

# **Climatological basis for planning in mountain recreation**

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## **Abstract**

The following paper contains the analyses of main climate elements with the special emphasis on snow regime, especially on snow depth, as well as minimum temperature and relative humidity relations. Annual course of relevant climatological parameters has been performed by means of 10-day period means. The example of the presentation of bioclimate conditions, which can be also applied for the mountainous resort planning, can be found in the paper by Zaninovic, 2001.

The analyses have been made for the northern part of the mountain Velebit in Croatian part of the Dinaric Alps (Zavizan, 1961-1990). This area has been mainly intended for tourism and recreation. This mountainous ridge presents the boundary between the maritime climate at the Adriatic coast and mountain continental climate over the inland. Its summit area experience abundant amounts of snow with long lasting snow cover especially on the eastern slopes exposed to the continental influence.

Key words: annual course, extreme value analysis, snowmaking, mountain recreation, Croatia

## **Introduction**

Planning of recreation activities and design of objects in mountainous regions requires meteorological analyses that pay special attention to the extreme climate conditions. In such cases the land use decisions do not primarily depend on thermal comfort values. In the case of ski resort planning the decisions are based in the first place on snow conditions which are supposed to be the natural resource for the development of winter snow recreation over the region. Depending on the frequency of simultaneous appearance of adequate minimum temperatures and relative humidity snowmaking could be introduced in order to make the ski season longer and in such a way a winter resort economically operational.

## Data and methods

Mountain Velebit is located along the eastern Adriatic coast 150 km in length with the highest summits of about 1700 m a.s.l. The specific mountain climate of Velebit under the strong maritime influence has been performed for the purpose of planning in mountain recreation by the annual course of 10-day period means and frequencies (number of days) of different climatological parameters. It is supposed that ten-day period is much more convenient for holiday planning than most frequently used monthly interval. The estimation of snow has been deduced by means of Jenkinson GEV distribution (general extreme value distribution). The appearance and duration of snow cover with different snow depths, as well as the frequency of simultaneous appearance of determined minimum temperatures and relative humidity have been analysed in more detail.

The data basis for these analyses have been meteorological measurements during the period 1961-1990 at the main meteorological station Zavizan located on the northern part of Velebit Mountain at 1594 m a.s.l.

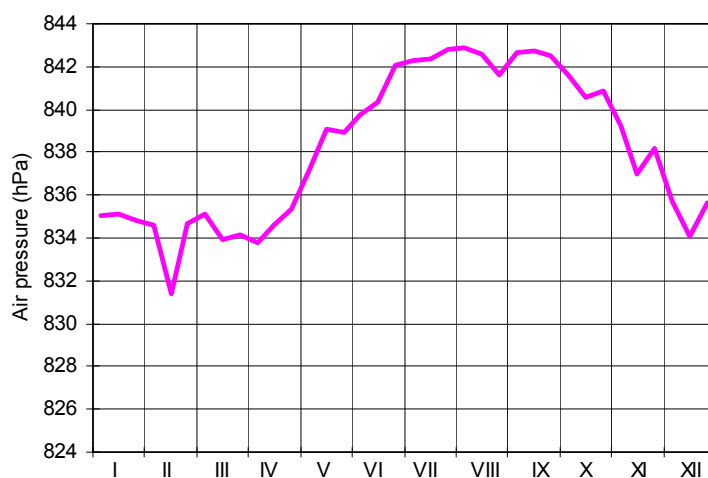


**Fig. 1** Position of meteorological station Zavizan at the top of Velebit Mountain, Dinaric Alps

## Results

### *Air pressure*

Time variations of air pressure presented by the ten-day period means (Fig. 2) show the dependence on general circulation of atmosphere, altitude, as well as continental or maritime influence of ground. During winter and early spring the air pressure changes are under the dominant influence of general circulation characterised by extended and well developed, frequently stationary anticyclones and cyclones with great pressure gradient at the boundary of the system. During the warm part of the year, especially during summer, general circulation is weaker, and the other influences, as dependence with altitude, are more expressed. The mean air pressure changes very little. At the summit area of mountain Velebit, which corresponds to the height of 850 hPa level, mean air pressure increases constantly from April to July, and reaches its maximum in August. This course is typical for the mountainous areas of Croatian continental inland.



