Distribution of meteor heights and solar cycle activity

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Abstract. Photographic observations of the Perseid meteors are analysed and discussed from the point of view of a possible long-term variation of meteor heights. The variation as suggested previously on the basis of radar observations is apparently a function of the solar cycle and is most evident on the endpoint heights distribution. The observed endpoint heights of the photographic Perseids, normalized and corrected for standard factors influencing the height distribution, exhibit no variation correlating with solar cycle activity.

Key words: meteors – activity of the Sun

1. Introduction

Studies of various correlations between meteor parameters and the changing upper atmospheric conditions have been enabled by meteor data statistics, substantially supported by radio observations. The correlations have both short-term and long-term characters and are attributed to the relevant changes in atmospheric properties caused by the solar radiation flux and geomagnetic activity.

As for the short-term variations, an enhancement of persistent overdense echoes of the Quadrantid meteor shower immediately after sunrise was observed by Hughes and Baggaley (1972). Analysing persistent echoes from sporadic meteors McIntosh and Hajduk (1977) found that the proportion of the echoes increases rapidly after sunrise at meteor heights. Similarly, Porubčan and Cevolani (1983) have observed mean sporadic echo heights to vary with respect to local sunrise, with a minimum height occurring after sunrise. Solar-influenced meteor rate changes on a time scale of days were studied by Lindblad (1978), and it

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has been shown that the rates appear to depend on geomagnetic activity and solar corpuscular radiation.

A long-term variation in meteor radar rates, with a peak occurring near the solar minimum has been reported by Lindblad(1967). His analysis was based on radar observations carried out at the Onsala Observatory (Sweden) in 1953-1965, later extended to 1972 (Lindblad 1976). Analysing radar meteor rates from New Zealand and Canada, Ellyett (1977) has confirmed an inverse relationship between meteor rates and solar activity as measured by sunspot numbers. Lindblad's analysis was also extended to the distribution of meteor heights and trail lengths. These quantities have been found to vary with the solar cycle; their changes seem to be an atmospheric affect, the explanation proposed for it being a Sun-controlled variation of the atmosheric density gradient at the meteor ablation height.

The present paper was aimed at verifying the variation of meteor heights on the basis of photographic observations as the most precise in positional measurements of meteors.

2. Analysis of the observations

Let us remind that the correlation between solar activity and meteor heights or trail lengths as suggested from radar observations has been derived on the basis of the heights obtained from combined radar-visual observations and, therefore, they are much less precise than the photographic heights. It is true, however, that the lower precision was compensated to a certain degree by the large sample of radar data, much larger than the one available from photographic observations.

Our analysis was restricted to the Perseid meteor shower which is the best represented meteor shower in photographic catalogues (254 Perseids, followed by 81 Geminids, photographed till 1967). The reason for this restriction is in the fact that the observed meteor heights depend on the velocity of the meteoroid entering the atmosphere, its mass, composition, structure and zenithal angle of the radiant. To verify the variation of the heights it is necessary to analyse a homogeneous set of data. Sporadic meteors form an inhomogeneous set in all aspects mentioned above, contrary to a meteor shower with all its members having similar orbital velocities and physical parameters. The analysis of the Perseids allows our results to be compared directly with Lindblad's.

Radar observations at the Onsala Observatory were performed regularly in August and the main observational sequence included the period of activity of the Perseid meteor shower. Lindblad (1967 and 1976) reported, from the observations, a long-term variation in the echo count rate and the Perseid echo heights. While the heights at which meteors appeared remained nearly constant, at about 110 km, the endpoint heights varied from the lowest value of 85 km near sunspot maximum to the highest value of 96 km near sunspot minimum.

The conclusion was that the hourly rates and endpoint heights vary periodically, apparently as a function of the solar cycle.

