# The current state of avalanche risk analysis and hazard mapping in Uzbekistan

Eleonora Semakova[1,*], Sergey Myagkov[1] and Richard L. Armstrong[2]
[1] Hydrometeorological Research Institute, Uzhydromet, Tashkent, Uzbekistan
[2] University of Colorado, National Snow and Ice Data Center, Boulder, Colorado, U.S.A.

ABSTRACT: This paper includes new results of avalanche mapping in Uzbekistan. The avalanche caused damage distribution in Uzbekistan is presented. The description of the "Snow Avalanches" database, allowing searching various weather, snow and avalanche parameters, is given. New criteria for potential hazard evaluation were developed for the conditions of Western Tien-Shan mountain regions. All mountain regions of the country were considered for mean scale avalanche danger mapping. An opportunity of avalanche risk assessment on the basis of available information for Southern mountainous regions is considered.

KEYWORDS: Potential danger territories, avalanche risk, avalanche hazard mapping.

## 1 INTRODUCTION

The mountain and foothill regions of the Uzbekistan Republic occupy about 12% of the country. They are located in the East and South-East (Tien-Shan and Gissaro-Alay mountains) (figure 1). Almost all mountain regions are an avalanche prone territory if there are steep slopes and snow cover of sufficient depth. Outstanding progress in the republic's economic development predetermines the future active development of Uzbekistan's mountain territories and these include adventure tourism, road-building and electric power line construction. The development and recreational activities in the mountains are threatened because of frequent, highly destructive avalanche activity, which is widely spread over the mountain terrain. Snow avalanches cause considerable damage to the economy of the state (table 1). Therefore, it is necessary to develop a general mean scale map assessment of the avalanche danger territory. Such a map is an informative tool. It takes on special significance for representation of avalanche characteristics and patterns and possible damage. Accordingly avalanche hazard maps are important for decision making about risk assessment, the engineering of protection structures, and the forecasting and monitoring of avalanches. These types of maps also support the development of early warning systems for avalanches. Because of the expected climate change, it is extremely important to estimate future avalanche risk in Uzbekistan.

*Corresponding author address:* E. Semakova, Hydrometeorological Research Institute, 72, K. Makhsumov str., Tashkent, 100052, Uzbekistan; tel: +998 71 235 40 72; fax: +998 71 233 11 50; e-mail: ella9sem@gmail.com

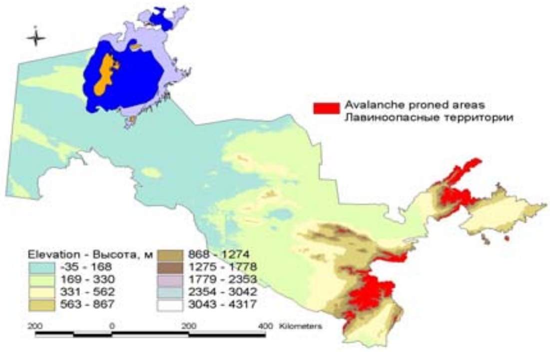


Figure 1. Avalanche prone areas of Uzbekistan

Table 1. The avalanche caused damage (%) for all period of standard observations

| | |
|---|---|
| Death of people | 1 |
| Destruction of houses, administrative buildings, objects | 3 |
| Blockage of motorways and railways | 89 |
| Cutting of high-voltage, telephone and telegraph lines, damage to gas-main and water-supply | 1 |
| Blockage of river channel flow, destruction of bridges, forests, ski ways | 6 |
| Total | 100 |

## 2 "SNOW AVALANCHES" DATABASE

Information about the regime and spatial pattern of avalanches and preceding meteorological conditions is required for effective avalanche protection. The database "Snow Avalanches" contains detailed data from 18 snow avalanche observation sites in Uzbekistan and general avalanche extent based on observations from helicopters.

Information in the database has been compiled into 4 tables (Avalanches Cadastre of USSR):
1) Description of avalanche recording stations;
2) Characteristics of avalanche catchments;

3) Avalanche observations at the stations;
4) Data of observations from helicopters.

The first table contains the information on administrative location, geography, elevation, and the period and program of avalanche observations. There are currently two avalanche observations stations operating in Uzbekistan. They are Chimgan, providing safety in a recreational zone and Kamchik, providing safety for the Tashkent - Osh strategic road.

The second table contains the information about morphometric characteristics of avalanche catchments, and anti-avalanche constructions.

