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Interactive comment on "Metal layers at high altitudes: A possible connection to meteoroids" *by* J. Höffner and J. S. Friedman

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1. Comments to referee 1:

1.1. Discussion of measurement uncertainties

To avoid large uncertainties in the metal densities we have performed the analysis at 113 km altitude only and not higher. Below say 110 km the influence of the main layer in winter time complicates the discussion. An analysis at much higher altitude shows similar results but is influenced by the background subtraction problem and photon statistics as mentioned by referees 1 and 2. We found that an analysis at such high altitude requires a more careful re-evaluation of all data because it cannot excluded that in some cases background correction problems dominate the picture.

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We therefore limited our discussion throughout this paper to 113 km altitude only. At 113 km altitude the density is in general neither limited by the photon statistics nor by the background subtraction problem. The example of potassium in figure 1 is shown with 200 m altitude resolution, whereas the data analysis has been performed at 1 km altitude resolution. Besides the improvement in the photon statistics, we have chosen an example with comparably low densities. The potassium density at 113 km altitude of figure 1 is approx. 0.1 atoms/ccm, which is a rather low density as seen in figure 4. The statistical error in figure 1 is 15%, which of course results finally in somewhat larger scatter as seen in figure 4. Still the statistical error is small compared to other possible effects on the density measurements such as different integration times of the instruments etc. An error in the order of 15% has a minor effect on the scatter of figure 4, where, at a potassium density of 0.1 atoms/ccm, the actual scatter is on the order of a factor of 10! The main scatter therefore must come from other sources such as differences in the chemistry or disturbances from sporadic layers or other short time variations. We also note that no systematic deviation from the regression at very low densities is apparent in figure 4, which would be the case for example if background subtraction problems were to dominate the picture. The typical signal and noise for Ca/Ca^{+}-measurements is in the same order. The stronger backscatter of Fe and Na results in even smaller statistical errors. We note that no a priori correlations between different metals must exist, and even if they exist the slope could be anything depending on the physical laws involved. This is indeed the case at the main layer.

Nevertheless we followed the comments of the referees about the error bars by including some comments about typical errors in the paper, and we have extended figure 1 by including a second example with higher densities as observed a few days before by the same potassium lidar to demonstrate that for densities at 113 km altitude statistical errors are unimportant. Both data sets have now been smoothed slightly to reduce the noise somewhat. We also added some comments about the influence of statistical errors in the text to figure 3.

1.2. Atom density at the extreme bottom side of the metal layers

At the bottom side the presence of Rayleigh scattering introduces further uncertainties. This is most important for K since the Rayleigh signal is very strong compared to the signal from the metal layer. Even though this is not important at high altitudes due to exponential decrease of the Rayleigh signal, we have recalculated the example of figure 1 with higher precision to avoid confusion.

1.3. Influence of sporadic layers

For the case of K, sporadic layers are quite common over Arecibo in summer, but this is not so over Kühlungsborn. Yet the topside extension is there in both. For Ca sporadic layers are uncommon above 110 km altitude. As mentioned above, it is likely that sporadic layers are a source for the larger scatter in figure 4. The role of sporadic layers at very high altitudes is out of the scope of this paper but certainly a question which need further investigation in the future.

1.4.

(a) Influence of the main layer at 113 km altitude:

As mentioned above, 113 km altitude has been chosen because of the advantage of being independent of the main layer.

b) Altitude variation of morphology with altitude

a) We claim this only for January for Kühlungsborn but not summer or other locations. The difference in the upper part in summer may be explained by the stronger activity of sporadic layers at Arecibo, and therefore, in the nomenclature of this paper, part of

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the main layer.

b) As mentioned above, a similar analysis as done in figure 4 at much higher or lower altitude will require more careful data analysis, and, moreover, a clear definition about the transition from the high metal layer to the main layer. It is therefore out of the scope of this paper. We agree with the general comments of both referees that further studies of the high metal layers can give new insights about the chemistry and the relation to meteors by for example a closer examination of the altitude dependency of the metal ratios. The example of Arecibo shows that below say 110 km altitude the increasing activity of sporadic layers makes the calculation of reliable metal ratios much more difficult.

1.5. Including Fe/Na/Ca^+ in figure 2

As stated in the text, the limited number of observations for Fe, Na and Ca^+ do not permit including them in figure 2, since the relatively short smoothing applied in figure 2 would result in a lot of artefacts due to larger gaps in the measurements. The seasonal behaviour of these species on a linear scale with a larger smoothing window has been already published by Gerding *et al.* (2000).

1.6. x% of the y enhancement correspond with meteor showers (figure 3)

This would require a) a clear distinction between the influence of meteor showers and sporadic meteoroids, a case that is not made in figure 3; and b) a better seasonal coverage of the measurements, since the influence of meteor showers on the metal layer can be on time scales as short as a day or less (for example Leonids). The limited amount of data makes it likely that some important meteor showers are missed.

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2. Comments to referee 2:

2.1. Background subtraction and photon noise

See discussion 1 of referee 1.

2.1.1. Extinction due to the metal layer

Due to the very low column densities extinctions in the main layer are totally unimportant for K, Ca, Ca^+, and they have a very small effect for Na and Fe. However this effect has been calculated in the past for sodium to be in the order of only a few % (Fricke, K.H., and U. von Zahn, Mesopause temperatures derived from probing the hyperfine structure of the D_2 resonance line of sodium by lidar, *J. Atmos. Terr. Phys. 47*, 499–512, 1985; Yu, J. R. and C. Y. She, Lidar-observed temperature structures and gravity-wave perturbations of the mesopause region in the springs of 1990Ű1992 over Fort Collins, CO, *Appl. Phys. B, 57*, 231-Ű238, 1993).

2.2. Data from meteor radar as a support for the topside metal layer

We included a reference to the publication "Diurnal and annual variations of meteor rates at the Arctic circle" (W. Singer, J. Weiß, and U. von Zahn, submitted to ACPD, 2003). Figure 6 show the annual variation in the meteor flux with a summer maximum.

2.3. Including Fe/Na/Ca^+ in figure 2

See comment 5 of referee 1.

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2.4. The role of chemistry

Included now in the introduction.

2.5. Recent compilations of meteor showers

More recent tables of meteor showers are available (Jenniskens, P., Meteor stream activity: I. The annual streams, *Astron. Astrophys., 287*, 990–1013, 1994.), but as already discussed, a correlation between such a table, collected over a long period and at different locations, and the sparse set of observations do not allow concluding that a peak in the densities is caused by a given shower, or vice versa, that a shower has no impact on the topside layer. As already discussed, the Leonid shower is a nice example that the impact on the metal layer differs largely from year to year for numerous reasons. A more complete table of meteor showers will therefore not change the conclusions of the manuscript. Similar to the discussion in literature for the main layer only simultaneous observations of showers and metal densities at a single location will allow a quantitative study of the influence of such showers on the topside layer.

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 399, 2004.