SNOWMAUS ERRORS IN SIMULATION OF SNOW WATER CONTENT

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Model SnowMAUS estimates a presence of snow cover, its depth, water content, and volume of precipitation in the form of snow. SnowMAUS is usable in crop simulation models for the assessment of the impact of climate change on crops overwintering. The aim of the study is to evaluate the SnowMAUS skill to simulate snow water content (SWC). SWC was calculated from daily sum of precipitation and extremes of air temperature. Evaluation was made by comparison with two reference datasets: weekly SWC station data and daily SWC derived by empirical algorithm designated by Němec (SWE model). SnowMAUS testing was done at 14 locations in the Czech Republic (altitude 158 – 1260 m) in the period 1961 – 2011. Timing of snow cover is in a good agreement with both validation datasets, however, SWC values are underestimated in SnowMAUS especially for high SWC values. The difference is rising with altitude. The reasons of poor SnowMAUS skills are associated with a selection of input meteorological parameters and their role in the SWC calculation. Liquid precipitation is not considered to contribute to SWC. Similarly there's too low accumulation of snow cover (and thus SWC rise) when air temperature is between -6 °C and 0 °C.

Keywords: snow cover, precipitation, snow water content

INTRODUCTION

Snow cover is the important factor in water fluxes between the earth surface and atmosphere and it also significantly influences soil water fluxes and runoff. Snow cover also affects radiation and water balance determinations that are inputs to hydrological cycle and climate studies (Yang et al., 1999). Furthermore the presence of snow cover accounts for the large difference between summer and winter land surface albedo. Snow may reflect up to 95 % of the incoming solar energy (Sellers, 1965), dropping to less than 20 % for snow-free surfaces such as soil or vegetation. Warming trend would result in decreased snow cover and consequently a decrease in reflected energy and therefore greater absorption of solar radiation, adding more heat to the climate system. The presence or absence of a snowpack controls energy fluxes and defines the development of frozen soil which has certain consequences for soil biological and chemical processes (Edwards et al., 2007). The insulating properties of snow influence the underlying soil temperature regime and the extent to which soil is directly exposed to freezing and thawing episodes. After making a detailed energy balance of the soil–snow–atmosphere continuum, Cline (1995) suggested that 30–40 cm of snow depth is sufficient to effectively decouple soil temperature from air temperature. When air temperature above 0.5 m thick snow cover drops below −30 °C, soil surface temperature will remain above
−10 °C. This insulation limits crop damage and enhances the survival of various pest species (Lamb et al., 1985). The presence of snow is particularly important when the minimum temperature is below the critical threshold for survival, which would result in large-scale economic losses in the absence of snow cover, even for winter-hardy crops (e.g., winter wheat). Measurements of precipitation in the form of snow, snow cover

height or water content of the snow cover are inherently difficult and prone to errors (e.g. Strangeways, 2007). Methods for estimating snow cover (and snow melt) using more readily available meteorological elements as proxies (e.g., air temperature) have been a focus of present study (Hock, 2003). Our goal is to test the SnowMAUS (*Snow* cover *M*odel for *A*grometeorological *US*e) skill to simulate snow water content (SWC) by comparison with empirical algorithm designated by Němec (SWE model) and station measurements at selected locations.

MATERIALS AND METHODS

SnowMAUS is strictly relied on the weather data used by all crop simulation models, i.e. diurnal temperature extremes and total daily precipitation. Such snow model can easily be used to preprocess input data in order to account for the presence or absence of snow cover whenever required by the crop modeler, without necessitating the acquisition of additional data. SnowMAUS was developed using data from 65 sites across Austria (see Trnka et al., 2010). As the input data SnowMAUS takes the following daily weather records: maximum and minimum air temperatures at 2 m above the surface, sum of precipitation, precipitation type, snow cover height and information about start/end of snow cover. The snow cover volume is expressed in terms of water content in mm (Trnka et al., 2010).

SnowMAUS assumed snow accumulation for precipitation events on days with (Tmax + Tmin)/2.0 < 0.0 °C, and that snow melted at a calibrated rate (0.042, cm.$°C^{-1}$ per day) when Tmin was above an empirical threshold (being −6.0 °C).

Snow accumulation estimated by SnowMAUS is driven by Tmin and its position to accumulation thresholds. If Tmin is below 0 °C (TminAccu1) some portion of precipitation is assumed to be snow. When Tmin is below or equal -6 °C (TminAccu2), all precipitation on that day is in the form of snow. If Tmin is between -6 °C and 0 °C snow accumulation (SnowAccu) in terms of snow water content (mm) is calculated as follows:

$$Snow_{Accu} = \left(1 - \frac{T_{\min} - T_{\min Accu2}}{|T_{\min Accu1} - T_{\min Accu2}|}\right) \times Precip$$

Snow melting is possible if Tmin is above -12 °C, impossible if Tmax is below 5 °C and Tmin is simultaneously below the freezing point. Snow melting is usually facilitated by other factors, such as sublimation, sun-driven ablation and often combined with the influence of wind.

