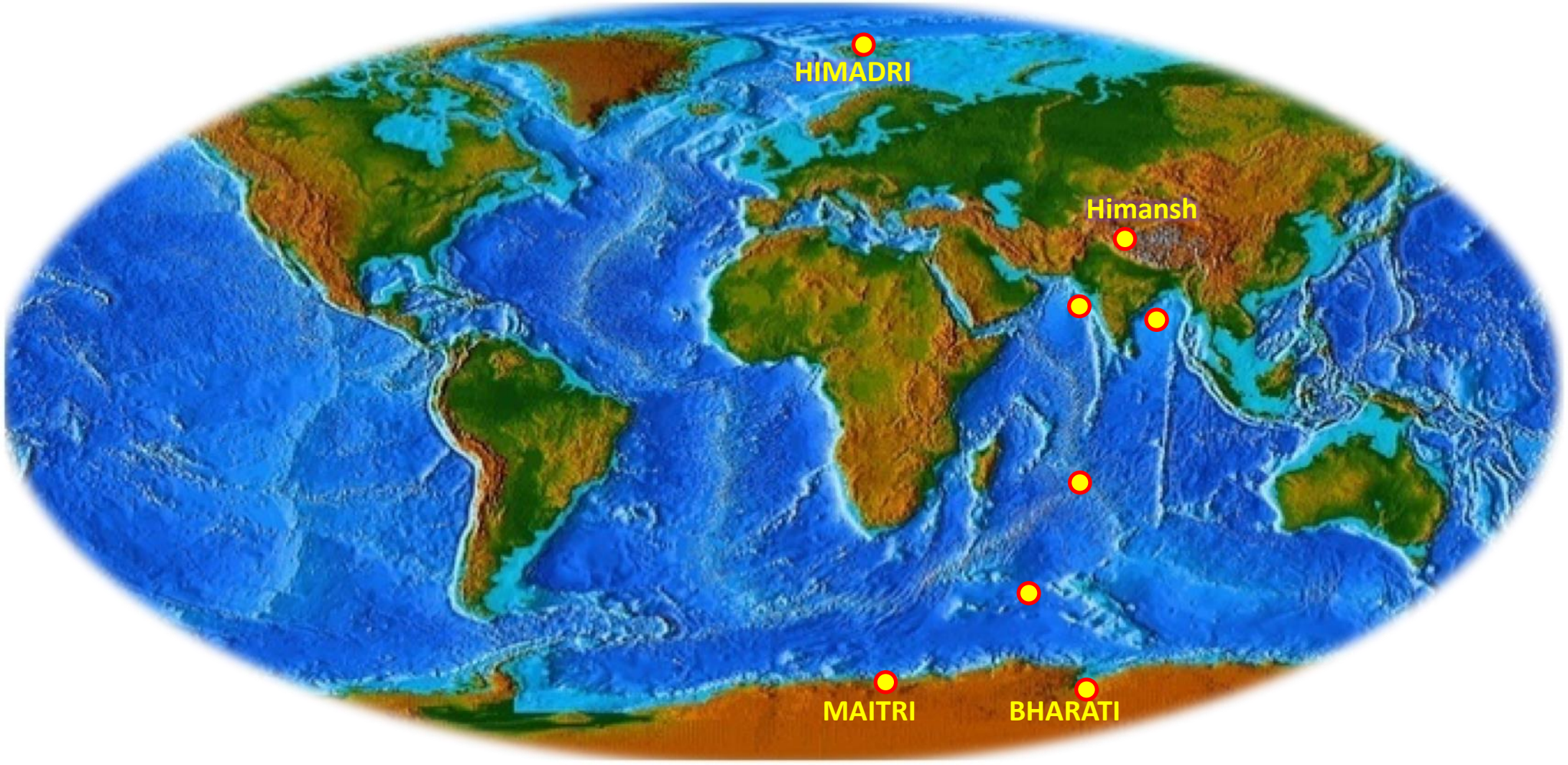
ESSO-National Centre for Polar and Ocean Research (ESSO-NCPOR)

Ministry of Earth Sciences

Goa, India

Inputs from Dr. Thamban and Dr. Vinay Kumar

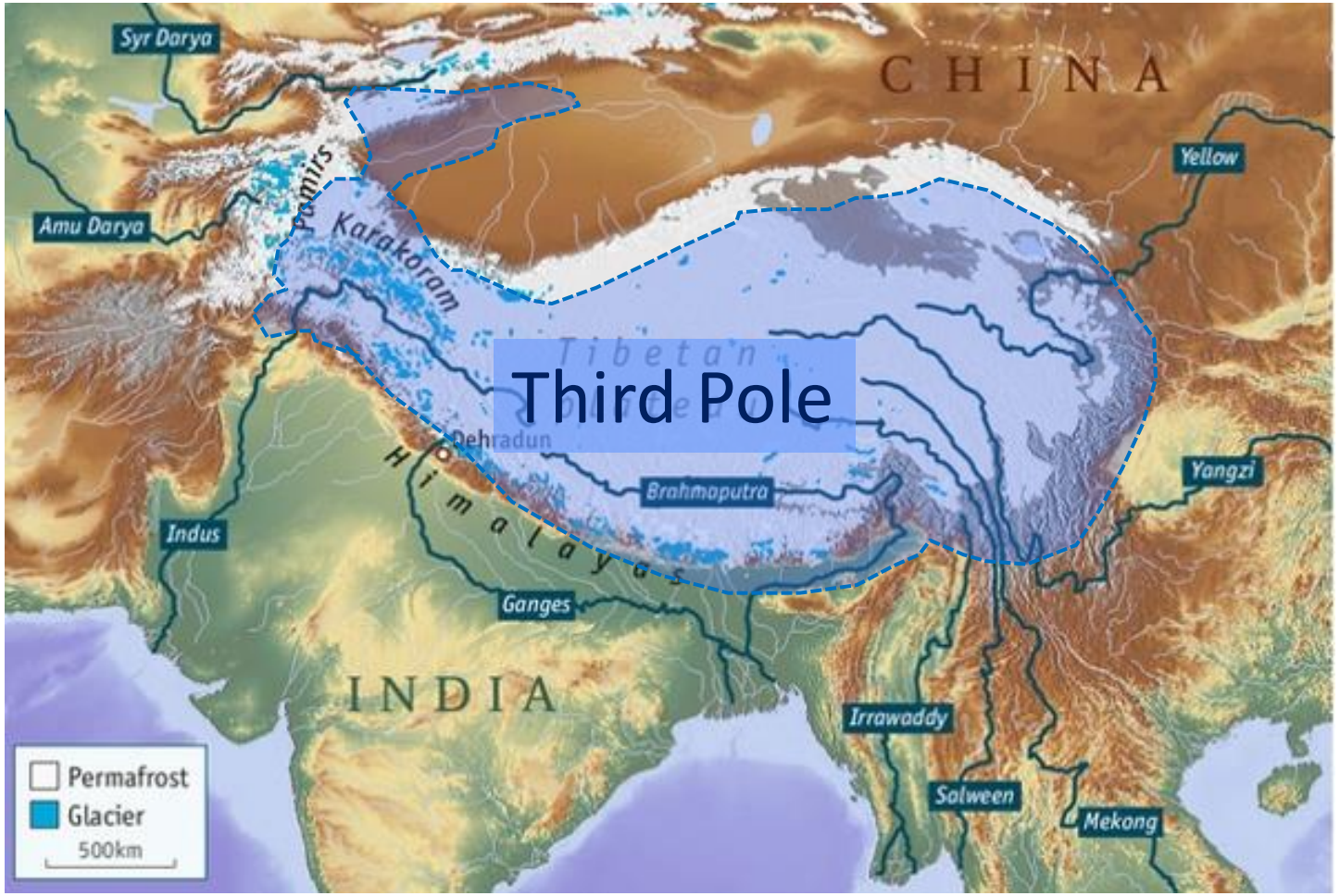
# POLAR
# NATIONAL CENTRE FOR ~~ANTARCTIC~~ AND OCEAN RESEARCH
## (NCPOR) – a trans-hemispheric research centre




