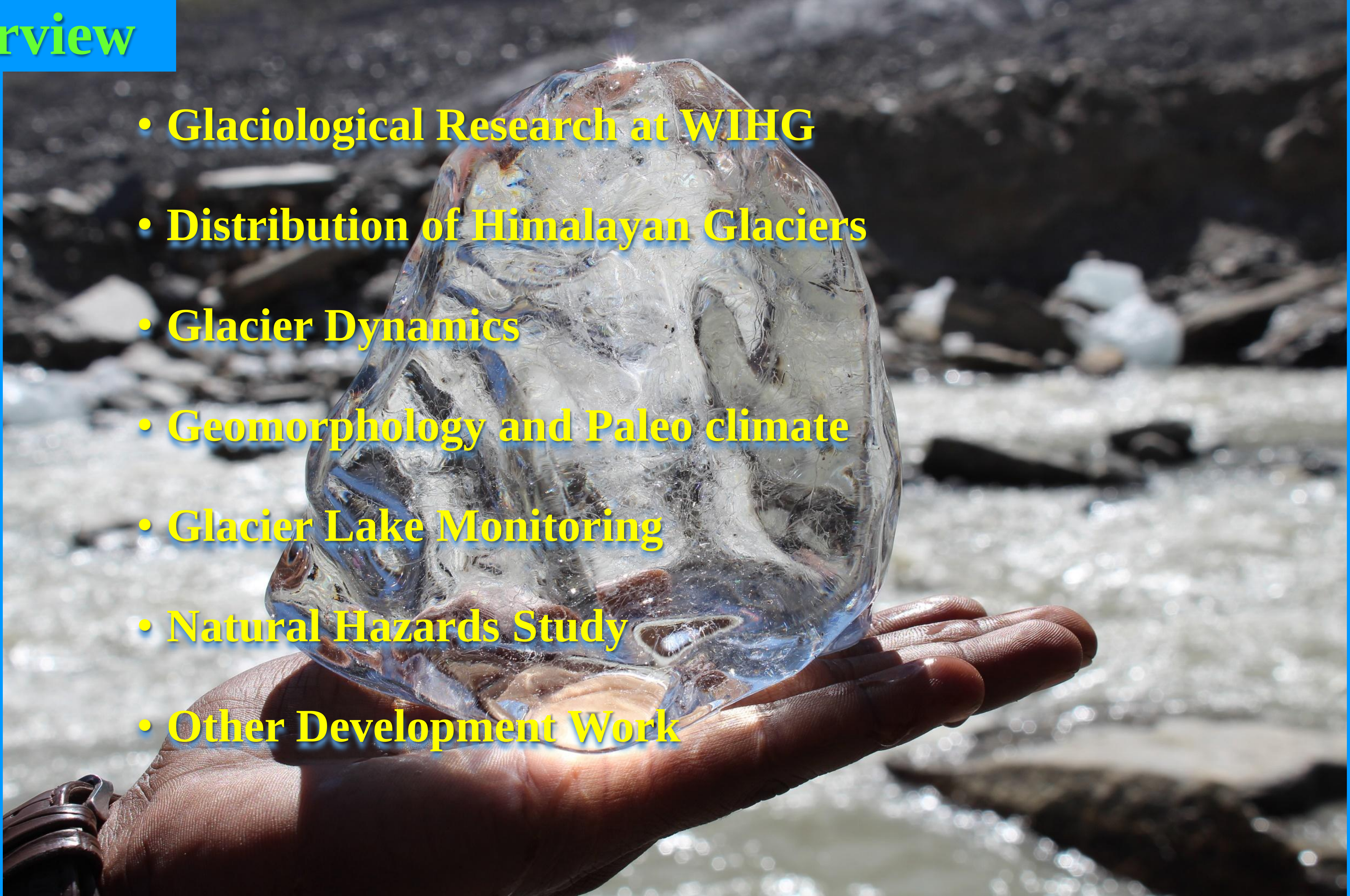
Monitoring of Himalayan Glaciers using Ground based Observations and Space

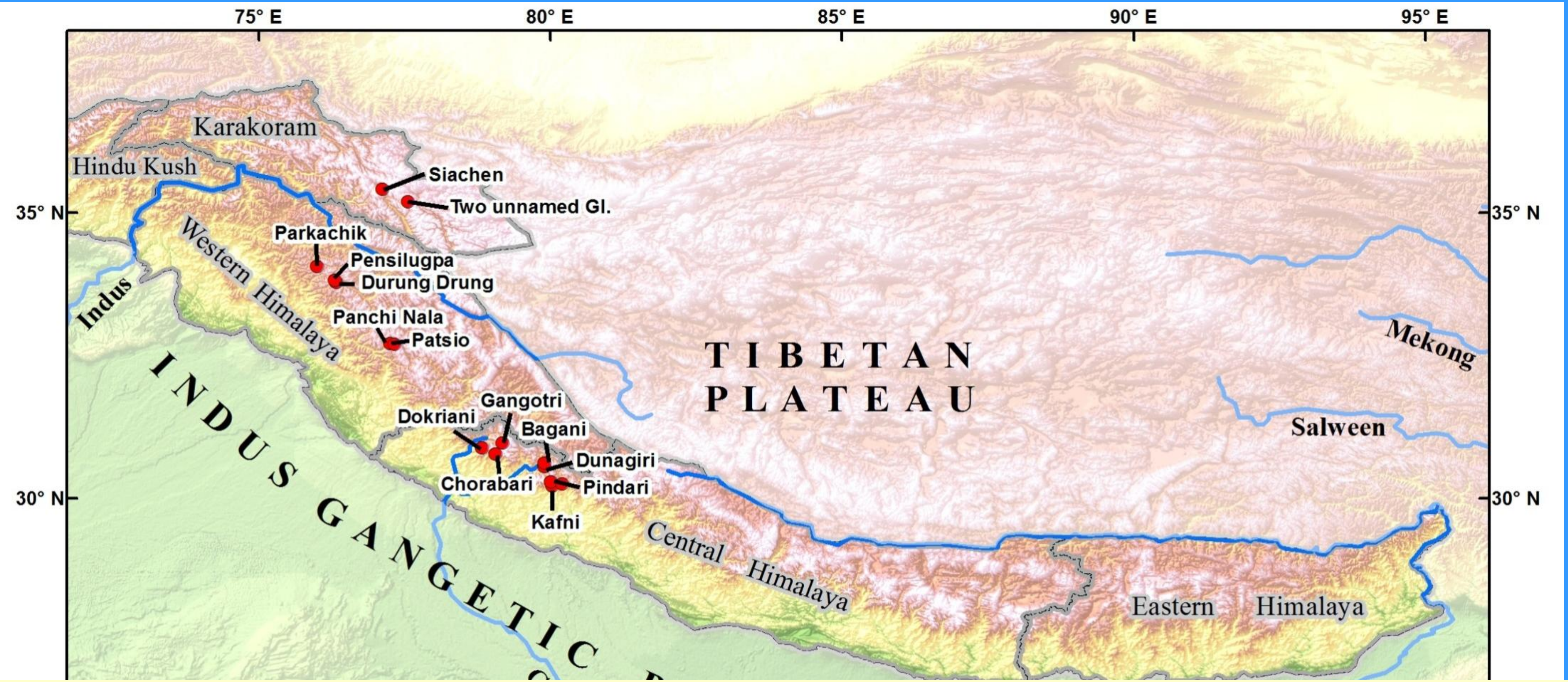
Manish Mehta
Scientist –E
WIHG

Overview



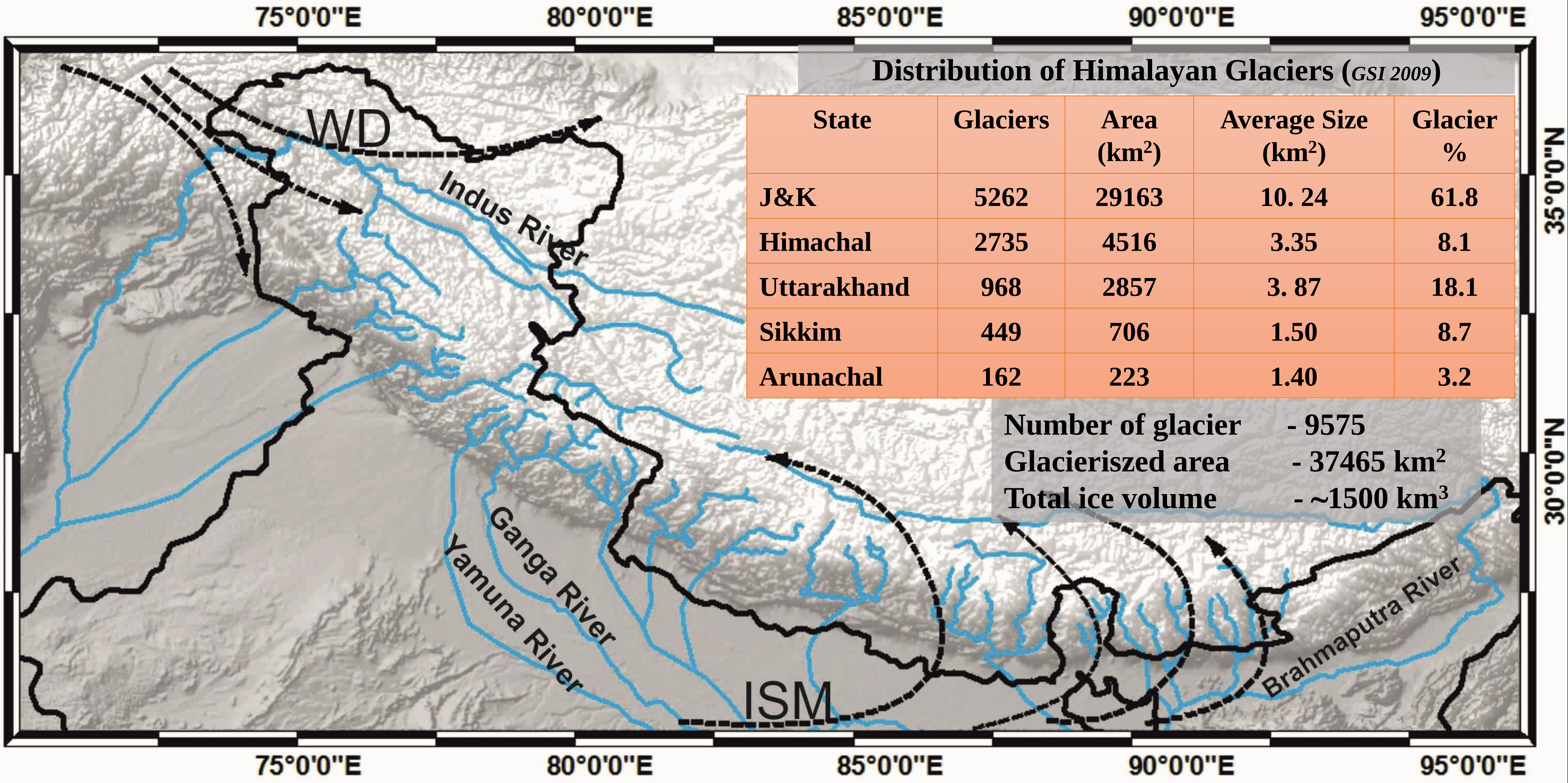
- Glaciological Research at WIHG
- Distribution of Himalayan Glaciers
- Glacier Dynamics
- Geomorphology and Paleo climate
- Glacier Lake Monitoring
- Natural Hazards Study
- Other Development Work

Glaciological Studies in Indian Himalayan Region (IHR)
By Wadia Institute of Himalayan Geology



- At present, WIHG is monitoring **07 glaciers in Uttarakhand** (Chorabari, Dokriani, Dunagiri, Bangni, Gangotri, Pindari, Kafni) and **six (6) glaciers (Pensilguppa, Prakachik, Durung Drang, Siachen, 02 unnamed in Karakoram) are located in Western Himalaya and Karakoram.** using the **ground-based observations and satellite data**.
- The monitoring includes **glacier dynamics** (mass balance, retreat, velocity), **meteorology** (air temperature, precipitation, radiation, aerosols), **hydrology** (discharge, sediment transfer, geochemistry, stable isotopes), and **glacier-related hazards** (glacial lake outburst flood, debris flow, moraine failure, etc.).

