Climate change study in the Himalayas

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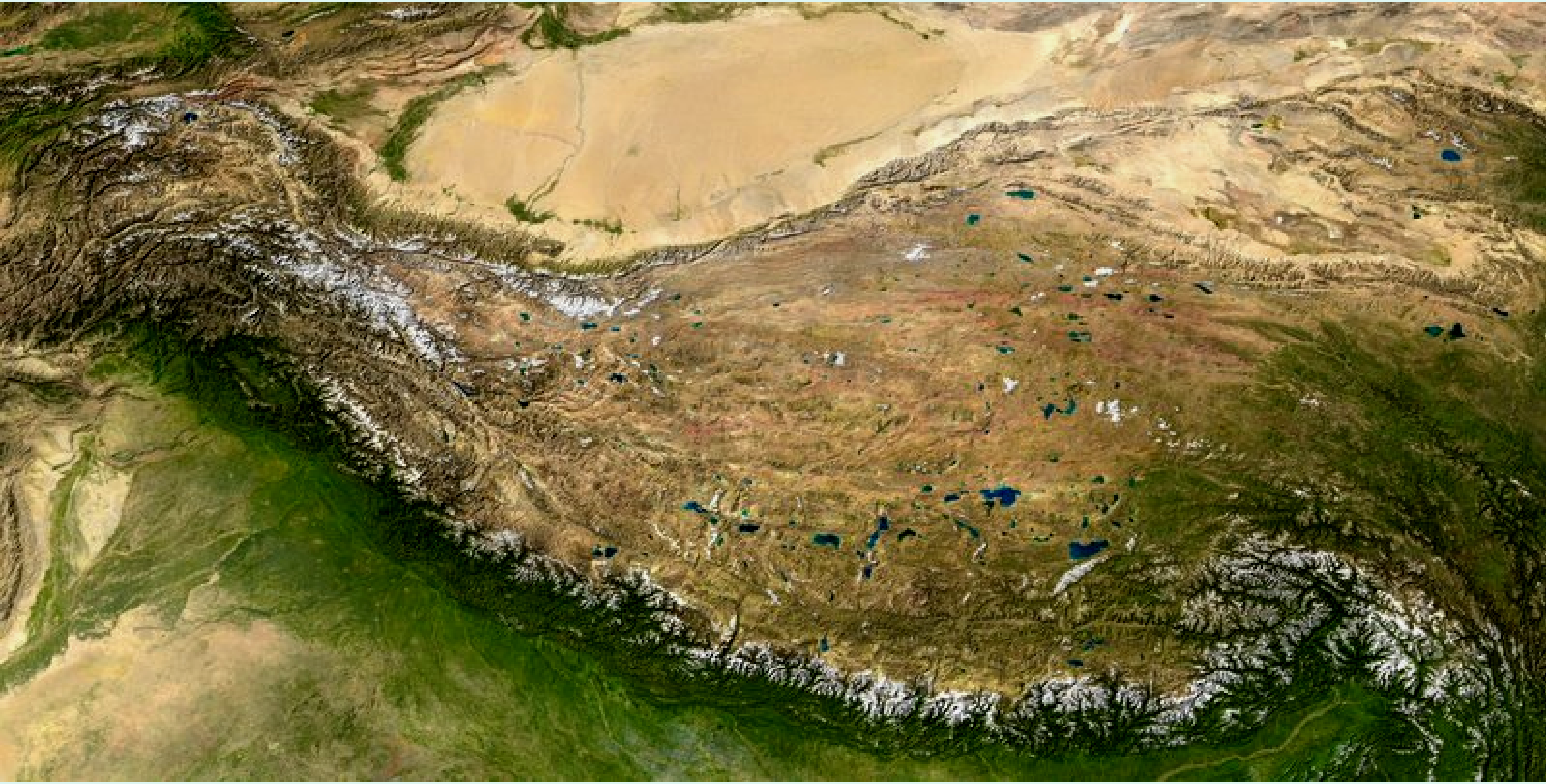
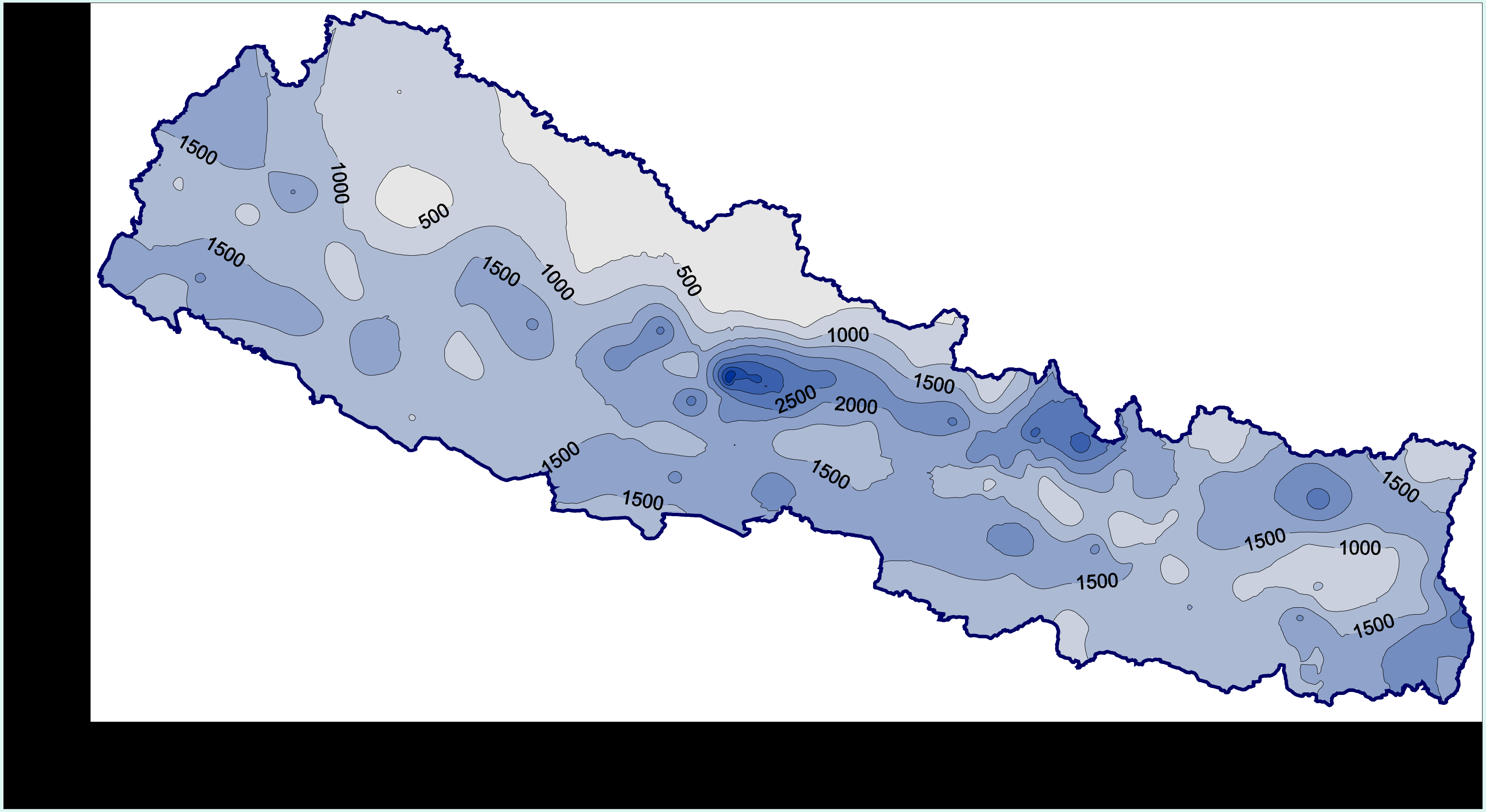


Spatial Distribution of Mean Monsoon Precipitation (mm)



The Himalaya

- Abode of Snow
- Youngest and largest mountain range
- All the mountains over 8,000 m are in and around it including Mt. Everest, the highest in the world
- Over 100 peaks with heights over 7,000 m
- Highly fragile with steep gradients
- Highly vulnerable to climate change and globalization
- Plays key role in SA Monsoon, regional and global climate system

The Himalayan Mountain Range

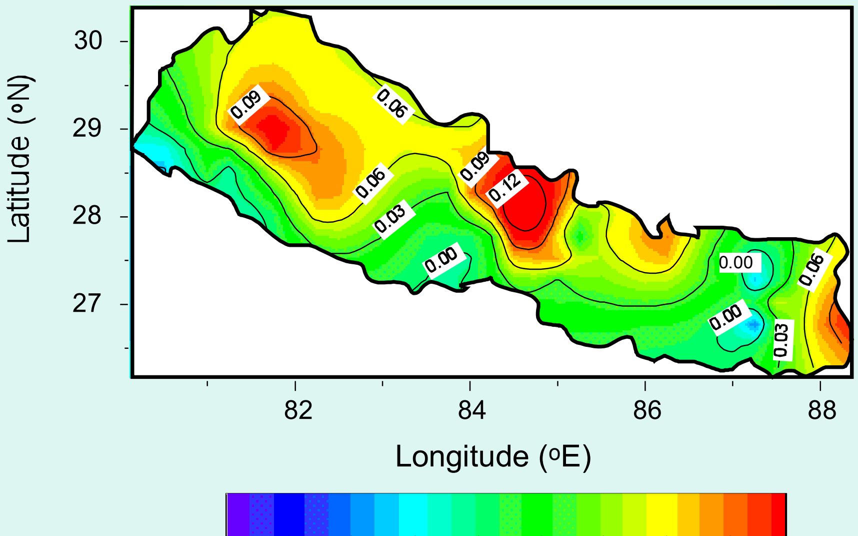
- Extends east - west to over 2,400 km from 35^{o}N, 74^{o}E to 27^{o}N, 95^{o}E
- Home for over 100 million people with unique cultural diversity
- Very rich in eco-diversity and biodiversity and also the storehouse of unique gene pool
- Water tower to over 500 million people in the down stream regions

Climate Change and its Impact

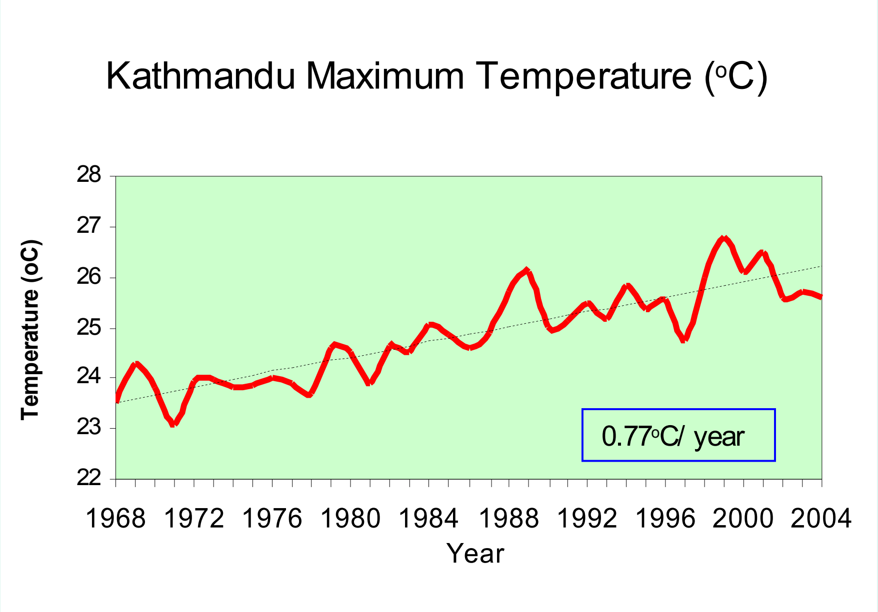
Impacts of Climate Change

- Cryosphere
- Hydrology and Water Availability
- Ecosystems and Biodiversity
- Geomorphology and Hazards
- Land Use and Socio-economy
  - Agriculture
  - Hydropower
  - Tourism
  - Air pollution
  - Human Health

