SNOW BASELINE CONDITIONS AND CHANGES FOR THE WINTER TOURISM

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ABSTRACT Croatian tourism is the most developed on the Croatian Adriatic coast and on the islands. Croatia’s highland areas consist of parts that belong to the Dinaric Alps and other isolated mountains in the northern lowlands. These areas are suitable for tourism, both in summer and in winter. Good snow conditions in the Croatian highlands, including depth of snow cover as well as its duration allow the development of winter tourism oriented also on snow related activities such as cross-country skiing or snow mobiling rather than on alpine skiing only.

This study focuses on the area of the Medvednica Mountain located in the south-eastern corner of the Alps. This is an isolated mountain in the vicinity of the Croatian capital Zagreb. But the snow regime on the Medvednica Mountain, which lies at about 1000 m, represents a very risky factor in winter tourism development plans. This is the reason why the interest in snow activities and the possibility to develop them (cost-benefit effect) depend not only on the snow regime characteristics, but also on the artificial snow production.

The climatological study includes analyses of the annual course and probability of snow parameters at different altitudes and comparisons to the reference period 1961/62-1990/91. Due to users request the relationship between air temperature and relative humidity at 7 a.m. was analysed with regards to snow making purposes for the period from November to February. We used these climatological data as they are generally available and are the closest to the daily temperature minimum.

At the same time concerns with climate variability and change put special emphasis on time analysis (fluctuations and trends) of snow parameters (intensity and frequency) and different meteorological parameters related to snow (air temperature, total precipitation and air pressure) during the second half of the 20th century.

KEYWORDS: Snow climate, fluctuations, trend, snow making, winter tourism, Croatia

INTRODUCTION

The main resources for tourism development in many countries, as well as in Croatia, are landscape characteristics and climate, which attract tourists to particular destinations (Weber et al., 2002). Therefore, information and knowledge of climate should be incorporated into the strategic plans of
particular areas. Nowadays, they have to be supplemented by the impact of climate change on tourism (Buerki et al., 2003, Gajić-Čapka and Horak, 2005).

Croatian tourism is most developed along the Croatian Adriatic coast and on the islands. At the same time, lots of other resources suitable for tourism development in Croatia are still not recognized nor valued up to their full potential. Croatia’s highlands within the Dinaric Alps, or the isolated mountains in the northern lowlands are highly attractive to tourists throughout the year, particularly in summer and, traditionally, in winter.

Snow conditions along parts of the Croatian highlands (snow cover depth and duration) allow the development of winter tourism focused mainly on snow-related activities such as cross-country skiing or snow mobiling rather than solely on alpine skiing.

At the same time, climate variability and change raise concerns as they could decrease the economic effects of tourism, increase adaptation costs and the necessary investments in winter tourism content. Therefore, a climatological base for tourism estimates should be determined which should include snow regime characteristics, with special emphasis on the time analysis (fluctuations and trends) of different meteorological parameters related to snow (air temperature, precipitation and air pressure) as well as on the snow parameters themselves (snow cover frequency, duration and magnitude).

An example of such a study refers to the area of the Medvednica Mountain, located at the SE edge of the Alps, an isolated mountain in the vicinity of the Croatian capital, Zagreb. Medvednica is an attractive destination for a large number of visitors during the winter skiing season. Most people come there for one-day vacation as this resort is close to the urban area. But the snow regime on the Medvednica Mountain, which lies only about 1000 m high, represents a very risky factor in its winter tourism development plans. For this reason, the existing interest in snow activities and the possibility to operate them (cost-benefit effect) depends not only on the snow regime characteristics, but also on artificial snow production.

**DATA AND METHOD**

This climatological study includes analyses of the annual course and probability of snow parameters at different altitudes and exposures 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 a snow cover ≥1 cm, ≥10 cm, ≥30 cm, and ≥50 cm, the number of days with snowfall (precipitation ≥0.1 mm), the daily snow depth and the maximum snow depth. The relationship between air temperature and relative humidity at 7 a.m., in the period from November to February, during the period 1981-1998, was checked at the mountain summit for snow-making purposes. These are climatological data generally available and the closest ones to the daily temperature minimum.
The indications are given for a correlation between some snow parameters (snow cover ≥ 1 cm, snow cover ≥ 10 cm, snow cover ≥ 30 cm, snowfall and snow depth) and air temperature, precipitation and air pressure for the winter period (December, January and February), as well as time fluctuations and trends in the snow parameters and winter temperature, precipitation and air pressure during the second half of the 20th century.

