



Blog- Estimation of Equilibrium Line Altitude (ELA) at Satopanth Glacier — Tracing the History of Glacial Cycles

As part of *Field School 2026 in the Indian Himalayas*, organised by ICED, IIT Roorkee, a team of 14 members comprising faculty, researchers, and students visited the Satopanth Glacier Terminus to explore its geomorphological features and understand how glaciers preserve evidence of past climatic conditions. The team included Prof. Dr. Ankit Agarwal (IIT Roorkee), Prof. Dr. Axel Bronstert (University of Potsdam), Dr. Jurgen Mey (University of Potsdam), and Prof. Dr. Sumer Chopra (IIT Roorkee), along with ten M.Tech. students and research scholars from IIT Roorkee.

During the field visit, we learned how we can infer past Equilibrium Line Altitudes (ELA) from ancient glacial moraines. The ELA is the altitude on a glacier where, over a year, the accumulation of snow and ice approximately balances the loss caused by melting, sublimation, and other processes. The position of the ELA is an important indicator of glacier health and climatic conditions. Due to ice flow dynamics, lateral moraines appear just below the ELA and thus the highest elevation of old lateral moraines should approximate the paleo ELA. With the assumption of a certain temperature lapse rate, the altitudinal difference between the reconstructed and the current ELA can help to reconstruct past temperature drops. This illustrates how features preserved in a mountain landscape can provide clues about changes in glacier mass balance and climatic conditions.

The ELA markings observed in the field offer valuable clues about the glacier's past extent and the environmental conditions under which it evolved. By examining these features, scientists can investigate changes in glacier behaviour and reconstruct aspects of the Himalayan region's climatic history. Earth's climate has experienced repeated glacial and interglacial cycles over geological time. During glacial periods, large quantities of water are stored in ice sheets and glaciers, while temperatures are generally lower. During interglacial periods, warmer conditions cause glaciers to retreat.

These cycles are associated with long-term variations in Earth's orbit and axial orientation, which influence the distribution of solar radiation received by the planet. The ELA can shift considerably between these climatic phases. However, identifying the precise glacial cycle represented by a particular ELA marking requires additional evidence, including reliable

dating, geomorphological interpretation, and paleoclimate reconstruction. The Satopanth Glacier therefore serves as a natural archive through which we can investigate the interactions between climate, ice dynamics, and the evolution of Himalayan landscapes.

Dating Past Glaciations: Cosmogenic Nuclides and Carbon Dating

Two important dating approaches that can help in this regard are cosmogenic nuclide exposure dating and radiocarbon dating.

1. Cosmogenic nuclide exposure dating

Cosmogenic nuclides are produced when cosmic rays interact with minerals in rocks exposed at or near Earth's surface. When glacial retreat leaves rocks or boulders exposed, cosmogenic nuclides gradually accumulate in their mineral grains. By measuring the concentration of these nuclides, scientists can estimate how long the surface has been exposed. This technique is particularly valuable for dating glacial landforms, moraines, and boulders deposited or uncovered by retreating glaciers. Depending on the nuclide, geological setting, and analytical method, cosmogenic nuclide dating can investigate exposure histories extending from thousands of years to hundreds of thousands of years and, in suitable circumstances, around a million years or more.

2. Radiocarbon dating

Radiocarbon dating measures the decay of carbon-14 in once-living organic material. It is widely used to determine the age of organic remains associated with past environmental conditions. Its practical dating range is generally up to approximately 50,000 years, although the reliable limit depends on the sample, preservation, contamination, and measurement method. Radiocarbon dating can help establish the chronology of past environmental changes when suitable organic material is available in sediments or other deposits associated with glacial events. However, it cannot directly date inorganic rocks or boulders themselves.

The visit to Satopanth Glacier helped to appreciate how field observations can connect present-day landscapes with climatic events that occurred thousands or even hundreds of thousands of years ago.

The visit to Satopanth Glacier was a valuable learning experience, demonstrating how the Himalayan landscape records the combined influence of climate, geological processes, and glacier dynamics.