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How Central Himalayan water towers respond to climate change? A particular emphasis on glacial lakes as useful impact index

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The impact of climate change on Himalayan water resources has become an important issue for the scientific community and media in the last years. Though evidence for global climate change has been well established by scientific communities around the world, the effects of these changes on regional climates still need to be investigated. Regional-scale forcings induced by the regional topographical features modify the effects and impacts of climate change. This is particularly true with regards to the special orographical features of the high Himalaya showing different climate change patterns across the mountain range. Since we are concerned about the consequences on water resources in the future, it is necessary to study the effect of climate changes on the regional scale.

Our attention is focused on Central Himalaya, particularly in the Southern side of the Mt Everest region considering the large glacial areas of this zone. Moreover recent studies which investigated the entire Hindu Kush-Himalaya (HKH) range have pointed out that in the East (India, Nepal and Bhutan) glacial lakes are bigger and more numerous than in the West (Pakistan, Afghanistan). In particular, both sides of Mt Everest region represent the region most characterized by Supraglacial and Proglacial lakes of the entire HKH range. In this region infact glaciers are melting more intensely than the rest of the HKH range and the debris coverage, protecting their surfaces from an excessive retreatment, makes lakes the major evidence of the impact of the deglaciation process and, therefore, they should be more considered within analysis concerning climate change impacts on water resources.

In this region generally researches focused on climate change impact on single glaciers (e.g. Khumbu Glacier) and single lakes (e.g. Imja Lake). These studies are often detached and a clear and broad use of both these entities as sensors of impact is still missing. Moreover the link between climate changes in terms of temperature and precipitation and relevant impacts on different water compartments (glaciers, lakes and rivers) is not enough clear and exhaustive.

In this context is born the requirement to reach a broad vision of the entire climate change pattern starting from the annual and seasonal temperature and precipitation changes until the impacts on glaciers, lakes, and river discharges. To achieve this goal land meteorological measurements were used starting the beginning '90s. These data have been integrated with tree ring samples and reanalysis data in order to have exhaustive annual and seasonal trends since the half of the past century. To detect and to quantify glacier and lake changes multi-temporal and multi-scale remote sensing data and maps ('60s and '90s) were used including Landsat (1992), Aster (2001) and Alos (2008) images. Delineation of glaciers and lakes was manually digitized on the panchromatic images. Results from other authors (evolution of glacier fronts) have been included and particular attention has been posed on the measurement of uncertainties considering the different sensors resolution. Changes in meteorological and river flow trends have been detected with the Wavelet Analysis considering that these processes are non-stationary.

First results for the time period between 1960 and 2008 starts revealing a general increasing of annual mean temperature, but exclusively confined during the winter season, when glacier are neither in accumulation and melting phase. An alternate behavior of annual precipitation seems an important factor driving the not-linear melting recessions. Glaciers which have lost the major surface are those of little sizes, while glaciers with bigger sizes have reacted with the fragmentation of the glacial front and the formation of supraglacial lakes. Glacial lakes no directly connected with glaciers, usually excluded in previous other works due to are not subject to GLOFs, seem a useful index for detecting precipitation regime changes and therefore an further useful element for the climate change impact studies on water resources.