Effective number of meteors in a reduced field of view

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A reduced field of view, such as in telescopic or video observations, causes an overestimation of the ZHR because partially observed meteor trails are counted as a whole rather than a portion of a meteor. Given that the observer does not know which portion of a meteor trail is observed, or if its mid-point is in the field of view or outside of it, the most probable number of meteors with the mid-points inside the field of view can be estimated by correcting the number of the observed meteors. We simulated an observation of a meteor shower, approximating the sky as a two-dimensional plane. Two parameters have been varied: a ratio of the radiant distance from the center of the field of view to the diameter of the field of view, and a ratio of the meteor trail length to its distance from the radiant. Observed meteors are classified in four classes, depending on which part of a meteor is in the field of view, and correction coefficients for each meteor class are computed.

1 Introduction

To calculate the ZHR of a meteor shower one needs to know the number of meteors observed in the field of view (FOV) for a given time period of observation. The problem with counting is that meteor trails are not point-like objects hence some meteors are only partially inside the FOV. Determining whether the partially observed meteor is located inside or outside of the FOV could be done by considering the position of a meteor trail mid-point relative to the FOV. In order to estimate the most probable number of meteors inside the geometric FOV, corrections to the total number of meteors seen should be computed.

An analytical approach for computing correction coefficients is applied by Kresáková (1977). In her work, the sky is approximated as a two-dimensional plane, and all meteors are of the same length, distributed randomly across the sky without preferred direction of the meteor trail. It is also assumed that the sensitivity of the instrument is the same across the entire FOV.

Our work is mainly inspired by the work of Kresáková. In this paper we re-examined the same problem with more diverse geometry by introducing the shower-like trail orientations and a relationship between the length of the meteor trail and its distance from the radiant. We approached the problem by running a Monte-Carlo simulation of the observation.

2 Simulation

We approximated the sky by a two-dimensional plane in which a square-shaped generative field is defined. The radiant is generated as a point-like object and the FOV is defined by a circle of diameter D. Inside the generative field, the meteors are generated by randomly choosing mid-points of meteor trails. Dependence of the length of the trail L on the distance of the trail mid-point from the radiant ψ is given by

$$L = \omega\psi \qquad (1)$$

where ω is the length parameter. Parameter ω is a characteristic of a meteor stream. For meteors of the same shower and same magnitude class (such as those considered in this paper) the value of ω depends strongly on the altitude of the radiant and the altitude of the beginning point of the trail. The value of ω is roughly constant if ψ is less than 30º. The distance between the radiant and the center of the FOV is recommended to be less than 40º (Koschack, 1990). Therefore, we neglected the dependence of parameter ω on the two mentioned altitudes, i.e. ω is approximated as a constant. With that in mind, equation (1) implies that $L/D = \omega * \psi/D$, i.e. that in our simulation L/D and ψ/D are the same parameter up to a multiplicative constant.

The orientation of a meteor trail is determined by the position of the trail mid-point and the position of the radiant in the sky which are defined in the simulation. The positions of the begin of a trail and the termination points can be calculated since the length of a trail and the direction of its orientation are known.

The observed meteors are classified in the following four classes (notation for each class is given in the quotes):

- Meteors with only beginnings in the FOV – "B"
- Meteors with only terminations in the FOV – "T"
- Meteors entirely in the FOV – "E"
- Meteors passing through the FOV – "P"

To examine whether the meteor belongs to one of the four classes, the following set of geometrical requirements are derived:

$$\left(x_b - x_{fov}\right)^2 + \left(y_b - y_{fov}\right)^2 < (D/2)^2 \qquad (2)$$

$$\left(x_t - x_{fov}\right)^2 + \left(y_t - y_{fov}\right)^2 < (D/2)^2 \qquad (3)$$

$$\left(x_b - x_{fov}\right)^2 + \left(y_b - y_{fov}\right)^2 < L^2 + (D/2)^2 \qquad (4)$$

$$\left(x_t - x_{fov}\right)^2 + \left(y_t - y_{fov}\right)^2 < L^2 + (D/2)^2 \qquad (5)$$

Table 1 – Classes of meteors seen and corresponding geometrical conditions that must be true (T) or false (F).

Meteor classes	Conditions				
	(2)	(3)	(4)	(5)	(6)
Beginnings-only	T	F			
Terminations-only	F	T			
Entire trail inside FOV	T	T			
Passing across FOV	F	F	T	T	T

Table 2 – Results of our simulation compared with the analytically computed results from (Kresáková, 1977). E_c – size of effective FOV; σ_{Ec} – standard deviation of the E_c distribution.

