# Assessing the GLOF Hazard and Risk of Lato Lake in Zanskar region of north-western Himalaya

Rayees Ahmed[1]

[1]*Department of Geography and Disaster Management, University of Kashmir, Hazratbal, Srinagar, 190006, India.*

**Abstract:** Glacial Lake outburst floods (GLOF's) and its associated hazards in the mountainous areas are a matter of great concern worldwide due to ongoing warming climate and glacier recession. About 90% of GLOF events in the Indian Himalayan Region have been reported in the Ladakh region. However, little attention has been given to this region to understand the problem in comparison to the other hazard-prone areas of the Indian Himalayan region. The region has witnessed heavy damages to property, agricultural and other asset loss during recent year's e.g., Gaya GLOF event in 2014 is the recent manifestation of the GLOF hazard in this region. Thus, keeping the worst scenario of GLOF events in this region under consideration, we have analysed the recent evolution of Lato glacial lake and its mother glacier to understand the probable initiation of a GLOF event and assessment of the hazard downstream through the channel up to the Lato settlement using high resolution satellite data sources from 1990 to 2020 (Figure 1). For this purpose, the volume of the lake was assessed using improved area-volume scale equations. It was followed by multiple hydrodynamic simulations performed by using HEC-RAS model for various scenarios with varied lake volume, breach width (bw) and breach formation time (bf) in the study. For the worst-case scenario, a breach hydrograph of 75% of lake volume, 20 minutes of bf and 30 m bw was considered for GLOF routing. The glacier depth and bed over-deepening's were identified using GlabTop (Glacier Bed Topography) version-2 and consequently future lake sites/formations were identified. Glacier velocity was also modelled using the Cosi-Corr software and SAR data, whereas glacier mass balance was derived by geodetic methods using high resolution ALOS-DEM data. The potential GLOF impacts on the downstream community including various landuse and land cover features was evaluated by overlaying the flood inundation map of the area. The results derived from the multi-temporal images reveal 17% loss in glacier area, whereas lake area has increased by 66% since past 40 years (Figure 2). The Lato Lake was found to be high hazard lake following multi-criteria decision-based approach using Analytical Hierarchy Process (AHP) method. The minimum and maximum ice thickness for the Lato group of glaciers was estimated to be 13.59 m and 164.35 m respectively, whereas mean thickness was calculated as 23.25 m. Average velocity of the glaciers was estimated as 3 m/year with maximum touching 7 m/year. The glacier has lost an average ice mass of 0.07 m we a-1 with maximum and minimum mass loss of 1.2 m we a-1 and 0.01 m we a-1 over the period of 15 years. The routed breach hydrograph through the channel potentially inundated 7.3 km2, which includes 65% barren land, 20% agricultural land, 5% built-up, 3% forest. The worst-case scenario generated a peak discharge of 1684 m3/sec with maximum flood depth and velocity goes up to 15 m and 7 m/s respectively at the Lato village. The findings of this study will be useful for decision makers and to formulate the strategies in the direction to mitigate and reduce the risks from hazards associated with glacial lakes. However, an in-depth field-based study for mass balance of the glacier and to investigate the other geological and geotechnical properties of the moraine-dam sediments obstructing the rapidly increasing glacial melt water is highly recommended. The details of the glacier and glacial lake characteristics derived using satellite data and hydrological models is depicted in the Figure 1.

**Keywords:** Cryosphere changes; GLOFs, Hydrological modeling, Ladakh region, Himalayas.

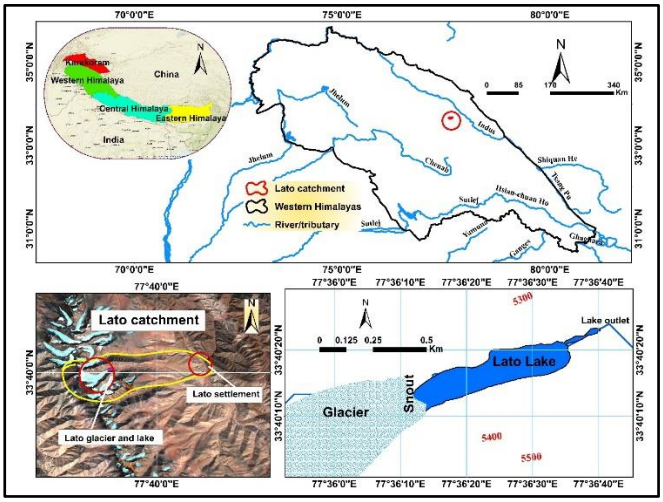


Figure 1. Location of the Lato lake and its feeding glacier

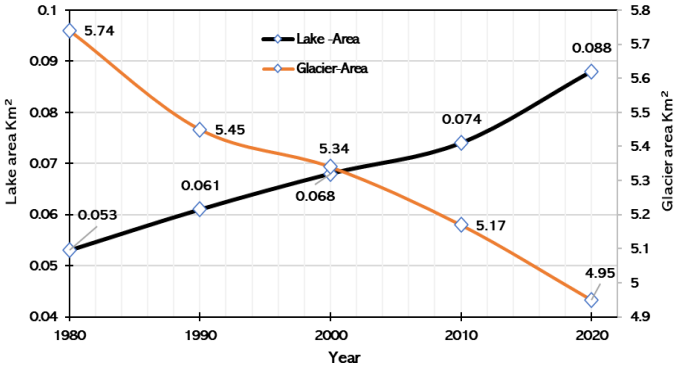


Figure 2. Retreat of Lato group of glaciers and expansion of Lato Lake from 1980 2020.