INVESTIGATING PERFORMANCE AND CORRELATION OF GROUND-BASED SNOW DEPTH AND PRECIPITATION MEASUREMENTS

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ABSTRACT: The performance of snow models is highly affected by the quality of precipitation input data. Particularly solid precipitation measurements in mountain regions are prone to systematic undercatch and larger errors caused by harsh meteorological conditions. The pluSnow project aims in evaluating the correction of solid precipitation in now-cast applications and for snow modelling using high accuracy snow depth measured from laser distance sensors in combination with best new snow density approximations. Further, existing formulas adjusting precipitation input for snow modelling were evaluated on the basis of an extensive station network. Applying the SNOWGRID snow cover model shows that the formulas are useful to correct for undercatch at some of the stations, but are not necessary at other stations, and may not explain the observed difference between precipitation and heights of new snow especially at higher elevation stations. In general, the comparison between snow depths and precipitation is very specific for the individual stations locations, and correlations vary accordingly. However, this local information has a high value for the application of snow models by operational hydrological and meteorological services.

KEYWORDS: precipitation correction, snow cover modelling, new snow density

1. INTRODUCTION

The European Alps hold the densest network of automatic weather stations (AWS) in mountain regions of the world. Thanks to the efforts of national weather-, hydrological and avalanche warning services, and various research institutions, the overall number of AWS has increased significantly in recent years and particularly stations using sophisticated instrumentation to record snow parameters at high elevations are becoming more and more ubiquitous.

In Austria, the Zentralanstalt für Meteorologie und Geodynamik (ZAMG) has currently mounted optical snow depth sensors (SHM30) to 82 stations of its operational network. The opto-electronic distance sensor is based on laser technology and has a markedly higher accuracy of a few millimetres, compared to the centimetre scale-accuracy of ultra-sonic sensors, which are more commonly used for operational snow depth observation. The pluSnow projects aims in evaluating the potential of using these high accuracy snow depth measurements for correcting solid precipitation for nowcast and snow modelling applications.

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2. HEIGHT OF NEW SNOW AND PRECIPITATION

Physically based snow models and nowcast applications make use of hourly weather data to determine the water equivalent of the snowfall and snow depth. In a first study, we compared snow depth changes measured using the opto-electronic distance sensor SHM30 to precipitation measurements during snow fall events (Helfricht et al., 2016). In general, a high correlation between precipitation and the height of new snow could be detected using hourly data of snow depth changes measured using the laser sensor SHM30 , also showing precipitation undercatch when applying widely used assumptions on new snow density. The need of additional analysis on new snow densities for comparing gauged precipitation and the water equivalent of snowfall directly was reported.

3. DENSITY OF NEW SNOW

Many empirical equations for approximating new snow density exist, which largely are based on daily new snow measurements derived from local field studies.

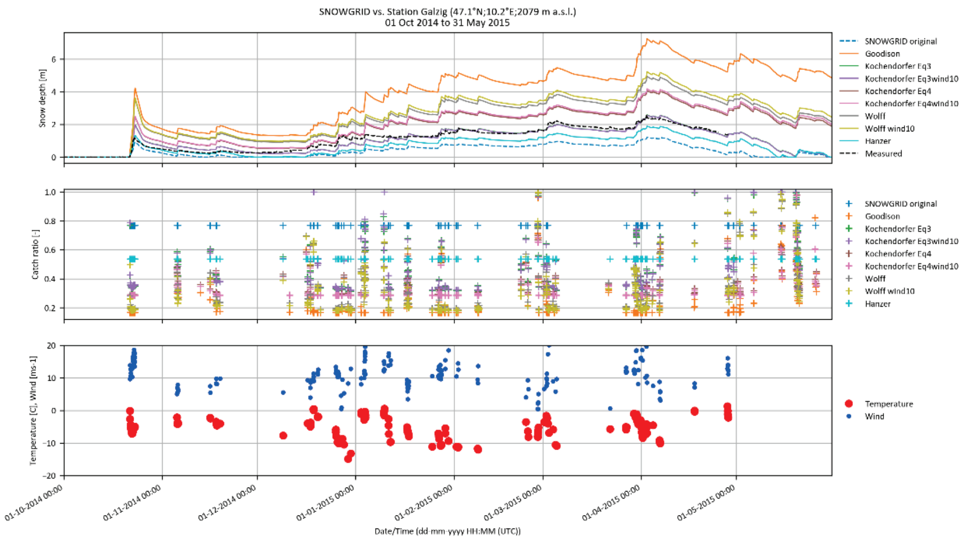

Figure 1: Top: Course of the measured and modelled snow depth at station Galzig (2079 m a.s.l.). Middle: Calculated catch ratios; and Bottom: measured temperature and wind data for the snow fall events.