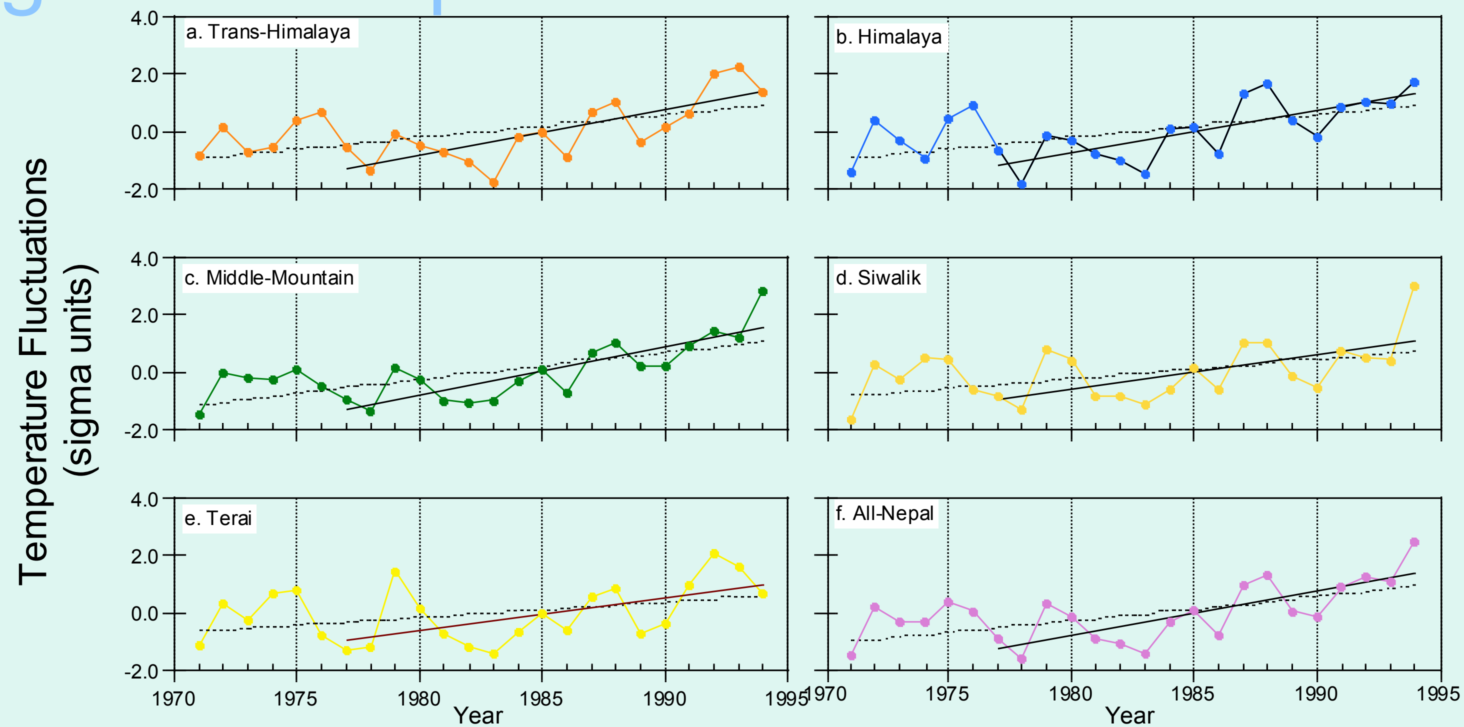
Spatial Distribution of maximum temperature trends in Nepal for the period 1977 to 1994.



Color Coding of temperature trends (^oC year^{-1})

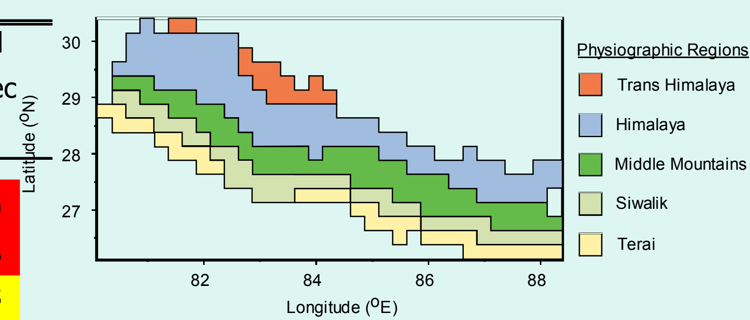


Regional Temperature Trends



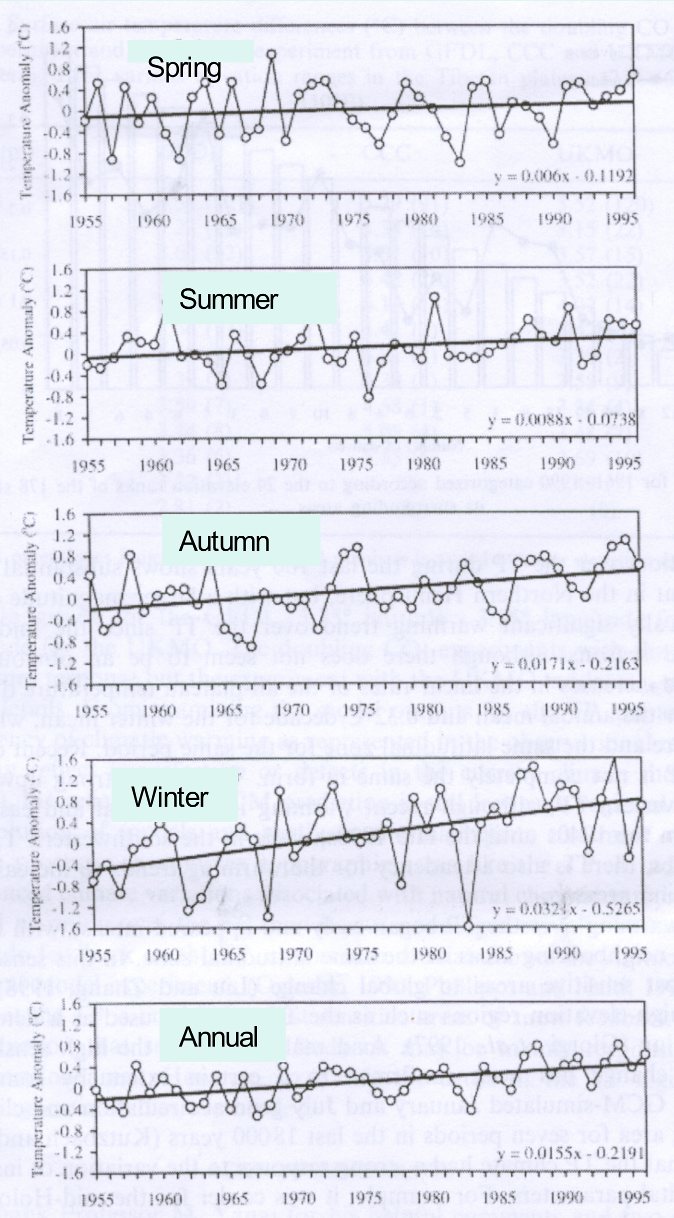
Regional Mean Temperature Trends for the period 1977-94 (°C per year)

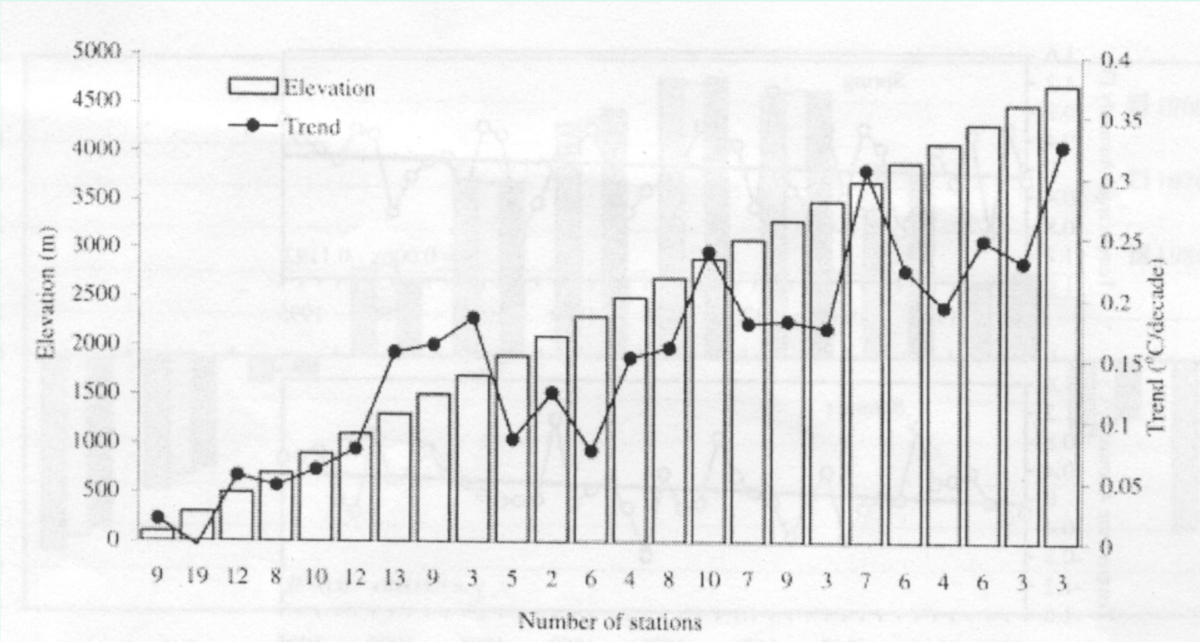
Regions	Seasonal: Winter Dec-Feb	Seasonal: Pre-monsoon Mar-May	Seasonal: Monsoon Jun-Sep	Seasonal: Post-monsoon Oct-Nov	Annual Jan-Dec
Trans-Himalaya	0.12	0.01	0.11	0.10	0.09
Himalaya	0.09	0.05	0.06	0.08	0.06
Middle Mountains	0.06	0.05	0.06	0.09	0.08
Siwalik	0.02	0.01	0.02	0.08	0.04
Terai	0.01	0.00	0.01	0.07	0.04
All-Nepal	0.06	0.03	0.051	0.08	0.06



Shrestha et al., 1999

Temperature changes in Tibetan Plateau





Liu and Chen, 2000

MAGICC/SCENGEN Analysis for Nepal

GCM Estimates for temperature and precipitation changes in Nepal

Year	Temperature change (°C) mean (standard deviation)			Precipitation change (%) mean (standard deviation)		
	Annual	DJF[4]	JJA[5]	Annual	DJF	JJA
Baseline average				*1433 mm*	*73 mm*	*894 mm*
2030	1.2 (0.27)	1.3 (0.40)	1.1 (0.20)	5.0 (3.85)	0.8 (9.95)	9.1 (7.11)
2050	1.7 (0.39)	1.8 (0.58)	1.6 (0.29)	7.3 (5.56)	1.2 (14.37)	13.1 (10.28)
2100	3.0 (0.67)	3.2 (1.00)	2.9 (0.51)	12.6 (9.67)	2.1 (25.02)	22.9 (17.89)

OECD, 2003

Example of vulnerability ranking of sectors

Resource/ranking	Certainty of impact	Timing of impact (urgency)	Severity of impact	Importance of resource
Water resources and Hydropower	**High**	**High**	**High**	**High**
Agriculture	Medium-low	Medium-low	Medium	High
Human health	Low	Medium	Uncertain	High
Ecosystems/Biodiversity	Low	Uncertain	Uncertain	Medium-high