D/L	E_c	σ_{Ec}	E_c (Kresáková)	P class con.[1](%)
0.1	13.65	5	13.73	85.4
0.2	7.33	0.9	7.37	72.9
0.3	5.25	0.4	5.24	61.9
0.5	3.55	0.2	3.55	43.6
1	2.27	0.04	2.27	12
2	1.64	0.02	1.64	1.7
3	1.424	0.008	1.42	0.56
5	1.255	0.004	1.25	0.14
10	1.127	0.002	1.13	0.02

Coordinates of the beginning point are (x_b, y_b), the termination point (x_t, y_t) and the mid-point of the meteor (x_m, y_m). The coordinates of the center of the FOV are (x_{fov}, y_{fov}). The meteor classes and the corresponding geometrical conditions are given in *Table 1*. Requirement denoted by (6) is that a line of the meteor trail intersects a circumference that represents the border of the FOV.

3 Results

Comparison with the analytical approach

In order to test the simulation and to compare it to the analytical approach, we modified the simulation settings so that our geometry corresponds to that used in the work of Kresáková. We varied a ratio of the diameter of the FOV to the length of the trails. Results computed in the two approaches are presented in *Table 2*. The results of our simulation are in agreement with those of Kresáková. One can notice that the contribution of the P class meteors to the total number of observed meteors is significant in the case of $D/L < 1$. Since the case of $D/L < 1$ is not suitable for practical use, omission of the P class seems reasonable, which was done by Kresáková.

Results for the new geometry

By varying a ratio of the radiant distance from the center of the FOV to the diameter of the FOV (ψ_{fov}/D), and the parameter of length ω, the correction coefficients for each meteor class are computed. The results are presented in *Figure 1*. As can be seen in *Figure 1*, the correction coefficients have a different behavior depending on whether the mean length of the trail L is greater or smaller than the diameter of the FOV. In the case that L is smaller than D (small ψ_{fov}/D), the correction coefficients are roughly constant. For L greater than D, the correction coefficients for B and T classes are rapidly decreasing. With the increase of the parameter of length, the rates of decrease of these classes are greater. In the case of the K_B and K_T equal to zero, the half-lengths of the B and T class meteor trails are greater than the diameter of the FOV, so it is impossible to see those meteors with mid-points in the FOV.

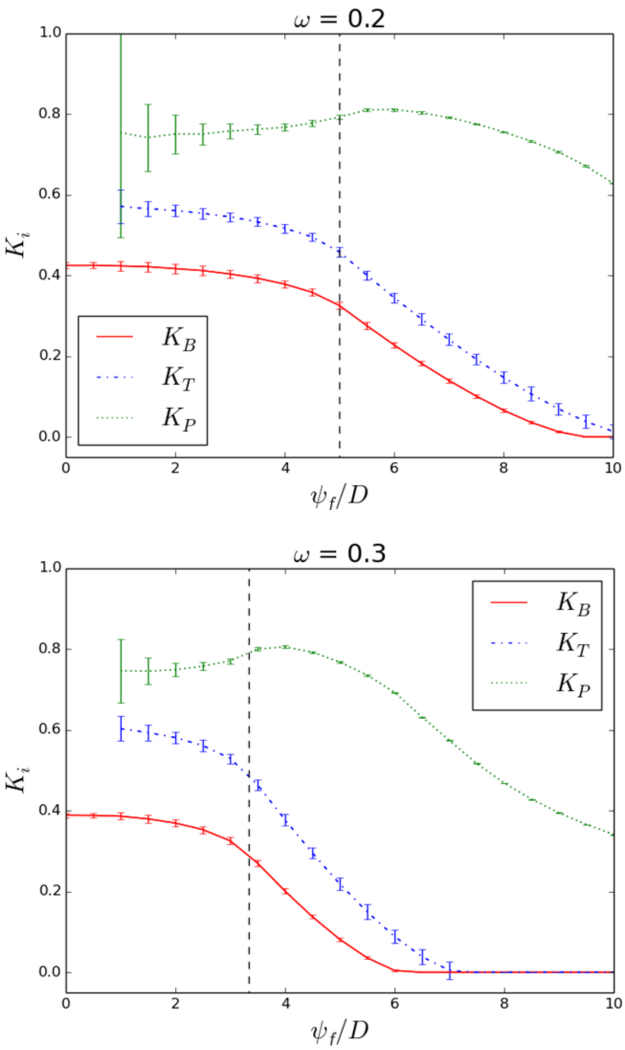

Figure 1 – Correction coefficients' dependence on a ratio of the radiant-center of the FOV distance to the diameter of the FOV (ψ_{fov}/D), and on the parameter of length ω. The vertical dashed line represents the geometry with the mean length of the observed meteor trails equal to the diameter of the FOV. Notations: K_B, K_T and K_P are the correction coefficients for classes B, T and P respectively. The correction coefficient for the E class meteors is not plotted because it is always equal to 1.

