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Reply on RC4

Bingkun Yu et al.

Author comment on "Comparison of middle- and low-latitude sodium layer from a ground-based lidar network, the Odin satellite, and WACCM–Na model" by Bingkun Yu et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-187-AC3, 2022

- This paper reports the climatology of sodium (Na) layer with lidar observations from 4 stations (with data ranging from 362 nights to 906 nights) at the middle- and low-latitude along 120oE operated by the Chinese Meridian Project (CMP). The results were compared to those with Infra-Red Imager System (OSIRIS) spectrometer onboard the Odin satellite and a global model of meteoric Na in the atmosphere (WACCM-Na); they found general agreement with some explainable differences. They also present the observations of sporadic Na layer (SSL) and the difference in correlation to sporadic E layer (Es) between mid-latitude stations and low-latitude stations. I find the study scientifically meaningful, clearly written with good connections to the past research. The paper is suitable for ACP. As stated below, I have a couple of major and minor queries; they can be accounted for with minor revisions.

Authors' response: We would like to thank the reviewer for the valuable comments and suggestions on our manuscript that help us improve our work. With respect to the comments of the reviewer:

Major queries:

- (1). Your brief description of 4 different methodologies used in Section 2 is appreciated. The aim is of course to help the readers to gain confidence on the reported describe physical quantities by the different methods used. Therefore, a clear connection between the "observed (calculated)" quantity and the quantity under study should be made in each case. Such descriptions would not be needed for a reader experienced in all 4 methods, not too many in our field. I think your descriptions on OSIRIS and WACCM-Na look good. In COSMIC, why is the S4max index a good measure of Es strength? Please give the definition of the S4 index! In the case of Na lidar, you could say something like, "If laser pulses with a fixed line-shape function are tuned to a fixed frequency within the Na D2-resonant absorption line at 589.6 nm, the received induced fluorescence intensity is proportional to the emitting Na density". People usually report on the uncertainty of the lidar measured Na density by its associated photon noise. There are two more sources of uncertainties. First, most practitioners convert the received photon profile at MLT to Na density there by assuming the lidar signal at a lower altitude (at 30 km for example) is the result of Rayleigh scattering from a "standard" atmosphere. The ignorance of air density at the time of measurement gives rise to uncertainty in Na density, please see Fig. 8(c) of Reference 1. Another uncertainty comes from the fact that most "stabilized" transmitting lasers do not lock to an absolute frequency reference, the laser light with bandwidth of 1.5 GHz for example could jump around within the Na fluorescence spectrum (FWHM about 1.2 GHz at 200 K). Likely with any luck, these two uncertainties would be smaller than the photon noise uncertainty reported. However, unlike the photon noise uncertainty, these unknown uncertainties remain the same with more data. My guess is that for climatology study as in this paper, there is no real concern. Therefore you do not need to go into the details in this paper, but you should in my view note their existence. However, as the CMP lidar data accumulated, it will be a concern, should one look for small effects like the long-term trends. See p. 399 of Ref. 2, if interested.

Authors' response: Thank you for your comments. In the revised manuscript, the definition of S4 and its correlation with ionosonde observations of Es layers are introduced. The description of Na lidar is also included in Section 2 according to the reviewer's suggestion: 'the received induced fluorescence intensity is proportional to the emitting Na density'. We also appreciate the reviewer's comments on the existence of the Na density uncertainties. These related references have been included. I agree with the reviewer. The uncertainties (normalization to atmospheric density at a lower reference height & laser frequency drift) is not the real concern in our climatology study. However, it will be a concern in the long□term change studies of Na layer in the future as the CMP lidar data accumulated.

- (2). Please expand the last two paragraphs of discussion in Section 3.2 between lines 303 and 328 somewhat to make the discussion on seasonal variation of SSL derived from the 4 latitudes clearer. The SSL formation has been researched in the past three decades and different mechanisms have been proposed. With the publication of Yu et al. (2021a) and Yu et al. (2021c), the authors claim that they've finally understood the formation of SSL in midlatitudes as well as in the tropics. Unfortunately, unlike other sections, these two paragraphs are overly compressed and not as clear as they need to be. For example, why do you show the intensity of the Es layer at the Na layer peak around 92 km (blue line), while the crucial thermospheric meridional circulations appeared between 100 - 120 km? Also, are most of SSL events occurred at the Na layer peak?

Authors' response: Sorry for the unclear statement of Figure 15 in the last two paragraphs. In the revision, the two paragraphs are revised to state more clearly and put in Section 4 Discussion.