**Fig. 2** Annual course of 10-day period means of air pressure. Zavizan, 1961-1990.

### *Air temperature*

Mean monthly air temperature values are on average between  $-4.2^{\circ}\text{C}$  in January and February and  $12.1^{\circ}\text{C}$  in July (Fig. 9). Mean daily temperatures less than  $0^{\circ}\text{C}$  appear from the middle of the second decade of November till the beginning of the third decade in March as well as about the middle of April. The warmest days are from the middle of July till the mid of August, when daily means are on average

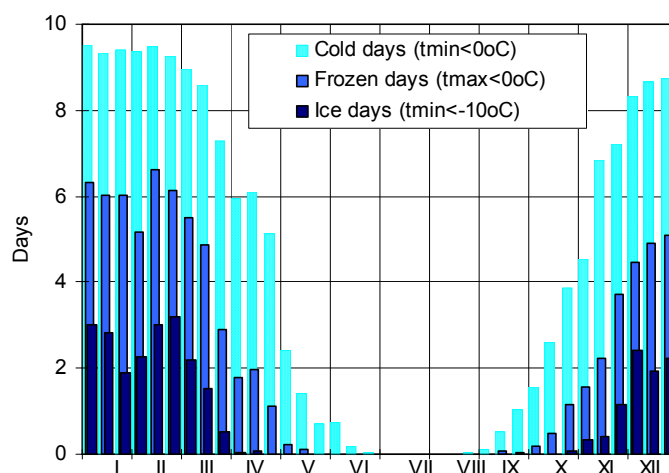
between 12°C and 14°C. Mean daily temperatures are more stable during summer (standard deviation is 3.3-3.4°C) than during winter (standard deviation is 4.8-5.1°C).

Annual maximum temperatures mainly do not exceed 25°C. Absolute maximum measured during the observed period was 27.6°C (Tab. 1).

Absolute minimum temperatures less than 0°C can be expected in all months except in July. They appear every year in the period from October to April. The probability for their non-appearance is very small in May (7%), and in September 37%.

**Table 1** Absolute maximum and minimum temperatures. Zavizan, 1961-1990.

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Max (°C)	11.2	13.7	16.5	16.6	20.6	22.6	27.6	25.7	27.2	20.3	16.4	14.4	27.6
Min (°C)	-24.5	-21.7	-22.6	-10.8	-9.8	-3.1	0.2	-0.4	-3.8	-10.1	-16.8	-23.2	-24.5



**Fig. 3** Annual course of 10-day period mean number of days with different extreme temperatures. Zavizan, 1961-1990.

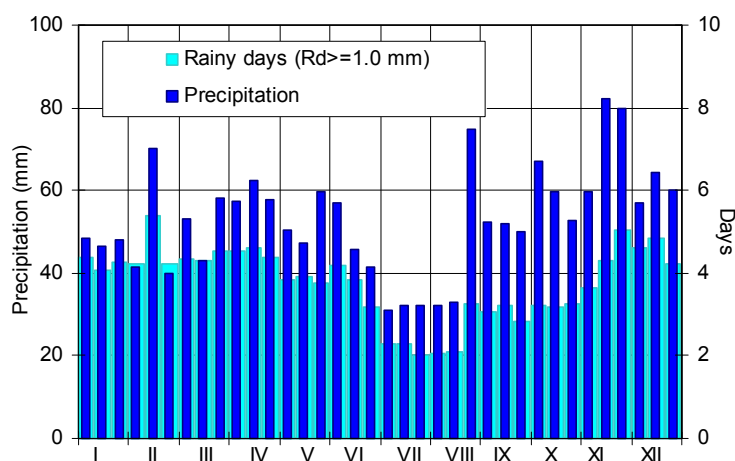
At the top area of mountain Velebit the hot days ( $t_{\max} \geq 30^{\circ}\text{C}$ ) do not appear, the day with the warm night ( $t_{\min} \geq 20^{\circ}\text{C}$ ) appeared only once during the observed 30 years and this happened in the third decade of July. Warm days ( $t_{\max} \geq 25^{\circ}\text{C}$ ) are also rare (6 in 30 years). Days with low temperatures are much more frequent. There are 29 days with  $t_{\min} \leq -10^{\circ}\text{C}$  during the year, 23 of them in winter. 79 days with  $t_{\max} < 0^{\circ}\text{C}$  appear during the period from the second decade of September till the second decade of May, the most frequently in winter (15-19 days per month, more rare in spring (0.3-13.6

