Atmospheric icing at Lomnický štít

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Abstract: Time series of the daily and monthly amounts of atmospheric icing at Lomnický štít covering the 1957-2003 period were used to study the seasonal variability of atmospheric icing in the high-mountain conditions. Obtained results were compared with the corresponding data from other mountain positions in the Central Europe. It was shown that at Lomnický štít there are suitable meteorological and other conditions for the accretion of atmospheric icing. The number of days with the atmospheric icing and its annual course at Lomnický štít are typical in these climatic characteristics for the corresponding mountain areas in the Central Europe. Whereas the annual courses of the number of days as well as of the mean daily amounts of atmospheric icing are relatively simple the annual course of the mean monthly amounts of atmospheric icing is not expressive.

Key words: atmospheric icing, occurrence, number days and amount of atmospheric icing, annual course

1. Introduction

Occurrence of atmospheric icing both in the ground atmospheric layer and at the higher atmospheric levels has a great practical importance, first of all for power-plant engineering, transport, especially air transport, agriculture, forestry and others. In spite of this fact, little attention was paid to the observation of atmospheric icing until the twenties of the last century. The development of aviation brought the necessity to search the means, which would be able to hinder the atmospheric icing accumulation on the airplane at its flight in cloud under the temperature below 0° C.

Systematic measurements of atmospheric icing in the previous Czechoslovak Republic started on the impulse of Wald in the region of the Czech-Moravian Highland in the thirties of the last century (*Wald, 1947*). As a catch body was used the following pair: a wire and a wooden rod of 1 m

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length and with a diameter of 0.06 m. Diameter of the wire was not unambiguously prescribed, because the difference in diameters of the applying line wires (25–150 mm^2) has not substantial influence on the formation of extreme quantities of atmospheric icing. The amount of atmospheric icing was given in g m^{-1} of wire. To estimate the maximal amount of atmospheric icing which was deposited on the electric wires a suitable adapted ice-meter was used (*Maška, 1958*). Although these measurements were carried out for different technical purposes and from this point of view were evaluated, nevertheless their results offer interesting data about character and formation of atmospheric icing from meteorological point of view (*Hrudička, 1934; Hrudička, 1935*).

2. Material and methods

For meteorological purposes the Polanský method is the most enlarged (*Maška, 1958*). By this method the long time series of atmospheric icing were received on the high-mountain observatories at Lomnický štít and at Chopok (*Ostrožlík, 1974; Ostrožlík, 1976*). This method also uses the catch body consisting of the pair of wooden rods, which are horizontally located, namely one in the N–S direction and the second in E–W direction in the standard height of 2 m. Diameter of the rods is 0.032 m, length of 1 m. The whole cylindrical surface of one rod is 1000 cm^2, i.e. 0.1 m^2. After the melting of ice in measuring cup of normal rain-gauge with the receiver 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 m^{-2}. The calculated average value of both the rods is recorded. The measurements are carried out 3 times a day in the climatic observational terms 7 h, 14 h, 21 h of the local time.

Naturally, the above described measurements do not give absolute values, because the atmospheric icing is created basically only on the windward part of the cylindrical surface. Relatively the most perfect method of the measurement of atmospheric icing represents an ice-meter, the so called "geligraf" in Slovak (on the left side of Fig. 1). A prototype of the geligraf was suggested by Konček in 1951 (*Konček, 1953; Guide book*). Based on the principle of this geligraf, the new type of geligraf was developed in the

