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Snow melt modeling for landslide prediction: applications in the Northern Apennines (Italy)

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Climate change driven landslide forecasting implementation in early warning activities is strictly dependent on the quality and timing of rainfall measurements and on an accurate empirical or deterministic relationship linking water infiltration to slope stability. The scientific literature offers a wide range of choices based on distributed physically based models or on empirical rainfall thresholds but a common weakness of all those approaches is that they are, for quite obvious reasons, very sensitive to errors in the rainfall estimation. This is especially true for temperate or cold climate regions in which a not negligible part of precipitation may be withhold in a snow cover until a temperature change that triggers a sudden water input in the ground.

Northern Apennines of Italy are no exception to this rule as demonstrated by the very recent event of Christmas 2009 in which several hundred landslides have been triggered by a rapid snow melt in Tuscany and Emila-Romagna regions.

In order to integrate for snow precipitation the existing models for landslide prediction, usually based on rainfall thresholds in Tuscany and Emilia-Romagna, a simple, physically based model for the snow melting is proposed. Landslides induced from rainfall or snowfall are frequent in Northern Apennines: the proposed model is dynamic and takes into account the buildup and melting of the snow cover in time. This model is based on two equations: the conservation of mass (input-output balance) and an empirical equation for modeling the snow density variation. From the conservation of mass a differential equation of snow cover depth, depending on density and average temperature of the air, can be obtained. The second equation is an empirical function for the density variation and depends on the snow cover depth (gravity effect) and the temperature of air, variable in time. We consider 0.5 °C as a threshold temperature between snowfall and rainfall. In the present form, this model depends on six empirical parameters: we calibrate their values employing empirical data of rainfall, depth of snow cover and temperature of the rain gauges in the study area. Then we use an algorithm (simplex optimized) to deduce the optimal values of the six parameters of the model. The final objective of the work is to increase the predictive capacity of the statistical models for landslide prediction.