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Unreported mass movement cascades and future Glacial Lake Outburst Flood (GLOF) hazard in Jammu and Kashmir, Western Himalaya

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Table S1: Remotely sensed data used in the present study

	Product	Spatial resolution	Temporal coverage	Purpose
Satellite Data	Landsat 7 ETM+	15 m (Band 8 PAN) 30 m (Bands 1 to 5, and 7) 60 m (Band 6)	1999-2012	Glacier and lake mapping
	Landsat 8 OLI	15 m (Band 8 PAN) 30 m (Bands 1 to 7, and 9) 100 m (Band 10 and 11)	2013-2015	Glacier and lake mapping
	PlanetScope image	3 m	2016-2024	Mapping crevasses, ice calving, avalanche release areas, and runouts
	Google Earth collection	< 0.5 m	2018-2024	Glacier and lake mapping
	ALOS PALSAR DEM	12.5 m	Acquisition date: 2011	Terrain
Auxiliary data	Land Use and Land Cover (ESRI)	10m	2023	Manning's N
	Open Building	NA	2023	GLOF exposure.

Table S2. Volume-Area scaling for calculating lake volume of Lake-B

References	**Volume-Area Scaling**
Cook and Quincey, 2015	$V=A \cdot D$, where $D=0.1217A^{0.4129}$ $V=A \cdot D$, where $D=0.5057A^{0.2884}$ $V=A \cdot D$, where $D=0.1746A^{0.3725}$ $V=A \cdot D$, where $D=0.3211A^{0.324}$ $V=A \cdot D$, where $D=0.1697A^{0.3778}$
Emmer and Vilímek, 2014	$V=0.054393A^{1.483009}$
Evans, 1986	$V=0.035A^{1.5}$
Fujita et al., 2013	$V=A \cdot D$, where $D=55A_{sqkm}^{0.25}$
Huggel et al., 2002	$V=0.104A^{1.42}$
Kapitsa et al., 2017	$V=0.036A^{1.49}$
Loriaux and Casassa, 2013	$V=0.2933A^{1.3324}$
Muñoz et al., 2020	$V=A(0.041L_w+2)$
Wang et al., 2012	$V=0.0354A^{1.3742}$ $V=A \cdot D$, where $D=0.087A^{0.434}$

Table S3. Time-series evolution of Lake-A and Lake-B

Year	**Lake-A**		**Lake-B**	
	Area (km^2)	Uncertainty (km^2)	Area (km^2)	Uncertainty (km^2)
1999	0.051	0.029	0.075	0.057
2005	0.035	0.024	0.084	0.057
2010	0.047	0.028	0.102	0.065
2016	0.064	0.004	0.239	0.012
2020	0.064	0.004	0.291	0.008
2022	0.061	0.003	0.296	0.008
2024	0.061	0.003	0.306	0.008

Table S4. Time-series evolution of alluvial fan associated with Lake-A

Year	Alluvial Fan Area	Uncertainty
1999	0.017	0.008
2004	0.029	0.011
2008	0.040	0.013
2012	0.044	0.014
2016	0.052	0.004
2020	0.060	0.004

Table S5. Volume-Area scaling for calculating sediment infill of Lake-A

References	Volume-Area Scaling
O'Connor et al. (2001)	$V=3.114\ A + 0.001685A^2$
Huggel et al. (2002)	$D=0.104\ A^{0.42}$ $V=0.104\ A^{1.42}$ $D=0.1217\ A^{0.4129}$ $D=0.5057\ A^{0.2884}$ $D=0.1746\ A^{0.3725}$ $D=0.3211\ A^{0.324}$ $D=0.1697\ A^{0.3778}$
Wang et al. (2012)	$V=0.0354\ A^{1.3742}$ $D=0.087\ A^{0.434}$
Kapista et al. (2017)	$V=0.036\ A^{1.49}$ $D=0.036\ A^{0.49}$ $V=0.2933\ A^{1.3324}$
Evans (1986)	$V=0.035\ A^{1.5}$
Munoz et al. (2020)	$V=A*(0.041*Lw+2)$ $Lw=360$ m $V=0.054293\ A^{1,483009}$

Tabe S6. Avalanche reconstruction scenarios and release volumes.

