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Hydrology and Earth System Sciences Discussions

Interactive comment on "Snow Accumulation-Melting Model (SAMM) for integrated use in regional scale landslide early warning systems" *by* G. Martelloni et al.

G. Martelloni et al.

samuele.segoni@unifi.it

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We would like to thank Anonymous Referee # 2 for his constructive comments. In his review, the referee identifies 4 main criticalities and some minor issues. All of them are addressed below.

1 Comment: It's not clear the reason of building a new snow accumulation-melting model. What is the added value of this model in comparison with the existing ones? Does it offer better performances than a simple temperature index model for the objective of a landslide warning system?

Answer: The incorporation of snow models into operative real time or forecasting warning systems for the occurrence of landslides at regional scale is a rather pioneer work: we could not find any reference about similar works in the existing scientific literature. In addition, our paper has (we believe) a marked practically-oriented approach. In other words, the model was built to address a specific problem which is twofold: scientific (snow can melt and trigger landslides) and technical (which data do we have at our disposal to be used in the regional warning system and thus, also in the model?). Therefore, one of the added values is that the model is specifically built for our needs, which include the possibility to make use of a very limited dataset (punctual real time measures of temperature and rainfalls and snowpack thickness for the calibration/validation) and the very particular objective of the model (to correct rainfall measures provided by heated rain gauges). Instead of using a simple temperature index model, we used an approach that tries to encompass (even if in a semi-empirical way) a larger number of processes and parameters. Our approach is more complex and brings to the following comment and answer:

2 Comment: Furthermore, a number of 13 empirical parameters seems to be very high for a model which is not a distributed modelling of the snowpack but just want to modify the rainfall measurements used as input data in a system based on a series of statistical rainfall threshold (SIGMA.

Answer: The high number of parameters comes from the decision of starting the formulation of the model with a physical approach. Since the data at our disposal are very limited, the final equation uses empirical parameters and approximations. So, even if their final number may seem exaggerate, the 13 empirical parameters have a physical meaning. In the operative implementation of the warning system, their number does not represent a computational problem (i.e. it does not demand additional computational resources). In the calibration stage, an efficient heuristic optimization algorithm (Flexible Simplex) is used to define the optimal configuration, therefore we believe that their number does not negatively affect the results; on the contrary this approach allows finding a rather complex solution to a physically complex problem. To explain our point of view, we added the following sentence to the conclusion: “In this regard, SAMM could be considered an intermediate approach between temperature index- and physically based models: from an operational point of view it simply uses air temperature as an index to take into account snow melting and accumulation, but the value of the threshold temperature (as all other parameters involved in the equations) are defined by means of a semi-physical approach, which starts from a conservation of mass equation but uses empirical approximations and calibrations to overcome the unavailability of dynamic data for an operational employ of the model at regional scale” Moreover, please consider that from an operative point of view, temperature and rainfall are the only parameters provided in real-time by the sensors network, therefore they are the only dynamic parameters used by the model. All other empirical parameters are constants, which are actually used to better calibrate the response of the model: the simplex flexible algorithm tune their values to find the optimal configuration which minimizes errors in the calibration dataset. We revised the text (at the end of 2.2.2 and in the conclusions) making explicit mention to these features of the model.

3 Comment The model seems to work only using heated rain gauges. Try to underline it since the beginning of the paper, as it is an essential help in the accumulation module.

Answer: Conceptually, the model works everywhere. Actually, it can be applied only to heated rain gauges: heated rain gauges melt the snow and they provide SWE (snow water equivalent) to the warning system. This is just what we want to avoid and the model is built mainly to correct this inconsistency. In the Territorial Units potentially affected by snowmelt induced landslides, all reference rain gauges are heated, therefore the model can be consistently applied to our case of study. As suggested by the referee, we improved the text in sections 2.1 and 4, making clear that SAMM was applied only to heated rain gauges, which are equipped in the mountain areas potentially affected by snowmelt phenomena.

4 Comment: Finally it is asked to better describe the results obtained by the implemen-

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tation of SAMM in SIGMA, with the exact number of false alarms, missed detects and hits (table 3).

