# THE IMPORTANCE OF THE SNOW COVER CONSIDERATION WITHIN WATER BALANCE AND CROPS GROWTH MODELING

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***The importance of the snow cover for field crops is within proper conditions for overwintering due to protection against low temperatures and it is significant income component from the water balance point of view. Both of these functions should be taken into account when applying so-called crop growth models for simulations of growth and the development of target field crops (if snow is present within the season). Although crop growth models are very sophisticated software, algorithms for estimating the occurrence and influence of snow cover are not always included. This is also the case with the HERMES model, which can be successfully used for modeling of whole crop rotations, but module for snow cover consideration is not originally included.***

***The main objective of this study is to test the importance of algorithms for estimating the snow cover on the results of growth and development of winter wheat (Bohemia variety) on the example of selected growing seasons. The snow cover estimates were conducted by the SnowMAUS model. The relevant field experiment was carried out at the Domaninek site (49°31'42"N, 16°14'13"E, altitude 560 m). Experimental site is characterized by dystric cambisol soil type, mean annual temperature of 7.2 °C and mean precipitation of 609.3 mm (1981–2010). For the purpose of presented study the necessary inputs like daily meteorological data for the HERMES and SnowMAUS (global radiation, maximal/minimal air temperature, precipitation, air humidity and wind speed) are available. Moreover observed values of phenological phases, leaf area index, yields and soil moisture were used for validation of HERMES model results and simulations with and without snow cover consideration.***

***Keywords: crop development, HERMES crop growth model, SnowMAUS model, soil moisture, grain yields***

## INTRODUCTION

Balanced water balance is important factor of plant growth and development which is incoming to difficult soil–plant–atmosphere system (Ritchie, 1981). Precipitation supply the soil by water, however, distribution and amount of precipitation is unequal and result in unstable crop yields. Especially, in the course of winter the amount of precipitation also affect the volume of available water in the soil in the spring of next year. A sufficiently hight snow cover positively influences the root system of winter crops. Almost 5 cm of snow significantly reduces the effects of low temperatures and 20 cm hight snow cover already eliminates the effect of strong frost (Brázdil et al., 2015; Trnka, 2015). The occurrence of the snow cover also affects herbivores (or other pests) or patogens which live/occure on the surface of the ground or on the snow cover and who may cause damage of yields (Hakala et al., 2011; Tkadlec et al., 2006).

Climate change and rising temperatures modify agroclimatic zones (Trnka et al., 2011) and reduce global crop production (e.g. Asseng et al., 2014). Higher temperature (as already mentioned above) implicate no snow winter or winter with shorter duration or lower of snow cover, thus favorable conditions for the onset of spring drought are constituted (Brázdil et al., 2015). Climate impacts studies and adaptation strategies are increasingly becoming major areas of scientific concern. It is related with water balance models that are frequently used to study the potential impact of climate change and risk assessment (Christensen et al., 2007). Crop growth models do not usually take into account ambient influences (e.g. biotic or abiotic). However, there are studies that attempt to model availability of soil water content depending also on the timing of snow melting (e.g. Hlavinka et al., 2011; Trnka et al., 2010).

In this paper the snow cover estimates were conducted by snow cover model – SnowMAUS. The HERMES crop growth model was considered as further approach which included SnowMAUS output weather data. According to Trnka et al. (2010), the SnowMAUS model used to evaluation liquid and solid precipitation which is usually not taken into account by other crop growth models (e.g. DSSAT, HERMES, STICS or WOFOST). It leads to provide less accurate estimates of winter soil moisture and temperature.

The main aim of current study was analyse results of HERMES crop growth modeling with/without using snow cover model (SnowMAUS).

## MATERIALS AND METHODS

The data for current study was obtained at the Domanínek experimental station (Bystřice nad Pernštejnem, Czech Republic) for the years 2014–2016. Domanínek is located 60 km northwest of Brno in altitude 560 m. The climate conditions were characteriside as cool and wet with potentional risk of late frosts. Mean annual temperature was 7.2 °C and mean annual precipitation was 609.3 mm (1981–2010). Typical soil type is dystric cambisol.

At the Domanínek experimental station, the winter wheat (variety Bohemia) was sown in 3 control variants in rainfed area on 30th September 2014 and 25th September 2015 (abbreviated as growing season 2014/2015 and 2015/2016 respectively). There were observed and measured phenological phases of winter wheat, soil moisture and yields. TDR sensors (Time Domain Reflectometry, CS 616, Campbell Scientific Inc., Shepshed, UK) were used for measuring soil water moisture to depth 0.3 m.