**Three Poles: The Arctic, the Antarctic and the Himalaya**

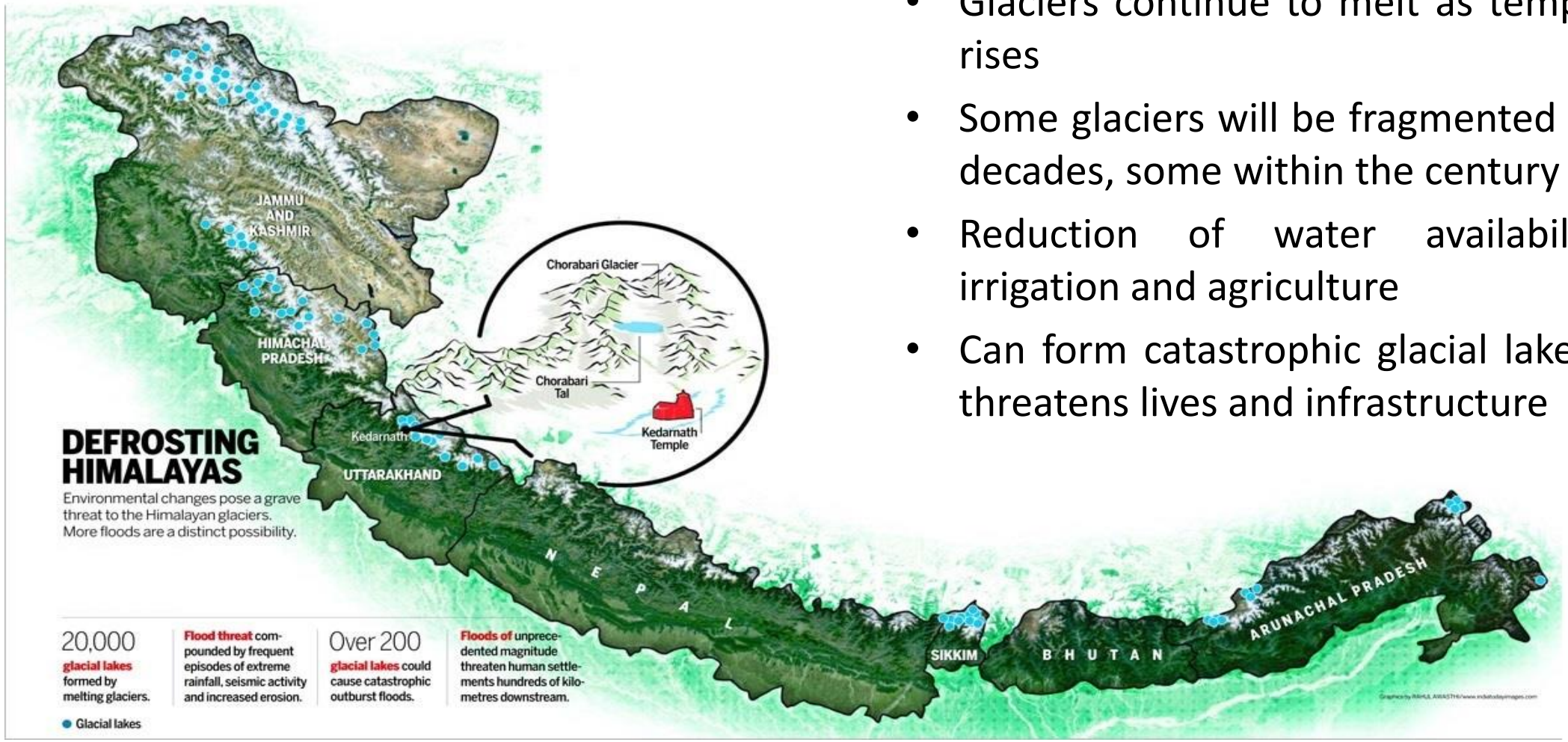
# THIRD POLE

- Melting Glaciers
- Extreme events and Disaster Risk
- Food and Water Security



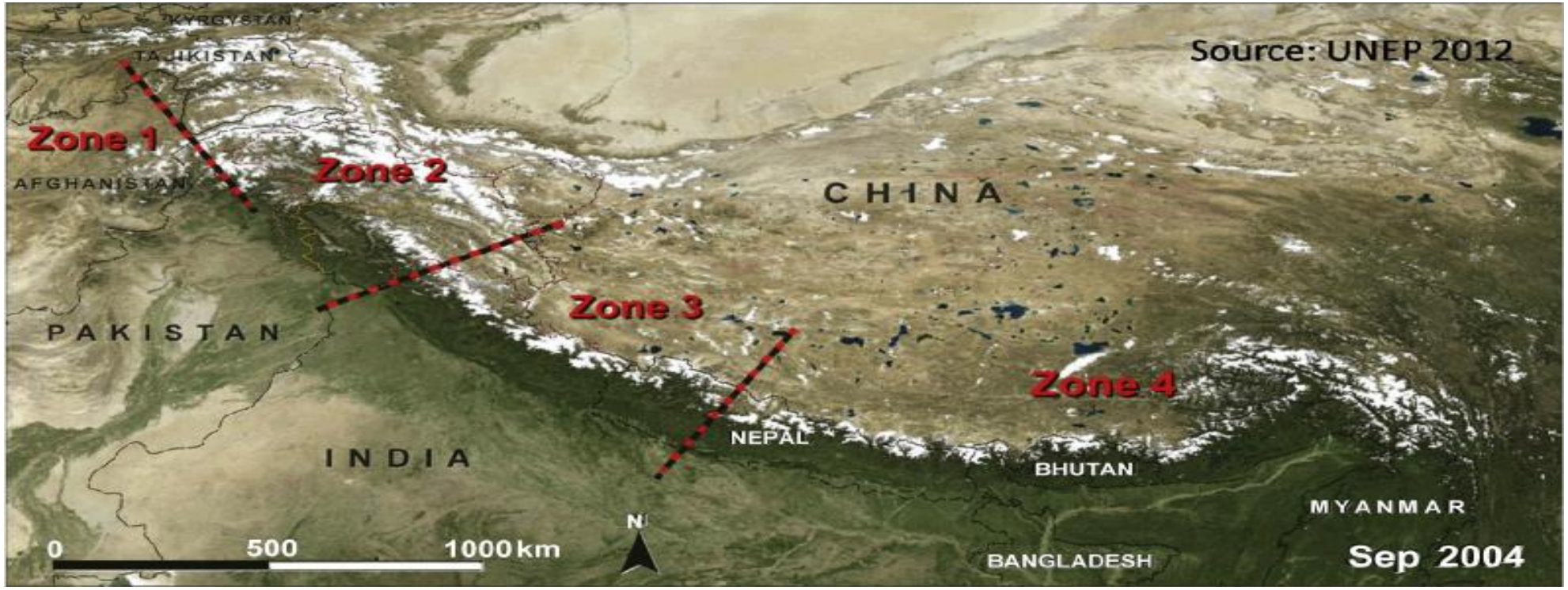

The unique geographic region centred around the Himalayas and Tibetan Plateau is known as the Third Pole, because its ice fields contain the largest reserve of fresh water outside the polar regions. This region is the source of the 10 major river systems that form the lifeline of over 1.3 billion people in Asia – nearly 20% of the world's population.

# Why is it important?




- Approximately 1.2 billion people are depend on snowmelt- or glacier-fed rivers for various socio-industrial activities
- Glaciers continue to melt as temperature rises
- Some glaciers will be fragmented in a few decades, some within the century
- Reduction of water availability for irrigation and agriculture
- Can form catastrophic glacial lakes which threatens lives and infrastructure

