Back-calculation of 8 January 2012 snow avalanche in Davraz Ski Center

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Abstract: A snow avalanche, which damaged ski lifts, occurred at 10:30, 8th January 2012 in Davraz Ski Center. According to field observations, avalanche release zone covers 33800 m^2. Its average slope and altitude are 39.3° and 2327 m (a.s.l.), respectively. In addition, there is no vegetation located in the avalanche area. In the present study, a back-calculation of this event was carried out by using RAMMS: Avalanche software. Snow rupture depth of release zone at the moment of avalanche was determined based on snowfalls during last three days by taking into consider contribution of transported snow by wind. Friction parameters, μ and ξ, were determined as 0.190 and 2500 as a result of many tests made for back-calculation until for obtaining simulation results which best fit with the avalanche. According to simulation results, maximum flow velocity, flow height, and impact pressure were obtained as 3.8 m, 34.0 m/s and 346.0 kPa, respectively. Because there is no observation of flow velocity and impact pressure, only flow height of back-calculation could be validated from damaged ski lifts. It was found that obtained flow height is well fitted with the avalanche event.
Keywords: Back-calculation, Davraz, Snow avalanche, RAMMS

1. Introduction

Snow avalanches can affect residential areas, energy and transportation corridors, industrial sites and back-country recreation (Jamieson et al., 2008; Aydın and Eker, 2016). That’s why, an accurate prediction of avalanche dynamics (such as flow velocity, flow height, impact pressure and run-out distance, etc.) in natural three-dimensional terrain is essential. For this aim, snow avalanche dynamics models (such as RAMMS) are widely used as an important tool in snow engineering (Christen et al., 2010). These models can be used for avalanche hazard/risk mapping, visualization of hazard impact, safety assessment for building/infrastructures, planning, design, and evaluation of technical counter-measures for protection against avalanches. Snow avalanche dynamics models can also be used to back-calculate documented avalanche events. For example, Maggioni et al. (2012) used RAMMS:Avalanche software to back-calculate four well-documented avalanches artificially triggered at the experimental test site of Seehore in Aosta Valley (Northwestern Italian Alps) and many others (see Casteller et al., 2008; Christen et al., 2010; Aydın et al., 2014; 2015).

Snow avalanche dynamics models use second-order numerical solution of the depth-averaged avalanche dynamics equations. Avalanche flow heights and velocities are calculated on 3D Digital Elevation Models (DEM). DEM is used for generating calculation grid. The model assumes that no internal deformations occur in the body of avalanche (Rudolf-Miklau et al., 2014). Because RAMMS employs a Voellmy-fluid model (Voellmy-Salm model), two friction parameters, which are responsible for the behavior of the flow, plays very crucial role in back-calculation of the events. These friction parameters are dry-Coulomb type friction (coefficient μ) that scales with the normal stress and a velocity-squared drag or viscous-turbulent friction (coefficient ξ). While μ dominates when the flow is close to stopping, ξ dominates when the flow is running quickly (Bartelt et al., 2013). That’s why, RAMMS was calibrated on the basis of many observed large avalanches in the avalanche winter of 1999, avalanches from the SLF avalanche database and from test site of Vallée de la Sionne (Switzerland).

Since analysis of former events is considered as starting point for avalanche studies, documentation/records of event is absolutely necessary (Hübl et al., 2002). Otherwise, prediction of avalanches is not so easy task when absence or limited existence of observation of events. Even though avalanches are a serious issue in Turkey, management of snow avalanches has not yet attracted the necessary attention (Aydın and Eker, 2016). That’s why, non-availability of proper records of snow avalanches in Turkey have become crucial problem. Only a few recorded events are available and there is no updated database for snow avalanches as well as meteorological data (release height, snow density, etc.). As mentioned above, RAMMS was calibrated for Switzerland in terms of friction parameters. In order to make realistic simulations of avalanches in Turkey, these two parameters should be calibrated. However, there are quite limited avalanche observation for Turkey. A well-documented avalanche event occurred in Davraz Ski Center (Isparta-Turkey) at 10.30, 8th January 2012. Fortunately, this event only caused damages on ski lifts. Since nobody found skiing in the area in the course of the avalanche event, it did not cause any injury or death. In the present study, back-calculation of avalanche event was carried out by using RAMMS:Avalanche. Because of this event well-documented, many simulations were made in order to calibrate friction parameters to obtain simulation result which fits best with observed flow extents and flow height.