Distribution of Himalayan Glaciers

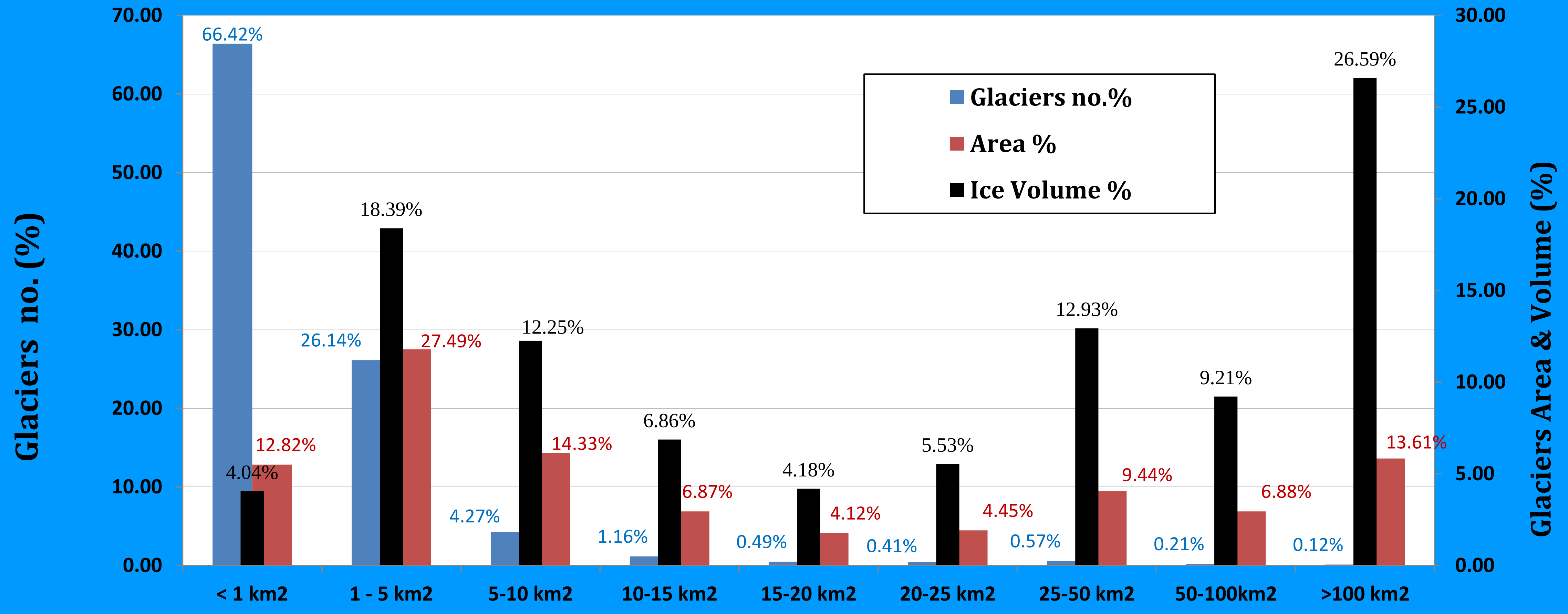


Distribution of Himalayan Glaciers (*GSI 2009*)

State	Glaciers	Area (km^2)	Average Size (km^2)	Glacier %
J&K	5262	29163	10. 24	61.8
Himachal	2735	4516	3.35	8.1
Uttarakhand	968	2857	3. 87	18.1
Sikkim	449	706	1.50	8.7
Arunachal	162	223	1.40	3.2

Number of glacier - 9575
Glacieriszed area - 37465 km^2
Total ice volume - ~1500 km^3

Glaciers number, Ice Volume and Area

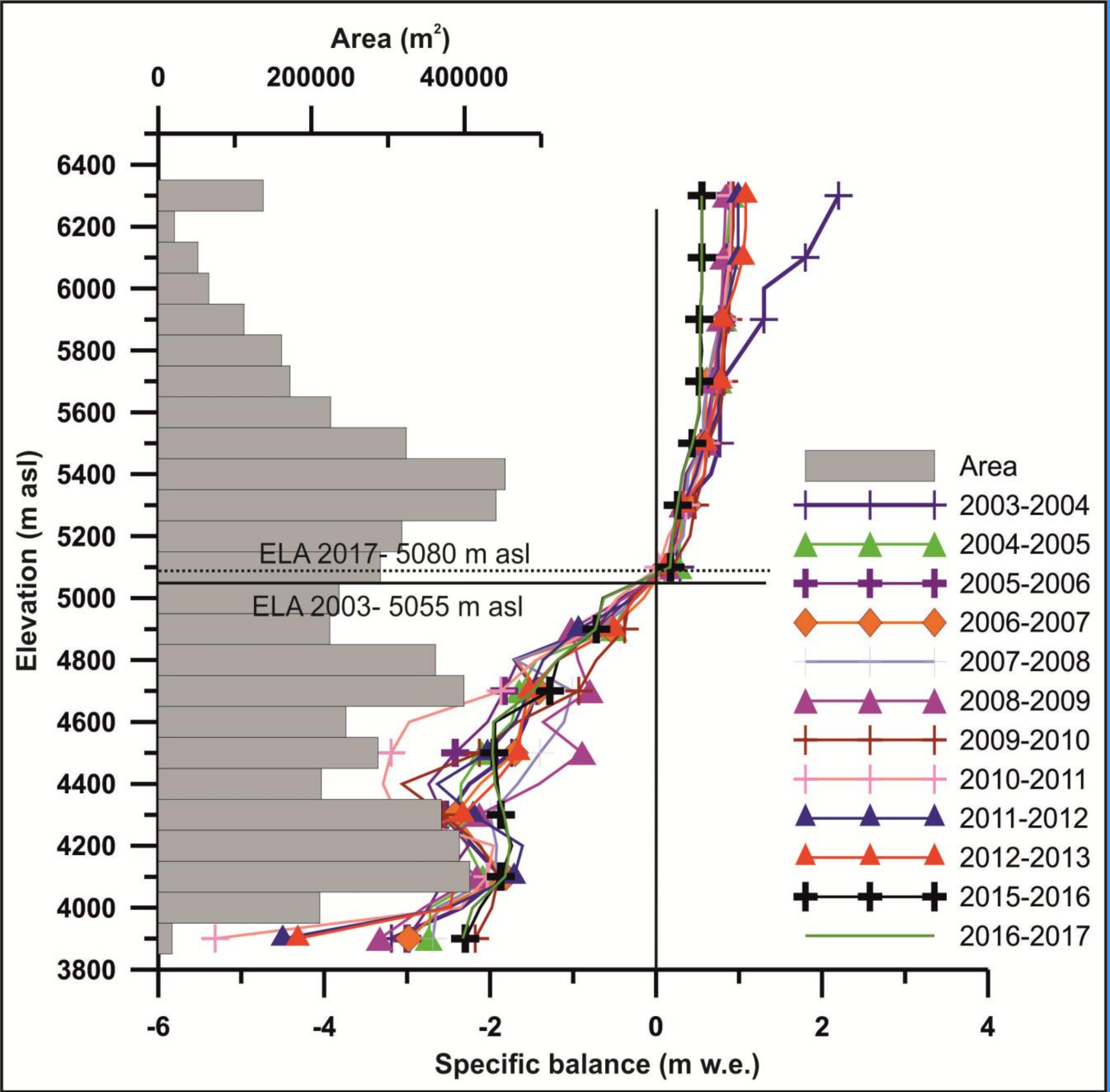


The studies have shown that large glaciers with an area > 10 km^2 are unlikely to get affected appreciably in the coming years. However, the small glacier of ~1-2 km^2 or < 1 km^2 may show rapid changes. In the Himalaya, concentration of small glaciers is about 60-65%, while the concentration of larger glacier (>10 km^2) is about 5%.

Source; Based on Glacier inventory,GSI,2009

Glacier Dynamics

1) Specific mass balance gradient vs elevation (2003 to 2017) and snout retreat by of Chorabari Glacier between 1962- 2022 *(Dobhal et al., 2013 and Mehta et al. 2025)*



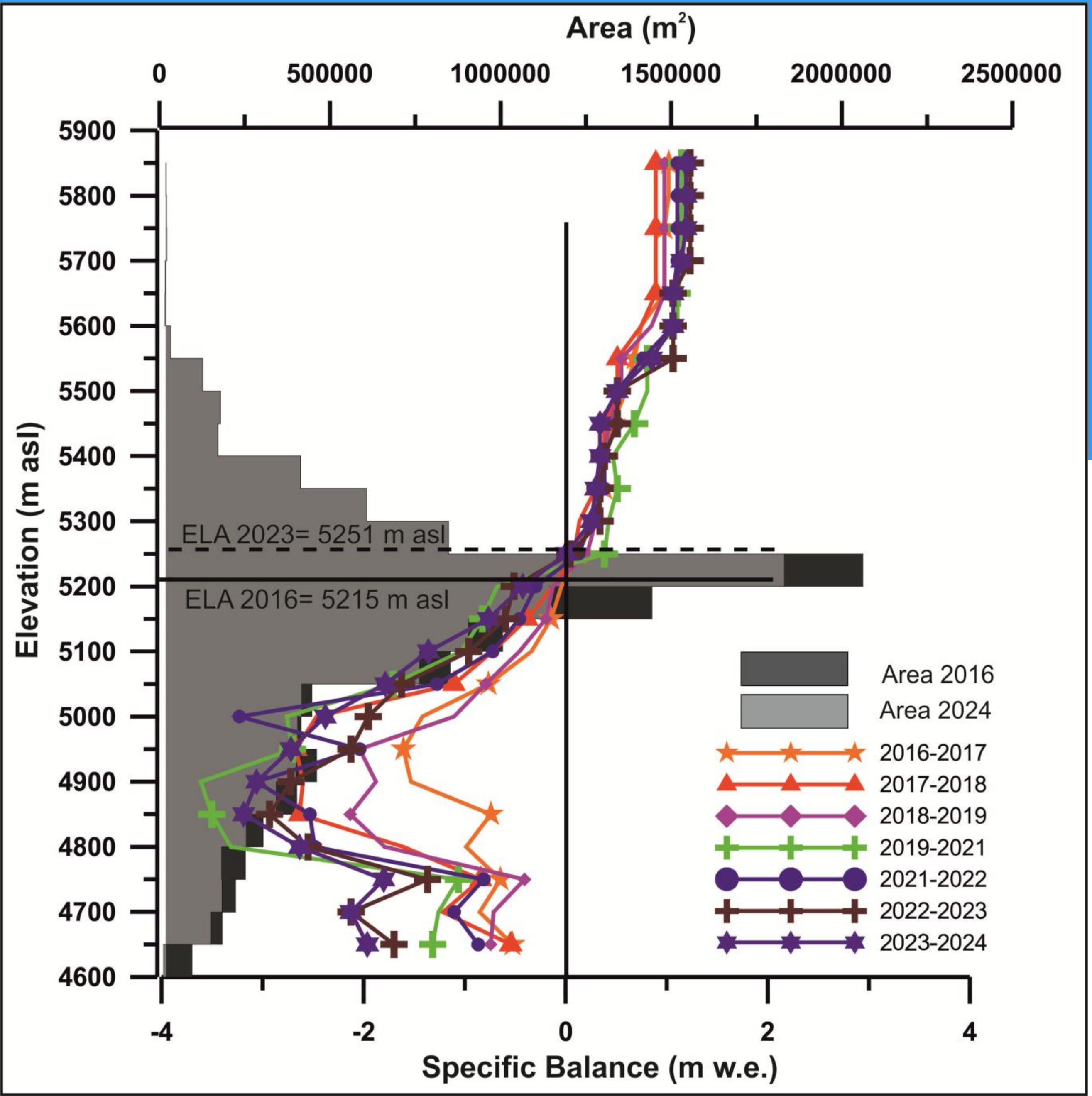
- Total Retreat 418 ± 26 m with rate of 6.9 m a^{-1} between 1962 and 2022
- Total Frontal area lost 117729 ± 8437 m^2 with rate of 1962 ±140 m^2
- Total mass volume lost between 2003 and 2017- (-) 54.9 x 10^6 m^3 w. e. with rate of (-) 4.6 x10^6 m^3 w.e. a^{-1}
- During the same periods the average specific balance was (-) 0.63 m w.e. and the average thickness lost by the glacier was ~8 m w.e.
- The altitude of average ELA of the glacier was 5072 m and the ELA shifted upward ~25 m between 2003 and 2017. Average AAR of the glacier was ~ 0.44
- The Response time for glacier advancement is ~17 year, while the lag time of glacier signal transferred from accumulation area to the snout by glacier flow is about 562 year

12 years data series of annual balance, AAR and ELA of Dokriani Glacier observed during 1992-2013.

