

## NUMERICAL MODEL APPLICATION ON SNOW AVALANCHE IN TURKEY

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**ABSTRACT:** Snow avalanches form a threat to human life in mountainous regions and significantly affect transportation condition. With recent developments in computer technology and programming, numerical models are inevitable tools which have been increasingly used in engineering. However, in Turkey, very limited number of numerical studies has been performed for avalanche simulations. So, in this study, RAMMS (rapid mass movement simulation), a numerical model developed by Swiss Avalanche Research (SLF) Center at Davos, has been applied for a selected avalanche track at Bozdag, Izmir, Turkey where a fatal avalanche disaster occurred in 2012-13 winter season. The model simulation result of run-out distance is found to be in good agreement with the measured value of run-out distance at the site right after the incident. Further simulations with new residential areas implemented are carried out at Bozdag Ski Center since the resort is planned to be in service with additional facilities from 2017. In this paper, some graphical representation of the results which consist of velocity, pressure and run-out distances are presented. Some input parameters in the model have been carefully reviewed in order to assign precise value for the area such as Voellmy-Salm friction factors ( $\mu$ ) and ( $\xi$ ) used in the RAMMS. Finally, discussion part of the paper presents a general remark of numerical model usage in Turkey.

**KEYWORDS:** Avalanche Velocity, Friction Factor, RAMMS, Voellmy-Salm.

### 1. INTRODUCTION

The avalanche hazard is a major natural disaster issue for Turkey considering that approximately 70% of the land of the country is situated on the high altitude mountains over 800 meters. Snow avalanche as a disaster causes many people to lose their lives and damage to property. Experienced fatal avalanche disasters in the 1990s in Turkey resulting in harmful effects have triggered initiation of national academic studies and some projects aimed at reducing avalanche losses. However, studies in the USA and in Europe on the subject date back to many decades. Prediction, prevention or damage reduction is possible precaution steps for an avalanche disaster. For this reason, it is indispensable to continue expanding the national studies focusing on prevention and damage reduction of snow and avalanche.

Snow avalanche simulation on computer is nowadays another key issue in terms of proactive studies. A numerical based model RAMMS (rapid mass movement simulation) which was developed by SLF (Institute for Snow and Avalanche Research in Switzerland) is used to simulate ava-

lanches for possible releases area with different scenarios on the project site. Many engineering projects involving preparation of hazard maps, land use planning, ski resorts, motorways, electricity poles, avalanche barriers, tunnels etc. need to use avalanche simulation models. Therefore, it is emphasized with this study that the necessity of the subjects of academic initiative and developing solution strategies.

As a pilot project area shown in Fig 1, ski resort Bozdag, situated in Izmir Province in Western Turkey is chosen considering many factors.



Fig 1. Case study area, Bozdag

Summit of pilot area Bozdag has 2159 m (asl) altitude. Slopes with the highest gradient in this region are the north-facing slopes of southern and eastern peaks. Dominating vegetation cover over the region includes very sparse foliage shrubs and herbaceous plants. Sparse pine forest are present at altitudes lower than 1600 m (asl) and as getting

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lower altitudes maquis shrub type cover the area. General view of the study area and avalanche paths are shown in Fig 2 and Fig 3.



Fig 2. Pilot project area (Google earth view)

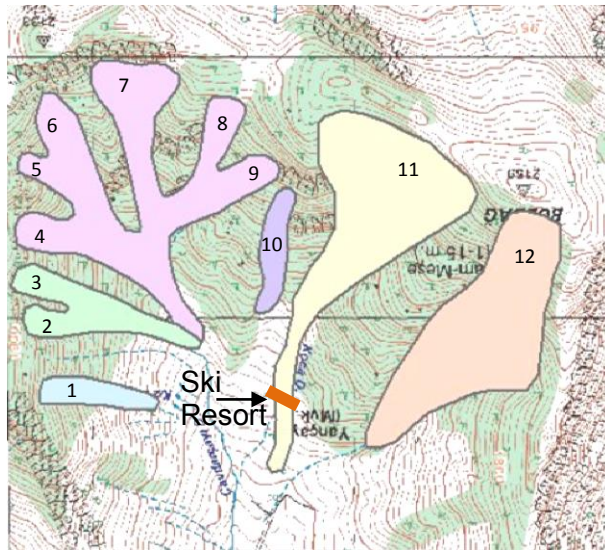


Fig 3. Avalanche paths at Bozdağ

## 2. NUMERICAL MODELLING OF AVALANCHES

Study on computer modeling of avalanche dates back 1980s and study on the subject is still under work. One preliminary numerical model developed by Perla in 1980.

