APPLYING NUMERICAL SNOW AVALANCHE SIMULATIONS FOR HAZARD ASSESSMENT IN THE KAMCHIK PASS AREA, UZBEKISTAN

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ABSTRACT: This paper presents new results of snow avalanche simulations using the RAMMS software for the Kamchik pass area located in the Ahangaran River basin, Western Tien-Shan range, where the highway connects the two most densely populated areas of Uzbekistan, Tashkent district with the Fergana Valley. Combining field observations, defense constructions, remote sensing data and numerical avalanche simulation can tackle avalanche hazard by estimating potential damage and to plan mitigation measures. We validate the sensitivity of the numerical simulations with respect to digital elevation models (DEM) generated at different dates and with different spatial resolutions. We present examples of simulations for small and large avalanche catchments intersecting with the highway as well as with existing mitigation constructions. We aim for a complete hazard assessment of the most important mountain road of Uzbekistan and present a plan how this could be achieved in the near future.

KEYWORDS: avalanche simulation, RAMMS, DEMs, Kamchik pass, Uzbekistan.

1. INTRODUCTION

The mountain and foothill regions of the Republic of Uzbekistan occupy about 12% of the country and are located in the East (Western Tien-Shan range) and South-East (Hissar-Alay mountains). Almost all mountain regions are avalanche prone territory if there are steep slopes and snow cover of sufficient volume (Semakova et al. 2009). Our focus area has many active slope processes (snow avalanches, mudflows, shallow landslides and rockfalls) and is located in the Ahangaran River basin, close to the Kamchik pass, which is part of the Tashkent-Osh highway, known as “The Great Silk Road” again activated by Chinese initiative. Often in winter, snowfall, snowdrift, and avalanche activity disrupt traffic for hours or even days at the most vulnerable segments of road. There are more than 50 avalanche tracks which intersect the road. In single years, more than 150 snow avalanches with different volumes, occurred in the study area, with dry-, mixed- and wet flow regimes. Monitoring of these sites is maintained by the staff of the Kamchik snow avalanche recording station, which operates since 1965 (Safronov et al. 2013). First mitigation measures such as avalanche sheds, galleries and tunnels, snow fences and dams allow are already installed to increase safety (Starigin et al. 2010). However, numerical models in combination with remote sensing data to generate up-to-date digital elevation models allow for a more detailed study of the hazardous situation in particular within remote release areas. Thanks to recent international research projects, financed by the Swiss National Science Foundation (SNSF) and provided radar and DEM data by German Aerospace Center (DLR) we can generate and use high spatial resolution DEMs for this region and apply numerical snow avalanche simulations. First experience of the simulations for two study areas including the popular ski resort in the Chimgan Valley was presented at the Swiss Geoscience Meeting, 2017.

2. STUDY AREA

According to climatic conditions, the Kamchik pass area is located in the middle of (1500-3000 m) continental zone of the eastern part of the Tashkent region (Figure 1). The region is characterized by low winter temperatures, intensive wind conditions, and uneven distribution of snow cover through the area. The minimal values for the winter period of air temperature and precipitation sum are -22.5°C and 243.6 mm, correspondingly, in average for the long-term period. The maximal values of these parameters are 23.0°C and 781.6 mm, respectively. The mean wind velocity in the study area is 1-9 m/s, and the maximum is from 25 to 30 m/s. The maximum humidity of air is up to 100%.

Elevation differences in the watersheds of the studied area are from 100-200 m to 300-500 m. The avalanche area (about 8 km^2) adjacent to

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the road is located in the altitude zone of 1900-2600 m and can cover about 3 km along the road. Avalanches typically occur in the period of stable snow cover from November till April. The large avalanches in years with the snowiest winters occur every 10-15 years, and extreme avalanches - once in 50 years. Avalanche volumes vary from several tens to several tens of thousands of cubic meters, the pressure - from several t/m^2 up to several tens of t/m^2.

Figure 1: Location of the study area

3. INPUT DATA AND METHODS

We used snow and avalanche data from the release zones of the catchments with the different area, release height and availability of constructions.

The base for the DEMs served the TerraSAR-X / TanDEM-X radar interferometric and ALOS / PRISM optical remote sensing data, and also topographic maps (Topo). We generated DEMs using SARScape ENVI software for the radar data, LPS ERDAS software – for the optical data, and ArcGIS – for the topographical schemes. The data processing details described in the Semakova and Bühler (2017). Furthermore, we applied the ready to use TanDEM-X DEM (2018) and ALOS PALSAR DEM (Dataset, 2015).