OECD, 2003

Monitoring of Himalayan Climate

- The Himalayan region poorly monitored by conventional or remote sensing systems
- Lack of a multifaceted observational system to monitor and better understand future changes in the complex Himalayan terrain
- Data gaps due to shortages of

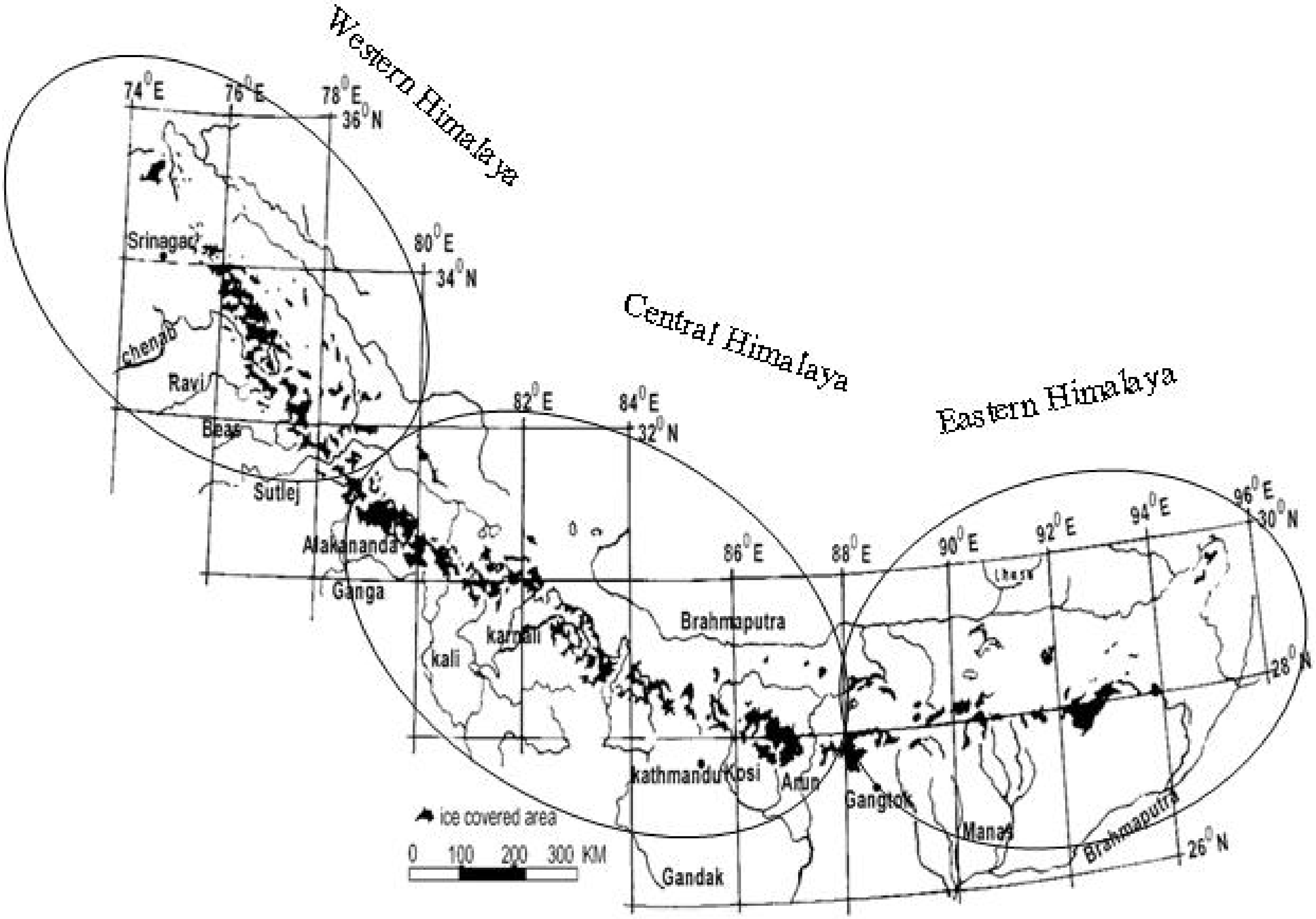
Projection of Himalayan Climate

- Inadequate resolutions of Climate Change models
- Large changes even in small areas due to the complex topography of the region
- Feedback effects due to deglaciation in terms of albedo and slope instability
- Even relatively small global perturbations can produce large local changes

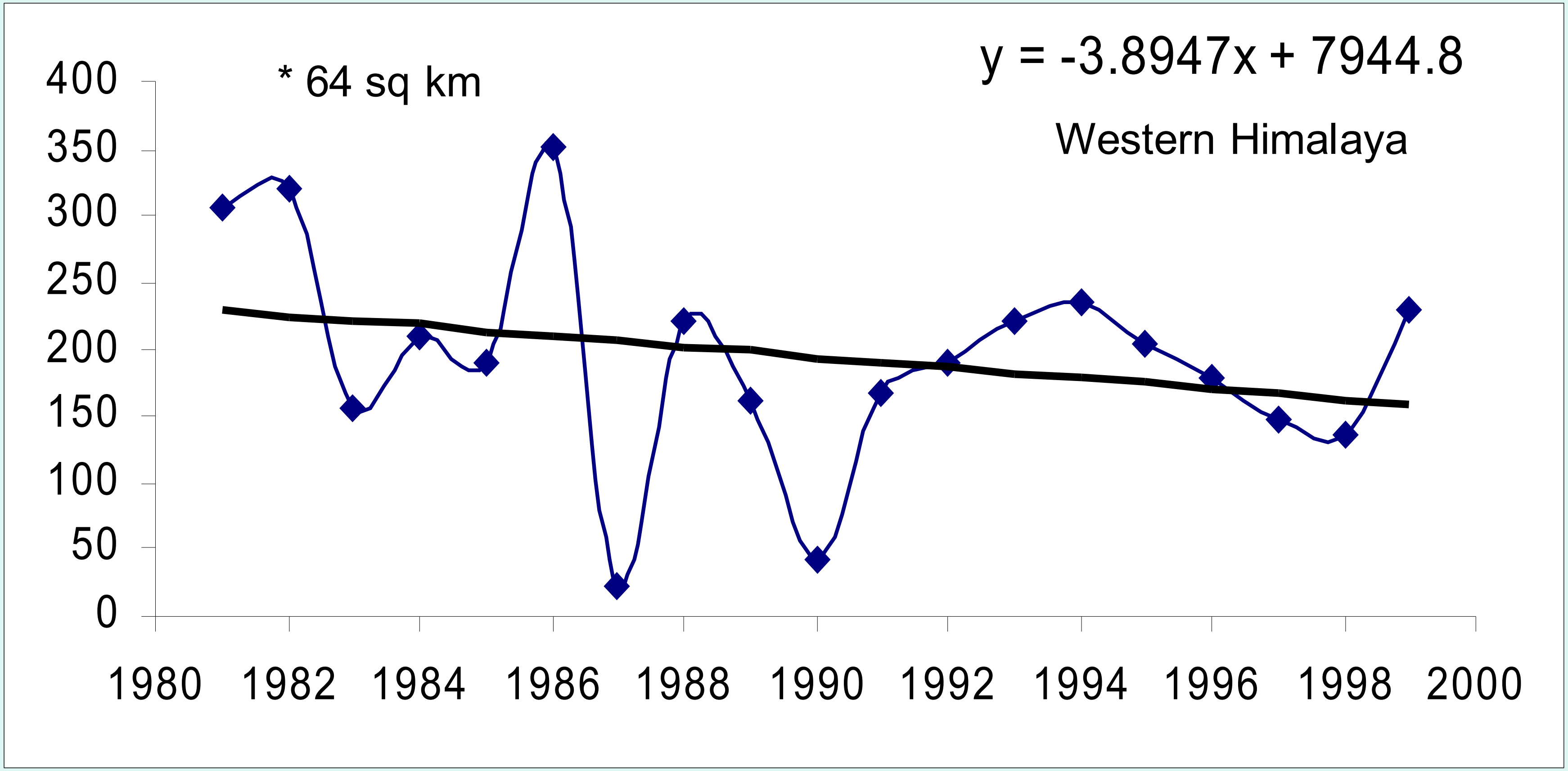
Cryospheric aspect in the Himalayan region

Cryospheric Change

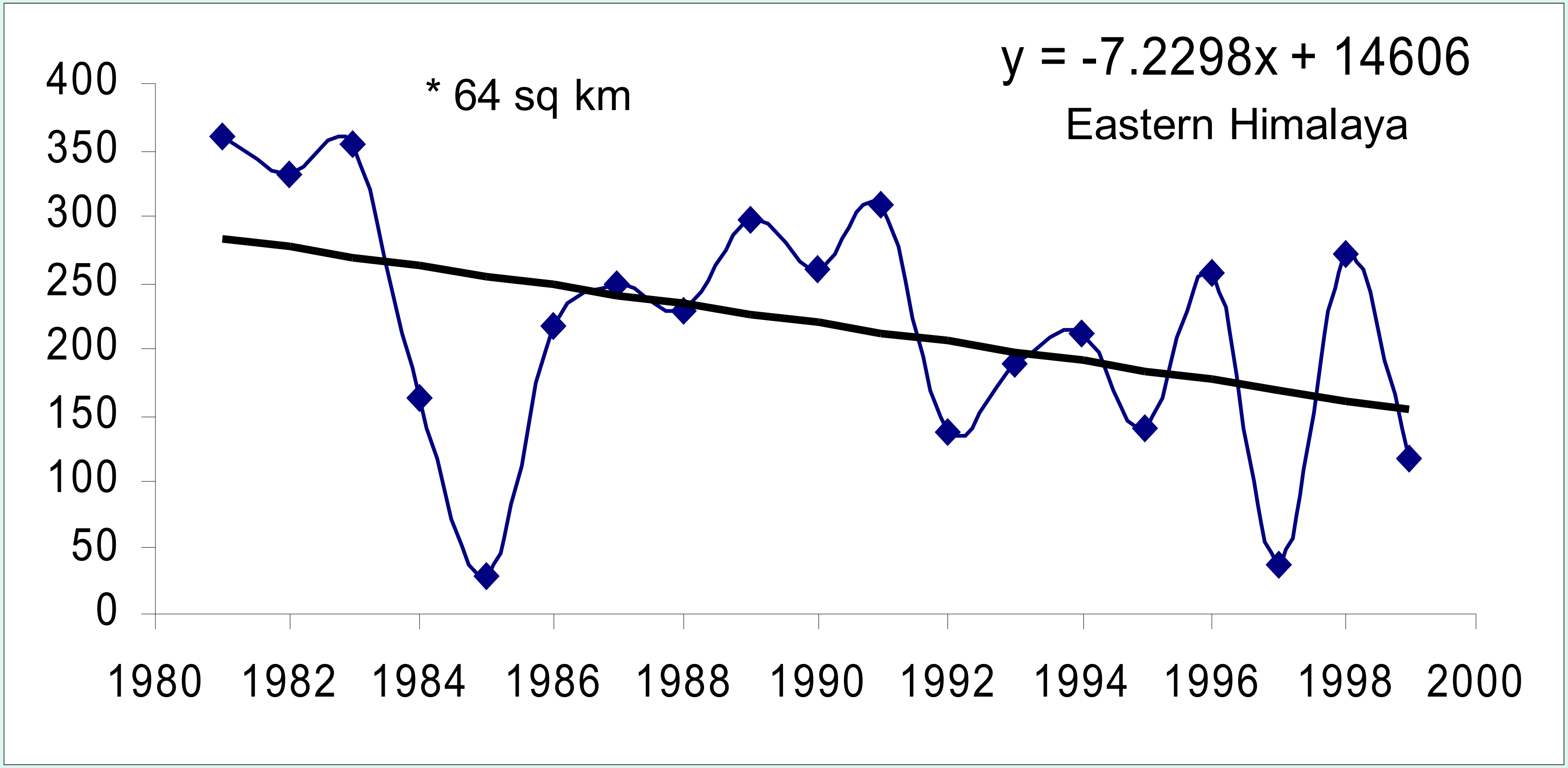
Values	Northern slope of Himalayan Arc	Trans-Himalayan Southern Slope	Eastern Himalaya	Western Himalaya
No. of receding glaciers studied	13	13	8	11
Average recession rate of glaciers (m/yr)	9.4	11.6	23	15.9
Standard Deviation	6.4	7.2	7.2	7.5