More results obtained from the simulation are presented in *Figure 2*. As shown in the graphs for the contribution of the E class meteors to the total number of observed meteors, for the minimal values of ψ_{fov}/D and ω the contribution of the E class meteors is maximal, which is a consequence of meteor trails getting smaller. The opposite holds for the P class: contribution of the P class

[1] Contribution of meteors passing across the FOV to the total number of meteors seen.

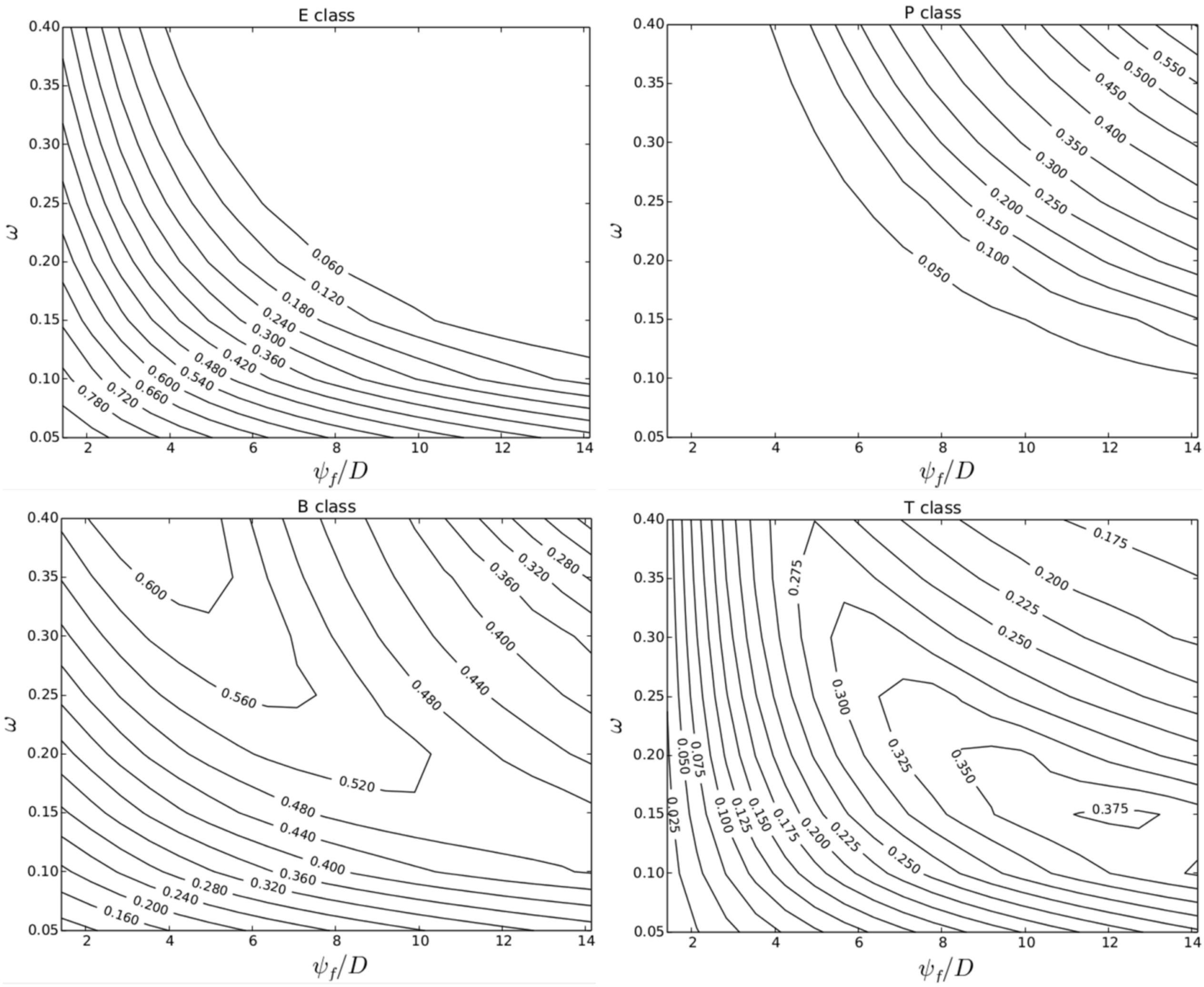

Figure 2 – Contributions of different meteor classes to the total number of observed meteors in the parameter space ($\psi_{fov}/D; \omega$).

is maximal for the maximum values of parameters ψ_{fov}/D and ω. For the combinations of ψ_{fov}/D and ω which imply $L \geq D$, the contribution of the *E* class is equal to zero, because the meteor trails are too long to be entirely observed in the given FOV. For $L \geq D$, the contribution of the *P* class becomes more significant, similarly to the results shown in *Table 2*.

