Geophysical Research Abstracts
Vol. 17, EGU2015-6859, 2015
EGU General Assembly 2015

Stochastic hydrological and degree-day model coupled for the Himalayan glacierized catchments: the case study of Dudh Koshi River, Nepal

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This contribution aims at linking temperature and precipitation trends detected with ground stations at high elevations of south slopes of Mt. Everest in the last twenty years, extended back with gridded and reanalysis data, with changes observed for discharges of Dudh Koshi River (3715 km2), Nepal.
The study is carried out though:
a) the daily temperature and precipitation reconstruction of the last twenty years (1994-2013) at 5050 m a.s.l. and 25 AWSs located at lower elevation and on the Tibetan Plateau (Salerno et al., on TCD);
d) all available gridded and reanalysis data set both for temperature and precipitation for extending our analysis back to ‘60s.
b) glacier surfaces (about 400 km2) changes since 60s using all available satellite imagery and glacier mass losses since the beginning of 2000s (Thakuri et al., 2014);
c) a stochastic hydrological model for detecting changes observed for discharges of Dudh Koshi river since 60s;
c) a degree day model for simulating the glacier melt since 60s.
In the last years physically-based hydrological models are started to be adopted for Himalayan glacierized catchments. However, such models present several limitations due to lack of data for the calibration/validation and to an over-parameterization.
In this paper, a simple statistical method to simulate the river discharge of a glacierized (∼14%) Himalayan basin, based on Standardized Precipitation Index (SPI), is proposed. The SPI approach is ground on these assumptions: a) as a first approximation discharges can be assessed at monthly time scale; b) in monsoon regimes the discharge is mainly dependent on precipitation taken into account at different time scales and with different “weights”; and c) the parameters linking the precipitation regime to discharge are considered constant over time. On the base of such assumptions, to seek for relationships between the precipitation regime and discharge (Q), a multi-linear regression model (called SPI-Q) is calibrated and validated at monthly scale using the least-square method.
We observed an increasing temperature trend occurred mainly in winter months, but during the summer ones we noted a slight decreasing of maximum temperature. We confirm for these high elevations the generalized weakening of the monsoon, already observed in literature, accounting here over 50% of reduction in the last twenty years! In the previous period (70s to 90s) gridded and reanalysis data revealed for our reference site a slight increasing mean temperature and weak increasing precipitation. As a result, glaciers experienced an overall surface area loss of 13% and an upward shift of the snowline altitude (SLA) by 182 m.. Moreover, since early ‘90s, we found a significant upward shift of SLA which increased almost three times. The accelerated shrinkage in recent decades has only affected glaciers with the largest sizes (>10 km2), presenting accumulation zones at higher elevations and along the preferable south–north direction of the monsoons. This finding leads to the hypothesis that Mt. Everest glaciers are shrinking, not only due to warming temperatures, but also as a result of weakening Asian monsoons (Thakuri et al., 2014).
Our hypothesis are corroborated by coupling of the stochastic hydrological and the degree-day model. The SPI-Q model implies that (i) the Dudh Koshi river discharge is mainly dependent on precipitation from 1960s to 2000s. In this period, the monsoon alone is able to describe over 90% of annual river discharge; (ii) however since the beginning of 2000s, we observed a non-stationarity in the river discharge and the model fails to predict correctly the increased summer discharge, not justified by the observed weakening monsoon; (iii) coupling SPI-Q with the degree-day model underline as in the last decades the summer discharges are affected by an accelerated glacier melting, even observed with the glaciological analysis.