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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Influence of Asian Summer Monsoon Anticyclone on the Trace gases and Aerosols over Indian region" *by* Ghouse Basha et al.

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Reply to Reviewer#1 Comments/Suggestions

This paper presents the spatial and temporal distributions of water vapour, ozone, carbon monoxide, temperature, and aerosols over the Asian Summer Monsoon Anticyclone (ASMA) region based on MLS, COSMIC GPS, and CALIPSO satellite observations and investigates the influence of ASMA on the tracers and tropopause parameters. Additionally, QBO and ENSO indices are used to identify the connection between these two climate patterns and tracers over the ASMA region. At the end, the manuscript shows the difference of several parameters under various monsoon condi-

tions. In general, it is valuable to understand the characteristic of tracers and aerosols over ASMA region and the effect of QBO and ENSO on them. However, this study only presents the preliminary results of the distributions of tracers and aerosols without insightful finds. The data (e.g. ENSO) and definition (e.g. tropopause) used in the study are not consistent. The descriptions of the results are often not precise. More importantly, some statements given in the manuscript are not supported by the figures (e.g. the influence of QBO and ENSO on the tracers). There are still a lot of detailed technical errors in the manuscript. Therefore, I suggest this paper should be majorly revised.

Reply: First of all we wish to thank the reviewer for handling this manuscript and for offering constructive comments/suggestions, which improved the manuscript content significantly. In the revised version, we have taken care of the reviewer's comments/suggestions, and suggestions are incorporated in the text and we hope the reviewer will find the revised version satisfactory. We have clearly mentioned the data used and definitions of different parameters in this study. We made sure that the results presented in the study are consistent with the figures. In addition, we have added a detailed discussion with respect to our results in the revised manuscript. We have taken the utmost care to reduce the grammatical mistakes and typos to the maximum possible extent in the revised manuscript.

We have used the below methodology to identify the relation between the tropopause altitude, tropopause temperature, WV, O3, CO, and ASR with QBO and ENSO (Niño 3.4 index).

'To identify the contributions of QBO and ENSO in the tropopause parameters, tracers, and aerosol measurements, complete data are subjected to the multiple linear regression analysis. This well-established method considers the relative influence of the considered climate indices on tropospheric variability. The regression technique is expressed as: y(t) = a1 QBO(t) + a2 ENSO(t) + c; t = 1,n where a1 and a2 are the regression coefficients, QBO and ENSO are the normalized QBO time series represented by the biennial modulations of the monthly mean zonal winds at 30 hPa measured by radiosonde in Singapore and normalized Niño 3.4 (ENSO) index, c is the random noise and residual 'c'. For more details about the regression technique and its further applications see Kunze et al. (2016). With this methodology, we have obtained the results below. But unfortunately, the results obtained with this methodology are not significant hence we have removed this part completely in the revised version.

Figure 5. Time series anomalies of (a) tropopause altitude, (b) tropopause temperature obtained from COSMIC, (c) WV, (d) O3, (e) CO at 100 hPa obtained from MLS satellite observations and (e) ASR obtained from CALIPSO (16-18 km averaged) subjected to multiple linear regression based on QBO proxies in ASMA region from 2006 to 2016. The resulting fits are shown here (blue line)

Figure 6. Time series anomalies of (a) tropopause altitude, (b) tropopause temperature obtained from COSMIC, (c) WV, (d) O3, (e) CO at 100 hPa obtained from MLS satellite observations and (e) ASR obtained from CALIPSO (16-18 km averaged) subjected to multiple linear regression based on Niño 3.4 index in ASMA region from 2006 to 2016. The resulting fits are shown here (blue line).

Specific comments P7. L.159-165 The description of the method used in the study is unclear. The equation should be explained in detail.

Reply: In the revised version of the manuscript, we have clearly written the methodology and explained the equations while providing details.

P8. L.180-181 Some references should be included here about the representation of ASMA with 16.75 km GPH. Reply: Reference added (Randel et al., 2006; Basha et al., 2019).

