

# Chapter 13

## Management of Snow Avalanche Risk in the Ski Areas of the Southern Carpathians–Romanian Carpathians

Mircea Voiculescu and Florentina Popescu

**Abstract** Snow avalanches represent an undeniable reality in the Southern Carpathians, both as a geomorphological process and as a type of natural hazard with the highest number of fatalities and injuries, and also substantial impact upon forests, highways, and people. This study focuses on the Făgăraș massif and on the Bucegi Mountains, representative mountain units in the eastern part of the Southern Carpathians with altitudes surpassing 2500 m, large quantities of snowfall, between 6 and 8 months/year of soil with snow cover, or even 10–11 months/year at high elevations, and a high occurrence of snow avalanches. The importance of management of snow avalanche risk resides in the fact that these mountains have important winter tourism activities. Today, the main management measures on snow avalanche risk are preventive temporary or permanent measures, passive and active defense points of intervention, temporary closure of ski pistes, and the issuance of danger level.

**Keywords** Management • Snow avalanche risk • Ski areas • Făgăraș massif • Bucegi Mountains • Southern Carpathians

### 13.1 Introduction

Management of snow avalanche risk represents a stringent aspect in several countries with a large proportion of mountain-covered areas that are endowed with characteristic and associated winter tourist activities in Europe, Canada, and the USA. Snow avalanche risk has an important impact on human life (Fuchs and Bründl 2005; Höller 2009) and, implicitly, on human activities such as skiing (Höller 2007, 2009; Stethem et al. 2003) or other recreational activities (Höller 2009; Keiler et al. 2006). Winter tourism is a very important economic activity (Rixen

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et al. 2003). Alpine skiing as an attribute of winter tourism, and at the same time a sport activity, has generated an entire industry within mountain areas (Agrawala 2007; Bürki et al. 2005; Hudson 2002; Lew et al. 2008). Winter sports entail a series of investments insofar as blueprinting, infrastructure, and connected activities are concerned, and they are destined for a tourist segment that is willing to invest time, money, and physical effort.

This item becomes important through its affiliation to the global concern regarding the relationship to tourist practices, especially skiing and natural risk within mountain areas, in the present case (Casale and Margottini 2004; Herwijnen and Jamieson 2007; Quinn and Phillips 2000; Schweizer and Camponovo 2001; Schweizer and Lütchg 2001; Schweizer and Jamieson 2001).

Snow avalanches are one of the most important natural risks and hazards that, acting on the mountain environment in ski areas, each year cause several fatalities (Höller 2007; Jamieson and Stethem 2002; Keiler 2004; Keiler et al. 2005; Voiculescu 2009, 2014) and serious damage to human settlements and infrastructures (Fuchs et al. 2004; Fuchs and Bründl 2005; Fuchs et al. 2005; Jamieson and Stethem 2002; de Scally 1994; Stethem et al. 2003; Voiculescu 2009).

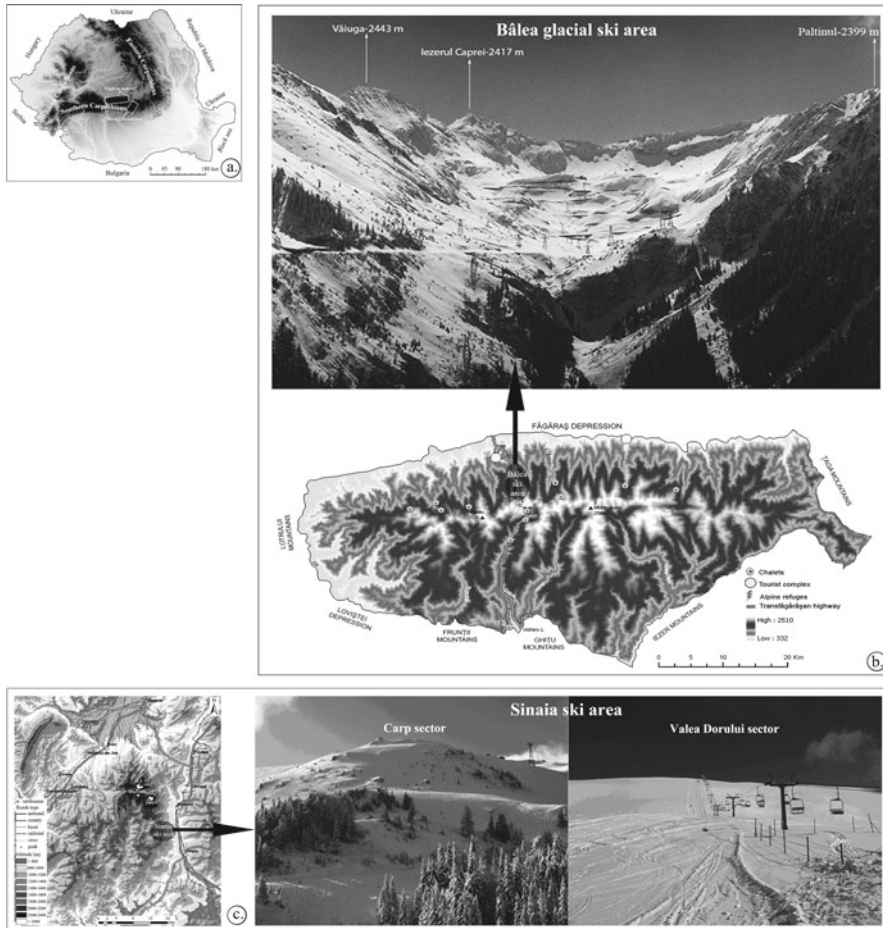
The purpose of this study is to (i) analyze the terrain factors and climatic variables that determine the development of ski activities, and (ii) present the state of the management of snow avalanche risk in two of the most representative mountain areas of the Southern Carpathians, the Bâlea glacial ski area of Făgăraș massif and the Sinaia ski area in the Bucegi Mountains. These areas are known for their natural potential with regard to winter tourism activities, especially ski activity, but also for the high incidence of snow avalanches, some of which are even triggered by skiers.

## 13.2 General Facts of the Studied Area

The Făgăraș massif is situated in central Romania at the intersection of the 45°30' parallel with the 24°30' meridian, within the Făgăraș group from the Southern Carpathians (Fig. 13.1a.).

These mountains are also known as the Transylvanian Alps because of their high altitude, which surpasses 2400–2500 m (Moldoveanu, 2544 m a.s.l.; Negoiu, 2535 m a.s.l.), their massiveness, their sharp glacial crests, their inherited glacial landforms (cirques and glacial valleys), and also because of their present periglacial processes of high spatial dynamics. The Făgăraș massif occupies more than 1500 m<sup>2</sup> and the alpine level, which represents the basis for skiing activities, occupies around 438.5 km<sup>2</sup>, from 148.8 km<sup>2</sup> on the northern slope and 684.7 km<sup>2</sup> on the southern slope (Voiculescu 2002). In the Făgăraș massif, skiing takes place traditionally in the Bâlea glacial ski area that includes the cirque and also the glacial valley (Fig. 13.1b.).

