28. SEASONAL VARIATION IN THE RADIANT DISTRIBUTION OF METEORS

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ABSTRACT

The seasonal changes in the sporadic radiant distribution are investigated on the basis of the complete data for different classes of echo duration from the Ottawa 32·7 MHz radar taken over the years 1958–62, using a more accurate response function for the Ottawa radar equipment recently determined by McIntosh (1966). A model of the radiant distribution with four point sources (i.e. apex, helion, antihelion, and toroidal) and a uniform background is assumed. The strengths of the sources have been calculated by a least-squares fit to the observed mean hourly rates in 5-day intervals. The seasonal variations have different trends for meteors with different echo duration, showing stronger shower properties for long-duration echoes (4–8 sec). Meteors with short duration echoes ($\leqslant$ 1 sec) show the same properties in radiant distribution, as was found in a previous paper based on preliminary Ottawa radar records. The toroidal source is without significant activity from August till November and shows a maximum in January. The diurnal variation calculated from this model is compared with the observed hourly rates. Some recent calculations have been made by Veverka and McIntosh (unpublished) using a continuous source model, elliptical in ecliptic longitude and exponential in latitude. The agreement of their results with observed diurnal rates is not as good. This suggests that the seasonal changes in the sporadic radiant distribution have a significant influence on the diurnal and annual variations of the hourly meteor rates.

In a previous paper presented at the Smithsonian symposium two years ago (Štohl, 1967) an effort to find qualitative features of the seasonal variation in the radiant distribution of meteors was made on the basis of the Canadian radar observations. The results showed that the main sporadic radiant sources, namely apex, helion and antihelion, change their strengths significantly during the year. However, because of the preliminary character of the radar data (Millman and McIntosh, 1963) and because of a lack of knowledge of the response function of the radar, the results required verification.

One might expect that the changes in radiant activity should be different for meteors with different magnitudes. For this analysis we used the complete Ottawa radar data, taken over the period 1958–62 at Springhill Meteor Observatory (lat. 45°.2 N, long. 75°.5 W), and numbering in total over 7000000 meteor echoes. The patrol radar equipment, operating at a frequency of 32·7 MHz with an antenna omnidirectional in azimuth and sensitive down to 15° elevation (Neale, 1966) is very convenient for such analysis. Its echoes give a complete count down to the fourth magnitude (Millman and McIntosh, 1964, 1966). The data are given in hourly rates for

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different classes of echo duration and have been corrected for the personal errors of the various film readers and for any interference present on the film record. As such they can be assumed to be the most complete and homogeneous radar material available at the present time.

The method used for calculation of the radiant strength variation is essentially the same as was used in the previous paper. A simple time-dependent model of the apparent radiant distribution is assumed, with a uniform background BG and four discrete sources: apex AP (0°;0°), helion HE (60°;0°), antihelion AH (−60°;0°), and toroid TO (0°;60°), the co-ordinates being given in ecliptic longitude relative to the Earth's apex, and in ecliptic latitude, respectively. For a sufficiently short time interval the total number of meteors is assumed to be given by superposing the activities of all sources according to their zenith distances. If T is the time of year and t the hour of the day, the hourly echo rate $F(T, t)$ is given by

$$F(T, t) = \Sigma\xi_i(T) \times \Phi(z_i(T, t)), \quad i = 1\text{·}5, \tag{1}$$

where $\xi_i(T)$ are the strengths of the individual radiant sources (i.e. AP, HE, AH, TO and BG), $\Phi(z_i)$ is the response function of the equipment, corresponding to the mass distribution of the meteors for the individual sources and to their zenith distances z_i.

The zenith distances of the radiants can be calculated from the known ecliptic co-ordinates for each radiant and time interval. The response function remains therefore as the main problem. For Ottawa radar equipment the theoretical response function was determined recently by McIntosh (1966). For the overdense echoes it corresponds to the equation, known for the visual observation,

$$\Phi(z) = \cos^n z, \tag{2}$$

with $n = 2\text{·}0$ for $z = 13$–90°, and $\Phi(z) = 0$ for $z = 0$–13°. A similar response function was used in the previous paper, except for the range of zenith distances 0°–13°. However, for the underdense echoes, which are dominant among the observed echoes, the response function is different, showing a maximum at $z = 46°$ for meteors with the mass exponent $s = 3\text{·}0$, at $z = 40°$ for $s = 2\text{·}0$, and at $z = 30°$ for $s = 1\text{·}5$. The response function will be different for individual radiant sources, which have different mass exponents. This was taken into account for final calculations. The velocity effect, which is important for long-duration echoes, was not taken into account, as only the classes of 0–1 sec and 4–8 sec were used in the final calculations.

