Latest scientific progress and status of the Langtang catchment in Nepal

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Utrecht University ICIMOD GEWEX INARCH

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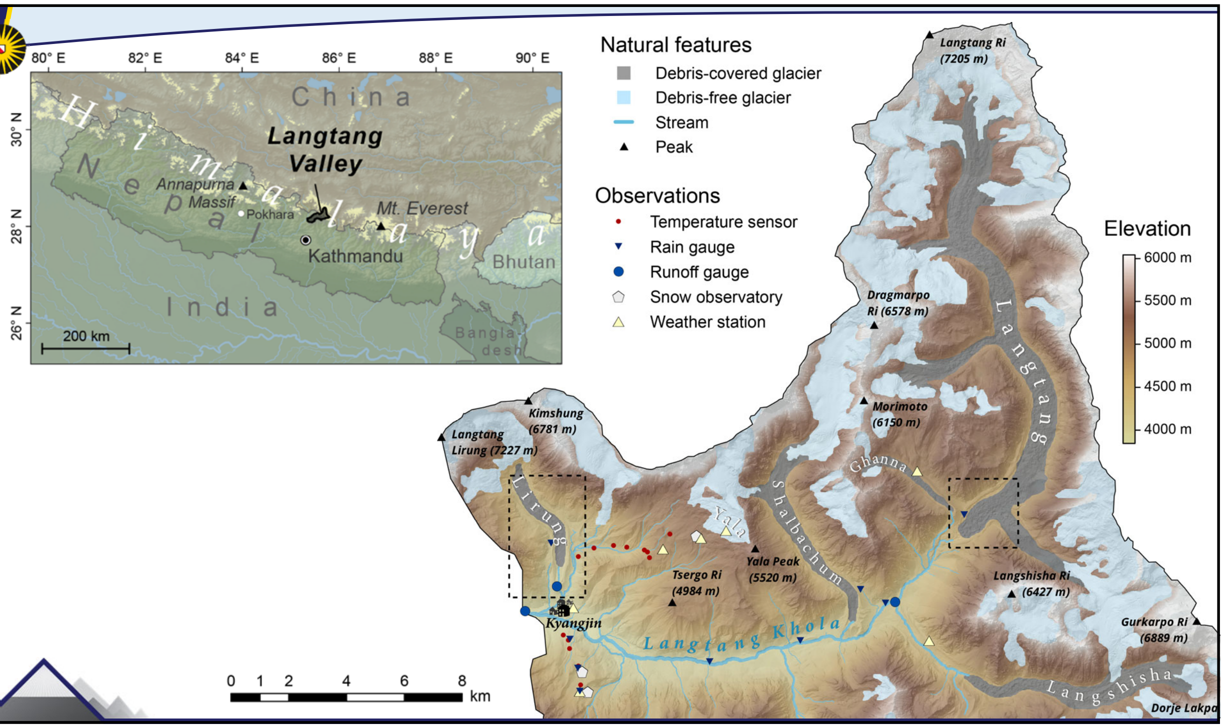

2

The Langtang observatory

- Partnership Utrecht University / ICIMOD / Kathmandu University / ETH / NVE since 2013
- Measurements
  - Meteorology (Full AWS (4) and mini-AWS (2))
  - Precipitation (LUFFT mini radar (2), OTT pluvios (3), tipping buckets (6))
  - Snow (snow water equivalent (1) and snow depth (SR50 (4)))
  - Soil moisture (5) and groundwater (5)
  - Runoff (2)
  - Eddy-Correlation flux tower (IRGASON, short campaigns)
  - Time lapse cameras (6)
  - Glacier (mass balance, debris properties, UAV)

