Selected Characteristics of Atmospheric Icing in the High-Mountain Conditions

Dr. M. Ostrožlík
Geophysical Institute of the Slovak Academy of Sciences, Dúbravská cesta 9, 845 28 Bratislava 45, Slovak Republic
Tel.: ++421 2 59410613, Fax: ++421 2 59410626, E-mail: geofostr@savba.sk
and
Ing. M. Mucha
Faculty of Electrical engineering and Information Technology, Slovak University of Technology Bratislava, Ilkovičova 3, 812 19 Bratislava 1, Slovak Republic
Tel.: ++421 2 602 91 352, E-mail: martin.mucha@stuba.sk

Abstract–Atmospheric icing measurements are carried out at Chopok (φ = 48°56′ N, λ = 19°35′ E, h = 2004 m a.s.l.) and Lomnický štít (φ = 49°12′ N, λ = 20°13′ E, h = 2634 m a.s.l.) 3 times a day in the climatic terms 7 h, 14 h, 21 h since 1957.

By processing of the extensive experimental material from the measurements of the atmospheric icing at Chopok and Lomnický štít many statistical characteristics were obtained. The obtained results confirmed that at Chopok, there are more suitable topographical conditions, altitude, as well as the higher wind velocity for the atmospheric icing accretion than at Lomnický štít. Likewise as the atmospheric icing amount also the total number of days with atmospheric icing is higher at Chopok than at Lomnický štít. In both localities the annual course of the number of days with atmospheric icing is more regular and expressive than the corresponding annual course of the atmospheric icing. At the same time the annual amplitude of the number of days with atmospheric icing at Chopok is two times higher than at Lomnický štít.

Some of these results were compared with the corresponding data from the other mountain positions in the Central Europe.

Keywords: atmospheric icing, occurrence and amount of atmospheric icing, annual course, statistical characteristics

I. Introduction

Atmospheric icing in the higher mountain positions represents an important contribution to its precipitation regime. Therefore, the study of the meteorological conditions during the atmospheric icing has an adequate importance in the problems of the mountain meteorology. Some branches of practical life, above all forestry, communication, power stations, etc. [17], have still more interest about atmospheric icing occurrence and its amount. In spite of this fact the atmospheric icing occurrence and its characteristics are not known in our mountain regions in detail, mainly for the absence of exact measurements. Hence, all works concerning of the atmospheric icing in our mountain regions represent a valuable scientific material about which we can put one`s back at an expanding of our study and knowledge about its occurrence and intensity.

II. Material and Methods

In meteorological practice the atmospheric icing observations are focused first of all to a record of days in which atmospheric icing was occurred. From the quantitative methods the Polanský method was the most extended [8]. By this method the long time series of atmospheric icing were received on the high-mountain observatories at Lomnický štít and at Chopok [12], [15] Measurements are performed on a horizontal pair of orthogonal (N – S and E – W) wooden rods in the standard height of 2 m [2]. Diameter of the rods is 0.032 m, length of 1 m. It follows that the whole cylindrical surface of one rod is 1000 cm^2, i.e. 0.1 m^2. After the melting of icing and its measuring in a cup of normal rain-gauge with the receiving-area of 500 cm^2, the number of millimetres precipitation, which specifies the measuring cup, ought to be multiplied by factor 0.5, to get the value of atmospheric icing in $kg \cdot m^{-2}$. The calculated average value of the both rods is put down into the records. The measurements are carried out 3 times a day at 7, 14, and 21 h of the local time.

Some theoretical works are focused to the modeling of the atmospheric icing creation [6], [7], but our solution of the investigated problem is based on experiment. The necessity experimental data were obtained at the meteorological observatories Chopok (φ = 48°56′ N, λ = 19°35′ E, h = 2004 m a.s.l.) and Lomnický štít (φ = 49°12′ N, λ = 20°13′ E, h = 2634 m a.s.l.) during the 1957–2005 period. Methods of mathematical statistics [1], [5], [9] were applied in the calculated characteristics of daily, monthly, and annual sums of atmospheric icing.

III. Results and Discussion

By processing of the extensive material of the atmospheric icing measurements at Chopok and Lomnický štít many statistical characteristics were obtained. Some of these characteristics have been evaluated yet and published in the previous papers with the analogous topic [11], [12], [13].