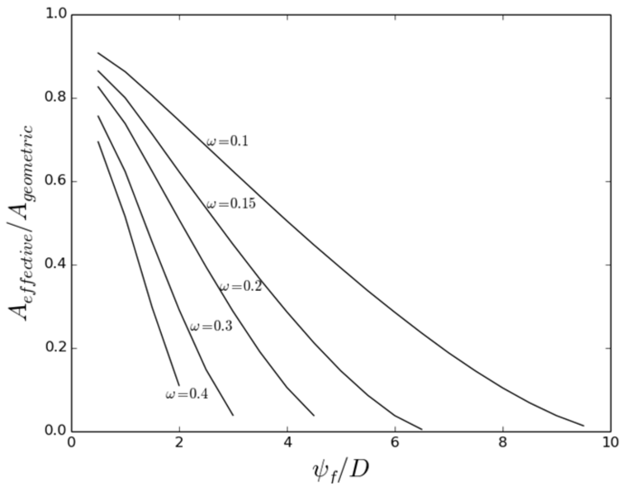

Figure 3 – Dependence of the size of the effective FOV on the ψ_{fov}/D ratio and the parameter of length ω.

Furthermore, in the graphs showing the *B* class and the *T* class, for $L = D$ the contributions of both classes are reaching the maximum values. By increasing ψ_{fov}/D and fixing $L = D$, the contributions of the *P* and *T* classes are converging to the value of 0.5. This is a consequence of the fact that *P* and *E* classes are becoming less important and the meteor trails inside the FOV tend to become parallel. In a limiting case of parallel meteor trails, the *B* and *T* class meteors increase the effective FOV by the same factor, and the contributions of these two classes to the total number of observed meteors are equal.

The region of a parameter space ($\psi_{fov}/D; \omega$) of interest for a practical purpose is one with $L < D$, because of the minimal contribution of the P class and the maximal contribution of the *E* class meteors. The E class is more favorable than the *P* class for computing a population index, because the estimate of the peak brightness is possible only if the entire trail is observed (otherwise one cannot be sure if the peak of brightness is observed). This also affects the estimation of the population index, since the brighter meteors tend to be longer, hence their observed number should be corrected by a smaller coefficient than the number of fainter meteors. Computing the population index from a distribution of entirely observed meteors can be done by introducing a correction for every class of brightness. Similarly to Kresáková, who computed the size of the effective FOV for the different lengths of meteor trails, one could compute the size of the effective FOV for different values of ω, which depends on the meteor brightness. This correction can be deduced from the functional dependence of the number of observed meteors of different classes of magnitude in the fixed size of the effective FOV. In *Figure 3* displays how the size of the effective FOV changes with ψ_{fov}/D and ω. As it is expected, the size of the effective FOV is decreasing with the increase of the length of meteor trails. The decrease is almost linear with the increase of ψ_{fov}/D.

4 Conclusions

From the results computed so far, several conclusions can be drawn. Under the observational conditions such that the mean length of the meteor trails is smaller than the diameter of the FOV, e.g. in visual observations with $D \approx 50^o$ and $\psi_{fov} < 40^o$, the dependence of the correction coefficients on ψ_{fov}/D is negligible. But in case of observations with a narrow FOV, e.g. in the telescopic or video observations where the diameter of the FOV goes down to around 5º, the dependence of the correction coefficients on ψ_{fov}/D should not be neglected. The same is true for the dependence of the correction coefficients on other geometrical parameters, such as the elevation of the radiant and of the beginning point, which are incorporated in parameter ω.

In order to examine how different geometrical parameters (ψ_{fov}, D, altitude of the radiant, altitude of the center of the FOV) and the parameters of the meteor stream (geocentric velocity, mass distribution) affect the correction coefficients, we suggest a three-dimensional simulation of the observation such as those done by (Gural, 2002) which would include all of the above parameters.

Knowing that the bright meteors have longer meteor trails than the faint ones, the use of the correction coefficients for the population index should be investigated. In other words, if a three-dimensional simulation that includes meteors of the different classes of brightness is done, the dependence of the correction coefficients on meteor brightness can be examined.

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