The experiment was based on crop modeling with using HERMES crop growth model (Kersebaum, 2008) and the SnowMAUS model (Trnka et al., 2010). The HERMES crop growth model is procces-oriented model working in daily steps. It is able to estimate development and growth of the field crop, soil water balance and nitrogen dynamics for arable land.

The incoming daily meteorological data to the HERMES model were modified by the SnowMAUS model (minimum and maximum temperature at 2 m height and total precipitation). In addition, measured data in the next part of this paper is referred to as MD and modified data by the SnowMAUS model is referred to as SM. Data with no indications determines measured data.

The SnowMAUS model is snow cover model used to evaluation liquid and solid precipitation. The model run on daily time step basis which certain key parameters for governing snow accumulation and melting. Snow accumulation is managed by the minimum temperature at which part of the precipitation occurs in the form of snow and minimum temperature at which all precipitation on the given day is in the snow form. In the case of melting snow (affected e.g. sublimation, sun-driven ablation or wind speed) the empirical parameters to account for daily snow loss, was introduced, i.e. all days with no snow cumulation on that day, a fixed loss of snow water due to sublimation was deduced (Trnka et al., 2010).

## RESULTS

Total rainfall was 242 and 295 mm at experimental location in Domanínek in periods of 2014/2015 and 2015/2016 (from November to April) respectively. Estimated amount of snow in form of water content (mm) by SnowMAUS model is depicted in Fig. 1. Simultaneously, Fig. 1 include measured total rainfall from September 2014 to August 2016.

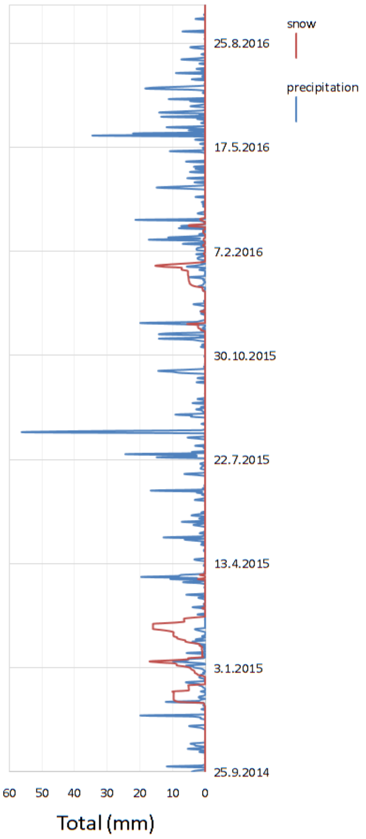


**Figure 1.** Total daily measured precipitation (included snowfall in winter season; blue line) versus modeled snow water content (red line) for period September 2014 to August 2016.

According SnowMAUS model the snow cover arose 27-11-2014 (0.1 mm) and 23-11-2015 (1.3 mm) and the last day with snow cover appeared on 02-04-2015 (1.67 mm) and 16-03-2016 (0.15 mm) for growing seasons 2014/2015 and 2015/2016 respectively. In growing season 2014/2015, 84 snow cover days were occured and 57 days were with a permanent snow cover. In contrast, in growing season 2015/2016, 58 snow cover days were occured and 28 days were with a permanent snow cover. The most significant accumulation of snow occurred in January (both growing seasons 2015 and 2016) and the snow depth was 16.96 and 15.28 mm (of water column) respectively.

More characteristics of the mentioned days with the most significant snow cover accumulations is found in Tab. 1.

**Table 1.** Characteristics the most significant accumulations of snow cover in growing seasons 2014/2015 and 2015/2016.

| Growing season | Date | Snow cover (mm) | Temperature (°C) | | |
|---|---|---|---|---|---|
| | | | MIN | MAX | average |
| 2014/2015 | 09.01.2015 | 16.96 | -3.7 | 5.8 | 1.01 |
| 2015/2016 | 24.01.2016 | 15.28 | -4.6 | 3.3 | -0.64 |

The HERMES crop growth model was calibrated on the basis of observed phenological phases (emergence, tillering, heading, flowering and maturity) when the modeled phenological phases were approximated to the observed phenological phases (see Tab. 2a). Results of the run of HERMES and HERMES (SM) represented HERMES differences for 2014/2015 growing season. Within tillering, model (SM) shifted this phenological phase by one day (from 100 to 101 day of the year). Another phenological phases remained in compliance. Results of modeled phenological phases of HERMES and HERMES (SM) (2015/2016) difference remained without fluctuating (see Tab. 2b).