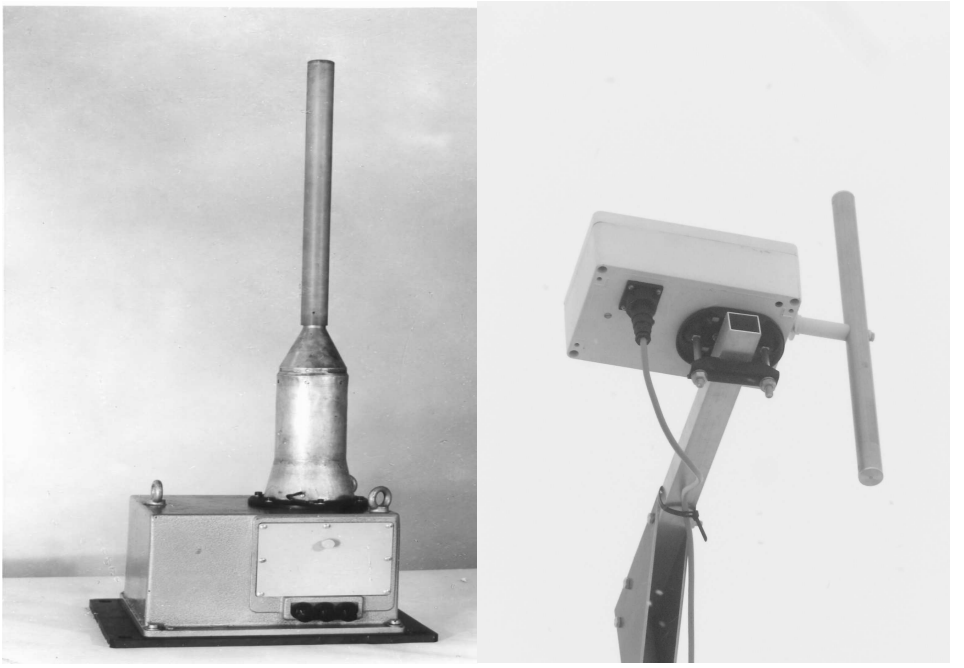

Fig. 1. Two types of ice detector: one according to *Konček (1953)* (left) and second by *Chum et al. (2005)* (right).

workshops of German Academy of Sciences in Berlin and later installed for example at Fichtelberg, Chopok, and Lomnický štít. The instrument enables an automatic registration of atmospheric icing, but at present it does not yet work in Slovakia. Another type of electronic ice-meter that automatically measures the accumulation of icing was developed in the Institute of Atmospheric Physics in Prague (on the right side of Fig. 1) (*Fišák et al., 2000; Chum et al., 2005*). Nowadays this instrument is installed in some localities in the Czech Republic (*Fišák et al., 2001).*

3. Results and discussion

Based on the extensive experimental material of atmospheric icing (47-year terminal amounts at Lomnický štít) which was obtained from the Slo-

vak Hydrometeorological Institute some results are presented.

3.1. Number of days with atmospheric icing

The analysis of the number of days with atmospheric icing shows that in average at Lomnický štít there are 121.7 days in a year with atmospheric icing. The monthly and annual values of the number of days with atmospheric icing vary in dependence on the air masses which occurred at our territory. Cold and moist air masses are the cause a more frequent icing accretion whereas the warmer and in the winter season freezing and dry air masses respectively have a consequence, that the atmospheric icing does not occur. The most frequent occurrence of atmospheric icing was in the year 1985 and the rarest in 1968. It was shown that the maximal occurrence in the year 1985 was 153 days, which represents 126% of the annual average. On the other hand, the minimal number of days with atmospheric icing, 84, in the year 1968 represents about 69% of the long-term average.

The annual course of the number of days with atmospheric icing is presented in Fig. 2. It can be seen that the shape of the curve is simple with a winter maximum and summer minimum. A secondary maximum is in April. The annual amplitude of the number of days with icing is small. Comparison of this course with the corresponding course of the mean monthly amounts of atmospheric icing (Fig. 4) showing the annual course of the number of days is substantially more regular and more expressive than the annual course of the mean monthly amounts of atmospheric icing. Similar difference can be also noticed in individual years, namely in the sense, that, unlike the amount of atmospheric icing, the maximal number of days with atmospheric icing occurs in the cold part of the year from November to April and minimum usually between May to October (the most frequently in August). According to our processing the highest number of days with atmospheric icing was 25 days in January 1976 and December 1988. On the contrary the lowest number of the days with icing (0 days) was recorded 12 times, in the period from June to September.