The main scope of the study is the global climatology of Na layer from the CMP lidars, the Odin/OSIRIS satellite, and the WACCM-Na. We found that the global distribution of Na from Odin/OSIRIS is fairly consistent with the distribution of Es layers. Therefore, we conducted further analysis of the SSL, Es, and Na climatology in Figure 15. It is preliminary result of the SSL not the conclusive evidence for the formation of SSL, based on RO observations of Es layer, lidar and Odin/OSIRIS observations of Na layer, and SSL events. The climatology of SSLs shows agreement with Es layers. We infer that the variations of Es layer, e.g., mid-latitude Es affected by the thermospheric meridional circulation (95-115 km) (Yu et al. 2021a) and low-latitude Es affected by the geomagnetic activity (Yu et al. 2021c) could be related to the SSL formation. However, more detailed studies are needed combined with the Na & Es observations and WACCM simulations. The Es layer intensity represented by S4max was at 96 km rather than 92 km by our mistake. It has been corrected in the revision. The S4max at the altitude around 96 km (95-97 km) is used to study the possible effect of metallic ions on SSL when the Es layer descends below 100 km under the influence of tides, since the peak altitude of SSLs is around 96 km (Fig. 5 of Dou et al., 2013). Furthermore, following another referee #2's comments, more discussion of the seasonal occurrence of SSL is also included in Discussion.

Minor queries:

- You mentioned "exceptionally high temporal and vertical resolution (usually 3 minutes and 100 m)" in line 54. Would you like to mention Reference 3, where the Na layer observed with "exceptionally" high-resolution (60 ms and 15 m) appears to be composed of many downward propagating SSLs. It would be fun to speculate the underline physics.

Authors' response: Yes, the high-resolution observations of the Na density real significant features of Na layers in greater detail. The study has been included in Introduction.

- Question about CMP lidar stations. You utilized data from 4 Na resonance fluorescence lidars at Beijing (40.2oN, 116.2oE), Hefei (31.8oN, 117.3oE), Wuhan (30.5oN, 114.4oE), and Haikou (19.5oN, 109.1oE). I know of two stations near Beijing: Yanqing (40.5°N, 116.0°E) and Pingquan (41.0°N, 118.7°E). Is the Beijing (40.2oN, 116.2oE) different from these two or it includes both? Please clarify.

Authors' response: The Na resonance fluorescence Beijing lidar is located at Yanqing. Different versions of the location of the station exist in publications. We double checked the location, and it is (40.5°N, 116.0°E). Therefore, the figures 10, 11, 13, and 15 are revised as the measurements of Na layers from OSIRIS made within ± 5◦ latitude and longitude square centred on Beijing station are changed.

Other points:

- Line 87: "the long-term routine measurements" is miss-leading as the word "long-term" has other connotations, as in "long-term linear trend". I would say "multi-year routine measurements", "continuing routine measurements", or simply "routine measurements".

Authors' response: corrected.

- Line 122: Please define "S4 index".

Authors' response: done.

- Line 171: “104oW” should be “105oW”.

Authors’ response: corrected.

- Line 177: What is “ares”?

Authors’ response: corrected to “areas”.

- Line 186: Please explain what is “and Na reference by Plane (2010).”?

Authors’ response: done.

- Line 191: Change “Na number density” in “Figure 9c shows the Na number density” by “Na density profile” or “the height dependent Na density”.

Authors’ response: done.

- Line 204: Should ”major reservoir” be ”major reservoir of the neutrals”?

Authors’ response: Yes, it has been revised.

- Line 254: By “analyzed later”, do you mean “analyzed below”?

Authors’ response: analyzed in Discussion section.

- Line 259: What happens to Fig. 11(g)? It appears empty in the figure.

Authors’ response: No OSIRIS data at Haikou location. It has been marked in Fig. 11(g) in the revision.

- Line 286: In figure 14, do we compare the data under sunlit condition (OSIRIS) to nocturnal observations (Lidar) and full diurnal means (WACCM), correct? Would this be problematic?

Authors’ response: In the revision, we compare the data from OSIRIS at ~6 LT, Na lidar at 4-6 LT and WACCM-Na at 6 LT. The comparison at 18 LT is not shown because the OSIRIS measurements at 18 LT are much less than those at 6 LT.

- Line 316: Do you have an explanation for why “an annual change in the Na column number density, with a summer minimum and a winter maximum”?

Authors' response: It has been explained in Figure 5 in 3.1 Global map of Na layer. "The significant summer-time depletion of high-latitude Na layers is primarily attributed to the temperature dependence of neutral Na chemistry with the very low temperature at the summer mesopause because of dramatic adiabatic cooling of upwelling air (Plane, 2003) and secondarily attributed to efficient removal of metallic species on noctilucent cloud particles (Plane et al., 2004; Raizada et al., 2007; Plane, 2012)". This is also our content of next research to investigate in detail, combined with the satellite and ground-based observations of Na and Es and WACCM simulations.

- Line 318: Should you delete "Hefei," at the end?

Authors' response: It has been corrected by replacing "Hefei" with "Haikou".

- Line 321: Should "lidaras" be "lidars".

Authors' response: corrected.

- Line 334: Should "Na concentration" be "Na column density"?

Authors' response: corrected.