Using the mean hourly rates and the values of the response function corresponding to the calculated zenith distances of radiants for a given time interval, we derive 24 equations of condition of the type (1). From these we calculate the strengths $\xi_i(T)$ of the individual radiants for each period of the year by the method of least-squares. In this way we have derived the seasonal variation in the strengths of radiants, presented in relative units in Figure 1. Differences in variation between the two classes of echo duration are immediately apparent. The results for short echo durations ($\leqslant 1$ sec) in general show a variation, similar to that found previously, with a strong

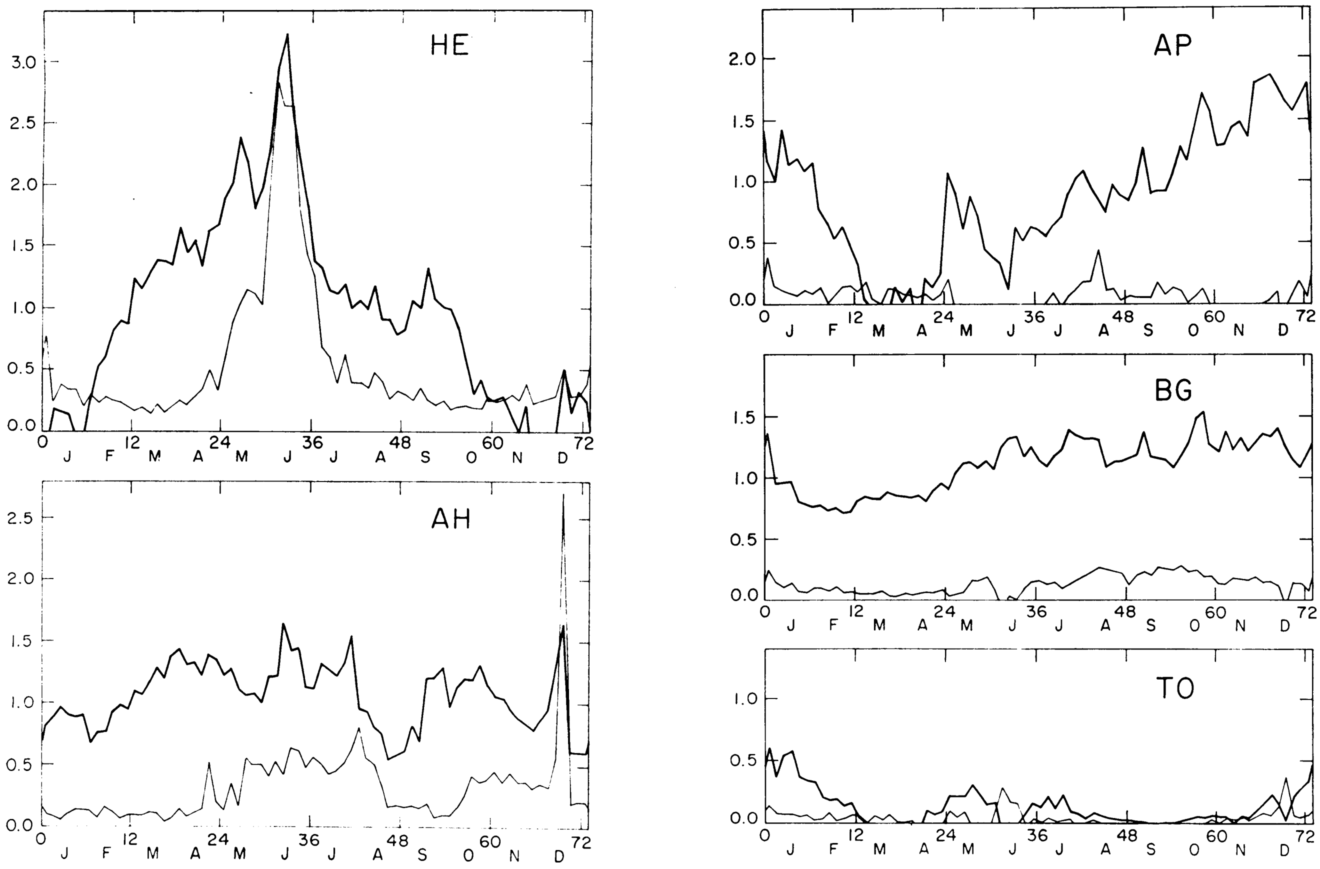

FIG. 1. *The seasonal variation in the relative strength of the main sporadic sources (HE = helion, AH = antihelion, AP = apex, BG = background, TO = toroid). The heavy lines correspond to the echoes of ⩽ 1 sec duration, the light ones to 4–8 sec.*

maximum in May–June and secondary maximum in September for HE source, with a slight maximum in May–July and in October for AH, a maximum in the second half of the year for AP, and relatively constant activity for BG. The toroidal source is without significant activity from August until November and shows a maximum in January. This maximum seems to be the main period of the toroidal activity.