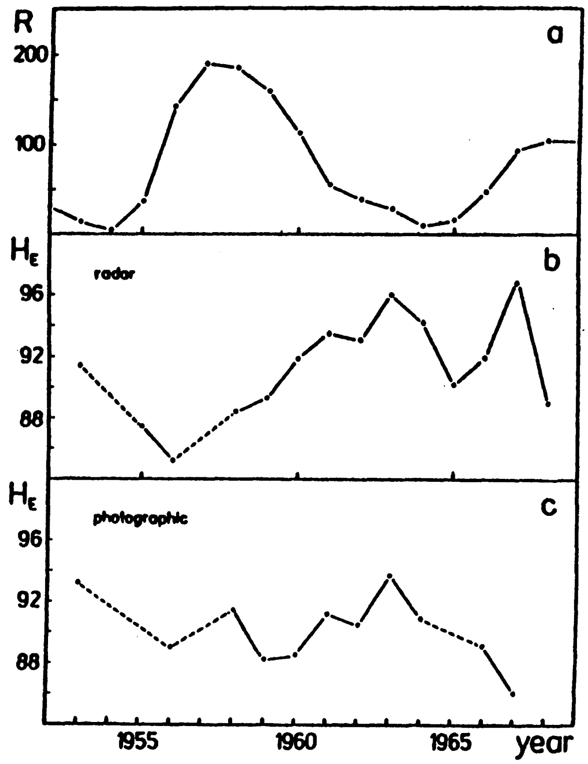

Figure 1. Mean solar activity represented by the mean annual Zurich sunspot numbers, R, (a) and the mean endpoint heights of Perseid meteors, H_E, from radar-visual observations (b) and photographic observations (c).

To minimize the influence of dispersion in velocity on meteor heights, as the first step only Perseids with heliocentric velocity V_H close to the mean velocity of the stream were included in the analysed sample. Fig. 1c depicts the mean endpoint heights H of the Perseids with $V_H = 41.5 \pm 1$ km/s (171 meteors) observed in 1953-1967 from all photographic catalogues (1954, 1955, 1957 and 1965 are missing). The observations cover a complete period of one solar cycle, which can be seen from Fig. 1a, summarizing the mean annual Zurich sunspot numbers in 1952-1969. Photographic endpoint heights do not display such a distinct variation as the radar heights shown in Fig. 1b (Lindblad 1976). Exceptionally high and deviating from the assumed course of the variation is the value of H_E in 1958 (a mean of three different catalogues), but, on the other hand, the photographic heights in the years following the 1963 peak seem to satisfy the suggested variation of H_E better than the radar heights.

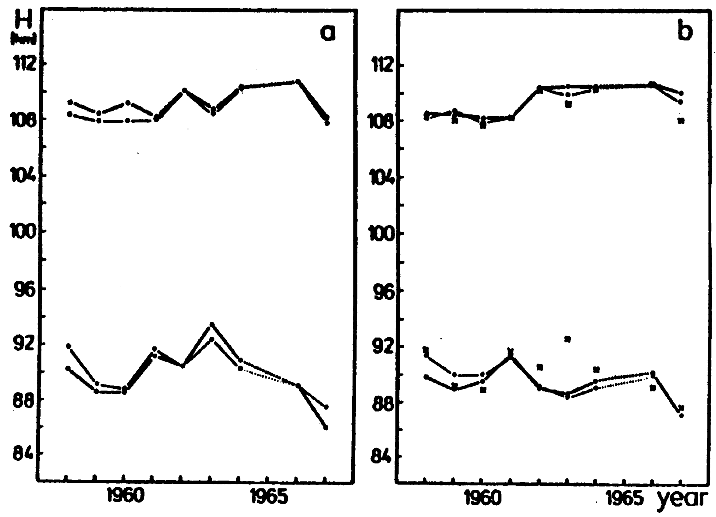

Figure 2. Mean photographic heights of Perseid meteors (upper plots - beginning heights, lower plots - endpoint heights) observed in Dushanbe and Odessa in 1958-1967: (a) observed distributions for Perseids with $V_H = 41.5 \pm 1$ km/s (bold lines) and for all Perseids (thin lines); (b) normalized distribution according to the maximum photographic absolute magnitude (crosses indicate distributions normalized with respect to V_H).

