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Climate and glacier changes in Mt. Everest region in Central Southern Himalaya (Nepal)

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Mount Everest region influenced by monsoon-dominated climate system is characterized by dense distribution of debris-covered glaciers. Very low number of papers has addressed on the interdisciplinary linkage of hydro-meteorological process and the glacier dynamics in high elevation areas. Here we present the glacier changes from 1958 to 2011 and the meteorological observations from 1992 to 2011 with the aim of understanding coupled climate-glacier dynamics using satellite imagery, historical maps and insitu field measurements. We developed reconstructed single series for temperature and precipitation through the monthly quantile mapping and expectation maximization techniques from the insitu observations in different automatic weather stations located in the Mt. Everest region. Multi-temporal satellite products and topographic maps were used for glacier terminus, surface and snowline altitude (SLA) analysis from 1958 to 2011. We observed the continuous shrinkage of glaciers since 1958 to 2011 with accelerated rate in the recent years. The average terminus retreatment of analyzed 29 glaciers was about 372$\pm$37 m (7.0 m a^{-1}) in 1958 to 2011 with retreat rate of 6.1$\pm$1.9 m a^{-1} in 1958-75 and nearly its double in 2008-11. The glacier surface area had loss of 14.3$\pm$5.9 % (0.27 % a^{-1}) from 396.2 km^2 to 339.5 km^2 in 53 years with the loss by 0.12 %a^{-1} in 1958-75 to 0.70 % a^{-1} in recent years. The smaller glaciers with $<$1 km^2 dimension had decreased by 43% in their surface area showing rapid disappearance of very small glacier/ice mass. The accumulation area decreased by 24.8%, whist ablation area increased by 17.7 % with nearly 6% increase in debris-cover surface in ablation zone in 1958 to 2011. The accumulation and ablation area changes are attributed to SLA position which was continuously moving upward from 5279 m a.s.l. (σ=144) in 1958 to 5472 m a.s.l. (σ=209) in 2011 with the overall vertical shift of 192$\pm$9 m (3.6 m a^{-1}). The rate of SLA shift was the highest in recent years with the rate of 12.8$\pm$2.9 m a^{-1} a.s.l. while the rate was observed 2.1$\pm$1.7 m a^{-1} in 1958-75. Not all the analyzed glaciers are showing uniform behavior, but are in a spatially and temporally discern manner. Majority of glaciers are retreating but some glaciers observed as stationary or even advancing in certain period of analysis. The overall glacier change behaviors are similar to glaciers observed in other part of the Himalayan region. The singular spectral analysis and monthly sequential Mann-Kendall test of the temperature and precipitation for 1992-2011 indicated that the temperature has increased by +0.03˚C a^{-1} but statistically significant only for winter months. The precipitation has decreased by around 180 mm in the analysis period. The decreases in precipitation are statistically significant for both winter and summer precipitation. We conclude by underlining that the observed variation of glacier surface and SLA changes could be explained by the increase of temperature and more importantly, by changes of precipitation in recent years as the glaciers in this region are strong summer monsoon-fed.