	Glacier A (GL-A)	**Glacier F (GL-F)**
Avalanche Scenarios for reconstruction	**Release volume (10^5 m^3)**	**Release Volume (10^5 m^3)**
R1	8.53069	8.69664
R2	11.3742	13.045
R3	17.0614	17.3933
R4	19.9049	21.7416

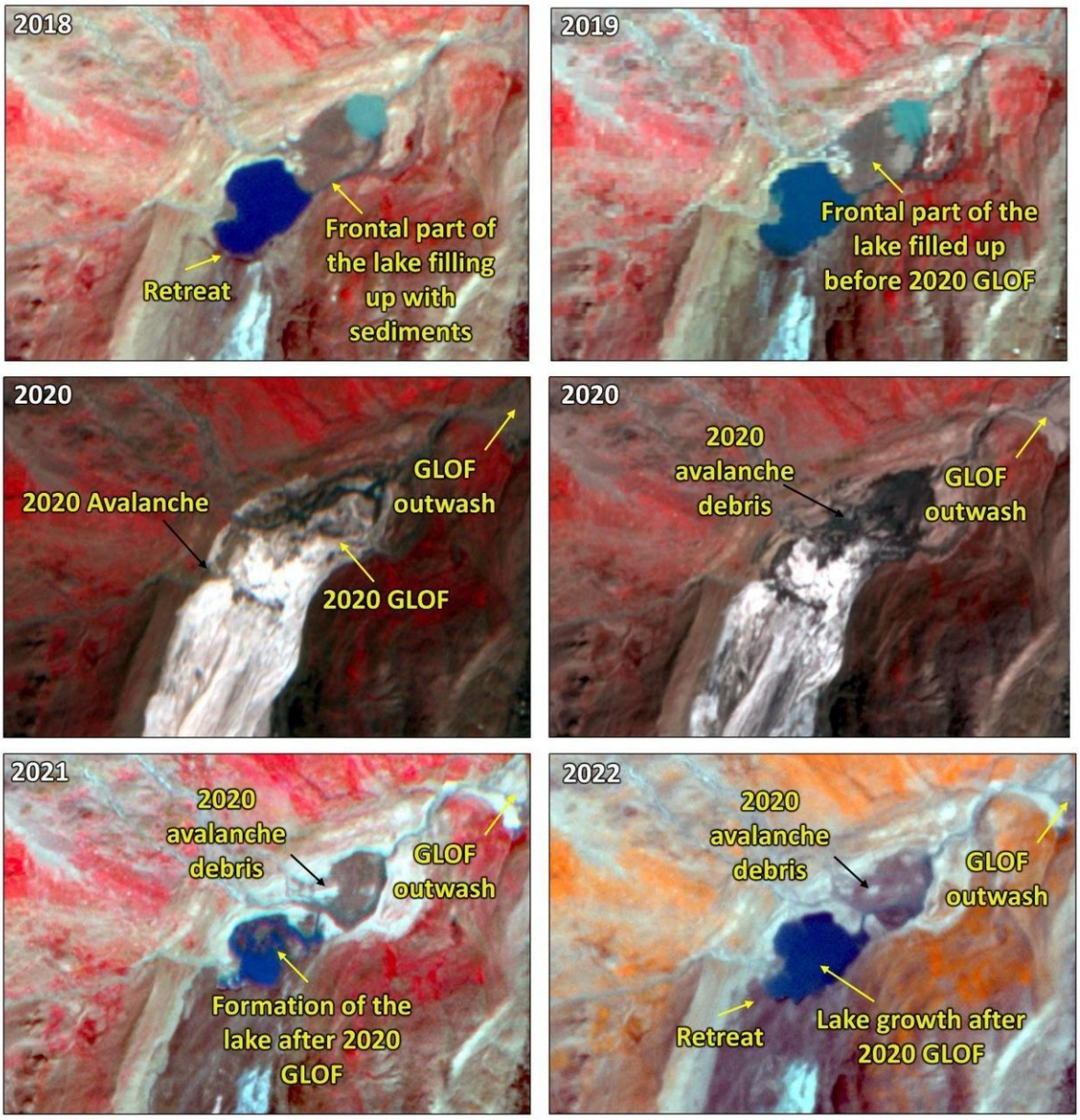


Fig. S1. Time-series images from 2019 to 2024 showing the avalanche-triggered