A. Annual Amounts of Atmospheric Icing

Annual amounts of atmospheric icing are presented in the following tables and figures and they are a subject of our study.

Table 1 contains some fundamental characteristics of annual sums of atmospheric icing at Chopok and Lomnický štít: average, median, extreme values, standard deviation, coefficient of variation, etc. As it can be seen from Table 1 conditions for the atmospheric icing creation are considerably different at both localities. These differences are mainly due to by the distinct altitude of both localities, as well as by the different topographical conditions. The vertical difference of 630 m causes first of all essentially different thermal conditions for icing creation under the various weather situations, if the rest conditions are for its formation satisfied.

TABLE 1
STATISTICAL CHARACTERISTICS OF THE ANNUAL AMOUNTS OF ATMOSPHERIC ICING IN Kg·m^{-2} AT CHOPOK AND LOMNICKÝ ŠTÍT DURING THE 1957-2005 PERIOD

	Atmospheric icing in kg·m^{-2}	
	Chopok	Lomnický štít
Sample size	49	49
Average	1942.381	903.496
Median	1913.480	859.510
Mode	1855.678	771.538
Geometric mean	1892.780	877.504
Variance	243700.50000	47267.58000
Standard deviation	493.66030	217.41110
Standard error	70.52290	31.05873
Maximum	1154.550	414.250
Minimum	4347.090	1397.050
Range	3192.540	982.800
Lower quartile	1740.180	772.000
Upper quartile	2081.740	1068.150
Interquartile range	341.560	296.150
Skewness	2.52135	0.35326
Kurtosis	11.35336	-0.09163
Coeff. of variation	25.41522	24.06331
Sum	95176.640	44271.300

According to obtained mean annual atmospheric sums at Chopok (1942.38 kg·m^{-2}) and at Lomnický štít (903.50 kg·m^{-2}) have been yet said that at the Chopok are on the whole essentially more suitable meteorological and another conditions than at Lomnický štít, where the annual sum of atmospheric icing represents only 46.5% from the total amounts at Chopok in the investigated period. This difference is partly due to on the whole more windiness at Chopok, where the annual mean of wind speed according to [16] 8.0 m·s^{-1}, while at Lomnický štít it is only 3.3 m·s^{-1} [14]. The rest part of the different amounts of atmospheric icing can be mainly assigned to the different thermo-hydrometric conditions. How is the quantitative part of the individual meteorological factors on the higher icing amounts at Chopok it can not be strictly estimated according to present results of icing measurements.

In individual years the mentioned annual sums of atmospheric icing varied in large ranges. For example, at Chopok it is between 4347.090 kg·m^{-2} (in year 1966) and 1154.550 kg·m^{-2} (in year 1986) and at Lomnický štít from 1397.050 kg·m^{-2} (in 1983) to 414.250 kg·m^{-2} (in 1963). From this it follows that the fluctuations of the annual sums of atmospheric icing are in a range of 3192.540 kg·m^{-2} at Chopok and 982.800 kg·m^{-2} at Lomnický štít. The standard deviation of 21492.5856 kg·m^{-2} at Chopok and 217.4111 kg·m^{-2} Lomnický štít, what represents 25.4% eventually 24.1% from the long-term average.

B. Annual Course of Atmospheric Icing

As it follows from the Fig. 1, the annual course of atmospheric icing amounts at Chopok is very expressive. On the whole, it is characterized by the simple cycle with an expressive winter maximum and summer minimum. Obtained results showed that this tendency of annual course of icing at Chopok is in good preservation also in individual years. Minimum falls on some summer month and maximum in some month from November to March.

According to the total tendency, the mean annual course of icing amounts at Lomnický štít is similar to the one at Chopok, e.g. it is characterized by simple course with the winter maximum and summer minimum. However, this course at Lomnický štít is less expressive and in individual years can be quite disturbed. It also confirmed the data, for example, the monthly sums of atmospheric icing in years 1960, 1968, 1974, and so on. The maximal monthly amounts of icing can occur at any month of the year, in this locality. Obtained results showed that the minimal values of atmospheric icing can also appear at any month, even if the highest probability for that is in the period from May to September. The ratio of the mean monthly sums of icing in December and August is 54.5 p.u. at Chopok, while at Lomnický štít the corresponding portion is only 2.1 p.u. in the investigation period.

