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# COMMENTS ON "A METEOR-ABLATION MODEL OF THE SODIUM AND POTASSIUM LAYERS" BY D.M. HUNTEN

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ABSTRACT

The published results of lidar observations of the atmospheric sodium layer show that any consistent change in the abundance of sodium during the night is very small, and that there is probably little change between day and night. These measurements also show that the winter increase in sodium observed at mid-latitudes occurs mainly on the bottomside of the layer. Recent 24-hour observations show that any 24-hour component in the diurnal variation in abundance is less than about 5% of the mean. The recently proposed meteor-ablation model, in which sodium atoms which enter the atmosphere during meteor ablation are lost by ionization and subsequent attachment of the ions to aerosols, is shown to be inconsistent with these experimental data.

Although there would appear to be little doubt that meteoric deposition constitutes the principal source of sodium in the upper atmosphere, both the process by which free sodium atoms enter the atmosphere and the loss processes which help to shape the sodium layer are open to discussion. In a recent paper, Hunten (1981) has presented a more rigorous development of the mechanism proposed by Gadsden (1970), whereby sodium atoms, entering the atmosphere by evaporation from ablating meteors, are lost by ionization and subsequent attachment of the ions to aerosol particles. Attractive though this mechanism is, obviating as it does the necessity for a photochemical sink, the evidence for which is not entirely satisfactory, we feel that Hunten has given inadequate consideration to the experimental evidence available to test his model.

In the model proposed by Hunten, sodium atoms, once ionized, are removed by their downward motion, caused by the "corkscrew mechanism" of Chimonas and Axford (1968), to heights at which they are lost by attachment to aerosol particles. With the ionization rate and ion drift velocity used by Hunten the Na atom lifetime against ionization, and the residence time of the ions in the layer, necessarily the same, are of the order of 12 hours. As a result of this short lifetime, changes in the ionizing solar radiation would produce inverse changes in the density of free sodium. Hunten suggests that this effect is responsible for the strong winter maximum in sodium abundance observed at middle and high latitudes, and cites the lack of a seasonal variation in twilight abundances observed at Kitt Peak ($32^{o}$N, Hunten, 1967) as supporting evidence. He also quotes winter increases in the height of the layer, as deduced from twilight measurements at $52^{o}$N (Saskatoon) and $44^{o}$N (Haute Provence), as being in the expected sense in that reduced ionization would lead to increased sodium mainly on the topside of the layer.

In using the twilight data from Saskatoon, Haute Provence and Kitt Peak, Hunten has ignored the very much more accurate lidar data from Winkfield ($51^{o}$N, Gibson and Sandford, 1971), Haute

Provence (44$^{\circ}$N, Megie and Blamont, 1977) and São José dos Campos (23$^{\circ}$S, Simonich et al., 1979). The data from 51$^{\circ}$ and 44$^{\circ}$N show strong winter increases in sodium abundance, but the increases in both cases are mainly on the bottomside of the layer. At 23$^{\circ}$S, where the annual variation in available ionizing radiation is very small, there is a factor of 2 seasonal variation in sodium abundance (Clemesha et al., 1979), and no variation in height. Twilight determinations of height distribution are notoriously inaccurate. They involve the deconvolution of the sodium distribution and a screening function which depends upon poorly known vertical distributions of ozone and atmospheric aerosols. In contrast, the lidar measurements are accurate to a fraction of a kilometer in height and better than ± 15% in absolute abundance. Short term abundance errors are probably less than ± 5%. Whereas seasonal variations in the screening height could be misinterpreted as seasonal variations in the height of the sodium layer, no such consideration applies to the lidar observations, where there are no systematic errors in the height determination, and any systematic errors in abundance will be independent of seasonal and diurnal cycles.

In view of the above, there can be no doubt that the seasonal variation in the height of the sodium layer is contrary to that predicted by Hunten (1981), and that the seasonal variation at 23$^{\circ}$S is much greater than that which he would predict. There exists, however, a third piece of experimental evidence which appears to leave no doubt that Hunten's model, at least as it stands, does not present a true picture of the processes which control the sodium layer. The lifetime against ionization for free sodium atoms in Hunten's model is of the order of 12 hours. Independently of the source of ionization, i.e. photoionization or charge exchange with nonmetallic ions, there would be an almost 100% diurnal variation in the ionization rate. With a lifetime as short as 12 hours, such a 24-hour modulation of the loss rate would lead to a strong diurnal variation in sodium abundance. A further contribution to this variation would be expected from the source variation, which, according to Gadsden (1969), would result in an approximately 20% diurnal variation in abundance if the residence time were 10 hours. Gibson and Sandford (1972) have reported daytime lidar measurements of atmospheric sodium at 51$^{O}$N in which they found no systematic difference between daytime and nighttime abundances. Gibson and Sandford did not present a 24-hour variation of abundance, but our own recent measurements, to be presented in detail elsewhere, show that any 24-hour component has an amplitude of less than 5%. As can be seen from Figure 1, which shows the average of 8 days of measurements made by lidar at São José dos Campos in May 1981, we observe a strong semi-diurnal variation, but no appreciable 24-hour component. That this is the case can be seen from the 12-hour running mean plotted as a dotted line in Figure 1.