For comparison of the high-mountain locations of the High and Low Tatras (Lomnický štít, Kasprový vrch, and Chopok) with the other peaks (Zugspitze and Snežka) from the point of view of icing occurrence, the annual courses of the number of days with atmospheric icing in these positions

are introduced (Fig. 3). For this purpose the values of the number of days with atmospheric icing in accordance with: *Hellmann (1915)* for Snežka (1602 m a.s.l.), *Orlicz and Orliczowa (1954)* for Kasprový vrch (1988 m a.s.l.), *Ostrožlík (1978)* for Chopok (2004 m a.s.l.), Schlegel in *Hauer (1950)* for Zugspitze (2962 m a.s.l.), and our results at Lomnický štít (2634 m a.s.l.) were used.

The course of the curves (Fig. 3) shows that there are two different types of the annual course of the number of days with atmospheric icing in the mentioned positions: on one hand – Snežka, Kasprový vrch, and Chopok, on the other hand – Lomnický štít and Zugspitze. The annual course of the mean number of days with atmospheric icing for Snežka, Kasprový vrch, and Chopok characterizes the conditions on the tops and peaks, where the negative air temperatures occur very rare in the summer. On the contrary, the annual course of the mean number of days with atmospheric icing at Lomnický štít and Zugspitze represents conditions which are typical for the higher peaks in the Central Europe (2500–3000 m a.s.l.), where the negative air temperatures at a fog occur often enough also in the months of the warm half-year.

3.2. Annual amounts of atmospheric icing

Rink (1938) shows that at Snežka the amount of melted water from atmospheric icing was 5.25 times higher than the precipitation total which was measured during the period from 2 November 1936 to 18 June 1937. At Lomnický štít the annual amount of atmospheric icing during the 1941-1944, 1947-1962 period represented 59% precipitation measured by normal rain-gauge (*Petrovič, 1963).* Hence, the yield of atmospheric icing is considerable at the high-mountain positions and ought to be also accounted in the calculation of the total water budget of the locality.

According to the mean annual amount of atmospheric icing (908.14 kg m^{-2}) it can be stated that at Lomnický štít there are suitable meteorological and other conditions for the formation of atmospheric icing. It was shown that both the absolute and the relative amplitude of annual amounts of atmospheric icing are high. For example, the maximal annual amount of atmospheric icing was recorded in the year 1983, 1397.05 kg m^{-2}, which represents 154% of the long-term average. On the contrary, the minimal

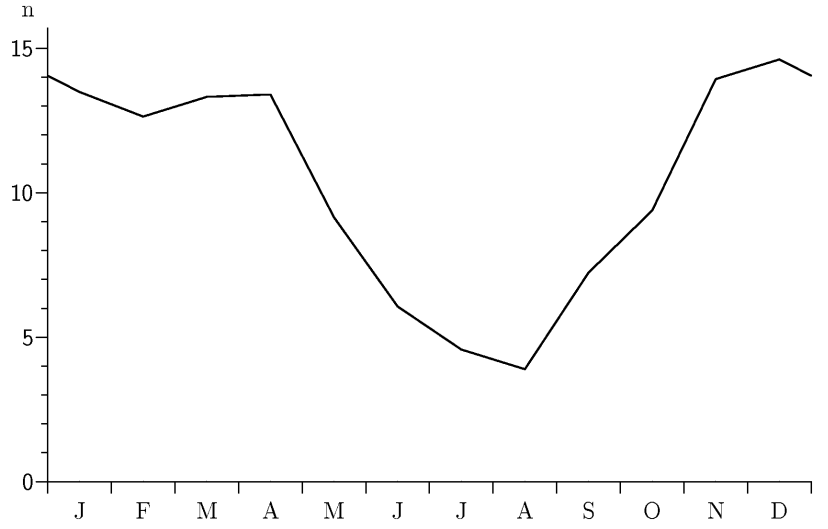

Fig. 2. Annual course of the mean number of days with atmospheric icing at Lomnický štít during the 1957–2003 period.

