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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Formation of a bottomside secondary sodium layer associated with the passage of multiple mesospheric frontal systems" *by* Viswanathan Lakshmi Narayanan et al.

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Response to the reviewer comments on "Formation of a bottomside secondary sodium layer associated with the passage of multiple mesospheric frontal systems"

We thank the reviewer for the time spent on the review and very useful suggestions for further improvement of the manuscript. Below, we give our responses to the reviewer's comments. Reviewer's comments are given between double backslashes and our responses follow below the comments.

(i.e \\ Reviewer Comment \\

Our replies).

\\ This paper reports the observation of a secondary Na layer which formed around 85 km in the mesosphere during the passage a frontal system. The study involved a Na wind-temperature lidar which made measurements in the vertical and at 4 cardinal points, as well as an all-sky OH airglow imager. The imager was used to record the passage of four frontal events, and the lidar measured Na, wind and temperature. This data was combined to show that the front caused a marked temperature increase in a layer between 80 and 85 km, where the secondary Na layer then appeared. The wind and temperature data were also used to calculate the static and shear instability surrounding the passage of each front. The Na increase is interpreted to be caused by release of atomic Na from its reservoir NaHCO3, due to the higher temperatures which activate the reaction NaHCO3 + H, as well as downward transport of H and O from above 85 km and a corresponding decrease in O3. This interpretation seems quite plausible. Overall, this is a very nice piece of work which illustrates the importance of using multi-instrumented observations. \\

We thank the reviewer for the assessment of our work and the positive remark.

\\ The first is there must be a statement somewhere acknowledging the limitations of making observations in a Eulerian framework. That is, you are not observing the same air mass over 8 hours. This means that your interpretation of events requires that the atmosphere is horizontally homogeneous over roughly 2000 km. Whereas, in fact you only know the degree of homeneity over about 35 km (the distance between the off-zenith lidar beams), with some additional information over a larger scale from the all-sky imager. There is nothing you can do about this, but it should be stated in the paper. \\

We agree with this point and as mentioned by the reviewer this is an unavoidable issue with ground based measurements. At the end of section 2, we have added the following

paragraph (revised manuscript will be uploaded after receiving all the comments during open discussion).

'Being ground based measurements made in the Eulerian framework, we cannot observe the same air mass for an extended period. Though we can observe the small-scale structures and their movements in the airglow images, they are also superposed with the background wind, which is derived from the lidar measurements in this work. While this is an unavoidable drawback in studying the atmosphere using ground based measurements, we assume that the processes occurring are sufficiently homogeneous in the horizontal directions.'

\\ The second issue is about the downward transport of H and O to below 85 km. From the way you describe this, the reader will imagine that the NaHCO3 reservoir is left unchanged below 85 km, to be joined by O and H from aloft. However, the NaHCO3 below 85 km will also be transported downwards. So it is actually a parcel of air containing NaHCO3, H and O from above 85 km that is transported downwards and heats adiabatically, releasing Na. Note that the mixing ratio of total Na increases with height up to the ablation peak of Na which is above 90 km (see recent papers e.g. Carrillo-Sanchez et al., (2020), Icarus, 335, art. no. 113395). So downward transport will also increase the total Na concentration (i.e. Na + reservoir species) below 85 km. \\

Thanks for rising this issue. We have included this in many parts of the discussion section. Now we mention 'downward flux of minor species' in many places and retain downflux of H and O only where they are particularly discussed. The downward flux of NaHCO_3, Na and O_3 are also mentioned in the discussion part. The recent reference Carrillo-Sanchez et al., (2020) is also included.

\\ A third issue is that you list a large number of temperature-dependent rate coefficients, but do not do anything quantitative with them. That looks a little odd. For example, at line 390 you provide the rate coefficient for H + O3, and state that this

increases with temperature. But why not say how much? For example: "the rate coefficient increases by 40% when T increases from 200 to 230 K". That gives the reader some quantitative understanding of the point you are making. \\

In the revised version, we include Table 3 (attached at the end of this reply as a figure), which contains the values of the rate constants from 200 to 230 K in steps of 10 K and indicate the percentage increase in the rate constants. We believe that this will give a better understanding on the increased release of sodium atoms and a reduction in their reconversion to reservoir species. We also refer to the extent of variations in some parts of the Discussion section.

