# Evaluation of snow avalanche hazard on the highway using high resolution UAV data: case of the Erzurum-Çat-Karlıova highway, Turkey

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## ABSTRACT

Snow avalanches that disrupt traffic and create serious safety problems are frequent events during winter season on the Erzurum-Çat-Karlıova highway in the eastern Anatolian Region of Turkey. The snow deposition on the highway during the winter averages 5-6 m. However it can accumulate as high as 9 – 10 m during the season (e.g. the winter of 2002 – 2003). Serious health and safety issues arise during snow clearance: a fatal accident (i.e. dozer operator) occurred during clearing avalanche debris off the road at the 75+800th and 76+300rd km of the highway in 2013. In the present study, potential snow avalanche release zones were determined, and then 2D snow avalanche simulations were carried out. A high resolution digital elevation model (DEM) was created through images from an unmanned aerial vehicle (UAV) using a camera with 12 MP and structure from motion algorithm. In total, 30 potential snow avalanche release zones, varying between 0.11–1.36 ha were determined. Simulations were performed using three different scenarios with 30–, 100–, and 300–year recurrence intervals for the avalanche release zones determined. The avalanche hazard was then evaluated. The simulations demonstrated that even snow avalanche with a 30–year recurrence interval may cause serious problems for the traffic safety and transportation. These results will help make a decision on how mitigation measures could be planned and designed.

## 1. INTRODUCTION

Snow avalanches pose a threat to the settlements, the infrastructure and the road network in the mountainous environments. Avalanches can have both direct and indirect negative impacts on the motorways including collusions between mass of avalanches and vehicles, traffic artery blockage as well as severe damages to the structure of the road (Kristensen et al. 2003). It is considerably costly for the governmental agencies, to minimize avalanche risks on the motorways with technical mitigation measures, including using snow supporting structures in the zones of avalanche starting zones, and avalanche galleries (Zischg et al., 2005). Due to great costs of reliable mitigation measures and limited financial resources, utilizing an integrated approach involving active, passive and organizational measures is required for an efficient and sustainable policy (Bründl et al., 2004). Collecting accurate information on the location and the extent of avalanche events is important for both forecasting and designing/planning mitigation measures. Traditional methods involving observations of individual experts in the field provide isolated information with a very limited coverage (Bühler et al. 2009). In the field of snow science, remote sensing has been used as an advanced tool in order to eliminate the shortcomings of the traditional methods. Recently, small unmanned aerial vehicles (UASs) continuously gain preference in remote sensing applications in scientific and practical areas as an alternative remote sensing platform (Nebiker et al., 2008) and/or a new photogrammetric measurement tool (Eisenbeiss, 2015). Snow avalanches that disrupt traffic and create serious

safety problems are frequent events during winter season on the Erzurum-Çat-Karlıova highway in the eastern Anatolian Region of Turkey. The snow deposition on the highway during the winter averages 5-6 m. However it can accumulate as high as 9 – 10 m during the season (e.g. the winter of 2002 – 2003). Serious health and safety issues arise during snow clearance: a fatal accident (i.e. dozer operator) occurred during clearing avalanche debris off the road at the 75+800th and 76+300rd km of the highway in 2013. In this study, it was aimed to understand snow avalanche potential and problem in the region and to propose solutions against avalanche hazard. Potential snow release zones and snow avalanche simulations were assessed in different scenarios. The main input, high resolution digital elevation model (DEM), was created from unmanned aerial vehicle (UAV) images.

## 2. MATERIAL AND METHOD

2D snow avalanche simulations were performed based on three different scenarios with 30–, 100–, and 300–year recurrence intervals for evaluation of snow avalanche hazard on the Erzurum-Çat-Karlıova Highway (Turkey) (Figure 1). For this, ELBA+ (Energy Line Based Avalanche) software (Volk and Kleemayr, 1999) were used. ELBA+ simulations are based on the Voellmy model containing two parameters: the Coulomb friction μ and the velocity squared dependent turbulent friction ξ. In addition to these two parameters, release areas (m2), release height (m), snow density in the release zone (kg/m3) and Digital Elevation Model (DEM) data are necessary inputs for simulations, with entrainment and resistance areas being optional. In order to obtain high resolution DEM data, UAV flights were carried out by using DJI Mavic Pro (Figure 2), allowing for the capture of 12MP DNG and RAW images. All flights were planned with Android-based DroneDeploy software. UAV images were then processed using structure from motion algorithm on Photoscan Agisoft 1.3.2 to create high resolution DEM and orthophoto. Before UAV flights were carried out, a total 12 of ground control points were surveyed on the field with RTK-GPS (Figure 2). Following processing UAV data, snow avalanche release zones were determined based on topographic parameters using high resolution DEM data and field observations. 2D snow avalanche simulations were then carried out based on three different scenarios with 30–, 100–, and 300–year recurrence intervals. Depending on the simulation results, some avalanche mitigation measures were proposed.