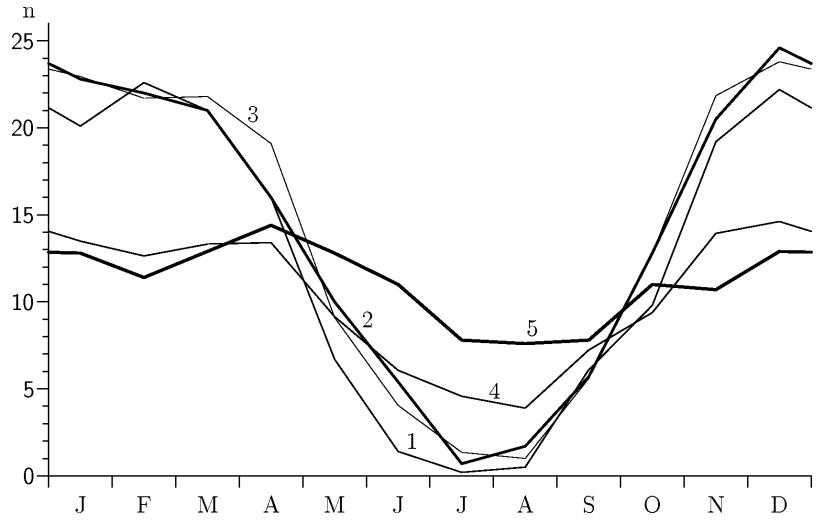

Fig. 3. Annual course of mean number of days with atmospheric icing at Snežka (1) in 1902–1913 period, at Kasprový vrch (2) in 1941–1944 and 1947–1953, at Chopok (3) in 1957–1976 period, at Lomnický štít (4) in 1957–2003, and at Zugspitze (5) in 1900–1949 period.

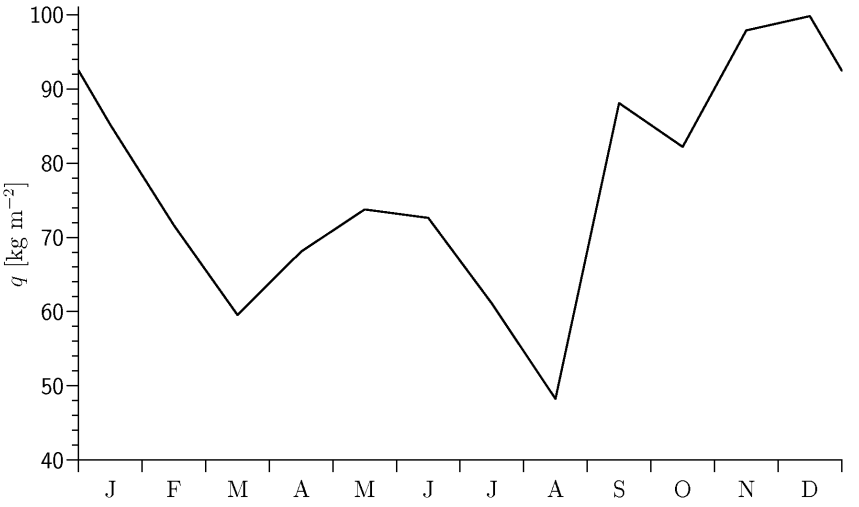

Fig. 4. Annual course of the mean monthly amounts of atmospheric icing at Lomnický štít during the 1957–2003 period.

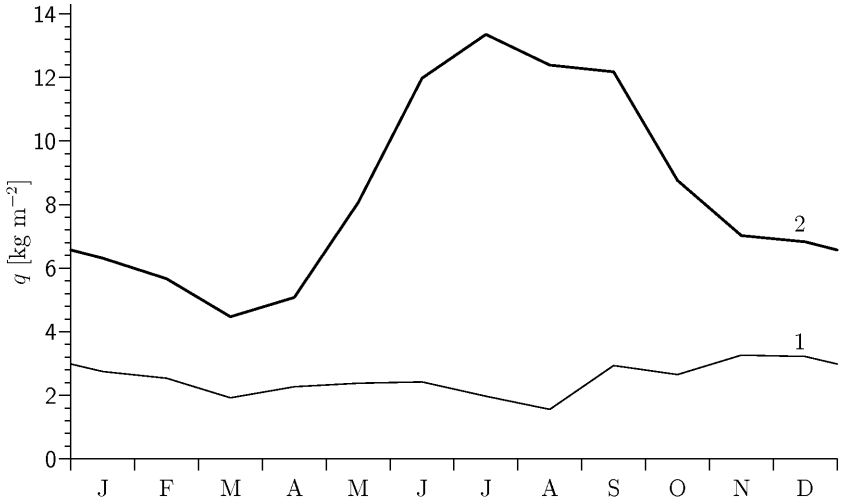

Fig. 5. Annual course of the mean daily amounts of atmospheric icing at Lomnický štít: 1 – during the all days, 2 – during the days with atmospheric icing. Average during the 1957–2003 period.