2. Material and methods

2.1. Study area

For this study, a well-documented snow avalanche, occurred in Davraz Ski Center located in the Mount Davraz (Isparta-Turkey), was selected as study area (Figure 1). Because following the announcement as a tourism center in 1995, the Mount Davraz with 2635 m (a.s.l.) where is suitable for winter activities, have become one of important ski areas in Turkey. Skiers not only from Turkey but also from Europe, Russia, Ukraine and Middle East Countries visit this area. The XY coordinates of the snow avalanche event in WGS 1984-UTM Zone 36N are 301380.16 and 4182969.07 for left and top, respectively, and 301705.66 and 4182331.59 for right and bottom, respectively. Snow release area covers 33800 m^2 with average altitude of 2330 m (a.s.l.) and with average slope of 39.3°.

2.2. Back-calculation of 8 January 2012 snow avalanche event with RAMMS

Back-calculation of 8th January 2012 snow avalanche event was carried out by using RAMMS (Rapid Mass Movement Simulation) software. RAMMS yields runout distance, flow height, flow velocities and impact pressure of dense flow snow avalanches, hillslope landslides and debris flows (for details see http://ramms.slf.ch). This software has three modules: I) RAMMS: Avalanche, II) RAMMS: Debris Flow, and III) RAMMS: Rockfall. In the present study, RAMMS: Avalanche module was used. In order to back-calculate/simulate an avalanche, Digital Elevation Model (DEM) is an important input. For this study, DEM was generated from topographic map with scale of 1/25000. This DEM data was generated by using ArcGIS 10.1, then was converted to ASCII format in order for using in RAMMS. In addition, release area and calculation domain of simulation were determined (Figure 3). Calculation domain was defined to avoid unnecessary process of unrelated areas in RAMMS. The definition of release areas and release heights have also a very strong impact on the results of RAMMS simulations. That's why, release area was drawn depending on field investigation. The release area was digitized in ArcGIS 10.1 as Shapefile (.shp) and imported into RAMMS. Fracture depth (d_0)(i.e. release height) (Figure 3) was calculated from snow depth data with intervals of 10 minutes measured by automatic weather observation system (AWOS) located at 1954 m (a.s.l.) within Davraz Ski Center. In Figure 4, ΔHS_3 is height of snow layer over the slope. Following elimination of biased or non-measured data from snow depth database, snow depth information with new snow from last 3 days (72 hours) before avalanche event (i.e. from 05.01.2012 to 08.01.2012) was used.

Figure 1. Location of 8th January 2012 Snow avalanche event

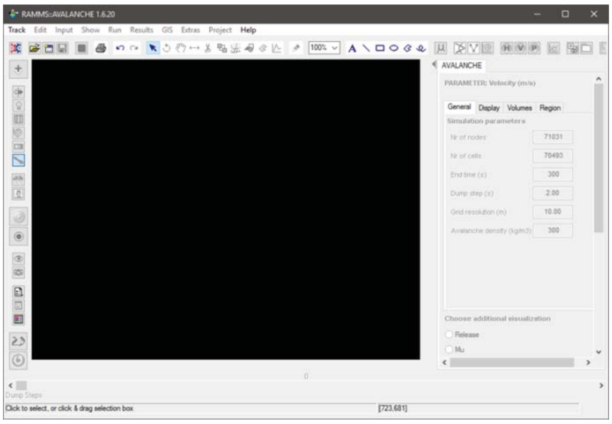
Figure 2. Graphical user interface of RAMMS: AVALANCHE

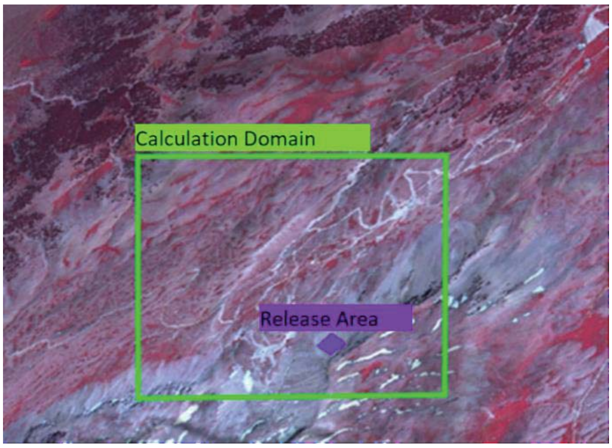

Figure 3. Release area and

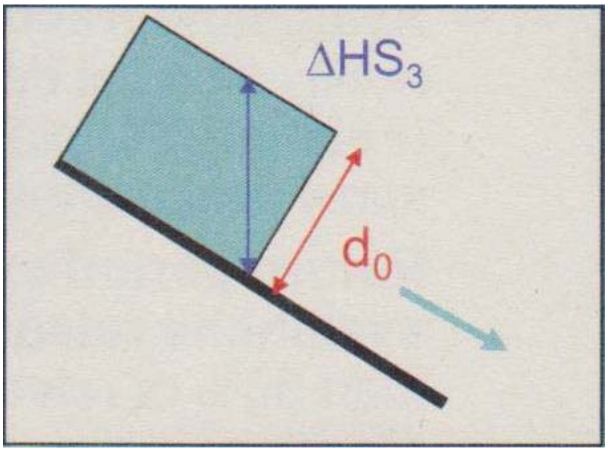

Figure 4. Snow friction depth and height of snow layer (SLF, 2012)

Snow depth measured for last 3 days before avalanche were given in Figure 5. In addition, snow depth and new snow for each day of last 3 days was given in Table 1. According to this, 89.95 cm of new snow was calculated for last 3 days.