GLOF event and post-GLOF changes in Lake-A. (Background images: ©PlanetScope).

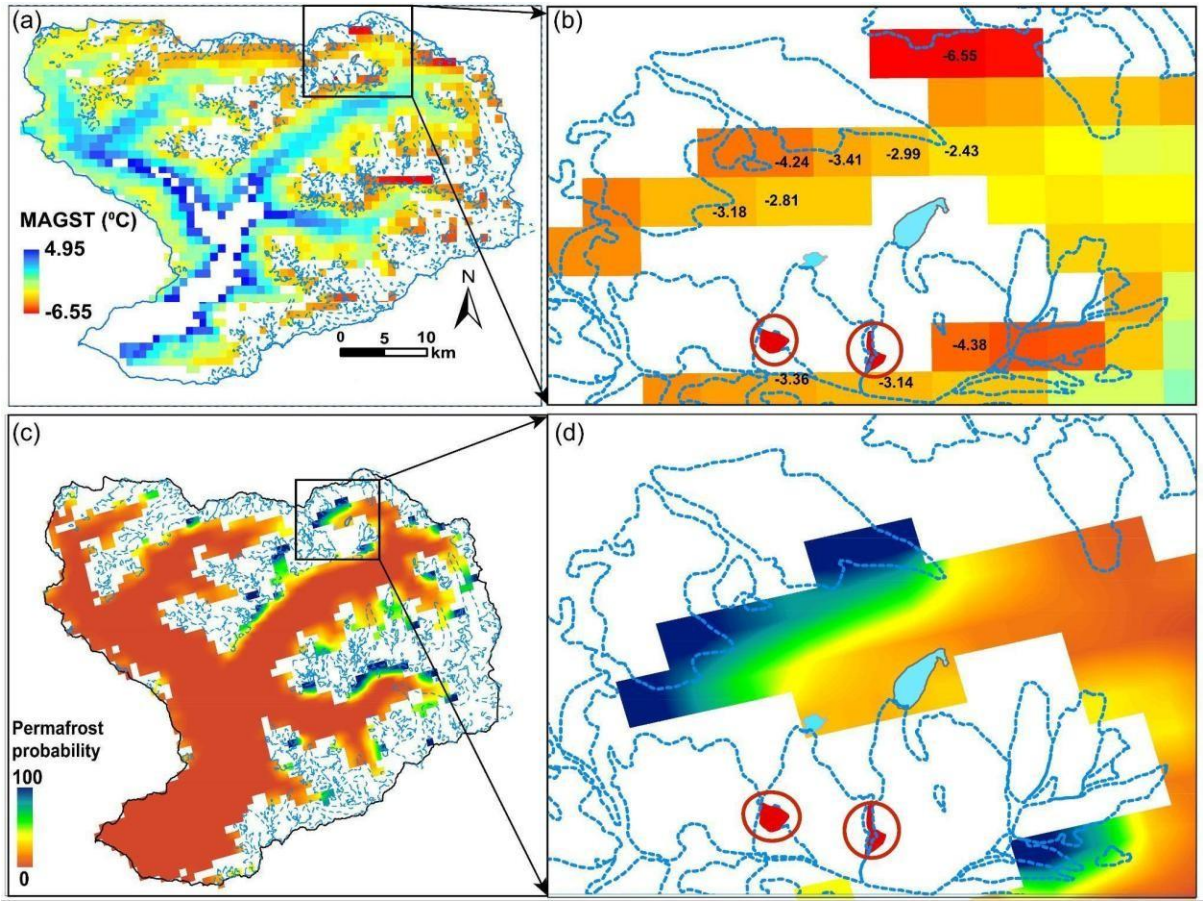


Fig. S2. Permafrost occurrence in the catchment and around the glacier complex (Ran et al., 2022). The red circle shows the failure zone of September 2005 and 2020 on GL-B and GL-A, respectively.

