INCREASING THE OPERATIONAL USABILITY OF THE SNOW COVER MODEL SNOWPACK

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ABSTRACT: Snow cover modelling has large potential to increase the spatial and temporal resolution of snow stratigraphy and stability information available for avalanche forecasting. Despite point information are commonly the starting points for every snow stability evaluation, the derived conclusions and approaches are different depending if practitioners are aiming to forecast the avalanche danger at regional or local scale. At the regional scale, all the acquired information is summarized to provide an indication for the entire area. At local scale the available information is projected to the area of interest to forecast the stability condition for a specific location, e.g. single path. Since avalanche forecasters have to evaluate a large number of information, especially in critical periods, the lack of time is a common problem. The usability of the different tools, i.e. snow cover models, is strongly defined by their efficiency in quickly providing the desired information. In this work we present different visualisation approaches to increase the usability of the snow cover model SNOWPACK. Independently of the approach, the common principles are: i) provide practitioners only the information they really need to tackle their problems and ii) all the information is organized according to the five typical avalanche problems. For practitioners assessing the slope stability of specific avalanche paths the daily-simulated snow cover information originates from a few stations only and may be summarized in graphs and tables, which are sent by e-mail. However, for a regionally valid avalanche bulletin, the simulations are based on a considerable number of automatic weather stations and are therefore grouped depending on their climatic area and visualized on a web dashboard. For general users, the point information is interpolated in order to provide spatially distributed thematic maps. Allowing the practitioners to quickly access the simulated snowpack information significantly increases both the usability and the actual use of the snow cover models. In this way, snow cover modelling revealed to be a useful tool for supporting the decision-making, both at regional and local scale. Enlarging the operational use of the snow cover models increases our knowledge about their strengths and weaknesses allowing a faster improvement of their performances.

KEYWORDS: avalanche forecasting, avalanche risk management, snow cover simulations, SNOWPACK model

1. INTRODUCTION

Avalanche forecasting, defined as the prediction of current and future snow instability in space and time relative to a given triggering level (McClung, 2002) is a difficult process that implies significant responsibility. Despite point information are commonly the starting points for every snow stability evaluation (LaChapelle, 1980), the derived conclusions and approaches are different if practitioners are aiming to forecast the avalanche danger at regional or local scale.

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At the regional scale, all the acquired information is summarized to provide an indication for the entire area. The conventional or synoptic approach is the most used among avalanche forecasting services and is described by LaChapelle (1980); individual forecasts are based on data rated according their relevance. The most important data are those defined as low-entropy data (e.g. avalanche observations or manual snow stability tests). If these data are not enough to clearly describe the situation, lower-entropy data have to be used (e.g. snow stratigraphy data or lastly meteorological data). At local scale, though, avalanche forecasting uses quantitative and qualitative approaches in order to project the available information to the area of interest and forecast the stability conditions for a specific location, e.g. a single avalanche path. Quantitative approaches may e.g. include interpolation algorithm of weather and/or snow data (Bavay et al. 2018). Qualitative methods are often based on experience and rough assumptions, e.g. by assuming changes in snow cover characteristics with aspect and/or elevation.