# Major characteristics of Himalayan Glaciers (Climate zones)




Kargel et al. , 2010

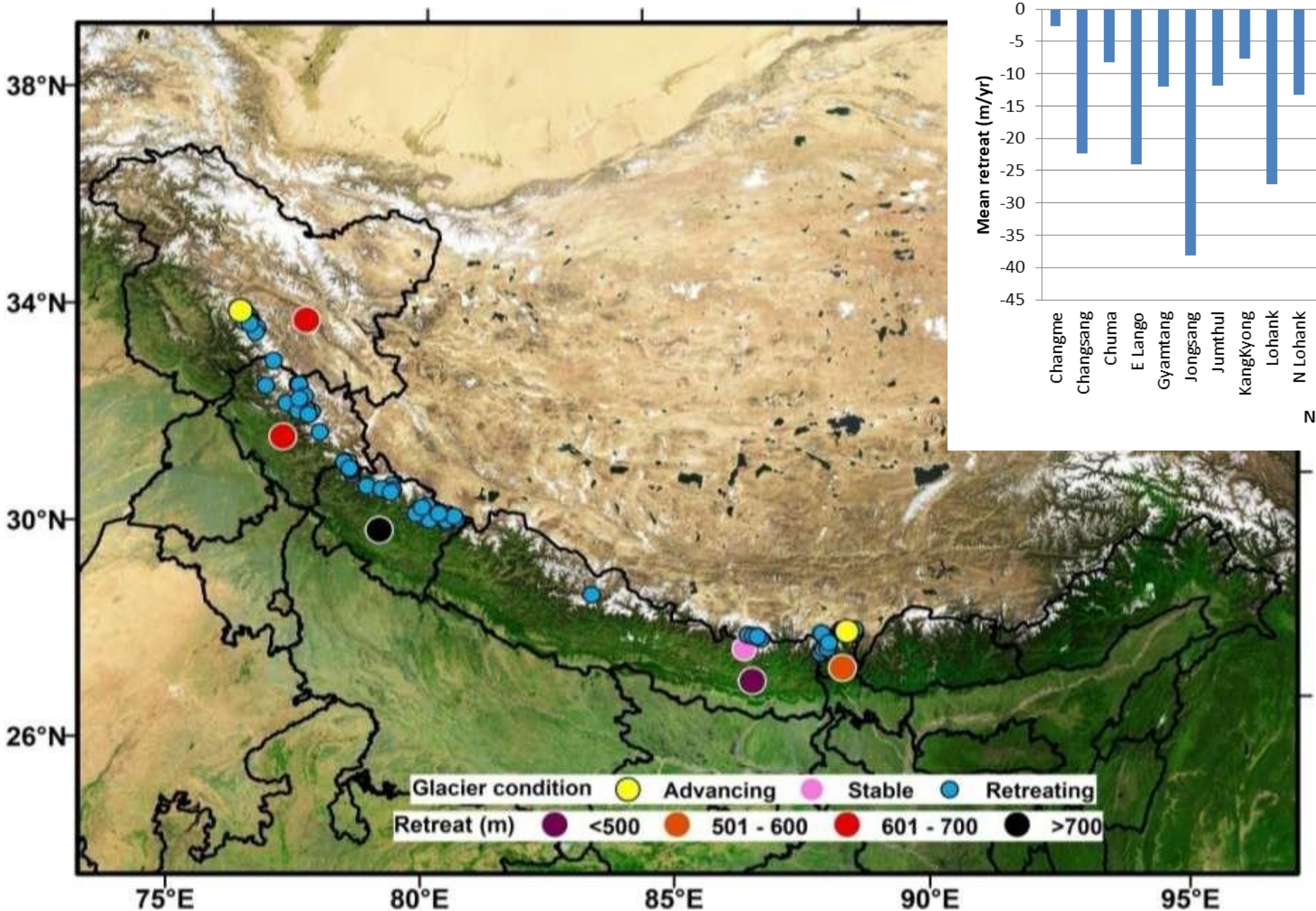
Zone 1- **westerlies dominated precipitation,** glaciers grow mainly by winter snow accumulation, Lakes growth, less glacier disintegration

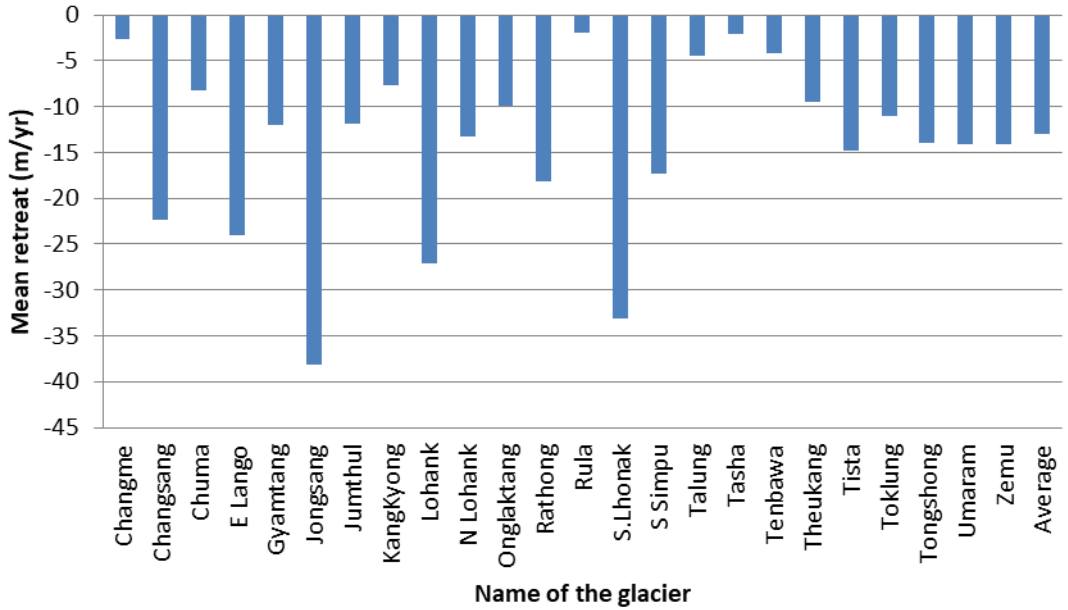
Zone 2- both **westerlies and summer monsoon**.

Zone 3-glaciers are **highly debris covered and retreat rate is high**.

Zone 4- **summer monsoon is dominated and glaciers are growing by summer snow accumulation** and are most unstable

