A PRACTICAL EXAMPLE OF AVALANCHE STUDY AND MODELLING AND ACTIVE TRIGGERING SOLUTION IMPLEMENTATION IN UZBEKISTAN

García-Sellés C[1], Riba S[1], and Berger T[2]*

1 Nivorisk, ANDORRA
2 MND SAFETY, Ste Helene, Francey
** Indicates the presenting author*

ABSTRACT:

A relevant project has been under progress on behalf of the Ministry of Investment and Foreign Trade (MIFT) of the Republic of Uzbekistan which aims at the development of the international all-season resort of the “Beldersay-Chimgan-Nanay” resort.

The first phase of two concerns in particular the construction of a four seasons resort. Beyond the development of the resort, the main driver of the project is to build a cable transport system starting from the resort to the summit of Mount Chimgan at 3309 m altitude. This transport chain includes 2 ropeways system and 4 stations. Some of these infrastructures are highly submitted to avalanche risk. After a mandatory extensive study avalanche phase, the works saw the installation of comprehensive avalanche mitigation in 2026, focused on 4 major high-risk zones. The primary objective was to protect critical pylone infrastructure and slopes with 14 RACS, remotely operated avalanche gas control systems, O’Bellx™.

Another key aspect of the project, which posed also a challenge from the perspective of snow conditions, was the analysis of snow and weather conditions in a mountainous region so geographically and conceptually distant from our Alpine and Pyrenean environment, usual business site.
The first step was to try to classify the snow climate into one of the three classic categories: continental, intermountain or maritime.
The working hypothesis was to assume a continental climate as this area is so far from coastal zones, where, in principle, the typical processes of a continental climate should be fundamental. Nevertheless, cold conditions may be moderated by a latitude like the Mediterranean Pyrenees and by a relatively modest altitude. All this means that we must be aware that a high level of uncertainty must be accepted when modelling reference avalanches, due to the lack of absolute certainty when reconstructing the snow conditions of avalanches with return periods of 100 and 300 years. For this reason, it has been important to maintain close contact with local meteorological authorities and with the academic sector involved in research and modelling of natural hazards. The paper aims at presenting the main outlines of this uncommon project.

KEYWORDS:

Gas RACS – Avalanche – Modelling – Tian Shan -

1. INTRODUCTION

Many of the central Asian countries do experience an increasing economic and touristic development ultimately. Central Eurasian mountains range also see the outstanding development of winter activities, creation of new resorts, which make the hazard of avalanche higher.

Among these projects a relevant one has been under progress since 2023 on behalf of the Ministry of Investment and Foreign Trade (MIFT) of the Republic of Uzbekistan which aims at the development of the Chimgan ski resort, located Northeastern of the country in the Tien Shan mountains range close to the boarder with Kirgizstan, see figure 1.

* *Corresponding author address:*
Thomas Berger. Projects Director, MND SAFETY,
Ste Helene du Lac, France;
email: Thomas.berger@mnd.com

https://doi.org/10.15788/1790099040

Figure 1. Location of the project.

The first phase of two concerns, particularly the construction of a four seasons resort. Beyond the development of the resort, the main driver of the project is to build a network of new chair lifts, gondola and a cable transport system starting from the resort to the summit of Mount Chimgan at 3309 m altitude.

Chimgan village is a well-known small ski resort. The site has been one of the very few observation stations of snow and avalanches in the country and has been a pilot site for the avalanche risk assessment and hazard mapping (Semakova et al, 2009).