**Table 2.** The observed and modeled phenological phases (as day of the year) of winter wheat under using of observed and modified (SM) data bySnowMAUS model for growing season 2014/2015 (a) and for growing season 2015/2016 (b).

**a)**

| Data (2014/2015) | Phenological phases | | | | |
|---|---|---|---|---|---|
| | emergence | tillering | heading | flowering | maturity |
| Measured | 286 | 342 | 153 | 164 | 218 |
| HERMES | 285 | 100 | 144 | 165 | 218 |
| HERMES (SM) | 285 | 101 | 144 | 165 | 218 |
| HERMES difference | 0 | -1 | 0 | 0 | 0 |

**b)**

| Data (2015/2016) | Phenological phases | | | | |
|---|---|---|---|---|---|
| | emergence | tillering | heading | flowering | maturity |
| Measured | 277 | 314 | 153 | 162 | 229 |
| HERMES | 281 | 90 | 144 | 168 | 229 |
| HERMES (SM) | 281 | 90 | 144 | 168 | 229 |
| HERMES difference | 0 | 0 | 0 | 0 | 0 |

Within LAI (Leaf Area Index) modeling, differences between HERMES and HERMES (SM) (HERMES minus HERMES_SM) were more apparent in the period 2014/2015 (the largest diferences were 0.10 $m^2 \cdot m^{-2}$ at the peak of growing season) than 2015/2016 (the largest differences fluctuated around the value of 0.03 $m^2 \cdot m^{-2}$ from April to July 2016).

With reference to results showed in Fig. 2a) evaluation of soil moisture (0.0–0.3 m) estimates using TDR sensors was more accurate for growing season 2014/2015 than for growing season 2015/2016. Snow cover depth is depicted by blue line for presenting accumulation and melting of snow cover under SnowMAUS modeling. Deviation between HERMES and HERMES (SM) modeling was again inconsiderable and it ranged from -0.2 to 0.1% (Fig. 2b). In comparison with soil moisture modeling in depth 0.3–0.6 m a deviation between HERMES and HERMES (SM) was also in range from -0.2 to 0.1%.