# Retreat of Individual Himalayan glaciers

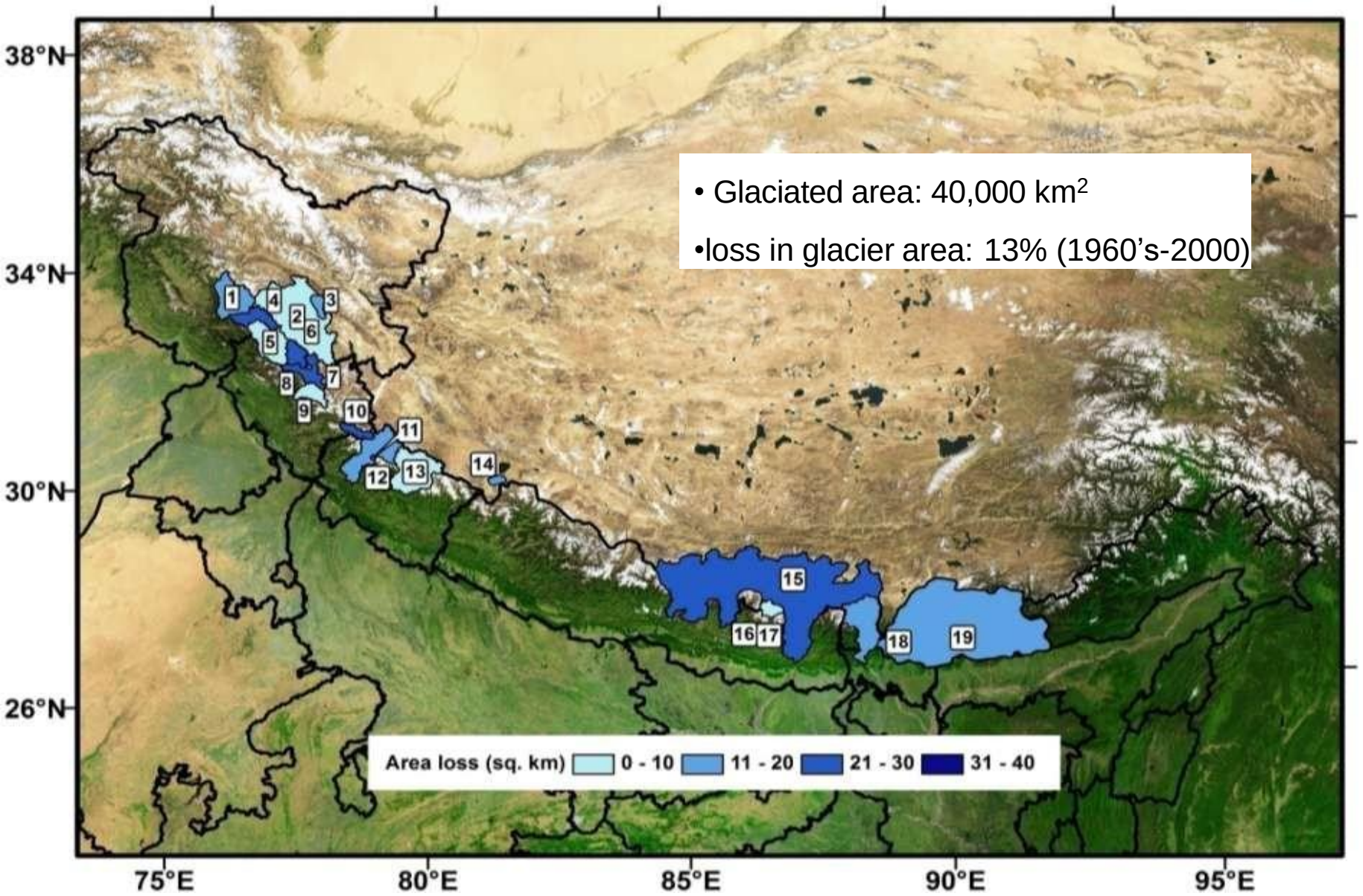



Glaciers in different regions of the Himalaya respond differently

**(Kulkarni and Karyakarte , 2014)**

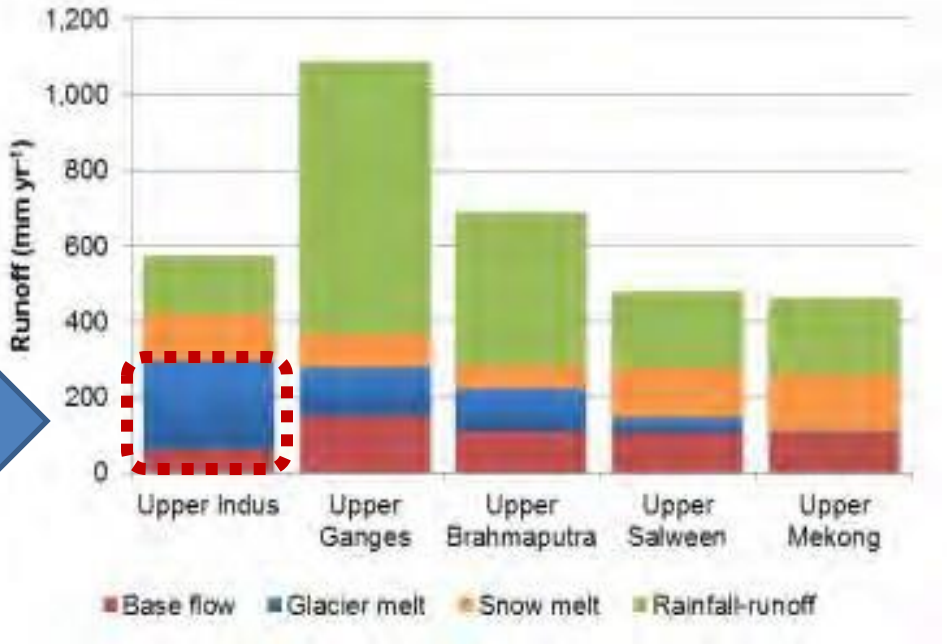
# Reported loss in glacier area

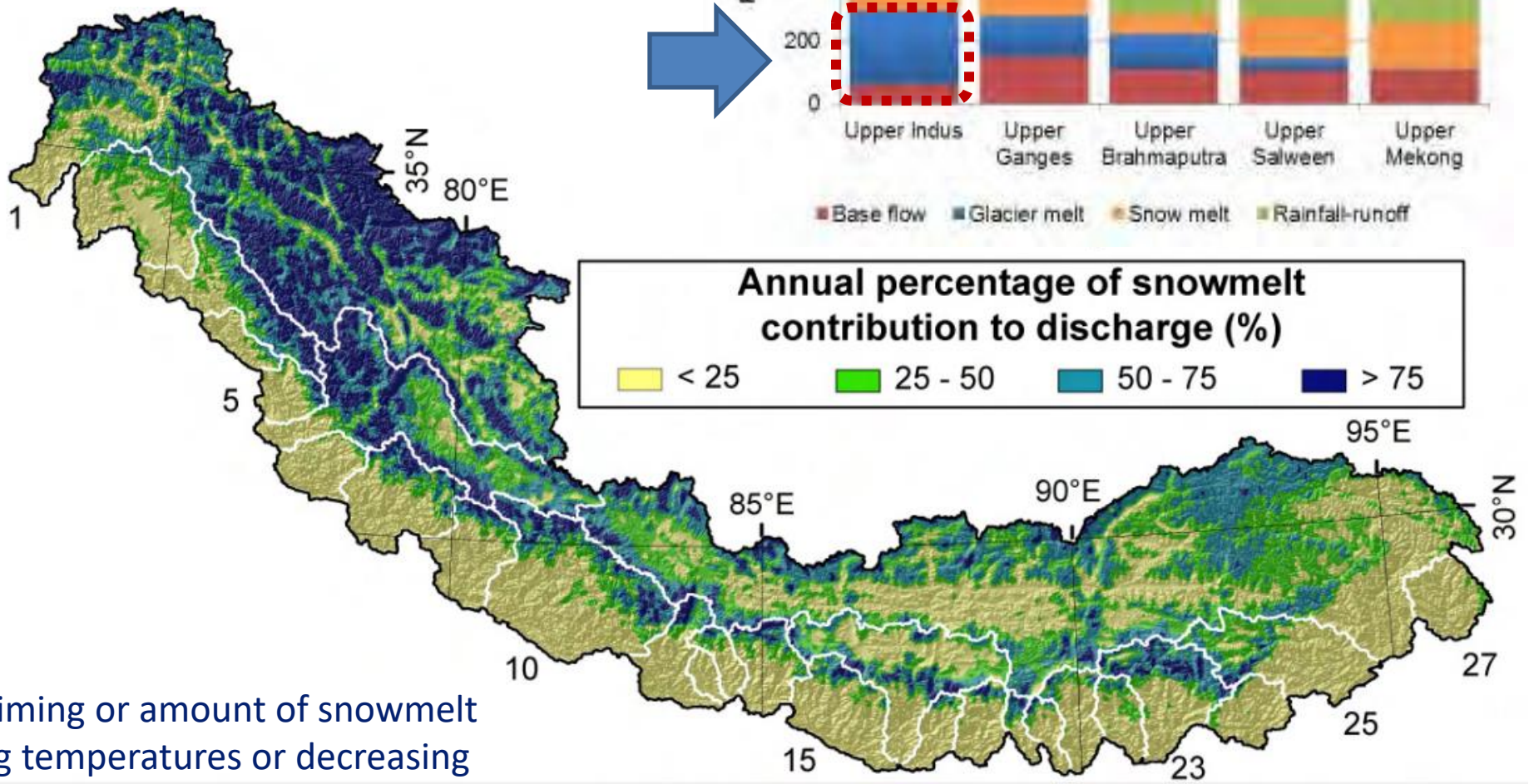



- Almost 4–30% overall loss in glacier area in the last 40 years (1960-2000), depending upon terrain and geomorphological parameters
- Mean loss in glacier mass in the Indian Himalaya has accelerated from –9 to -20 ± 4 Gt/year from the decade 1975–1985 to 2000–2010

(Kulkarni and Karyakarte,2014)

# Glacier melt's contribution to stream flow in present decade



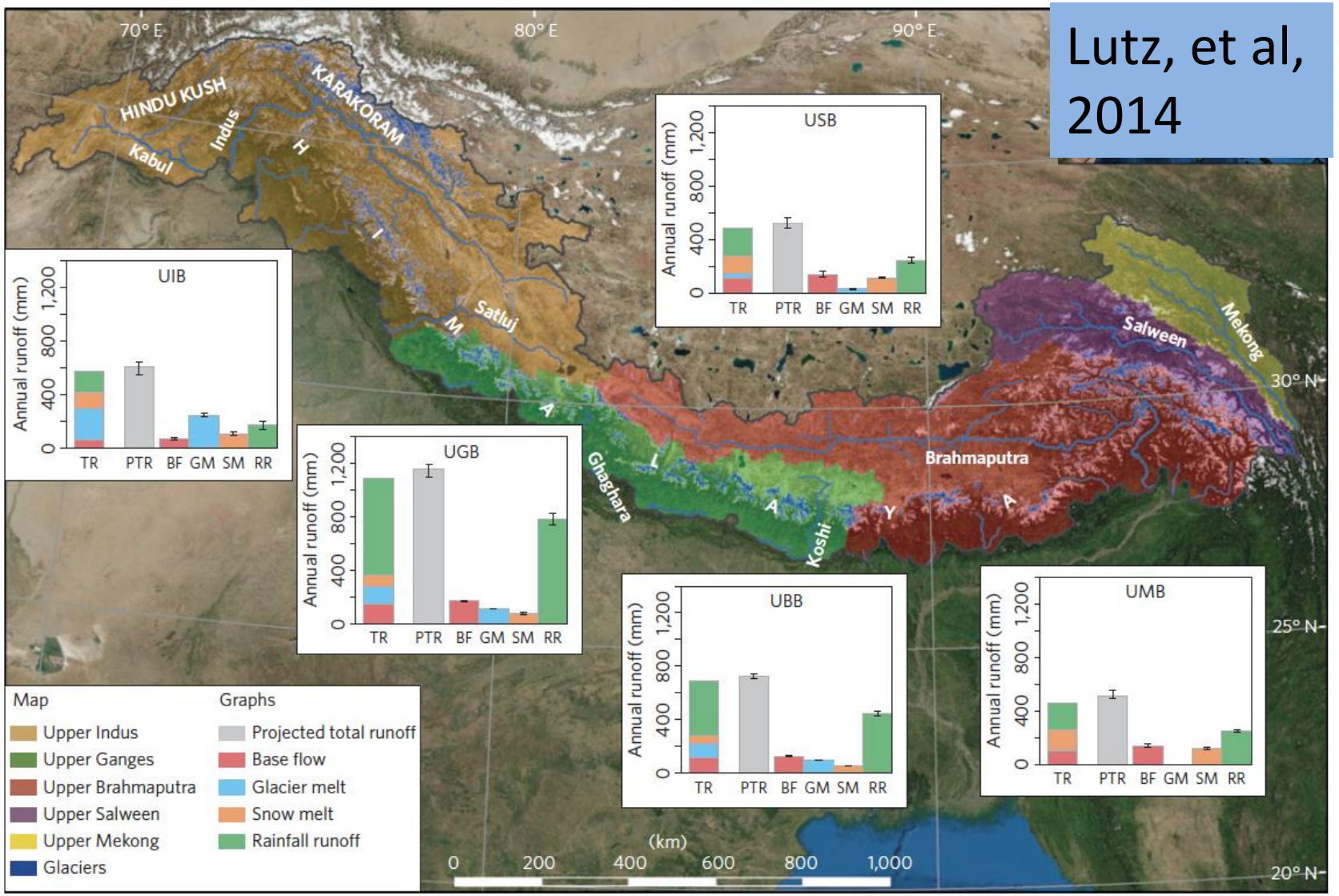

Changes in the timing or amount of snowmelt due to increasing temperatures or decreasing winter precipitation may have far-reaching societal consequences.

