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A study of sporadic sodium (Ns) layers observed at Sao Jose dos Campos (23 degrees S, 46 degrees W) shows that during their occurrence the form of the background sodium layer is different from that which it normally takes when Ns layers are absent. During Ns events, peak sodium in the background layer typically occurs below 90 km, whereas the peak of the average layer observed at our location is around 93 km. The observed change could be caused either by a loss of sodium on the topside of the layer or by a displacement of sodium to lower heights. The consistency of these two mechanisms with our observations, and with the known properties of Ns layers, is examined, but we are unable to determine which of the mechanisms is responsible for the observed phenomenon.

KeyWords Plus:
LIDAR OBSERVATIONS, DUST PARTICLES, NA LAYERS, MESOSPHERE, ATMOSPHERE, ALOHA-90, ARECIBO, ORIGIN, RADAR, EVENT

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Formation of sporadic sodium layers

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Abstract. A study of sporadic sodium (Ns) layers observed at São José dos Campos (23°S, 46°W) shows that during their occurrence the form of the background sodium layer is different from that which it normally takes when Ns layers are absent. During Ns events, peak sodium in the background layer typically occurs below 90 km, whereas the peak of the average layer observed at our location is around 93 km. The observed change could be caused either by a loss of sodium on the topside of the layer or by a displacement of sodium to lower heights. The consistency of these two mechanisms with our observations, and with the known properties of Ns layers, is examined, but we are unable to determine which of the mechanisms is responsible for the observed phenomenon.

Introduction

The sporadic occurrence of thin layers of metallic atoms (Ns) in the lower thermosphere has received considerable attention in recent years. Despite the fact that more than 40 papers have been published on the subject, there is still no satisfactory explanation for the generation of these layers. Most of the experimental studies published have concentrated on the characteristics of the observed layers, but several have reported simultaneous measurements of other phenomena such as *E* region ionization [*Alpers et al.*, 1993; *Mathews et al.*, 1993; *Kane et al.*, 1993; *Kirkwood and von Zahn*, 1993], winds [*Alpers et al.*, 1993; *Kirkwood and von Zahn*, 1993], temperature [*Quian and Gardner*, 1995], or airglow [*Gardner et al.*, 1991; *Kane et al.*, 1993]. In the present study, based on lidar measurements of atmospheric sodium made at São José dos Campos over the past 24 years, we will examine the characteristics of the background layer during the occurrence of Ns, rather than the characteristics of the Ns layers themselves. It should be noted that although the abbreviation, Ns, refers to sporadic neutral layers in general (by analogy with Es for sporadic E), in this paper we will use Ns to designate specifically sporadic sodium layers.

Observations

Sporadic sodium layers are an infrequent phenomenon at the latitude of São José dos Campos. A study of the lidar data from our station published by *Batista et al.* [1989] reports only 65 layers in 3500 hours of observations. This comparative rarity in the occurrence of Ns layers makes it possible for us to search for any possible special characteristics which the main sodium layer might show during Ns events. A visual search of our Na profiles, for the days on which strong Ns events occurred, suggested that on these occasions the form of the background layer does, indeed, differ from that of the regular sodium layer. Although the normal sodium layer at our latitude suffers large changes from day to day, and even during the same day, on the average it peaks at around 93 km, and the density falls off more rapidly on the topside of the layer than on the bottom. The occurrence of layers with secondary peaks below 90 km is not unusual, but the main peak normally occurs above 90 km. On occasions when Ns was present it was noticed that the maximum background Na concentration typically occurs at much lower heights, and the gradient is largest on the bottomside of the layer. A typical example of this is shown in Figure 1, where a profile averaged over 5 min during an Ns event is compared with the long-term average of all our measurements. In Figure 1, curve a, the background sodium layer peaks at around 87 km, and the sodium concentration falls very rapidly below this height. In the example shown, the normal layer appears to be depleted above 87 km, but on some occasions the alterations in the shape of the sodium layer appear to result from a displacement of sodium toward lower heights, rather than a depletion. For this reason, profiles of this sort will be referred to as displaced profiles.