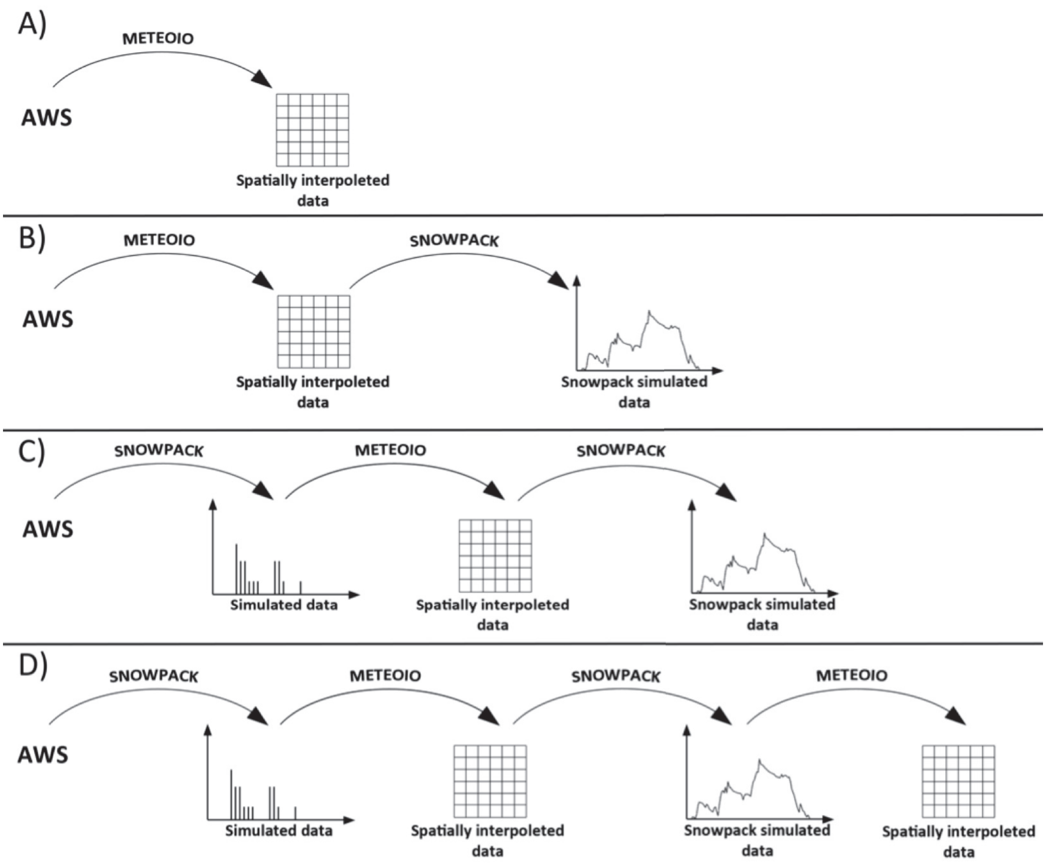


Figure 1: Different possible operational combinations of the 1-D snow cover model SNOWPACK model and its library METEOIO handling input and output data for the model.

In other words we are using a quantitative and qualitative downscaling.

There are two major disadvantages regarding both regional and local scale approaches: i) the availability of low- or medium-entropy data is typically very limited; ii) the data analysis is time consuming, which is bad for forecasters since they are notoriously short in time as more and more high-entropy and unstructured (or non numerical) data have to be interpreted (Monti et al., 2012).

Snow cover modelling, e.g. with the 1-D physics based snow cover model SNOWPACK (Lehning et al., 2002a; Lehning et al., 2002b), has large potential to address the first weakness by increasing the spatial and temporal resolution of snow stratigraphy and stability information available for avalanche forecasting (Monti et al., 2014; Monti and Schweizer, 2013; Schweizer et al., 2006; Schirmer et al., 2009). However, at the same time, the information produced with snow cover models represents further data to be processed by the forecasters. Thus, the usability of different snow cover models is strongly related to their efficiency in quickly providing and communicating the desired information to the forecaster.

In this work, we present different visualisation approaches to increase the usability of results produced with the snow cover model SNOWPACK in function of the forecasting purposes of practitioners.

2. METHODS

The SNOWPACK model and its pre-processing library METEOIO (Bavay et al. 2018; Bavay and Egger, 2014) were used to: i) processes weather data (i.e. interpolating and filtering); ii) perform spatial interpolations; iii) derive snow physics parameters (i.e. snow energy balance); iv) simulate snow cover characteristics. Bash codes, R programs (R Core Team, 2013), Java scripts and HTML language were used to elaborate and provide the user interfaces.

The combination of the METEIO library and the SNOWPACK model is very flexible especially regarding the data interpolation: i) weather and snowpack parameters can be interpolated directly as they are measured from automatic weather stations (AWS) (Fig. 1A); ii) AWS data can be interpolated to other locations and then simulated by SNOWPACK (Fig. 1B); iii) AWS data sets can be completed by interpolating the missing parameters from the other AWS and then simulated by SNOWPACK (Monti et al., 2016) (Fig. 1C); iv) finally, these simulations can be interpolated (Fig. 1D).