**Lutz, et al, 2014,**

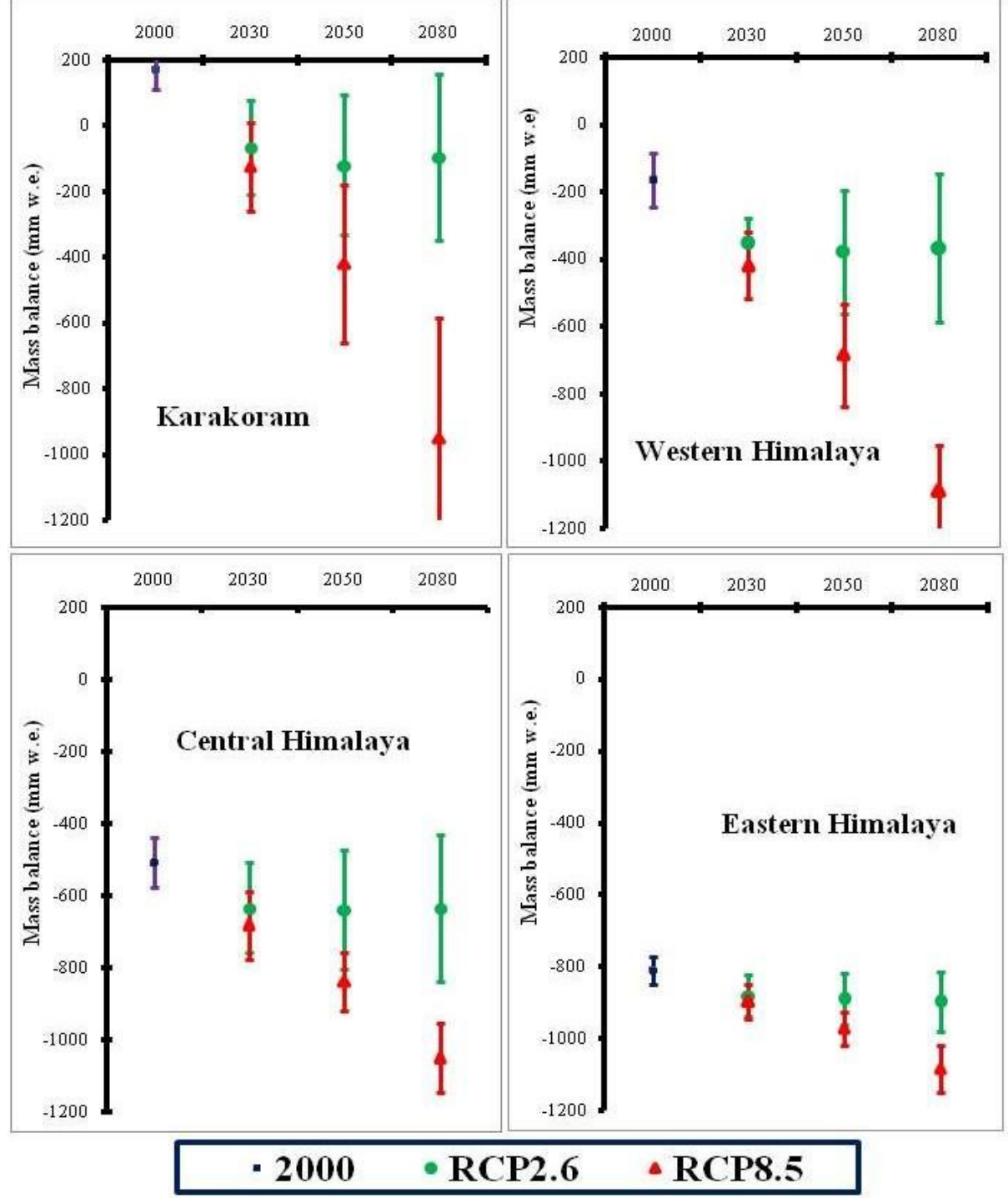
# Upstream basins of Indus, Ganges, Brahmaputra, Salween and Mekong

- TR: Average runoff (1997-2007)
- PTR: Mean Projected runoff (2014-2050 – RCP 4.5)
- BF: Baseflow
- GM: Glacier melt
- SM: Snow melt
- RR: Rainfall runoff

- Model is forced with an ensemble of 4 GCMs



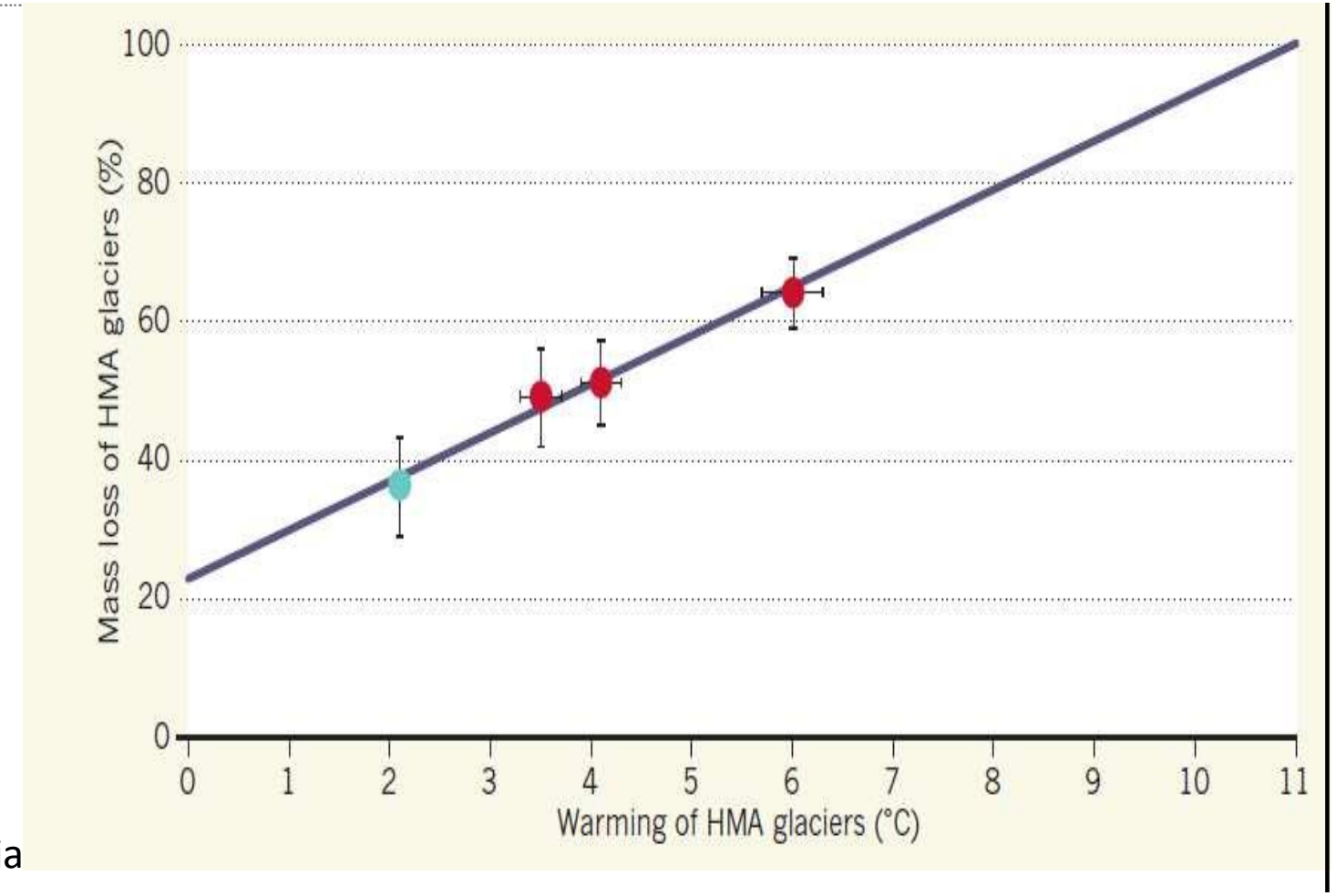
# Modelled changes in mass loss conditions in HKH region under various scenarios




