Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2020-1079-RC2, 2021

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Sporadic sodium layer: A possible tracer for the conjunction between the upper and lower atmospheres" *by* Shican Qiu et al.

Anonymous Referee #1

Received and published: 29 January 2021

This paper describes a study of sporadic sodium layers (Nas) and their possible relationship with strong lightning discharges causing the overturning of the electric field in the upper atmosphere. An impressive range of instruments was used for the study: two Na lidars in Hefei, one of which also measured wind and temperature; a third Na lidar in Wuhan; and an ionosonde and electric field mill in Wuhan. An Nas layer was observed by the Hefei lidars (though not by the Wuhan lidar?), which coincided with an overturning of the vertical electric field. Strong lightning was observed in the region, and the authors postulate that highly charged clouds led to the overturning of the electric field, and that this may be causally linked to the appearance of the Nas.

While the possible link with the overturned electric field and lightning is an interesting idea and certainly worth investigating, I am not sure that a link with the overturned elec-

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tric field is needed to explain the observed Nas. Figure 1(d) shows a very clear shear in the zonal wind, which descends below 100 km around 1330 hrs. This coincides with the observed descent of the Es layer to 100 km (Figure 2b), after which it disappears and the Nas appears (Figure 1a and 1b). The Na density in the Nas layer peaks around 1.2e4 cm-3. The strength of the Es layer as it descends to 100 km is around 4 MHz, corresponding to an electron density of 2e5 cm-3. Most of the metallic ions in the Es layer would be Fe+ and Mg+, with a smaller amount of Na+. Assume all the Na+ ions were neutralised when the Es layer descended below 100 km and the ion-molecule chemistry becomes very fast (the theory proposed quantitatively by Plane). Then, if you divide the peak Na density in the Nas layer by the Es electron density, this implies that the fraction of Na+ in the Es layer was around 6%, which sounds sensible (see the results of rocket-borne mass spectrometers flown by E. Kopp, for example).

What this exercise shows is that the Nas can be explained by the sporadic E layer descending below 100 km. The authors therefore need to explain what the additional effect of the overturned electric field might be. If it is not needed to explain the appearance of the Na layer, then the two phenomena could be quite unrelated to each other.

In fact, the statistics summarized in Table 1 indicate that the overturned electric field is often associated with the termination or significant decrease in Es layers (80% of the time). So the question is what is the link? Does the reversal of the electric field accelerate the Es downwards, leading to its destruction through fast ion-molecule chemistry and the appearance of Nas?

Other matters to address:

1. The Na lidar measurements in Figure 1(a) and 1(b) have concentrations varying by a factor of 2, even though co-located in Hefei. This cannot be correct. Even if the lidars have different vertical resolutions, the integrated Na density across the Nas layer should be the same.

2. The statement on page 6 (line 28): “Thus, we conclude that the ionospheric echoes and the lightning activities exhibit an obvious synchronous behaviour.” Presumably Es layers are observed over Wuhan in the absence of lightning activity. So the implication of this statement is that whenever strong lightning is present Es is observed – is that correct?

Minor issues:

page 2, line 4: I don’t think the MLT is the “least known part of our planet” – what about the deep oceans? I think you mean “our planet’s atmosphere”.

page 2, line 6: changed “sodium species” to “sodium atoms”, since that is the form of Na that can be observed from the ground.

page 2, lines 15-30: in this discussion there is no mention of the magnetic field, which is part of the classical VxB mechanism for sporadic E formation

page 4, line 10: “prefers the Es mechanism” implies that the Nas is an intelligent being that can make a choice! I would rephrase “is better explained by the Es mechanism”

page 4, line 16: “suggests”

page 5, line 4: provide a citation for the equation

page 5,line 29: the phrase “could be supported by a classic electrodynamics textbook” should be omitted. Either this is very well understood by the community, or you should provide reference to such a textbook.

page 6, line 6: I cannot believe that the energy of this lightning stroke is known to 7 significant figures!

page 6, line 12: the shading in the figure is too faint to see.

page 6, line 17: the statement “such an idea/picture has been proposed long time ago” must be referenced.

page 6, line 30: the statement “The Sodium ions and electrons recombine much faster during the overturning period, leading to a depletion of the Es” needs further discussion. As I state above, I think this can only happen if the Es descends rapidly. Another possibility is that somehow the Es becomes compressed so that the plasma concentration increases – that seems unlikely.

page 7, line 12: change “consequential occurrence” to something like “consequent production”

page 9, line 5: the journal requires that the data is archived and accessible to the reader. Not through writing to someone.

page 19. Figure Caption 3: change “another Nas companying” to “another Nas being produced” Figure 4 should be redrawn. The site of the electric mill is hidden. The units of power are W, not J, and these “powers” contain too many significant figures. The map and shading are too faint to read.

Figure 5. The legend in the figure needs to be explained in the figure caption.

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