Year	Annual balance (b_a) (10^6 m^3 w.e.)	Annual balance (b_a) m w.e.	ELA m asl	AAR	Reference
1992-93	-1.54	-0.22	5030	0.70	Dobhal et al. (2008)
1993-94	-1.58	-0.23	5040	0.69	
1994-95	-2.17	-0.31	5050	0.68	
1995-97	---	---	---	---	
1997-98	-2.41	-0.34	5080	0.67	
1998-99	-3.19	-0.46	5100	0.66	
1999-2000	-2.65	-0.38	5095	0.67	
Cumulative/Average 1992-2000	-13.54/ -2.25	-1.94/ -0.32	5065	0.67	
2007-08	-2.52	-0.36	5095	0.668	Dobhal et al. (2021)
2008-09	-2.9	-0.41	5100	0.664	
2009-10	-1.61	-0.23	5050	0.688	
2010-11	-1.67	-0.24	5055	0.683	
2011-12	-2.41	-0.33	5080	0.675	
2012-13	-2.36	-0.35	5090	0.672	
Cumulative/Average 2007-2013	-13.47/-2.24	-1.92/-0.32	5078	0.675	
Cumulative/Average 1992-2013	-27.01/ -2.25	-3.86/ -0.32	5072	0.67	

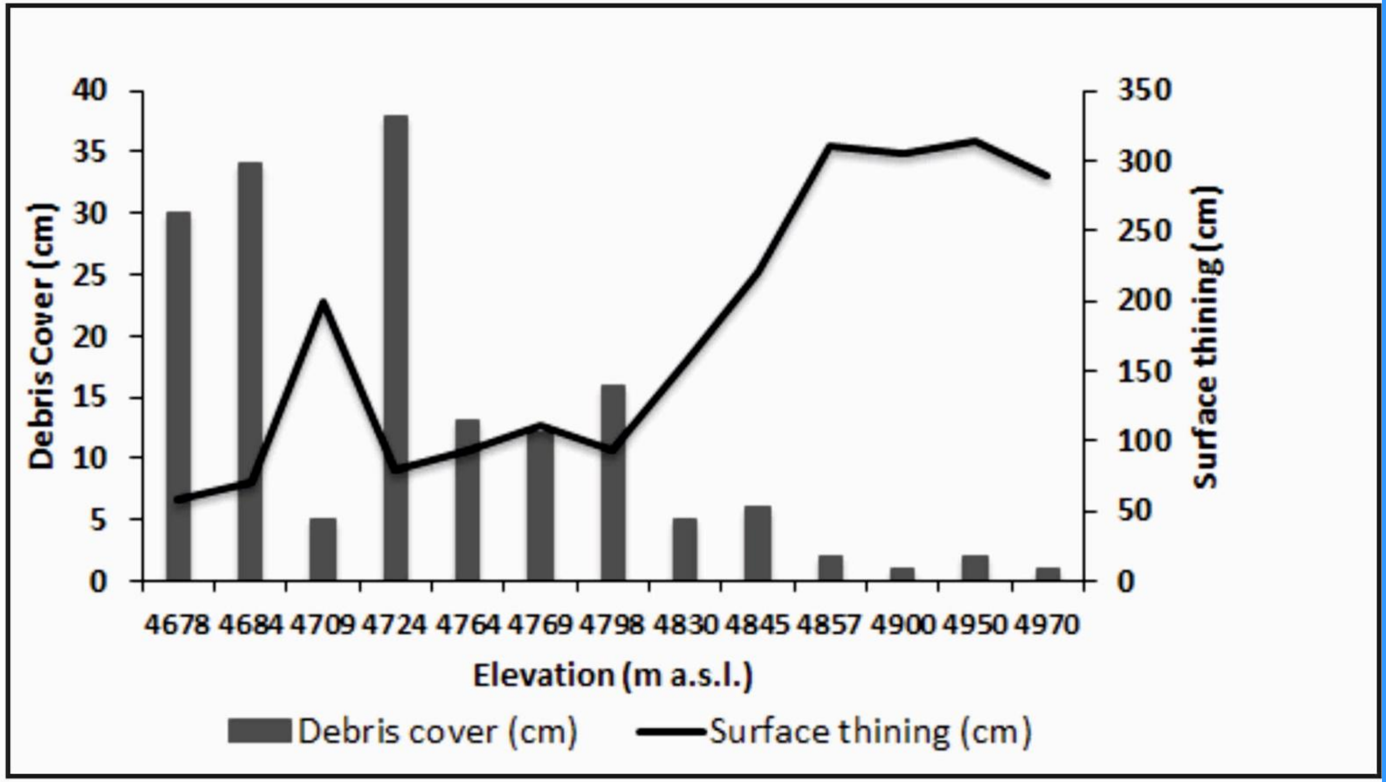
- Total Retreat 1032 ± 73.8 m with rate of 17.2 m a
- T 5 m^2 w
- T 00 (-) 1 10^6 m^3 w age s
- T 13 (-) 1 10^6 m^3 w age s
- T was 5 n b the g
- T nt is ~ al tr snout b

Specific mass balance gradient vs elevation (2016 to 2024) of Pensilungpa Glacier (*Mehta et al., 2021*)



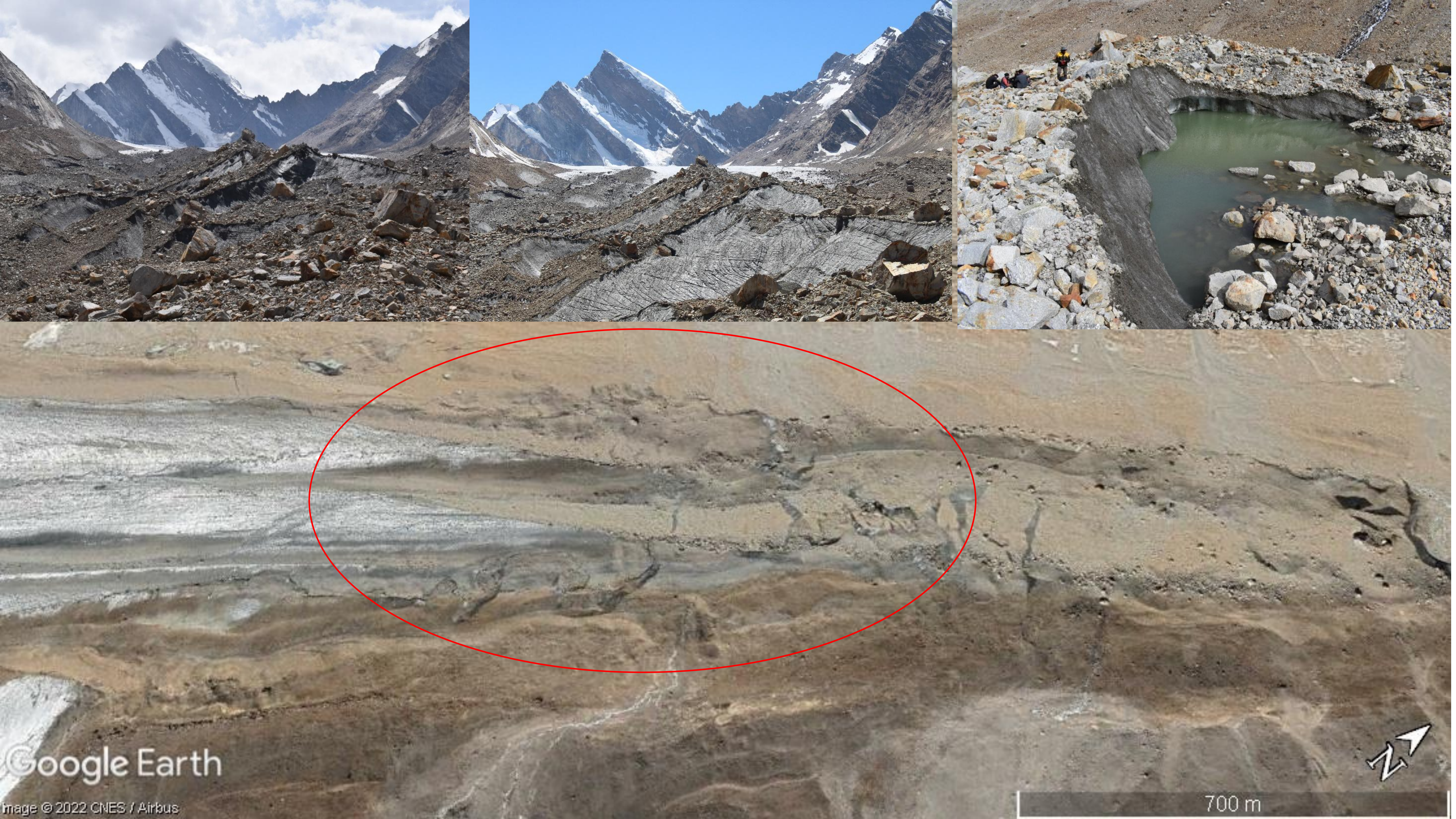
- ✓The average net balance of the glacier to be -5.7 x10^6 m^3 w.e. a^{-1} with an average specific balance of -0.57 m w.e. a^{-1} during the periods 2016 to 2024. Whereas, the ELA ascended by ~36 m.
- ✓Glacier lost ~38.73 x10^6 m^3 w.e. ice volume between 2016 and 2024 and lost approximately 4 m average ice thickness.
- ✓Glacier lost about 6% of total area between 2016 and 2024.
- ✓The Response time for glacier advancement is ~22 year, while the lag time of glacier signal transferred from accumulation area is about 890 year

Debris thickness and Ice melting



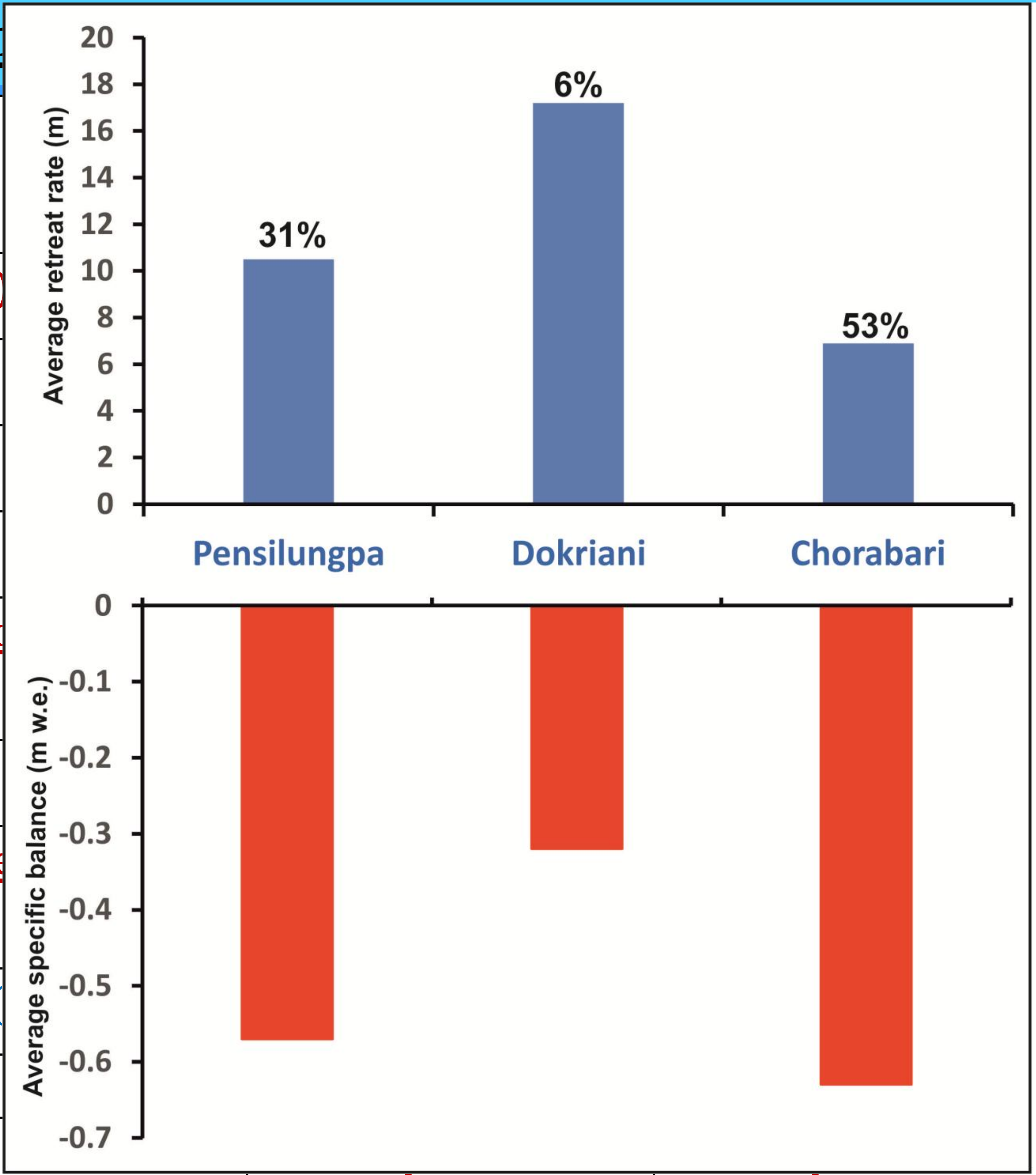
- Old stake over the thick debris cover (2018) showing the surface melting.
- New stake installed over the thick and patchy debris cover (2018).
- Relationship between debris thickness and ice melting along the center line of Pensilungpa Glacier (up to 5000 m a.s.l.) between 2018 and 2019.

