CALIBRATING ABOVE AND BELOW SNOW LINE PRECIPITATION AS INPUTS TO MOUNTAIN HYDROLOGY MODELS

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Abstracts Scientific Papers

Eidgenössische Technische Hochschule Zürich
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Calibrating above and below snow line precipitation as inputs to mountain hydrology models

ABSTRACTS SCIENTIFIC PAPERS

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Title	**The importance of observed gradients of air temperature and precipitation for modeling runoff from a glacierised watershed in the Nepalese Himalayas**
Journal	Water Resources Research (March 2014)
Authors	Immerzeel, W.W., Petersen, L. Ragettli, S. Pellicciotti, F.
Impact factor	3.71
Open Access	Yes

Abstract:

The performance of glaciohydrological models which simulate catchment response to climate variability depends to a large degree on the data used to force the models. The forcing data become increasingly important in high-elevation, glacierized catchments where the interplay between extreme topography, climate, and the cryosphere is complex. It is challenging to generate a reliable forcing data set that captures this spatial heterogeneity. In this paper, we analyze the results of a 1 year field campaign focusing on air temperature and precipitation observations in the Langtang valley in the Nepalese Himalayas. We use the observed time series to characterize both temperature lapse rates (LRs) and precipitation gradients (PGs). We study their spatial and temporal variability, and we attempt to identify possible controlling factors. We show that very clear LRs exist in the valley and that there are strong seasonal differences related to the water vapor content in the atmosphere. Results also show that the LRs are generally shallower than the commonly used environmental lapse rates. The analysis of the precipitation observations reveals that there is great variability in precipitation over short horizontal distances. A uniform valley wide PG cannot be established, and several scale-dependent mechanisms may explain our observations. We complete our analysis by showing the impact of the observed LRs and PGs on the outputs of the TOPKAPI-ETH glaciohydrological model. We conclude that LRs and PGs have a very large impact on the water balance composition and that short-term monitoring campaigns have the potential to improve model quality considerably.

Title	**Unraveling the hydrology of a Himalayan watershed through integration of high resolution in- situ data and remote sensing with an advanced simulation model**
Journal	Advances in Water Resources (February 2015)
Authors	Ragettli, S., Pellicciotti, F., Immerzeel, W. W., Miles, E.S., Petersen, L., Heynen, M., Shea, J. M., Stumm, D., Joshi, S., Shrestha, A.B.
Impact factor	2.78
Open Access	No

Abstract:

The hydrology of high-elevation watersheds of the Hindu Kush-Himalaya region (HKH) is poorly known. The correct representation of internal states and process dynamics in glacio-hydrological models can often not be verified due to missing in situ measurements. We use a new set of detailed ground data from the upper Langtang valley in Nepal to systematically guide a state-of-the art glacio-hydrological model through a parameter assigning process with the aim to understand the hydrology of the catchment and contribution of snow and ice processes to runoff. 14 parameters are directly calculated on the basis of local data, and 13 parameters are calibrated against 5 different datasets of in situ or remote sensing data. Spatial fields of debris thickness are reconstructed through a novel approach that employs data from an Unmanned Aerial Vehicle (UAV), energy balance modeling and statistical techniques. The model is validated against measured catchment runoff (Nash–Sutcliffe efficiency 0.87) and modeled snow cover is compared to Landsat snow cover. The advanced representation of processes allowed assessing the role played by avalanching for runoff for the first time for a Himalayan catchment (5% of annual water inputs to the hydrological system are due to snow redistribution) and to quantify the hydrological significance of sub-debris ice melt (9% of annual water inputs). Snowmelt is the most important contributor to total runoff during the hydrological year 2012/2013 (representing 40% of all sources), followed by rainfall (34%) and ice melt (26%). A sensitivity analysis is used to assess the efficiency of the monitoring network and identify the timing and location of field measurements that constrain model uncertainty. The methodology to set up a glacio-hydrological model in high-elevation regions presented in this study can be regarded as a benchmark for modelers in the HKH seeking to evaluate their calibration approach, their experimental setup and thus to reduce the predictive model uncertainty.