Until the 1989 Romanian Revolution, only alpine skiing was practiced here, but afterward and especially in recent years skiing activities have been extended to snowboarding, telemark skiing, ski-touring, heli-skiing, etc. On the other hand,



**Fig. 13.1** Geographic location of Făgăraș massif and Bucegi Mountains

free-ride and free-style skiing have emerged here as in other mountain areas of the world (Hudson 2004; Pickering et al. 2003). All these forms therefore complete the range of tourist activities available in the Făgăraș Massif and pertain to the alternative forms of tourism according to Beedie and Hudson (2003), to Buckley (2006), and to Pomfret (2006). It is the only area that apart from a good accommodation infrastructure has also ski pistes that are unattended, unequipped, are not delineated by pennons, and lack warning signs. As for cable transportation, this ski area has only one cable car.

The Bucegi Mountains are located in the eastern part of the Southern Carpathians, within the mountain group that bears their name (see Fig. 13.1a.). The Bucegi Mountains are bordered by cliffs on three sides (on the east toward the Prahova valley, on the west toward the Rucăr-Bran-Dragoslavele Corridor, and on the northern

side toward the Braşov Basin), and by the Ialomiţa's Subcarpathians on the southern side. They have the form of an amphitheatre with its opening toward the south, where the Ialomiţa valley lies. The highest altitudes are concentrated in the northern part. The foremost important orographic knot is situated in the northern part of the Bucegi Mountains and is represented by the Vf. Omu at 2505 m a.s.l. The mountain mass appears as if suspended: the altimetry differences oscillate between 1200 m, above the Prahova River (a favorable element for the implementation of ski pistes, because of the relief's high potential), and 500 m against the Rucăr–Bran corridor and the Subcarpathians, pointing out their genetic connection rendered by the detailed morphology, by the biopedoclimatic levels, and also by the local diversity thrusts by exposition, declivity, and even by shelter conditions. The most important ski area in these mountains is to be found in their southern part, above the tourist resort of Sinaia that covers about 116 ha (Bogdan 2008): it entails two sectors, the Carp sector on the eastern part and the Valea Dorului sector on the western part of the Sinaia ski area (Fig. 13.1c.).

### 13.3 Terrain Factors and Climatic Variables Analysis as Favorable for Ski Activities

The natural ski potential is favored first and foremost by the parameters of two components of the mountain environment (Jamieson and Johnson 1998; McClung and Schweizer 1999; Schweizer and Jamieson 2001): terrain factors and climatic variables.

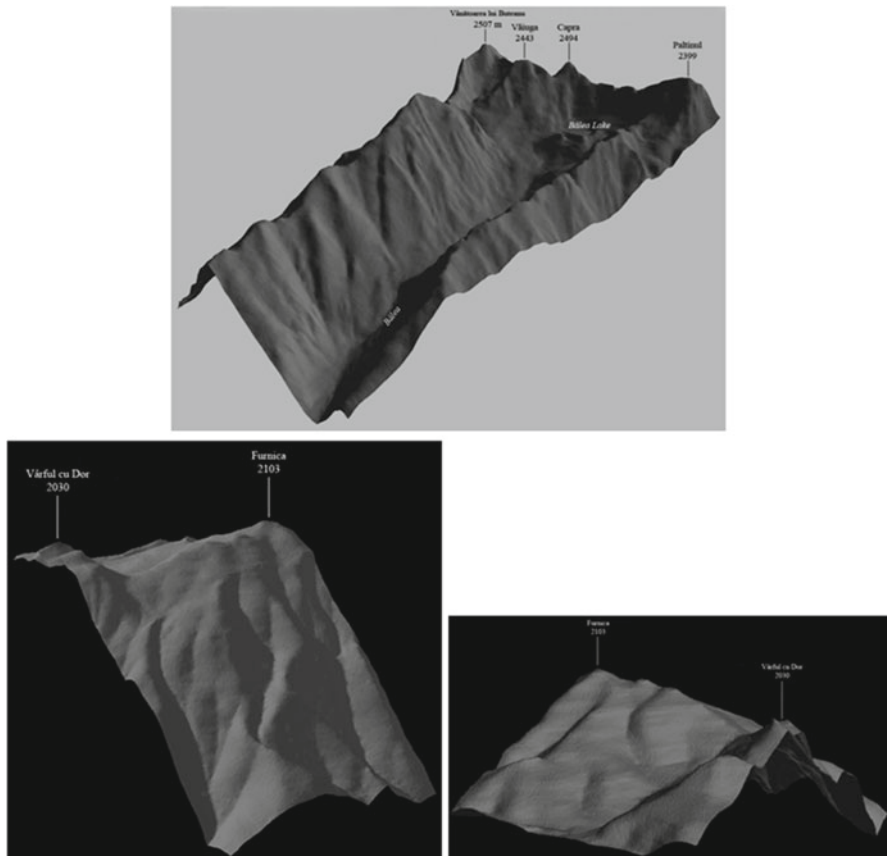
#### 13.3.1 Terrain Factors

Terrain factors are represented by elevation, slope, and aspect. Altitude is essential for skiing activities, and for the latitude of temperate climate in which our country is located, it must be at least 1000 m (Besancenot 1990) to maintain a favorable snow layer for at least 3 months/year.

Slope represents another factor of great importance for skiing activities. This is the element that separates the categories of this activity's practitioners into two large categories: skiers and beginners. The first category was defined as *users of skis, snowboards or other gravity-propelled recreational devices whose design and function allow users a significant degree of control over speed and direction on snow* (Penniman 1999, p. 36), and for beginning skiers or beginners as *those individuals who are using one or another of these devices for the first time or who possess marginal abilities to turn or stop on slopes with incline greater than 20%* (Penniman 1999, p. 36).

Performing a more analytical classification in accordance with the degree of slope declivity, the following categories have been established: beginners or novices who make use of slope gradients with a declivity not higher than  $11.5^\circ$ , intermediates who use the slope gradients between  $18^\circ$  and  $19^\circ$ , advanced skiers, who use the slope gradients of  $19^\circ$ , and experts who use slope gradients that surpass  $19^\circ$  or even  $39^\circ$  (Borgersen 1977; Gaylor and Rombold 1964, quoted by Penniman 1999). For economic exploitation we need to consider the slopes between  $10^\circ$  and  $45^\circ$ . Any ski area needs to include all the categories of slope gradients. It is well known that most of the skiers would rather ski on slopes less than  $30^\circ$  and that beginners will usually not use those greater than  $10^\circ$ .

Using the applications of ArcGIS and respecting their working methods (Török 2001–2002), we have created the digital elevation model (DEM) (Fig. 13.2) that we used in generating the thematic maps (elevation, slope, and aspect) for the Bălea glacial ski area and for the Sinaia ski area.