(Mehta et al., 2021; REEC)


Google Earth
Image © 2022 CNES / Airbus
700 m

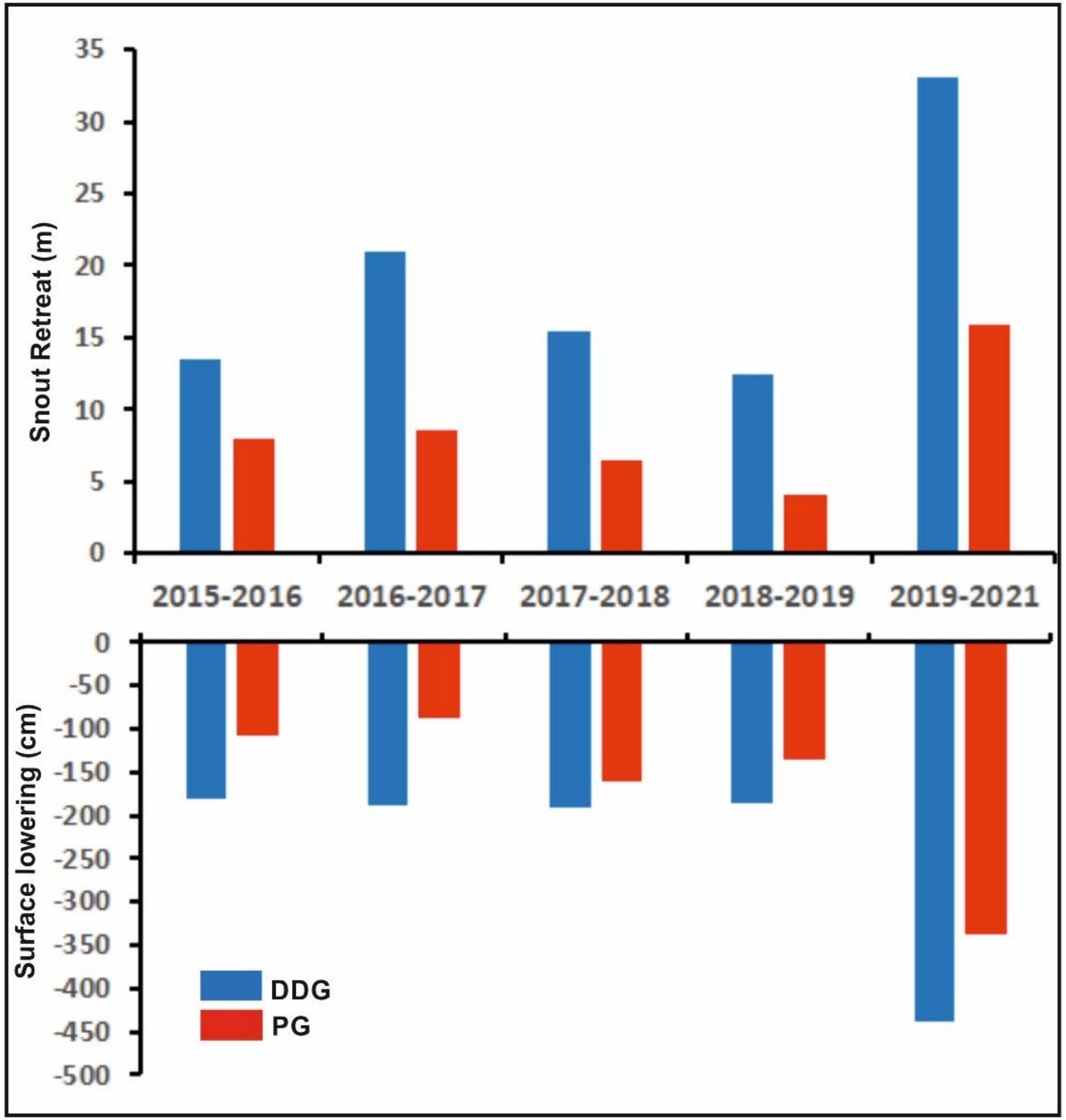
Geome

Status of Glaciers o western Himalaya



Parameters	Pensilungpa Glacier
Snout Height (m asl)	4673
Length (km)	7.5
Area (km^2)	9.98
Debris Cover (%)	31
Av. Ann. Precipitatio	600
Retreat Rate (m/y)	10.5
Specific balance rate	(-) 0.57 (2016-2024)
ELA of the Glacier (	5228
AAR	0.43
Response Time - lag	22- 890 years

Snout Retreat and Surface lowering of Durung-Drung Glacier (DDG) and Pensilungpa Glacier (PG)



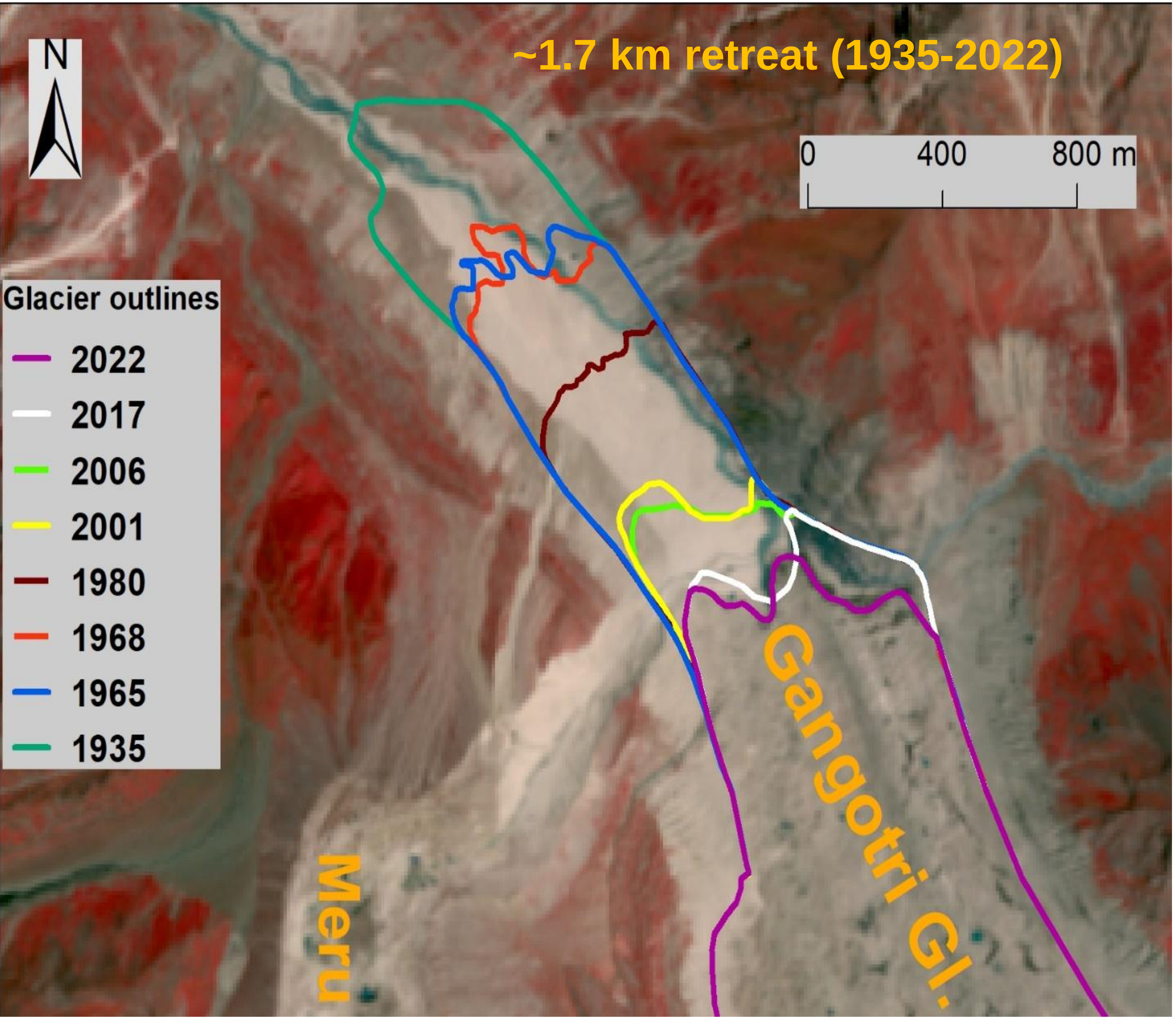
Comparison of surface lowering between the contour interval of 200 m (year 2015-2021) in lower ablation zone and snout retreat of the DDG and PG. The data from 2019 to 2021 is obtained from 02 stakes of PG and 01 stakes of DDG

- ✓Observation suggests that thick debris covered PG retreat with slower rate and lost less thickness compared to partly debris covered DDG.
- ✓Similarly since 2015 to 2021 PG retreat 45±18 m with rate of 6.4±3 ma^{-1} and lost~ 8 m surface thickness between 4690 m asl and 4830 asl.
- ✓Whereas, DDG retreat 95.5±53 m with rate of 13.6 ±7.5 ma^{-1} and lost ~ 11 m surface thickness between 4140 m asl and 4350 asl.

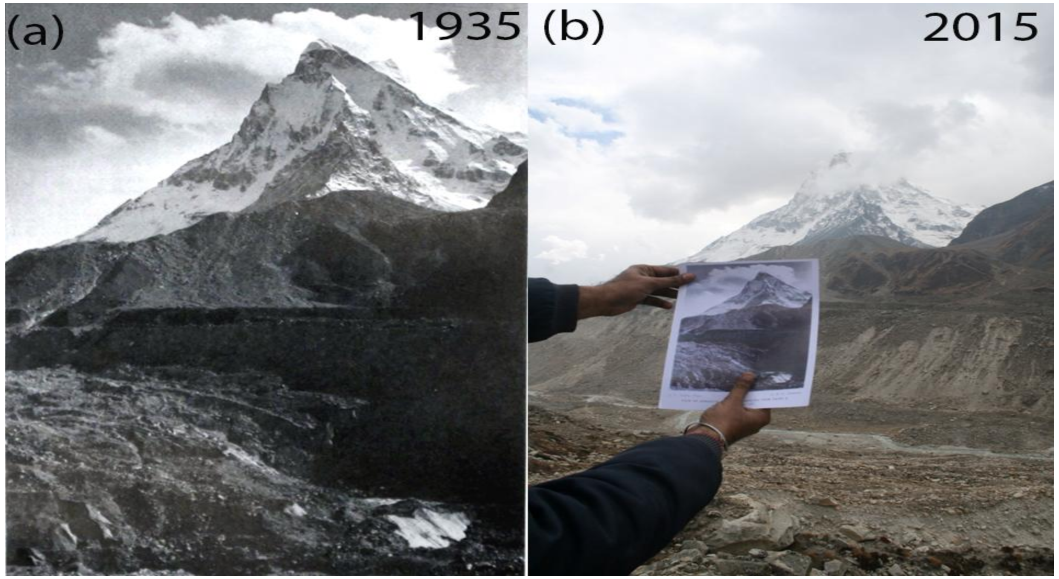
(Mehta et al., 2021)

Frontal retreat of Gangotri Glacier between 1935 and 2022 (*Bhambri et al., 2024*)