On a number of occasions we have observed a transition from a normal layer to a displaced layer with the subsequent appearance of Ns. Examples of such sequences are shown in Figures 2 and 3. In Figure 2, curve a, the sodium layer averaged over a period of 3 hours shows a normal distribution, peaking at 94 km. In curve b, averaged over the next 2 hours, the sodium is depleted between 90 and 98 km. Curve c, averaged over the subsequent 3-hour interval, shows increased depletion of the background layer, with the layer peak reduced in height to 87 km, together with a strong Ns layer at 95 km. It is important to note that the layer is depleted before the appearance of the Ns layer, that is the Ns layer is not simply a result of the redistribution of the sodium in the upper part of the normal layer. In Figure 3, curve a, a 2-hour average shows a normal sodium layer distribution peaking at 94 km. In curve b, averaged over the next 2 hours, the peak height has dropped to 90 km, and in curve c, the background layer peak continues at 90 km, but an Ns layer appears at 96 km. In Figure 3 the change in the shape of the background layer appears to be caused by a growth at heights below 94 km, rather than a depletion around this height.

Displaced sodium profiles similar to that of the background layer shown in Figure 1 are not invariably associated with Ns layers, but they are unusual. On the other hand, most

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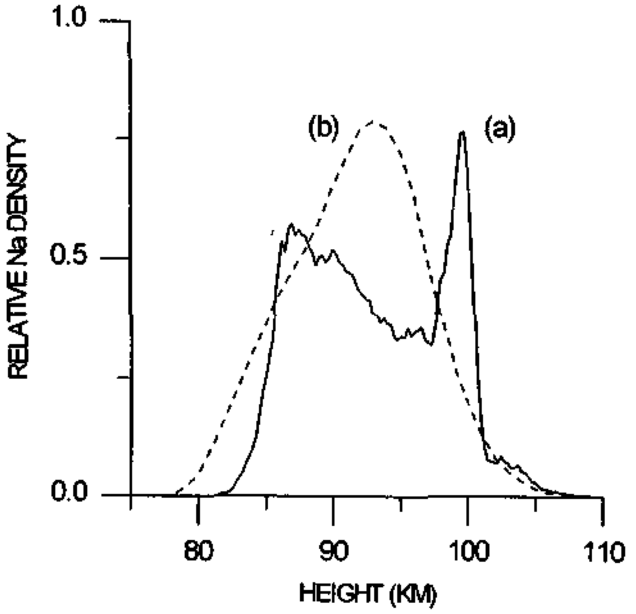

Figure 1. Curve a shows a 5-minute average Na profile for 1955 LT, October 8, 1993; b shows the average Na profile for 1972-1994.

Ns events appear to be associated with this type of background layer. In Figure 4 we show 15 of the strongest Ns events observed by our lidar. In 12 out of the 15 examples the background layer is displaced. It should be noted that, in order to make the background layer as representative as possible, the profiles shown in Figure 4 are averaged over as long a time interval as possible without destroying the main characteristics of the Ns layers. Since the heights of the layers usually change with time, the Ns layers shown in Figure 4 are of smaller amplitude and wider than they would be in individual profiles. To determine the average background layer shape during Ns events we have averaged the background layers shown in Figure 4. Before averaging, the Ns layers were removed by interpolating between the adjacent sections of the profiles, as indicated by the dashed lines in Figure 4. In order that each profile should contribute equal weight to the mean, they were normalized to a constant abundance before averaging. The resulting profile is shown as curve a in Figure 5. Curve b of Figure 5 shows the long-term average profile for our station, and curve c shows the same average as curve a, but without removal of the Ns layers. The long-term average is based on monthly averages of data obtained between 1972 and 1994, excepting those months in which one or more Ns layers were observed. Owing to the rarity of Ns layers at our location, curve b of Figure 5 differs little from the long-term average of all our measurements. Since the profiles averaged to obtain curve a of Figure 5 were normalized before averaging, the density scale in this figure is in arbitrary units. The relative scales for curves a and b were adjusted to make them fit as closely as possible outside the height range of the Ns layers.

Discussion

The observations presented above show that before and during Ns events the vertical distribution of sodium is skewed toward lower heights. The implications of this behavior depend on whether the observed change in the layer shape results from a depletion of sodium on the topside of the layer or a displacement of the topside sodium toward lower heights.

Depletion

A depletion of sodium on the topside of the layer suggests that Ns layers could be formed from sodium atoms which have previously been removed from the upper part of the normal sodium layer. This does not imply, of course, that Ns layers are produced by a simple redistribution of the existing sodium. What is implied is that the sodium is first converted to some form other than that of free atoms, in which form it becomes concentrated into a thin layer, and that it is subsequently reconverted to atomic Na. It is possible that the loss and production processes involved occur not only in association with Ns events but at all times and that the form of the upper part of the sodium layer depends on the equilibrium between them. Ns layers would occur when the sodium in its nonatomic form undergoes layering before being reconverted to free sodium. For this mechanism to work, there must exist an adequate mechanism for interchange of sodium between its atomic and "reservoir" forms. There appear to be three possibilities for the nonatomic form of sodium: ions, neutral compounds, and aerosols. All of these have been investigated in the literature as possible sources of Ns layers, but the results of these investigations have not been very encouraging.