Permanent glaciers area across Himalaya

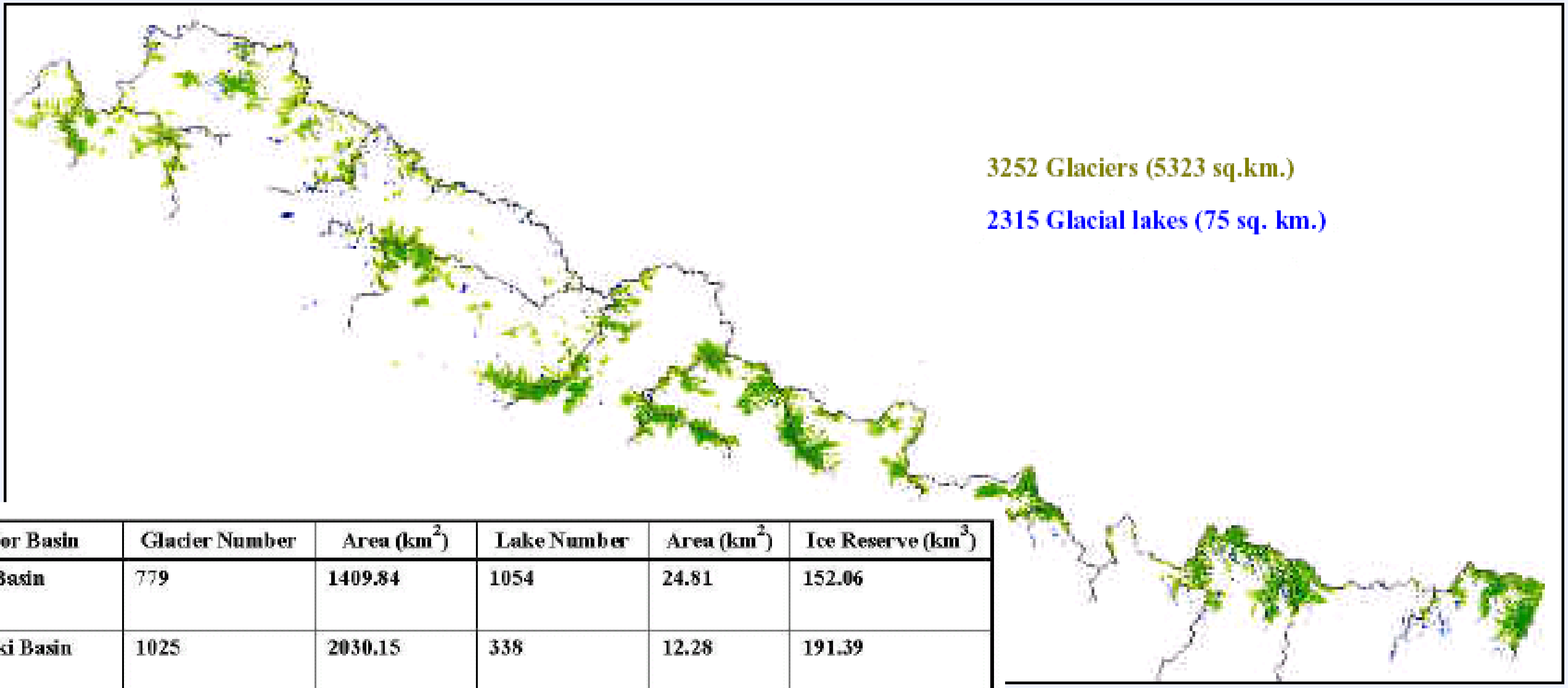


The time series of winter snow cover in Western Himalaya 1981 –1999.



The time series of winter snow cover in Eastern Himalaya, 1981 –1999.

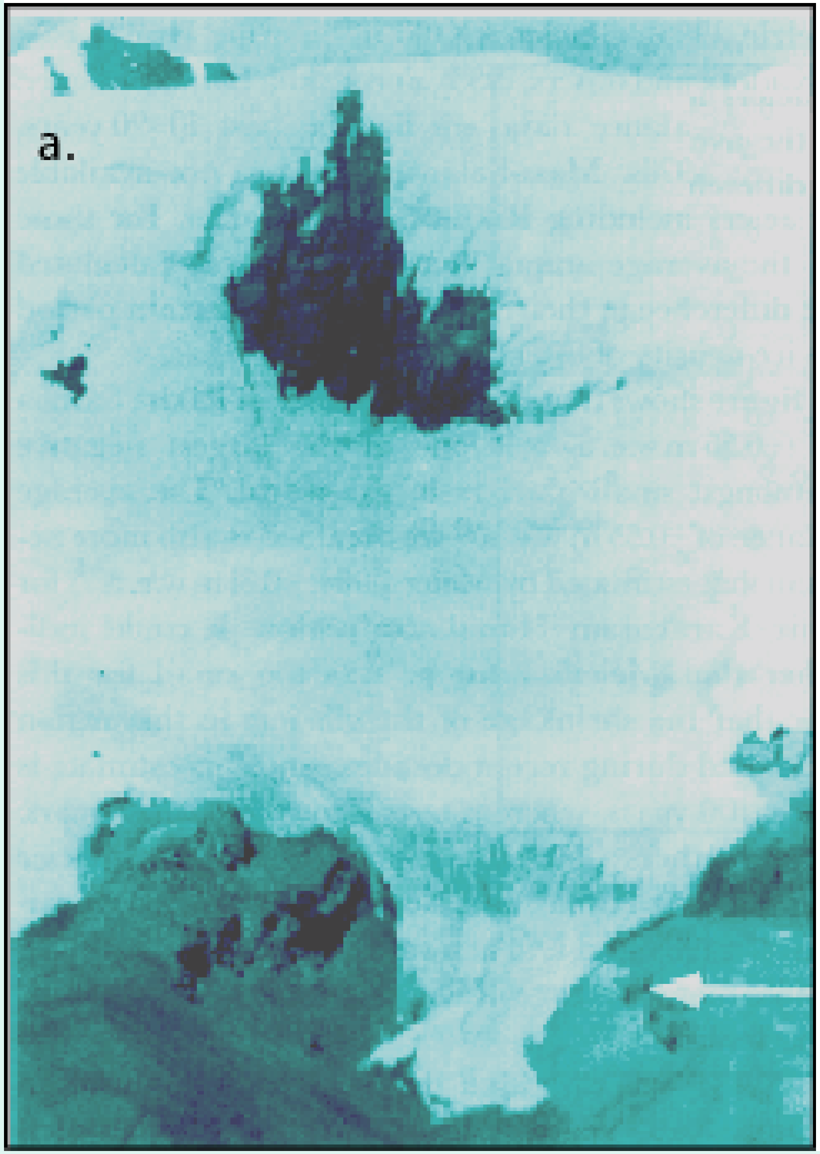
Map of Glaciers and Glacier Lakes Distribution

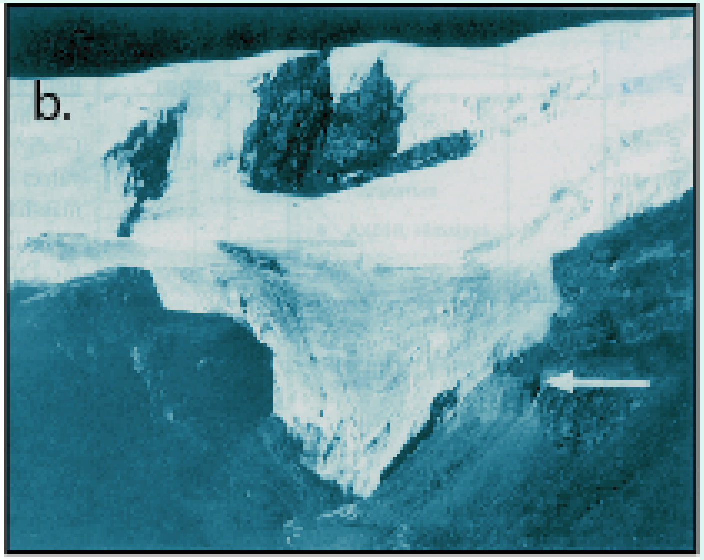


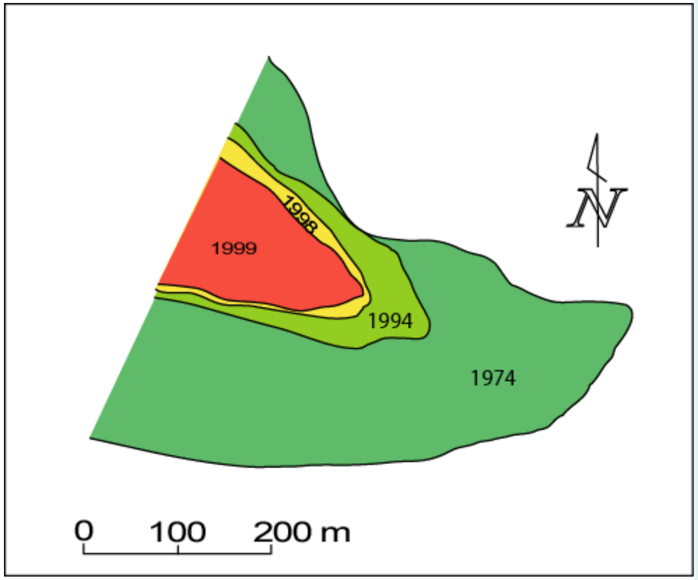
Major Basin	Glacier Number	Area (km^2)	Lake Number	Area (km^2)	Ice Reserve (km^3)
Koshi Basin	779	1409.84	1054	24.81	152.06
Gandaki Basin	1025	2030.15	338	12.28	191.39
Karnali Basin	1361	1740.22	907	37.66	127.72
Mahakali Basin	87	143.23	16	0.38	10.06
Total	3252	5323.44	2315	75.13	481.23

ICIMOD/UNEP (2000)

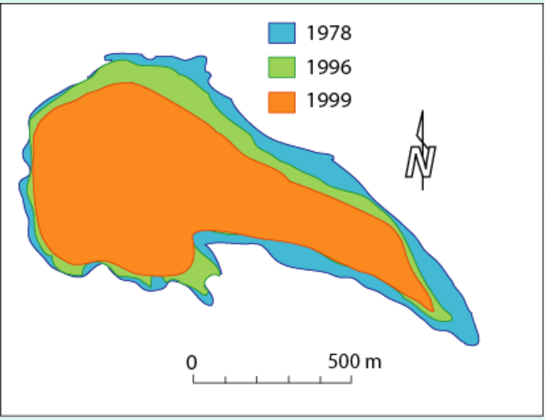
Rikha Samba Glacier in a. 1974 and b. 1994