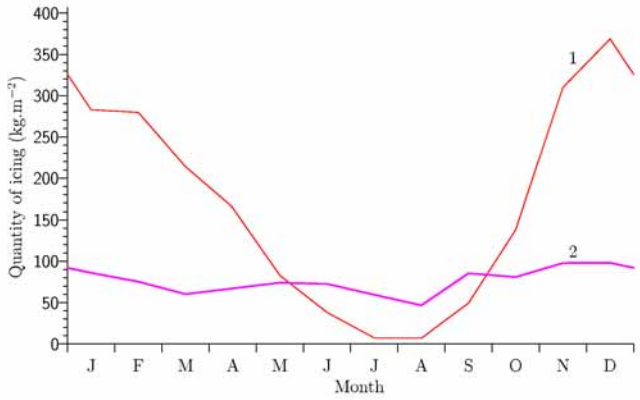

Fig. 1. Annual course of mean monthly amount of atmospheric icing at Chopok (1) and Lomnický štít (2) during the 1957-2005 period.

Using the measured data, only in the warm part of the year – from June to September, the mean monthly sums of atmospheric icing are at Chopok smaller than at Lomnický štít. In the rest part of the year, the sums are higher at Chopok. At the same time, the highest difference of the total amount of icing between both localities is in the months which are the most abundant on atmospheric icing from November to February.

C. Annual Course of Days with Atmospheric Icing

The analysis of the number of days with atmospheric icing at Chopok and Lomnický štít shows that in average there are 165.8, eventually 121.8 days in a year.

The annual course of the mean number of days with atmospheric icing at Chopok and Lomnický štít is illustrated in Fig. 2. A comparison its curves with the ones in Fig. 1 shows, that equally as the atmospheric icing amounts, the mean number of days with icing at Chopok has also a very expressive annual course with summer minimum in July (3.8% from all days) and winter maximum in December (77.5%). The fluent course of the number of days with icing is disturbed in winter period by relative increasing in March, opposite to February and April. In individual years, the maximum of days with atmospheric icing can occur also in some month in winter period – from November to March and minimum in a summer month (June – August). The highest number of days with icing formation was recorded in December 1991 – 31 days (100%) and in February 1966 – 28 days (100%). On the other hand, the absolute and relative minimum of days with icing (0 days) occurred in the investigated period in 60 days from May to September at Chopok.

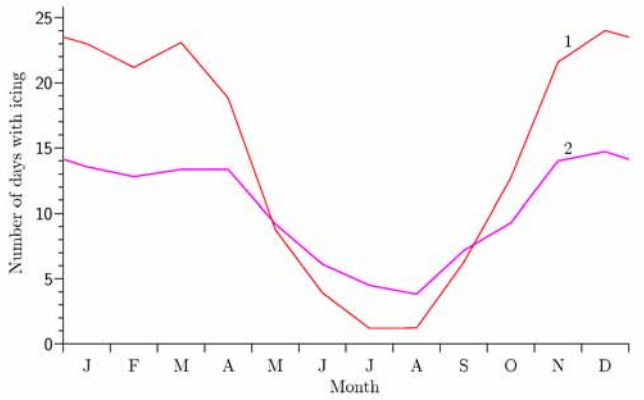

Fig. 2. Annual course of the mean number of the days with atmospheric icing at Chopok (1) and Lomnický štít (2) during the 1957-2005 period.

The annual course of the number of days with atmospheric icing at Lomnický štít has similar character like that one at Chopok. Hence, it is characterized by winter maximum and summer minimum, however, its annual amplitude is approximately two times smaller than that one at Chopok. Winter maximum is also in December and minimum is in August. As it can be seen from Fig. 2, in months from May to August, the atmospheric icing occurs more frequently at Lomnický štíte than at Chopok. More detail comparison of the annual course of the days with atmospheric icing in Fig. 2, with the annual course of atmospheric icing amount in Fig. 1 shows, that at Lomnický štít the annual course of icing occurrence is more regular and essentially more expressive than the corresponding course of the icing amounts. Similar difference we can find in the individual years of the investigated period. That means, on the contrary to atmospheric icing amount, the maximal occurrence of icing is always in any month in the cold part of the year – from November to May and minimum in some month – from June to October, above all in July and August. Maximal number of days – 25 days (84%) in a month – was at Lomnický štít recorded two times (January 1976 and December 1988). The smallest occurrence (0 days) was recorded 13 times from June to September.