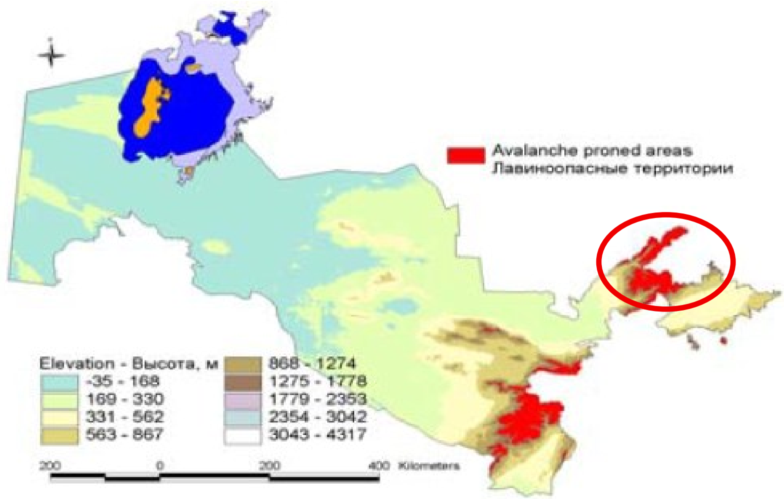

Figure 2. Avalanches proned areas Uzbekistan map, (Semakova et al, 2009).

2. AVALANCHE STUDIES

Chimgan ski resort is in the Western Tyan Shan mountains, at minimum altitude of 1600 m, in the eastern corner of Uzbekistan. Ranges and valleys are disposed generally from east to west; highest peaks surrounding Chimgan reach 3000-3300 m height. Arising from a semi-arid ecosystem, both features favor the reception of depressions conducting moisture-bearing westerly winds from the Atlantic Ocean leading to avalanche activity.

In Uzbekistan, various studies employing RAMMS have been conducted to improve the prediction of avalanche runout and eventually inform the construction of mitigation infrastructure. Long records of avalanches including observations, characterization of morphometry, time of release and their weather conditions have been compiled (Gidrometeoizdat, 1984) and used for mitigation infrastructure construction, especially on Kamchik Pass in the Tian Shan (Semakova and Bühler, 2017; Semakova et al., 2018, 2009).

2.1 Reported avalanche information

Avalanche activity in the study area is frequent, as described by the meteorologist chief of the observation site (Mr. Albert Stepanovich by means of personal interviews). Extreme avalanches reached the motorway from Chimgan to Gazalkent in 1968 and also around 1941-44.

In the avalanche starting zones above roughly 2000 m, observed avalanches are mainly slabs with notable fracture propagations along the open slopes. Prevalent winds blow from SW-S-SE and intensity is generally low at level of the observational site (1678 m). At ridge level, prevailing winds from snowstorms are from west and do not blow especially strong. Even wind is not essentially strong, it is able to drift the ridges and transport snow to the lee side. Anyway, it seems that extremely strong winds as usual in some areas of the Alps and Pyrenees are not frequent in this region. Considering both the wind behavior and the observations of usually dry and faced snowpack, avalanche slabs would mostly correspond to the persistent weak layer avalanche problem (figure 3).

Below 2000 m, wet avalanches are common and sometimes even fall from higher altitudes due to episodes of rain on snow. In these cases, avalanches attain destructive sizes (figure xx2).

Figure 3. Slab avalanche and large fracture propagation. (Source: Mr. Stepanovich files).

Figure 4. Wet deposit arrives at the bottom of the main valley affecting some infrastructures (Source: Mr. Stepanovich files).

2.2 Snow and avalanche climate

Attending to the Koppen climate classification, it is mediterranean continental (Dsa), characterized by dry summers and humid, cold winters. An official meteorological observation site exists in the study area, Chimgan (1678 m, 41º 31’ 36’’ – 70º 01’ 24’’), very close to the concerning area. Any study on snow and avalanche climate of the zones was found when looking out into existing research.

In preparing the weather data to model the avalanche zones, it was noticed that accumulation of new snow in 24 h is not an observed parameter in the meteorological site. Therefore, this variable has been roughly calculated by means of the difference between the snow depth on the ground in two consecutive days. It supposes to slightly underestimate the actual snowfall accumulation in 24 h, since incipient settlement begins to work. The same reasoning is applicable to the new snow accumulation in 72 h. Nevertheless, in this case the accumulation in 72 h considering the settlement is a scenario much closer to reality as new snow can reduce its depth up to 30% after 72 h (depending on temperature and humidity) (Barbolini et al. 2005). This parameter is called maximum releasable snow depth in 72 h (dHS3d).