The existence of a loss mechanism on the topside of the layer is evidenced by the fact that the mixing ratio of free sodium decreases rapidly above a height of about 96 km. Most modeling studies have assumed that the loss results from the formation of ions, either by direct photoionization or by charge exchange [*Hanson and Donaldson*; 1967, *Helmer and Plane*, 1993], and the latter process appears to be adequate for explaining the small topside scale height of the layer. Ions could easily be concentrated into a thin layer by electrodynamical effects, but unfortunately, both the modeling studies

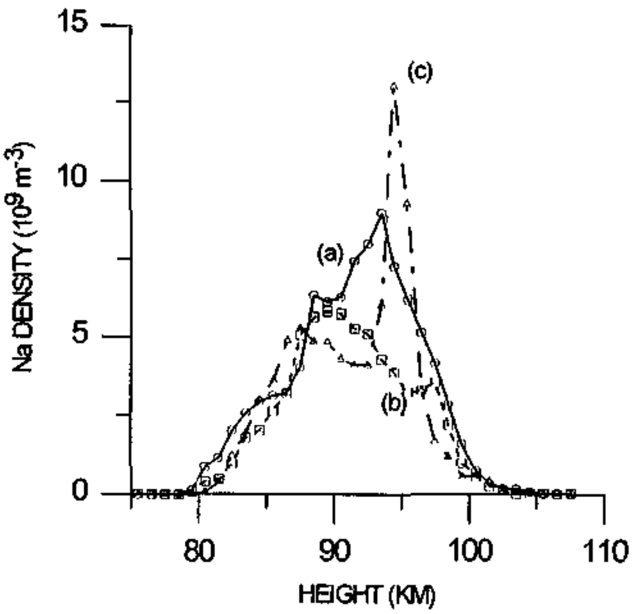

Figure 2. Na profiles observed on August 7-8, 1981: curve a, 1834-2140 LT; curve b, 2153-2352 LT; and curve c, 0007-0308 LT.

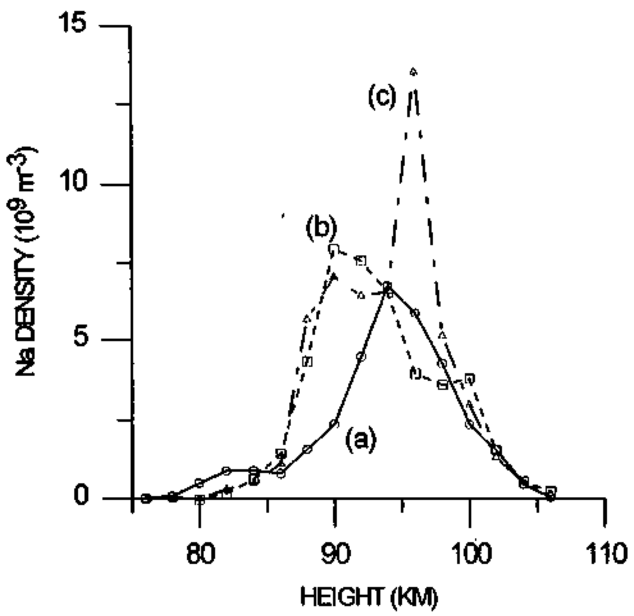

Figure 3. Na profiles observed on August 4-5, 1979: Curve a, 1819-2019 LT; curve b, 2125-2329 LT; and curve c, 2340-0024 LT.

[*Helmer and Plane*, 1993] and ion concentration measurements [*Kopp and Herrmann*, 1984] indicate that this mechanism would be too slow to explain the formation of most Ns layers, and it does not seem very likely that the sodium lost by ionization is their main source. A possible exception to this exclusion is constituted by the small Ns layers seen above 100 km, especially at high latitudes. In the case of these layers the amount of sodium involved is sufficiently small for ions to constitute a plausible source [*Hansen and von Zahn*, 1990].

