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DIURNAL VARIATION OF OVERDENSE METEOR ECHO DURATION AND OZONE

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Abstract

The diurnal variation of the median duration of overdense sporadic radar meteor echoes is examined. The meteors recorded in August, December and January by the Ondřejov meteor radar during the period 1958-1990 have been used for the analysis. A maximum median echo duration 1-3 hours after the time of local sunrise in the meteor region confirms the already known sunrise effect. Minimum echo duration occurring at the time of sunset seems to be the most important point of diurnal variation of the echo duration, when ozone is no longer dissociated by solar UV radiation. The effect of diurnal changes of the echo duration should be considered when the mass distribution of meteor showers is analysed.

1. Introduction

An enhancement of the proportion of long-duration radio echoes from Quadrantid meteors recorded after sunrise was found by Hughes and Baggaley (1972). The term "sunrise effect" was introduced by Nicholson and Poole (1974) from the analysis of Quadrantid shower echo rates but similar changes during non-shower period were not found.

McIntosh and Hajduk (1977) examined the occurence of long-duration sporadic meteor echoes recorded by the Ottawa patrol radar in the period 1963-1967. They demonstrated an increase in the relative proportion of long-duration echoes during sunlit periods over comparable rates in the dark hours. The authors discussed the mechanism for effecting echo duration changes and noted that ozone concentration changes could play a significant role.

The influence of ozone to the duration of overdense radio meteor echo was described by Jones et al. (1990). This work is based on the theory of Baggaley and Cummack (1974) that the most effective process of free electron loss in a meteor trail results from reactions such as

$$M^+ + O_3 \qquad MO^+ + O_2$$
$$MO^+ + e \qquad M + O$$

where M^+ is the meteoric ion. Jones et al. pointed out the lack of a formula for determining the mass distribution index of meteoroids from the observationally-obtained duration distribution of overdense meteor echoes resulting from the fact that the concentration of O_3 versus altitude and its diurnal and seasonal variation are complicated and not well known.

It is possible, however, to examine the diurnal variation of median echo duration, which could reflect the influence of atmospheric chemical processes on the duration distribution.

2. Median echo duration

The number of echoes, N_c, with durations T or greater, is given in integral form as

$$(1) \qquad \log N_c = -3/4\ (s - 1) \log T + \text{const.},$$

where s is a distributive constant which is proportional to the slope of $\log N_c$ vs $\log T$ plot. Assuming s to be a function of T, McIntosh and Šimek (1974) derived a modification of Eq (1) in the form

$$(2) \log N_c = -3/4\ [s_0 - 1 + s_1(\log T) + s_2(\log T)^2] \log T + \text{const.},$$

where $s = s_o + s_1 \log T + s_2 (\log T)^2$.
Providing s is a function of T one can associate values of s with the median and end points of the duration interval. Median duration $\bar{T}$ corresponding with median value $\bar{s}$ is then expressed as

$$(3)\quad \log \bar{T} = - \frac{4 \log[0.5(T_A{}^{-3(sA-1)/4} + T_B{}^{-3(sB-1)/4})]}{3(\bar{s} - 1)}$$

where substripts A and B designate values at the end points. If the duration interval is open, i.e. a count down to a limiting duration $T_A = 1$ s, then Eq (3) is modified as

$$(4)\quad \log \bar{T} = - \frac{4 \log 2}{3(\bar{s} - 1)}$$

Whole range of echo durations $0.4 \leq T \leq 50$ s was divided into 16 classes to determine s and s values. Eqs (2) and (5) were combined in an iterative process to calculate the final median duration $\bar{T}$.

Two periods of sporadic activity were examined. Due to diurnal echo rate variation and a lower number of observed periods between 15^h and 20^h LT, the number of echoes available was very low, and, though the data were collected over many years, it was necessary to combine December and January observations into one set of data. August sporadics represent the second investigated period. While the data from the December-January months consist of 77739 echoes (maximum number of 8626 at 3^h LT, minimum number of 206 at 19^h LT), the August period contains 47888 echoes (maximum of 3233 at 0^h LT, minimum of 654 at 18^h LT). Note that total observing time in particular hours is not equal.

3. Results and discussion

Values of $\bar{T}$ are plotted in Fig. 1. Both curves show diurnal variation with significant comparable features.

1) The maximum value of $\bar{T}$ occurs 1-3 hours after the time of local sunrise at a height of 93 km, an effect similar to that determined by McIntosh and Hajduk (1977).
2) Even when the August curve is so flat from 17^h to 21^h that there seems to be no clear minimum value of $\bar{T}$, the lowest point on the $\bar{T}$ curve leads to the suggestion that the time of sunset is an important turning point in both examined periods.
3) Median echo durations are characterized by a slow rate of increase during the first hours of darkness-up to midnight.
4) A more rapid increase in the proportion of long-duration echoes starts about 5-6 hours before the time of the sunrise effect.
5) The decrease of $\bar{T}$ from maximum to minimum takes place in about 8 hours. This period corresponds with daylight in December--January, while in the August results it extends only slightly past noon, with the remaining daylight hours showing only a slow variation and minor fluctuation.
6) The pronounced low value of $\bar{T}$ at 6^h in August coincides with maximum elevation of the Apex of the Earth's way. A similar effect is possible, but not so definitive, in the December--January data when the Apex is lower.
7) Absolute values of $\bar{T}$ are similar on both curves within the intervals $9^h - 12^h$ and $15^h - 19^h$.

