

Climatic Preconditioning and Catastrophic Slope Failure in High Mountain Asia: A Multiscale Assessment of the 2026 Langtang Lirung Event

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Abstract: On 26 August 2026, a catastrophic rock-ice-sediment failure at Langtang-Lirung, Nepal, triggered a debris-flow and flood cascade through the Bhote Koshi. ERA5/ERA5-Land reanalysis, precipitation-phase and trend analyses (Mann-Kendall and Sen's slope), gravitational energy estimation, and 2 m WorldView-3 DEM differencing assessed climatic conditions and geomorphic impacts. Annual temperature increased by $0.31\text{ }^{\circ}\text{C decade}^{-1}$ (1940–2025), while rainfall rose by $64.8\text{ mm decade}^{-1}$ (1980–2025), with no significant snowfall trend. August 2026 was exceptionally warm and wet across the Hindu Kush Himalaya. Approximately 130 million m^3 of detached material had an estimated gravitational potential energy of $2.6 \times 10^{15}\text{ J}$ over a 2300 m descent. DEM differencing at Syabrubesi and Rasuwagadhi indicated 33.2 million m^3 of scour, 5.0 million m^3 of deposition, and 28.3 million m^3 of net sediment export. Findings indicate climatic preconditioning and downstream geomorphic transformation without establishing direct climatic causation, highlighting the importance of integrated atmospheric, cryospheric, terrain, and hydrological monitoring.

Keywords: *Langtang-Lirung, Slope-failure, Cryospheric-hazard, Energy-budget, Geomorphic-change, Hazard-cascade, ice-rock avalanche.*

Introduction

The 26 August 2026 Langtang-Lirung collapse triggered rapidly propagating debris flow and flooding through the Bhote Koshi and downstream river system (The Kathmandu Post, 2026; ReliefWeb, 2026). The study examines long-term climatic preconditioning, event-month anomalies, energy available to the cascade, and downstream terrain change, rather than assigning a deterministic climatic trigger.

Methodology

Temperature conditions were evaluated using ERA5 (Hersbach et al., 2020) and ERA5-Land reanalysis data (Muñoz-Sabater et al., 2021), while precipitation phase

was assessed from ERA5-Land precipitation and snowfall fields. Long-term trends were quantified using the Mann-Kendall test (Mann, 1945) and Sen's slope estimator (Sen, 2012). Event-scale conditions were compared with historical August variability in the Langtang region (Steiner et al., 2021) and Hindu Kush Himalaya. Geomorphic changes were assessed using 2 m WorldView-3 DEMs and downstream visual observations (CLaSH, 2026).

The first-order energy assessment used detached volume of approximately 130 million m^3 (HimalPress, 2026), representative bulk density of 900 kg m^{-3} , and approximate descent of 2300 m:

$$E_p = mgh = \rho Vgh \quad (1)$$

Where, E_p = Gravitational potential energy, m = Mass, ρ = Bulk density, V = volume, g = gravitational acceleration, and h = vertical descent.

Results and discussion

Annual temperature at Langtang-Lirung increased at $+0.31\text{ }^{\circ}\text{C decade}^{-1}$ during 1940–2025, an approximately $2.58\text{ }^{\circ}\text{C}$ rise between the 1940s and 2016–2025 (The Small Earth Nepal, 2026). Warming was significant in all seasons and strongest in winter. Total precipitation increased $62.9\text{ mm decade}^{-1}$ in 1980–2025, with rainfall increasing $64.8\text{ mm decade}^{-1}$; snowfall had no significant trend ($-0.6\text{ mm decade}^{-1}$; $p = 0.872$), and the snowfall fraction declined by approximately one percentage point decade^{-1} (Krogh & Pomeroy, 2021; Pradhananga & Pomeroy, 2022).

The Hindu Kush Himalaya experienced its warmest August in the 1980–2026 record (C3S, 2026), with area-weighted temperature anomaly near $+1.85\text{ }^{\circ}\text{C}$. The local site recorded its second-warmest August ($9.38\text{ }^{\circ}\text{C}$), $0.72\text{ }^{\circ}\text{C}$ above its 1980–2025 August climatology. Regional August precipitation reached 339 mm, about 50 mm above climatology, predominantly as rainfall (The Small Earth Nepal, 2026). The estimated detached mass was

1.17×10^{11} kg, with gravitational potential energy near 2.6×10^{15} J. Most of this energy was dissipated through fragmentation, friction, deformation, entrainment, and channel interaction rather than remaining as bulk translational motion (Lei et al., 2025; Wei et al., 2024).

DEM differencing identified 22.2 million m³ of scour and 4.4 million m³ of deposition at Syabrubesi (17.8 million m³ net export), and 11.1 million m³ of scour and 0.6 million m³ of deposition at Rasuwagadhi (10.5 million m³ net export). Combined reported values were 33.2 million m³ of scour, 5.0 million m³ of deposition, and 28.3 million m³ net sediment export. Channel aggradation and floodplain disturbance were documented downstream (CHWRR, 2026; CLaSH, 2026).

Table 1, Reported downstream sediment budget (million m³)

Reach	Scour	Deposit	Net Export
Syabrubesi	22.2	4.4	17.8
Rasuwagadhi	11.1	0.6	10.5
Total (reported)	33.2	5.0	28.3

Conclusion and recommendations

Sustained warming, declining snowfall fraction, and anomalously warm and rainfall-dominated August conditions provide a coherent preconditioning context for the Langtang-Lirung event, not proof of direct causation. Integrated atmospheric monitoring, precipitation-phase observations, cryospheric indicators, terrain change detection, and downstream hydrological observations can improve assessment of cascading high-mountain hazards.

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