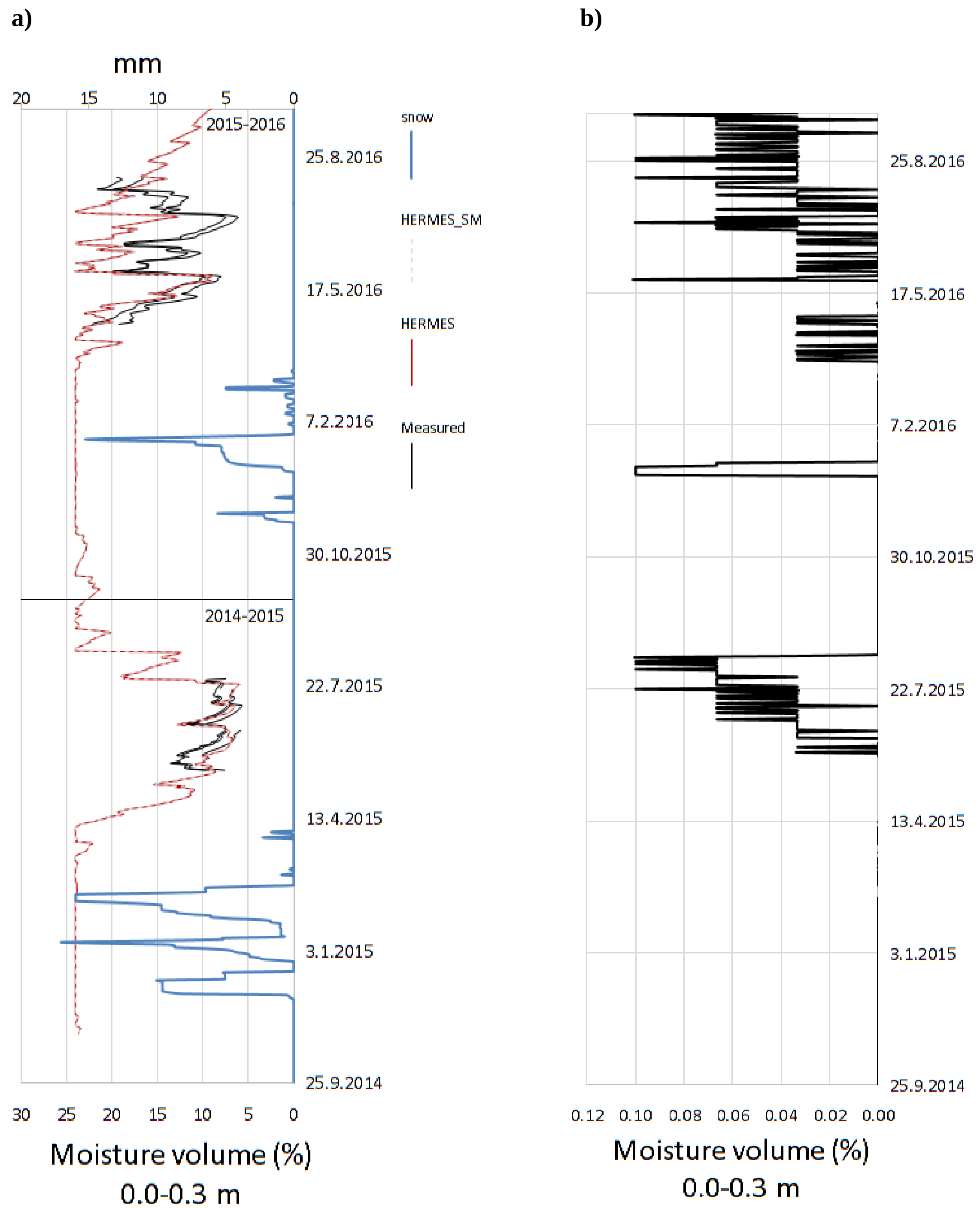


**Figure 2.** Soil water content in depth from 0.0 to 0.3 m for 2014/2015 and 2015/2016 growing seasons. Three control measurements are depicted by black lines. Results of HERMES modeling (HERMES) and HERMES modeling based on weather data modified by SnowMAUS (HERMES_SM) are represented by red line and grey dashed line, respectively. Snow cover depth (water column) is depicted by blue line (a). Difference of soil water content in depth from 0.0 to 0.3 m within HERMES modeling (HERMES minus HERMES_SM) (b).

Result of modeled aboveground biomass showed differences under growing season 2014/2015 and 2015/2016 (see Fig. 3a). In growing season 2015/2016 the soil water contain was more available for crops (Fig. 2a) to form biomass better. However, according to Fig. 3b) difference between HERMES and HERMES (SM) was minimal (-0.004–0.163 t·ha$^{-1}$).

The current study compares real yields (MD) and modeled yields as well as modeled values between HERMES and HERMES (SM) under 2014/2015 and 2015/2016 growing season (see Fig. 4). In both cases of growing seasons 2014/2015 and 2015/2016, the yields were overestimated by HERMES model under modeling by HERMES and HERMES (SM). In 2014/2015 HERMES and HERMES (SM) overestimated the average real yields by approximately 0.5 t·ha$^{-1}$ simultaneously in the contrast to growing season 2015/2016 when the HERMES and HERMES (SM) overestimated the average real yields by approximately 1.3 and 1.2 t·ha$^{-1}$ respectively. The differences between the modeled yields were approximately 0.04 t·ha$^{-1}$ for both growing seasons.