Frontal retreat



Repeated photography



Time interval	Total retreat (m)	Rate of retreat (m a^{1})
1935-1965	-498 ± 51	-16.6± 1.7
1965-1968	-17.7 ± 12.8	-5.9 ± 4.2
1968-1980	-323.2 ± 21.5	-26.9 ± 1.8
1980-2001	-441.0 ± 26.2	-21.0 ± 1.2
2001-2006	-37.0 ± 20	-7.4 ± 4
2006-2017	-241 ± 20.9	-21.9± 1.9
2017-2022	-169 ± 33.5	-33.8± 6.7
Total	-1726.9 ± 51	-19.8± 0.3

Bhambri et al. (2023, JoGSI)

Palaeoglaciation & Paleoclimate study in Suru Basin, Ladakh

Stages	Age (ka)	Area (km^2)	Average Ice thickness (m)	Ice Volume (km^3)	Mean ELA (m asl)
Stage-I	33±6 - 23±4	640	173	111	4836
Stage-II	16±6	569	150	85	4852
Stage-III	13±2 -11±2	398	95	39	4995
Stage-IV	10±1 - 7 ±0.7	299	86	27	5141
Stage-V	2.8±0.4	214	76	16.3	5169
PD	-	138	65	8.8	5374
	Area Lost	502 (78%)	Volume lost	102 (92%)	∆ELA = 538

- ✓ The glaciers in Suru Basin have fluctuated greatly throughout the Marine Isotope Stages (MIS) 3/2 to the Little Ice Age (LIA), and are critical in understanding the linkages between regional and global climate change.
- ✓ The data provide a record of six glacial advances of decreasing magnitude, dated (i) 33–23 ka, LGM (ii) 16 ka, Henrich event, (H 1) (iii) 13–11 ka, Younger Dryas (YD) (iv) 10–7.3 ka, Global cooling (v) 2.8–2.3 ka, Late-neoglaciation vi) 0.7–0.4 ka. LIA

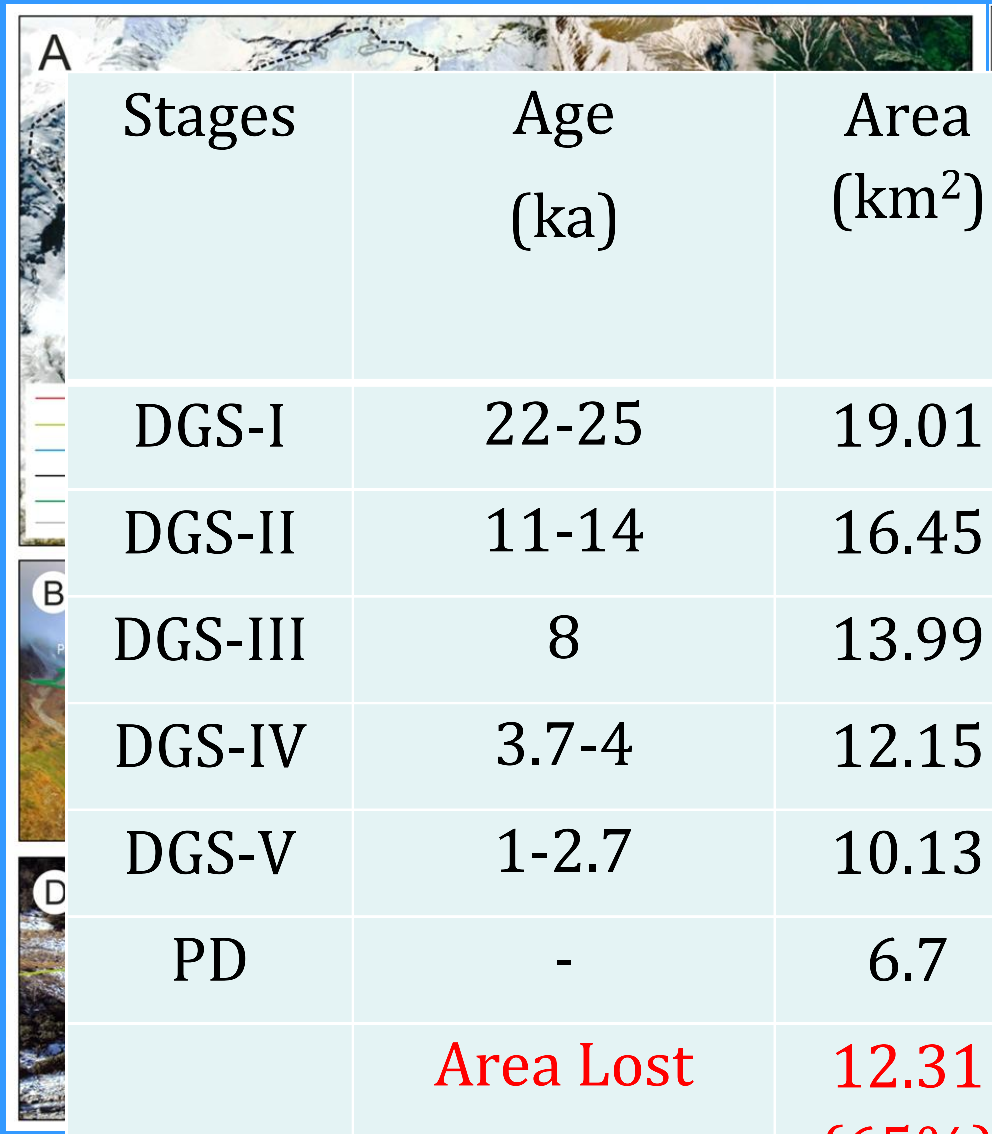
Kumar et al., 2021, (QSR); Mehta et al., 2021 (REEC)

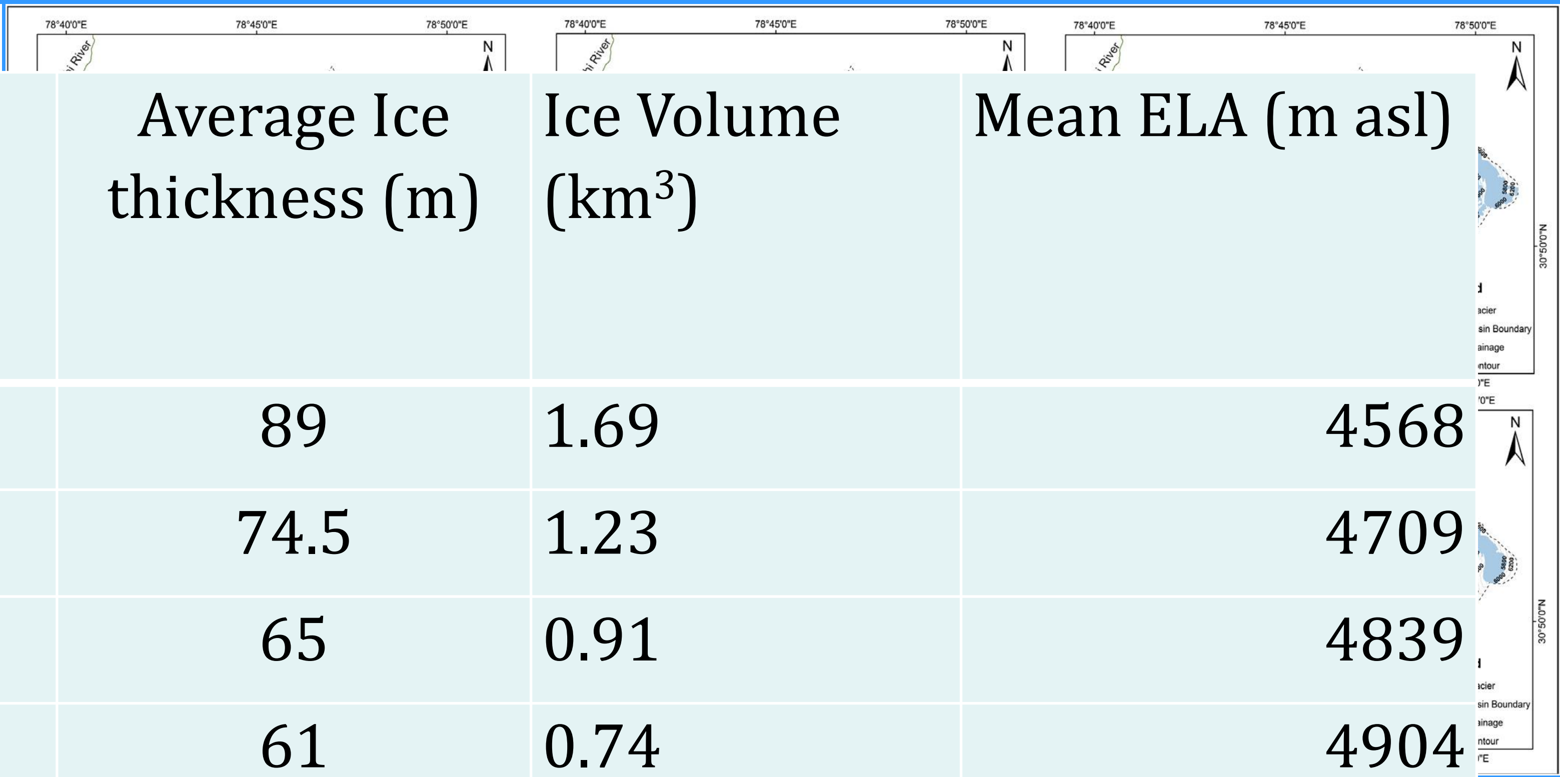
Glacier advance stages at Mandakini and Tons River basin

Location	Stages	Dates (ka)	ELA (m)	Pred.Sp. bl. (m w eq.)	Area (km^2)
Mandakini River valley (Chorabari Glacier)	RGS	13±2	4747±229	(+) 0.31	~ 31
	GhGS	9±1	4817±224	(+) 0.08	~ 30
	GGS	7±1	4951±197	(-) 0.34	~ 23
	KGS	5±1	5022±190	(-) 0.57	~ 22
		PD	5120±10	(-) 0.73	~ 15
		∆ELA	~ 373 m	Area Lost	~ 16 (51.6%)
Tons River valley (Jaundhar Glacier)	HDGS 1	20±3	4510±320	(+) 0.5	~141
	HDGS 2	16±2	4640±250	(+) 0.6	~137
	SGS	8±1	4700±216	(+) 0.16	~131
	OGS	6±1	4800±152	(+) 0.09	~123
	GGS	3±0.6	4878±72	(+) 0.09	~118
		PD	4960±46	(-) 0.08	~96
		∆ELA	~ 450 m	Area Lost	~ 46 (32 %)

Mehta et al 2013; Mehta et al 2014

Glacier advance stages at Dingad basin





Stages	Age (ka)	Area (km^2)	Average Ice thickness (m)	Ice Volume (km^3)	Mean ELA (m asl)
DGS-I	22-25	19.01	89	1.69	4568
DGS-II	11-14	16.45	74.5	1.23	4709
DGS-III	8	13.99	65	0.91	4839
DGS-IV	3.7-4	12.15	61	0.74	4904
DGS-V	1-2.7	10.13	52	0.53	4958
PD	-	6.7	49	0.28	5062
	Area Lost	12.31 (65%)	Volume lost	1.42 (83%)	ΔELA = 494

Shukla, Mehta et al. 2018

Glacial Stages identification and compared

Glacial Stages	Suru River Basin	Tons River Basin	Dingad valley	Mandakini Basin
Stage I	25-33 ka	20 ka	22-25 ka	
Stage II	16-20 ka	16 ka	11-14 ka	13 ka
Stage III	9-13 ka	8 ka	8 ka	9 ka
Stage IV	6-7 ka	6 ka	4- 3.7 ka	7 ka
Stage V	0.6-2.8 ka	1-2.7 ka	3 ka	5 ka

Glacier Lake inventory of Uttarakhand *(Bhambri et al. 2013)*

Main type	Sub type	Total number	%	Total area $(m)^2$	%	Mean area $(m)^2$
Moraine- dammed lake	End moraine-dammed lake	44	3.5	1596367	21.0	36281
	Lateral moraine-dammed lake	67	5.3	652054	8.6	9732
	Recessional moraine-dammed lake	214	16.9	1589375	20.9	7427
	Other moraine-dammed lake	4	0.3	98143	1.3	24536
Ice-dammed lake	Supra-glacial lake	809	63.9	2000524	26.3	2473
Glacier erosion lake	Cirque lake	48	3.8	1174222	15.5	24463
	Other glacial erosion lake	77	6.1	466491	6.1	6058
Other glacial lake	Other glacial lake	3	0.2	17695	0.2	5898
	Total	1266		7594871		