For the long-duration echoes (4–8 sec) the variation is different. The HE source shows constant activity all year, except for a sharp maximum in May–June. In the AH source activity the Geminid shower produces a dominant maximum, because of its very close position to the AH-point. The activity of the AP source is without any notable variation. These differences can be explained by weaker shower properties of smaller meteors, in the sense that their orbits are more diffused.

In Figure 2 are shown the observed hourly echo rates (plotted as points) for six

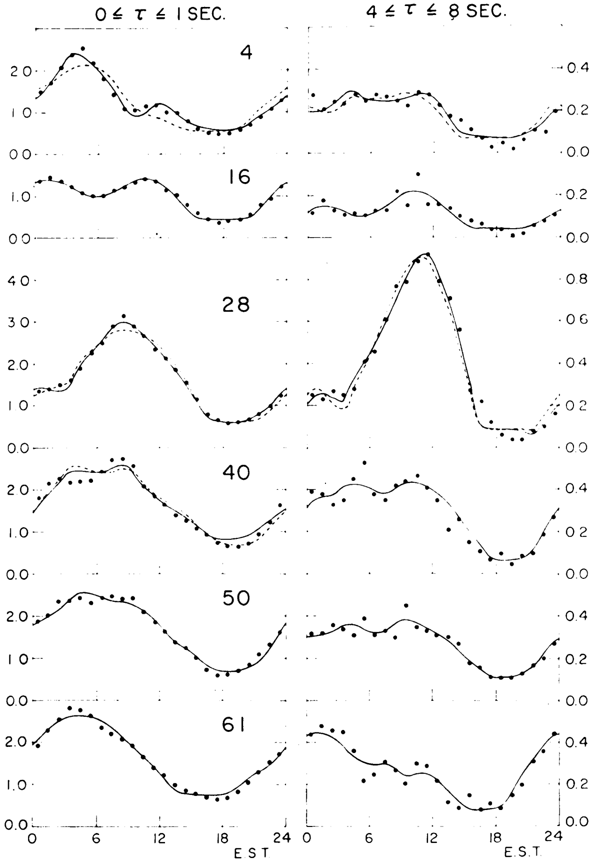

FIG. 2. *Observed and calculated diurnal variations for some intervals of the year. Points correspond to the observed hourly echo rates, the smooth curves to the rates calculated for the model including TO source, the dotted curves to the model without TO source.*

different periods of the year, both for short- and long-duration echoes. The calculated diurnal variations for each period, which corresponds to the obtained variation in the strengths of the radiants, are plotted (Figure 2) as the smooth curves. The dotted curves correspond to the model without the toroidal source. It is apparent that in some cases the neglect of the toroidal source can change significantly the calculated diurnal variation. The numbers of the 5-day intervals are given according to the notation used by Millman and McIntosh (4, Jan. 16–20; 16, March 17–21; 28, May 16–20; 40, July 15–19; 50, Sept. 3–7; 61, Oct. 28–1).

The radar data used for our calculations include not only the sporadic, but also the shower meteors. This would seem to be inconsistent with our method assuming a model with sporadic radiant distribution only. But, the activity of the showers is significant only in the long-duration echo rates, and is practically lost in the background of the faint sporadic meteors (Millman and McIntosh, 1964). By neglecting the shower activity in our calculations we may expect only the results for long-duration echoes to be significantly influenced, and this only for showers with position close enough to the sporadic radiant sources, and with a sufficiently long duration of activity. This is the case for the Geminid shower, the influence of which is of little importance for the general results.

As results of this analysis the following conclusions can be made: (1) the variation of the activity of the main sporadic sources is so evident, that it should be taken into account for all radiant distribution models; (2) the seasonal changes in the activity of the sporadic radiant sources have a significant influence on both the diurnal and annual variations of the hourly meteor rates; therefore, (3) it would be very useful to study this variation in more detail on the basis of both radar and photographic meteor orbits.

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DISCUSSION

Southworth: Have you made any numerical experiments on the effect of broad sources rather than point sources? I am afraid that the results would be quite different.

Štohl: No, this was not made.

Elford: In commenting on Dr. Southworth's question I would like to report that I have carried out a similar type of analysis using both broad and point sources. There is a significant difference between the results. And now I would like to direct a question to the speaker. Have you compared your results with those of the New-Zealand workers?

Štohl: Yes, it was done in the previous paper, in which the results were very similar to those for short-duration echoes.

Belkovič: Did you take into account effects of the meteor-train initial radius?

Štohl: That was not taken into account.

Lebedinec: Since the equipment permitted a record only of meteors brighter than $+4^{m}$, the effect of the initial radius was insignificant and it was obviously possible to neglect it.

Kaiser: I do not think our present knowledge is sufficiently good for us to make accurate corrections for the effects of initial radius, but we do know that in some circumstances they may be large. Thus in cases where the effects are large, we cannot yet rely on statistical analysis even when a correction has been attempted.

Southworth: McCrosky and I are trying to start a program which may answer the initial-radius problem among others. We will observe the same meteor with a television camera and the Havana Radar System.