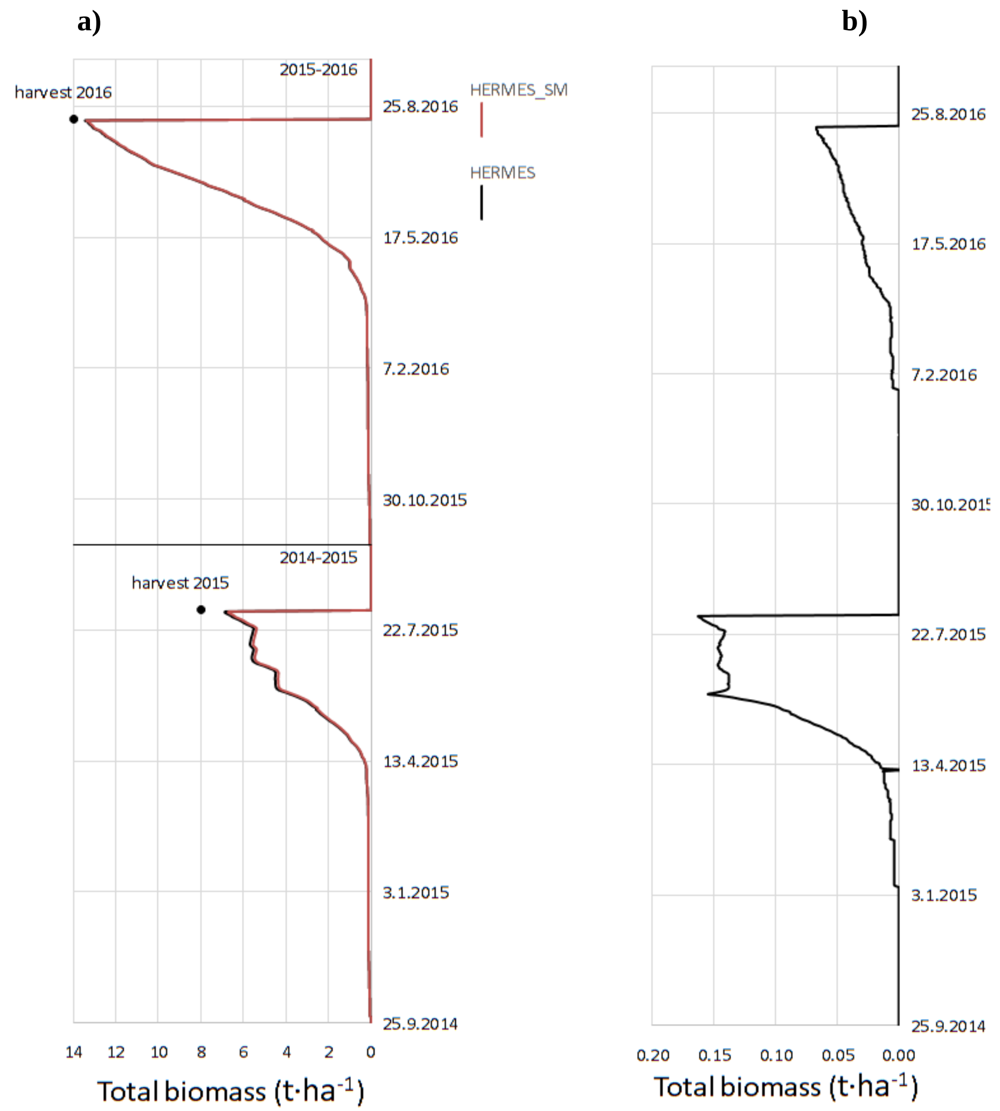


**Figure 3.** HERMES aboveground biomass (t·ha$^{-1}$) for 2014/2015 and 2015/2016 growing season. Results of HERMES model (HERMES) are depicted by black line and results of HERMES modeling based on weather data modified by SnowMAUS (HERMES_SM) are depicted by red line. The harvest days are showed by black point (a). Difference of total biomass within HERMES modeling (HERMES minus HERMES_SM) (b).

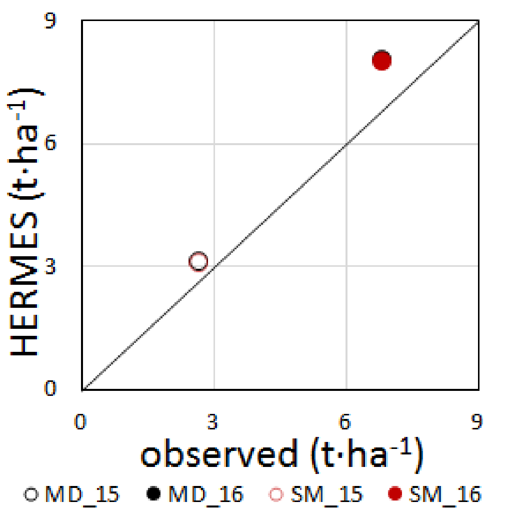


**Figure 4.** Comparison between observed (average values) and modeled winter wheat yields (t·ha$^{-1}$) for 2015 and 2016. For observed and modeled values measured (MD) and SnowMAUS modified (SM) data are considered.

## CONCLUSION

In the current study the SnowMAUS model was used for assessment of snow cover. Modified temperatures were the output of SnowMAUS calculation in case of snow cover and redistribution precipitation due to accumulation and snow melting. These weather data input consequently into HERMES crop growth model, thus it resulted in testing by using snow cover model which was compared with result of measured/observed and simulated data (observed weather data incoming to HERMES). Based on achieved results could be concluded that the result of modeling data (phenological phases, soil moisture contain, aboveground biomass and yields) with SnowMAUS (HERMES_SM) did not make any major differences compared to standard modeling (HERMES) within selected seasons. Despite the fact, it is appropriate to work with the snow cover simulation procedure because of many seasons the results will not significantly deteriorate and in the event of extremely low winter temperatures or more snow cover can improve the impact of weather conditions on growth and development of winter crops (see Trnka et al., 2010).

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