SWE model developed by Němec (Němec, Stříž, 2011) at Czech Hydrometeorological Institute (CHMI) calculates the amount of water in snow cover directly from daily meteorological measurements of sum of precipitation (0.1 mm), new snow cover depth (cm), total snow cover depth (cm), and daily mean water vapour pressure (hPa). The latter is not available on all meteorological stations, but due to its rather small spatial variability a value from the nearest suitable station can be taken instead at any desired locations where remaining parameters are recorded. Accumulation and reduction of snow water content in the SWE model are driven only by observed changes of snowpack, input of water due to precipitation and its loss by sublimation. Water exchange between snowpack and soil is not taken into consideration.

Snow cover properties are currently measured on more than 700 CHMI stations. While heights of total and newly fallen snow are observed daily at 7 am in the morning, snow water content is recorded only once a week, on Monday at 7 am. Measurements are based on melting or weighting of a snow sample profile, depending on the station altitude. Both methods are quite demanding on observer skills and can be time consuming. Unfortunately it leads to often errors in the SWC data that should be handled with an extra caution.

For the comparison of simulated SWE by two models daily meteorological data from 14 locations in altitude range from 158 to 1260 m in the Czech Republic were taken. The validation was performed in the 41 year long period, 1961 – 2011. We tested snow cover timing, duration (start and the end of snow cover), snow cover increase or decrease and snow water content. SnowMAUS SWC was tested with two reference datasets: i) SWC values derived by Něměc SWE model, ii) measured snow data by CHMI.

RESULTS

Comparison of SWC estimated by the SnowMAUS, Němec model and CHMI observed data has showed the significant differences among all three datasets. The most agreement was detected between Němec model and CHMI measured data expressed by high Pearson correlation coefficient (R = 0.95) (Fig. 1).

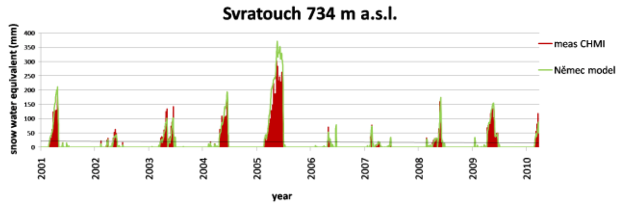

Figure 1 Svratouch: comparison of snow water content by CHMI observed data (red line) and Němec model (blue line) in winters 2001 - 2010

This is quite expectable since the Němec model was developed and validated against the observed data in the Czech Republic. Because of high correlation between Němec model and observed data the subsequent data testing present in this study focused SnowMAUS and CHMI data only. Graphic expression shows SWC estimated by SnowMaus and CHMI data during 10 winters in the period 2001 – 2010 in Doksany (158 m a.s.l.) (Fig. 2) and Svratouch (734 m a.s.l.) (Fig. 3).

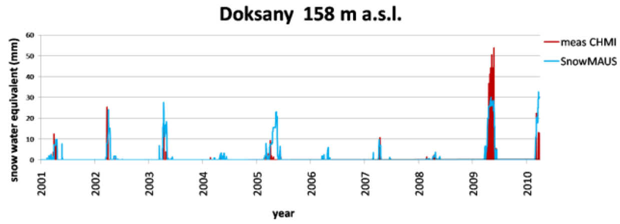

Figure 2 Doksany: comparison of snow water content by CHMI observed data (red line) and SnowMAUS (blue line) in winters 2001 - 2010

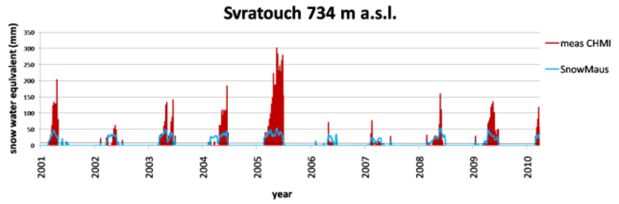

Figure 3 Svratouch: comparison of snow water content by CHMI observed data (red line) and SnowMAUS (blue line) in winters 2001 - 2010

Fig. 2 reveals that SnowMAUS is sufficiently capable of capturing snow cover timing but not increase/decrease trends of snow cover volume. Accurate value of SWC is modelled almost up to 25 mm, above this level the model lost it's reliability (R = 0.80). This is even more obvious at higher elevated locations (see Fig. 3), where SnowMAUS strongly underestimates SWC values, sometimes even on more than 80 % of observed SWC as was expressed by lower correlation between SWC according to SnowMaus nad CHMI data (R = 0.78). In addition, seasonal maximum of SWC, both the timing and volume, is not well estimated.

We have managed to identify one reason why SnowMAUS is insufficient to well estimate SWC. When liquid or mixed precipitation falls into snow cover, water is considered to infiltrate into the soil and not contribute to SWC. In reality this can be one of the most important processes of SWC increase. In SnowMAUS this case occurs when air temperature is between -6 °C and 0 °C.

Following steps in SnowMAUS altering will include the process of testing various ranges of temperature accumulation thresholds, modification of temperature interval for snow cover accumulation, testing of more methods of SWC calculation in terms of snow accumulation formula in temperatures near 0 °C.

CONCLUSION

In present study there were two snow cover models. SnowMAUS and Němec model provide the assessment of the presence/absence of snow cover, its start/end, and volume in terms of snow water content. Results of both models were validated with usage of observed snow cover data and the comparison has detected i) Němec model high reliability in the estimation of all items, ii) SnowMAUS capability to well express the presence/absence, timing and duration of snow cover but insufficient estimation of SWC. Testing and improvement of the snow accumulation in temperatures between -6 °C and 0 °C will be the objective of the next study.

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