It is subdued to both daily and seasonally heavy thermal oscillations. This typical continental treat is accompanied by high insolation; there are about 2500 hours of sunshine each year or 300 sunny days a year but, at the same time, abundant snowfall in winter. Nevertheless, the winter season is relatively short, ranging from late fall to ending March. Minimum temperatures are sometimes below -20°C at 1700 m in winter; annual precipitation ranges from 800 to 2000 mm, from the bottom of the valleys up to altitudes of 2500-2700 m. Mostly precipitation concentrates in winter and spring.

Attending to the snow and meteorological data recorded in the Chimgan meteorological site (1678 m), the average snowfall by year is 272 cm, with a minimum of 178 cm (1994-95) and a maximum of 398 cm (1993-94) (figure xx3). As the observational site is located at low altitude, and average around 300 cm per year could be expected above 2000 m, where most of the avalanche starting zones are located. Compared to Alps or Pyrenees, this overall is relatively low and like those recorded in the driest part of the Pyrenees, the southeastern border facing the Mediterranean Sea. Total amount of precipitation from November to April is 677 mm, which means that more than 50% of the precipitation is rainfall during the season, at least at the bottom of the ski resort. If we consider the precipitation in the coldest part of the season (Dec-Feb), it reduces dramatically to 295 mm. It means that even though rainfall is frequent during the beginning and the end of the season, precipitation falls mainly as snow in the winter at least over 2000 m, but scarce episodes of rain-on-snow are recorded.

In this way, average temperatures of the period December to February are minus 0 ºC at 1678 m, and reaching a monthly average of -2,7 ºC in the coldest month, January. Daily averages less than -10 ºC are frequent during the winter, recording the absolute coldest day on 11th January 2023 with -21,2 ºC. At the same time, as usual in continental climates, temperature oscillation is notable, and to measure every year daily averages between 5 ºC to 10 ºC in the coldest month is normal.

Both the huge thermal threshold at daily and monthly scale and the big difference between total precipitation and snowfall in the period Novembre-April favor snowpack scenarios of rain-on-snow and also powder, cold new snow accumulations. Of course, instability conditions of the snowpack triggering avalanches are assured.

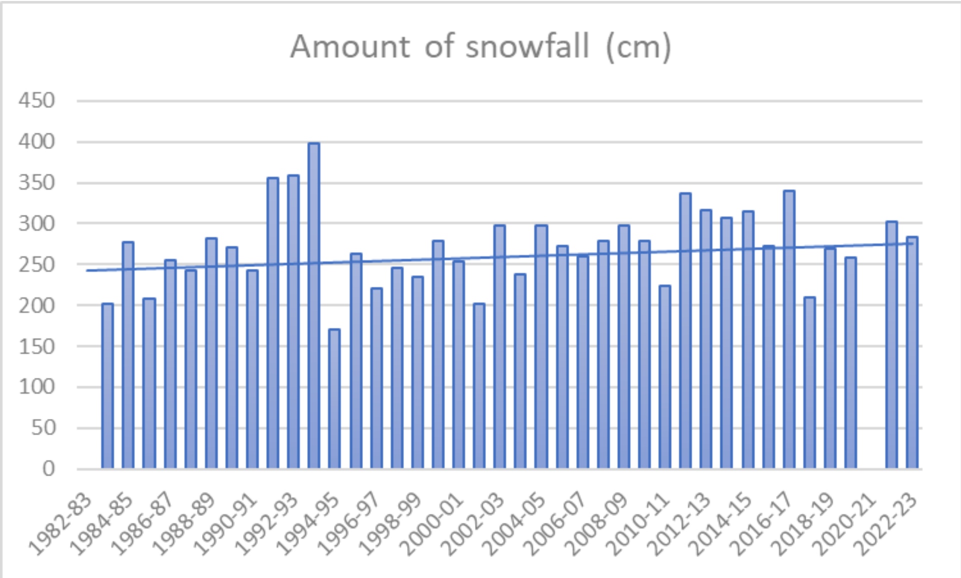

Figure 5. Evolution of the snowfall, annual accumulated new snow, and annual trend from 1982-83 up to 2022-23 in Chimgan (1678 m).