The third table contains the measured characteristics of snow avalanches. They are place and time of avalanche release, size, weather conditions (before and during avalanche descent), release factor, kind of released snow, vegetation, type of sliding surface, contamination of deposits, elevation and morphometric characteristics of zones of formation, transition and avalanche cone and estimations of damage.

The fourth table is divided into two blocks containing the information, obtained during helicopter observations, both on selected avalanches, and widespread avalanching.

## 3 DATA AND METHODS FOR THE AVALANCHE DANGER MAPPING

Now modern geographical information technologies (GIS) allow automation of the process of identification of avalanche prone zones. The basis of the GIS used here was a Digital Elevation Model (DEM) which has varying precision depending on the size of the region covered and specific application (Avalanches of Uzbekistan, 2003).

It is assumed in this work that potential avalanche danger exists irrespective of the extent of human activities and future development projects in the mountains. However, an actual avalanche risk appears only when human activity is present in close vicinity to avalanche prone areas.

Using database information about the minimal altitude of avalanche release and by taking into account the most snowy winter (1968/69) we were able to prepare the maps of maximum possible spreading of avalanches (figures 2 and 3).

For mapping of avalanche danger for the Tashkent district we have selected 4 degrees of avalanche danger (strong, moderate, weak, and potential) (Figure 4). Input data included 1:200,000 scale topographical maps; digital satellite data in snow-covered territories; snow cover depth on meteorological stations; “Uzbekistan Avalanches” database and expeditionary observations. A 200 m DEM accurately corresponding to the local hydrology was created by digitising the input maps (Semakova et al., 2005).

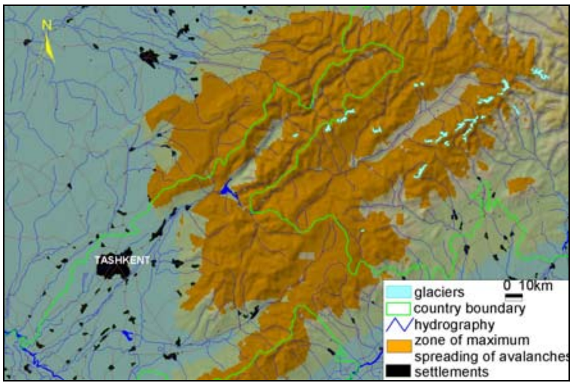

Figure 2. Maximum avalanche spreading for Northern mountain part of Uzbekistan

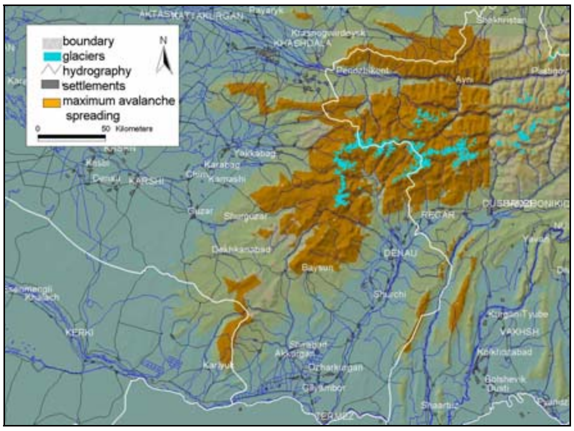

Figure 3. Maximum avalanche spreading for Southern mountain part of Uzbekistan

The NOAA images with 1 km resolution on the ending of March for 16 years allowed defining a snow-covered area for different years and revealing a lower boundary of avalanche danger and also the long-term change of seasonal snow-covered territories.

The method to identify relief ruggedness and other relief characteristics influencing on snow avalanche formation was offered (Batirov and Semakova, 2005). It is effective for investigating of insufficiently studied and remote mountain territories.

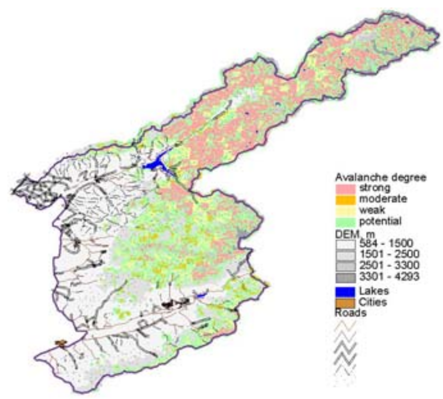

Figure 4. Avalanche hazard map for Tashkent district

The link to geographical coordinates, translation in UTM projection for meter units calculations provided the opportunity to receive any information concerning characteristics of a relief (terrain elevation, slopes exposition and steepness, vertical and horizontal surface roughness), seasonal snow-covered territories for the certain survey year and snow cover depth, avalanche activity parameters (frequency and volume of avalanches, genesis and humidity of avalanches (wet or dry snow) and duration of avalanche hazard period) for any region of Tashkent district.