Especially countries faced to avalanche problem developed their computer models such as RAMMS, ELBA+ etc. However, the models developed by those countries could not been widely applied across Turkey. So, verification of the models was very limited so far.

Aydin (2010), Kose et al. (2010), and Aydin et al. (2014) have published some research papers related modeling of avalanches in Turkey.

Aydin et al (2014) undertook a two-dimensional model studies to simulate some of the past avalanche incidents in Turkey. These numerical model simulations are usually calibrated against recorded run-out distance and accumulated snow depth at run-out zone. Since it is not possible to compare values of avalanche velocity, avalanche flow depth and avalanche impact pressure. Therefore, avalanche stopping point accumulated snow depth observed after avalanche incident and findings obtained from face to face conversations made with local people are used in numerical models for estimation of several parameters. Hence, a numerical model set up under these conditions is ready to be run. The new generation of numerical models is being developed in conjunction with GIS. Numerical avalanche models such as ELBA+ and RAMMS work compatible with GIS and the simulation results obtained from such models can be visualized on three-dimensional digital maps (Aydin,2010). A similar application of ELBA+ numerical model to simulate avalanche incidents occurred at Kayaarkasi village of Kastamonu Province is an example of such studies (Kose et al., 2010).

The model used in this study, RAMMS, numerically solves a system of partial differential equations, governing the depth-averaged balance laws for mass, momentum and random kinetic energy using first and second order finite volume techniques. The details of the governing equations and solution techniques are given in Christen et al. (2008)

The model runs for the 12 avalanche paths shown in Fig 3. Avalanche incidents occurred in the past over 11th track. This track is more dangerous than the others since many factors. One important factor is being ski resort hotel located on the path. For this reason runs with the RAMMS has been performed for this track.

Input parameters for RAMMS are topographical properties, friction values, release zone area, calculation domain, end of simulation time and time interval. Friction coefficients for RAMMS are used Voellmy-Salm (Salm et al., 1990; Salm 1993) approach. Two friction coefficients ( $\xi$ ,  $\mu$ ) based on slope angle, altitude and curvature of the topography. Return period of avalanche, release volume and forest information are others important parameters as input value. Computational cell resolution is chosen 10 m, density of the snow is assumed 300 kg/m<sup>3</sup> and end of simulation time set 300 secs. Also one of the very important parameter is release height is selected as 0.5 m. The runs



have been performed considering different return periods. Return periods selected 300, 100, 30 and 10 years. Maximum avalanche height ( $h_{\max}$ ), maximum avalanche velocity ( $v_{\max}$ ) and maximum avalanche pressure ( $P_{\max}$ ) has been obtained and the results shown in Fig 4.