P8. L.185-186 "The height of the tropopause reaches 18-18.5 km in the northwest of the ASMA region". From Fig.2a, the region with tropopause height 18-18.5 km lies in the southwest of the ASMA region.

Reply: In the revised version of the manuscript, the sentence was rewritten as 'The height of the tropopause reaches ~18-18.5 km in the southwest of the ASMA region.'

P9. L.203-205 The statement here is unclear. This sentence should be revised. Reply: We have re-written this sentence with better clarity.

P9. L.209-211 Fig.2f shows large amount of aerosol in the southern part of the ASMA. The values of ASR inside the anticyclone are in the range of 1.1-1.15.

Reply: The text and values are changed according to figure 2. 'These observations clearly indicate the presence of enhanced aerosols in the anticyclone region with ASR magnitude ranging from 1-1.15. These large amounts of aerosol are seen in the middle and southern part of the anticyclone.'

P11. L.253-255 The correlation coefficients between ASR and other parameters are quite small. I can not conclude they are highly correlated.

Reply: We agree with the reviewer's comment. We have included the statement regarding the lower correlation of ASR with other parameters. 'The correlation between ASR with other parameters are found to be less'

P11. L.257-262 The conclusions given here are too general. More explanation and the connection to the figures should be included.

Reply: In the revised manuscript, we have included the lag lead analysis in connection with Figure 4. We have included more explanation in the revised version

P11. L.276-277 Fig.5 does not always show positive values of ASR during eastward phase of QBO and vice versa. This sentence should be revised.

P12. L.278-280 Section 2.3 describes MEI ENSO index is used in this study. Later, Section 3 shows Nino 3.4 ENSO index is applied. Here, SOI ENSO index is used to analyze. Later, ONI ENSO index is also used. Which index did you really use? Why do you use several kinds of ENSO index? To help understand the figure, the definition of ENSO from different indices should be also included.

P12. L.282-283 Can you specify the lag between QBO and the parameters used here?

P12. L.286-287 Can you specify how much are seasonal, annual, QBO and ENSO components for all parameters?

Reply: In the revised version of the manuscript, we have removed the Figure5 and Figure 6 discussion as they are not significant as mentioned in reply to the first comment.

P12-13. L.299-303 I can not conclude that the tropopause altitude and CO increase and the tropopause temperature and O3 decrease over the whole ASMA region during the active days of monsoon from Fig.7. The results from Fig.7 present more like increase (decrease) of tropopause altitude and water vapour (tropopause temperature and O3) in the southern ASMA region which may be connected to the deep convection region (BoB and the indian subcontinent). It looks like CO in the southern ASMA region slightly decreases instead of increases, the result will be clearer if you change the colourbar range of CO (Fig.7e).

Reply: In the revised version of the manuscript, we have changed the color bar of the figure and modified the text according to Figure 7. 'The tropopause altitude and temperature anomalies depict scattered pattern (increases and decreases throughout the ASMA). The tropopause altitude (temperature) increases (decreases) particularly overhead BoB during the active phase of the Indian monsoon. The WV depicts a significant increase over the BoB and the southern part of the anticyclone. Particularly O3 values are low over east and south of the ASMA region. The CO concentration shows low values over the head BoB and southern part of the ASMA during the active days of monsoon. These low and high values in different parameters are related to the deep convection region (BoB). '

P13. L.316 Fig.8d does not show that ozone decreases over the ASMA region during strong monsoon years. Maybe it is also affected by other factors (e.g. ENSO, QBO,

mixing). You should include some explanation here.