3

Photo: Joe Shea

4

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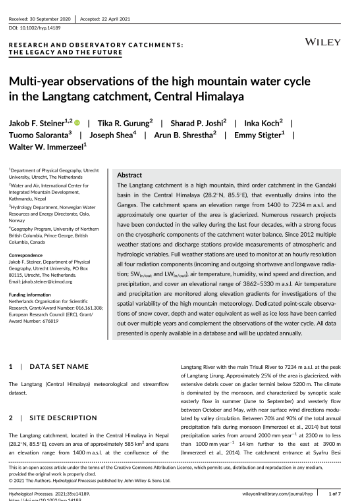
Data availability



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RESEARCH AND OBSERVATORY CATCHMENTS: THE LEGACY AND THE FUTURE

WILEY

Multi-year observations of the high mountain water cycle in the Langtang catchment, Central Himalaya

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Abstract
The Langtang catchment is a high mountain, third order catchment in the Gandaki basin in the Central Himalaya (28.2°N, 85.5°E), that eventually drains into the Ganges. The catchment spans an elevation range from 1400 to 7234 m a.s.l. and approximately one quarter of the area is glacierized. Numerous research projects have been conducted in the valley during the last four decades, with a strong focus on the cryospheric components of the catchment water balance. Since 2012 multiple weather stations and discharge stations provide measurements of atmospheric and hydrologic variables. Full weather stations are used to monitor at an hourly resolution all four radiation components (incoming and outgoing shortwave and longwave radiation; $SW_{in/out}$ and $LW_{in/out}$), air temperature, humidity, wind speed and direction, and precipitation, and cover an elevational range of 3862–5330 m a.s.l. Air temperature and precipitation are monitored along elevation gradients for investigations of the spatial variability of the high mountain meteorology. Dedicated point-scale observations of snow cover, depth and water equivalent as well as ice loss have been carried out over multiple years and complement the observations of the water cycle. All data presented is openly available in a database and will be updated annually.

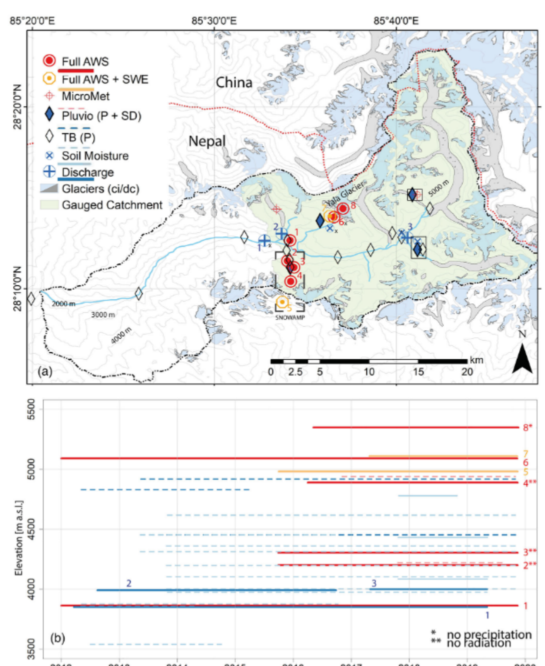
1 | DATA SET NAME

The Langtang (Central Himalaya) meteorological and streamflow dataset.

2 | SITE DESCRIPTION

The Langtang catchment, located in the Central Himalaya in Nepal (28.2°N, 85.5°E), covers an area of approximately 585 km² and spans an elevation range from 1400 m a.s.l. at the confluence of the Langtang River with the main Trisuli River to 7234 m a.s.l. at the peak of Langtang Lirung. Approximately 25% of the area is glacierized, with extensive debris cover on glacier termini below 5200 m. The climate is dominated by the monsoon, and characterized by synoptic scale easterly flow in summer (June to September) and westerly flow between October and May, with near surface wind directions modulated by valley circulation. Between 70% and 90% of the total annual precipitation falls during monsoon (Immerzeel et al., 2014) but total precipitation varies from around 2000 mm year^{-1} at 2300 m to less than 1000 mm year^{-1} 14 km further to the east at 3900 m (Immerzeel et al., 2014). The catchment entrance at Syafru Besi