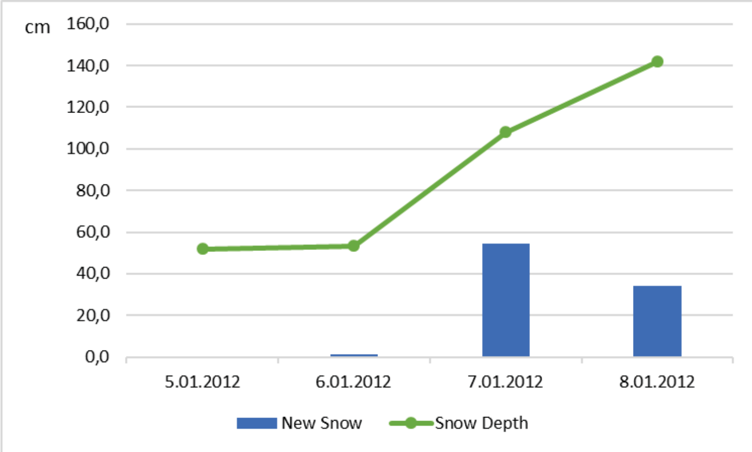

Figure 5. Snow depth and new snow for last 3 days before avalanche event

Table 1. Snow depth and new snow for each day for last 3 days before avalanche event

Dates	Snow Depth (cm)	New Snow ($d0_{new}$) (cm)
5.01.2012	51.92	0
6.01.2012	53.37	1.45
7.01.2012	107.88	54.51
8.01.2012	141.87	33.99
		$\sum d0_{new}$ = 89.95

Due to elevation difference between location of AWOS and avalanche release area, average snow depth calculated for location of AWOS was interpolated by adding 20 cm (i.e. 5 cm for each 100 m a.s.l). In addition, snow drifts by wind, which was predicted as 40 cm, was added to calculated snow depth. That's why, in total, 148.3 cm of new snow depth was calculated for snow release area. In final, a reduction factor$f(\psi)$ was applied for correction of fracture depth according to slope inclination of release area. Model for calculation of reduction factor, which was developed by Burkard and Salm (1992), was used. According to this model if $\tau_s/\tau \leq 1$ then failure can happen. Here, τ_s is shear strength, τ is shear stress (for details see SLF (2012)). Reduction factor is calculated by following equation:

$$f(\psi) = \frac{d_0}{d_0^*} = \frac{\left(\frac{1}{\rho g}\right)\left(\frac{c}{d_0^*}\right)}{\sin\psi - tg\varphi\cos\psi} = 0.291/(\sin\psi - 0.202\cos\psi) \quad (1)$$

where $\left(\frac{1}{\rho g}\right)\left(\frac{c}{d_0^*}\right)$ is cohesion factor and generally assumed as 0.291 depending on the experiences (SLF, 2012). Because cohesion is increasing proportional to the thickness of the slab (d_0^*) by sintering of the snow grains. In equation, $tg\varphi$ is angle of internal friction, which is accepted as constant as -0.202. In the present study, reduction factor was estimated as 0.61. Corrected fracture depth was obtained 90.5 cm for release area (i.e. 148.3 x 0.61). Following estimation of release height for avalanche event, many simulation was performed until obtaining fit results with the known avalanche flow extents and flow height in order to calibrate friction parameters.

3. Results

In this study, average release height was calculated as 90.5 cm for this simulations. According to this, in total, 40272.8 m^3 snow mass released from the release area. Best fitting simulation result was obtained when friction parameters were used as 0.190 for Coulomb friction (μ) and 2500 for turbulent friction (ξ). Maps for maximum flow speed, maximum flow height and maximum impact pressure were given in Figure 6, Figure 7, and Figure 8, respectively. According to these maps, maximum flow height was obtained as 3.8 m. The maximum flow height of the avalanche was about 1.5 m at places where ski lift is located. Maximum flow speed and maximum impact pressure were obtained as 34 m/s and 345 kPa, respectively. Unfortunately, these results could not be validated because there was no observation about flow speed of the avalanche. However, maximum flow height could be validated by using observations of height of snow mass that caused damage on ski lift towers. Simulation result showed good fit in with the observed flow height.