days per month) and in autumn (0.1-7.5 days per month). Cold days ( $t_{\min} < 0^{\circ}\text{C}$ ) can be expected in all months except in July, although they are extraordinary rare in June and August. They appear in more than 25 days per month in the period from December to March (Fig. 3).

### Precipitation

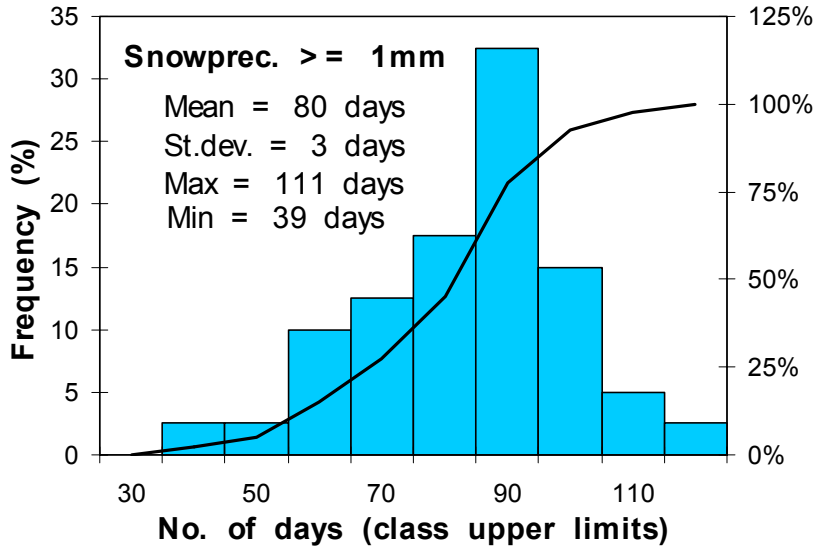
Annual course of precipitation show maritime characteristics with primary maximum in November (222 mm) and secondary one in May (178 mm), and minimum in July (95.5 mm) (Fig. 3).

The area at the top of northern Velebit experiences more than 10 rainy days monthly from October to June (about 14 days in December), and minimum in July (about 7 days). The mean number of rainy days for the 10-day periods is presented in Fig. 4.



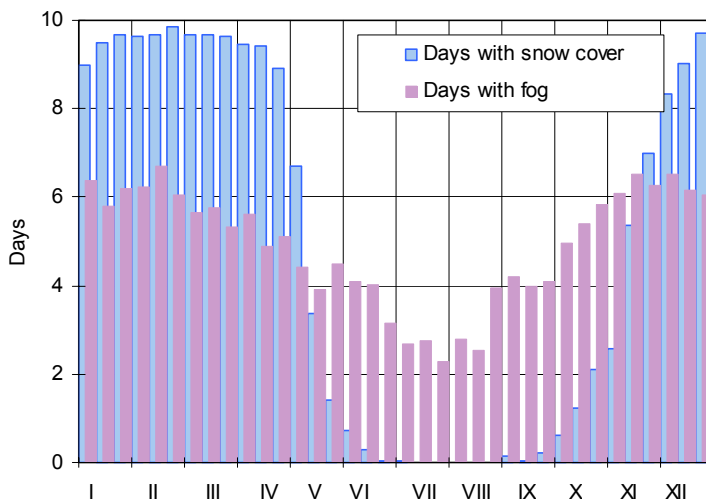
**Fig. 4** Annual course of 10-day period precipitation totals and mean number of rainy days. Zavizan, 1961-1990.