Hydrological Processes. 2021;35:e14189. https://doi.org/10.1002/hyp.14189 wileyonlinelibrary.com/journal/hyp 1 of 7



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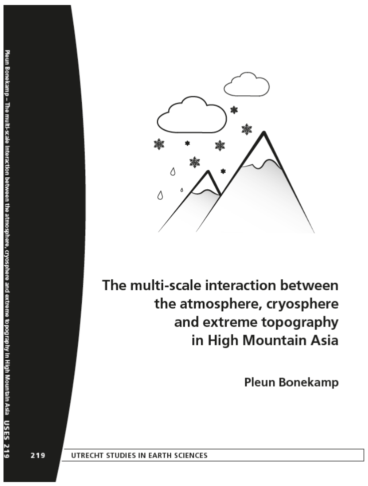
Scientific progress: meteorology



frontiers in Earth Science
ORIGINAL RESEARCH
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Contrasting Meteorological Drivers of the Glacier Mass Balance Between the Karakoram and Central Himalaya

Pleun N. J. Bonekamp[1]*, Remco J. de Kok[1], Emily Collier[2] and Walter W. Immerzeel[1]

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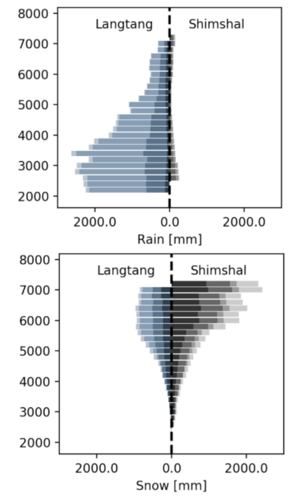
There is strong variation in glacier mass balances in High Mountain Asia. Particularly interesting is the fact that glaciers are in equilibrium or even gaining mass in the Karakoram and Kunlun Shan ranges, which is in sharp contrast with the negative mass balances in the rest of High Mountain Asia. To understand this difference, an in-depth understanding of the meteorological drivers of the glacier mass balance is required. In this study, two catchments in contrasting climatic regions, one in the central Himalaya (Langtang) and one in the Karakoram (Shimshal), are modeled at 1 km grid spacing with the numerical atmospheric model WRF for the period of 2011–2013. Our results show that the accumulation and melt dynamics of both regions differ due to contrasting meteorological conditions. In Shimshal, 92% of the annual precipitation falls in the form of snow, in contrast with 42% in Langtang. In addition, 80% of the total snow falls above an altitude of 5000 m a.s.l, compared with 35% in Langtang. Another prominent contrast is that most of the annual snowfall falls between December and May (71%), compared with 52% in Langtang. The melt regimes are also different, with 41% less energy available for melt in Shimshal. The melt in the Karakoram is controlled by net shortwave radiation (r = 0.79 ± 0.01) through the relatively low glacier albedo in summer, while net longwave radiation (clouds) dominates the energy balance in the Langtang region (r = 0.76 ± 0.02). High amounts of snowfall and low melt rates result in a simulated positive glacier surface mass balance in Shimshal (+0.31 ± 0.06 m w.e. $year^{-1}$) for the study period, while little snowfall, and high melt rates lead to a negative mass balance in Langtang (−0.40 ± 0.09 m w.e. $year^{-1}$). The melt in Shimshal is highly variable between years, and is especially sensitive to summer snow events that reset the surface albedo. We conclude that understanding glacier mass balance anomalies requires quantification and insight into subtle shifts in the energy balance and accumulation regimes at high altitude and that the sensitivity of glaciers to climate change is regionally variable.