About wind, there is not enough recorded data to explain the behavior, just two years (2017-18 and 2018-19). Nevertheless, some pattern is observed from the two years. Prevalent winds blow from SW-S-SE and intensity is generally low at level of the observational site. Interviewing Mr. Stepanovich, he states that prevailing winds are from west at ridge level and do not blow especially strong. About 80% of the snowstorms are accompanied by westerly winds; northern wind is rare. Even if wind is not essentially strong, it is able to drift the ridges and transport snow to the lee side as it is observed through pictures and videos. Anyway, it cannot sweep snow away from flat and convex terrain well windward faced. Cornices hanging on north-eastward slopes are common. It seems that extremely strong winds, as usual in Pyrenees or some alpine areas, are not frequent in this region.

Using the well-known snow climates classification: coastal, transitional/intermountain and continental (Mock and Birkeland, 2000), Chimgan area probably matches with the continental mode. Relatively few snow, low snow density, cold temperatures and long dry periods are characteristics of a continental snow climate. Nevertheless, the lack of snowpack structure data hinders specifically the type of snow climate and associated avalanche regime in Chimgan area.

To know the snow and avalanche climate classification of this mountain region was essential to plan a location-specific avalanche mitigation solution. In the absence of snow profiles to identify typical structural instability (slabs and weak layers characteristics), we used the classic Mock and Birkeland flowchart to discriminate snow and avalanche climates based on meteorological data estimated at 2200 m high, average level of the avalanche starting zones defined in the ski resort project. Those parameters are snowpack thermal gradient in December, rainfall in winter months (Dec to Mar), winter average temperature, total precipitation as SWE in winter, total snowfall.

When considering typical continental parameters, the average winter temperature (-3,8ºC at 2200 m) is not low enough, but colder than a coastal pattern. Snowpack thermal gradient in December (7,7ºC/m) is not low enough to be considered continental snow climate either. Snow climate could be considered transitional/intermountain, but the snowfall (302 cm) is quite a bit lower than what is typical of an intermountain pattern and fits very well within the threshold of the continental snow climate. Surprisingly, Chimgan's snow climate accomplishes a clear condition of a coastal pattern such as rainfall over 80 mm from December to March at 2200 m of altitude (117 mm). Similarly to other mediterranean climates, a latitude as a border between boreal lows and subtropical high pressures accounts for precipitations with a remarkably high snow line even in the middle of the winter.

By this point, climate data reveal a transitional snow and avalanche climate with a component of rain. In terms of precipitation, it could be classified as continental climate, but as the temperatures are not low enough, the most appropriate classification is transitional snow and avalanche climate. However, the amount of rainfall during the winter weighs so much in Mock and Birkeland classification that it directly classifies it as a coastal climate. Normally, this kind of snow and avalanche climate exists in regions near to the coast and receives the maritime influence as frequent episodes of rain on snow. In recent literature (Meloche et al., 2025; Ikeda et al., 2009), the term 'Rainy Continental' has been coined to describe a continental snow climate with maritime influences that account for rainfall exceeding the 80 mm threshold during winter in the Central Japanese Alps, the Northeastern Appalachian Mountains (Mount Washington – New Hampshire, USA), Chic-Choc Mountains (Gaspé Peninsula, Quebec, Canada). In the same way, the Chimgan Mountains are characterized by rainfall, but occurring within a transitional climate with continental influences.

In the case of the Chingam mountains, the rain is not due to maritime influences from being close to the coast, since they are more than 1500 km from the Caspian Sea and the Indian Ocean. Instead, it comes from centers of atmospheric activity and circulation patterns in Central Asia, which define this area as Continental-Mediterranean.