annual amount of atmospheric icing was in the year 1963, 414.25 kg m^{-2}, what is 46% from the long-term average. Hence, it follows that the annual amounts of atmospheric icing vary in wide ranges at Lomnický štít.

3.3. Monthly amounts of atmospheric icing

Using the average annual value of atmospheric icing the mean monthly amount of icing can be easily calculated. Annual course of the mean monthly amounts of atmospheric icing is illustrated in Fig. 4. It is interesting that the course of the curve is not as simple as it was in the event of the number of days with atmospheric icing and in individual years it can be quite disturbed. The maximal monthly amount of atmospheric icing may occur at any month of the year. Up to now the highest monthly amount was measured 527.75 kg m^{-2} in September 1996. Likewise the minimal monthly amount of icing can fall to any month although the highest probability for that is from May to September. A secondary maximum in the part of the year from April to July is evidently influenced by thermal and circulation factors. As stated above, the occurrence of the atmospheric icing in these months of the year is rare but the invasion of the cold and moist air masses can lead to the formation of abundant atmospheric icing > 100 kg m^{-2}.

3.4. Daily amounts of atmospheric icing

The knowledge of the daily amounts of atmospheric icing, above all their maximal values, has a great importance for the various branches of the practical life: building, power-plant engineering, communications, railroads, forestry, etc. In these branches of the national economy a heavy loading by atmospheric icing can lead to great material damages. Therefore, in the practice we are more and more interested in the results of the observed extreme amounts of atmospheric icing. At the same time it is a characteristic which is at our higher altitudes relatively little known.

The highest mean daily amounts of atmospheric icing during the days with icing (Fig. 5) are in the months of the warm part of the year from June to September with maximum in July (13.35 kg m^{-2}). The other months from October to May have considerably smaller mean daily amounts of atmospheric icing with minimum in March (4.47 kg m^{-2}). In the analyzed

1957–2003 period the maximal daily amount of atmospheric icing at Lomnický štít was recorded on 8 September 1996 (228.60 kg m^{-2}) under the invasion of cold maritime mass. On the other hand, the smallest absolute daily maximum of atmospheric icing 59.60 kg m^{-2} was measured on 2 April 1995. In addition, the obtained results have shown that at Lomnický štít the daily amounts of atmospheric icing > 100 kg m^{-2} are already relatively rare phenomenon with the mean probability of occurrence approximately once in the 5.9 years.

4. Conclusion

Relatively long time series of atmospheric icing measurements in the climatic observational terms by Polanský method at Lomnický štít (1957–2003) enable to obtain the new knowledge of the regularities of atmospheric icing occurrence and its intensity on the tops of Western Carpathian Mountains.

The obtained results have shown that both the number of days with atmospheric icing and its annual course at Lomnický štít are typical in these climatic characteristics for the corresponding mountain zones in the Central Europe. The annual amounts of atmospheric icing at Lomnický štít and the values from other regions of the Central Europe (*Prestin, 1935*) show that in the mountain regions of the Central Europe the total annual amount of atmospheric icing relatively quickly increases with altitude to a certain height and above this level slow decreasing can be seen. According to our results Lomnický štít already lies in the layer of decrease of total amount of atmospheric icing. However, this dependence of atmospheric icing amount on altitude varies in the course of the year. In the cold part of the year the total amount of atmospheric icing has the same dependence on altitude as in the event of the annual amount of icing. But in the warm part of the year from the level in which the atmospheric icing is formed, the amount of icing increases with altitude in the whole vertical measure of the Carpathian Massif.

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