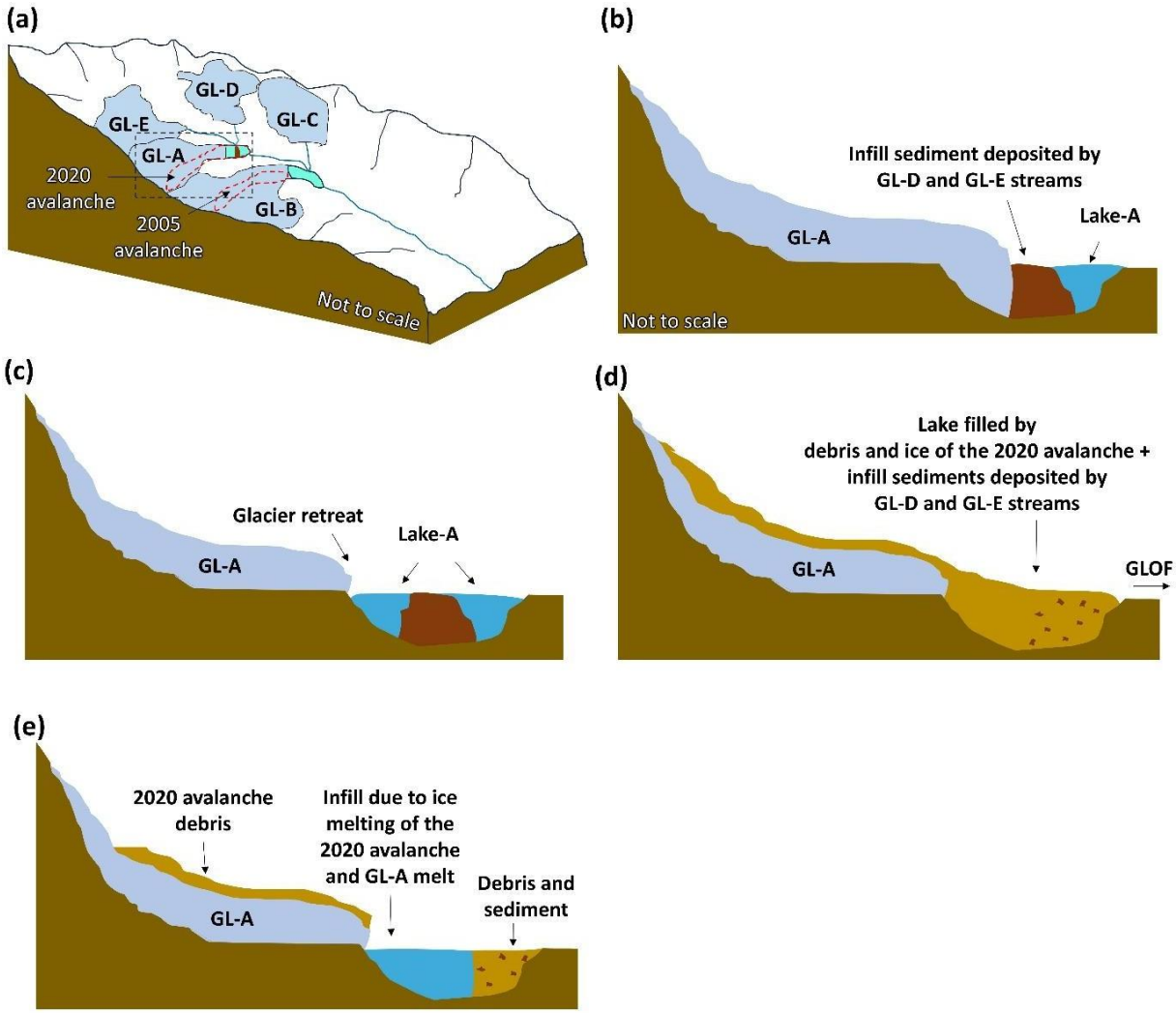


Fig. S3. Schematic showing (A) the glacier valley and the glacier complex (GL-A, GL-B, GL-C, GL-D, and GL-E) and the glacier where the 2005 and 2020 avalanche-triggered GLOF occurred; (B-C) process showing the evolution of GL-A glacial lake before the 2020 avalanche impact; (D) the 2020 avalanche filling up the lake basin completely, draining the lake, and causing a GLOF event.