The possibility of a chemical source for Ns layers has been investigated by *von Zahn and Murad* [1990], who suggested that free sodium atoms might be liberated from $NaHCO_3$ by a process of electron attachment. There appear to be two major objections to this suggestion: first, modeling studies do not indicate significant concentrations of $NaHCO_3$ in the appropriate height range and second, there does not appear to exist an adequate mechanism for concentrating the $NaHCO_3$ into a narrow layer. In another suggestion for a chemical source, *Cox et al.* [1993] have postulated that meteoric ablation might release silicate molecules such as $NaAlSiO_4$ or $Na2SiO_4$ and that sodium atoms could be released from these by energetic electrons. The need for energetic electrons would appear to rule out this mechanism for Ns layers formed at low latitudes.

A number of workers have suggested that Ns layers might be produced from sodium-bearing aerosol particles [*von Zahn et al.*, 1987; *Beatty et al.*, 1989; *Kirkwood and von Zahn*, 1991]. It is possible that such aerosols might constitute a loss mechanism for sodium, as suggested by *Hunten et al.* [1980], so interchange between free sodium and sodium adsorbed onto the surface of aerosols could provide the required mechanism. *Kirkwood and von Zahn* [1991] have suggested that charged dust particles could be lifted to Es layer heights by electric fields, and that the interaction between the high-density plasma in an Es layer and the aerosol particles would result in the release of free sodium. There is some evidence for a correlation between auroral activity and the occurrence of high-latitude Ns layers, and it has been suggested that auroral energetic particles might sputter sodium atoms from aerosols [*von Zahn et al.*, 1987; *Gu et al.*, 1995]. Although there appears to be no evidence contrary to this mechanism, the existence of a suitable aerosol population is entirely

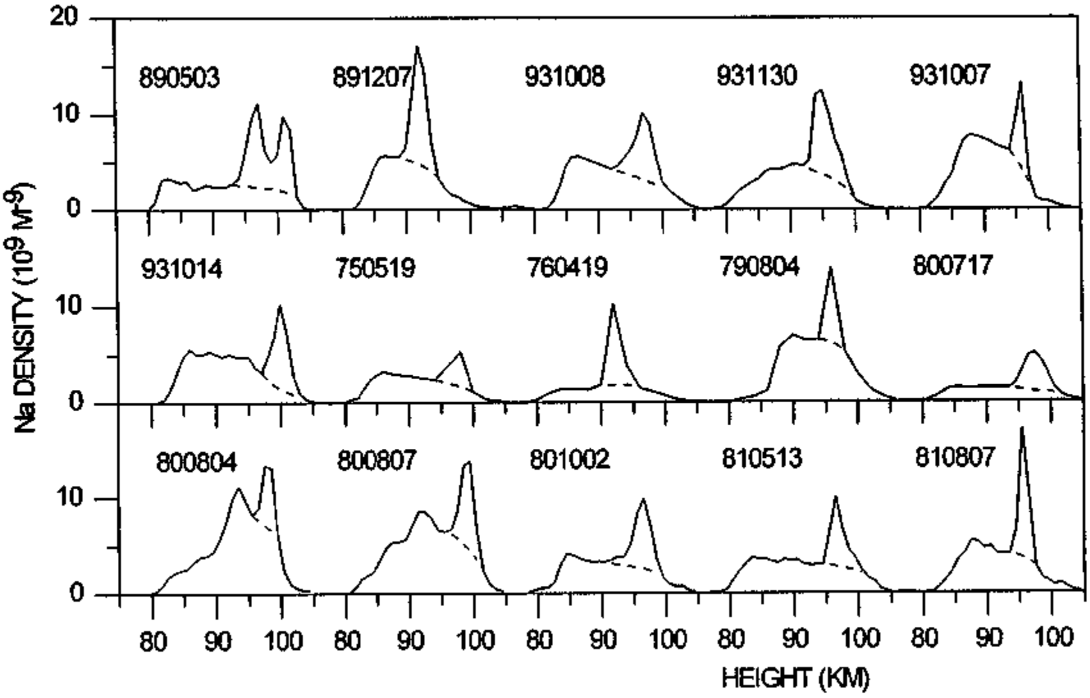

Figure 4. Examples of strong Ns layers observed at São José dos Campos.