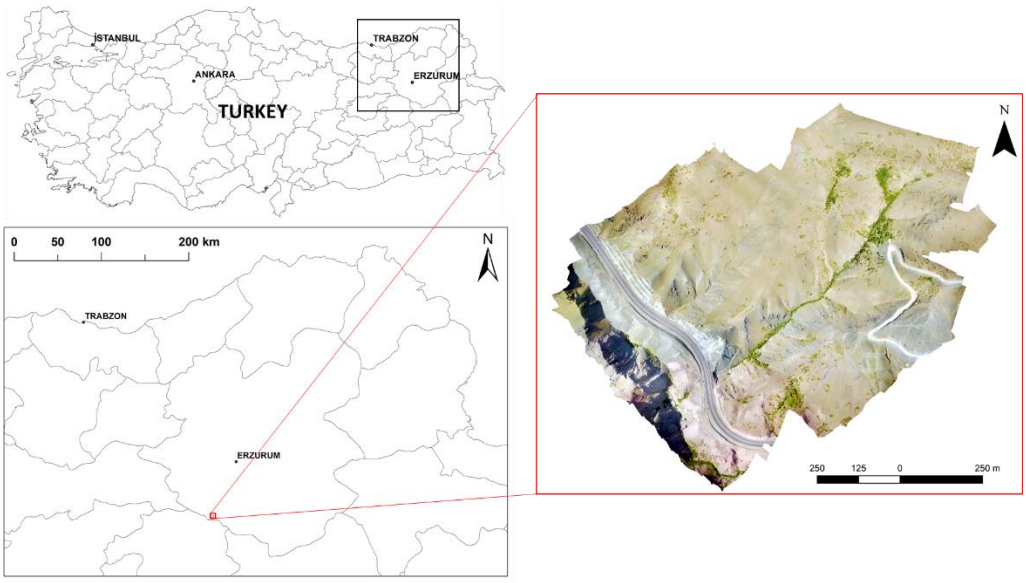
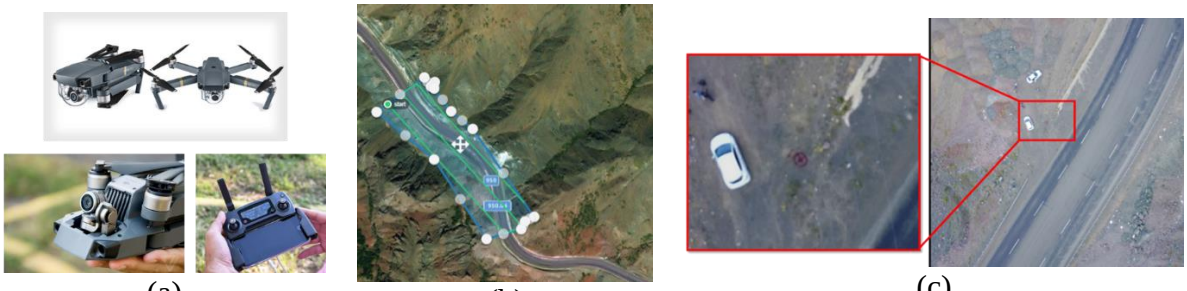



Figure 1 Location of study area.