The variation of H_E in Fig. 1c represents the mean heights of the Perseids from all photographic catalogues, i.e. observed in different places and with various cameras. The longest and at the same time very homogeneous series are formed by the observations of Perseids from Dushanbe (38.6°N, 68.6°E) and Odessa (46.6°N, 30.6°E) made at both stations with the same type of camera (Babadzhanov and Kramer 1967). Therefore, these observations were analysed separately. Fig. 2a shows the mean beginning (H_B) and endpoint (H_E) heights of the Perseid meteors observed in Dushanbe and Odessa in 1958-1967 (Babadzhanov and Kramer 1963 and 1967; Babadzhanov and Getman 1985; Babadzhanov et al. 1969). The data since 1962 are only from Dushanbe. The bold lines depict the Perseids with $V_H = 41.5 \pm 1$ km/s (100 meteors) and the thin lines the Perseids with of $V_H = 41.5 \pm 4$ km/s (148 meteors; from the set of all Perseids were omitted those with exceptionally high or low V_H exceeding approx. the 3σ limit, where the standard deviation in V_H, $\sigma = 1.4$ km/s). The distribution of H shows no systematic variation with the solar cycle in agreement with the radar results. However, in the distribution of H_E, especially in the sample of the Perseids from the narrow range of V_H, there is a systematic variation, with an H_E peak in 1963. Lindblad concluded that the higher radar rates are observed 4-6 years after the solar maximum, and the lowest 1-2 years before the solar maximum, and that the mean endpoint height and trail length of meteors of a given shower vary consistently with the radar rate curve. The maxima of the solar cycle covering the analysed period (Fig. 2) appeared at the end of 1957 and at the beginning of 1969. The variation of H_E in Fig. 2a is consistent with Lindblad's conclusion. Unfortunately, photographic observations after 1967 are missing and, therefore, the variation cannot be considered conclusive.

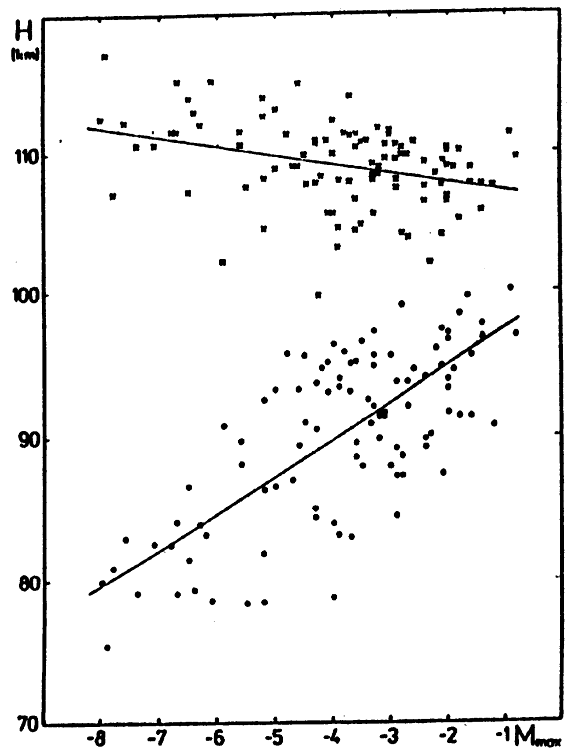

Figure 3. Heights of photographic Perseid meteors vs. maximum photographic absolute magnitude (crosses - beginning height, points - endpoint heights).

Endpoint heights of meteors strongly depend on the masses of meteoroids. This fact must be taken into account and the heights of individual meteors have to be normalized according to their masses or brightnesses in order to derive an objective variation of the heights. In Fig. 3 are plotted the beginning and endpoint heights of the Perseids from Dushanbe and Odessa, versus the maximum photographic absolute magnitude, M_{max}. A very significant correlation between H_E and M_{max} is evident. Applying the derived regression lines from Fig. 3 to the data (H_B = 106.9 - 0.53 M, H_E = 99.3 + 2.41 M), the observed heights were corrected and normalized to a common absolute magnitude M_{max}