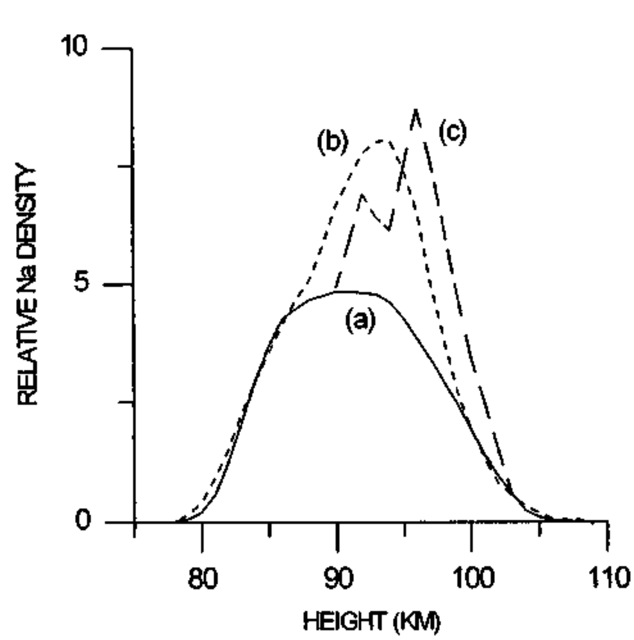

Figure 5. Curve a shows the average background layer for the 15 examples of Ns layers shown in Figure 4; curve b shows the average Na profile for 1972-1994, excluding days when Ns was observed; and curve c shows the average of the 15 profiles shown in Figure 4, without the removal of the Ns layers.

speculative, and our understanding of the processes of attachment and detachment of sodium atoms from the postulated aerosols is inadequate.

The average normal layer observed at São José dos Campos can be closely approximated as the sum of 2 Gaussian curves: a lower layer, centered on 86 km, and an upper one, centered on 93.6 km, as illustrated in Figure 6. If we believe that the source of Ns layers is also the source of the upper part of the normal layer, then this would be represented by the upper Gaussian. It is interesting to note that the height variation in the occurrence of Ns layers fits the upper Gaussian quite well. This can be seen in Figure 7 where the height distribution taken from *Batista et al.* [1989] is superimposed on the double Gaussian representation of our average layer. Also consistent with the idea that the upper Gaussian corresponds to sodium production from the same source as Ns layers is the fact that if we average the 15 profiles shown in Figure 4, without removing the Ns layers, the result is quite similar to the average normal layer, as shown in Figure 5. In both cases the Ns layer distribution is similar to the upper Gaussian but centered on a height about 2 km greater. During the presence of Ns the upper Gaussian would be diminished. This is illustrated in Figure 8, where curve a shows the double Gaussian curve with the amplitude of the upper Gaussian halved, compared with the background layer shown as curve b.

Although the evidence suggests that the source of the Ns layers which we observe could be the same as the source of the upper part of the normal sodium layer, it should be pointed out that the average total sodium abundance measured on days when Ns was observed was 28% greater than on normal days. In order to eliminate seasonal variations, this value was arrived at by calculating the average abundance on Ns days for each month of the year and comparing this value with the seasonal abundance for the same month. A possible interpretation of this increase in abundance is that the conversion to free sodium might be more efficient when the layering mechanism is active.

Displacement

If the changes in the form of the layer result from a displacement of sodium toward lower heights, then the most likely cause of the displacement would appear to be tides. That a tidal oscillation could cause the sort of change observed is demonstrated in Figure 9, where we show the effect of such an oscillation on our average sodium layer. The displaced layers shown in Figure 9 were produced by applying an oscillatory vertical displacement to our average layer and assuming that the mixing ratio of sodium is conserved. The oscillation applied had an amplitude of 2.5 km at a height of 90 km, an *e*-folding growth height interval of 15 km, and a vertical wavelength of 30 km. The height of zero phase for each curve is shown in Figure 9 by the numbers in parentheses. This simple simulation ignores the effects of the atmospheric density perturbation associated with the wave, but such effects would be small compared with that of the vertical displacement. The tidal parameters chosen are in reasonable accord with the average semidiurnal tide observed in the sodium layer by *Batista et al.* [1985], except for the amplitude, which is considerably greater. Figure 9 demonstrates how a tidal oscillation might cause a transition from a "normal" layer, peaking around 95 km, to a displaced layer with its maximum about 10 km lower. The suggestion is, then, that large tidal amplitudes would occasionally produce the observed strongly displaced sodium layers with their corresponding Ns layers. Since tidal amplitudes depend on the interaction of many modes, and the strength of excitation depends on how each

