

SNOW REGIME CHARACTERISTICS FOR TOURISM IN THE NATURAL PARK MEDVEDNICA, CROATIA

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Abstract: Mount Medvednica, situated at the SE edge of the Alps as an isolated mountain presents an attractive destination for large number of visitors during the whole year. Snow regime over Medvednica (about 1000 m high), presents very risky factor in winter tourism. This study investigates snow cover frequency, duration and quantity for the referent period 1961-1990 at different profiles. At the top of Medvednica snow is falling on average on 54 days and at the altitude of 600 m on 30 days, most frequently 41-70 days, and 21-30 days respectively. Snow winter lasts from 121-239 days at the top to 104-186 days at 600 m a.s.l., but not with continuous snow cover. Days with snow cover ≥ 30 cm, necessary for alpine skiing and snowboarding, appears in 15% days annually at the top and in 7% of days at 600 m, that is a rather short duration for ski season. Snow cover ≥ 10 cm, necessary for development of cross-country skiing or snow mobiling has been analysed as well. Because of rather short duration of snow cover ≥ 30 cm, climatological analysis of relations between minimum temperatures and relative humidity have been done as a base for estimation of snow making possibilities at higher altitudes.

Key words – *snowfall, snow cover, snow depth, snow making, Mount Medvednica, Croatia, Dinaric Alps*

1. INTRODUCTION

The main resources for tourism development in many countries, as well as in Croatia, are landscape characteristics and climate that attract tourists to particular destination (Weber et al., 2002). Therefore the information and knowledge on climate should be incorporated into strategic plans of certain areas. Nowadays they have to be supplemented by climate change impact on tourism (Buerki et al., 2003, Gajić-Čapka and Horak, 2004). Croatian tourism is the most developed along the Croatian Adriatic coast and on the islands. At the same time, lot of other resources suitable for tourism development in Croatia exist, like Croatia's highland area belonging to the Dinaric Alps, or isolated mountains in northern lowland. That is the case with Medvednica Mountain in the vicinity of Croatia's capital Zagreb, which implies a lot of visitors during all seasons. Their interest in snow activities and the possibility to run them lies not only in the snow regime characteristics, but greatly depends on the artificial snow production.

2. DATA AND METHOD

The probability and time distribution of snow parameters have been analyzed at different altitudes and expositions for the period 1961/62-1990/91. The snow parameters selected for this analysis are: the beginning and the end of the snow season, the number of days with snow cover ≥ 1 cm, ≥ 10 cm, ≥ 30 cm, and ≥ 50 cm, the number of days with snow precipitation ≥ 0.1 mm, the daily snow depth and the maximum snow depth. The relation between air temperature and relative humidity at 7 a.m. have been performed for the interval November to February during the period 1981-1998 at the top area for snow making purposes. These are the climatological data generally available and the closest ones to the daily temperature minimum.

3. RESULTS

3.1 Snowfall

The mean annual number of days with snowfall (precipitation ≥ 0.1 mm) is 54 days over the top area, about 30% of days less at heights of about 600 m (St. Gora – 30 days), and about 20 days at heights of 200-250 m. During the year, it falls the most frequently in January and February.