Keywords: atmospheric modeling, glacier mass balance, WRF, High Mountain Asia, precipitation, weather, climate, high-resolution



Scientific progress: meteorology

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RESEARCH ARTICLE

International Journal of Climatology RMetS

Measurements, models and drivers of incoming longwave radiation in the Himalaya

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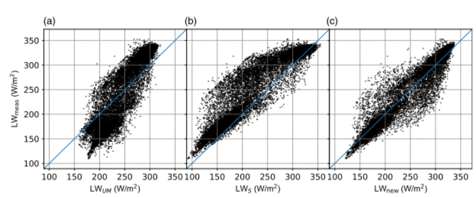
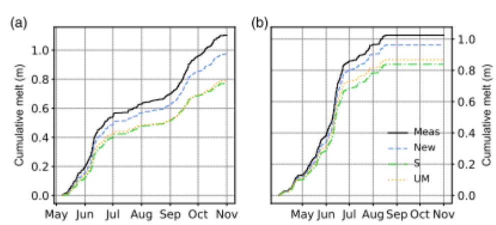
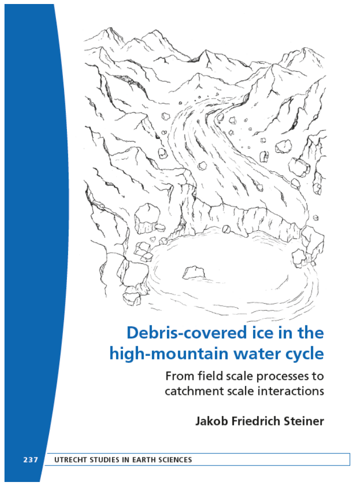
Abstract
Melting snow and glacier ice in the Himalaya forms an important source of water for people downstream. Incoming longwave radiation (LW_{in}) is an important energy source for melt, but there are only few measurements of LW_{in} at high elevation. For the modelling of snow and glacier melt, the LW_{in} is therefore often represented by parameterizations that were originally developed for lower elevation environments. With LW_{in} measurements at eight stations in three catchments in the Himalaya, with elevations between 3,980 and 6,352 m.a.s.l., we test existing LW_{in} parameterizations. We find that these parameterizations generally underestimate the LW_{in}, especially in wet (monsoon) conditions, where clouds are abundant and locally formed. We present a new parameterization based only on near-surface temperature and relative humidity, both of which are easy and inexpensive to measure accurately. The new parameterization performs better than the parameterizations available in literature, in some cases halving the root-mean-squared error. The new parameterization is especially improving existing parameterizations in cloudy conditions. We also show that the choice of longwave parameterization strongly affects melt calculations of snow and ice.

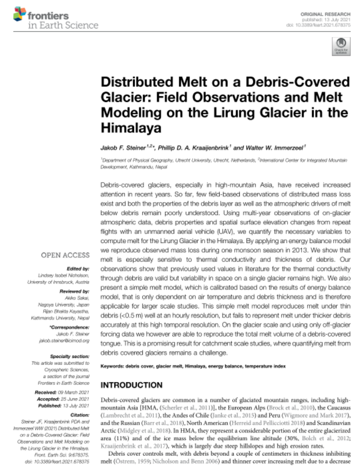
KEYWORDS
glaciers, Himalaya, longwave radiation, melt, snow





Scientific progress: glaciers





frontiers in Earth Science

ORIGINAL RESEARCH

Distributed Melt on a Debris-Covered Glacier: Field Observations and Melt Modeling on the Lirung Glacier in the Himalaya

Jakob F. Steiner[1,2]*, Phillip D. A. Kraaijenbrink[1] and Walter W. Immerzeel[1]