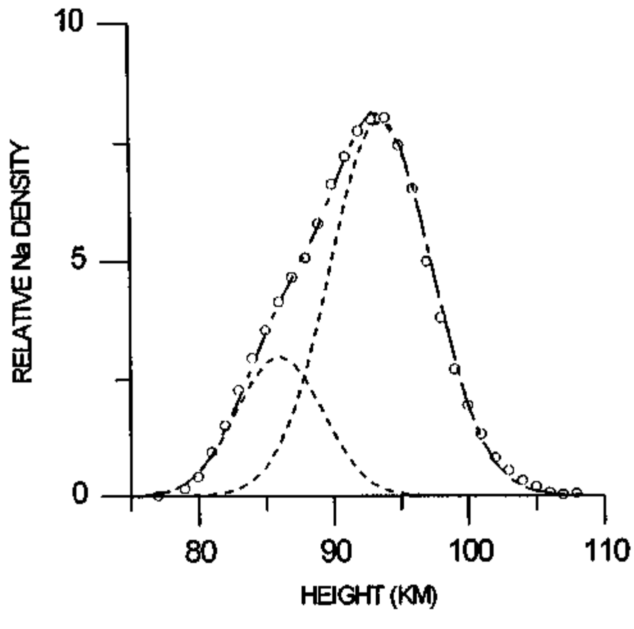

Figure 6. Double Gaussian representation of the average Na layer observed at São José dos Campos. The circles show the average measured profile.

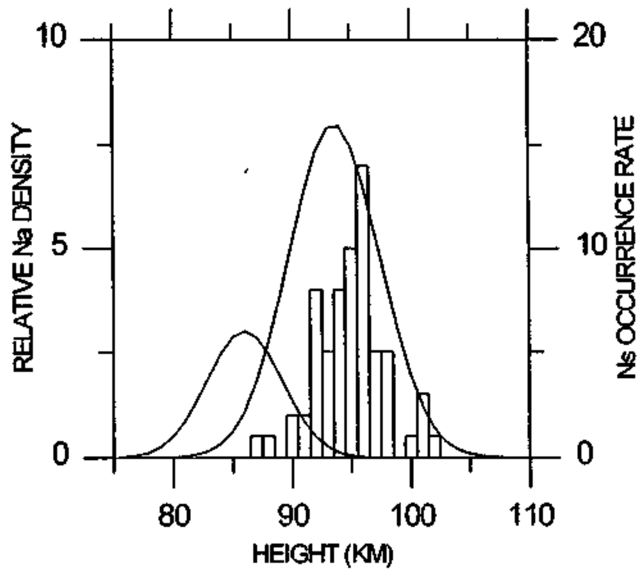

Figure 7. Height variation in the frequency of occurrence of Ns layers compared with the double Gaussian representation of the average Na layer.

mode is matched by the forcing function, the sporadic occurrence of much larger than average tidal amplitudes is to be expected.

That Ns layers might be related to tidal oscillations has been emphasized in a recent paper by *Zhou and Mathews* [1995, p. 1314], who comment that "The evidence for the generation of SSLs by tides seems to be very strong. The strong local time dependence of SSLs [*Kwon et al.*, 1988; *Hansen and von Zahn*, 1990] and, more compellingly, the large horizontal extent exhibited by SSLs [*Kane et al.*, 1991] clearly suggest that tides play a very important role." *Zhou and Mathews* [1995] suggest that Ns layers could result from heating in thin turbulent layers generated by the breaking of gravity waves or tides. With respect to the role of tides, they point to the well-known correlation between Ns layer occurrence and sporadic E, and to the fact that some forms of the latter appear to be produced by the accumulation of ionization in thin layers via tide-related windshear. The possibility that the displaced layers which we observe could result from tidal effects is consistent with the arguments of *Zhou and Mathews* [1995]. On the other hand, we again confront the problem of the lack of evidence for a suitable reservoir for the source of the Ns layers.

Regardless of whether the displaced sodium layer is caused by a loss of sodium on the topside or a tidal distortion of the basic layer, it is interesting to consider the implications of the association between this type of layer and Ns. In the first report of the observation of a sporadic sodium layer [*Clemesha et al.*, 1978] we concluded that its origin must have been a direct deposition of meteoric material. The results presented in the present paper appear to invalidate this conclusion. If Ns layers were formed by material released during the entry of unusually large meteors, there would be no reason for their association with a particular form of background layer. The observed association does not eliminate the possibility that Ns result from the windshear distortion of an initially isotropic cloud of high-density sodium [*Clemesha et al*, 1988], although the evidence against this mechanism from other sources is very strong [*Clemesha*, 1995]. Unfortunately, none of the other possible mechanisms that have been proposed in the literature appear to be invalidated by our observations.