Title	**A comparative high-altitude meteorological analysis from three catchments in the Nepalese Himalaya**
Journal	International Journal of Water Resources Development (April 2015)
Authors	Shea, J.M., Wagnon, P., Immerzeel, W. W., Biron, R., Brun, F., Pellicciotti, F.,
Impact factor	0.895
Open Access	Yes

Abstract:

Meteorological studies in high-mountain environments form the basis of our understanding of catchment hydrology and glacier accumulation and melt processes, yet high-altitude (.4000m above sea level, asl) observatories are rare. This research presents meteorological data recorded between December 2012 and November 2013 at seven stations in Nepal, ranging in elevation from 3860 to 5360m asl. Seasonal and diurnal cycles in air temperature, vapour pressure, incoming short-wave and long-wave radiation, atmospheric transmissivity, wind speed, and precipitation are compared between sites. Solar radiation strongly affects diurnal temperature and vapour pressure cycles, but local topography and valley-scale circulations alter wind speed and precipitation cycles. The observed diurnal variability in vertical temperature gradients in all seasons highlights the importance of in situ measurements for melt modelling. The monsoon signal (progressive onset and sharp end) is visible in all data-sets, and the passage of the remnants of Typhoon Phailin in mid-October 2013 provides an interesting case study on the possible effects of such storms on glaciers in the region.

Title	**Modelling glacier change in the Everest region, Nepal Himalaya**
Journal	The Cryosphere (May 2015)
Authors	Shea, J.M., Immerzeel, W.W., Wagnon, P., Vincent, C., Bajracharya, S.
Impact factor	4.374
Open Access	Yes

Abstract:

In this study, we apply a glacier mass balance and ice redistribution model to examine the sensitivity of glaciers in the Everest region of Nepal to climate change. High- resolution temperature and precipitation fields derived from gridded station data, and bias-corrected with independent station observations, are used to drive the historical model from 1961 to 2007. The model is calibrated against geodetically derived estimates of net glacier mass change from 1992 to 2008, termini position of four large glaciers at the end of the calibration period, average velocities observed on selected debris-covered glaciers, and total glacierized area. We integrate field-based observations of glacier mass bal- ance and ice thickness with remotely sensed observations of decadal glacier change to validate the model. Between 1961 and 2007, the mean modelled volume change over the Dudh Koshi basin is $-6.4\pm1.5 km^3$, a decrease of 15.6% from the original estimated ice volume in 1961. Modelled glacier area change between 1961 and 2007 is $-101.0\pm11.4 km^2$, a decrease of approximately 20% from the initial extent. The modelled glacier sensitivity to future climate change is high. Application of temperature and precipitation anomalies from warm/dry and wet/cold end-members of the CMIP5 RCP4.5 and RCP8.5 ensemble results in sustained mass loss from glaciers in the Everest region through the 21st century.

Title	**Reconciling high altitude precipitation in the upper Indus basin with glacier mass balances and river runoff**
Journal	Hydrology and Earth System Sciences Discussion (May 2015)
Authors	Immerzeel, W.W., Wanders, N., Lutz, A.F., Shea, J.M., Bierkens, M. F. P.
Impact factor	3.642
Open Access	Yes

Abstract:

Mountain ranges in Asia are important water suppliers, especially if downstream cli- mates are arid, water demands are high and glaciers are abundant. In such basins, the hydrological cycle depends heavily on high altitude precipitation. Yet direct observations of high altitude precipitation are lacking and satellite derived products are of insufficient resolution and quality to capture spatial variation and magnitude of mountain precipitation. Here we use glacier mass balances to inversely infer the high altitude precipitation in the upper Indus Basin and show that the amount of precipitation required to sustain the observed mass balances of the large glacier systems is far beyond what is observed at valley stations or estimated by gridded precipitation products. An independent validation with observed river flow confirms that the water balance can indeed only be closed when the high altitude precipitation is up to a factor ten higher than previously thought. We conclude that these findings alter the present understand- ing of high altitude hydrology and will have an important bearing on climate change impact studies, planning and design of hydropower plants and irrigation reservoirs and the regional geopolitical situation in general.