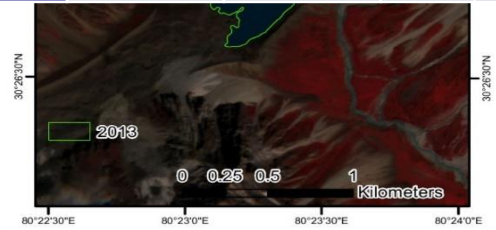
Glacier Lake inventory of Himachal Pradesh *(Bhambri et al., 2019)*

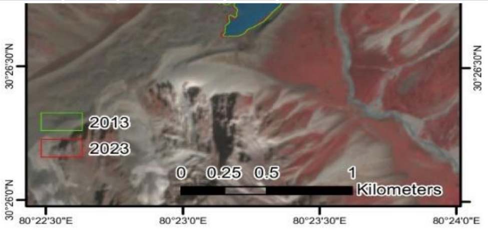
Main type	Sub type	Total number	%	Total area $(m)^2$	%	Mean area $(m)^2$
Moraine- dammed lake	End moraine-dammed lake	65	6.8	2284636	23.8	35148
	Lateral moraine-dammed lake	36	3.8	321685	3.4	8936
	Medial moraine-dammed lake	3	0.3	21339	0.2	7113
	Other moraine-dammed lake	241	25.2	2514578	26.2	10434
Ice-dammed lake	Supra-glacial lake	228	23.8	439442	4.6	1927
	Glacier-Ice dammed lake	50	5.2	269549	2.8	5391
Glacier erosion lake	Cirque lake	7	0.7	316576	3.3	45225
	Other glacial erosion lake	291	30.4	3126277	32.6	10743
Other glacial lake	Debris dammed lake	28	2.9	220309	2.3	7868
	Artificial Lake	9	0.9	79703	0.8	8856
	Total	958		9594094		

Potentially dangerous glacial lakes in Uttarakhand

Hazard category	Cumulative Weightage (CW)	Number of Lakes

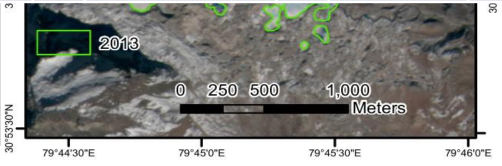
Lake ID	Latitude	Longitude	Area 2013 (sq. m)	Area 2023 (sq. m)	W	Change in Area (sq m)	W	Valley Name	Elevation	W	Downstream Slope (in degree)	W	Distance Between GL & PG (m)	W	Dam Height (in m)	W	Dam Type	W	Distence Between GL & Settlements (in km)	W	Upstream slope (in degree)	W	CW	Hazard Category	Name of Lake
L1	30°44'44.86"N	78°59'7.66"E	244613	366871	50	122258	50	Bhilangana	4760	40	31	30	0	50	6	40	Moraine Dammed	50	21	10	32	50	370	A	Masar Tal
L2	30°33'52.61"N	80°10'35.53"E	199089	215479	50	16390	50	Goriganga	4900	40	17	20	0	50	17	20	Moraine Dammed	50	17	20	26	40	340	A	Safed Tal
L3	30°23'30.34"N	80°31'55.11"E	110030	127498	50	17468	50	Dhauliganga	4785	40	27	20	0	50	15	20	Moraine Dammed	50	17.0	20	24	30	330	A	
L4	30°54'4.20"N	79°45'18.64"E	201705	211187	50	9482	50	Alaknanda	4697	40	13	10	0	50	5	50	Moraine Dammed	50	18.0	20	10	10	330	A	Vasudhara
L5	30°26'43.97"N	80°23'14.58"E	114890	119060	50	4170	40	Dhauliganga	4341	30	38	30	0	50	4	50	Moraine Dammed	50	28.4	10	13	20	330	A	Mabang Tal
L6	30°49'50.16"N	79°53'37.69"E	54661	59915	30	5254	50	Alaknanda	5205	50	28	20	85	50	6	40	Moraine Dammed	50	17.0	20	15	20	330	A	
L7	30°53'24.74"N	79°18'12.96"E	22275	26188	20	3913	40	Alaknanda	5372	50	24	20	0	50	13	30	Moraine Dammed	50	18.0	20	30	40	320	B	
L8	30°59'26.25"N	79°21'33.95"E	37173	41155	30	3982	40	Alaknanda	5360	50	28	20	515	10	5	40	Moraine Dammed	50	9.0	30	30	50	320	B	
L9	30°59'38.33"N	79°21'17.29"E	17459	23773	20	6314	50	Alaknanda	5431	50	12	10	0	50	6	40	Moraine Dammed	50	20.0	10	17	30	310	B	
L10	30°15'50.58"N	80°42'46.88"E	28238	30814	30	2576	30	Kutiyangti	4550	40	16	20	0	50	11	30	Moraine Dammed	50	21.5	10	21	30	290	B	
L11	30°20'12.78"N	80° 4'26.30"E	3521	27220	20	23699	50	Goriganga	4241	30	14	10	0	50	4	50	Moraine Dammed	50	13.0	20	10	10	290	B	
L12	30°29'28.09"N	80°22'27.54"E	53309	53490	30	181	10	Dhauliganga	5079	50	18	20	370	10	3	50	Moraine Dammed	50	8.7	30	23	30	280	B	
L13	30°22'20.78"N	80°36'13.13"E	46828	46849	30	21	10	Kutiyangti	4860	40	11	10	94	50	6	40	Moraine Dammed	50	34.0	10	16	30	270	C	
L14	31° 8'16.48"N	79°18'31.69"E	23425	24473	20	1048	20	Bhagirathi	5692	50	24	20	110	10	30	10	Moraine Dammed	50	5.3	50	25	40	270	C	
L15	30°54'51.47"N	78°47'41.29"E	10396	12142	20	1746	20	Bhagirathi	4670	50	31	30	612	10	11	30	Moraine Dammed	50	20.1	10	31	50	270	C	
L16	30°16'34.07"N	80°27'8.28"E	7191	9805	10	2614	30	Dhauliganga	4284	30	10	10	0	50	4	50	Moraine Dammed	50	30.9	10	16	30	270	C	
L17	31° 9'5.73"N	79°16'1.54"E	47030	45873	30	-1157	10	Bhagirathi	5451	50	23	20	269	10	8	40	Moraine Dammed	50	8.5	30	15	30	270	C	
L18	30°48'48.23"N	79°55'33.24"E	52650	55691	30	3041	30	Alaknanda	4965	40	87	50	585	10	12	30	Rock Dammed	10	9.9	30	21	30	260	C	
L19	30°54'29.15"N	79°49'27.84"E	74609	74810	30	201	10	Alaknanda	5061	50	27	20	750	10	19	20	Moraine Dammed	50	8.8	30	28	40	260	C	Geldhang Tal
L20	30°24'30.27"N	80°30'40.53"E	31293	31649	30	356	10	Dhauliganga	4750	40	20	20	1227	10	9	40	Moraine Dammed	50	19	20	29	40	260	C	
L21	30°38'22.34"N	79°41'39.93"E	16655	16829	20	174	10	Alaknanda	4270	30	18	20	840	10	31	10	Moraine Dammed	50	12.0	20	35	50	220	C	Machchhi Tal
L22	30°26'16.83"N	79°57'34.22"E	38219	43025	30	4806	40	Alaknanda	4520	40	21	20	NA	10	23	10	Lateral Moraine Dammed	40	33.4	10	55	50	250	C	
L23	30°54'42.55"N	78°57'28.11"E	93674	85913	50	-7761	10	Bhagirathi	4726	40	13	10	NA	10	20	10	Lateral Moraine Dammed	40	9.5	30	43	50	250	C	Kedar Tal
L24	30°53'30.98"N	78°49'5.42"E	38336	38133	30	-203	10	Bhagirathi	4670	40	8	10	NA	10	5	50	Lateral Moraine Dammed	40	23.0	10	30	40	240	C	
L25	30°27'21.25"N	80°30'56.55"E	54068	53413	30	-655	10	Dhauliganga	5274	50	35	30	1500	10	16	20	Moraine Dammed	50	22.7	10	17	30	240	C	Pyungru Tal

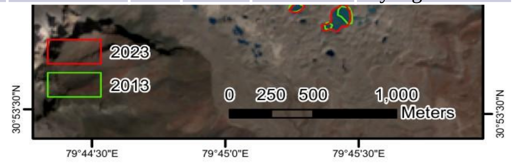




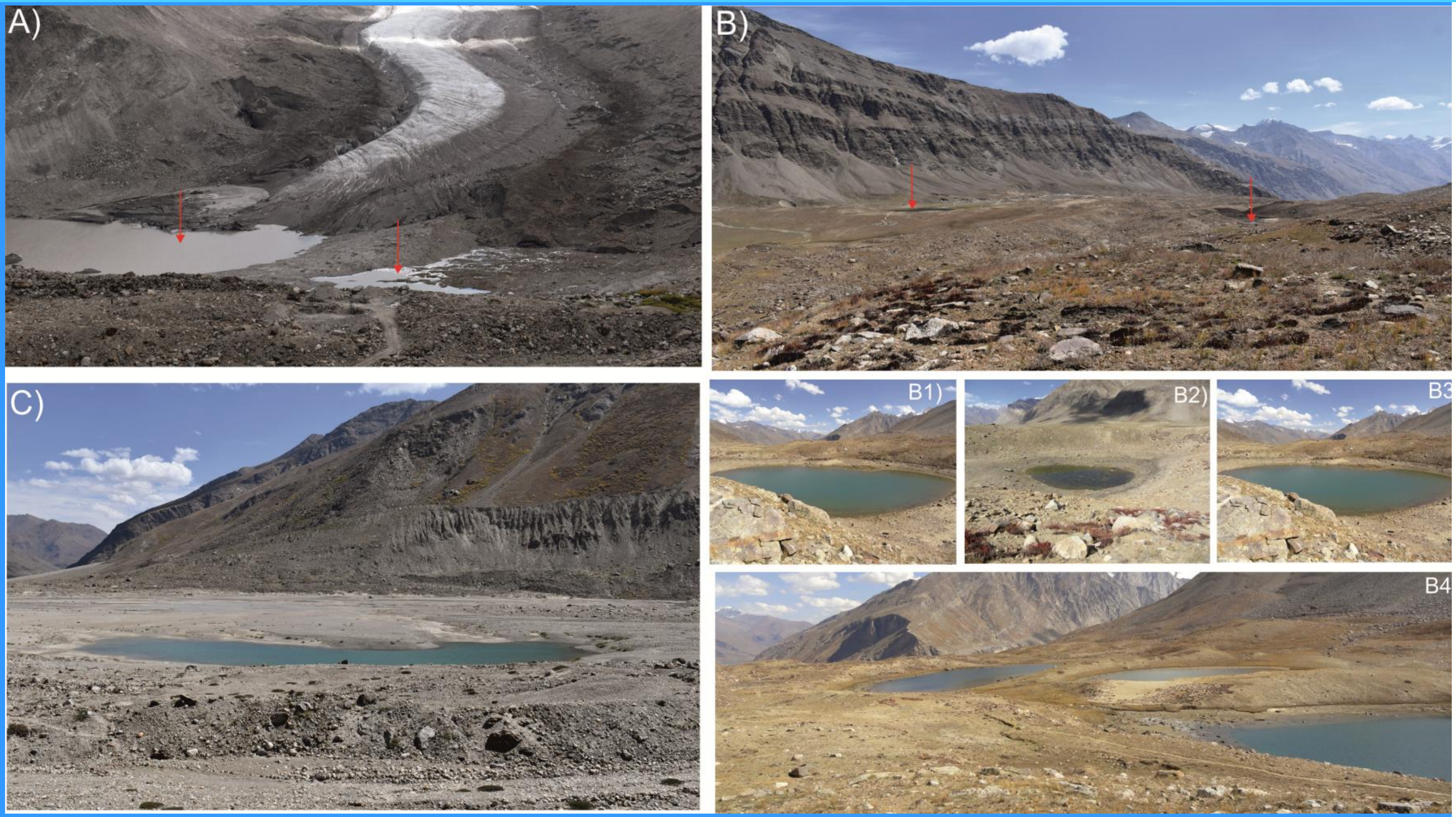
2023- 119060 m^2 Total area increased- 3.6%