The literature on Central Asia climate describes these episodes of abrupt raising of the isotherm of 0 ºC during the winter. Bothe et al. (2012) documents warm upper-air intrusions associated with humid western troughs that break the Siberian High. Chen et al. (2020) shows that the Tian Shan receives pre-frontal warm advection that temporarily raises the snow line.

Strictly focused on the goal of our project to understand the snow and avalanche climate context, a preliminary snow climate classification of the Chimgan Mountains (western Tian Shan range), suggests that, like other regions named before, do not fit completely into traditional classifications of continental, maritime or transitional snow and avalanche climates. These conditions result in a snow cover structure characterized by both transitional and continental elements but strongly by rainfall.

Probably the snow climate of the Chimgan mountains could be similar to that of the Eastern Pyrenees climate (Andorra and northeastern of Spain), where the structure of the snowpack is characterized by facets, depth hoar and frequent ice/melt freeze layers in a regime of mild temperatures (García-Sellés et al. 2013). In the absence of an in-depth study of the similarities of the snow climates of both regions, a hypothesis for future work could be that mountain ranges affected by avalanches within a mediterranean climate could reveal treats of a rainy transitional snow and avalanche climate.

3. OPERATION SET UP

3.1 The Mitigation Concept

The mitigation concept has been designed by the Customer and his planning consultant and includes an active removal of snow from the avalanche paths in a controlled way using Remote Avalanche Control Systems (RCAS). The timing of active avalanche control will be decided by an on-duty avalanche forecasting team at Chimgan assessing the snowpack and incoming weather.

3.2 *Remote Avalanche Control Systems*

The Obellx+ Remote Avalanche Control System (RACS) is an autonomous, gas-based solution, in operation for more than 15 years now. Each unit comprises modular gas generators mounted on a 4-meter-high tower, anchored to the ground and deployed via helicopter, eliminating the need for on-site personnel and reducing logistical risks. With an operational autonomy of up to 22 shots per module, the system ensures sustained functionality throughout the winter season on the Chimgan Site. Obellx+ is remotely operated from the patroller's office through radio network using a dedicated Software and/or web platform. As a backup the units will be operated with a mobile suitcase on a radio mode.

The software modular architecture allows for both individual and synchronized multi-tower activations, enabling operator to combine energy outputs for enhanced avalanche release efficiency and time efficiency. This system offers significant advantages over traditional methods, including improved safety, operational flexibility, and minimal environmental impact.

3.3 *Implementation of the RACS system*

The above mentioned avalanche study consisted among other objectives to identify the most active and avalanche prone corridors. The conducted RAMMS simulations lead to the proposal of implementations of active measures in order to mitigate the avalanche risk over the assets (towers of the gondola and at a minimum level the protection of the ski slopes). The authors liberally do not give too many technical results of the study. The following figure presents some results of the simulation and the resulting proposal of location of active measure.