RESULTS

SNOW CLIMATE CONDITIONS

Snowfall
The mean annual number of days with snowfall (precipitation ≥ 0.1 mm) is 54 days at the mountain’s summit, 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. Over the course of the year, snow falls most frequently in January and February.

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

Snowfall does not necessarily result in a snow cover. Whether the fallen snow will accumulate on the ground or melt depends on the amount of snow, on the air and ground temperature and the exposure of the location to wind and direct solar radiation. During low-temperature periods, when the air temperature is below 0 °C for most of the day, the snow cover will remain on the ground for a longer time even after snow has stopped falling.

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

The annual course of the mean monthly number of days with snow cover of 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 in the mean monthly number of
days with a snow cover $\geq 1$ cm and $\geq 50$ cm indicates that snow melting in spring is faster than snow formation at the beginning of the snow season.

A snow cover $\geq 1$ cm at the mountain’s summit can be expected for 32% days/year on average. 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. On the northern slopes, at an altitude of about 600 m, the average duration of a snow cover $\geq 1$ cm is 22 % days/year and of a cover of over 30 cm only 7 %. At heights of 200 m, the snow cover appears for 9-13 % days/year, and a cover higher than 30 cm is very rare (3-6 days). The appearance of a snow cover at altitudes higher than 600 m, during the period December – March, is relatively stable, while it varies considerably from year to year in the other months. High interannual variability is present, especially at the beginning and at the end of the snow season. The last date of occurrence of snow depths $\geq 10$ cm, $\geq 30$ cm and $\geq 50$ cm is more stable than the date of their beginning (Fig. 2). There is also a high variability in snow abundance.

According to the annual frequency distribution of the number of days with snow cover $\geq 30$ cm (Fig. 3), such a snow cover can be expected for up to 90 days at St. Gora and for 140 days at Puntijarka. The frequency of all classes of number of days with snow cover $\geq 30$ cm at Puntijarka is equally small, 10 % and 20 % for classes 1-10 days and 41-50 days, and 10 % or less for all other classes. At St. Gora, the class of 1-10 days is slightly more frequent.
Table 1: Duration of snowy winters (days), period: 1961/62-1990/91, Medvednica Mountain, NW Croatia.

<table>
<thead>
<tr>
<th>Locations</th>
<th>shortest</th>
<th>average</th>
<th>longest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountain top (988 m a.s.l.)</td>
<td>121</td>
<td>168</td>
<td>239</td>
</tr>
<tr>
<td>NW slopes (620 m a.s.l.)</td>
<td>104</td>
<td>147</td>
<td>186</td>
</tr>
<tr>
<td>NW slopes (180 m a.s.l.)</td>
<td>38</td>
<td>92</td>
<td>167</td>
</tr>
<tr>
<td>NE slopes (205 m a.s.l.)</td>
<td>50</td>
<td>95</td>
<td>154</td>
</tr>
</tbody>
</table>

Figure 2: The first and the last date of occurrence of a snow depth ≥10 cm, ≥30 cm and ≥50 cm at the top of the Medvednica Montain, period 1946/47-2004/05

Snow depth

The limits of "normal" and "extreme" conditions were determined according to the cumulative frequencies (area under the theoretical distribution curve, in percentages) (Juras and Juras, 1987). A daily snow depth of 12-49 cm can be normally expected (interval 25-75 percentile) at the mountain’s summit and 10-33 cm at 600 m altitude (St. Gora). A snow depth higher than 78 cm (mountain top) and 54 cm (600 m a.s.l.) is rarely expected (91 percentile). The snow cover is very rarely thicker than 108 cm (mountain top) and 70 cm (600 m a.s.l.), according to the 98 percentile (Fig. 4).

The annual maximum snow depths during the observed 30-year period at Puntijarka was measured 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 141 cm at Puntijarka in February 1969, at St. Gora 108 cm in December 1963, 74 cm at the NW slopes and 53 cm at the NE slopes at the bottom of Medvednica Mt.
The relationship between air temperature and relative humidity at 7 a.m.