Conclusions

The background sodium layer observed at São José dos Campos when Ns layers are present is different from that observed in their absence. During Ns events the peak of the background layer moves to lower heights. If we represent our average layer as the sum of two Gaussians, centered on 86 km and 93.6 km, respectively, the relative amplitude of the upper Gaussian is typically halved during the presence of Ns. Our measurements do not enable us to determine whether the change in the shape of the layer results from a loss of sodium on the topside of the layer or a displacement of the sodium to lower heights. If the change is due to a loss of sodium then it seems probable that the source of the upper part of the normal layer is the same as that of the Ns layers. In the case of a displacement of sodium to lower heights the most likely cause is tidal oscillations. In support of the latter mechanism there is considerable evidence for a connection between tides and Ns layers. The existence of an association between the form of the background layer and the occurrence of Ns virtually eliminates the possibility, suggested by *Clemesha et al.* [1978], that sporadic layers result directly from an injection of additional sodium via meteor deposition.

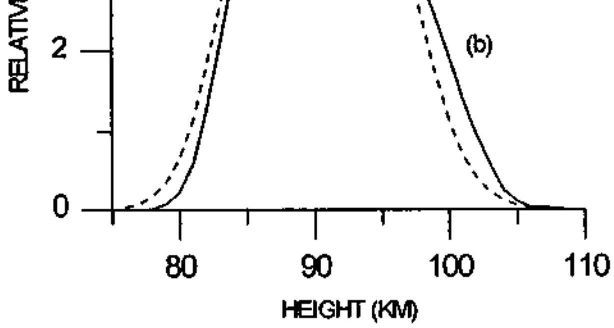

Figure 8. Curve a shows the double Gaussian representation of the average Na layer observed at São José dos Campos, with the amplitude of the upper Gaussian halved. Curve b is the same as curve a in Figure 5.

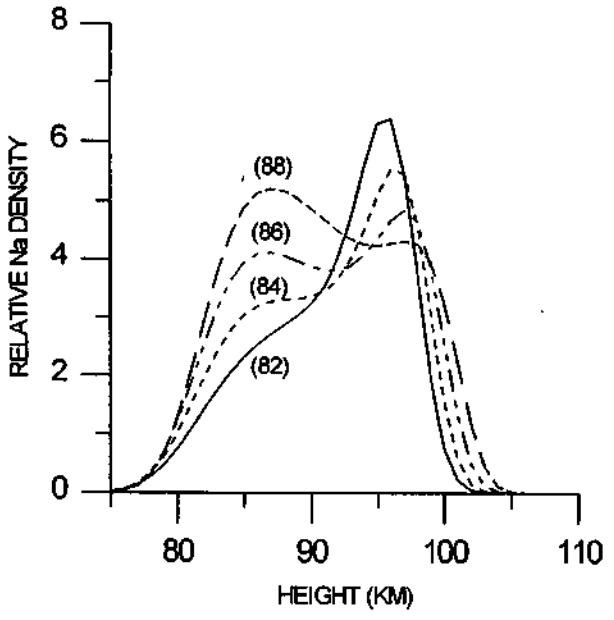

Figure 9. Simulation of a tidal perturbation on the average Na layer. The numbers in parentheses refer to the height at which the perturbation is zero, as explained in the text.

References

Alpers, M., T. Blix, S. Kirkwood, D. Krankowsky, F. J. Lubken, S. Lutz, and U. von Zahn, First simultaneous measurements of neutral and ionized iron densities in the upper mesosphere, *J. Geophys. Res.*, *98*, 275-283, 1993.

Batista, P. P., B. R. Clemesha, D. M. Simonich, and V. W. J. H. Kirchhoff, Tidal oscillations in the atmospheric sodium layer, *J. Geophys. Res.*, *90*, 3881-3888, 1985.

Batista, P. P., B. R. Clemesha, I. S. Batista, and D. M. Simonich, Characteristics of the sporadic sodium layers observed at 23° S, *J. Geophys. Res.*, *94*, 15,349-15,358, 1989.

Beatty, T. J., R. L. Collins, C. S. Gardner, C. A. Hostetler, and C. F. Sechrist, Simultaneous radar and lidar observations of sporadic E and Na layers at Arecibo, *Geophys. Res. Lett.*, *16*, 1019-1022, 1989.

Clemesha, B. R., Sporadic neutral metal layers in the mesosphere and lower thermosphere, *J. Atmos. Terr. Phys.*, *57*, 725-736, 1995.