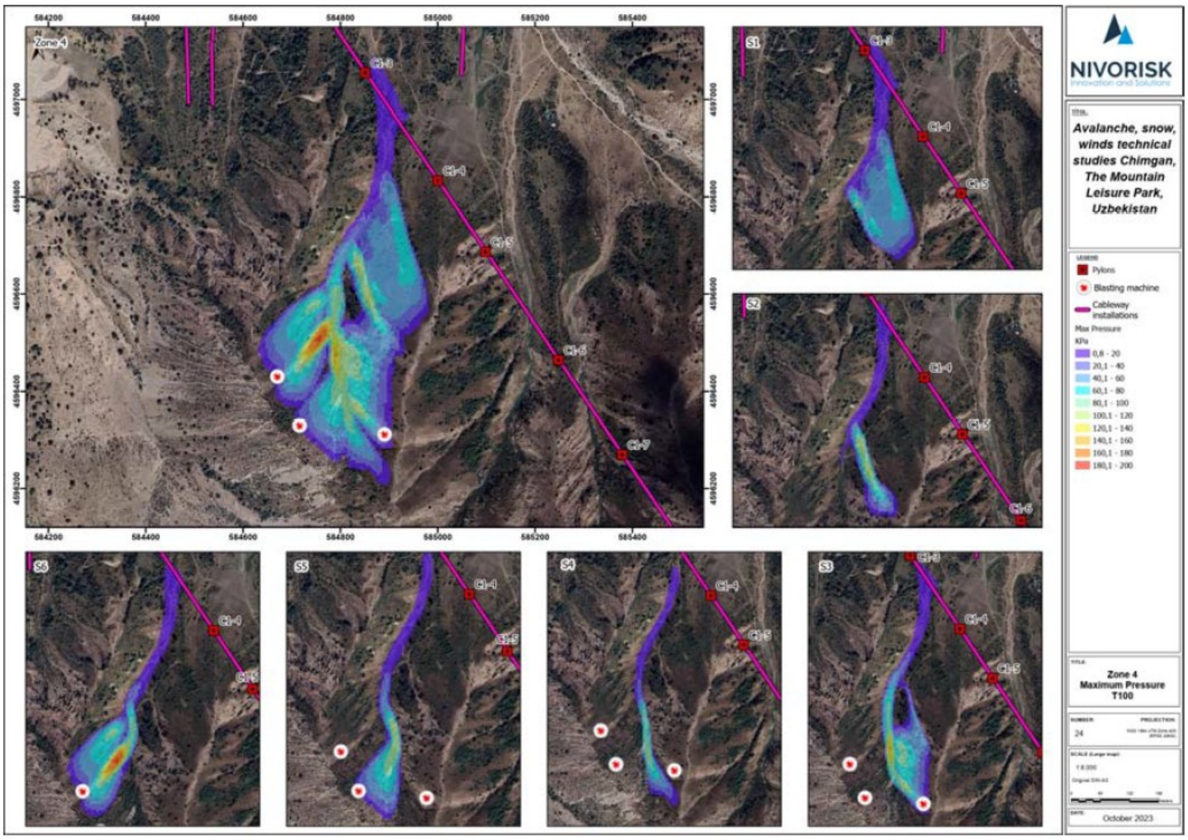

Figure 6 : Results of RAMMS extended simulation presenting impact pressure for T=100years, over one of the sector of the project.

Given the extent of the work and the site accessibility in Chimgan's challenging terrain, the installation work has been carried out over two summer seasons. Another big constraint has been the absence of helicopter support for the delivery of equipment and material on each of the site implementation due to very scarce availability of such machine in the country.

Another challenge has been the resulting geological superficial terrain consisting of meteorized granodiorite. The local studies (Uzbek adaptation studies) combined with strong para sismic measures have imposed a self standing foundation on almost all the units .A few units have been founded according to a mixed (anchored /weight basement) foundation.

The concrete pouring phase has been also challenging. The contractor has setup a temporary Tyrolean Line from an upper location from which concrete was delivered. In total, 14 tower foundations were drilled, shuttered, cast, and installed.

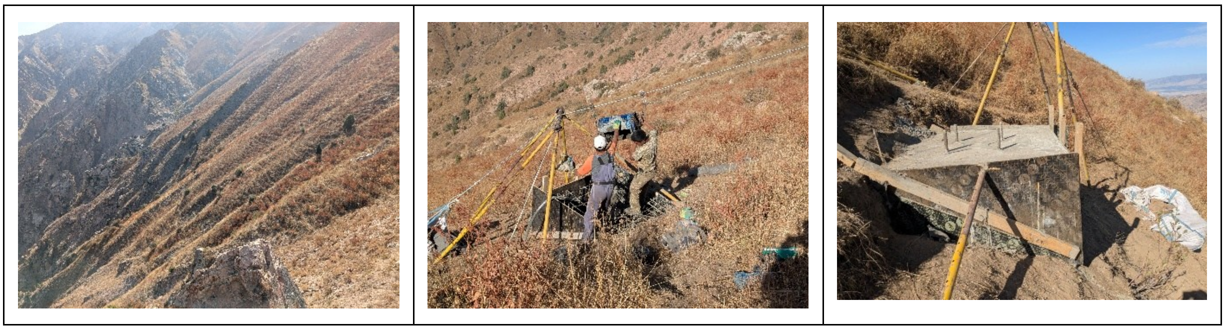

Figure 7: Illustration of the civil works of the O'Bellx foundations in the northern slopes (a) undergone with local means in challenging environment (b & c).