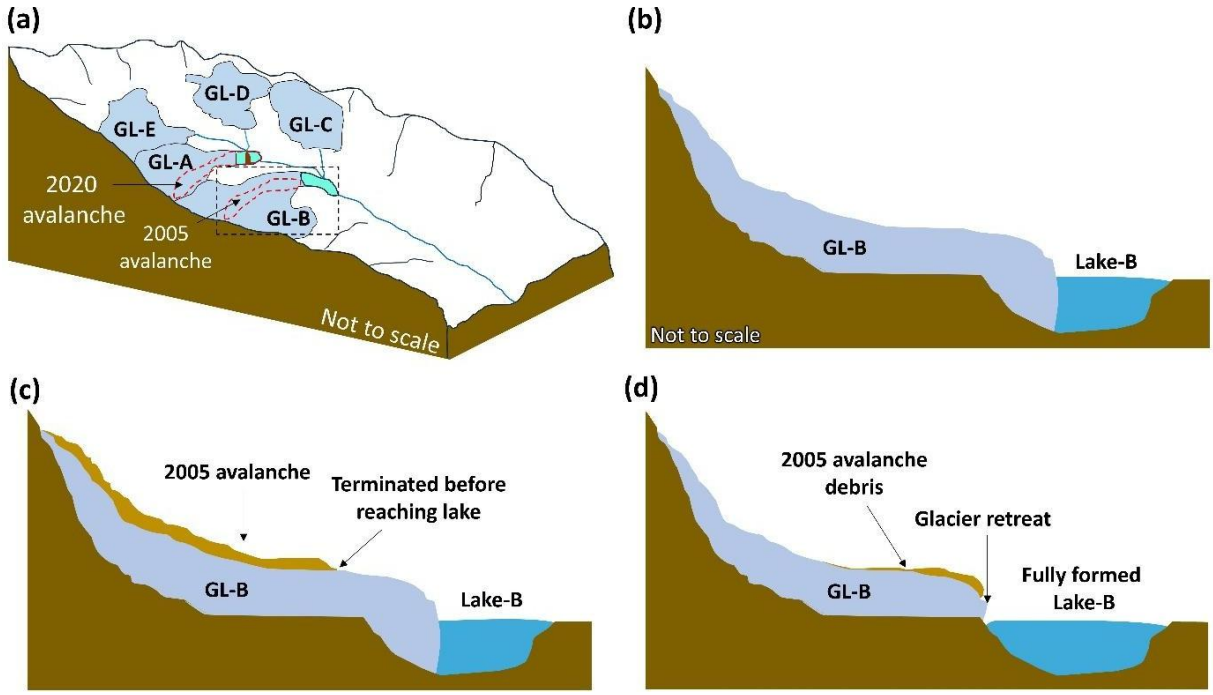


Fig. S4. Schematic showing (A) the glacier valley and the glacier complex (GL-A, GL-B, GL-C, GL-D, and GL-E) and the glacier where the 2005 and 2020 avalanche-triggered GLOF occurred; (B) process showing the evolution of GL-B glacial lake before the 2005 avalanche; (C) the 2005 avalanche terminated before lake impact on GL-B; (D) the GL-B lake grew to its full extent.