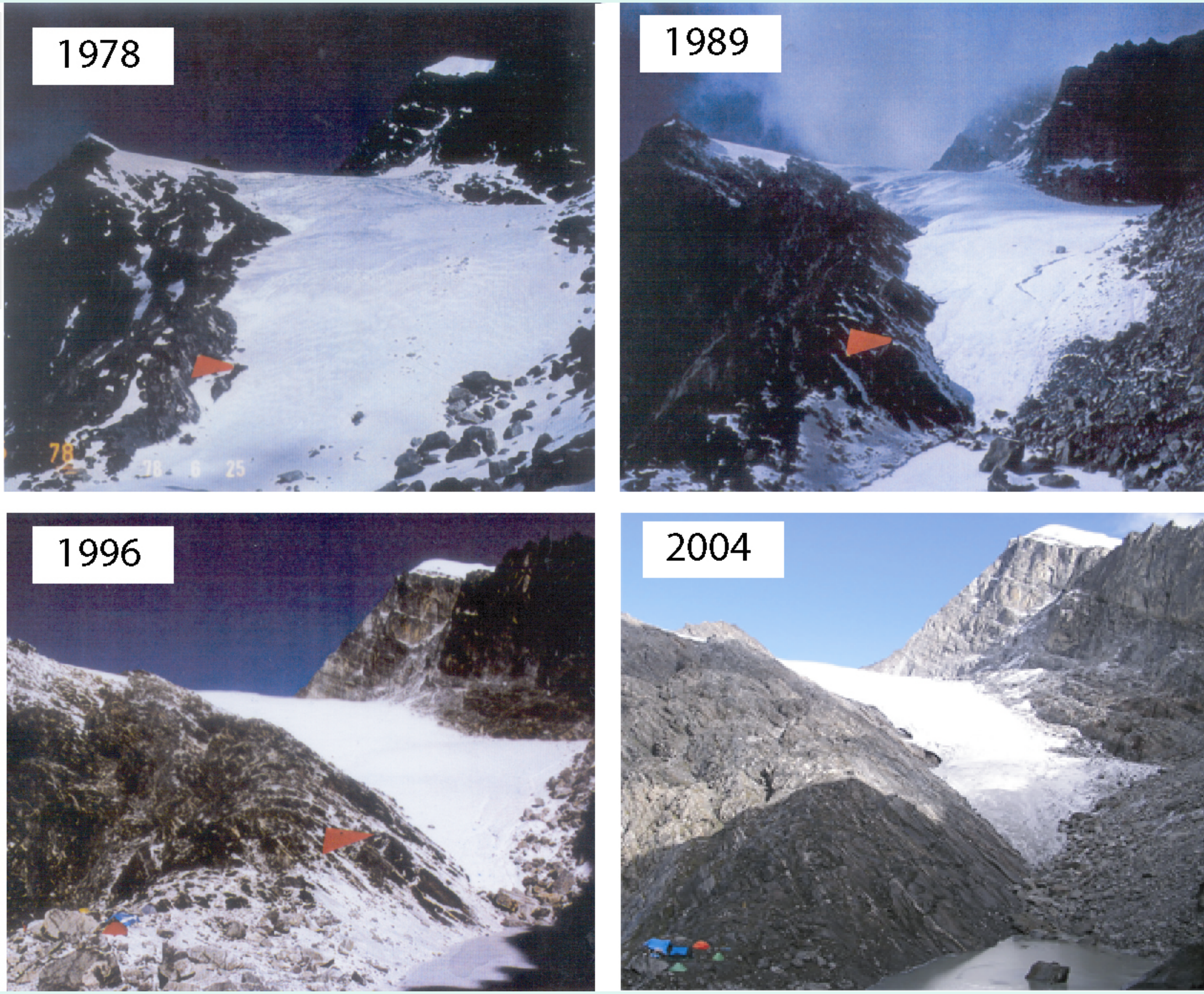






Retreat of AX010 Glacier



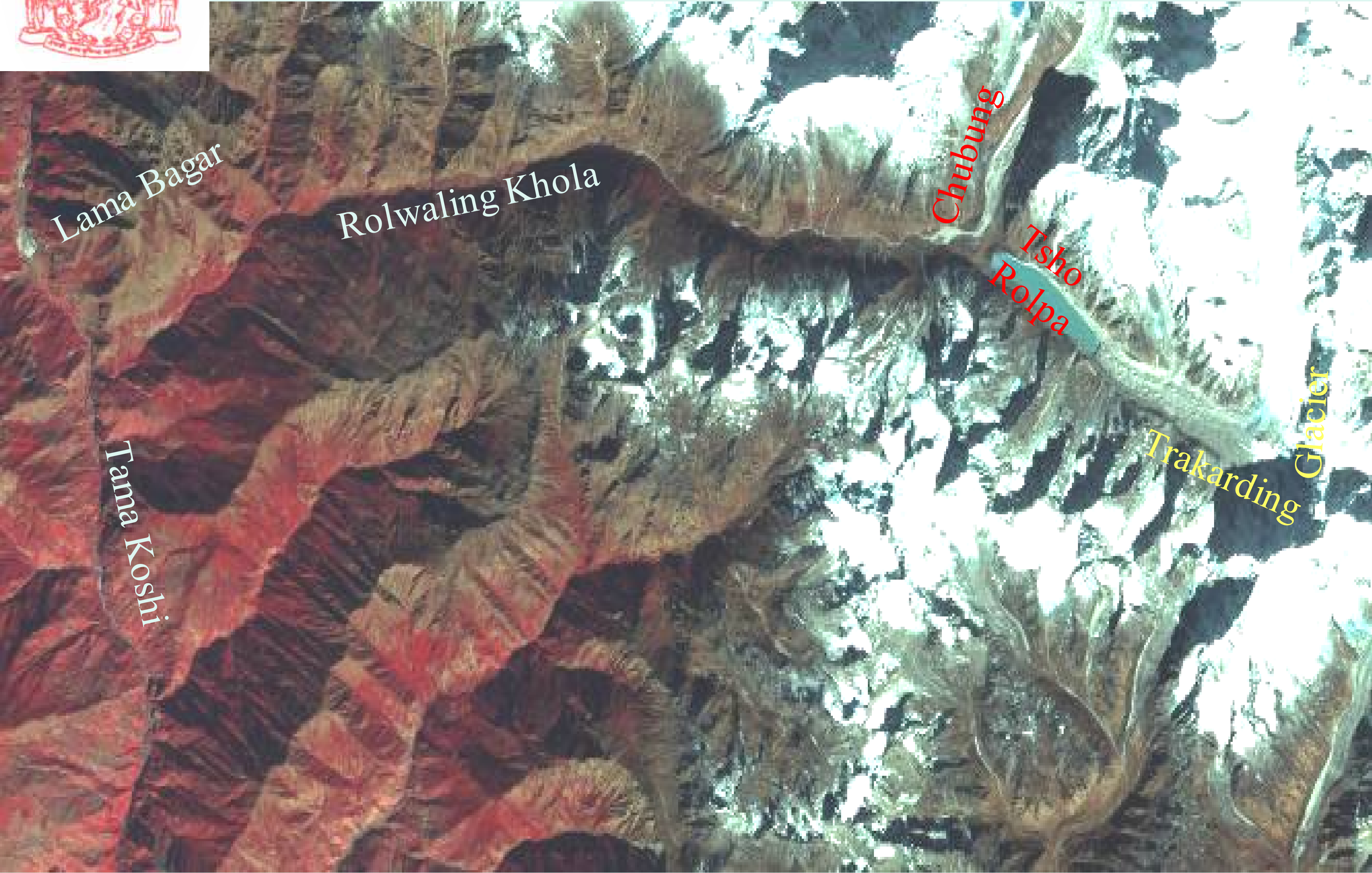


General Glacier Condition in Nepal

- AX 010: This small clean glacier is shrinking at an alarming rate. If it continues to shrink at the same rate it will disappear by 2060.
- Rika Samba: The terminus of this glacier is retreating by 10 m per year
- Other glaciers in Hidden Valley, Dhaulagiri Region are also retreating at the rate of 1.5 to 3 m per year
- Lirung: About 4 m of surface lowering in one year
- Khumbu: This large debris covered glacier the surface lowering between 1978 and 1995 was 10 to 30 m (max 2 m/yr). This glacier might divide into two at 5000 m
- Majority of glaciers in Kanchenjunga area are also retreating

Consequences of Glacier Retreat !

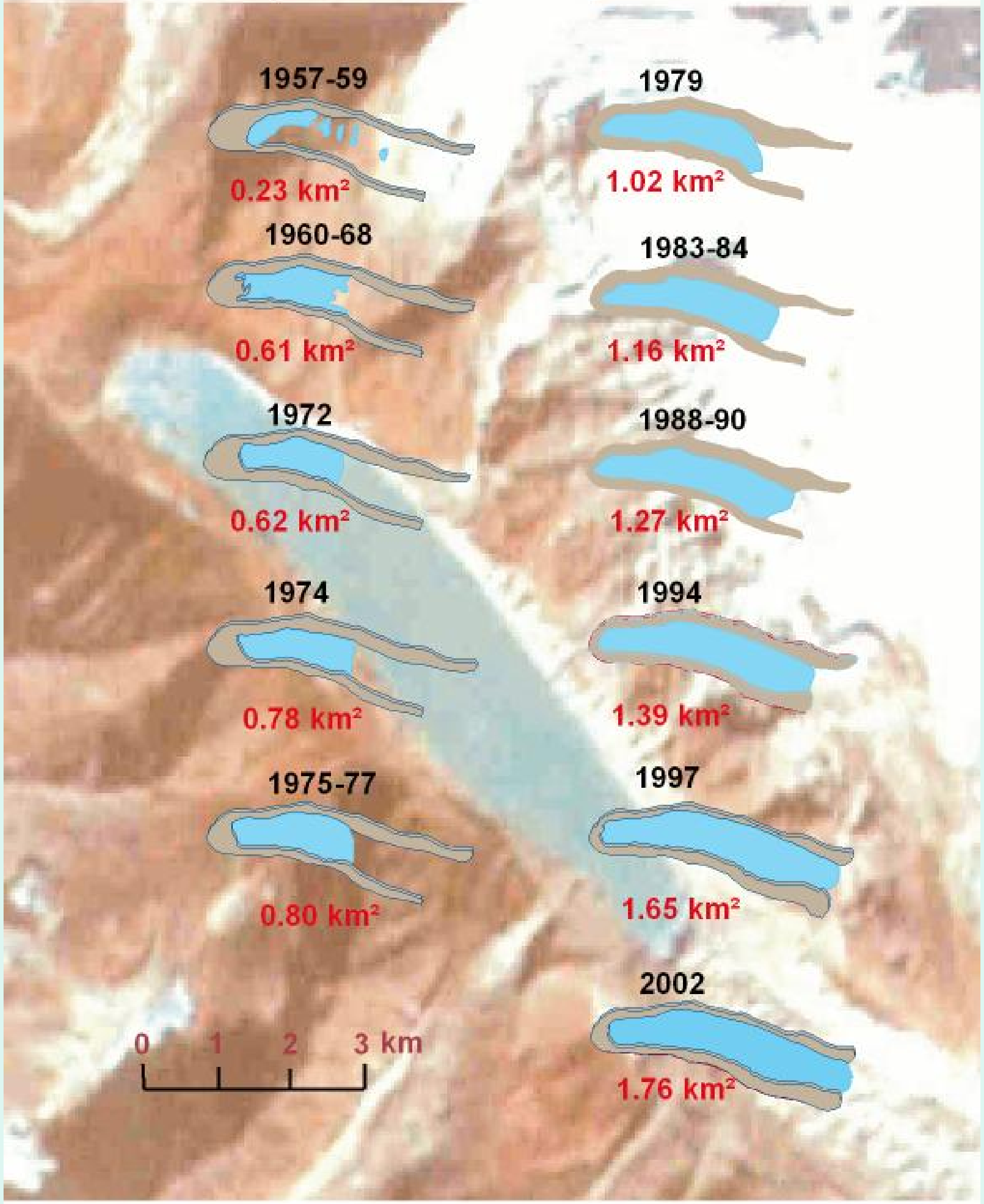
- Variations in runoff is related to percentage of glaciated area.
  - Variability in runoff is inversely proportional to percentage of glaciation
  - Decrease in the glaciated area will cause extreme flow conditions, i.e.., floods and droughts
- Initially the discharge will increase due to higher rate of melting, but later it will decrease as ice mass is depleted
- Glacier lake formation
- Glacier Lake Outburst Flood (GLOF)