DISCUSSION

The active protection system is expected to be commissioned during the fall 2026 and should be operated by the patrollers or avalanche team of the resort as part of the avalanche control plan under definition. Another upcoming challenge remains in the strong capitation of this local avalanche team required in order to operate safely such a resort in compliance with the Uzbekistan standards.

ACKNOWLEDGEMENTS

Special thanks to Dra. Semakova for her support in Uzbekistan, to Mr. Stepanovic for sharing his legacy with us and to Mansurbek Rakhmatullayev, director of the Project Office for the construction and operation of the international all season resort "Beldersay-Chimgan-Nanay".

REFERENCES

Barbolini, M., Pagliardi, M., Natale, L., Savi, F., 2005. Snow avalanche risk assessment and mitigation measures. In: Snow Engineering: Recent Advances and Developments. London: Taylor & Francis / Balkema. pp. 491–500.

Bothe, O., Fraedrich, K., Zhu, X. H., 2012. Precipitation climate of Central Asia and the large-scale atmospheric circulation. Theoretical and Applied Climatology, 108(3), 345–354. doi:10.1007/s00704-011-0537-2.

Chen, Y., Li, Z., Fang, G., Deng, H., 2020. Climate change impacts on water resources in the arid region of Northwest China: A review. Earth-Science Reviews, 204, 103135.

García-Sellés, C., Manguan, S., Martí, G., Oller, P., Martínez, P., 2013. Combined temperature–precipitation winter modes and major avalanche activity in the Eastern Pyrenees. In Proceedings of the International Snow Science Workshop, Grenoble–Chamonix Mont-Blanc, 1264–1269.

Gidrometeoizdat. 1984. Kadastr Lavin SSSR. Gidrometeoizdat. Leningrad.

Ikeda, S, Wakabayashi, R., Izumi, K., Kawashima, K., 2009. Study of snow climate in the Japanese Alps: Comparison to snow climate in North America. Cold Regions Science and Technology 59, 119–125. doi:10.1016/j.coldregions.2009.09.004

Meloche, F., Imbach, B., Madore, J.B., Reuter, B., Langlois, A., Gauthier, F., 2025. The Rainy Continental snow and avalanche climate: International comparison with 40 years of snow cover modeled in the Chic-Chocs, northeastern Appalachian Mountains. Journal of Glaciology 71, e58, 1–18. https://doi.org/10.1017/jog.2025.35

Mock, C.J., Birkeland, K.W., 2000. Snow avalanche climatology of the western United States mountain ranges. Bulletin of the American Meteorological Society 81, 2367–2392. doi:10.1175/1520-0477(2000)081<2367:SACOTW>2.3.CO;2

Semakova, E., Myagkov, S., Armstrong, R. L., 2009. The current state of avalanche risk analysis and hazard mapping in Uzbekistan, in: International Snow Science Workshop, Davos, Switzerland, 27 September–2 October 2009, ISSW, 509–513, 2009.

Semakova, E., Bühler, Y., 2017. TerraSAR-X/TanDEM-X data for natural hazards research in mountainous regions of Uzbekistan, JARS, 11, 036024, https://doi.org/10.1117/1.JRS.11.036024, 2017.

Semakova, E., Safronov, V., Mamaraimov, A., Nurtaev, B., Semakov, D., Bühler, Y., 2018. Applying numerical snow avalanche simulations for hazard assessment in the Kamchik pass area, Uzbekistan, in: International Snow Science Workshop, Innsbruck, Austria, 7–12 October 2018, ISSW, 701–704, 2018.