We used the RAMMS software (Christen et al. 2010) for dynamic modeling of snow avalanches with different sizes and frequencies to calculate the runout distances, flow velocities, flow heights and impact pressures based on different scenarios. To define simulation sensitivity to the various DEMs we used the approach (Bühler et al. 2011).

4. RESULTS

In according with field data we selected the more commonly encountered avalanche paths in this area with average conditions of snow accumulations and avalanche formation, to see a general map of the catchments around the more attackable part of the road (Figure 2).

The tools in this version of the RAMMS are commonly used to simulate extreme events with at least 10-year return period and 5,000 m^3 volume. In this work, we tried to simulate frequent cases of avalanches with small volume because even they can threaten the road. We were not able to use the EXTENDED scientific version of the RAMMS due to lack of such measurements as snow temperature in the release zone, and predominant type of avalanche genesis (drifting snow). Our experience showed that used version with recommended friction coefficients (variable calculation mode) is also suitable for such type and size of avalanches. The good agreements between the simulation results and field observations were found if we specified the release area location, release height, and modern DEM with high resolution and winter time of acquisitions.

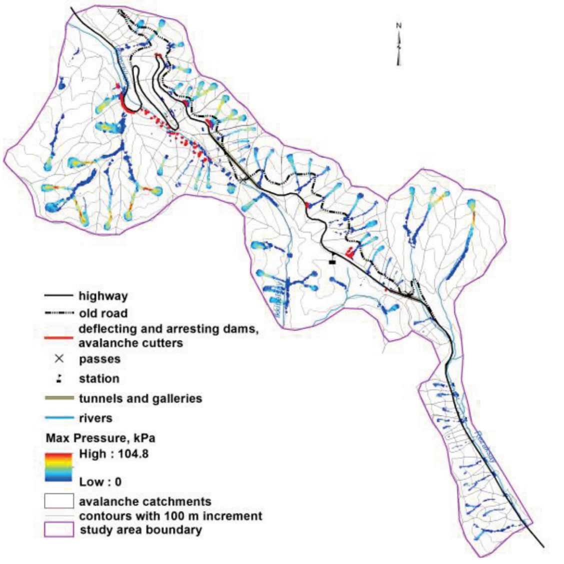

Figure 2: Kamchik pass area with the simulated avalanche paths in the dedicated catchments

On the example of a catchment with an area of 40 ha through which the main and old road pass and there is an arresting dam before the main road, we selected release height as 25 cm and simulation parameters as constant for all used DEMs. We did not take into account the location of the dam during the simulation process. It was revealed that the best DEMs describing the real case of avalanche movement (its sizes in the transit and runout zone, arresting point location, and deposition value) were TanDEM-X DEMs.

Topo DEM did not consider the changes in the terrain which were caused by the presence of the roads and other constructions, and the simulated avalanche reached the bottom of the catchment. Three of the four winter ALOS PALSAR DEMs showed some little-sized avalanche tails behind the dam (Figure 3). The flow shape and values of maximal flow height are the same for the February acquisitions DEMs of 2007 and 2008, and they are naturally bigger than the parameters calculated with January DEMs. The dynamic parameters calculated on the base of January 2008 DEM are less than the same parameters derived from January 2009 DEM.

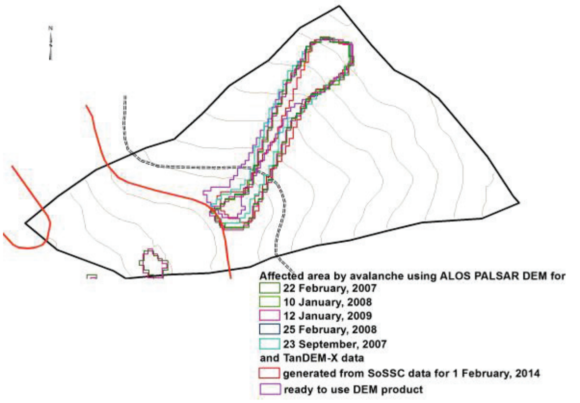

Figure 3: Simulated avalanche runout distances using various DEMs.

In general, there are some differences between the dynamic parameters derived on the base of all winter DEMs and these parameters from summer DEMs what is possibly caused by snow mass entrainment to the avalanche body (Figure 4 and 5).