On the average the snow falls for the first time in the first half of October, and for the last time at the end of May. This means that the mean snow season lasts over more than seven months. Mean annual number of days when snow falls and snow precipitation amounts  $\geq 1\text{mm}$  is 80 days at Zavizan. During the year it falls in nearly equal number of days in each month from December to April (11.4-13.0 days) and in other months is rather rare (Tab. 2). Snow falls in 30-120 days annually with the greatest probability for the duration of 80 to 90 days.



**Fig. 5** Frequency of the mean number of days with snow precipitation  $\geq$  1 mm. Zavizan, 1953/54-1992/93.

Snow cover  $\geq$  1cm can be expected from mid October to the second half of June. The occurrence of higher snow cover can be expected during shorter periods: snow cover  $\geq$  10 cm from November the 10<sup>th</sup> till May the 13<sup>th</sup>, snow cover  $\geq$  30 cm from November the 28<sup>th</sup> till May the 3<sup>rd</sup>, and snow cover  $\geq$  50 cm from December the 22<sup>nd</sup> till April the 25<sup>th</sup>. During these periods snow cover of respective depths occurs in 83%, 84% namely 90% of days. The first and the last date of occurrence of snow cover with different depths are very variable from year to year.

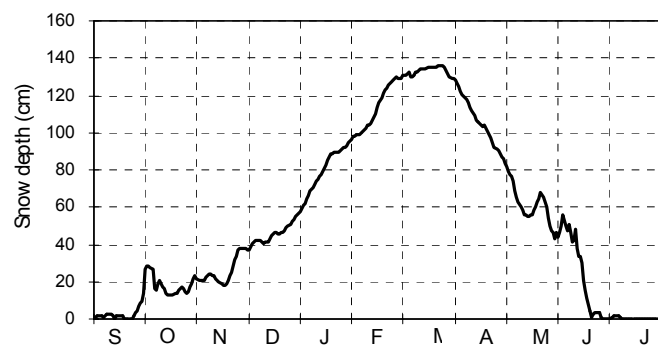


**Fig. 6** Annual course of 10-day period mean number of days with snow cover and days with fog. Zavizan, 1961-1990.

A snow cover  $\geq 30$  cm can be expected on average on 36% days/year and on 31% days/year it is not lower than 50 cm. These data are interesting as they provide information about the period when skiing is possible without greater problems.

In a “normal” snow season snow cover is present in all days in each month during the period January to March, in December in 22-31 days and in April in 26-30 days. At the end of autumn (November) snow will be on ground in 9-18 days and at the end of spring (May) the duration of snow cover is between 5 days and two weeks. Outside this interval snow cover is rather seldom phenomenon.

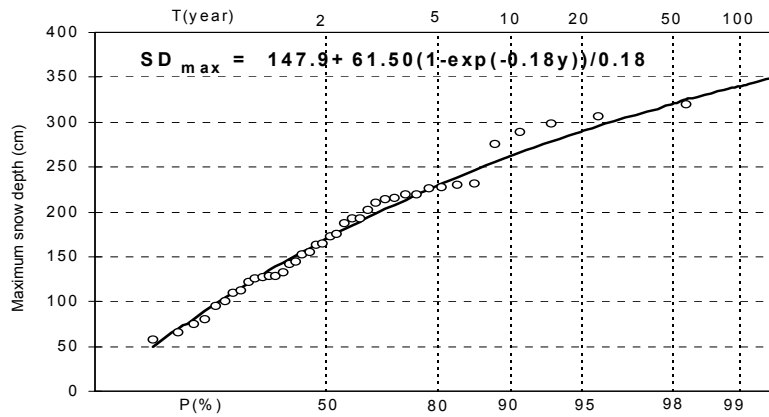
Annual course of mean daily snow depth, obtained as the 5-day period averages, presents an important information for different users (Fig. 7). Snow cover of about 20 cm during October and the first half of November rises up to about 60 cm till the end of December. At the end of January it achieves about 100 cm, in February 130 cm, and during March mean daily snow depth varies about this value. In April snow melts rather rapidly and at the end of month it amounts about 80 cm. In May and during the first half of June snow depth is very variable showing certain peaks.