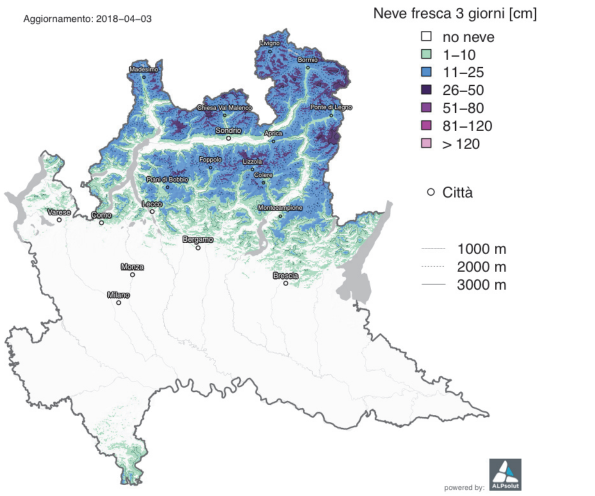


Figure 2: example of 3 days new snow amount map elaborated by SNOWPACK and METEIO.

Independently of the final avalanche forecasting purpose, the common principles at the base of the supplied products are: i) provide practitioners only the information they really need to tackle their problems and ii) all information is organized according to the five typical avalanche problems (EAWS, 2017).

The different users do not only have different forecasting purposes (e.g. local versus regional forecasts) but also the working places can be completely different (e.g. directly in the field for local avalanche forecasters and in the office for the regional ones). Thus, the supporting information and tools helping practitioners have to take into account these variables as well. Moving from these assumptions, we developed specific visualization approaches.

For general users, the point information is interpolated in order to provide spatially distributed thematic maps; which can quickly provide a general overview of actual snow and weather condition. Practitioners assessing the slope stability of specific avalanche paths can prefer daily-simulated snow cover information originated from a few stations only and may be summarized in graphs and tables, which are sent by e-mail. On the other hand, for a regionally valid avalanche bulletin, the simulations are based on a considerable number of automatic weather stations and are therefore grouped depending on their climatic area and visualized on a web dashboard.

3. RESULTS

Figure 2 shows an example for an interpolated map of modeled new snow height (HN24) produced for forecasting purposes at regional scales (in this case the Region of Lombardy in North Italy). The spatially interpolated input data are take from the different combinations of METEIO and SNOWPACK (Figure 1).