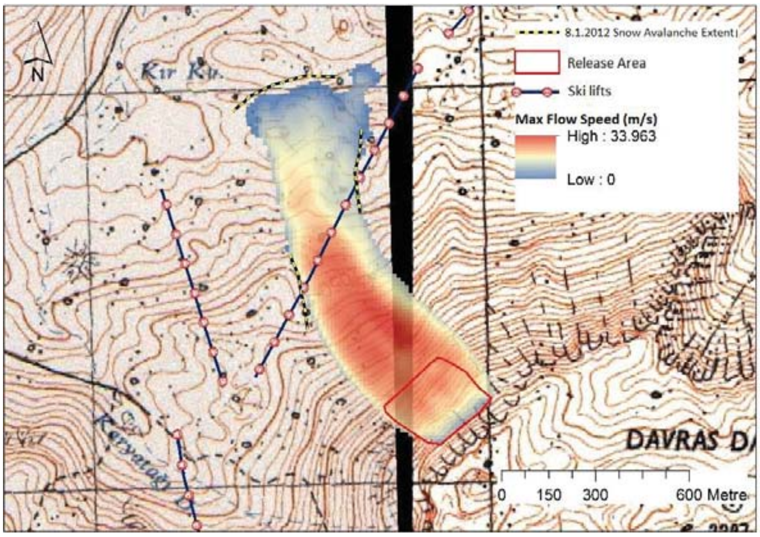

Figure 6. Maximum flow speed of 8th January 2012 snow avalanche event

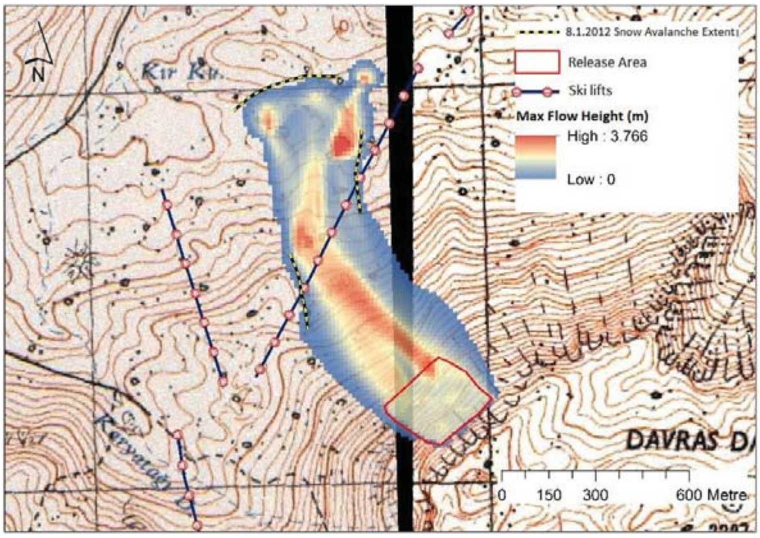

Figure 7. Maximum flow height of 8th January 2012 snow avalanche event

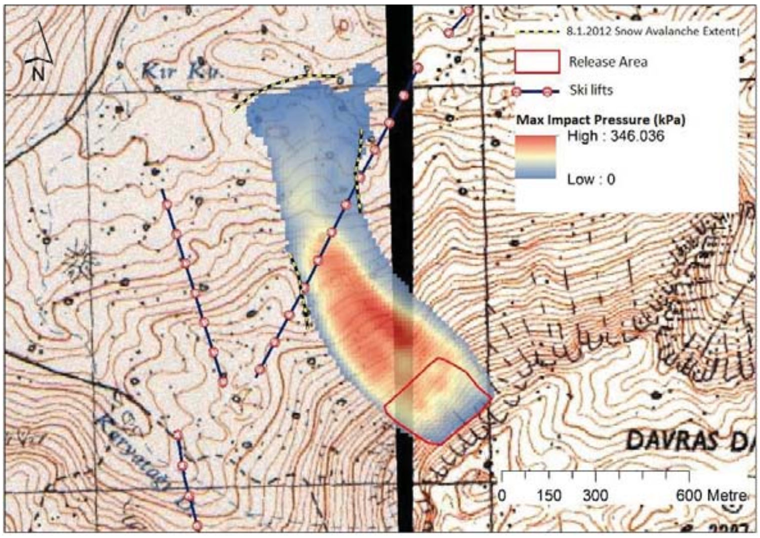

Figure 8. Maximum impact pressure of 8th January 2012 snow avalanche event

4. Conclusions

Snow avalanche dynamics models allow the user to back-calculation of snow avalanche events, thus to obtain friction parameters requiring for realistic snow avalanche simulations. This is very crucial especially when lack of adequate avalanche observations. Snow avalanche occurred in Davraz Ski Center is such a well-documented event in Turkey, thus it makes back-calculation possible. RAMMS:Avalanche software was used in the present study for back-calculation of 8th January 2012 snow avalanche event. It was observed that simulation results showed good fit in with field observations in terms of flow height and flow extent.

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