It might be argued that both Gibson and Sandford's (1972) measurements and our own daytime observations cover rather short time periods and thus might be unrepresentative. Against this, however, are the very small average nocturnal variations in abundance observed by Megie and Blamont (1977) and Simonich et al. (1979), for data averaged over many nights during several years of observations. For a constant source the virtual cessation of ionization at night should lead to an approximately 60% increase in abundance during a 12-hour period.

It seems to us that the only way in which Hunten's model might be reconciled with the experimental evidence would be if the source function were to follow the same diurnal variation as the ionization sink. This could be the case for sublimation from aerosols. Fiocco et al. (1974) have shown that heating by solar radiation during the day could raise the temperature of such particles sufficiently for sublimation of sodium to occur, and that in the absence of radiation at night sublimation would virtually cease. In this way, except during winter at very high latitudes, the time variations of both the source and sink would be rectangular (assuming photoionization rather than charge exchange) and both production and loss would cease at night. A major difficulty with this scheme is the lack of experimental evidence for the changes which would be expected to occur in the layer due to diffusion during the night. Although an increase in the scale height above 100 km, ascribable to diffusion, has been observed by Megie and Blamont (1977) and Simonich et al. (1979), little change is observed at other heights.

A further difficulty in Hunten's model concerns the sodium ion densities. Mass spectrometer measurements (see for example Zbinden et al., 1975) typically show peak ion concentrations of $10^2$ to $10^3$ $cm^{-3}$ at about 95 km, decreasing to between 1 and 10 $cm^{-3}$ at 80 km. Figure 1 from Hunten (1981) shows an ion density of about 300 $cm^{-3}$ at all heights below 85 km, and decreasing densities above this height. Such a distribution is obviously in very poor agreement with the experimental evidence. It should also be pointed out that this problem would be aggravated if Hunten had used a more realistic ion drift velocity, decreasing drastically in the region of 85 - 90 km, and thus increasing the ion densities at heights where few ions are encountered in the mass-spectrometer measurements.

Our criticism of Hunten's (1981) model for the atmospheric sodium layer does not detract from the importance of Hunten et al's (1980) work concerning the vertical distribution of sub-micron-sized aerosols produced by condensation of meteor-ablation products, upon which it is based. The condensation of nonvolatile atmospheric species on these aerosols may well constitute an important sink for such constituents, and this process appears to be plausible as the ultimate sink for sodium compounds in the mesosphere and stratosphere.

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## Figure Caption

Fig. 1. Mean diurnal variation of sodium abundance, May 1981: (a) hourly values; (b) 12-hour running mean.

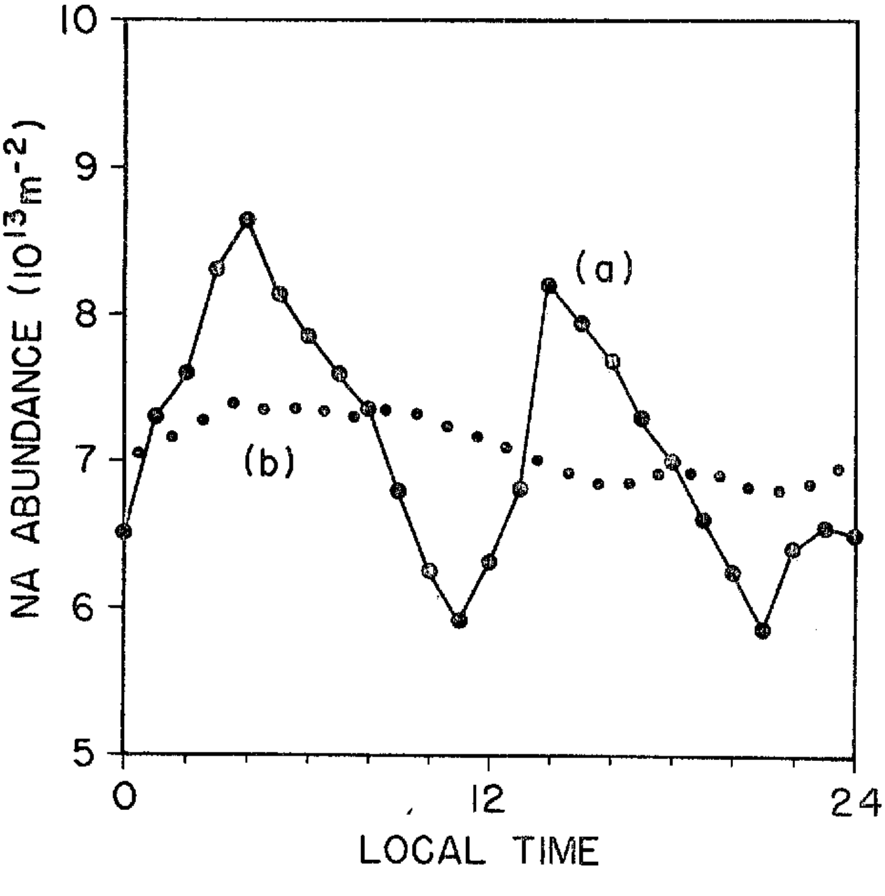


Fig. 1