**Fig. 7** Annual course of 5-day period mean snow depth. Zavizan, 1961-1990.

Annual maximum snow depth appears most frequently in March and in February. During the period 1953/54 to 1992/93 the greatest snow depth in particular winter was from 58 cm in winter 1988/89 to 320 cm in winter 1983/84 (Fig 7).

The estimation of annual maximum snow depth according to the Jenkinson GEV distribution (Jenkinson, 1969) enable the determination of expected maxima for particular return periods. For example, for the 50-year return period maximum snow depth of 320 cm can be expected to be exceeded by only a 2% probability on the top area of the mountain Velebit (Fig. 8).



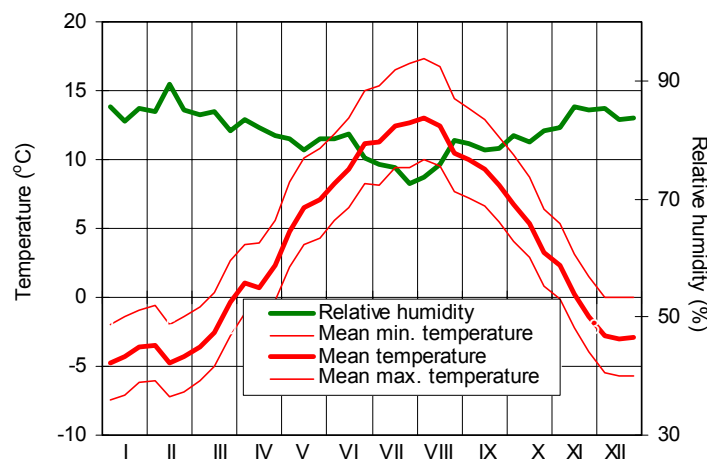
**Fig. 8** Estimates of maximum snow depth according to the Jenkinson GEV distribution for Zavizan. Period: 1953/54 - 1992/93.

**Table 2** Annual course of various snow parameters. Zavizan, 1953/54 - 1992/1993.

	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	Snow season
No. of days with snow cover $\geq 10$ cm													
Mean	0.0	0.1	2.0	9.5	22.1	27.9	27.0	29.8	26.1	9.2	0.5	0.0	154.0
No. of days with snow cover $\geq 30$ cm													
Mean	0.0	0.0	0.9	4.5	15.8	24.7	26.0	29.2	23.7	6.7	0.3	0.0	131.7
No. of days with snow cover $\geq 50$ cm													
Mean	0.0	0.0	0.3	2.5	10.6	21.0	24.4	27.5	20.5	4.6	0.2	0.0	111.6
No. of days with snow precipitation $\geq 0.1$ mm													
Mean	0.0	0.6	3.4	8.2	12.5	12.5	13.0	13.0	11.4	4.0	1.0	0.2	79.6
Maximum depth of snow cover (cm)													
Max.	0	18	87	142	167	230	287	320	298	272	106	3	320

### Relative humidity

Mean monthly values of relative humidity have small annual amplitude. Minimum in July is 75% and maximum in February 84% (Fig. 9).



**Fig. 9** Annual course of 10-day period mean air temperature, mean maximum temperature, mean minimum temperature and relative humidity. Zavizan, 1961-1990.

*Relation between air temperature and relative humidity*

In order to make the skiing season longer it is recommended to introduce snowmaking. This process demands the determined minimum temperature and relative humidity conditions. According to the technological requirements the frequency of simultaneous appearance of temperatures less or equal  $-2^{\circ}\text{C}$  and relative humidity less or equal 80% measured at 7 a.m. has been analysed for the period winter 1961/1962 to winter 1997/1998.