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Debris-covered glaciers, especially in high-mountain Asia, have received increased attention in recent years. So far, few field-based observations of distributed mass loss exist and both the properties of the debris layer as well as the atmospheric drivers of melt below debris remain poorly understood. Using multi-year observations of on-glacier atmospheric data, debris properties and spatial surface elevation changes from repeat flights with an unmanned aerial vehicle (UAV), we quantify the necessary variables to compute melt for the Lirung Glacier in the Himalaya. By applying an energy balance model we reproduce observed mass loss during one monsoon season in 2013. We show that melt is especially sensitive to thermal conductivity and thickness of debris. Our observations show that previously used values in literature for the thermal conductivity through debris are valid but variability in space on a single glacier remains high. We also present a simple melt model, which is calibrated based on the results of energy balance model, that is only dependent on air temperature and debris thickness and is therefore applicable for larger scale studies. This simple melt model reproduces melt under thin debris (<0.5 m) well at an hourly resolution, but fails to represent melt under thicker debris accurately at this high temporal resolution. On the glacier scale and using only off-glacier forcing data we however are able to reproduce the total melt volume of a debris-covered tongue. This is a promising result for catchment scale studies, where quantifying melt from debris covered glaciers remains a challenge.

Keywords: debris cover, glacier melt, Himalaya, energy balance, temperature index

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INTRODUCTION

Debris-covered glaciers are common in a number of glaciated mountain ranges, including high-mountain Asia [HMA, (Scherler et al., 2011)], the European Alps (Brock et al., 2010), the Caucasus (Lambrecht et al., 2011), the Andes of Chile (Janke et al., 2015) and Peru (Wigmore and Mark 2017), and the Russian (Barr et al., 2018), North American (Herreid and Pellicciotti 2018) and Scandinavian Arctic (Midgley et al., 2018). In HMA, they represent a considerable portion of the entire glacierized area (11%) and of the ice mass below the equilibrium line altitude (30%, Bolch et al., 2012; Kraaijenbrink et al., 2017), which is largely due steep hillslopes and high erosion rates.

Debris cover controls melt, with debris beyond a couple of centimeters in thickness inhibiting melt (Östrem, 1959; Nicholson and Benn 2006) and thinner cover increasing melt due to a decrease

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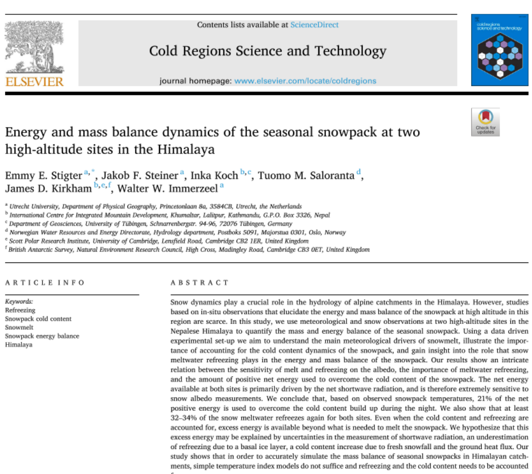
Scientific progress: snow



Contents lists available at ScienceDirect

Cold Regions Science and Technology

journal homepage: www.elsevier.com/locate/coldregions

Energy and mass balance dynamics of the seasonal snowpack at two high-altitude sites in the Himalaya

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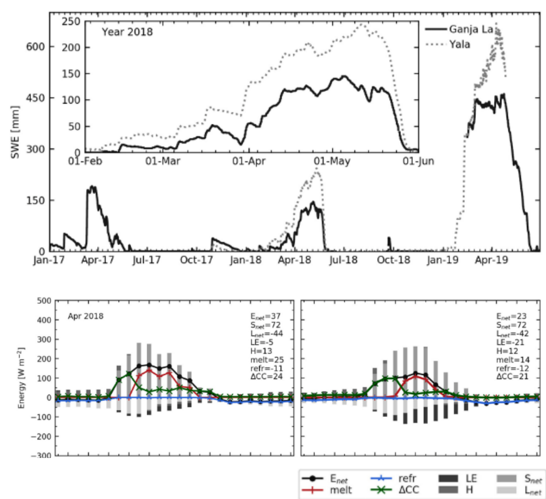
ABSTRACT

