ON THE OPTIMAL LENGTH OF THE HAIL SUPPRESSION SEASON

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Summary. The length of a hail suppression season should depend on the climatology of the hail occurrence. We use hail occurrence data for a large number of stations and a 19-year record of seeding activities in order to show that the hail suppression season in Serbia has the proper starting date, but that there is a strong possibility that a season could end earlier.

1. INTRODUCTION

In order to obtain the optimal length of a hail suppression season, hystorical data ought to be examined. The opening and the closing of the season should depend on the hail climatology over the protected areas.

Currently, the hail suppression season in Serbia starts on 15 April and continues until 15 October. These dates being rather arbitrary, we were interested in determining if the season could be shortened. We were primarily interested in the following three fortnight periods: the end of April, the end of September and the beginning of October.

Available data consisted of the yearly records of graupel and hail occurrences from the 95 meteorological stations in Serbia. Sample sizes ranged from 21 to 44 years, most of them from 30 to 40 years. We have used these records to estimate point and areal probabilities of the hail occurrences.

In addition, we have analyzed seeding records from the 19 seasons of hail suppression that have been conducted in Serbia.

2. POINT HAIL OCCURRENCE

For each fortnight period, for each station, we have estimated the probabilities of the occurrence of hail days. As the estimate of the probability, we have used relative frequency $p=m/n$, where m is the number of years with at least one hail day observed in a given fortnight period and n is the sample size in years.

A summary of the analysis is given in the Table 1. The first column of this table defines a fortnight period. The next five columns give the number of stations with a hail occurrence probability in a given interval. The last column shows the hail probability averaged over all the stations.

For the beginning fortnight of the season, most of the point probabilities are below 0.1. Since the occurrence of at least one hail day is a binomial type variable, its recurrence interval is simply the inverse value of the probability. Thus, for the average probability of 0.082 at the end of the April, the average return period is 12.2 years. For the end of September, the average return period is 83.3 years, and for the last fortnight of the season it reaches even 200 years.

3. AREAL HAIL OCCURRENCE

Generally, the probabilities of hail occurrence are higher over an area than for any given point inside it. The hail suppression system is supposed to protect the area, and this was the reason that the second step of the analysis was to estimate the areal hail probabilities.

For each year in the period 1941-1983 and for the same fortnight periods we have calculated the fraction of the stations experiencing hail. The probabilities of the hail occurrence somewhere in the area are estimated as the ratio of the number of years with recorded hail to the total number of years.

Results are summarized in the Table 2. The first column of this table defines the fortnight period and the second contains the areal hail probabilities. The third column gives the return periods of the hail occurrence and the fourth shows the mean annual fraction of stations recording hail, averaged over the years with hail

Table 2 shows that the return period of the hail in the first half of October is larger than 5 years and that hail affects only some 2% of the stations. On the other hand, in the second half of the April, hail occurs almost every year, and affects almost 10% of the stations.

Table 1. Summary of point data analysis

Period	Number of stations with a p in the interval					Average p
	.00-.05	.05-.10	.10-.15	.15-.20	.20	
16.-30.Apr	35	30	13	7	10	0.082
16.-30.Sep	89	6	0	0	0	0.012
1.-15.Oct	93	2	0	0	0	0.005

Table 2. Summary of the areal analysis

Period	Probability of hail occurrence	Return period of hail occurrence (years)	Mean fraction (%) of stations with hail occurrence
16.-30.Apr.	0.88	1.1	9
16.-30.Sep.	0.37	2.7	3
1.-15.Oct.	0.19	5.4	2

4. SEEDING RECORDS

The most direct way to see whether the season should be shortened or not is, of course, to look into the seeding records. If they show a virtual absence of seeding during a particular period, the answer is straightforward.

In this particular case we had at our disposal seeding records from 1967 to 1986 (except for the 1979). The summary of these records is given in Table 3. The first column of the table defines the period, the second shows the number of years with seeding, and third gives the total number of seeding days over all the seasons. The fourth column gives the total rocket expenditure, which can be used as a rough measure of the hail process intensity.

Table 3. Summary of seeding data

Period	Number of years with seeding	Number of days with seeding	Total expenditure of rockets
15.-30.Apr.	13	46	4098
15.-30.Sep.	13	34	1416
1.-15.Oct.	8	10	195

The most striking feature of this table is that for the 19 seasons there were only 10 seeding days in October, with the 195 rockets used. For the comparison, total number of seeding days over all the seasons was 1190 with 182,348 rockets used.

5. CONCLUSION

The simple analysis described above has shown that risk of hail in the first half of the October is truly marginal. Low probabilities of hail occurrence are underlined by the *de facto* absence of seeding. This clearly points toward an earlier closing date of the season.

Data for the beginning of the hail suppression season seem to confirm its opening date.

Concerning the end of September, the authors feel that additional subregional analysis is needed to see whether the hail affects all of the protected teritory or only some of its parts. If the latter is true, there is possibility of keeping only part of the suppression system active, which would reduce its overall cost.

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