**Fig. 13.2** Digital model of terrain of Bălea ski area (*top*), of Carp ski sector of Sinaia ski area (*bottom left*), and of Valea Dorului ski sector of Sinaia ski area (*bottom right*)

The altitude of the ski pistes is a crucial element for practicing specific activities. The Bâlea glacial ski area is situated at high altitudes where skiing is practiced on the glacial cirque walls, just under the cliffs, within the cirque, but also along the glacial valley, on the eastern slope especially. Voiculescu et al. (2011) identified 29 main snow avalanche tracks: 5 on the western slope of the glacial valley, 21 on the eastern slope of the glacial valley, and 3 on the glacial cirque. The vast majority of snow avalanche accidents were recorded on the glacial cirque and on the eastern slope, where are the main ski pistes. The elevation map of the Bâlea glacial ski area highlights this mathematic element (Fig. 13.3). The Bâlea glacial ski area is endowed with pistes that are not groomed, or even named for that matter, which have high slopes, and can only be used by expert or advanced skiers. The slope map points out the high degree of declivity for the studied area (see Fig. 13.3). The values between  $1^\circ$  and  $15^\circ$  represent 6.9% (3.4 km<sup>2</sup>), the values between  $15^\circ$  and  $25^\circ$  represent 18.1% (9 km<sup>2</sup>), the values between  $25^\circ$  and  $35^\circ$  represent 11.1% (5.5 km<sup>2</sup>), the values between  $25^\circ$  and  $35^\circ$  represent 33.2% (16.4 km<sup>2</sup>), the values between  $35^\circ$  and  $45^\circ$  represent 31.8% (15.8 km<sup>2</sup>), and the values above  $45^\circ$  represent 9.5% (4.7 km<sup>2</sup>) of the total of the Bâlea glacial ski area.

Another important topographic factor is the aspect of the slopes, especially because it is the one factor that influences the radiation of the sun and also the presence of the wind. The radiation of the sun controls snow surface temperature more than air temperature (Tremper 2001), affecting snow instability and determining the snow avalanche type (McClung and Schaerer 2006). If the snow avalanche is produced in spring, the temperature increase enhances the stability of the snowpack on shady slopes and its instability on sunny slopes (Ancey 2001, p. 3). For this purpose, we made the aspect map. For the Bâlea glacial ski area the aspect map shows that western slopes cover 27.1% (1.8 km<sup>2</sup>) of the area, the northeastern slopes 20.3% (1.3 km<sup>2</sup>), and the eastern slopes 19.5% (1.3 km<sup>2</sup>) (see Fig. 13.3). Within this topographic context, the ski pistes in the Bâlea glacial ski area are designed especially for the advanced and expert skiers who practice free-ride or free-style skiing. Unfortunately, under these circumstances, the snow avalanche risk is imminent, and therefore human victims, fatalities, and injuries/burials are recorded.

The Sinaia ski area has gradually enlarged its surface, the number of ski pistes and their length, from 85.1 ha and 12 ski pistes with a length of 15.1 km in 2001 (Țigu 2001), to 16 ski pistes measuring 23 km (Bogdan 2008) and even to 24 ski pistes with a total length of 22.3 km (according to Institutul Național de Cercetare–Dezvoltare în turism 2009; Voiculescu et al. 2012). The average declivity of this ski area ranges between  $13.3^\circ$  and  $32.5^\circ$ , which agrees with the skier's preference (of less than  $30^\circ$ ), but neglects or overworks the beginners. Within the Sinaia ski area there are 13 main ski pistes of which 23% are intended for expert skiers, 61.7% for medium-ability skiers, and 15.3% for beginner skiers (Table 13.1).

The mathematic parameters of the terrain underline the high potential of the Sinaia ski area for tourist activities. Therefore, the altitude of the ski pistes is relatively high, around 2000 m for both sectors of the ski area, Carp and Valea Dorului (Fig. 13.4). The slopes map emphasizes the predominance of high values, explaining the classification of ski pistes predominantly for expert and advanced skiers (see Fig. 13.4).



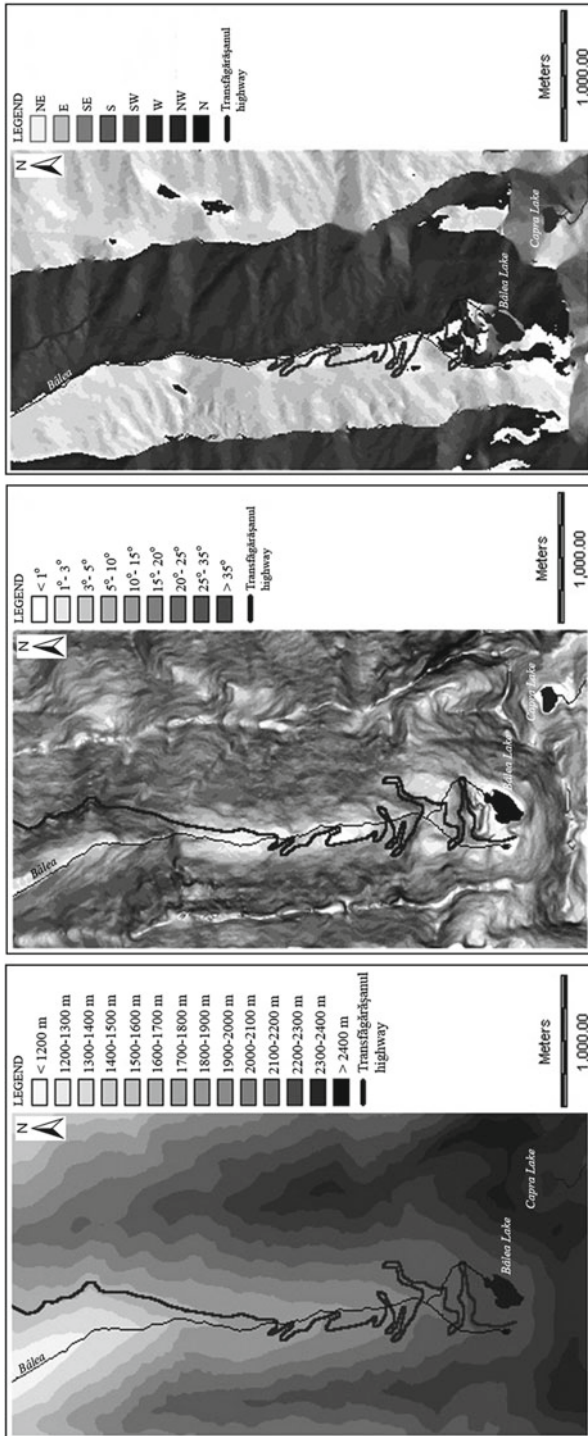


Fig. 13.3 Bălea ski area: elevation map (left), declivity map (center), and aspect map (right)