Lama Bagar
Rolwaling Khola
Chubung
Tsho Rolpa
Trakarding Glacier
Tama Koshi

Tsho Rolpa Glacier Lake, Nepal

Hydropower Production at TshoRolpa Glacier Lake

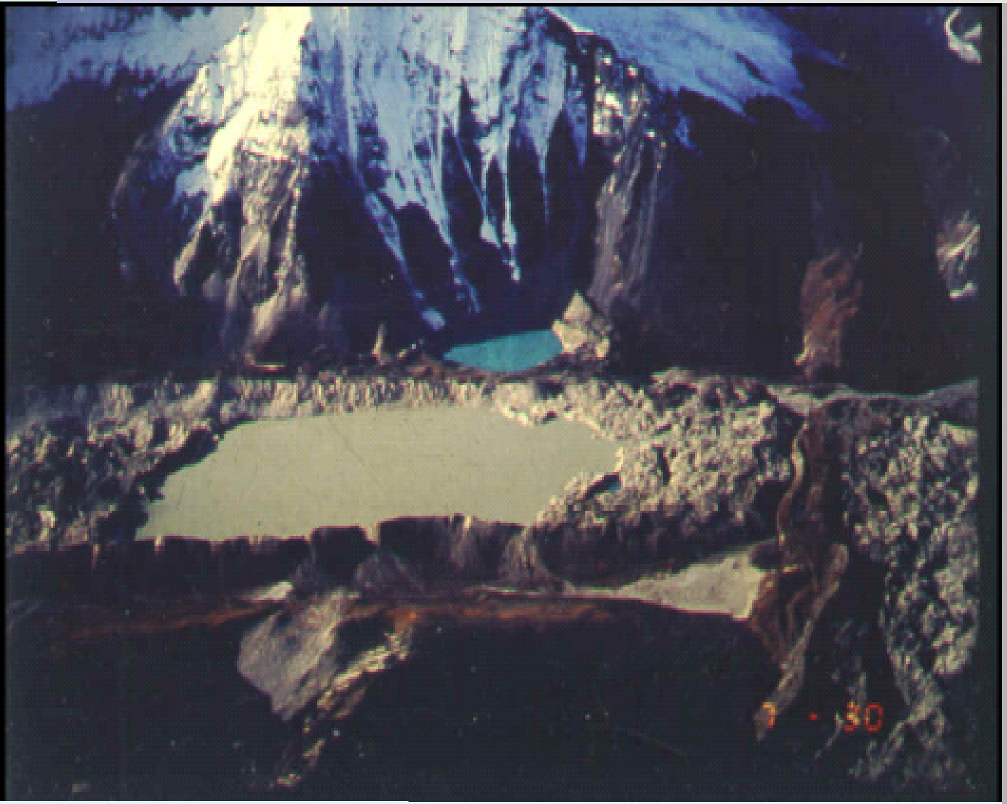
Development of Tsho Rolpa Glacier Lake



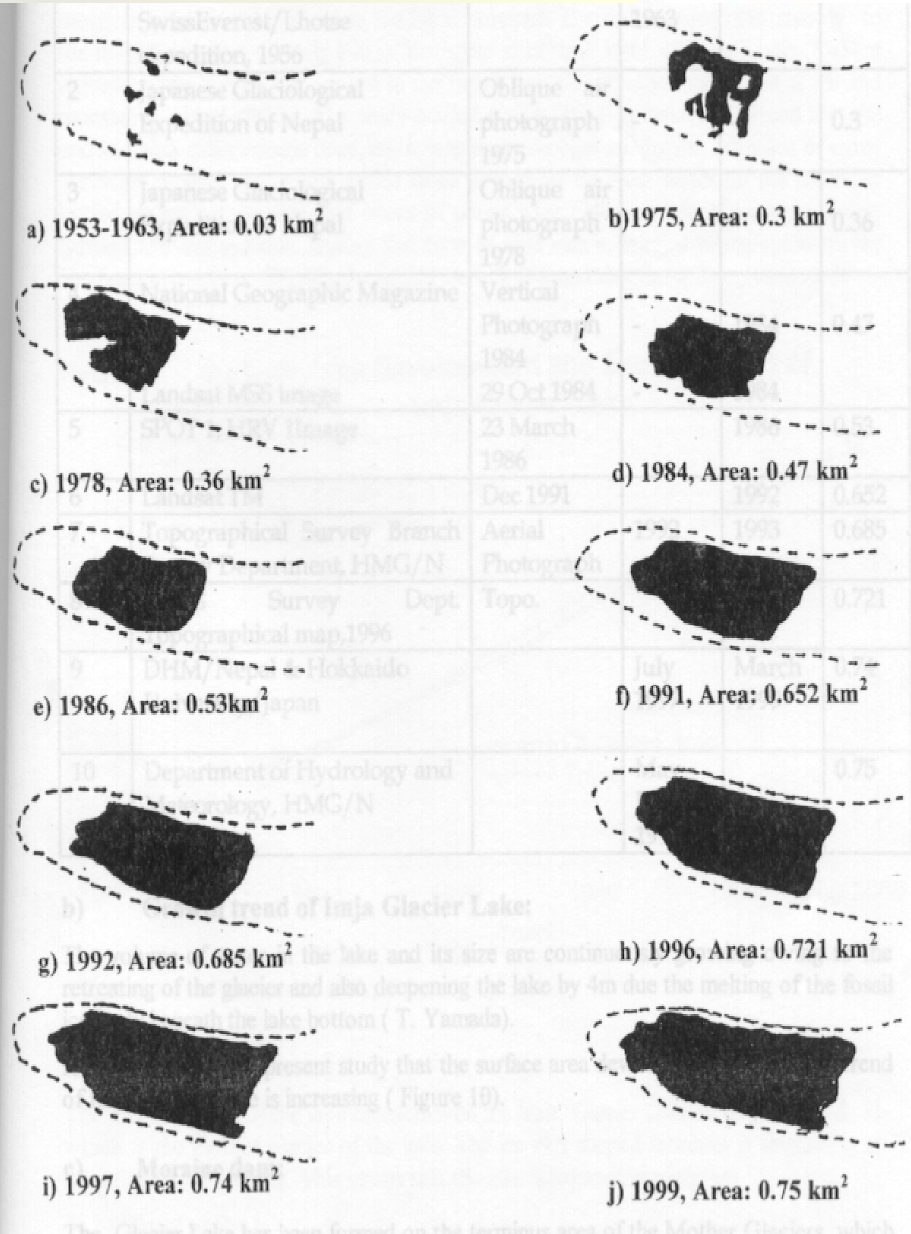
Modified after WECS 1994, Department of Hydrology and Meteorology,2004