To compare the high-mountain locations of the High and Low Tatras (Lomnický štít, Kasprový vrch, and Chopok) with the others peaks (Zugspitze and Snežka) from the icing occurrence point of view, the annual courses of the number of days with atmospheric icing are introduced (Fig. 3). For this purpose the values of the number of days with atmospheric icing according to: [4] for Snežka (1602 m a.s.l.), [10] for Kasprový vrch (1988 m a.s.l.), *Schlegel* [3] for Zugspitze (2962 m a.s.l.), and our results for Chopok (2004 m a.s.l.) and Lomnický štít (2634 m a.s.l.) were used.

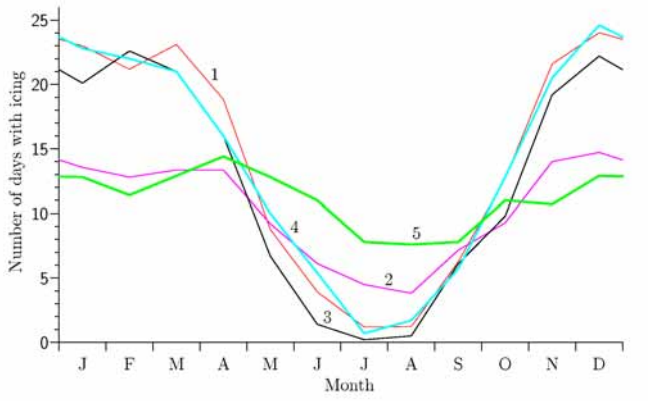

Fig. 3. Annual course of mean number of days with atmospheric icing at Snežka (1) in 1902-1913 period, at Kasprový vrch (2) in 1941-1944 and 1947-1953, at Chopok (3) and Lomnický štít (4) in 1957-2005, and at Zugspitze (5) in 1900-1949 period.

According to Fig. 3, in the mountain positions of the Central Europe with the rare occurrence of the negative air temperature in the summer months, the annual course of the number of days with atmospheric icing is very expressive, characterized by the summer minimum and the winter maximum. It can be seen a great decrease of the number of days with atmospheric icing in the spring months, whereas in autumn months, in the opposite, a strong increase. The higher mountain localities of the Central Europe (2500-3000 m a.s.l.) have basically a similar tendency of the annual course, but this course is less expressive. The difference between the winter maximum and the summer minimum becomes smaller at the transition from the lower localities towards the higher ones. It is apparently connected by the fact that the number of days with atmospheric icing decreases in winter period and, on the other hand, it increases in summer period with the growing altitude.

IV. Conclusion

By processing of the extensive experimental material from the measurements of the atmospheric icing at Chopok and Lomnický štít many statistical characteristics were obtained. The obtained results confirmed that there are more suitable topographical conditions at Chopok, altitude as well as the higher wind velocity for the atmospheric icing accretion than at Lomnický štít. Likewise as the atmospheric icing amount also the total number of days with atmospheric icing is higher at Chopok than at Lomnický štít. In both localities the annual course of the number of days with atmospheric icing is more regular and expressive than the corresponding annual course of the atmospheric icing. At the same time the annual amplitude of the number of days with atmospheric icing at Chopok is two times higher than at Lomnický štít.

Some of these results were compared with the corresponding data from the other mountain positions in the Central Europe. The higher mountain localities of the Central Europe (2500-3000 m a.s.l.) have basically a similar tendency of the annual course, but this course is less expressive. The difference between the winter maximum and the summer minimum becomes smaller at the transition from the lower localities towards the higher ones. It is apparently connected by the fact that the number of days with atmospheric icing decreases in winter period and, on the other hand, it increases in summer period with the growing altitude.

V. Acknowledgment

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