**Table 13.1** The main patterns of the Sinaia ski area

Ski piste	Patterns of the ski pistes										Facilities	
	Difficulty level	Length (m)	Departure elevation (m)	Arrival elevation (m)	Mean slope (°)	Vertical drop (m)	Mean width (m)	Surface (km <sup>2</sup> )	Homologation date	Type of cable car	Artificial snow	
Valea Dorului sub telescaun 2	M	804	2,049	1,818	28.7	231	40	0.032	02.07.2008	Chairlift	No	
Valea Soarelui	M	1,191	2,035	1,820	18.1	215	40	0.048	02.07.2008	Chairlift	No	
Valea Dorului variantă	M	896	2,033	1,834	22.2	199	40	0.036	02.07.2008	Chairlift	No	
Valea Dorului sub telescaun 1	M	776	2,040	1,822	28.1	218	40	0.031	02.07.2008	Chairlift	No	
Carp	D	1,382	2,056	1,607	32.5	449	50	0.069	02.07.2008	Chairlift	No	
Papagal	M	847	1,870	1,649	26.1	221	40	0.034	02.07.2008	Chairlift	No	
Drumul de vară	M	2,971	2,044	1,650	13.3	394	30	0.089	02.07.2008	Chairlift	No	
Scândurari	M	505	1,969	1820	29.5	148	30	0.025	02.07.2008	Ski-lift	No	
Începători	B	173				20			Not homologated			
Legătura	D	173				91			Not homologated			
Târle	D	534				221			Not homologated			
Fumica	B	270				77			Not homologated			
Noua Turistică (Cota 1400)	M	2,154				402			Not homologated			
			12,676					0.374				
	23 % for advanced skiers											
	61.5 % for medium skiers											
	15.3 % for beginner skiers											

According to National Institute of Research+Development in Tourism, 2009, and Voiculescu et al. 2012 with additions



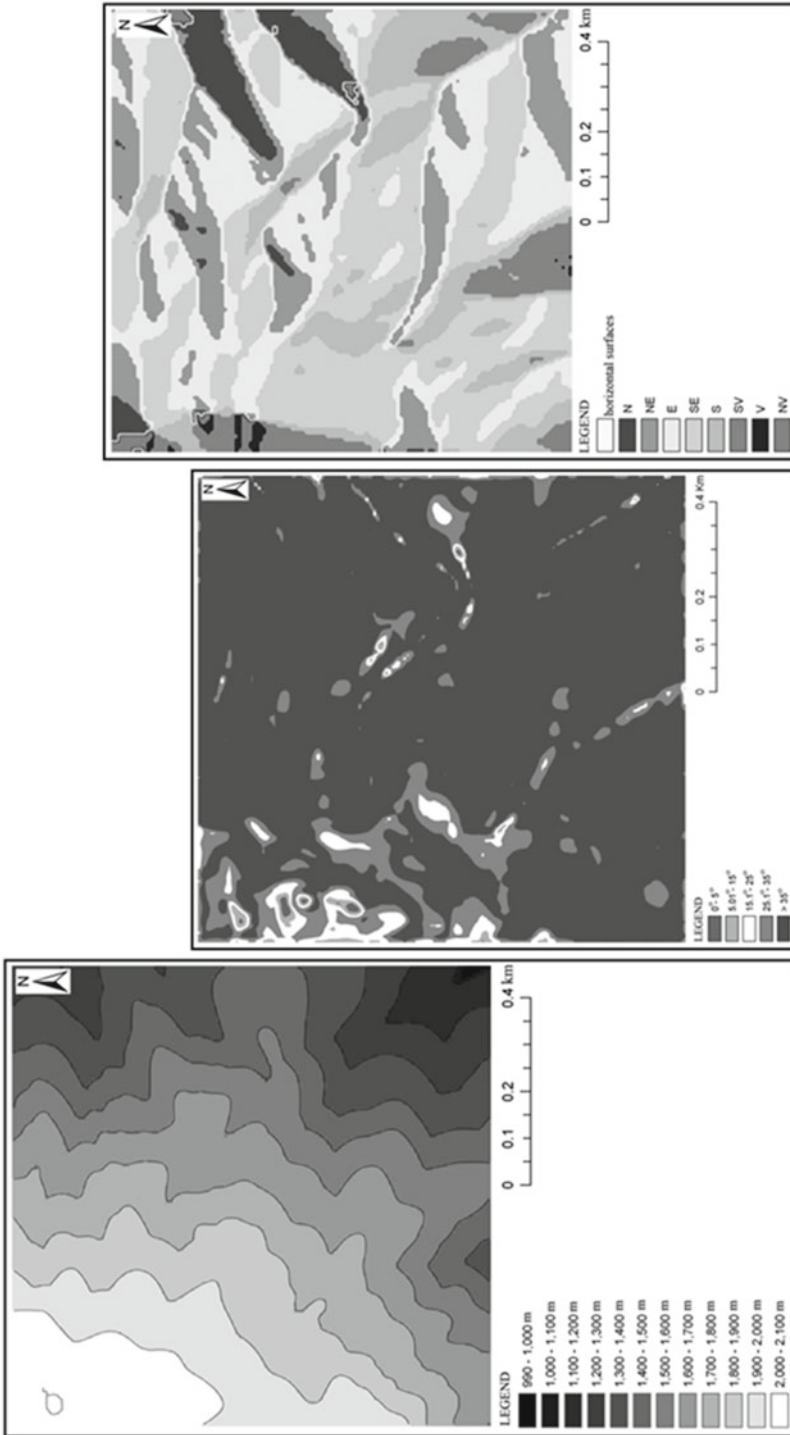


Fig. 13.4 Sinaia ski area: hypsometric map (left), declivity map (center), and aspect map (right)

The aspect map shows two different situations: within the Carp sector eastern slopes are predominant, whereas in the Valea Dorului sector the western orientation is predominant, both profiting from good radiation. In detail, especially for the Carp sector, we note the eastern, southeastern, and northeastern aspects, the latter favoring the persistence of snow until late spring. Small surfaces have south and southwestern aspects; these are the beneficiaries of the best insulation, but having in view the high slopes, which range between  $25^\circ$  and  $35^\circ$  and the lack of woodland vegetation, we need to consider their inclination toward generating avalanches (see Fig. 13.4).

### 13.3.2 Climatic Variables

The climate through its variables becomes an important tourist resource (Besancenot 1990) and is analyzed considering the snow depth with regard to the ski activities, being safe to say we have a snow-reliable area if *in seven of ten winters there is snow covering of at least 30 cm on at least 100 days between 1 December and 15 April* (Becken and Hay 2007, p. 38).