(Chaturvedi et al, 2014)

# Projected Warming and HKH Glacier mass loss

| | | |
|---|---|---|
| $T_{2005}$ | → | 14% |
| 1.5 °C | → | 36±7% |
| RCP4.5 | → | 49±7% |
| RCP6.0 | → | 51±6% |
| RCP8.5 | → | 64±5% |




HMA-High mountains of Asia

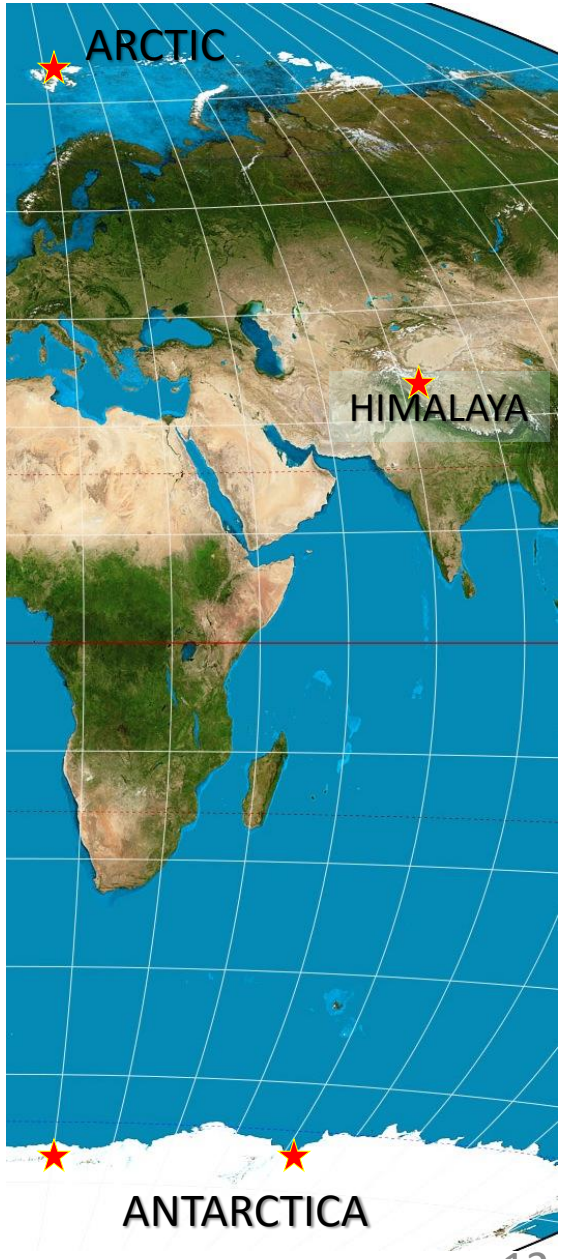
Kraaijenbrink et al, 2017

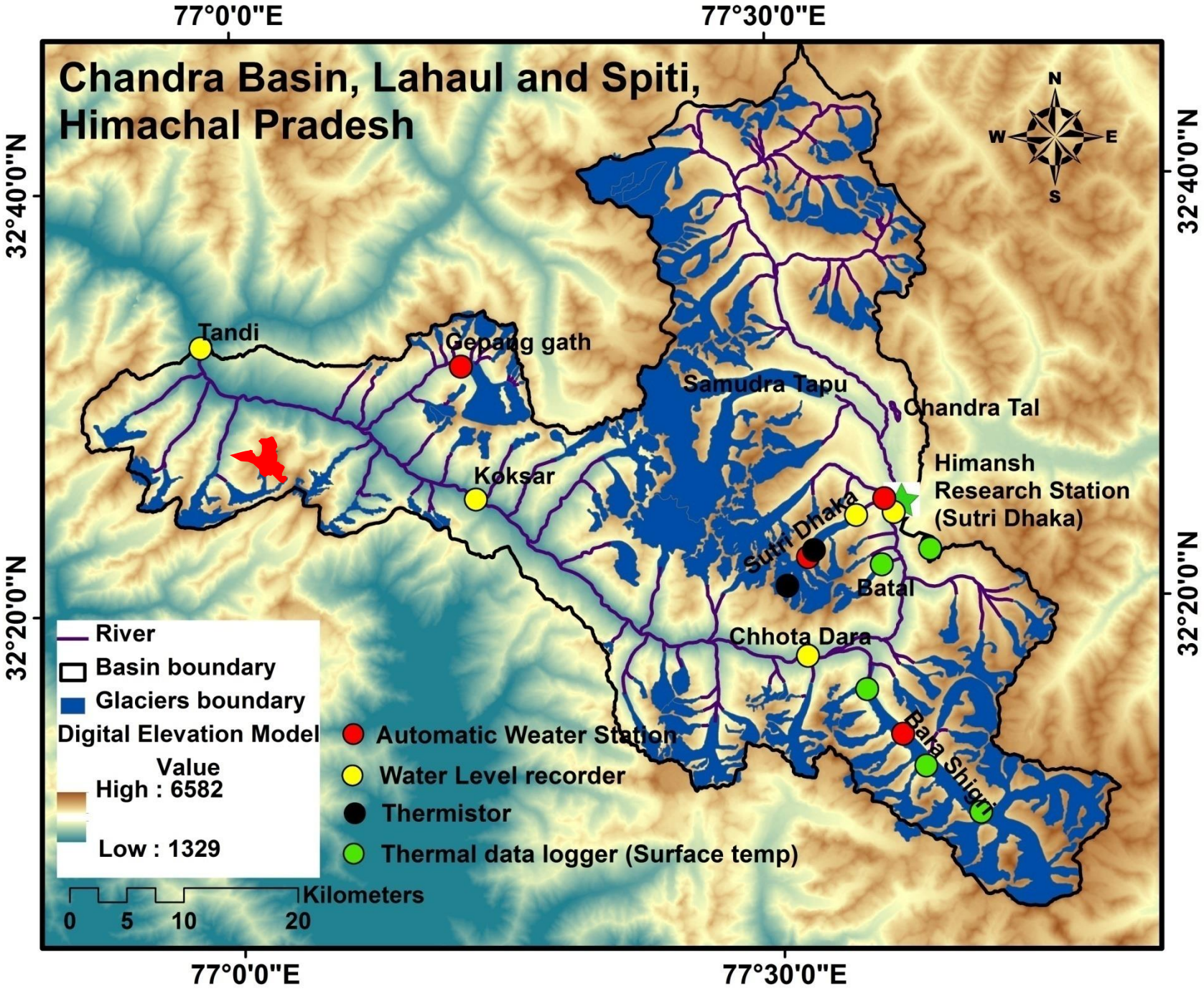
# CRYOSPHERE & CLIMATE

## - ESSO / MoES Project

**Objectives:**

1. To study the Antarctic climate variability and its global linkages during the past 2000 years using ice core records.
2. To study the biogeochemical cycling within the supraglacial ecosystems like snow, ice, etc.;
3. To study the glaciological processes, dynamics, and evolution of Antarctic ice shelves and ice rises;
4. To study the glacier processes and mass balance in selected glaciers of Svalbard, Arctic;
5. **To study the dynamics and the rate of change of selected Himalayan glaciers to understand its impact on hydrology.**




Chandra Basin, Lahaul and Spiti,
Himachal Pradesh
77°0'0"E
77°30'0"E
32°40'0"N
32°20'0"N
N
W
E
S
Tandi
Gepang gath
Samudra Tapu
Chandra Tal
Koksar
Himansh
Research Station
(Sutri Dhaka)
Sutri Dhaka
Batal
Chhota Dara
Bara Shigri
River
Basin boundary
Glaciers boundary
Digital Elevation Model
Value
High : 6582
Low : 1329
Automatic Weater Station
Water Level recorder
Thermistor
Thermal data logger (Surface temp)
Kilometers
0 5 10 20

# HIMANSH – Field Station @ 4000 m, Lahaul-Spiti


# Ongoing Major Activities

- **Long term monitoring** programme for glaciological observations and modelling in Western Himalaya for better understanding of glacier dynamics and their link with hydrology and climate:
    - *Mass balance (SMB, Ice Flux, Glacier Flow)*
    - *Energy/Heat Balance (Energy Budget, Degree Day Model)*
    - *Hydrological Balance (discharge measurements and modelling)*
- **Mass balance studies** – *field glaciological, geodetic, geospatial data based*