= -4. The corrected variations are plotted in Fig. 2b. These show no systematic change of the mean heights of the Perseids in the analysed period of 9 years. In order to check to what extent the variations in Fig. 2a are influenced by the dispersion of the velocity and angle of incidence, the regression lines for H_B and H_E as functions of V_H and cos z_R (z_R is the zenithal distance of the radiant) were also found from the same sample of data ($H_B = 75.6 + 0.79\ V_H$, $H_E = 79.2 + 0.28\ V_H$ and $H_B = 109.7 - 1.96 \cos z_R$, $H_E = 89.8 + 1.54 \cos z_R$). The corrected distribution for V_H (normalized to $V_H = 41.5$ km/s) are depicted in Fig. 2b by crosses. The variations do not differ too much from the observed shown in Fig. 2a, indicating that the differences in velocity contribute very little to the observed trend of the Perseid meteor heights. This is due to the relatively small dispersion of V_H, as almost 70 % of the Perseids in the sample have V_H within the limits of 41.5 ± 1 km/s. Similarly, almost no contribution of the changing incidence angle in the observed variation of Perseid heights was observed.

As is evident from Fig. 3, the beginning height of a meteor is not as sensitive to the mass of the meteoroid as the endpoint height. Consequently, the mean H_B, as opposed to the mean H_E, should not vary as appreciably with the varying mean mass, which has been confirmed by both the radar and photographic samples of the Perseids.

3. Discussion

Summarizing the results, the variations of the photographic Perseid endpoint heights observed in 1958-1967 can be explained by the different mean mass of the meteoroids observed in successive returns of the shower. However, due to the small sample of the photographic data (on an average 16 heights per year), though of much higher accuracy, this cannot be conclusive in explaining the variation derived from the radar data (on an average 109 heights per year). The long series of visual observations made at the Skalnate Pleso Observatory in 1944-1954 (Kresáková 1966) has revealed that the mean magnitude of the observed Perseid meteors may vary from year to year and also systematically over several years. In the densest part of the shower ΔM was observed to change by as much as one magnitude. It can then be suggested that also the radar variation of meteor height may be influenced, at least to some extent, by a similar effect. Hughes (1976) and Ellyett(1980) have suggested that the sign of the variation in meteor rates changes with the mass distribution index of meteoroids; the observed rate near solar minimum increases if $s > 2$, remains constant if $s = 2$ and decreases if $s < 2$. This variation of the rate as a function of s has not been proved. From a direct correlation of the variation of rates and endpoint heights derived from radar observations, the bright photographic meteors analysed here, with $s < 2$, should exhibit a minimum in heights near solar minimum, however, this was not observed either. In conclusion it can be said that the distribution of the photographic meteor heights displays no definite variation which might correlate with solar activity over a period of the whole cycle.

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References

Babadzhanov, P.B., Getman, T.I.: 1985, *Bull. Inst. Astrophys. Tadjik Acad. Sci.* **76**, 28
Babadzhanov, P.B., Getman, T.I., Zausayev, A.F., Karaselnikova, S.A.: 1969, *Bull. Inst. Astrophys. Tadjik Acad. Sci.* **49**, 3
Babadzhanov,P.B., Kramer, E.N.: 1963, *Rez. M.G.G., Ionosfera i meteory* **12**,
Babadzhanov, P.B., Kramer, E.N.: 1967, *Smithson. Contrib. Astrosphys.* **11**, 67
Ellyett, C.D.: 1977, *J. Geophys. Res.* **82**, 1455
Ellyett, C.D., Kennewell, J.A.: 1980, *Nature* **287**, 521
Hughes, D.W.: 1976, *Space Res.* **16**, 333
Hughes, D.W., Baggaley, W.J.: 1972, *Nature* **237**, 224
Kresáková, M.: 1966, *Contrib. Astron. Obs. Skalnaté Pleso* **3**, 75
Lindblad, B.A.: 1967, *Space Res.* **7**, 1029
Lindblad, B.A.: 1976, *Nature* **259**, 99
Lindblad, B.A.: 1978, *Nature* **273**, 732
McIntosh, B.A., Hajduk, A.: 1977, *Bull. Astron. Inst. Czechosl.* **28**, 280
Porubčan, V., Cevolani, G.: 1983, *Bull. Astron. Inst. Czechosl.* **34**, 213