We have used SRTM 3" data for the creation of avalanche danger maps for the rest districts of Uzbekistan (figure 5), including mountain areas of Namangan province (1); the southern portion of Fergana province (2); Nuratau and Aktau mountain ranges (3); Zaamin and Sanzar river basins (4); Kashkadarya, Surkhandarya, Karadarya river basins and Kughingtau mountain area (5) and Babatag range (6). The DEM precision is about 93 m. Topographic maps of 1:200,000 scales have been digitally processed including hydrographical information and data on settlements, roads, etc. Permanent settlements are located mostly in the lower reaches of rivers and along roads. There was only one station (L.Severcova) operated in the south part of Uzbekistan until 1993 and some helicopter observations in these regions. Kamchik station is in Namangan province.

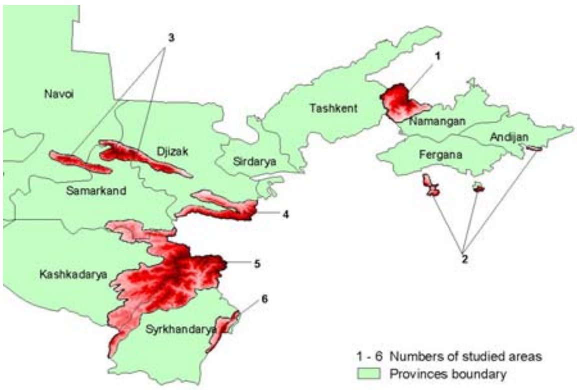


Figure 5. Studied territories of Uzbekistan

The lack of valuable continuous and comprehensive standard snow avalanche observation records in these territories required the use of other methods to assess potential danger. The steepness of slope more than 25 degrees and corresponding depth of surface roughness were used to define a zone of avalanche formation. A computer-simulated network of watersheds (avalanche catchments) allowed revealing the zones of possible area of the runout zone. A whole watershed (including starting zone, track and runout zone) was identified as a potentially dangerous catchment if areas with a steepness of more then 25 degrees were found in the area of the watershed. The influence of model's precision to identify avalanche catchments and river networks to define the area of potential danger territory was investigated. It was known that an avalanche path with a minimum length of 0,5 km (including starting zone, track, and runout zone) could cause some damage. It was defined that minimum area of avalanche catchment comprises an area of 25 cells for given DEM precision.

The territories with strong, moderate and weak avalanche danger were derived by taking into account the relief categories allowing classifying mountain territories of Uzbekistan according to degree of avalanche danger and the aspect effect of slopes on avalanche activity from well-studied basins.

Using this method we compiled the maps of avalanche activity and avalanche hazard for all mountainous parts of Uzbekistan.

For an avalanche risk assessment there is the need to know not only avalanche danger but socio-economic factors, for example settlements, roads and communications lines.

The full social avalanche risk (collective risk) was evaluated for the largest region including Kashkadarya, Surkhandarya, Karadarya river basins and Kughingtau mountain area using the method of Seliverstov and others (2007). The risk has been expressed in terms of the number of possible victims per year.

For definition of population size we used an atlas of human settlements produced on topographic maps. A population density by 1 km$^2$ was derived by taking into account population size for settlements which occur within a radius of up to 5 km away from a center of settlements. Of course, travel away from population centers can occur for recreational and other purposes causing residents to freely move over greater distances beyond that specific radius, but, considering the scale of the initial maps, it is possible to neglect such details at estimation of the given risk.

The following indices were used for calculations: vulnerability of the population over time by taking into account the maximum duration of avalanche hazard period[1] to assess duration of the inhabitant remaining in the endangered areas during the year and the presence of settlements, roads and communication lines in the studied area to assess the duration of staying in the danger area during the day; vulnerability of the population in space by considering the potential hazard zone area and full social (or collective) risk including above two vulnerability's

[1] This value was derived by means of a conversion factor based on the well-studied Tashkent district.

factors, frequency of avalanches[2] and population density.

It was found that avalanche frequency did not exceed 1 avalanche per year in all territories exposed to risk (figure 6). This needs to be confirmed through field observations. The maximum full risk of 0,40 was found in the area of the settlement Sarchashma (upper square in Figure 6) (this cluster is located in the zone of potential avalanche danger) and risk is 0,47 in the area of the settlement Bashdara (lower square). In the area of settlements Palvansay, Kizilsay and Shahshar, etc. the risk changes from 0,1 up to 0,3, though these populated areas are located in non-hazardous zones. This is caused by the closeness of danger zones. Isolines of risk smoothly bend around some close together clusters located along the river Aksu, covering both non-hazardous, and hazardous areas.