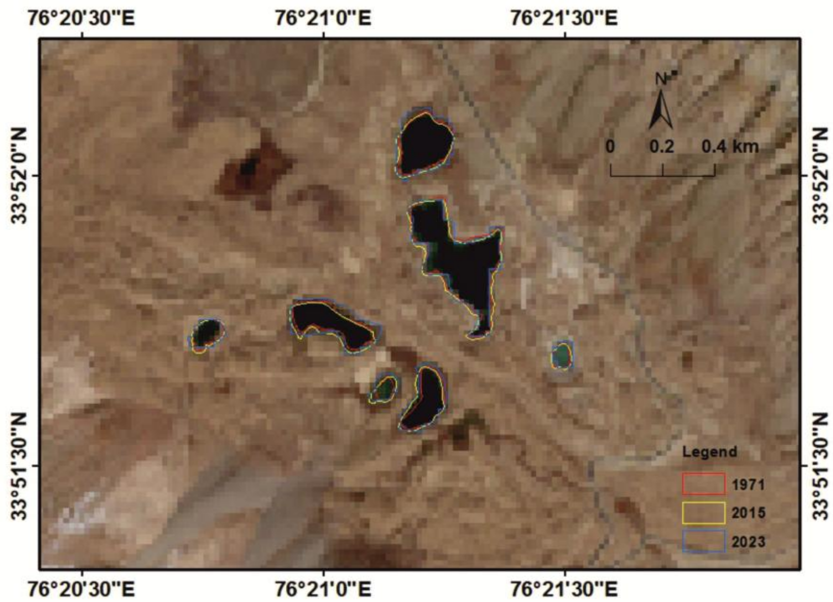
211187 m^2 increased- 4.7%

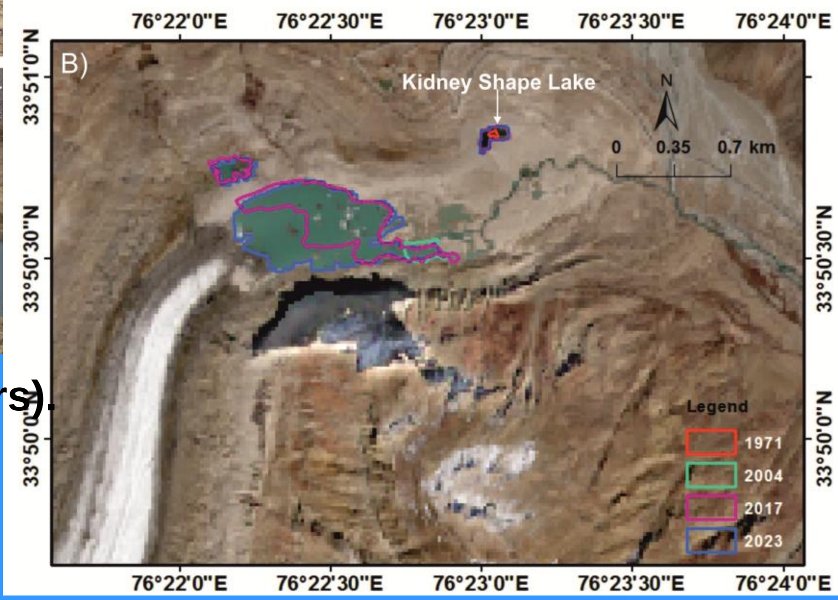




Glacier Lake Changes in Suru and Doda River Basins







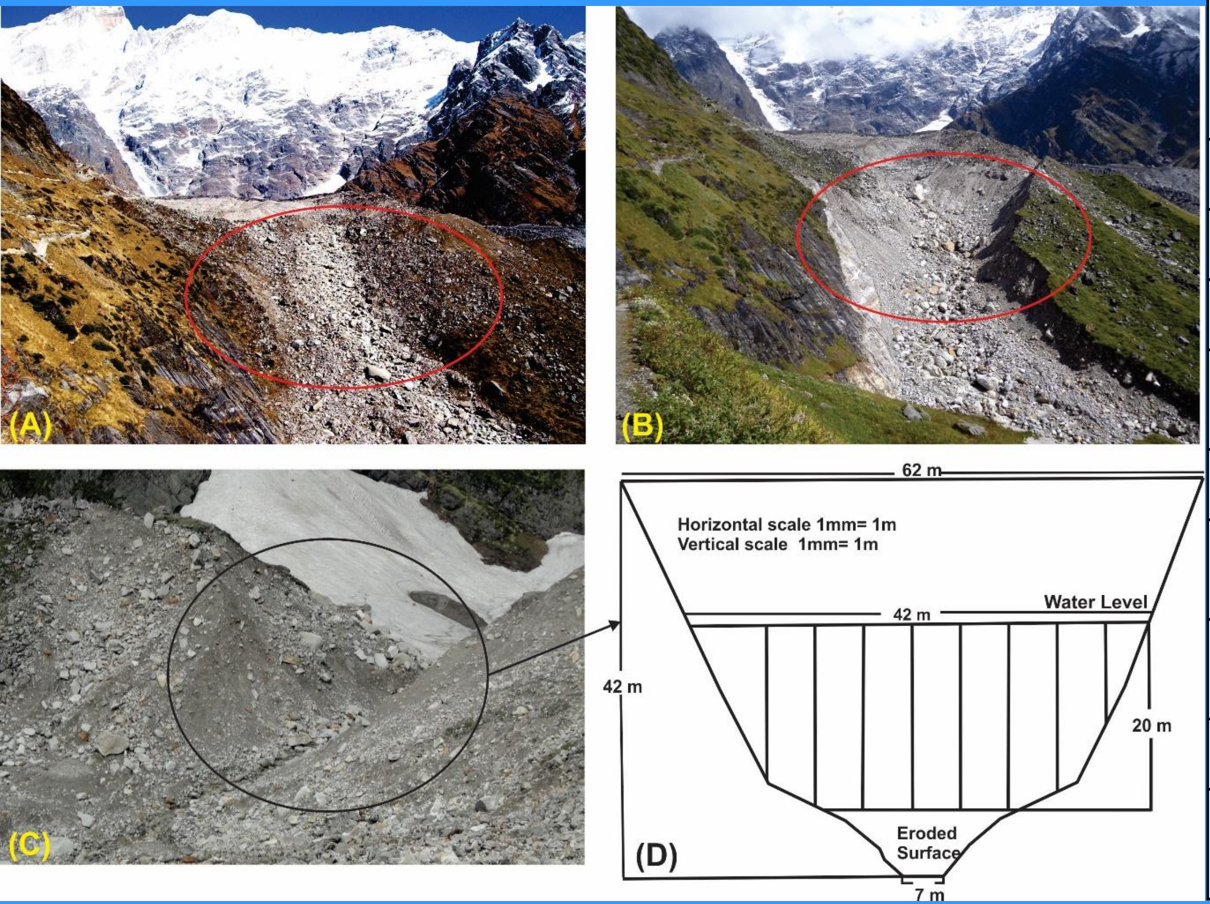
1) **Peri Glacial Lake (08 Lakes) increased 13 % area between 1971 and 2023 (52 years).**

2) **The expansion of the proglacial lake near snout of Durung-Drung Glacier was notable, with approximately a 164% increase in area between 2004 and 2023.**
Area 2004= 17251 m^2 **Area 2023= 286659 m^2**

Kunmar et al., 2024)

Natural Hazards- 2013 Kedarnath Disaster

Estimated discharge of Chorabari Lake during lake burst, June 2013, using area slope method



Parameters	Unit	Value	Equations (methods)
Area of Cross-section (A)	$meter^2$	1375	
Hydraulic Radius (R)	meter	1.93	$R=A/P$
Wetted Perimeter (P)	meter	713.25	$P= b+2(((T-b)/2)^2+h^2)^{1/2}$
Slope gradient of stream bed (S)	meter/meter	0.35	
Roughness coefficient (n)	---	0.21	$n=0.32S^{0.30}R^{-0.16}$
width of cross-section at top (T)	meter	42	
width of cross-section at base (b)	meter	7	
Water level height (h)	meter	20	
Discharge (Q)	**$meter^3/sec$**	**1429.01**	**$Q= 1/n\ AR^{2/3}S^{1/2}$**

Equation adopted from Manning (1891), Lane (1955), Jarrett (1988).

(Mehta et al., 2017)

The volume of debris deposited (+) and removed (-) during the disaster of 16-17 June 2013

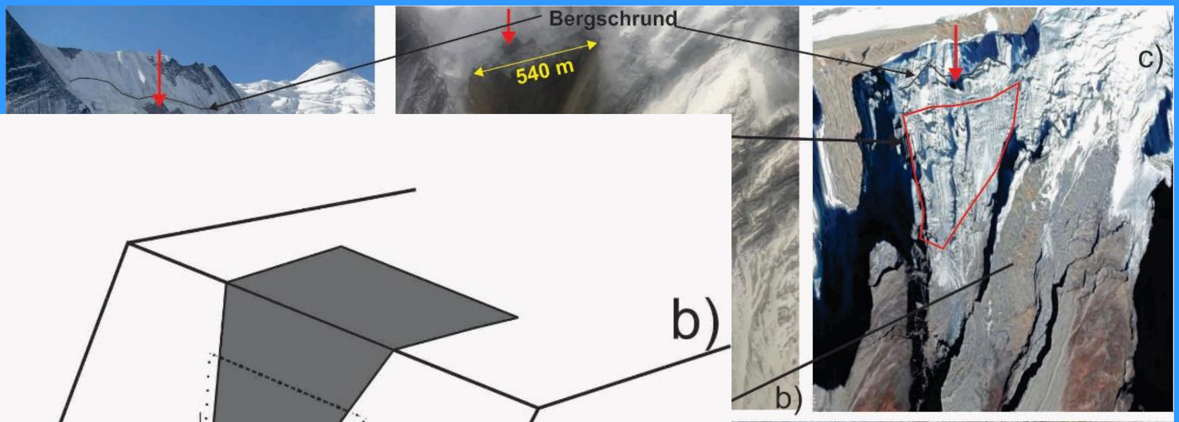
SN	River Valley	Location	Site	Length of River (km)	Area affected (m^2)	Estimated Volume Deposited/Removed (m^3)	Stream Gradients
1.	**Alaknanda**	Lambaghar	JP Dam and upto confluence of Alaknanda and Khiro Ganga	~1.3	21.2×10^4	~ (+) 2.44×10^6	**49 m/km**
		Govindghat	Govindghat town	~0.65	3.6×10^4	~ (+) 0.3×10^6	**45 m/km**
	Laxman Ganga	Bhyundar Village	Village and cultivated land	~0.83	4×10^4	~ (-) 2.9×10^6	**75 m/km**
		Pulna village	Village and cultivated land	~0.70	3.6×10^4	~ (+) 0.72×10^6	**62 m/km**
2.	**Mandakini**	Kedarnath	Chorabari Lake and Glacier moraine up to 3970 m asl	~0.60	5.9×10^4	~ (-) 2.1×10^6	**243 m/km**
			Kedarnath town	~0.67	43×10^4	~ (+) 3.9×10^6	**70 m/km**
		Rambara	Rambara town and surrounding area	0.46	2×10^6	~ (-) 2.6×10^8	**235 m/km**
		Gaurikund	Gaurikund town	0.38	0.84×10^4	~ (-) 0.29×10^6	**222 m/km**
			Ghodapadav	0.10	0.31×10^4	~ (-) 0.04×10^6	
		Sonprayag	Sonprayag town	0.50	7.3×10^4	~ (+) 1.4×10^6	**52 m/km**