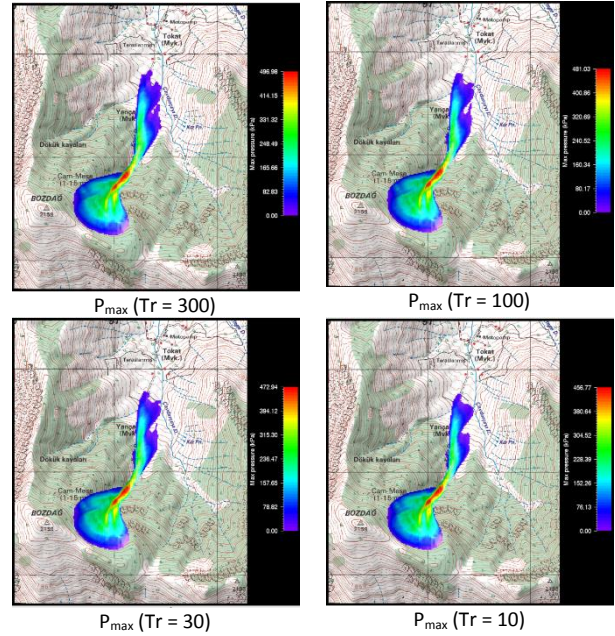
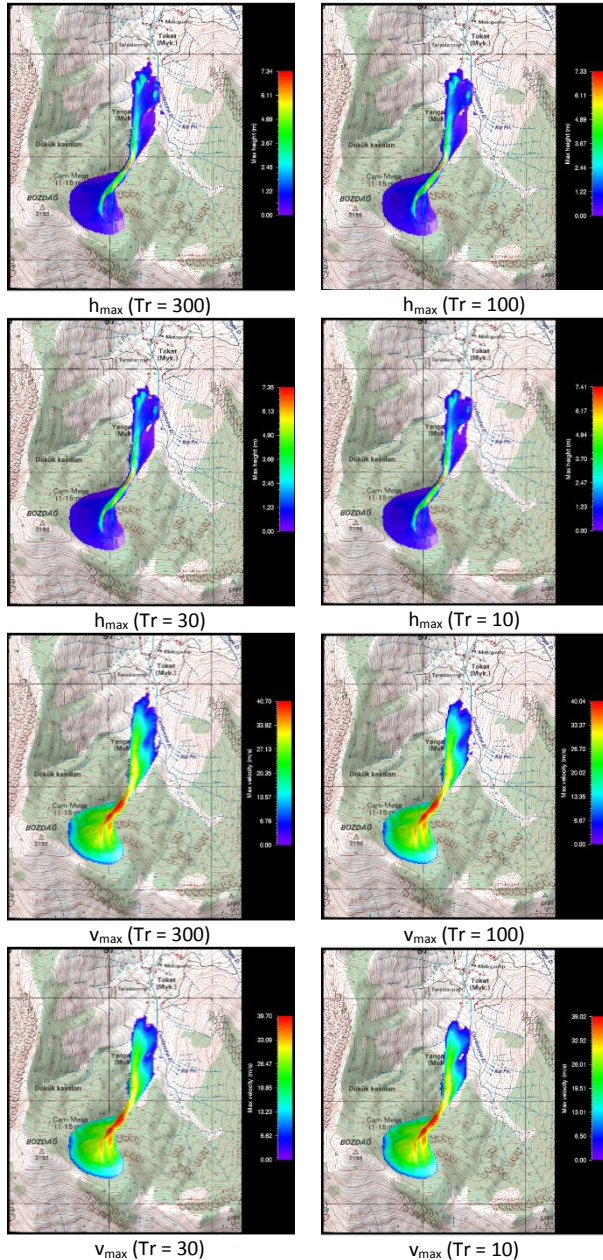


Fig 4. Results of simulations ( $h = 0.5$  m)

Maximum avalanche heights are between 7.3 – 7.4 m, maximum velocities are 39.0 – 40.7 m/sec and maximum pressures are between 457– 497 kPa as a result of the analyses for 300, 100, 30, and 10 years return periods.

### 3. CONCLUSIONS

Overview of the results shows that using different return periods in the model slightly affects the maximum values of avalanche height, velocity and pressure. On the other hand, the size of release zone greatly affects model results. As expected larger release zone produces longer run-out distances. Special attention should be given to the selection of release zone which is known to produce better model results. In this study the worst possible release zone was chosen in order to get the worst run-out distances.

As shown in Fig 3, ski resort building is right in the middle of avalanche flowing channel. Therefore the building is under high risk in terms of avalanche impact. In these scenarios, the pressure is found to be approximately 300 kPa around building as shown in Fig 4. This pressure value is clearly enough to collapse the building. When the flow height in run-out zone is considered the results are found to be highly satisfactory since these results are in good agreement with field measurements. Therefore avalanche modeling in Turkey using RAMMS is thought to be helpful in planning and design stages of ski resorts even though the mod-

el was developed for climatically completely different regions like Switzerland.

Results of the numerical model simulations with different return periods are found to be encouraging for our research team to carry on further studies. In the next stage of the research, different scenarios are planned to be performed with back calculation. Model should be applied for other tracks and avalanche sites as well.

## ACKNOWLEDGEMENTS

This work was supported by the Scientific and Technological Research Council of Turkey (TUBITAK) under Grant 114M311 and authors would like to acknowledge to TUBITAK for their support.

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