Imja Lake

DHM



SOURCE: WECS

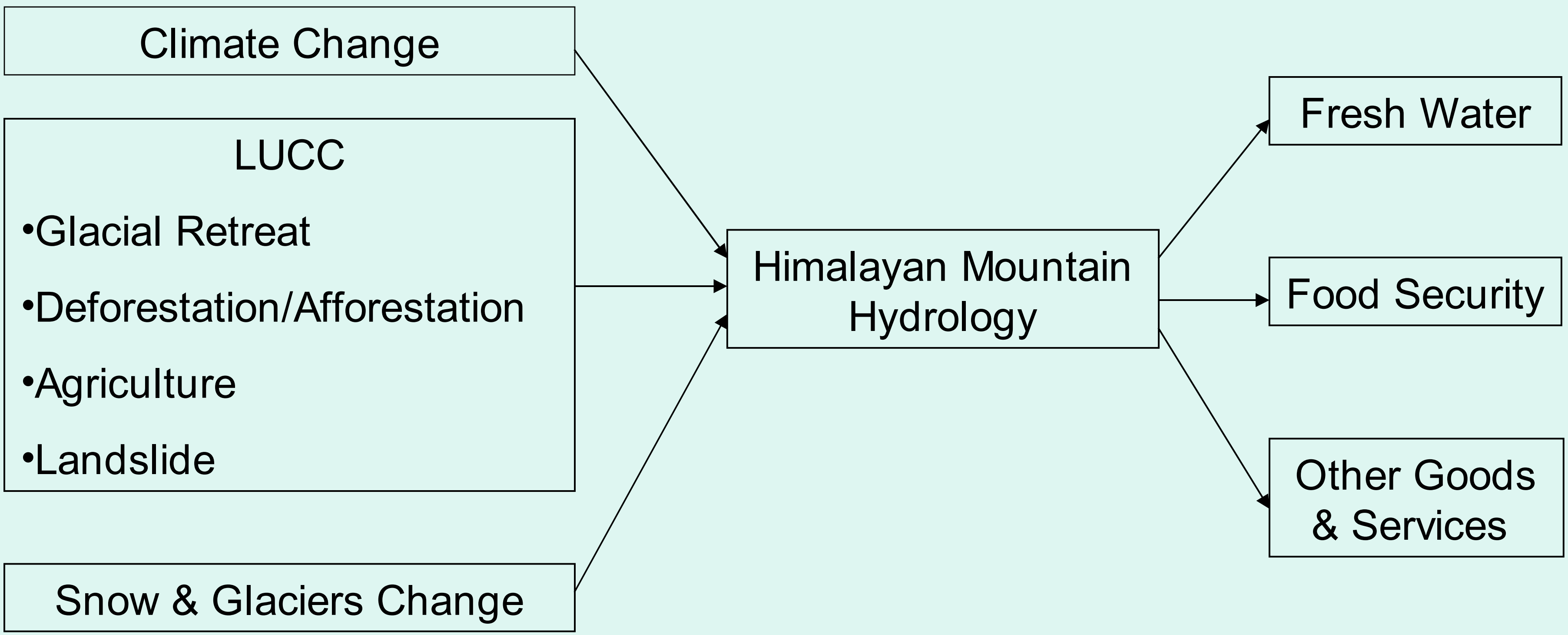


SOURCE: DHM

Glacier Lake and their Outburst Floods

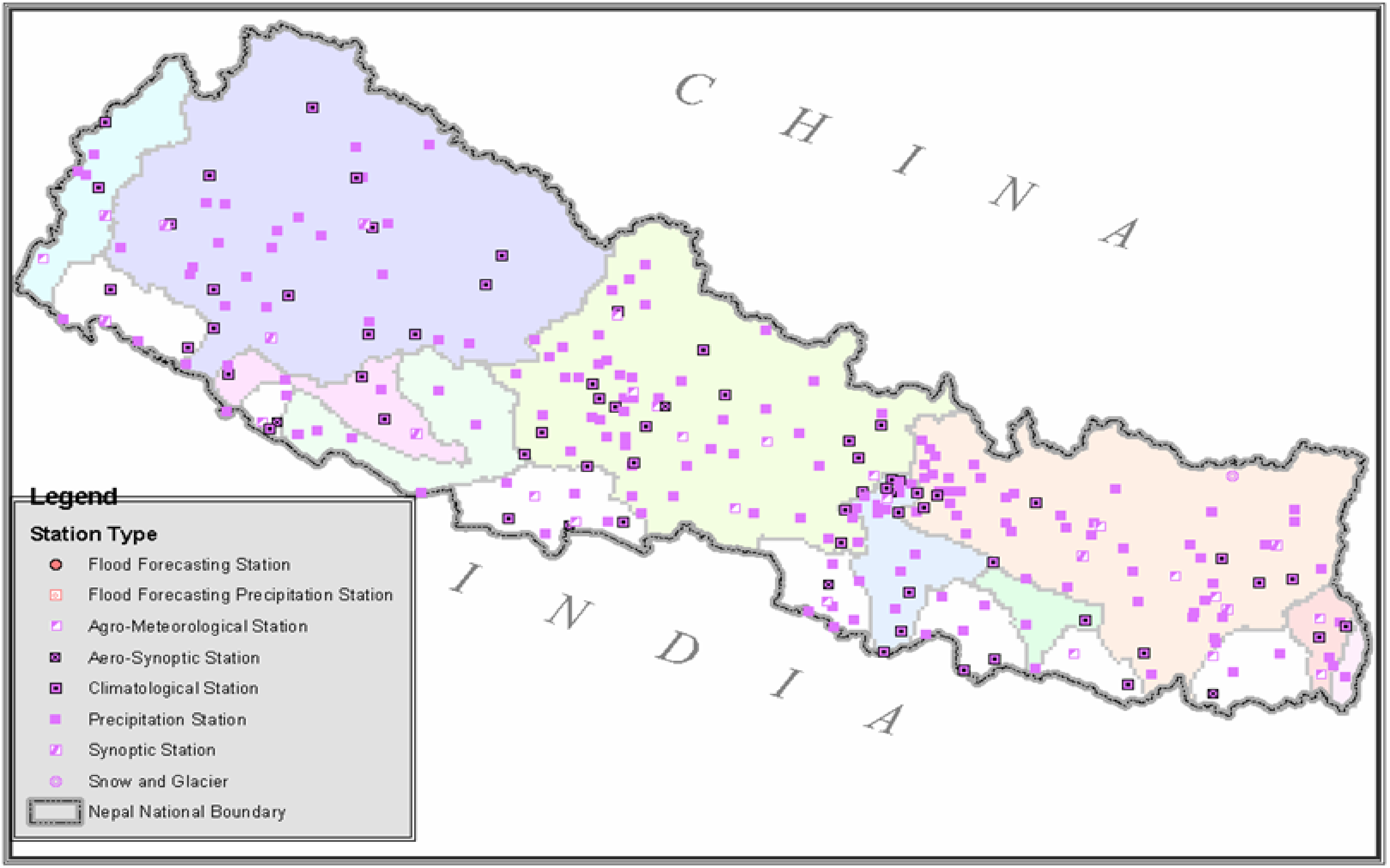
- The formation and growth of glacier lakes is a phenomenon closely related to the deglaciation in Nepal.
- Nepal has experienced more than 15 events of GLOFs.
- A GLOF is characterized by a sudden release of a huge amount of lake water, which in turn would rush down along the stream channel downstream in the form of dangerous flood waves.
- GLOF is likely to be a major hurdle in water resource development in Nepal
- For this the early warning system is preferable.