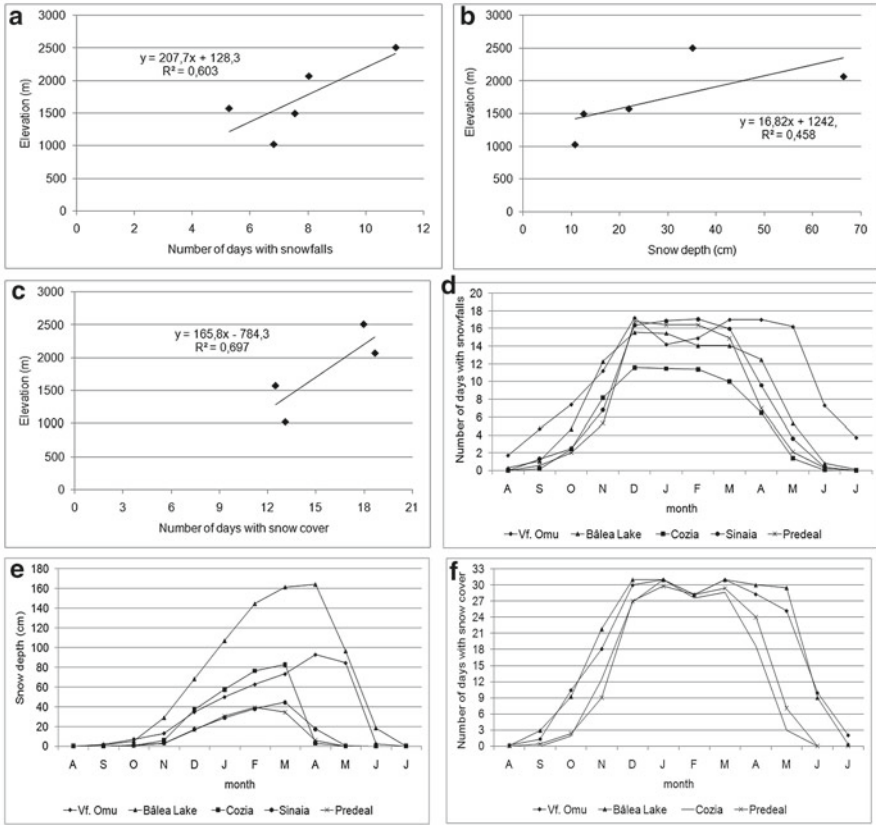
Romania is located within the temperate-continental climate zone, which is characterized by large quantities of snowfall and snow avalanches when near maritime and transitional zones (Birkeland and Mock 2001; Hægeli and McClung 2004; McClung and Schaerer 2006; Mock 1996; Mock and Birkeland 2000). As a consequence of its geographic position, many types of climatic influences can be identified on the mentioned ski areas. The northern slope of the Făgăraș massif, where the ski area of Bâlea can be found, is under the humid oceanic influence. The Sinaia ski area is under continental influences. Therefore, the regional climate also determines the solar radiation, temperature, snowfall quantity, and type of snow (McClung and Schaerer 2006; Zingg 1966). Characteristics of the climate of the Făgăraș massif are registered at the weather stations of Bâlea Lake (2070 m a.s.l.) and Cozia (1577 m a.s.l.) and at the weather stations of the Bucegi Mountains at Vf. Omu (2505 m a.s.l.), Sinaia (1500 m a.s.l.), and at Predeal (1030 m a.s.l.). The main climatic characteristics of the Făgăraș massif and of the Bucegi Mountains are presented in Table 13.2.

Snow is a very important resource for winter tourism, especially for ski activity (Breiling and Charamza 1999). Snowfall, snow cover, and snow duration have a major role in environmental and socioeconomic practices in mountain regions (Beniston 1997, 2003; Beniston et al. 2003) and also in the Romanian Carpathians (Micu 2009). On the other hand, snow can generate natural hazards (i.e., snow avalanches) (Beniston et al. 2003; Elsasser and Messerli 2001).

The variation in time and space of snow depth is caused by climatic influences, snowfall frequency, the elevation of the  $0^\circ\text{C}$  isotherm, slope aspect, and topographic features. The best Pearson correlation was given by elevation and number of days with snowfall and snow depth and elevation (Fig. 13.5a, b.). The number of days with snow cover is another important factor for ski activity. In our study area the

**Table 13.2** The main climatic characteristics of the Făgăraș massif and the Bucegi Mountains

Weather station altitude (m a.s.l.)	Geographic coordinates		Time period	Climatic influence	Air temperature (0 °C)		Total rainfalls (mm)		Snow depth (cm)
	Latitude	Longitude			Annual	Winter season	Annual	Winter season	
Vf. Omu (2505)	45°27'	25°27'	1961–2011	Eastern	-2.5	-9.7	995.7	184.8	62.6
Bălea Lake (2070)	45°36'	24°37'	1979–2011	Western	0.2	-7.3	1213.7	225.7	66.1
Cozia (1577)	45°18'	24°20'	1980–1994	Southern	3	-5.2	844.2	157	39.5
Sinaia (1500)	45°23'	25°30'	1961–2011	Eastern	3.7	-4.5	1057.4	191.8	47.6
Predeal (1090)	45°30'	25°33'	1961–2011	Eastern	4.9	-1.3	942.5	54.9	30.9



**Fig. 13.5** Monthly variation of snowfalls (a), of snow depth (b), and of number of days with snow cover (c); correlation between altitude and number of days with snowfalls (d), between altitude and snow depth (e), and between altitude and snow cover (f)

best Pearson correlation was given by elevation and number of days with snow cover (Fig. 13.5c.).

The snow parameter is subjected to altitude variations but also to local conditions. Therefore, for the Bălea glacial ski area the highest values are registered within the December–March interval, the total number within the October–May interval, summing up 150 days. For the Sinaia ski area, the highest values regarding the days with snow cover is reached in the November–March interval at the highest altitudes and November–April in the middle and lower part of the area. The total number of days with snow cover is 224 at the highest altitudes, about 66 in the middle, and only 45–46 days in its lower part. Therefore we can ascertain that in the case of the Bălea glacial ski area and also in the case of the higher part of the Sinaia ski area there is a minimum of 100 days of snow coverage, as is stated in the dedicated literature (Besancenot 1990; Becken and Hay 2007). For skiing activity to take place in good conditions, it is necessary that the snow depth be at least 30 cm

(Agrawala 2007; Besancenot 1990; Becken and Hay 2007; Freitas 2005; Hall and Higham 2005). In accordance with the snow depth we have determined the type of the seasonal variation of snowfall or the type of nivometric regime (Besancenot 1990) (Fig. 13.5d.). Thus, for the Bâlea glacial ski area the characteristic nivometric regime is bimodal, characterized by a secondary maximum of the snow depth in February and the main maximum in April, with a relative winter minimum between the two. This type of regime is characteristic for high altitudes. For the Sinaia ski area we noticed a difference from the monomodal regime, with a single maximum in full winter toward the type of balanced regime, displaying similar quantities of snowfall in the months of December, January, and February. Toward the highest altitudes the type of nivometric regime is bimodal as well. Snow depth increases with altitude (Fig. 13.5e.). The highest values are recorded between February and April or even May. Snow cover is very important for ski activity and is directly related to snow depth. This parameter is determined by altitude and occurs between 6 and 8 months/year. At high altitudes 8–10 months/year are recorded with snow cover and at highest altitudes even 11 or 12 months/year (Fig. 13.5f). The necessary 30 cm of snow is provided in all cases (Agrawala 2007; Besancenot 1990; Becken and Hay 2007; Freitas 2005; Hall and Higham 2005).