This analysis is based on the assumption that the skiing season on the Medvednica Mt. should last for the four-month interval November to February (120 days). The natural characteristics of the snow regime are not economically sound enough for the operation of skiing infrastructure. Therefore, snow-making procedures should be introduced. This technique requires that air temperature is below or equal to -2 °C and that relative humidity is at least 80%. The most suitable conditions are during the night or in the early morning, when minimum air temperatures are measured. Consequently, the frequency of the simultaneous appearance of such temperature and relative humidity at 7 a.m. (climatological observing term) at the mountain top shows that in 55 days the morning temperatures are expected to be less or equal to -2 °C, in 77 days the relative humidity would be greater or equal to 80%, but the chance that both conditions be fulfilled at the same time happens on average only on 45 days (37%). During the study period, variations from year to year were considerable. During 18 seasons, the required conditions were fulfilled on only 32 days in 1992 and 1997 and as many as 91 days in 1993.

Snow parameters in relation to temperature, precipitation and air pressure

Snow is significantly negatively correlated with temperature at $\alpha=0.01$ level. This means that warmer winters are associated with less snowfall, lower snow depth and a shorter duration of snow.
cover. The same relations have been obtained for the European Alps, the Swiss Plateau, and for sites at lower altitude of up to 1000 – 1500 m a.s.l. (Rebetez, 1996). At the same time, snow exhibits also a negative correlation with air pressure and a positive one with the amount and duration of precipitation (Tab. 2).

Due to the high correlation of snow and some meteorological parameters it seemed reasonable to calculate trends in winter temperatures (mean and mean minimum), precipitation (amount and duration) and air pressure, as indicators of possible causes of changes in the snow regime (Fig. 5).

Table 2: Correlation between snow parameters and temperature, precipitation and air pressure for the winter period (December, January and February) (bold –significant at 0.01 level, bold italic – significant at 0.05 level)

<table>
<thead>
<tr>
<th>WINTER (DJF)</th>
<th>Mean temperature</th>
<th>Mean tmin</th>
<th>Precipitation</th>
<th>Prec. days</th>
<th>Daily prec. rates</th>
<th>Air pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow cover&gt;=1cm</td>
<td>-0.442</td>
<td>-0.313</td>
<td>0.044</td>
<td>0.215</td>
<td>-0.122</td>
<td>-0.253</td>
</tr>
<tr>
<td>Snow cover&gt;=10cm</td>
<td>-0.548</td>
<td>-0.187</td>
<td>0.284</td>
<td>0.442</td>
<td>0.009</td>
<td>-0.277</td>
</tr>
<tr>
<td>Snow cover&gt;=30cm</td>
<td>-0.537</td>
<td>-0.108</td>
<td>0.267</td>
<td>0.372</td>
<td>0.057</td>
<td>-0.243</td>
</tr>
<tr>
<td>Snowfall</td>
<td>-0.677</td>
<td>-0.184</td>
<td>0.415</td>
<td>0.803</td>
<td>-0.152</td>
<td>-0.527</td>
</tr>
<tr>
<td>Snow depth</td>
<td>-0.246</td>
<td>-0.175</td>
<td>-0.044</td>
<td>0.150</td>
<td>-0.178</td>
<td>-0.199</td>
</tr>
</tbody>
</table>

TIME-SERIES ANALYSIS - winter (DJF) 1946/47-2004/05

The anomalies show a large variability in all observed meteorological parameters (Fig. 5). They show a statistically insignificant positive trend in winter air pressure and temperature (mean and tmin). These changes are the result of an increase in the frequency of anticyclonic weather types (Gajić-Čapka and Zaninović, 1997). A slight decrease in precipitation totals is the result of infrequent but more intensive precipitation events, which are in the winter season in 77 % of cases in the form of snowfall. Snow parameters show a slight decrease in the mean daily snow depth and the duration of snow cover ≥ 10 cm, but a statistically significant decrease in snowfall frequency.

CONCLUSION

Spatial and time variation in the amount and duration of snow in the region of Medvednica Mt. indicate that the variation does not ensure suitable snow conditions for commercial winter skiing tourism without introducing adaptation strategies such as artificial snow production. Therefore, there has been demand by the tourist industry for a climatological analysis of the relationship between the meteorological parameters needed for snow-making. According to the snow climatology of the Medvednica Mt. and the meteorological conditions required for technological purposes during the four-month interval (November to February), the stakeholders should assess the cost-effectiveness of a ski center in such an area, taking into account ecological consequences, time variability and trend features, and not only climatic conditions.
Figure 5 - Variations of mean winter air pressure, mean temperature, mean minimum temperature and precipitation (left) and mean winter number of days with snowfall (daily precipitation ≥ 0.1 mm), mean daily snow depth, mean duration of snow cover ≥ 10 cm and mean daily precipitation (right), their 11-year binomial moving average series and linear trends at the mountain top (Puntijarka) during the period 1946/47 – 2004/05.
REFERENCES