Snow dynamics play a crucial role in the hydrology of alpine catchments in the Himalaya. However, studies based on in-situ observations that elucidate the energy and mass balance of the snowpack at high altitude in this region are scarce. In this study, we use meteorological and snow observations at two high-altitude sites in the Nepalese Himalaya to quantify the mass and energy balance of the seasonal snowpack. Using a data driven experimental set-up we aim to understand the main meteorological drivers of snowmelt, illustrate the importance of accounting for the cold content dynamics of the snowpack, and gain insight into the role that snow meltwater refreezing plays in the energy and mass balance of the snowpack. Our results show an intricate relation between the sensitivity of melt and refreezing on the albedo, the importance of meltwater refreezing, and the amount of positive net energy used to overcome the cold content of the snowpack. The net energy available at both sites is primarily driven by the net shortwave radiation, and is therefore extremely sensitive to snow albedo measurements. We conclude that, based on observed snowpack temperatures, 21% of the net positive energy is used to overcome the cold content build up during the night. We also show that at least 32–34% of the snow meltwater refreezes again for both sites. Even when the cold content and refreezing are accounted for, excess energy is available beyond what is needed to melt the snowpack. We hypothesize that this excess energy may be explained by uncertainties in the measurement of shortwave radiation, an underestimation of refreezing due to a basal ice layer, a cold content increase due to fresh snowfall and the ground heat flux. Our study shows that in order to accurately simulate the mass balance of seasonal snowpacks in Himalayan catchments, simple temperature index models do not suffice and refreezing and the cold content needs to be accounted for.



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Scientific progress: snow

Journal of Glaciology

IGS

Article

Spatial and temporal patterns of snowmelt refreezing in a Himalayan catchment

Sanne B. M. Veldhuijsen[1], Remco J. de Kok[1], Emmy E. Stigter[1], Jakob F. Steiner[1,2], Tuomo M. Saloranta[3] and Walter W. Immerzeel[1]

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Catchment; Himalaya; modeling; refreezing; snow hydrology; snowmelt

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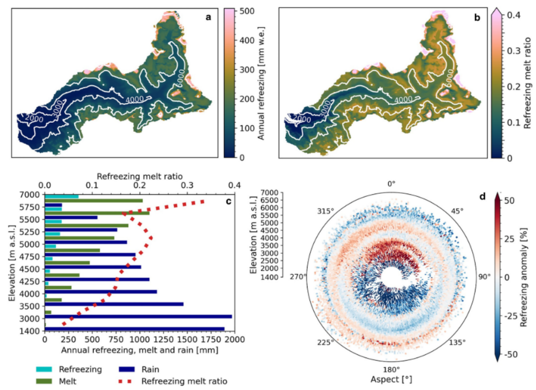
Abstract

Recent progress has been made in quantifying snowmelt in the Himalaya. Although the conditions are favorable for refreezing, little is known about the spatial variability of meltwater refreezing, hindering a complete understanding of seasonal snowmelt dynamics. This study aims to improve our understanding about how refreezing varies in space and time. We simulated refreezing with the seNorge (v2.0) snow model for the Langtang catchment, Nepalese Himalaya, covering a 5-year period. Meteorological forcing data were derived from a unique elaborate network of meteorological stations and high-resolution meteorological simulations. The results show that the annual catchment average refreezing amounts to 122 mm w.e. (21% of the melt), and varies strongly in space depending on elevation and aspect. In addition, there is a seasonal altitudinal variability related to air temperature and snow depth, with most refreezing during the early melt season. Substantial intra-annual variability resulted from fluctuations in snowfall. Daily refreezing simulations decreased by 84% (annual catchment average of 19 mm w.e.) compared to hourly simulations, emphasizing the importance of using sub-daily time steps to capture melt–refreeze cycles. Climate sensitivity experiments revealed that refreezing is highly sensitive to changes in air temperature as a 2°C increase leads to a refreezing decrease of 35%.



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COVID-19 impact

- Last visit to all station in November 2019, so considerable impact expected
- Partner ICIMOD visited main AWS in 2021
- Planned joined visit November 2021
  - Inventory (power, memory, maintenance)
  - Download newly installed groundwater, soil moisture and precipitation radar

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