Meteor trail characteristics observed by high time resolution lidar

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Abstract

We report and analyze the characteristics of 1382 meteor trails based on a sodium dataset of ~680 hours. The observations were made at Yanqing (115.97°E, 40.47°N), China by a ground-based Na fluorescence lidar. The temporal resolution of the raw profiles is 1.5 seconds and the altitude resolution is 96 meters. The occurrence heights of the trails follow a double-peak distribution with the peaks at ~83.5 km and at ~95.5 km, away from the peak height of the regular Na layer. ~4.7% of the trails occur below 80 km, and ~3.25% above 100 km. ~75% of the trails are observed in only one 1.5-s profile, suggesting that the dwell time in the laser beam is not greater than 1.5 seconds. The peak density of the trails as a function of height is similar to that of the background sodium layer.

1. Introduction

Ablating meteoroids produce spatially well-defined trails of meteoroid debris in the atmosphere, called meteor trails, which last from seconds to tens of minutes before they are dissipated into the ambient atmosphere by chemical and/or diffusive processes. The characteristics of these trails depend on the properties of the meteoroids and their interaction with the atmosphere. This being the case, the study of the trails can provide additional insight into the meteoroid properties, the ablation process, and the dynamics and chemistry of the region. Ground-based resonance lidars have demonstrated the capability of measuring quantitatively these meteor trails as well as the regular metal layers, thus providing a powerful tool to study directly the source of the metal layers in the MLT region. In this paper, we report the characteristics of 1382 meteor trails based on the extensive lidar observations at the temporal resolution of 1.5 seconds at Yanqing (115.97°E, 40.47°N), China, including the occurrence height, the duration, and the distribution of the peak density of both the trails and the regular metal layer.

2. Characteristics of meteor trails

2.1 Occurrence height

Figure 1 shows the height distribution of the 1382 lidar observed meteor trails. These trails appeared between the altitudes of 76.7 km and 106.1 km, and ~64% of them occurred below 91 km. The most distinguishing feature of the trail occurrence is that it follows a bi-modal distribution, with an upper peak around 95.5 km and a lower one around 83.5 km. This is considerably different from the observations of Kane and Gardner [1] and Zeng and Yi [2] , where meteor trail occurrence tended to peak around 90 km. This behavior may be related to our higher detection capability, able to detect weaker trails far from the peak height, while the other two groups only counted the most dense trails near the background peak height. We believe that this altitude distribution is most likely to reflect the sources (and hence velocities) of incoming meteoroids, because faster moving meteoroids ablated at higher altitudes .

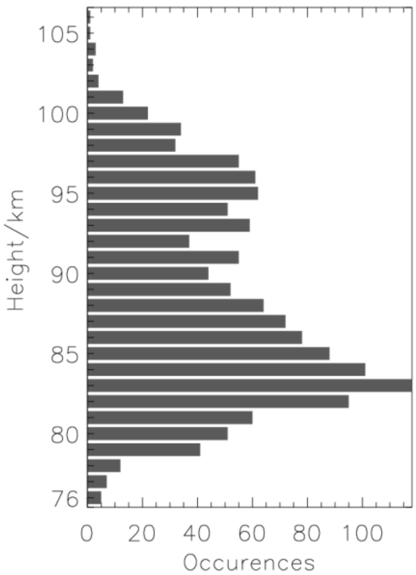

Figure 1. The height distribution of the lidar observed meteor trails.

The investigation of the long term variation of the trail occurrence height shows that quite a number of trails were observed around 95 km in August and September, 2010, which may be associated with the 2010 Perseid meteor shower; another factor may be the increased contribution of meteoroids from the Helion source during summer at mid-latitudes. During the other months quite a few trails were observed above 91 km. This bi-modal distribution may reflect a combination of meteoroids from the Helion, anti-Helion, North Toroidal and South Toroidal sources, which have a velocity of around 30 km s^{-1} , together with anti-Apex meteoroids in near-prograde orbits with velocities of around 17 km s^{-1} [3].