There are basically two different features of both curves in

Fig. 1 which should be considered:

a) the striking difference in the absolute values of $\overline{T}$ at the time of the sunrise effect between the August data and the December-January data. $\overline{T}$ is higher for the former by 0.73 ± 0.12 s than for the latter. Minimum $\overline{T}$ values at the time of

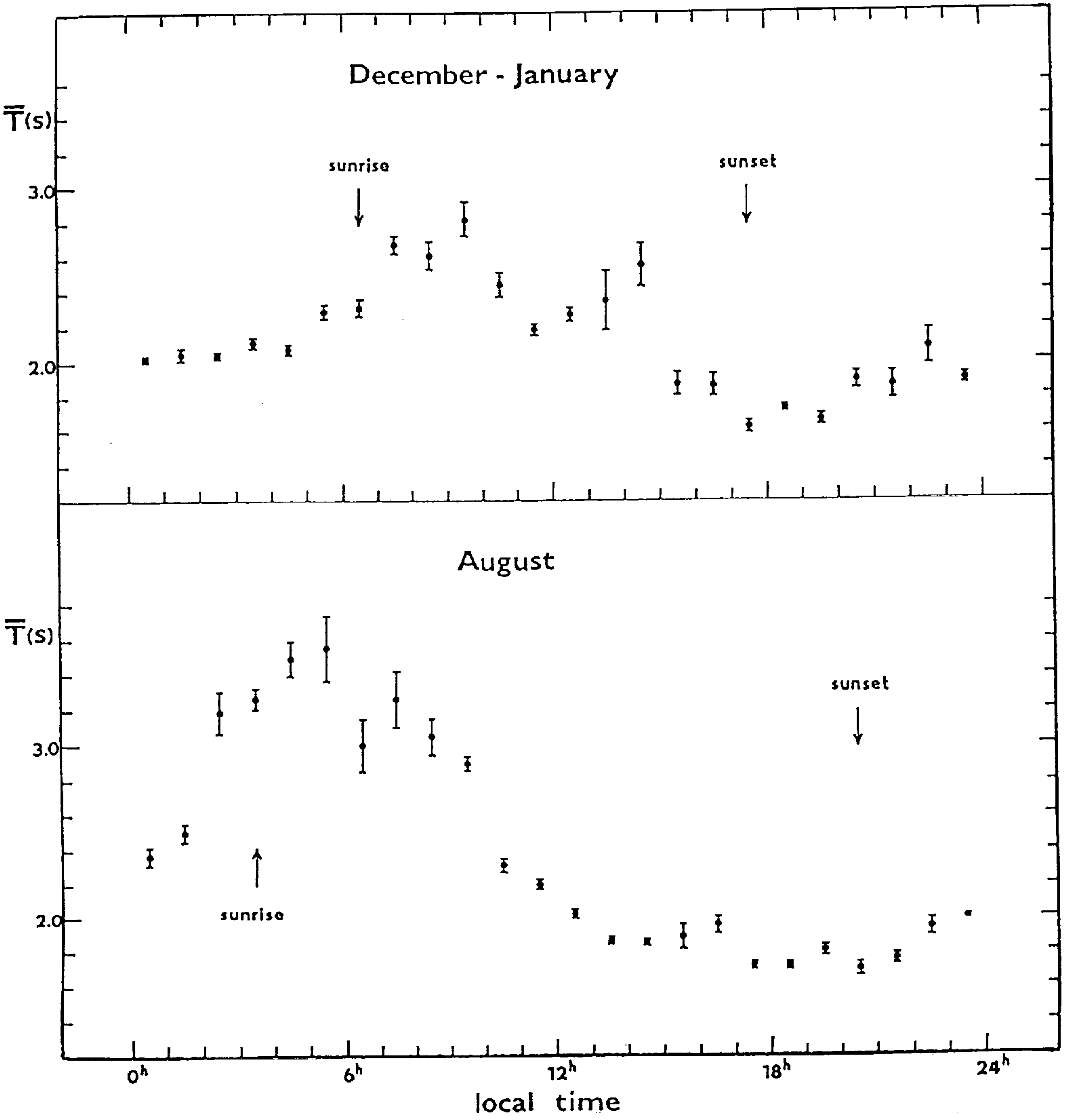

Fig.1. Median duration $\overline{T}$ of sporadic meteor echoes with durations $T \geq 1$s

sunset are in both periods practically the same;

b) the secondary maximum of *T* in the December/January data between 12^h and 15^h is unusual and not understood.

McIntosh and Hajduk (1977) analyzed the rates of long-duration echoes recorded by the Ottawa patrol radar for the period 1963-1967. The results of their study and the work presented here are consistent and matually confirming. We will not repeat here their explanation of different features of the results with respect to the phenomena which may significantly influence the variations under discussion.

The diurnal variation of meteor velocity affects the heights at which meteors ionize. The diurnal change in the distribution of meteor velocities depends on the distribution of sporadic meteor sources and on the time of year (and varies also with the echo duration). The velocity effect is superimposed on diurnal variation of echo duration. Echo duration depends on particle mass, velocity, and height;and height depends mostly on the first two. Because of the higher elevation of the Apex at 6^h and consequent higher mean velocity, smaller particles produce echoes with the same duration as from larger particles at 18^h. We record meteors in a fixed interval of durations. The mass at the short-duration treshold changes with velocity and therefore is a function of time of day and time of year (i.e., Apex elevation). The duration interval in which we measure can be thought of as sliding up and down the mass curve over the diurnal cycle of velocity variation producing both the observed variation of duration-distribution slope and the absolute differences in median duration.

The behaviour of diurnal and seasonal variations of median echo duration has certain consequences in determining the mass--distribution coefficients either of the sporadic complex or of a meteor shower. Particular attention should be given when data collected at different hours are to be used and the results compared. This is significant mainly in the analysis of meteor showers having a short period of activity. It is possible that analyses similar to the one carried out here of the diurnal variation of *T* for meteors of individual meteor showers where the velocity is constant and known, will show to incorporate the features discussed here into mass-distribution studies of overdense echoes.

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