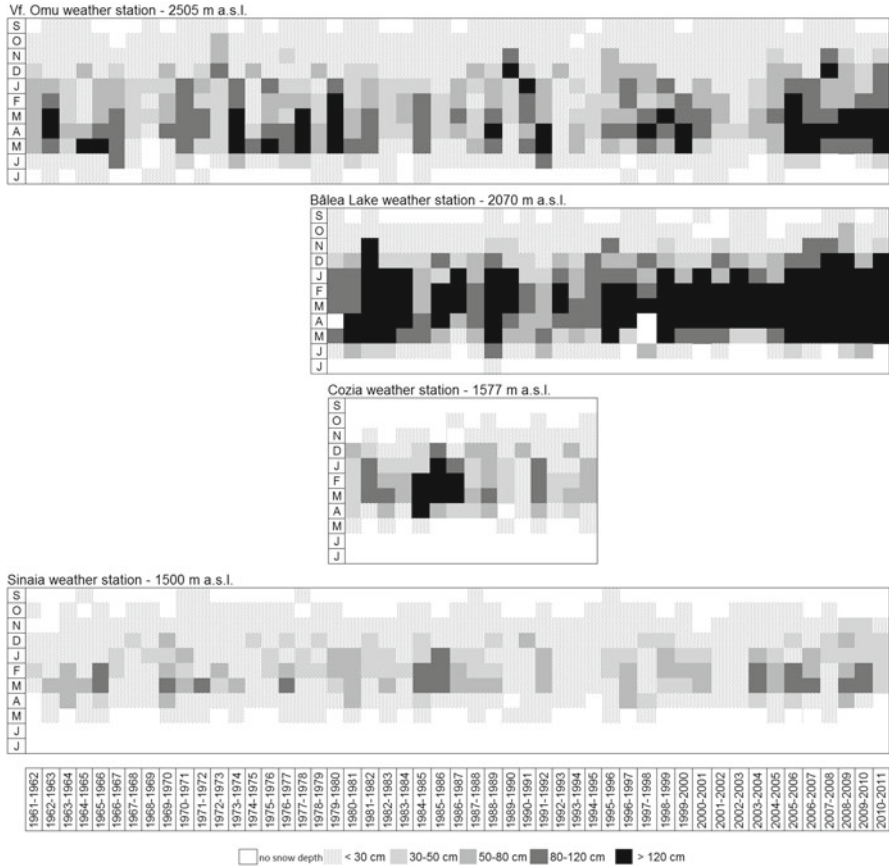
Schweizer et al. (2003) described five factors that contribute to avalanche danger: terrain, precipitation (or new surplus snow), wind, temperature (including radiation effects), and snowpack stratigraphy. The snow depth is very important in producing snow avalanches (McClung and Schaerer 2006). According to Salm (1982, quoted by Schweizer et al. 2003), the new snow depth causes snowpack instability. In this context and according to Schweizer et al. (2003), we considered different snow depth thresholds that produce snow avalanches as less than 30 cm, 30 to 50 cm, 50 to 80 cm, 80 to 120 cm, and greater than 120 cm) (Fig. 13.6).

## 13.4 Management of Snow Avalanche Risk

The history of management of snow avalanche risk in Romanian mountains registered two important moments (Voiculescu 2009).

The first moment was when the Mountain Rescuer Public Services (MRPS) was formed according to Ministerial Decision 140/1968. This service is administrated by district councils. The MRPS have the role to prevent survey, coordinate, and organize mountain rescues in the event of snow avalanches and other damaging events. For the Făgăraș massif, the MRPS has two units on the northern slope, namely, Sibiu and Victoria, and another two units on the southern slope, namely, Făgăraș Sud and Curtea de Argeș. For the Bâlea glacial ski area, the unit is located in the Bâlea glacial cirque, above 2000 m a.s.l. For the Bucegi Mountains, the MRPS has one unit, namely, the Sinaia MRPS, located at 2000 m a.s.l.

The second moment was in 2003 when the Programme of Nivometeorology was set within the National Administration of Meteorology (PN-NAM) in partnership with Météo France, Centre d'Études de la Neige-Grenoble. The main purpose of the



**Fig. 13.6** Snow depth thresholds for determining snow avalanche risk, according to Schweizer et al. (2003) classification, between 1961 and 2011 for Vf. Omu and Sinaia weather stations, between 1979 and 2011 for Bălea Lake weather station, and between 1980 and 1994 for Cozia weather station

program is to study snow and its future evolution as well as snow avalanche-triggering conditions. All nivometeorological data are analyzed by means of two systems developed by Centre d'Études de la Neige-Grenoble known as GELINIV and CROCUS-MEPRA PC (Voiculescu 2009). For the Bălea glacial ski area, PN-NAM has Bălea Work Nivology Laboratory (Bălea WNL), located at 2070 m a.s.l. in the Bălea glacial cirque on the northern slope of the Făgăraș massif. For the Bucegi Mountains, PN-NAM has two work nivology laboratories, at Vf. Omu weather station (2505 m a.s.l.) and at Sinaia weather station (1500 m a.s.l.).

Experience from past years suggested that values at risk and spatial planning should be increasingly considered within the framework of natural hazard risk reduction (Fuchs et al. 2005; Keiler et al. 2006; Zischg et al. 2005). To meet this goal, integral risk management strategies seem to be a valuable instrument to reduce



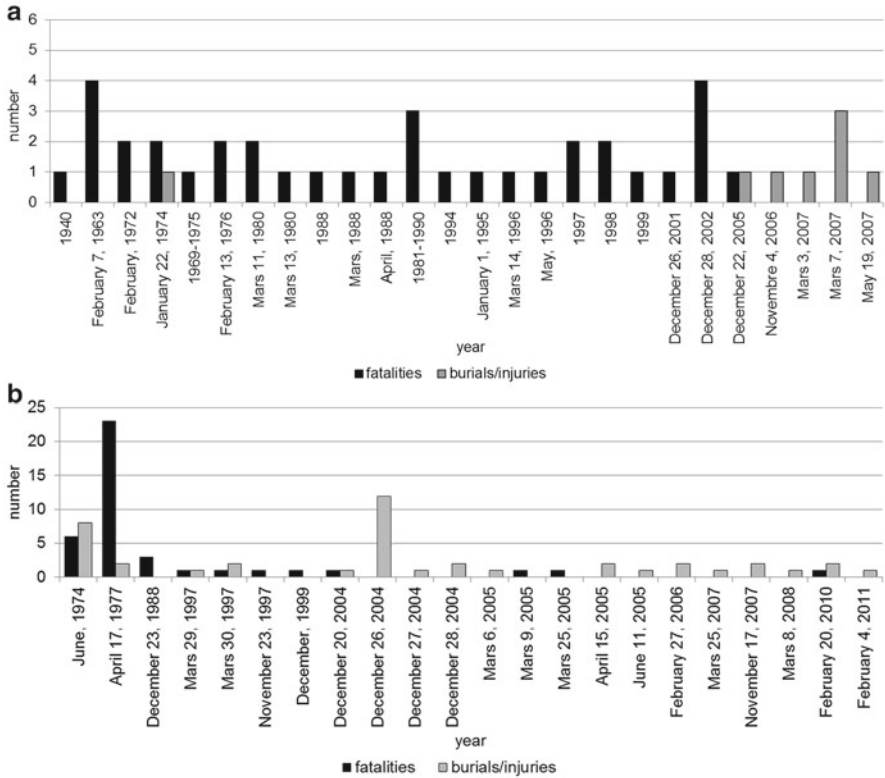
the susceptibility of buildings and infrastructure to natural hazards and to develop strategies for a strengthened resistance (Fuchs et al. 2005), above all by means of local protection measures.