Mountains the link between Climate & Hydrology

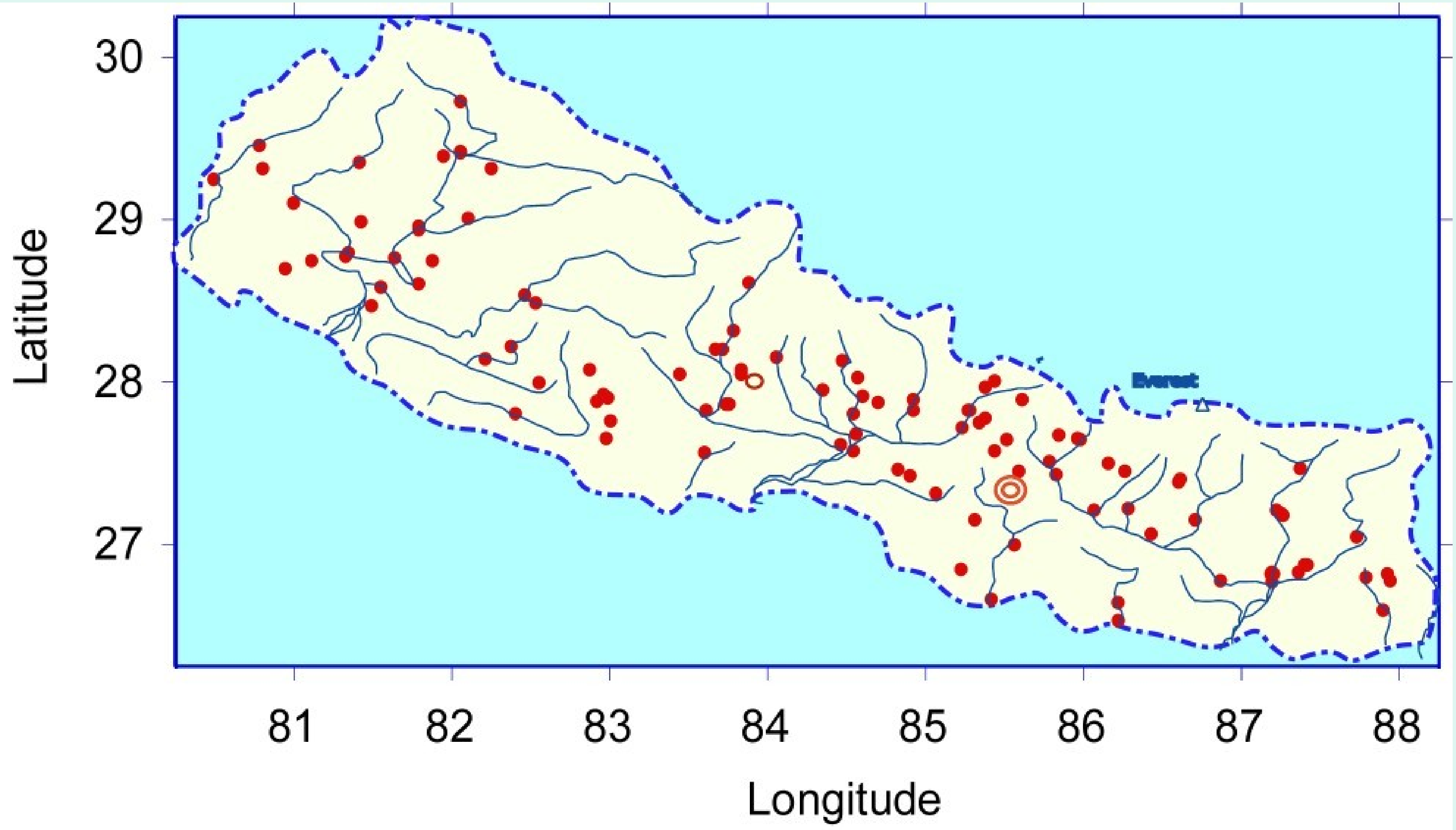


Station Network

Meteorological Stations

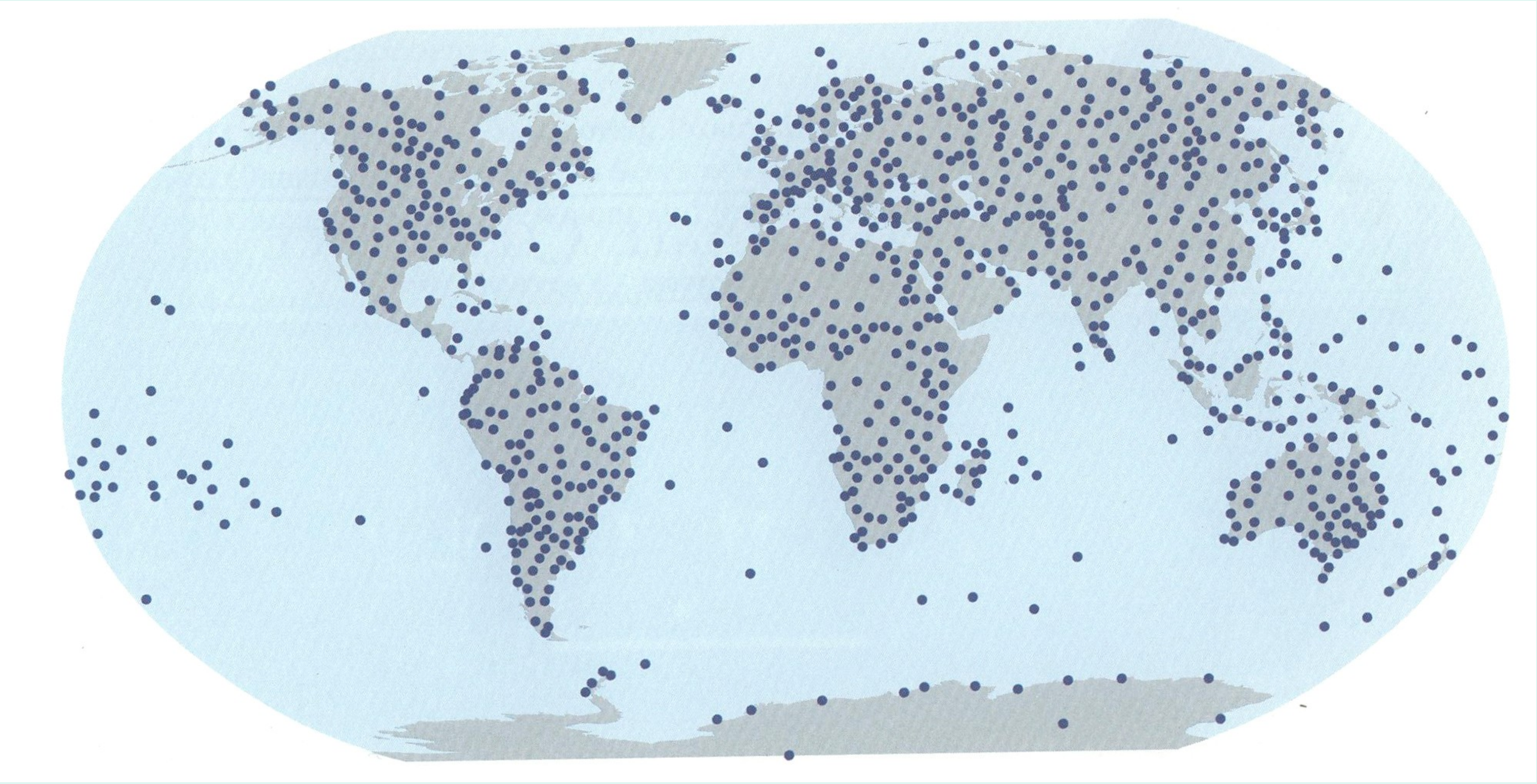


Hydrological Stations

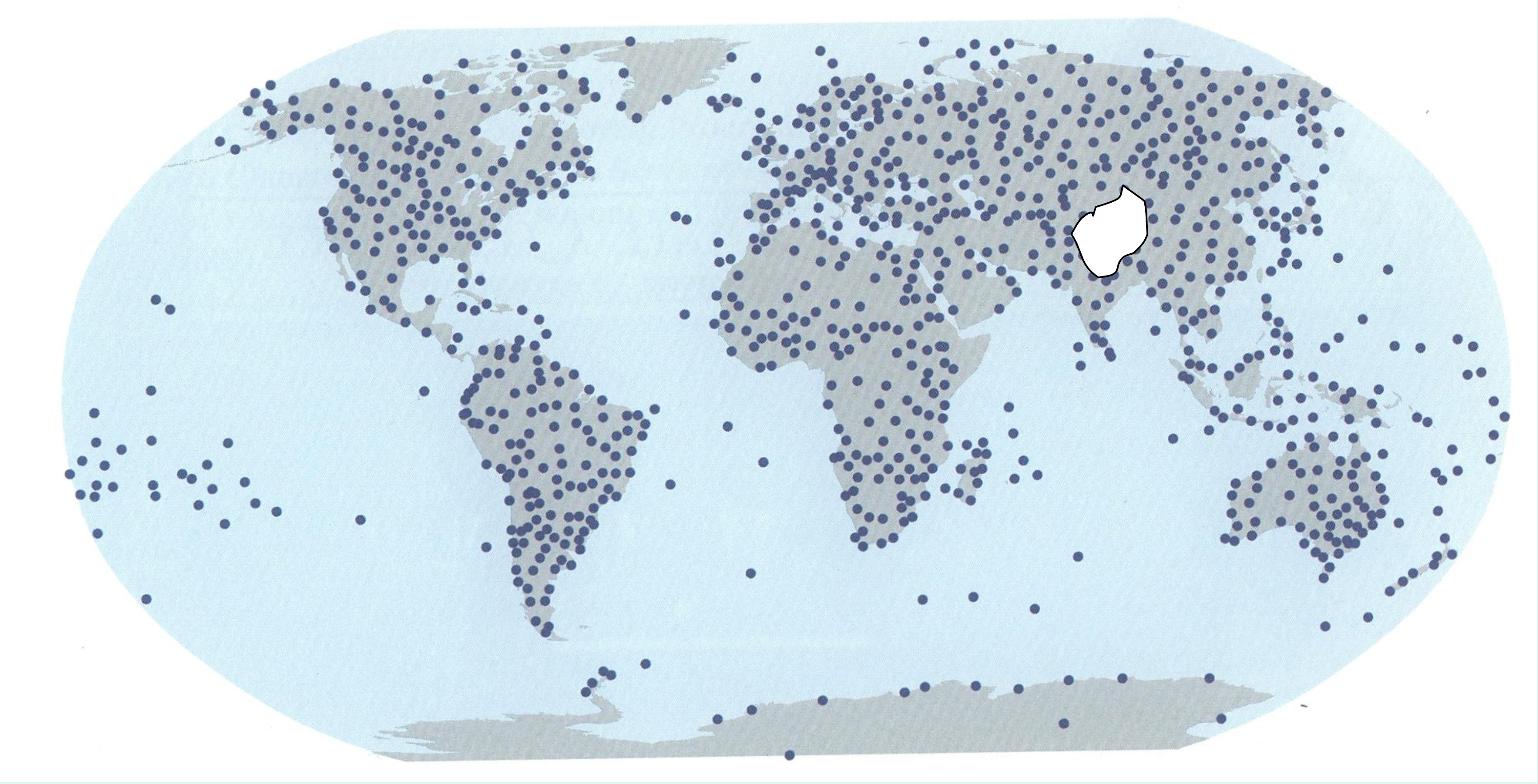


GCOS Upper Station Network

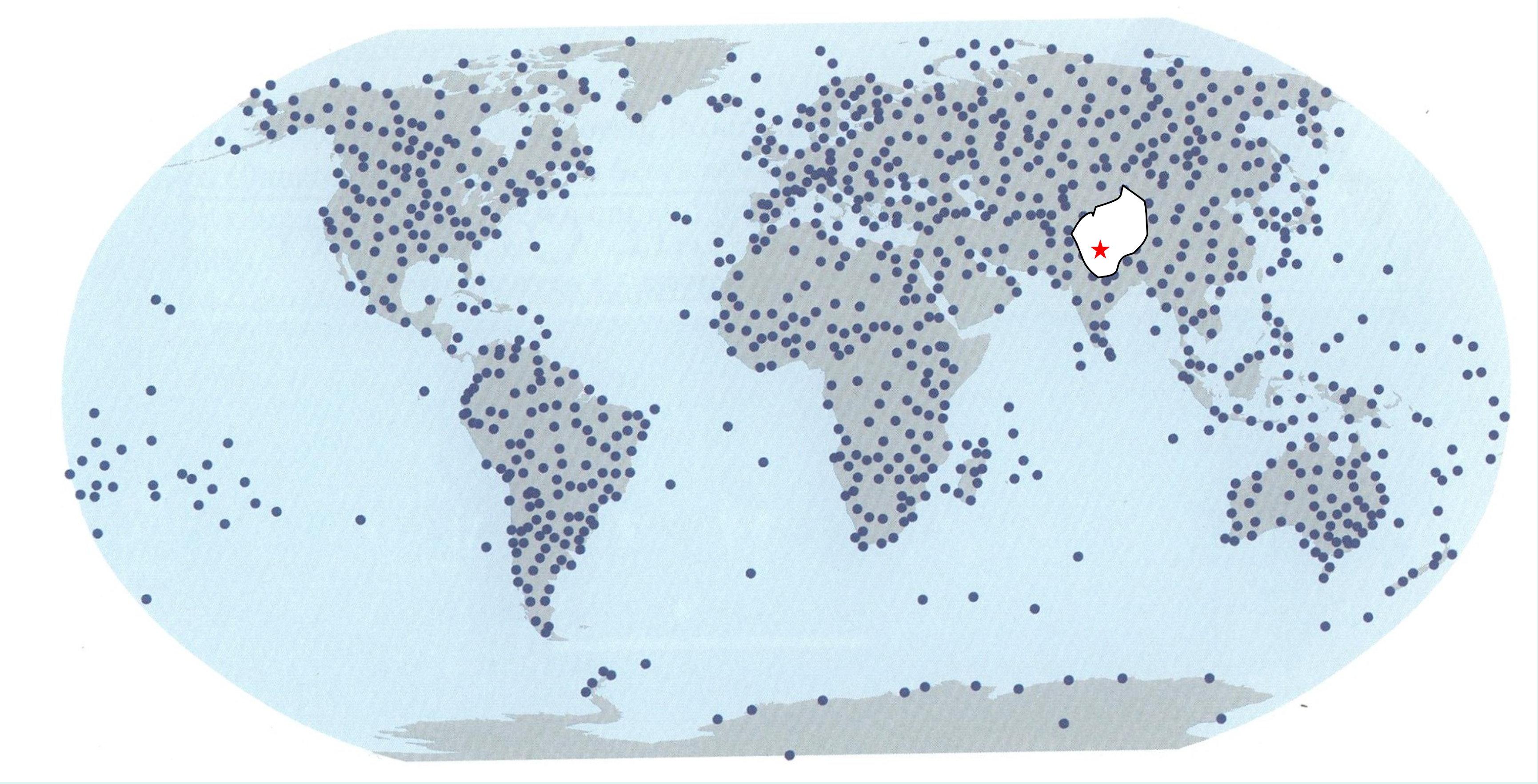
GCOS Surface Station Network



GCOS Surface Station Network



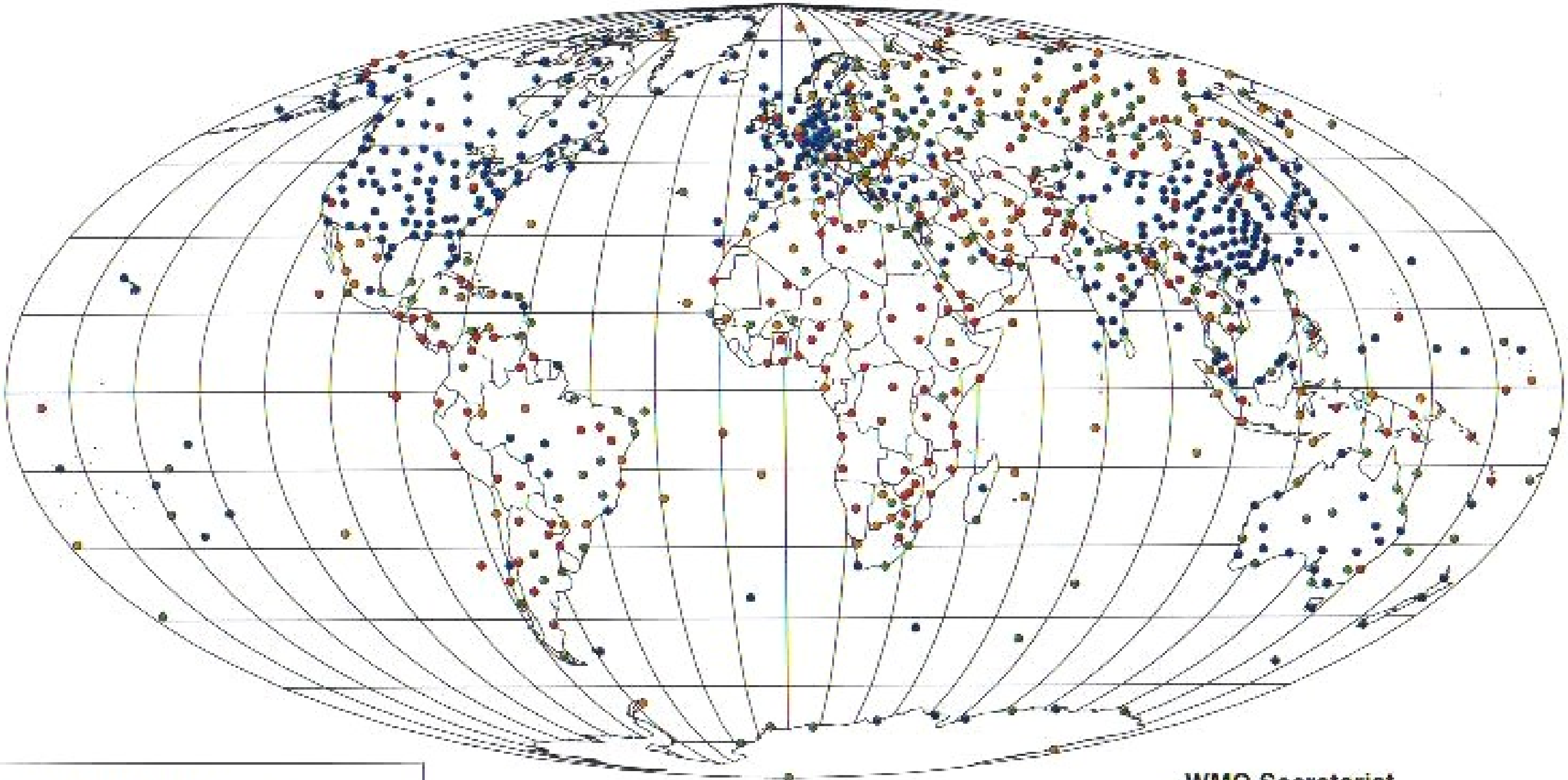
GCOS Surface Station Network



CBS-Ext.(02)/Doc. 5, Figure 4

SMM 1-15/7/2002

Parts A of TEMP reports made at 00 and 12 UTC at RBSN stations



Percentage of reports received:

- 90 to 100 per cent (399 stations)
- 50 to 90 per cent (151 stations)
- Less than 50 per cent (102 stations)
- Silent stations (166 stations)

WMO Secretariat

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Summary and Conclusions

- ❖Himalaya provides an opportunity to study land – atmosphere interactions in terms of energy and moister transfer in a unique condition
- ❖The ensemble of climate changes in the Himalayas represents complex interactions and their past, present and projected studies can lead to valuable insights into the climate forcing factors and their interactions

Summary and Conclusions (Contd.)

- Himalayan Cryosphere is undergoing rapid changes and their monitoring are important as the indicators of global change and also as drivers of hydrological change in the region
- Lack of three dimensional field observations especially in the Central Himalayan region
- Precipitation mechanism has not yet fully understood

Summary and Conclusions (Contd.)

The needs therefore are to:

- **Understand the three dimensional atmospheric behavior in Himalayan region**
- **Incorporate the Himalayan topography in the hydro-meteorological models as well as in the regional models**
- **Understand the role of Himalaya in the CTCZ**
- **And help the people of this region**

THANK YOU