Clemesha, B. R., V. W. J. H. Kirchhoff, D. M. Simonich, and H. Takahashi, evidence of an extraterrestrial source for the mesospheric sodium layer., *Geophys. Res. Lett.*, *5*, 873-876, 1978.

Clemesha, B. R., P. P. Batista, and D. M. Simonich, Concerning the origin of enhanced sodium layers, *Geophys. Res. Lett.*, *15*, 1267-1270, 1988.

Cox, R. M., J. M. C. Plane, and J. S. A. Green, A modeling investigation of sudden sodium layers, *Geophys. Res. Lett.*, *20*, 2841-2844, 1993.

Gardner, C. S., T. J. Kane, J. H. Hecht, R. L. Walterscheid, J. H. Yee, R. J. Niciejewski, R. P. Lowe, and D. N. Turnbull, Formation characteristics of sporadic Na layers observed simultaneously by lidar and airglow instruments during ALOHA-90, *Geophys. Res. Lett.*, *18*, 1369-1370, 1991.

Gu, Y. Y., J. Qian, and G. C. Papen, Concurrent observations of auroral activity and a large sporadic sodium layer event during ANLC-93, *Geophys. Res. Lett.*, *22*, 2805-2808, 1995.

Hansen, G., and U. von Zahn, Sudden sodium layers in polar latitudes, *J. Atmos. Terr. Phys.*, *52*, 585-608, 1990.

Hanson, W. B., and J. S. Donaldson, Sodium distribution in the upper atmosphere, *J. Geophys. Res.*, *72*, 5513-5514, 1967.

Helmer, M., and J. M. C. Plane, A study of the reaction $NaO_2 + O \rightarrow NaO + O_2$: Implications for the chemistry of sodium in the upper atmospheres, *J. Geophys. Res.*, *98*, 23,207-23,222, 1993.

Hunten, D. M., R. P. Turco, and O. B. Toon, Smoke and dust particles of meteoric origin in the mesosphere and stratosphere, *J. Atmos. Terr. Phys.*, *37*, 1342-1357, 1980.

Kane, T. J., C. A. Hostetler, and C. S. Gardner, Horizontal and vertical structure of the major sporadic sodium layer events observed during the ALHOA-90 campaign, *Geophys. Res. Lett.*, *18*, 1365-1368, 1991.

Kane, T. J., S. C. Gardner, Q. Zhou, J. D. Mathews, and C. A. Tepley, Lidar, airglow and radar observations of a prominent Na/sporadic E event at Arecibo during AIDA-89, *J. Atmos. Terr. Phys.*, *55*, 499-512, 1993.

Kirkwood, S., and U. von Zahn, On the role of auroral electric fields in the formation of low altitude sporadic-E and sudden sodium layers, *J. Atmos. Terr. Phys.*, *53*, 389-408, 1991.

Kirkwood, S., and U. von Zahn, Formation mechanisms for low-altitude Es and their relationship with neutral Fe layers: Results from the METAL campaign, *J. Geophys. Res.*, *98*, 21,549-21,561, 1993.

Kopp, E., and U. Herrmann, Ion composition in the lower ionosphere, *Ann. Geophys.*, *2*, 83-94, 1984.

Kwon, K. H., D. C. Senft, and C. S. Gardner, Lidar observations of sporadic sodium layers at Mauna Kea Observatory, Hawaii, *J. Geophys. Res.*, *93*, 14,199-14,208, 1988.

Mathews, J. D., Q. Zhow, C. R. Philbrick, Y. T. Morton, and C. S. Gardner, Observations of ion and sodium layer coupled processes during AIDA, *J. Atmos. Terr. Phys.*, *55*, 487-498, 1993.

Quian, J., and C. S. Gardner, Simultaneous lidar measurements of mesospheric Ca, Na, and temperature profiles at Urbana, *J. Geophys. Res.*, *100*, 7453-7462, 1995.

von Zahn, U., and E. Murad, $NaHCO_3$: A source of Na atoms for sudden sodium layers, *Geophys. Res. Lett.*, *17*, 147-150, 1990.

von Zahn, U., P. von der Gathen, and G. Hansen, Forced release of sodium from upper atmospheric dust particles, *Geophys. Res. Lett.*, *14*, 76-79, 1987.

Zhou, Q., and J. D. Mathews, Generation of sporadic sodium layers via turbulent heating of the atmosphere, *J. Atmos. Terr. Phys.*, *57*, 1309-1320, 1995.

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