Many snow avalanches are triggered by backcountry skiers, off-piste skiers, and climbers, as is mentioned in several reports (Grímsdóttir and McClung 2006; Tremper 2001; Schweizer and Camponovo 2001; Schweizer and Lütschg 2001). The Făgăraș massif is characterized by high snow avalanche activity, especially in the Bâlea glacial ski area. A considerable ratio of fatalities and burials/injuries is represented by backcountry skiers, off-piste skiers, and climbers (100% in Făgăraș massif and 95% in Bâlea glacial area) (Voiculescu 2014), similar to that recorded in Europe (Tschirky et al. 2001; Zweifel et al. 2012). In the database statistics of Sibiu MRPS a large number of snow avalanche accidents was recorded. The Făgăraș massif holds the record in terms of the number of cases, with 76 fatalities and 50 burials/injuries (62 fatalities and 50 burials/injuries on the northern slope and 14 fatalities on the southern slope). In the Bâlea glacial ski area, 40 fatalities and 42 burials/injuries were recorded for the months November–June for the years 1940 (1968)–2011 (Voiculescu 2009, 2014) (Fig. 13.7). Here it should be noted that the 1977 snow avalanche killed 23 skiers (with the eldest person being 53 years and the youngest being 15 years) and injured 2 people. In the history of the Romanian Carpathians, this snow avalanche is known as the most tragic snow avalanche event.

Within the Sinaia ski area the frequency of snow avalanches does not have the intensity of those in the Făgăraș massif. Unfortunately, the Sinaia MRPS and Sinaia PN-NAM database statistics remain incomplete, perennial, and difficult to use. Therefore we used other sources of information (Table 13.3). Nevertheless, because of the large number of skiers in the past years and also the terrain and climatic factors that are favorable for skiing, here also some accidents have occurred that have determined the local authorities to take some precautionary measures.

Risk management of tourism practices is based on two strategies (Fig. 13.8): duration of protection–preventive temporary or permanent measures (snow pack support structures, drainage system to reduce roughness surface of avalanche moving, closing of highway) and passive and active defense points of intervention (snow sheds, wall support, deflecting dike, splitter to protect electricity poles) (Höller 2007, 2009; Jamieson and Stethem 2002). The Transfăgărașan highway was built between 1970 and 1974. It is 90 km long and connects the northern and southern slopes stretching through two major Romanian regions, Transylvania and Muntenia. The passage from one slope to another is made through a 900-m-long tunnel under Paltinul Peak (2399 m) between 2025 and 2042 m. The Transfăgărașan highway is affected by snow avalanches both in its alpine level and in its forest level. For the safety of both vehicles and tourists, the Transfăgărașan highway is temporarily closed between October 1 and July 1, as determined by the Roads National Authority. To protect the Transfăgărașan highway and to highlight the risk management in sectors that are the most vulnerable to snow avalanche, some measures have been applied.

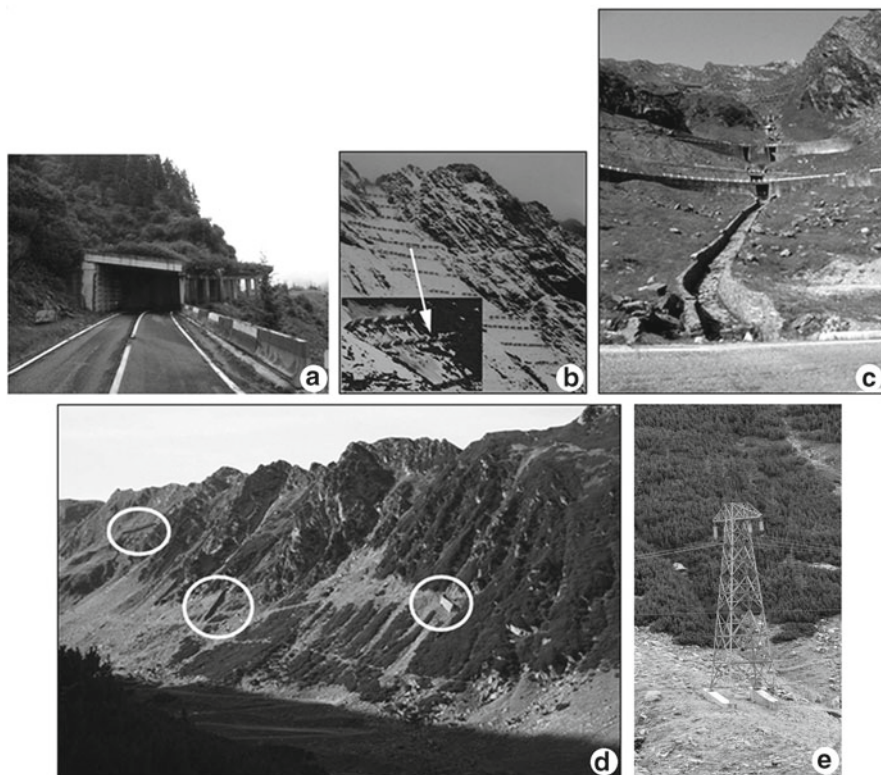
Unfortunately, the implementation of standardized pennons according to the French system, especially within the Bâlea glacial ski area (where the ski pistes are



**Fig. 13.7** Number of fatalities and injuries/burials in the Făgăraș massif (a) and the Bâlea glacial area (b) between 1940 and 2011

**Table 13.3** Recorded main snow avalanches that have caused fatalities and burials/injuries on the Sinaia ski area

Year of snow avalanche event	Fatalities and/or burials/injuries	Source
February 1981	Two fatalities	Commemorative plaque and croix
February 11, 2005	One person buried	PN-NAM, 2004–2005
January and February 2006	Eight burials/injuries and roads blocked	PN-NAM, 2005–2006
February 21, 2009	One fatality	PN-NAM, 2008–2009
February 10, 2010	Four burials/injuries	<a href="http://avalanse.blogspot.ro/2010/03/bucegi-sinaia-carp-februarie2010.html">http://avalanse.blogspot.ro/2010/03/bucegi-sinaia-carp-februarie2010.html</a>



**Fig. 13.8** Traditional forms of snow avalanche management: snow sheds (a), snowpack support structures (b), systems drainage (c), deflecting dikes (d), and splitter to protect electricity poles (e). (From Voiculescu 2004, 2008)

unequipped) and warning panels, according to European or North American systems, are still not current. In this context it is necessary to place (according to the North American and European systems) display panels that read, for example, “No Stopping” or “Avalanche Area” along the roads or in the ski areas where the snow avalanche hazard is imminent.