2.2 Duration of trails observed in the lidar beam

The duration of meteor trails reflects the combined effects of meteoroid ablation and altitude-dependent chemical removal, together with molecular and eddy diffusion dilution. Here we investigate the duration of these 1382 lidar-observed meteor trails. They spanned a wide range of time. The shortest duration trail was observed only in one profile, that is, not more than 1.5 seconds; the longest duration trail was observed in 50 consecutive profiles, ~75 seconds. 1039 trails (~75%) were observed only in one profile, ~1.5 seconds. Trails with a duration longer than 1.5

seconds were seen only rarely, which suggests that most of the meteor trails observed here are associated with sporadic meteoroid populations. Figure 2 shows the distribution of trail duration with the occurrence height. Although they were dispersed over a wide range, it can be seen that longer-duration trails tended to appear within a certain height range.

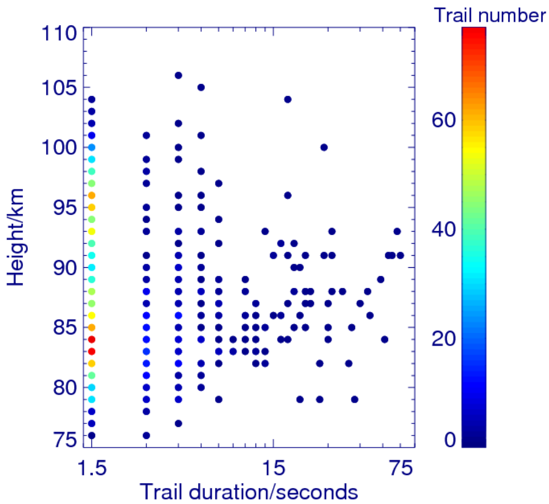

Figure 2. The distribution of the meteor trail duration with the occurrence height.

2.3 Peak density

Figure 3 shows the peak density of the 1382 meteor trails plotted as a function of height. The continuous line in this figure shows the average background layer. The minimum peak density of these trails was 625 cm^{-3} and the maximum was 24815 cm^{-3}. The mean peak density was 3540 cm^{-3}, which indicates that our lidar is capable of detecting very weak meteor trails. Although the occurrence height of these trails took on a bi-modal distribution as shown in Fig. 1, their peak densities were distributed much like the background Na layer, which could be associated with the rapid diffusion on the topside and the dominant chemical removal of metal atoms on the bottom side of the layer.

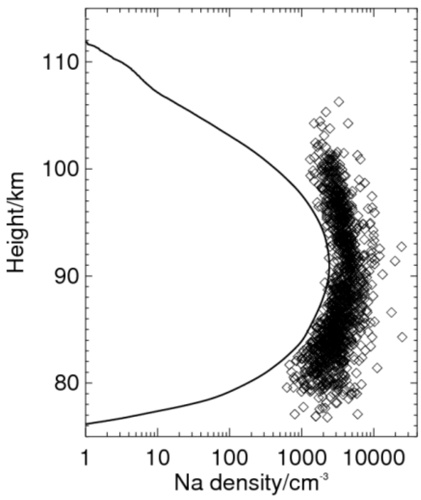

Figure 3. The distribution of the meteor trail peak density with the occurrence height.

3. Summary

Based on a total of ~680 hours of 1.5-s sodium lidar observations made at Yanqing, China, we extracted 1382 meteor trails and analyzed the characteristics of these trails. This is so far the largest dataset that has been used to analyze lidar-observed meteor trails. The occurrence height of these trails was found to follow a bi-modal distribution. We analyzed the duration of the trails in the laser beam and found that it varied from ~1.5 seconds to ~75 seconds; ~75% of trails were observed in only one profile, which indicates that their residence time in the laser beam was not greater than 1.5 seconds. Considering the laser beam divergence of less than 0.2 mrad, the advection of these trails through the laser beam cannot be excluded, although the lifetime due to diffusional/chemical removal is also of the order of 1 s for meteoroids less than 1 mg in mass. Further experiments with different laser beam divergences will help clarify this question. The trail peak density exhibited a vertical distribution similar to that of the long-term background Na layer, which suggests that the stronger trails determine the shape of the trail peak density distribution and that the weaker trails tend to occur away from the background peak height. The raw occurrence height distribution needs to be corrected taking account of three factors which affect the relative lifetime of a trail as a function of height: the meteoroid velocity (which controls the ratio of Na/Na^+ ablated); diffusional spreading of the trail; and chemical removal of Na. This will be done in the future. The properties of meteoroids that generate these trails will also be studied through numerical simulation.

4. Acknowledgements

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5. References

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