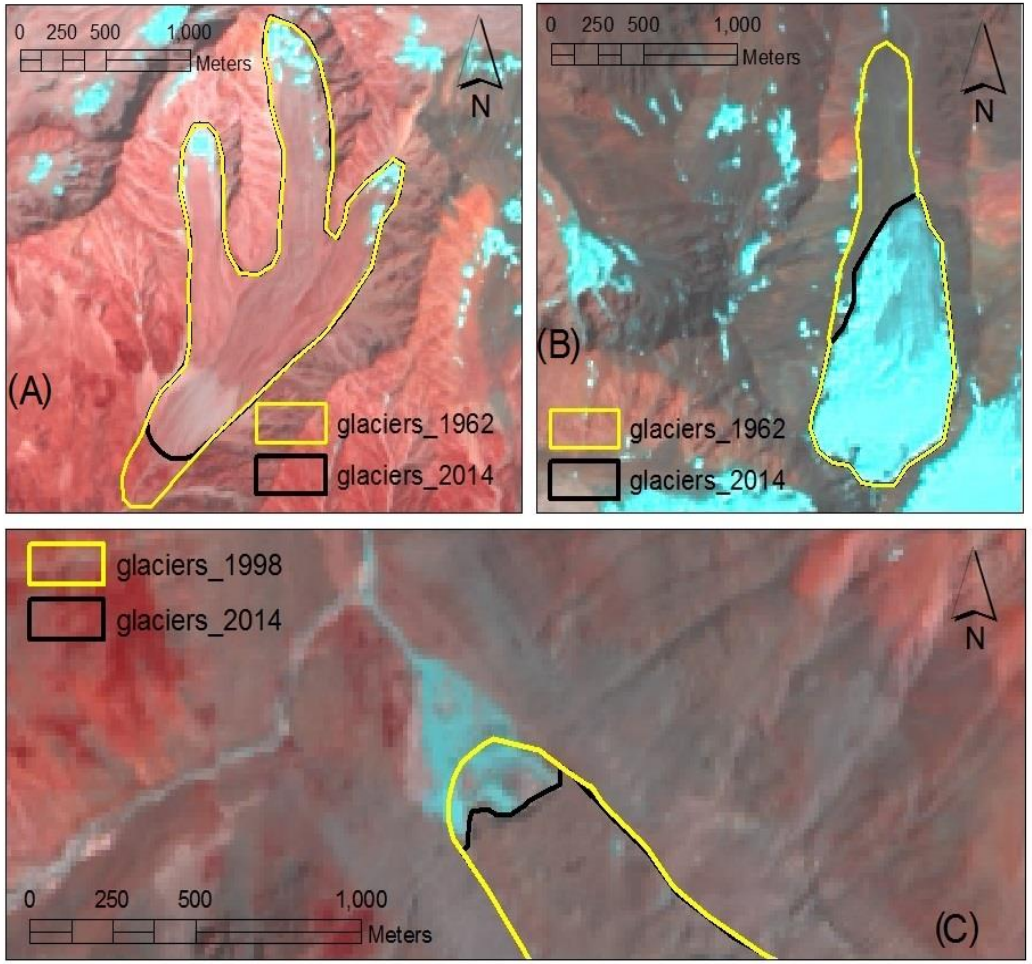
  Regular monitoring of an extensive stake network for annual, spring and summer mass balance are carried out for all six glaciers (Sutri Dhaka, Batal, Samudra Tapu, Bara Shigri , Gepang Gath and Kunzam); Ice thickness measurements by GPR
- **Energy balance studies** – *a network of AWS systems*

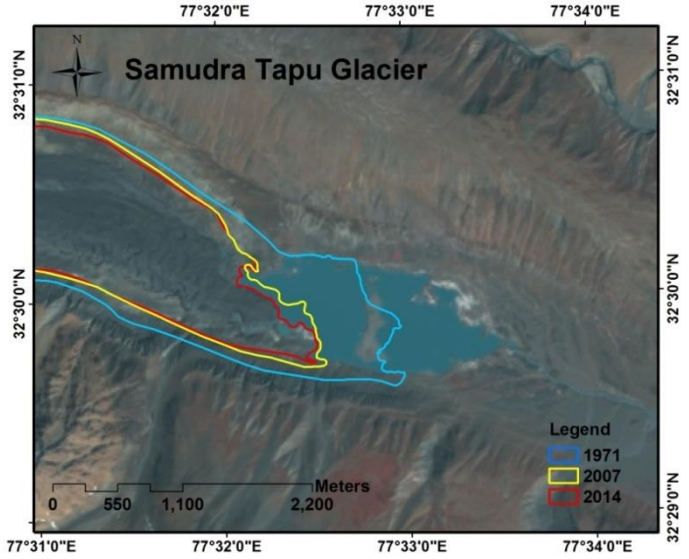
  Surface energy fluxes near the glacier areas measured using 4 AWS systems installed at Sutri Dhaka (ELA), Bara Sigri (4300m), Gepang Gath (4400 m) and the Himansh station
- **Hydrological balance studies** – *a network of water level recorders in Chandra R.*

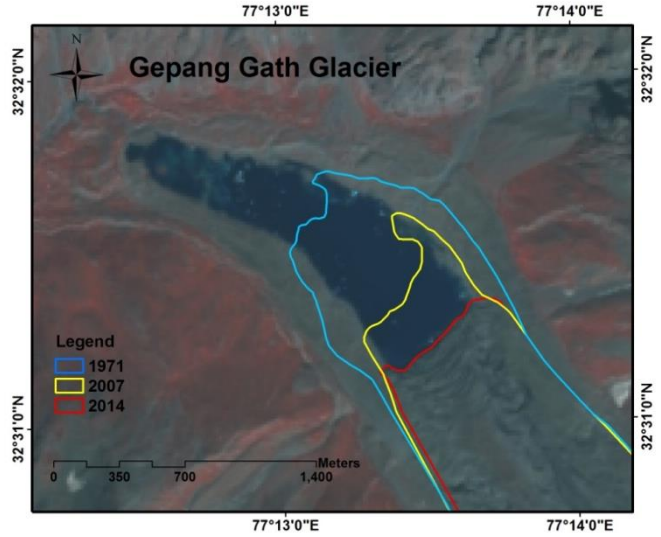
  Five recorders (Waterlog Radar series) at Sutri Dhaka, Chatru, Chota Dhara, Sissu, Tandi)



# Glacier retreat observed by satellite monitoring between 1960's and 2014 in Western Himalaya – retreat of glaciers and expansion of proglacial lakes