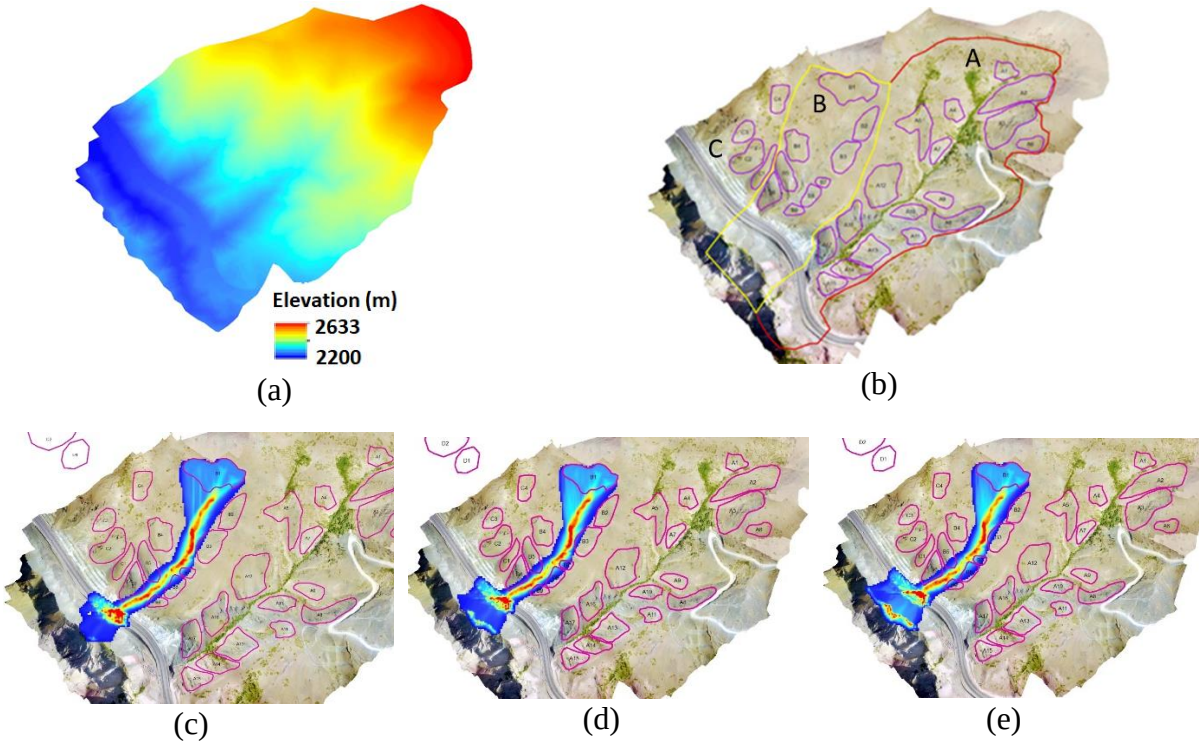


(a) (b) (c)

Figure 2 (a) DJI Mavic Pro model UAV, (b) an example of flight plan, (c) GCP surveyed.

## 3. RESULTS

The high resolution DEM and orthophoto generated from 585 of UAV images are given in Figure 3. DEM data were generated in different spatial resolutions; 20 cm, 1 m, 2 m, 5 m, and 10 m to evaluate effect of spatial resolutions on the simulation results. In the study area, in total, 30 potential snow avalanche release zones varying from 0.11 ha to 1.36 ha were determined (Figure 3). The study area were categorized into two sub-catchments, called as A, B, and C (Figure 3). While 17 of release areas were located in catchment A, 9 of them were located in catchment B, and remains are located in catchment C. 2D snow avalanche simulations were made for each release zones in each scenario of the 30–, 100–, and 300–year recurrence intervals. Thus, in total, 90 avalanche simulations were run. Three examples of simulations for each recurrence intervals are given in Figure 3.




(a) (b) (c) (d) (e)

Figure 3 (a) DEM, (b) orthophotos with snow avalanche release zones determined, (c) 2D snow avalanche simulation result with 30-year recurrence interval, (d) 2D snow avalanche simulation result with 100-year recurrence interval, (e) 2D snow avalanche simulation result with 300-year recurrence interval.

For the 30-year recurrence interval, the results indicated no avalanche that can reach up to the road for the catchment A. However for both catchment B and C, snow avalanches had a considerable potential to reach up to that road and could pose a threat to the traffic safety. In the case of the scenario with 100-year recurrence interval, there was only one snow avalanche that had the potential to threaten the traffic safety for catchment A. The remaining release zones in catchment A did not potentially pose a threat to the road. However all potential snow avalanches in catchment B and C could reach up to the road, posing a great potential risk to the traffic safety. For the 300-year recurrence interval, five snow avalanches in catchment A could potentially reach up to the road. Depending on the analysis in the area, two alternative mitigation measures were proposed. The first alternative for mitigation is to construct a 715-me avalanche tunnel that over the highway. The Second alternative is to build snow bridges with 4 m in height and 3034 m in length against avalanches potentially threatening the road safety.

## 4. CONCLUSIONS

Snow avalanches that disrupt traffic and create serious safety problems are frequent events during winter season on the Erzurum-Çat-Karlıova highway in the eastern Anatolian Region of Turkey. Nevertheless, neither active nor passive mitigation measures were planned or carried out so far. In this study, it was aimed to understand snow avalanche potential and problem in the region and to propose solutions against avalanche hazard. Potential snow release zones and snow avalanche simulations were assessed in different scenarios. UAV based high resolution data were successfully used for this aim. Depending on the evaluations, mitigation measures were proposed.

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