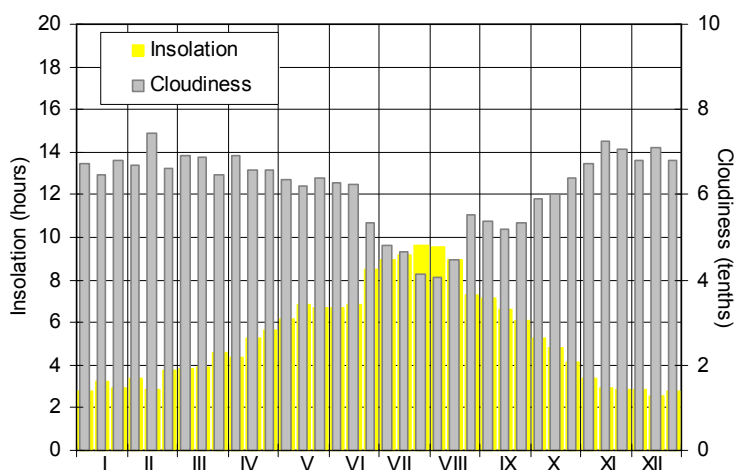
On average 20 days with such conditions can be expected during winter, rather rare in each month from about 2 days in November and April to about 5 days in January (Tab. 3).

**Table 3** Days with temperatures less or equal  $-2^{\circ}\text{C}$  and relative humidity less or equal 80% at 7 a.m. Zavizan, 1961/1962 –1997/1998.

Month	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	winter
Average	0.0	0.0	0.0	0.5	1.5	3.2	5.4	4.3	3.5	1.6	0.1	0.0	20.2
St. dev.	0.0	0.0	0.2	0.7	1.4	2.1	3.0	2.6	2.5	1.5	0.4	0.0	5.5
Min.	0	0	0	0	0	0	0	0	0	0	0	0	10
Max.	0	0	1	3	5	7	14	9	10	8	2	0	34

### Sunshine duration

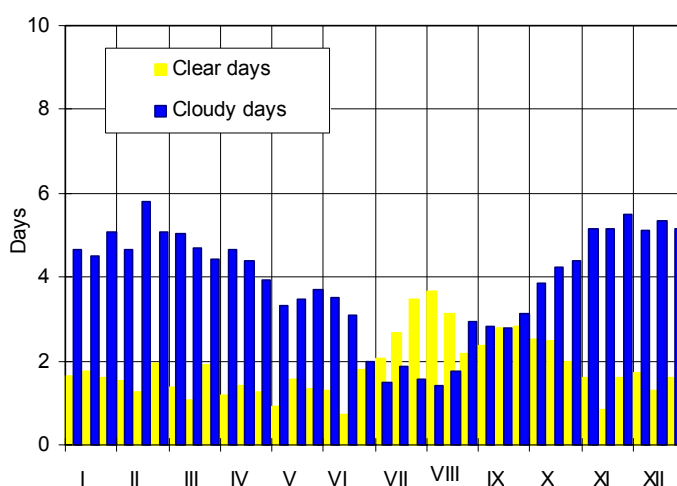
The area of Zavizan has on average 1969 hours of sunshine during the year, with maximum mean daily insolation of 9.3 hours in July and minimum of 2.7 hours in December (Fig. 10).



**Fig. 10** Annual course of 10-day period mean daily sunshine duration and cloudiness. Zavizan, 1961-1990.

### Cloudiness

On the top area of northern Velebit Mountain 39% of the days during the year are cloudy, mostly during the cold part of the year. It is the most clear from July to October with 7-9 clear days monthly (Fig 11).



**Fig. 11** Annual course of 10-day period mean number of clear and cloudy days. Zavizan, 1961-1990.

## **Discussion**

The presented climate analyses performed in the first place for selection of ski resort, can be later on also used for the biometeorological prospect in the frame of tourist promotion, which pays special attention to the thermal comfort conditions of the location or region.

## **References**

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