In the Sinaia ski area from the Bucegi Mountains, attention was drawn quite recently to management of snow avalanche risk by several accidents that took place here. This response mainly consists of delineating the ski pistes by signs and marking the degree of difficulty on the already-mentioned signs, but also of the implementation of snow pack structures where the occurrence of snow avalanche is imminent, which are the most common and the most efficient form of avalanche preventions. Also, warning signs such as those seen in other mountain areas have been implemented (Weir 2002), which read “Danger of avalanches” or “Trail closed during winter” (Fig. 13.9). Finally, another measure is the temporary closure of ski pistes.

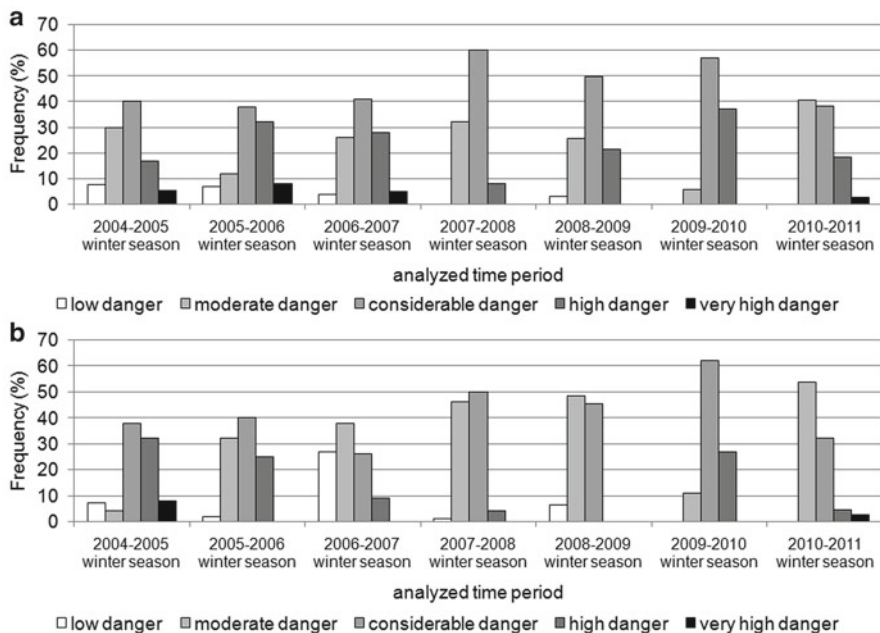


**Fig. 13.9** Delineated pistes and snowpack support (a, b) and display panels (c, d). (From Popescu 2009)

Since the 2004–2005 winter season, according to European Scale, PN-issued avalanche danger levels (Administrația Națională de Meteorologie 2004–2005; 2005–2006; 2006–2007; 2007–2008, 2008–2009, 2009–2010, and 2010–2011) (Fig. 13.10). This is another form of management of snow avalanche risk. Above 2000 m a.s.l., the highest rate was recorded in March, sometimes in April, or even in May, when the snow depth is the greatest. In the Făgăraș massif in all analyzed winter seasons the moderate, considerable, and high danger levels have the highest frequency. In some winter seasons a very high danger level was recorded. In the Bucegi Mountains the moderate and considerable danger levels have the highest frequency, sometimes high and very high danger levels.

It is an important fact that Romania has joined other European Union countries in both monitoring and snow avalanche hazard prevention; thus after the European snow avalanche risk scale was launched in 1993–1994, Romania adopted it because of the need for unique snow avalanche prevention criteria. In this respect, there are permanent broadcasts regarding snow avalanche risks during periods with large quantities of snowfall (PN-NAM, 2004–2005, 2005–2006, 2006–2007, 2007–2008).

A large part of the Romanian Carpathians, such as Eastern Carpathians and Southern Carpathians (except the Western Carpathians), are areas exposed to snow avalanches. They are recorded in the European Spatial Planning Observation Network (ESPON). On the other hand, research institutes grant a heightened attention to the phenomenon. Therefore, the Geographic Institute of the Romanian Academy is developing a general map (using ESRI GIS ArcView) of geomorphological risks,



**Fig. 13.10** Frequency of danger level in Bălea glacial ski area (a) and Sinaia ski area (b)

including snow avalanche hazards. In this respect it need be mentioned that hazard mapping snow avalanches, which includes the zoning criteria, *does not prevent avalanches; they only reduce the probability of damage* (Höller 2007, p. 96), and therefore are of high necessity within mountain areas with winter sports potential.

### 13.5 Conclusions

Unfortunately, the management of snow avalanche risk does not yet represent a major concern. The increasing incidence of snow avalanches affects not only skiers (backcountry skiers and off-piste skiers), but also the entire economy of the ski areas. The authorities responsible for the management of the ski areas need to invest in the following:

- Surveillance of the phenomena;
- Sending warnings through special services that would transmit nivometeorological bulletins;
- Drawing up vigilance maps on groups or mountain massifs;
- Emitting codes;

- Risk reduction, the consolidation and extension of snow avalanche protection structures such as deflecting dikes, snow pack support structures, snow sheds, and the introduction of explosive controls, as well as artificial release of snow in ski areas and along roads;
- Integrating and using the European avalanche risk scale, especially as Romania is part of the European Spatial Planning Observation Network (ESPON) database insofar as mountain hazards are concerned;
- Implementing standardized pennons (as in the French system) especially within ski domains (which would display trail number, type, or off-trail domain) and to implement warningpanels (European or North American system);
- Placing display panels that read, for example, “No Stopping” or “Avalanche Area” along the roads or in the ski areas (Weir 2002) where snow avalanche hazard is imminent;
- Implementing more nivometeorology laboratories of the PN-NAM within mountains with snow avalanche risk to collect meteorological data useful for GELINIV and CROCUS-MEPPA PC programs. Using these programs, snow avalanche risk maps will be produced as well as warnings for skiers and tourists.

Also, a more serious preoccupation regarding the construction of preventive measures (may be temporary or permanent and of intervention points active or passive) needs to be undertaken.

On the other hand, the management of crisis situations (present emergencies and future misfortunes) need to be prepared and also the blueprints of the territory need to be revised by elaboration of snow avalanche zoning maps and other thematic maps of exposure to natural risk phenomena.

And last but not least, Romania needs to achieve international standards through the provision of good education regarding the understanding and management of natural hazards or risk phenomena.

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