Answer: As suggested by all Referees and Editor, to fully highlight that the performance of the SAMM+SIGMA system is better than the performance of SIGMA alone, we presented the results of this comparison in deeper detail. A table is provided to show the confusion matrix (true positives, false positives, true negatives, false negatives) and a series of indexes commonly used to evaluate the performance of similar models (e.g. sensitivity, specificity, likelihood ratio, ecc...). The table is accompanied by additional text that describes and discusses these outcomes.

ANSWERS TO SPECIFIC COMMENTS:

P9395 L26: what is the meaning of “reference rain gauge”? For each TU, SIGMA uses just one rain gauge to evaluate threshold exceeding?

It means that SIGMA makes reference to that rain gauge to evaluate the behaviour of the whole Territorial Unit. SIGMA uses a unique rain gauge for each TU to standardize the accuracy of the model. This choice certainly represents a limit of the model, but it helps to simplify its management and to better understand its outputs. Anyhow, TUs are rather small and homogeneous (from a geomorphological and meteorological point of view) and the selected rain gauges are well representative of the whole TU. We added some additional explanation in the text and we provided a reference: “The choice of using a unique rain gauge for each TU certainly represents a limit of the model, but it helps to standardize the accuracy of the model, to simplify its management and to better understand its outputs (Martelloni et al., 2011).”

P9400 L18: Eq. (22) doesn’t exist in the paper

The correct reference is to Eq.17.

P9401 L2: in Fig. 1 there are the position of the references rain gauge. Are the snow depth sensors in the same positions?

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Yes. The text has been revised to make it clearer.

P9403 L10: is Fig. 9 correct? Or the effects of change are displayed in Fig. 10?

Sorry, we made reference to the wrong figure. The correct text is "... are displayed in Fig. 10", as correctly guessed by the referee.

P9403 L10-15: try to better explain; furthermore the great sensibility shown with the change of 1_C seems not to agree with the analysis displayed in Fig. 9

Here a misunderstanding arose because we made reference to the wrong figure. How explained in the previous answer, the figure that explains the text is Fig.10. This should make the text clearer without need of further explanations. In addition, since we had to revise Fig 10 (see last comment), we also modified the data shown, substituting the -1.3°C series with the -0.7°C series. We believe this is in line with the comment of the referee: this change should help a more straightforward comparison between the displayed data (optimum threshold temperature, a threshold temperature increased by 1°C and a threshold temperature decreased by the same amount).

P9405 L10: check if the atmospheric pressure is indeed an important parameter in snow modelling (also P9393 L28: Surface pressure)

Even if many other parameters play a more important role in the modelling, some works also make use of surface atmospheric pressure (e.g. Zanotti et al., 2004; Liston and Elder, 2006). However, if the referee still thinks that the use of pressure is inappropriate, we are ready to remove both occurrences. References: Zanotti, F., Endrizzi, S., Bertoldi, G. and Rigon, R.: The GEOTOP snow module, Hydrological Processes, 18, 3667-3679, doi: 10.1002/hyp.5794, 2004. Liston, G. E., Elder, K.: A Distributed Snow-Evolution Modeling System (SnowModel), J. Hydrometeor, 7, 1259–1276, 2006.

P9418 Fig. 6: the use of a moving average seems to create important mistakes in reproducing the single snowfalls, differences in the snow height values and in the snow depletion immediately after the snowfall. Could it have been a problem in the validation process?

In the calibration dataset, hourly data were aggregated on a daily basis. For the validation dataset, the moving window has a total width of 10 days, which means from -5 days to +5 days. Because of the exponential weights, the -1 and +1 days heavily influence the average; conversely the – 5 and + 5 days have a very little influence on it. Therefore, the two criteria used in the validation and calibration datasets are quite homogeneous and not so dissimilar. We used the "10 days exponential weight" filter to better clear anomalous hourly oscillations (short-period noise). The presence of short-period noisy oscillations in fig 6 is evident if the curve in the upper panel of figure 6 is compared with figures 7 and 8: the measured and modelled curves in Fig. 7 and 8 are as smooth as the filtered experimental data displayed in Fig. 6 (lower panel).

P9422 Fig. 10: insert the measured values.

Figure 10 was modified and the measured values are now displayed.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 9391, 2012.