NEAR REAL-TIME MAPPING OF SNOW CONDITIONS IN REMOTE HIGH-MOUNTAIN HIMALAYA

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ABSTRACT: In the Nepal Himalayas snow and avalanches can cause major disasters. Snow melt water is also an important water resource, especially during the dry season. We combine data from robust automatic solar-powered snow/weather measurement stations with simulations from a numerical snow model to provide useful regional estimates of snow depth, snow water equivalent, extent of snow-covered area and the snow line elevation in near real-time. The resulting snow maps may be useful for e.g. hydropower and disaster risk reduction applications.

KEYWORDS: snow modelling, Himalaya, disaster risk reduction.

1. INTRODUCTION

The seasonal snow cover is an important source of melt water for human use, irrigation and hydropower production in many regions of the world. On the other hand, the snow cover and melt water can also be a cause of disastrous floods and avalanches. Snow cover is also a key factor in the weather and climate system, both regionally and globally, and an important playground for tourism. Consequently, many countries run an operational snow mapping service to provide information of snow conditions for planning hydropower production and water resources management, for natural hazard forecasting (flood, avalanche), for informing the public and tourists on trekking or skiing conditions in the mountains, etc.

In the Nepal Himalayas snow and avalanches can cause major disasters. For example, in autumn 2014 at least 32 people were killed when a sudden snowstorm in the country’s Annapurna region trapped hundreds of trekkers. A half year later in the spring 2015 anomalously large snow amounts and a major earthquake triggered numerous avalanches, of which a massive one with estimated volume of approximately 7 million m3 (Fujita et al., 2017) hit the Langtang village killing more than 350 locals and tourists.

In the light of the planned hydropower development initiatives in Nepal and of the recent snow-related disasters, it seems obvious that there is a great demand for up-to-date information on the snow conditions in the remote high-altitude Himalayan environments.

We present a snow mapping approach where we combine data from robust automatic solar-powered snow/weather measurement stations with simulations from a numerical snow model to provide useful regional estimates of snow depth (SD), snow water equivalent (SWE), extent of snow-covered area (SCA) and the snow line elevation in near real-time. The resulting snow maps may be useful for e.g. hydropower and disaster risk reduction applications as well as for local citizens and tourists.

2. DATA AND METHODS

Our case study area is the remote Langtang valley in the Nepal Himalayas, approximately 100 km north of Kathmandu. In this region, seasonal snow cover is abundant above 4000-5000 m above sea level (a.s.l.) but routine snow monitoring (manual snow surveys) is demanding as the approach to the snow-covered areas is difficult and/or expensive (several days trekking and acclimatization needed, helicopter transport as an alternative).

Four automatic solar- and wind-powered measurement stations were installed in the Langtang catchment on a mountain face between 4200 and 5000 m a.s.l. In September 2015 (Saloranta et al. 2016; Figure 1). All the four installed stations measure hourly air temperature and humidity, ground temperature, snow depth, precipitation (3 out of 4 stations) and include a time-lapse camera taking frequent images of the station surroundings. Moreover, the highest station (Ganja-La) is also equipped with an extra precipitation gauge and measures in addition SWE, air pressure, long- and short-wave radiation, as well as wind-speed and direction. The sensors are attached to lightweight aluminum masts and transmit their data in real-time via the Iridium satellite system.
The snow simulation model applied in this study is the seNorge snow model, which was originally developed for operational snow mapping in Norway (www.seNorge.no). The input data requirements for the model are air temperature and precipitation. The high-mountain version (v.2) of the model, described in Saloranta et al. (2016), is applied here.

Our model application is aiming to be used in practical purposes in remote mountain areas, and is therefore simplified somewhat (compared to e.g. detailed multi-layer energy-balance snow models) in terms of the required model input data types and number of calibrated parameters. Our aim is also to select from all the applied sensors a robust, almost maintenance-free subset of primary sensors that are at minimum needed for a successful and simplified year-round snow mapping application. Data of SCA derived from MODIS satellite images is also used in evaluating the model results.

In order to simulate the integral effects of gravitational snow transport due to avalanching activity in the steep Himalayan terrain, the SnowSlide algorithm (Bernhardt and Schultz, 2010) is applied. This algorithm distributes snow between model grid cells whenever a snow holding depth ($S_{hd}$) and a minimum slope angle ($S_{m}$) are exceeded. The $S_{m}$ is set to 25°, as in Bernhardt and Schultz (2010), and an exponential relation between the slope angle and $S_{hd}$ is used, as proposed by Bernhardt and Schultz (2010). With the selected parameter values (Saloranta et al., 2016), slope angles of 35, 50, and 65°, for example, can hold 1000, 250 and 60 mm of SWE, respectively.

3. RESULTS

Our setup for near real-time snow mapping application for remote high-altitude mountain areas has utilized robust and rather maintenance-free sensors to provide data for model forcing. The passive gamma-radiation SWE-sensor (CS725) has been a central instrument in the monitoring setup. Using the CS725 in combination with a tipping bucket precipitation gauge at lower elevation has provided us year-round time series of precipitation, reducing the potentially substantial catch correction uncertainties for snow commonly encountered with traditional precipitation gauges. In addition, the model’s snow melt rate parameters are estimated on the basis of the SWE time-series obtained from the CS725.

Figure 2 shows an example of a simulated SWE map (log10-transformed SWE-values) for the Langtang catchment in October 29, 2017, as well as comparison of observed and simulated SD in July 2016-June 2018 at around 4250 and 4925 m a.s.l. elevations.

The preliminary results are promising and the near-real time snow map application will be further refined and made operational in near future. We believe it can provide useful and cost-effective information on snow cover, snow depth and water equivalent, as well as on weather conditions for the purposes and needs of e.g. hydropower companies, local authorities and other practical applications in remote mountain areas.

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REFERENCES


Figure 1: The monitored mountain face in Langtang valley. The view is southwards towards the Ganja-La pass at 5100 m a.s.l. Photo: automatic time-lapse camera.
Figure 2: (a) Example of a simulated SWE map (log$_{10}$-transformed SWE-values) for the Langtang catchment in October 29, 2017. The cumulative area-fraction vs. elevation distribution is also shown. (b) The observed snow depth in July 2016-June 2018 at the Lower and Middle stations (red and orange lines), as well as at the Upper and Ganja-La stations (light and dark blue lines). The simulated snow depth at the average elevation of the station-pairs is shown by black lines.