Abstract

The Himalayan cryosphere, also termed “the Third Pole, " acts as a natural storehouse to several mega river systems, such as the Ganges, Indus, and Brahmaputra, serving billions of people with fresh water. However, the high mountain ranges of the Himalayas are also susceptible to various categories of hazards, such as snow/rock-ice avalanches, landslides, earthquakes, and glacial lake outburst floods (GLOFs). The present study attempts to perform a series of investigations to better understand the dynamics of snow/glaciers in the Himalayan region and their contribution to perennial river streams. It also includes studying the major types of Himalayan hazards that have occurred in the recent past.

Satellite remote sensing has been used to study the spatio-temporal variations in the snow cover of the Sikkim Himalayas. An integrated approach of multivariate statistics and band ratio between 1989 and 2019 at an interval of 2-4 years helped capture the effective snow coverage. The intra-annual effective snow cover change has been observed to correlate inversely with the Extended Reconstructed Sea Surface Temperature (ERSST.v5) in Niño 3.4 region. The snow line altitude (SLA) has been observed to have a two-fold periodicity in the last 30 years.

Studying the composition of stable isotopes ($\delta^{18}O$ and δD) within the primary sources of the Teesta and Rathong river systems helped in understanding the spatio-temporal variability in the isotopic composition of water and moisture sources. A deterministic Monte Carlo-based three-endmember $\delta^{18}O$-d-excess mixing model helped quantify the source endmembers' contribution to the river streams and waterfalls. Another Monte Carlo-based four-endmember strontium (Sr) model helped segregate the contribution of dissolved Sr flux from different lithologies. Moreover, an investigation of two natural thermal springs at North Sikkim showed arsenic contamination in one of the thermal spring samples indicating an isolated geothermal aquifer with an arsenic source near the Changme glacier.

An investigation conducted for the Shisper glacial lake outburst on 7th May 2022 revealed various factors such as glacial mass balance, reduced snow cover, and abnormal hike in the land surface temperature resulting in rapid glacial melt and breach of an ice-dammed glacial lake. The after-effects of the event were studied in terms of changing water quality and land cover along the stream using optical and SAR datasets. Another investigation conducted to capture the impacts of the MW5.7 earthquake on 20th March 2020 around lake Dingmu in Tibet showed reduced co-seismic coherence around the lake periphery through Sentinel-1 Radar datasets corroborating with the increased soil moisture captured through temporal difference liquefaction index (TDLI). An extensive study was conducted over glacial lakes in the Sikkim Himalaya using remote sensing, analytical methods, field- and lab-based analysis. The analytical hierarchy process (AHP) based assessment showed 7 lakes in Sikkim, 3 lakes in Nepal, and 3 in China as highly vulnerable to future outburst floods. Moreover, three backpropagation multilayer perceptron neural network (BPMLPNN) models showed good prediction accuracies with AHP-based target scores. Further, field-based geophysical techniques such as multichannel analysis of surface waves (MASW) and ground penetrating radar (GPR) were performed to understand the subsurface properties of soil and glaciofluvial deposits in the high-altitude Sikkim Himalayas. This was followed by the geotechnical and mineralogical analysis of glacial moraine and lacustrine deposits near the snout of Changme and Rathong glaciers in North and West Sikkim, respectively.

In the process of investigating episodes of Himalayan avalanches, the Chamoli disaster of 7th Feb 2021 was investigated for the triggering mechanism where prolonged glacial mobility was seen as a possible factor behind the formation of a prismatic wedge structure over the north-eastern slope of the Trisul mountain resulting in devastation along the Rishiganga-Dhauliganga valley, Uttarakhand.

Kinematic analysis and numerical modeling explained the failure as stress-controlled. Another attempt was made to identify the activation zones of snow avalanches that occurred on 17th Jan 2020 around some of the major peaks of the Annapurna mountain range using C-band Sentinel 1 synthetic aperture radar (SAR) datasets and ALOS PALSAR digital elevation model (DEM).

Where the Himalayan region experiences frequent earthquakes, the remotely located glaciers remain isolated in terms of studying seismic impacts. Therefore, it was attempted to understand the impact of earthquakes on and around Himalayan glaciers using C band SAR datasets of Sentinel 1. Eight earthquake events of various magnitudes and hypocenter depths having their source in the vicinity of Himalayan glacial bodies were analyzed using Sentinel-1 datasets which showed vertical deformation within and around glacial bodies along with changes in the glacial moraine deposits as captured through a reduction in co-seismic coherence response.