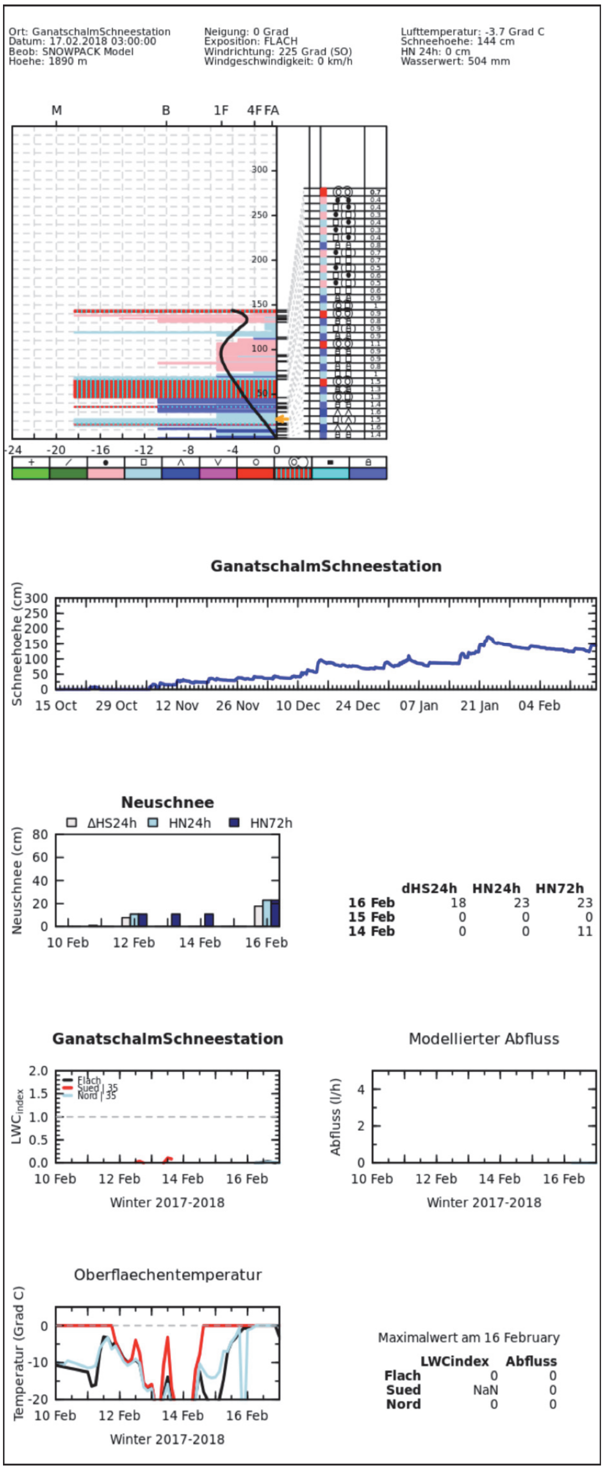
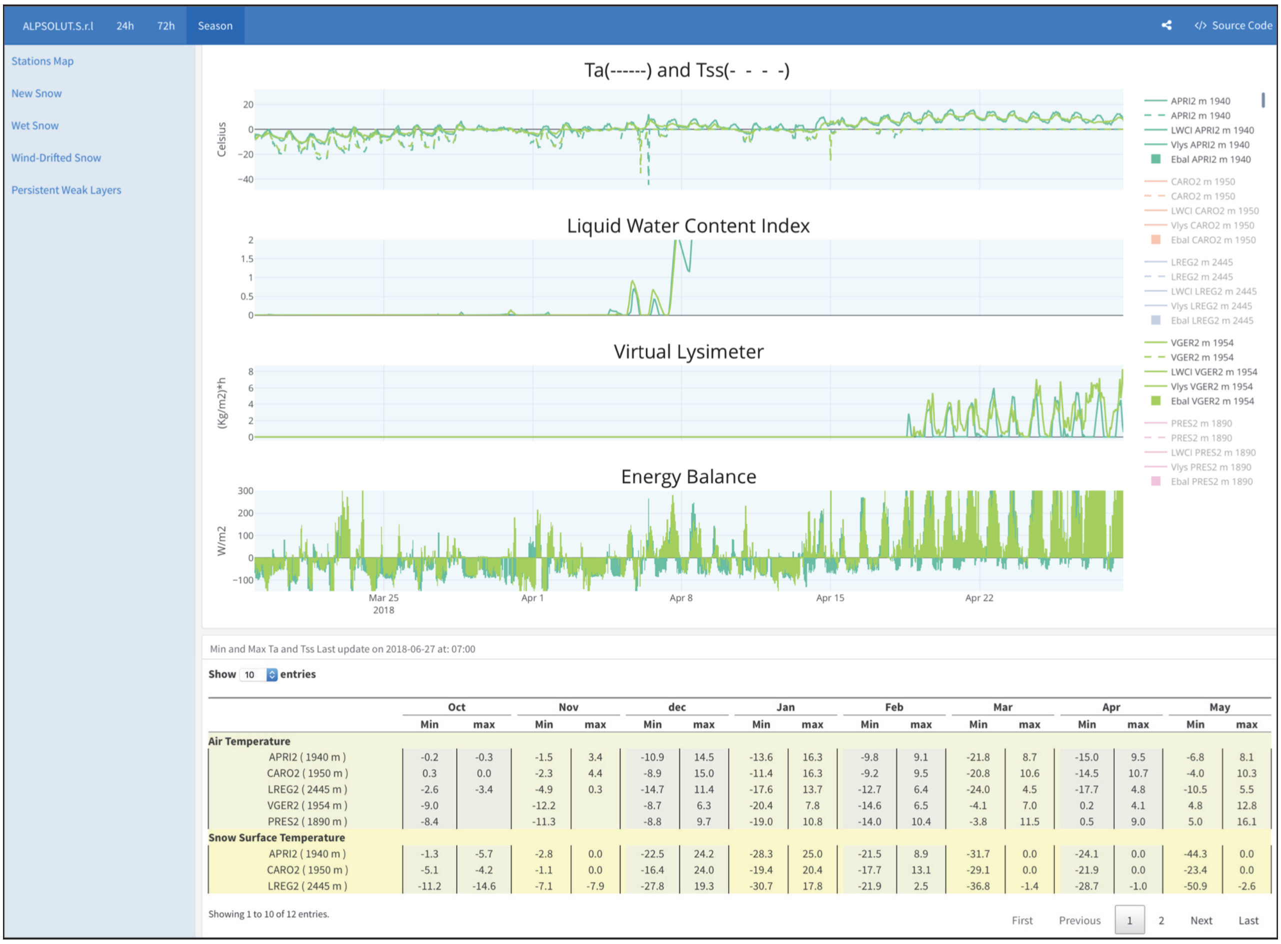