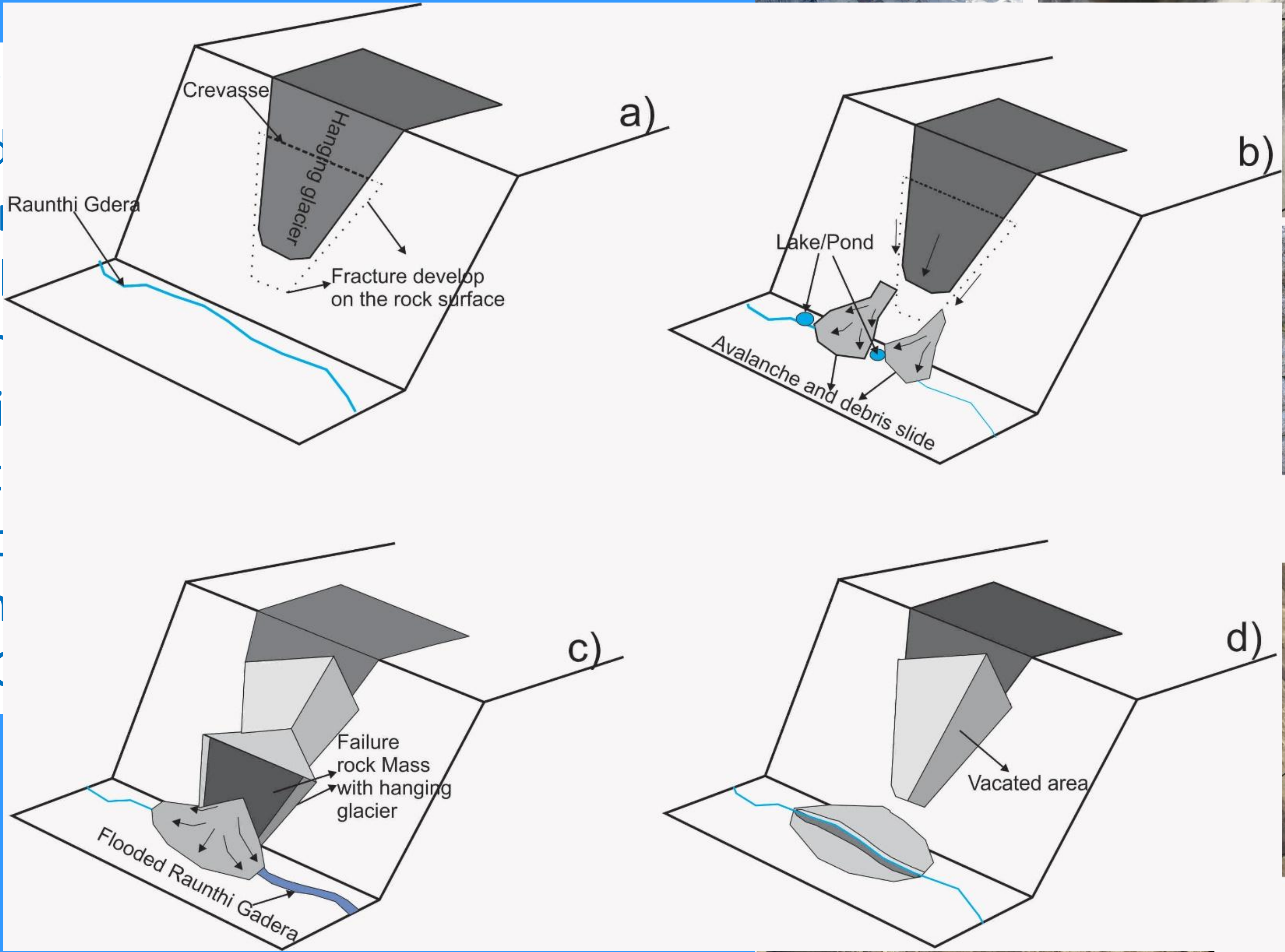
Consequences

Consequences

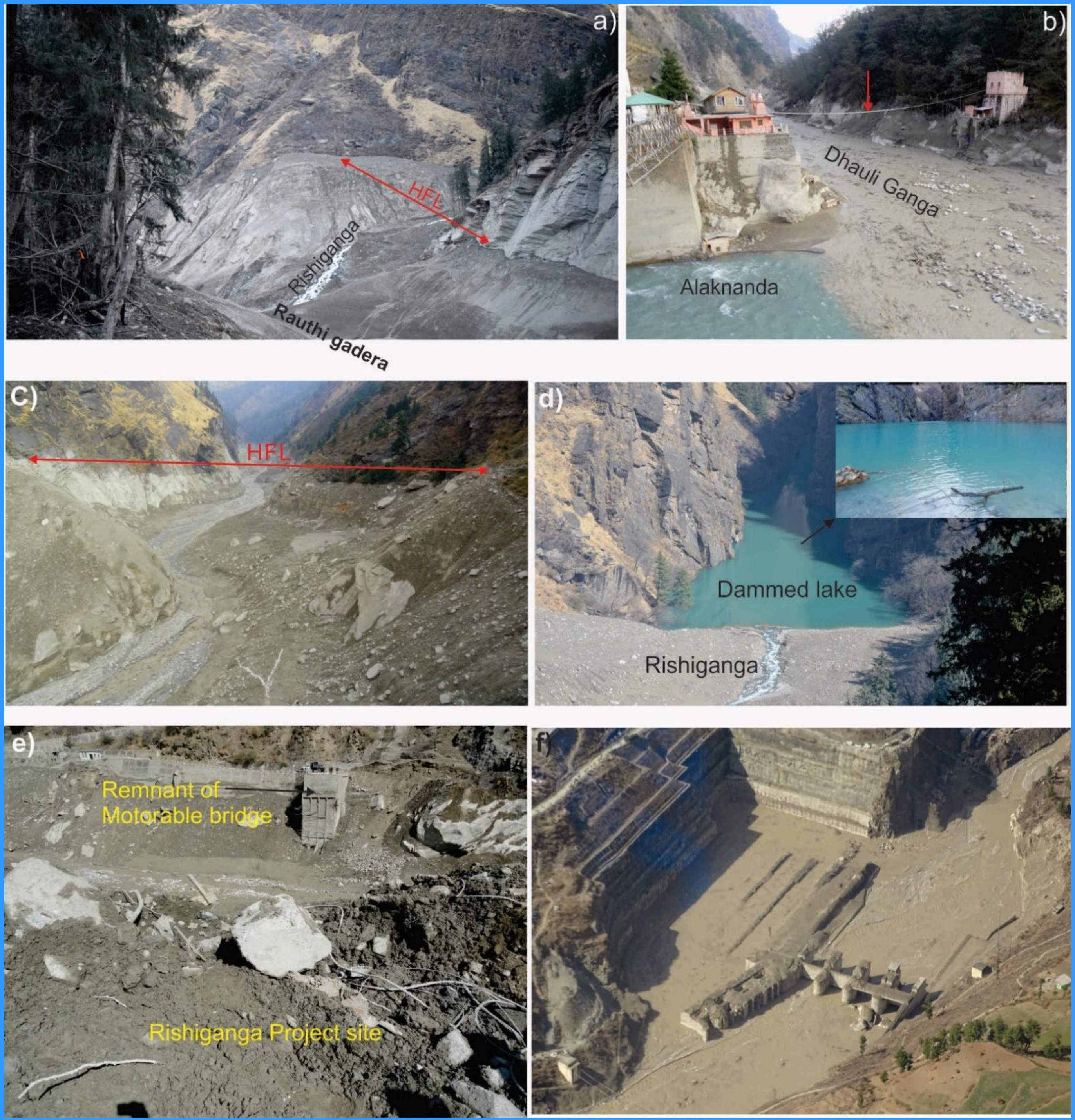
Rishiganga Disaster, 2021

- A hug
  m wid
  hangi
  main
  towar
- Rock i
  Schist
- The ro
  rock m
  20 MC





Consequences



Conclusion- Why are Himalayan glaciers receding? major concern

- Based on the our findings, it can be assumed that the recent climate warming in the Himalaya may be traced back to the end or even the coldest time of the LIA. The Himalayan glaciers have responded sensitively to the enhanced midlatitude westerlies during the LIA.

- The temperature and precipitation data (1901–2021) suggest an increase in the temperature and no changes in precipitation during winter period. This increase in temperature (shift from solid to liquid precipitation) has been identified as one of the major factors responsible for decrease in snowfall over the Indian Himalayan region

- This might have caused reduction in the glaciated area in the region as the precipitation and temperature of winter periods play an important role in nourishing the glaciers.

- The data also suggested that the climate change is mainly the result of a temperature increase in winter periods with a much smaller increase in the summer season. This means that summer time is expanding and winter time is shrinking.

- The study also assumed that due to continuous rise in the air temperature in line with the global trend, the melting would increase, and it is possible that the precipitation of summer periods at higher altitudes will change from snow to rain and that may influence the summer accumulation pattern. Moreover, extreme events such as cloudbursts, excessive rainfall, flash floods and avalanches may increase in the future

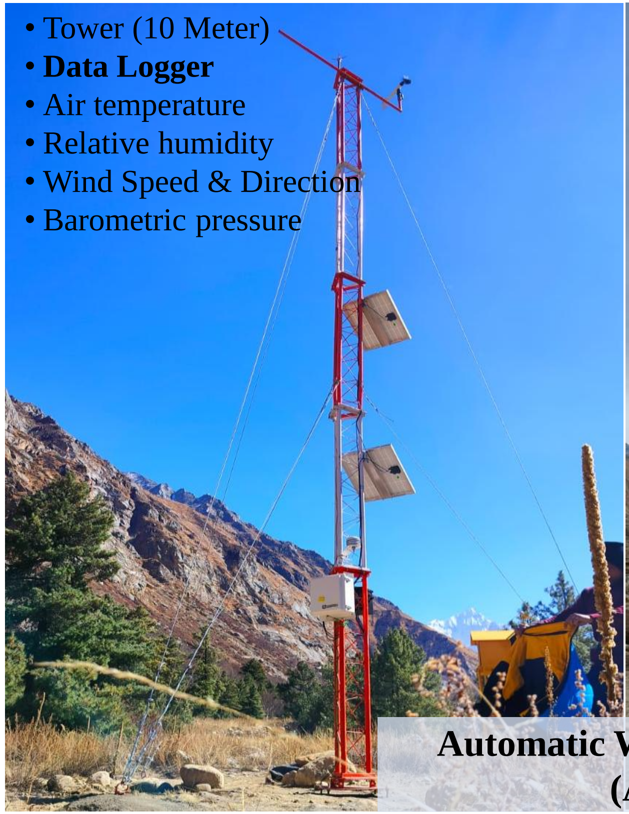
- Consequently, more negative mass balance will translate into a pronounced to increase the size of glacier lake and which will increase the future risk of GLOF in the Himalaya and adjacent regions.

Long-term Monitoring and Establishment of Observatories at Gangotri, Dokriani and Chorabari Glaciers

Base camp (Bhojwasa ~3800 m)

Automatic Water Level and Velocity Recorder (AWLVR)

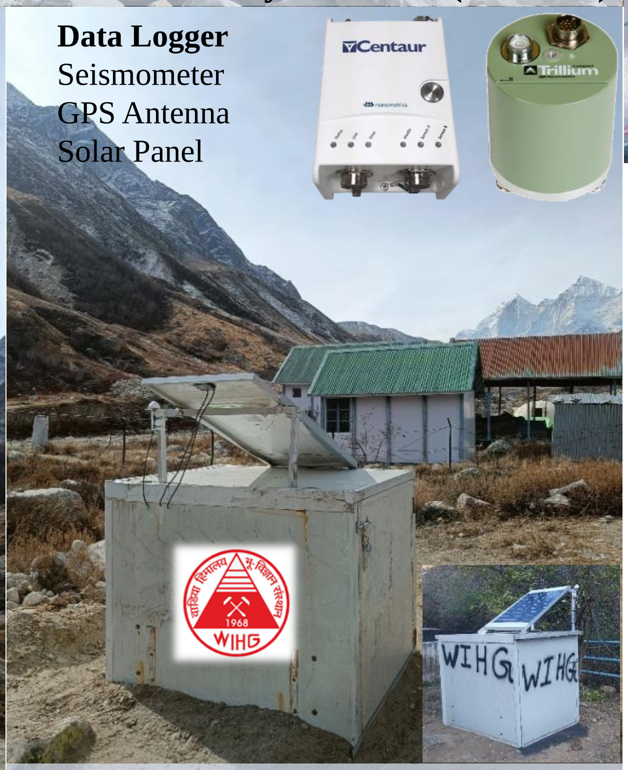
- Tower (10 Meter)
- **Data Logger**
- Air temperature
- Relative humidity
- Wind Speed & Direction
- Barometric pressure



- Tower (10 Meter)
- Snow Depth
- **Data Logger**
- Air temperature
- Relative humidity
- Precipitation
- Wind Speed & Direction
- Barometric pressure

Automatic Weather Stations (AWS)

Data Logger
Seismometer
GPS Antenna
Solar Panel



Broadband Seismic Stations (BBS)

Mapping and monitoring of the Gangotri group of glaciers and glacial lakes

Round the year hydro-meteorological observations

Risk assessment of glacial hazards (GLOF, debris flow, flash floods) using meteorological, hydrological, seismological and satellite data

USDMA Project, 1.83 Cr.


THANK YOU