The availability of more exact population data will provide an opportunity to estimate Individual avalanche risk as probability of premature death of individual of the particular community within the researched territory per year.

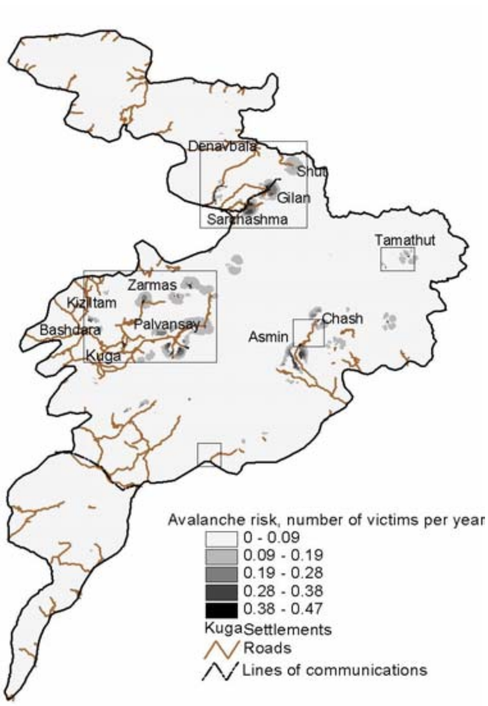


Figure 6. An avalanche risk for south mountain part of Uzbekistan

On the basis of such general maps it is possible then to begin to evaluate the risk for concrete objects when combined with long-term observations.

[2] The average long-term frequency of avalanches per year is estimated by average long-term maximal snow cover depth.

*3.2 Avalanche risk assessment for the separate sites (Chimgan, Dukant, Kamchik)*

Pilot areas for these objectives are small local river basins in area of the Chimgan, Dukant and Kamchik snow-avalanche stations. The longest period of observations was realized on Dukant station (44 years).

Input data were digital version of 1:10 000 topographic maps, meteorological variables (precipitation and air temperature), data on snow depth measured by remote stakes and avalanching information.

Different features of the terrain topography (plan and tangential curvature, directional derivative, etc.) were tested to reveal the regularities in the spatial pattern of snow depth. There was a formalization of the use in GIS geomorphologic terms such as ridge, thalweg and favourable slopes relative to wind direction. The approach for the definition of snow cover depth with varying probability and avalanche frequency for one of most popular resorts in Uzbekistan - Chimgan valley was developed (Pertziger, 2001). Slopes reliable for downhill skiing were identified for this region (figure 7). It was revealed that surface lifts is more preferably situated then chair lifts, because snow is better protected on slopes where a snow depth of more than 1 m for a given year with 50% probability and the terrain aspect is Northern or close to it.

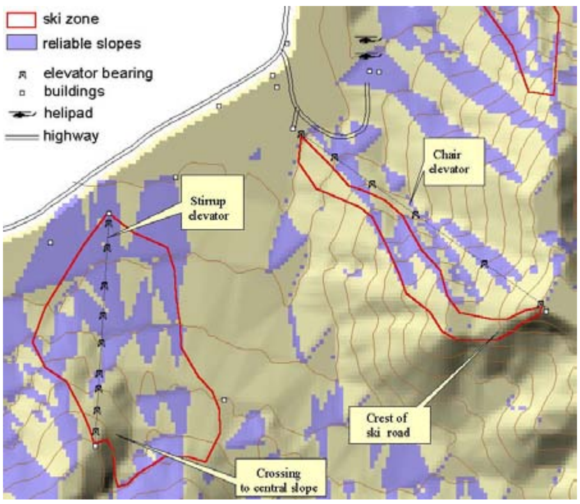


Figure 7. Slopes reliable for downhill skiing

The map of avalanche risk as a function of snowfall amount with the use of the universal method of avalanche forecast for Central Asia conditions was developed for Dukant station. It included such characteristics as snow depth before snowfall, snow depth increment, and average daily air temperature and wind velocity. Also, the GIS tools allow the identification of the best observation points with maximal view for this dangerous territory.