Figure 3: Example of an automatically generated E-mail which is sent to practitioners managing single avalanche paths.

In contrast, Figure 3 gives an example of an e-mail message sent to the practitioners assessing the slope stability of specific avalanche paths. Data are selected in order to provide information related to: i) new snow problem (i.e. new snow amount and snow height); ii) wind-drifted snow (i.e. wind speed and direction); iii) persistent weak layer problem (i.e. snow stratigraphy and skier stability index (Monti et al., 2016)); wet snow problem i.e. snow surface



	Oct		Nov		dec		Jan		Feb		Mar		Apr		May	
	Min	max	Min	max	Min	max	Min	max	Min	max	Min	max	Min	max	Min	max
Air Temperature																
APRI2 (1940 m)	-0.2	-0.3	-1.5	3.4	-10.9	14.5	-13.6	16.3	-9.8	9.1	-21.8	8.7	-15.0	9.5	-6.8	8.1
CARO2 (1950 m)	0.3	0.0	-2.3	4.4	-8.9	15.0	-11.4	16.3	-9.2	9.5	-20.8	10.6	-14.5	10.7	-4.0	10.3
LREG2 (2445 m)	-2.6	-3.4	-4.9	0.3	-14.7	11.4	-17.6	13.7	-12.7	6.4	-24.0	4.5	-17.7	4.8	-10.5	5.5
VGER2 (1954 m)	-9.0		-12.2		-8.7	6.3	-20.4	7.8	-14.6	6.5	-4.1	7.0	0.2	4.1	4.8	12.8
PRES2 (1890 m)	-8.4		-11.3		-8.8	9.7	-19.0	10.8	-14.0	10.4	-3.8	11.5	0.5	9.0	5.0	16.1
Snow Surface Temperature																
APRI2 (1940 m)	-1.3	-5.7	-2.8	0.0	-22.5	24.2	-28.3	25.0	-21.5	8.9	-31.7	0.0	-24.1	0.0	-44.3	0.0
CARO2 (1950 m)	-5.1	-4.2	-1.1	0.0	-16.4	24.0	-19.4	20.4	-17.7	13.1	-29.1	0.0	-21.9	0.0	-23.4	0.0
LREG2 (2445 m)	-11.2	-14.6	-7.1	-7.9	-27.8	19.3	-30.7	17.8	-21.9	2.5	-36.8	-1.4	-28.7	-1.0	-50.9	-2.6

Figure 4: Screenshot of the dashboard created for regional avalanche forecasters.

temperature, simulated Run-off and liquid water content index, LWC_{index} (Mitterer et al., 2013).

Figure 4 demonstrates the dash board created for regional avalanche forecasters. Again, the information is organized for typical avalanche problem and, since the forecasters may use the information for different purposes (e.g.: i) avalanche danger level assessment; ii) regional risk alerts; iii) seasonal snow reports) three different time frames can be selected: i) day; ii) three days; iii) whole season. In case of forecasted weather data are available, there is the possibility to show the forecasted snow values as well.

4. CONCLUSIONS

The key factor to spread the use of snow cover models is to make their outputs usable for the practitioners. Quite often they are not operationally used not for poor results, but rather because they are too time demanding or too complex to use.

We customized the SNOWPACK model results for specific needs of general users, local and regional avalanche forecasters. In this way, snow cover modeling revealed to be a useful tool for supporting the decision-making, both at regional and local scale. The effects of these customized output revealed to be really useful for the developers as well: enlarging the operational use of the snow cover models increases the general knowledge about their strengths and weaknesses allowing a faster improvement of their performances.

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