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Interactive comment on "A new time-resolved model of the mesospheric Na layer: constraints on the meteor input function" *by* J. M. C. Plane

J. M. C. Plane

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Both referees are very positive about the paper. Most of the points that they raise simply require clarification and/or correction, and the changes that I have made are listed below.

The second referee (B. Clemesha), has raised an interesting question regarding equation (6). He points out that when the particle radius is comparable to or smaller than the radiating wavelength, the radiative heat loss will no longer follow Stefan's law. This is because the emission efficiency will depend on $2\pi R/\lambda$, where R is the radius of the meteoroid and λ is the wavelength of the emitted radiation (this process is the opposite of Mie absorption). Thus, small particles might not be able to radiate heat effectively (depending on their imaginary refractive index as a function of λ), and would then heat up more rapidly and ablate more efficiently. An upper limit to this effect is produced by running the meteor ablation model with the radiative heat loss term in equation (6) set to zero. For the standard LDEF distribution of mass and velocity (mean infall velocity = 18 km^{-1}), the model then predicts that there will be essentially complete ablation of the incoming material (compared with 60% assuming radiative loss as described in equation (6)). The peak ablation still occurs around 92 km, with an increased input at higher altitudes. However, it is likely that only those particles with a radius less than about 1 μm will not be able to radiate efficiently. Since these comprise only about 10% of the total meteoric mass (according to the LDEF results), the departure from Stefan's law should in practice have a small (less than 4%) effect. Nevertheless, this effect should be investigated further.

The following sentences have been added to Section 2.3:

"Small particles will not be able to radiate efficiently when their size is comparable to or smaller than the emission wavelength λ (i.e., $2\pi R/\lambda < 1$, where R is the radius of the meteoroid and λ is the wavelength of the emitted radiation). Their emission rate will then depart from Stefan's Law (Bohren and Huffman, 1983), causing them to heat more rapidly and hence ablate more efficiently. A black body at 1000 K has a peak emission at 2.9 μm, so that only particles smaller than about 1 μm should deviate from Stefan's Law at this temperature. However, these small particles contribute only about 10% of the total meteoroid mass (according to the LDEF experiment (McBride et al., 1999)), so that the effect of reduced heat loss from these particles should cause only a slight increase in the total ablation rate."

Referee 1

1. I have removed the word "new" from the title of the paper, since the referee is correct that this is, to my knowledge, the first time-resolved model of the layer which treats the major sodium species explicitly.

2. The referee is correct in his assumption here. I have made this clearer in the paper by inserting the following sentence in Section 2.1:

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"Note that for this study we are concerned with averaging over relatively long periods (hours to days), so that short-term fluctuations in the meteor ablation rate and atmospheric turbulence are averaged out."

3. See point 2: most meteor trails diffuse into the background metallic layers relatively quickly (on a time-scale of minutes), unless they are exceptionally large as in the case of the long-enduring Leonid trains that the referee refers to.

4. I have clarified the sentence at the end of Section 3.1: "Furthermore, the rate of molecular diffusion varies inversely with the pressure, so that trails produced higher up are increasingly likely to decay by diffusion into the background metallic layers before they can be observed."

5. Yes, the meteoric smoke concentration profile is calculated for each meteoric input profile. The following sentence has been inserted in Section 3.2:

"Note that the concentration profile of meteoric smoke particles is calculated separately for each of these model runs."

6. Figure 7 now has units and contour labels added.

Referee 2 (Clemesha)

1. The referee is correct that referring to phase transitions and vaporization here is confusing. In this simple ablation model we do not consider melting and phase transitions, and vaporization is treated in eqn. 8. I have therefore rewritten the relevant sentences in Section 2.3:

"The second term represents the energy losses due to heating of the particle, where ρ_m ($=2\times10^3$ kg m^{-3}) is the meteoroid density, C ($=1\times10^3$ J K^{-1} kg^{-1}) the meteoroid specific heat, T_m the mean temperature of the particle, and t is the time. Note that vaporization is treated separately (see eqn. 8 below)."

2. This is of course correct, and so I have changed the relevant sentence in Section

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2.3:

“and T_a is the temperature of the earth’s lower atmosphere for the fraction of meteoroid surface pointing earthwards, and the temperature of deep space for the rest of the particle surface (in practice, T_s » T_a and so setting T_a to zero is a good approximation).”

3. This is an interesting point which requires further work. Meteoroids that are smaller than 250 microns (the vast majority) can be treated as isothermal because of rapid heat conductivity. Hence, they could melt completely when they heated up to a nominal melting point. However, meteoroids have a complex mineral structure (Fe-Mg-Al-Ca-silicates), so that in practice phase transitions should occur which produce solid and liquid components, making the particles less likely to sputter than completely liquefied droplets.

Finally, I would like to thank Anne Smith and Jiyao Xu (Atmospheric Chemistry Division, National Center for Atmospheric Research, Boulder) for pointing out a typographical error in equation 4, and incorrect labelling of Figures 3b and 5a.

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 39, 2004.