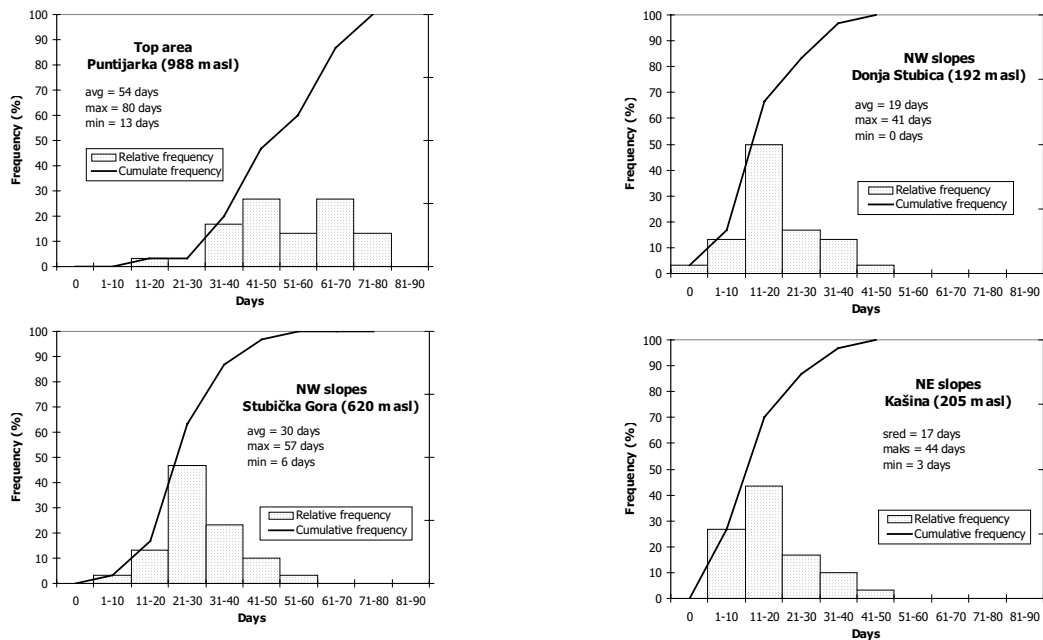


Figure 1. Frequency of the number of days with snow precipitation ≥ 0.1 mm. Period: 1961/62-1990/91.

According to the annual frequency distribution of the number of days with snow precipitation ≥ 0.1 mm (Fig. 1) snow falls at the summit for 13 -80 days mostly lasting 41 to 50 days and 61 to 70 days (Puntijarka), while already at the height of 600 m it falls at most 60 days annually and thus most frequently between 21 and 30 days (St. Gora). At lower altitudes of about 200 to 250 m it falls mostly 11 to 20 days (all slopes). The longest falling on NW and NE slopes was 44 days and at the edge of the urban area 35 days.

The snowfall doesn't necessarily result with a snow cover. Whether the falling snow accumulates on the ground or melts depends on the amount of snow, air and ground temperature, the exposure of the location to wind and direct solar radiation. During low-temperature periods, when the air temperature is below 0°C during the longer part of the day, the snow cover will stay on the ground for a longer time even after snow has stopped falling.

3.2 Snow cover

A snow cover ≥ 1 cm can be expected at the top of Medvednica from the first half of November to the end of April. This means that snow winter lasts more than five months on average, of course not with the continuous duration of snow cover (Tab. 1). On northern slopes at altitude of 600 m snow cover lasts a little bit shorter (from mid November till the first half of April). At the edges of the Park the duration of snow winter is about 40% shorter than at the top area.

The annual course of the mean monthly number of days with snow cover with different depth classes (≥ 1 cm, ≥ 10 cm, ≥ 30 cm, and ≥ 50 cm) indicates that autumn (September - November) and the first part of winter (December) are characterized by a rarer appearance of snow cover than the second half of the snow season (January and February). The difference between the mean monthly number of days with

snow cover ≥ 1 cm and ≥ 50 cm indicates that the snow melting in spring is faster than the snow formation at the beginning of the snow season (Fig. 3).

A snow cover ≥ 1 cm at the top area can be expected on average for 32% days/year, for 25% days/year it is higher than 10 cm, for 15% days/year higher than 30 cm and for 8% days/year not lower than 50 cm. At northern slopes of altitude about 600 m average duration of snow cover ≥ 1 cm is 22% days/year, those above 30 cm only 7%. At heights of 200 m at the edge of the Park snow cover appears on 9-13% days/year, those higher than 30 cm very rarely (3-6 days).

The appearance of a snow cover at altitudes higher than 600 m during the period December - March is relatively stable, while in the other months it varies considerably from year to year.

Table 1. Duration of snow winters (days). Period: 1961/62-1990/91.

Locations	shortest	average	longest
Top area 988 m asl	121	168	239
NW slopes 620 m asl	104	147	186
NW slopes 180 m asl	38	104	172
NE slopes 200 m asl	50	95	154

Table 2. Number of days with snow cover ≥ 30 cm at the top area (Puntijarka – 988 m asl) and NW slopes (St. Gora – 620 m asl) and their return periods (T – years).

Days	T _{Puntijarka}	T _{St. Gora}
0	30	10
1-10	6	3
11-20	10	6
21-30	15	8
31-40	30	30
41-50	8	15
51-60	30	30
61-70	30	10
71-80	15	
81-90	15	
91-100	10	30
101-110	30	
111-120	15	
121-130	30	
131-140	30	

According to the annual frequency distribution of the number of days with snow cover ≥ 30 cm (Fig. 4), such a snow cover can be expected in up to 90 days at St. Gora and to 140 days at Puntijarka. The frequency of all classes of number of days with snow cover ≥ 30 cm at Puntijarka are equally small, 10% and 20% for classes 1-10 days and 41-50 days, and 10% and less for all other classes. At St. Gora a class of 1-10 days is a little bit more frequent. The mean return periods for the appearance of particular annual number of days with snow cover ≥ 30 cm are presented in Table 2.