\\ One other point - although the paper is well written and straightforward to read, there are many grammatical errors - particularly the absence of the definite article "the" and indefinite article "a". It is not the job of a reviewer to correct these basic errors. \\

We are sorry for the grammatical errors. In the revised version, we have tried our level best to correct them and we are certain that most of the mistakes are corrected, if not all.

Minor corrections:

\\ line 23: change to: "...as a consequence of meteoric ablation (e.g. Plane ....)" \\

Changed.

\\ line 24: the statement "In high latitude winters, the peak altitudes are close to 88 km due to atmospheric circulation." is not really correct - it is chemistry which determines the height of the Na layer; the role of circulation is principally in changing the local temperature profile. \\

While it is true that the chemistry determines the equilibrium height of the Na layer not only in the high latitudes but in all the latitudes, the particular subsidence of peak height in winter polar region is believed to be due to the circulation and is observed with satellite based measurements (Fussen et al., ACP, 2010, in particular Figure 12).

\\ line 41: "occur at lower altitudes" \\

Corrected.

\\ line 73: "sodium lidar and airglow imaging observations from a high latitude location" \\

Corrected.

\\ line 79: in what way is the lidar "state of the art"? Please specify. The performance parameters you mention sound fairly standard. \\

The lidar is operated maintanence-free and uses a solid state laser diode end pumped Nd:Yag laser system to achieve high stability. The lidar functions without any manual adjustments required at the laser or telescope systems for the whole season as explained in Kawahara et al., Opt. Express, 2017. However, the lidar is being operated for the past 10 years and hence we remove the term 'state of the art' in the revised version. Instead, we include the above mentioned sentences to highlight the speciality of the lidar hardware.

\\ line 200: "This is further confirmed by the ..." \\

Changed.

\\ line 225: "...UT. The front continued ..." \\

Modified as suggested.

\\ line 269: "above 93 km before..." \\

Modified as suggested.

\\ line 314: "thermal ducting was possible" \\

Changed.

\\ line 319: "m and k stand for" \\

Corrected.

\\ line 384: "would have been initiated" \\

Changed.

\\ line 399: in fact, the Na compounds (NaOH, NaHCO3 etc.) photolyse in the near-UV above 200 nm. So change EUV to UV. \\

Changed. Thank you for this information.

\\ line 446: "have led to " \\

Changed.

\\ The References need to be sorted out and checked. They are not all in alphabetical order, and the same author appears with different initials in difference references! \\

We apologize for this mistake. We have extracted the references in bibtex format from the journal websites and created the list. We have checked and corrected the mistakes in the revised version (will be uploaded after the discussion closes).

We once again thank the reviewer for the evaluation of the work and useful suggestions that led to its improvement.

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-803, 2020.

Reaction	Rates from 200 to 230 K				% increase with respect to 200 K			
	200 K	210 K	220 K	230 K	200 K	210 K	220 K	230 K
R1	1.34×10^{-11}	1.49×10^{-11}	1.65×10^{-11}	1.81×10^{-11}	0	12	24	36
R2	7.09×10^{-14}	9.38×10^{-14}	1.21×10^{-13}	1.53×10^{-13}	0	32	71	116
R3	2.56×10^{-12}	2.91×10^{-12}	3.28×10^{-12}	3.66×10^{-12}	0	14	28	43
R4	2.20×10^{-10}	2.25×10^{-10}	2.31×10^{-10}	2.36×10^{-10}	0	2	5	7
R5	6.16×10^{-10}	6.33×10^{-10}	6.49×10^{-10}	6.64×10^{-10}	0	3	5	8
R6	5.00×10^{-30}	4.71×10^{-30}	4.45×10^{-30}	4.22×10^{-30}	0	-6	-11	-16
R7	1.59×10^{-33}	1.41×10^{-33}	1.26×10^{-33}	1.14×10^{-33}	0	-11	-20	-28
R8	2.69×10^{-16}	4.39×10^{-16}	6.86×10^{-16}	1.03×10^{-15}	0	63	155	283

Fig. 1. Table 3