Helfricht et al. (2017) analysed a data set of automated hourly meteorological measurements at four stations located in the European Alps and over several winter seasons. They calculated the density of the new snow from combined measurements of snow water equivalent and snow depth, and compared the results to density estimates using these existing formulas. The average density of the new snow for hourly snowfall data was found to be 68 ± 9 kgm^{-3}, which is distinctly lower than calculations from most existing equations for new snow density related to meteorological conditions and lower than the frequently used bulk approximation of 100 kgm^{-3} often used for daily snowfall amounts.

4. PRECIPITATION CORRECTION IN SNOW MODEL

We tested the application of different precipitation corrections based on the performance of the SNOWGRID snow cover model (Olefs et al., 2013) compared to measured snow depths. Precipitation correction was applied to the INCA analysis data (Haiden et al., 2011) serving as model input. First, the original INCA precipitation correction was reversed and the precipitation corrections presented by Goodison et al. (1998), Hanzer et al. (2014), Wolff et al. (2016) and Kochendorfer et al. (2017) were successively applied. Equations for different wind levels were also considered.

To show an example, results for one winter season at the high mountain station Galzig (2079 m a.s.l.) are presented in Figure 1. This station shows a high dependence of the model performance in relation to wind speed, but a systematic underestimation using INCA precipitation input. An overestimation of precipitation input results from several of the tested equations including wind dependence. However, in this special case, a good fit to measured snow depths could be simulated applying Eq. 3 of Kochendorfer et al. (2017).

In general, it turns out that the applicability of precipitation corrections using measured wind and temperature values for snow depth modeling is very station specific (Figure 2). The mean BIAS appears to be low for low elevation sites, but spreads for high mountain stations. The model performance could be increased using precipitation correction in relation to temperature and wind speed, but the respective best equations differ between the stations. Nevertheless, using precipitation corrections improves snowpack simulation particularly at higher altitude stations, although overestimation caused by high wind speeds particularly for hourly to sub-hourly time steps has to be considered.

The results help to: (i) identify stations with significant wind influence on the precipitation measurement, (ii) identify stations where no wind dependent precipitation correction is needed or (iii) identify stations where the underestimation of precipitation cannot be explained on the basis of measured wind and temperature data.

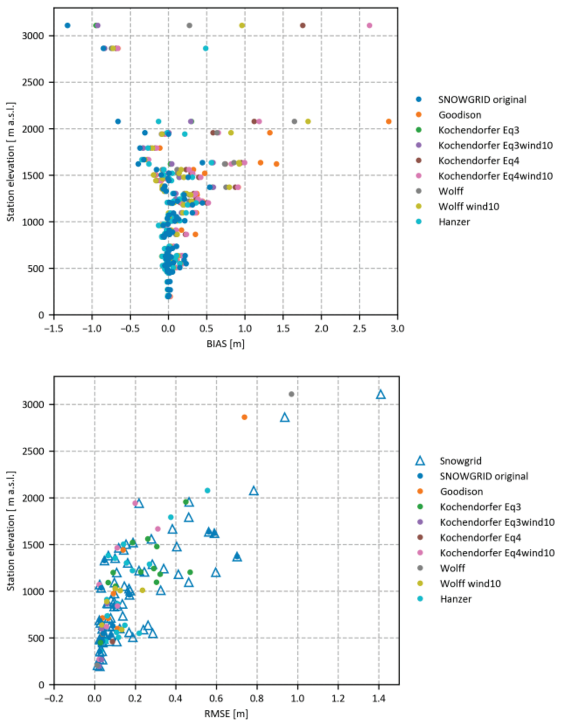

Figure 2: Top: Season mean BIAS between modelled and measured snow depth using different precipitation correction formulas. Bottom: Original SNOWGRID model results (triangle) and best performing precipitation correction formulas with the lowest root mean squared error for hourly values of modelled compared to measured snow depth.

5. CONCLUSION AND OUTLOOK

The correlation between measured heights of new snow and precipitation was shown to be high and a range of measured hourly values of new snow density was determined for Alpine station locations. In a next step these information can be incorporated in testing a validation and correction method for now-cast of solid precipitation based on measured snow depth. The knowledge on specific station performance can thereby be useful to improve local and regional snow model results. Considering bias-correction of winter precipitation input at distinct observation sites are relevant in a general sense to operational hydrological and meteorological services, which are using spatially distributed precipitation maps calculated from point information for further applications.

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