3.3 Snow depth

According to the cumulative frequencies (area under the theoretical distribution curve, in percent) (Juras and Juras, 1987) the limits of "normal" and "extreme" conditions are determined. Daily snow depth of 12-49 cm can be normally expected (interval 25-75 percentile) at the top area and 10-33 cm at the 600 m altitude (St. Gora). The snow depth higher than 78 cm (top area) and 54 cm (600 m asl) are rarely expected (91st percentile). The snow cover is extremely rare thicker than 108 cm (top area) and 70 cm (600 m asl) according to the 98th percentile (Fig. 5).

The annual maximum snow depths during the observed 30-year period at Puntijarka appeared most frequently in March (10 winters) and in January (9 winters), at St. Gora in February (9 winters) and in January (7 winters) and at lower locations in January. The greatest snow depth in a particular winter was from 141 cm at Puntijarka in February 1969, at St. Gora 108 cm in December 1963, 74 cm at the NW edge and 53 cm at the NE edge of the Park.

3.4 Relationship between air temperature and relative humidity at 7 a.m.

There is an assumption that ski season should be active on Medvednica during the four-month interval November to February. The natural characteristics of the snow regime themselves cannot be economically reasonable to run skiing infrastructure. Therefore snow making procedures should be introduced. One of them requires that air temperature values are less or equal -2°C and relative humidity

less or equal 80%. The most convenient conditions are during the early morning, when minimum air temperatures appear. Consequently, the frequency of the simultaneous appearance of such temperatures and relative humidity at 7 a.m. at meteorological station Puntijarka during the period 1981-1998 have been analysed. The results indicated that during the four month period of 120 days (November to February), in 55 days morning

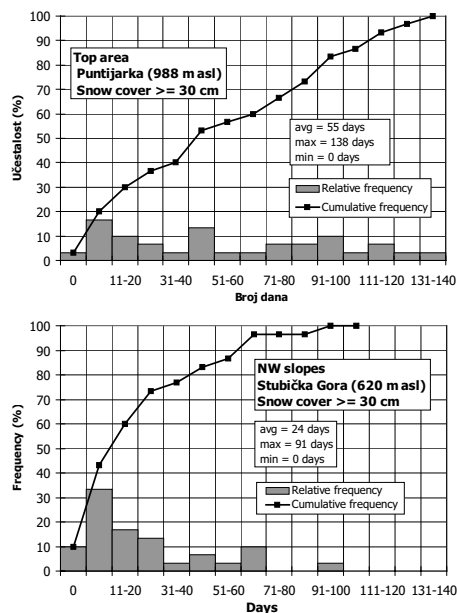


Figure 2. Frequency of the number of days with snow cover ≥ 30 cm. Period: 1961/62-1990/91.

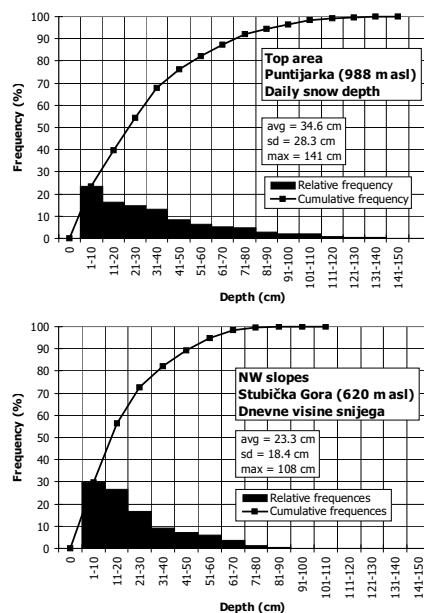


Figure 2. Frequency of the mean daily snow depth. Period: 1961/62-1990/91.

temperatures are expected to be less or equal -2°C , in 77 days relative humidity would be greater or equal 80%, but the limitation that the both conditions are fulfilled at the same time, happens on average on 45 days (37%) during the observed season. The variations from year to year are considerable. During 18 seasons, the required conditions were from 32 days in 1992 and 1997 to 91 days in 1993.

4. CONCLUSION

Spatial and time variations of the amount and duration of snow over the Medvednica Mountain indicated that they do not insure suitable snow conditions for pay out winter ski tourism without introducing adaptation strategies such as artificial snow production. Therefore the tourist industry asked for the climatological analysis of relationship between the meteorological parameters needed for snow making. According to the snow climatology of Madvednica Mountain and defined meteorological conditions required for technological purposes during the four month interval (November to February), the users should assess cost effectiveness of ski center in such an area, taking into account the ecological consequences and not only the climatic conditions.

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