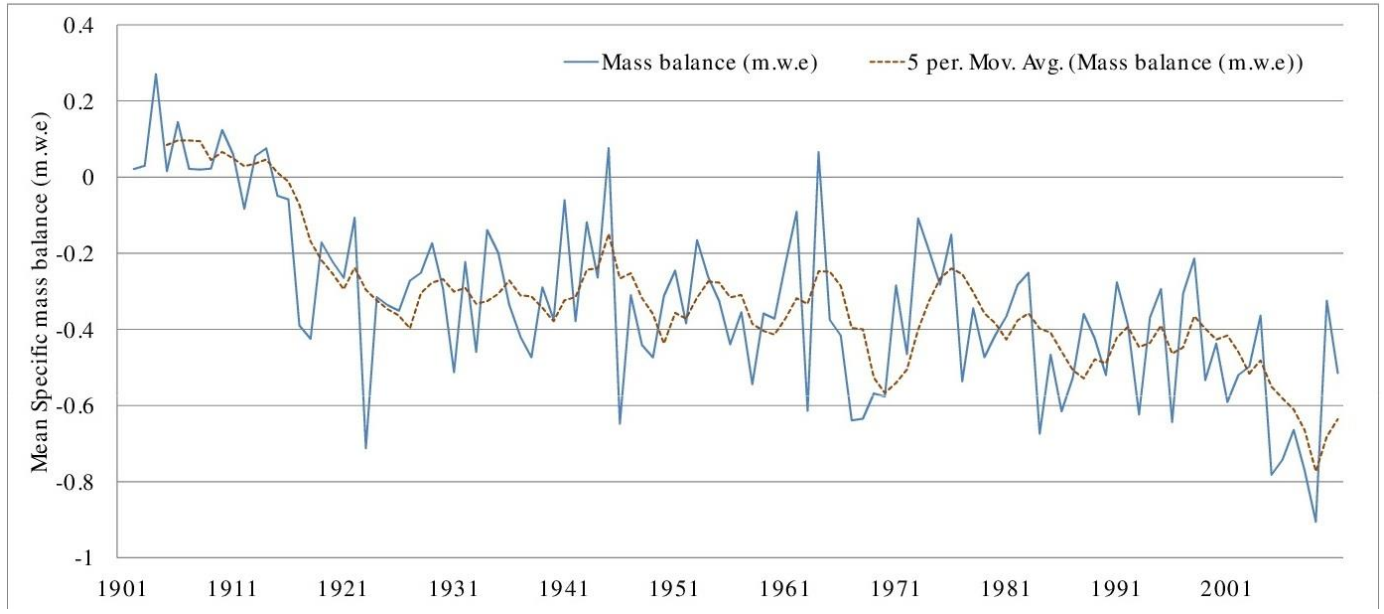


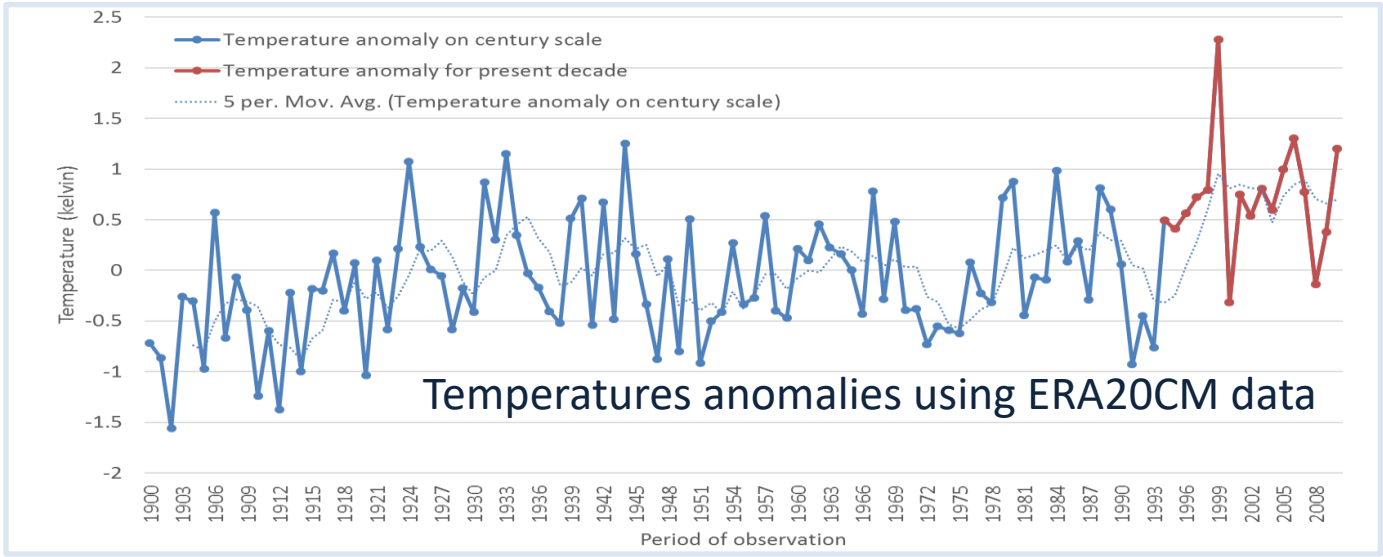




Gaddam et al., 2016; Patel et al., 2017

# Mean Mass Balance of glaciers in Baspa basin (1900 – 2010)



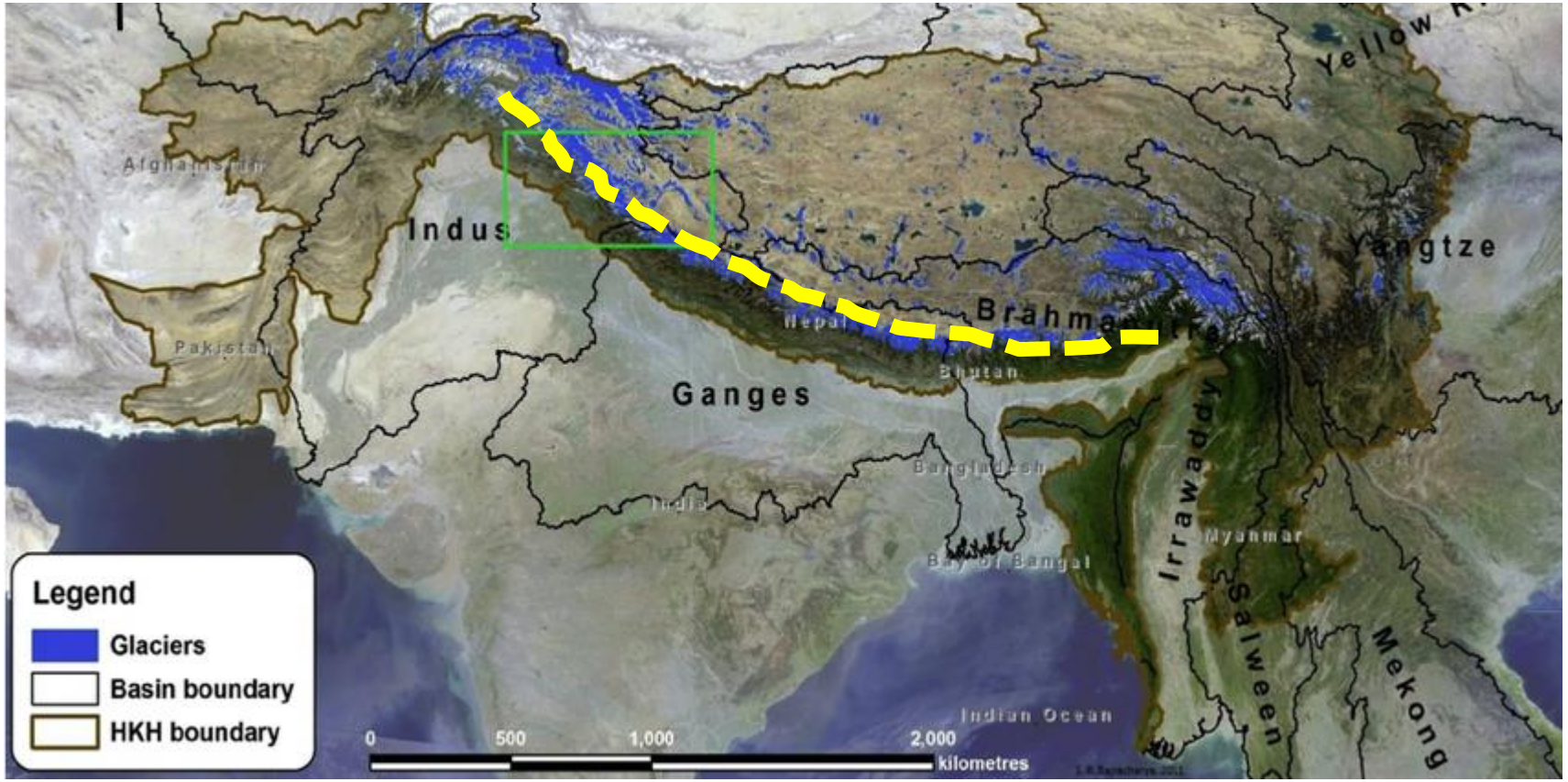




(Gaddam et al. 2017a)

# **HiCOM** Project

## (**Hi**malayan **C**ryospheric **O**bservations and **M**odeling)

**NCAOR coordinated, multi-organizational project for study of benchmark Himalayan glaciers to understand the impact on glaciers and hydrology**



# HiCom: Objective

**Major Questions to be addressed**

- Why there are differential glacier responses across Himalaya and what are the driving forces?
- What are the dynamics and control of snow cover changes in Himalaya?
- What is the response of Himalayan cryosphere to climate change/variability and associated hydrological impacts?

**Work Plan [NCAOR, IISER(Pune, Kolkata), IIT (Bombay, Roorke), University (JNU, Himachal, J&K, Jharkhand….]**

- Integrated mass balance studies on benchmark glaciers from sub-basins of Western, Central and Eastern Himalaya using glaciological, geodetic, geospatial and modelling approaches;
- Glacio-hydrological budgeting and modelling of selected basins
- Snow cover and volume estimation in major basins of Himalaya

# Challenges and Way forward

- Himalayan region is consistently warming more than Global average
- Glaciers and permanent snows are melting rapidly in the recent years
- Shrinkage and melting of glaciers /Formation and expansion of glacial lakes
- Increased Risks and Hazard: Glacial lake outburst flood (GLOF) is a serious problem.

- Enhanced Monitoring network (in-situ and Remote sensing-satellites/Drown)
- Strengthening Modeling efforts to understand and forecast
- Knowledge and understand  the possible impacts of cryosphere changes
- Need effective adaptive and mitigation strategy to prevent risks and uncertainties
- Strengthening Capacity building
- Regional collaboration and Data & Information exchange

Thank You for your attention