The vicinity of Kamchik pass is the part of Tashkent-Osh motorway known worldwide as “The Great Silk Road”. This road is of great importance for the country because it connects the two most densely populated parts of Uzbekistan. There are 18 avalanche catchments affecting the road. The motorways, tunnels and the avalanche catchments locations are shown on figure 8. For artificial release of avalanches in this region, the location of a minimum number of gun placements have been identified with use of GIS-tools.

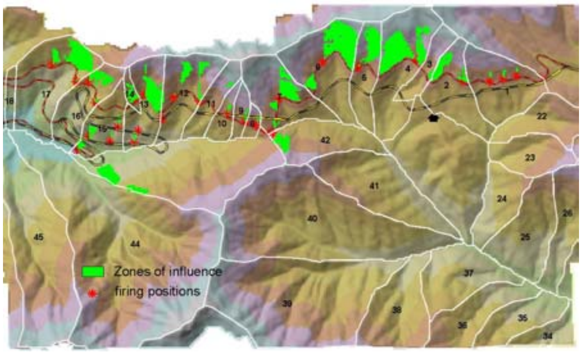


Figure 8. Zones of influence from firing position

The data on 51 avalanche catchments in the Kamchik pass region were analysed for evaluation of avalanche risk components (Kakurina, 2001). The probability of avalanches all over the region was computed. The avalanche risk estimation took into account the interaction of snow avalanches with functioning automobile highway. Length of highway in studied area was assumed 24 km; however calculations were carrying also for the most dangerous part with length is 12 km.

The results shown the risk is increased when vehicles velocity is reduced. The risk is increased with reduction of length of a study site, as the density of avalanches on the unit of length is increased. The usual road situation in winter conditions (ice, drifts) assumes formation traffic jams with a multi-hour delay of transport in avalanche risky places. The increase of avalanche risk for last years is explained by sharp increase of transport intensity through the pass and the presence of the construction and road services.

Protection actions here include avalanche forecasting, artificial release of avalanches and various protective constructions (avalanche sheds and tunnels; snow fences, retarding mounds; deflecting and arresting dams), which will allow considerable increased traffic safety. The development of such highway defences against avalanches is in progress.

## 4 CONCLUSION

It is our plan to continue the monitoring of snow cover and avalanches with updating of the corresponding databases connected to the specified maps. Also, we will create additional layers containing the information on climatic characteristics and connected with them distribution of a snow cover and avalanches. However, such research is possible only in specific areas where adequate data are available.

The creation of new methods for avalanche mapping based on modern technologies and also the calculation of avalanche risk is expected to be one of the most important tasks of future practical avalanche studies.

## 5 ACKNOWLEDGMENTS

This work represents the beginning of a collaborative avalanche danger assessment project with the University of Colorado, with funding provided by the Civilian Research and Development Foundation (CRDF).

## 6 REFERENCES

Avalanches Cadastre of USSR. Vol. 1-20. L.: Gidrometeoizdat, 1984-1991.

ArcView GIS (Using ArcView GIS). Environmental Systems Research Institute, Ins. Redlands, CA 92373, 1996, 340 pp.

Batirov R.S., Kakurina E.G., Pertziger F.I., Semakova E.R., Starigin G.N., Yakovlev A.V., 2003. Avalanches of Uzbekistan - Tashkent: SANIGMI, 119 pp.

Batirov R.S., Semakova E.R., 2005. The assessments of characteristics of mountain relief for definition of potentially dangerous avalanche sites with use GIS. Proceedings of NIGMI, vol. 5(250), pp. 18-23.

Isaev A.A., Kakurina E.G., Pertziger F.I., 2001. A technique of large-scale avalanche frequency mapping. Proceedings of SANIGMI, vol. 161(242), pp. 43-54.

Kakurina E.G., Pertziger F.I., Yakovlev A.V., 2001. An experience of large-scale mapping of a snow depth. Proceedings of SANIGMI, vol. 161(242), pp. 83-95.

Kakurina E.G., Kanaev L.A., Starigin G.N., 2001. Avalanche risk assessment (Kamchik saddle-point as an example). Proceedings of SANIGMI, vol. 161(242), pp. 55-61.

Seliverstov Y., Glazovskaya T., Shnyparkov A., Vilchek Y., Sergeeva K., 2007. Estimation of influence of snow avalanches on activity of the person. - International Symposium on Snow Science, Moscow, 3 - 7 September 2007, p.90.

Semakova E.R., Batirov R.S., Karandaev S.V., Starigin G.N., Tarasov Yu.A., Tupaeva N.K., Fadeicheva L.V., 2005. The mapping technique of avalanche danger on example of Tashkent area. Proceedings of NIGMI, vol. 5(250), pp. 86-95.