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SHALTOP as a snow avalanche modeling software: seismic and radar data validations

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Nowadays, the combination of numerical modeling with experimental measurements is one of the most useful procedures to understand the behavior of rockfalls, landslides and snow avalanches. Each model is based on a specific formulation, designed to represent a specific type of mass movement. Each model, has difficulties to take into account all the possible phenomenon involved in the natural mass movement. However, one model may have the capability to represent specific conditions very well.

As such, the SHALTOP numerical model (IPGP-LAMA) is designed to model homogeneous continuous granular flows over a 3-D topography using a depth averaged thin layer approximation and was successful to reproduce both experimental granular flows and natural landslides using Coulomb friction. Although SHALTOP was not originally designed to model snow avalanches, its formulation might be suitable to model the dense part of avalanche flows. Thus, we modeled the dense part of well-known avalanches which occurred at the Ryggfonn experimental site (Norwegian Geotechnical Institute NGI) using SHALTOP.

With the combination of seismic data, radar and video information, we collect information related to the dynamic behavior of avalanches. In particular, the seismic signal is supposed to be mostly produced by the interactions of the avalanche front and the dense part of the avalanche flow with the slope. Thus, seismic signals are particularly suited to be used as validating data for the modelling of snow avalanches using SHALTOP.

We used SHALTOP to model in 1.5D (z=f(x)) several natural or artificially triggered avalanches that occurred at the Ryggfonn experimental site. Finally, we decided to focus on one Dry/Mix Large artificially triggered avalanche (April 22th, 2008). The initial geometry was fitted to reproduce as best as possible the observed initial snow thickness, volume and size of the rupture area. The Coulomb friction angle Δ was set following the law proposed by Lucas et al. (2014) for landslides: Δ=atan(1/Volumê0.0774). The decrease of the effective friction for increasing volumes is also reported for snow avalanches, although other friction laws were proposed.

The simulations outputs show very good agreement with the experimental data: the location of deposits is well reproduced, the modeled front velocity fits quite well the evolution of the front velocity derived from radar measurements, and the modeled basal friction force, which depends on the flow acceleration/deceleration relates well to the evolution of the envelope of the seismic energy.

The SHALTOP modeling software seems promising to model the dense part of dry/mix snow avalanches, indicating strong similarities of the physical phenomenon occurring during granular flows and snow avalanches. However, the relationship between initial mass volume and friction parameters should be revised for snow avalanches modelling. Seismic signal has a lot of potential on avalanche modelling validations, being able to give qualitative and quantitative information for decision making during the modelization workflow.

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