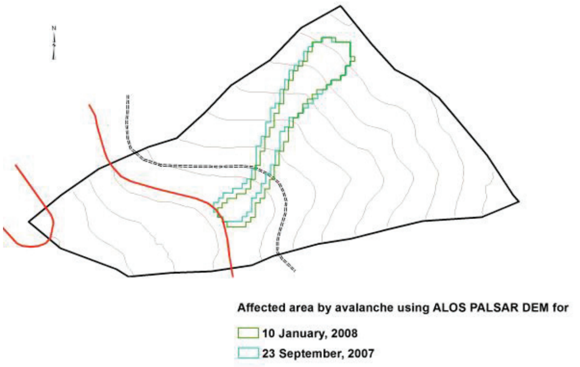

Figure 4: Affected avalanche area calculated on the base of winter and summer ALOS PALSAR DEMs

Comparing all simulated avalanche flows we can see some small shifts between ready to use TanDEM-X DEM and other DEMs. In further research, we plan to use new GLAC/ICESat or DGPS data to co-register the DEMs before running the simulations.

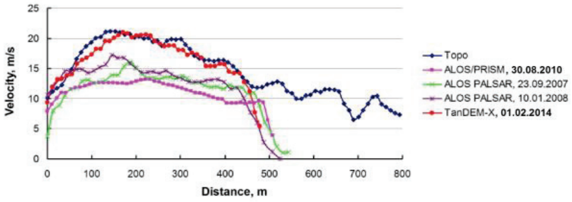

Figure 5: Profiles of the maximal flow velocity

Using another catchment with an area of 1 km^2 having 5 sub-catchments and 6 release zones, we used the position of avalanche cutters located in the bottom of the catchment during the simulation processes. There are also the deflecting dams on the left side of the road loop which rather well deflect avalanches released from adjacent catchment and fields of snow fences in three release zones of the study catchment (Figure 6).

All DEMs showed that simulated avalanches reached the river (thalweg) and did not cover the road. This corresponds to real cases for the mean snow accumulation conditions (40 cm in the release height). The longest runout was calculated on the base of Topo DEM. A few wider starting zone was derived from ALOS /PRISM DEM (the lack of GCP-points evenly distributed on the triplet) and TanDEM-X DEM. A few wider transit zone was derived from ALOS PALSAR DEM (12,5 m against 10 m for other DEMs). TanDEM-X DEM is also some shifted to the left from the others DEMs. The winter DEM generated from TerraSAR-X/TanDEM-X data processing seems optimal. However, all DEMs are close to each other and reflect the real avalanches cases.

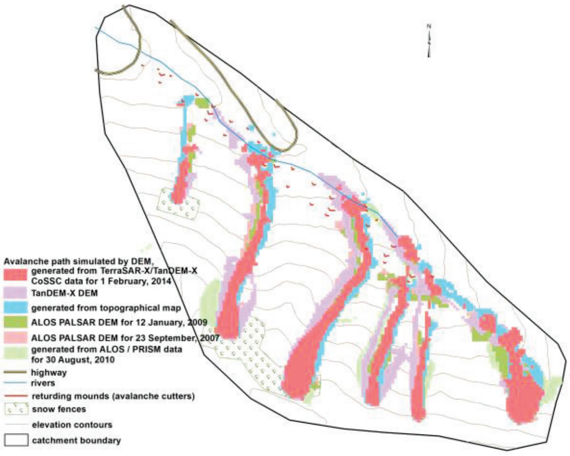

Figure 6: Simulated avalanches runout distances using various DEMs for one of the large catchments.

5. CONCLUSION AND DISCUSSION

Verification of the output results showed good agreement with field observations on the examples of small and large avalanche catchments for extreme and small-sized, frequent snow avalanches. The best way is to use 10 m resolution DEM for this area that would reflect recent changes in relief and situation after construction activity. The winter time acquisition DEM reflects a surface that is modified after previous avalanche release or redistribution of snow due to snow storms or wind activity. In our opinion, such DEM allows not to calibrate the friction coefficients (a dry-Coulomb and viscous-turbulent type friction), which depend on topographic features (slope angle, altitude, and curvature), forest information, and return period and avalanche volume. Because there were no data on measured flow height, velocity, and pressure, we were assessed the agreement between real and simulated runout distance only.

The tool in RAMMS software designed to consider the location of deflecting dams and obstacles appeared very useful to get the real picture of avalanche dynamics in the studied area. This research will be continued for other avalanche catchments with the new infrastructure to estimate the current adequacy and effectiveness of the protective constructions that actively appeared in last time in the area.

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