Reply: It is well known that water vapor exhibit enhanced values within the anticyclone, conversely ozone shows relatively low values owing to convective transport (Dessler and Sherwood, 2004). Deep convective clouds occurred over the South Asian subcontinent, the southern Himalayan region, and the Tibetan Plateau that caused lightning activity (Qie et al., 2014). NOx produced by lighting has an impact on upper tropospheric ozone via photochemical reactions (Kita et al., 2002; Schumann and Huntrieser, 2007; Fadnavis et al., 2015; Gottschaldt et al., 2018). Uplifted ozone precursors and NOx produced by lighting contribute to photochemical ozone production in the upper troposphere in the ASM anticyclone. This may be one of the factors for increase in O3 but most of the studies showed a decrease in O3 during strong convection. Yan et al., (2018) reported that ozone patterns after La Niña winters and springs show in-mixing over the east and central Pacific, while the ozone patterns after El Niño winters and springs are more zonally symmetric in ASMA. The intrusions from the high latitude stratosphere reach much deeper into the tropics for La Niña compared to El Niño. This discussion was added in the summary and conclusion part in the revised version.

P13-14. L.323-327 The statements here are not clear. Do you mean the tropopause altitude, water vapour, CO and ASR (tropopause temperature and ozone) increase (decrease) during La Nina years? If it is true, the results shown here are contradict to the statements before (L278-280) based on Fig.6. Or, you mean the tropopause altitude, water vapour, CO and ASR decrease during La Nina years? Check the data and confirm the statements. If it is contradict to the result before, what is the explanation? If it is not, this paragraph should be revised.

Reply: We are sorry for this statement. We have edited this statement properly in a revised version of the text. During strong La Nina years, tropopause altitude, water vapor, CO, and ASR increases (Figure 7). However, it should be noted that QBO and ENSO relations are removed in the revised version due to insignificant results.

P15. L.360-362 Again, the results shown here are contradict to the statements before (L278-280).

Reply: In the revised version of the manuscript was edited as per our results and removed the contradictory statements.

P15. L.371-373 I can not see that the tracers and aerosols in the ASMA are significantly impacted by the transport processes of moisture and pollutants from the northern part of Tibetan Plateau based on your study. Can you specify the connection?

Reply: This type of general statement was removed in the revised manuscript and we have highlighted the only results obtained from our study.

Technical corrections There are many detailed errors regarding tense, punctuation, and grammar... The manuscript should be edited thoroughly.

Reply: We have taken the utmost care in revising the manuscript to reduce the grammatical mistakes or typos to the maximum possible extent.

Since the concentration units of water vapor, ozone, and CO are all mixing ratio, it might be better to just use "WV" instead of "WVMR" in several places of the manuscript. Reply: As per reviewer suggestion we have changed to WV instead of WVMR.

P12. L.296 The reference Rajeevan et al. (2010) is missing. Reply: Reference added.

P26. Figure 2 The results would look clearer if you make the range of colorbar smaller (e.g. WV, CO, and ASR).

Reply: As per the reviewer's suggestion, we have changed the color bar scale.

P28-30. Figure 4-6 It will be easier to connect the text about the years with special conditions to the figures if you change the x-coordinate to yyyymm (year-month) or yyyy instead of using pure months (1,...,121).

Reply: Changed as per reviewer suggestion.

Once again, we would like to thank the reviewer for his/her thoughtful comments and suggestions that led to substantial improvements in the revised manuscript.

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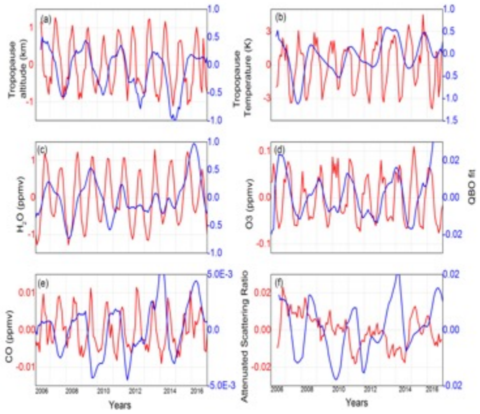

Fig. 1. Figure 5. Time series anomalies of (a) tropopause altitude, (b) tropopause temperature obtained from COSMIC, (c) WV, (d) O3, (e) CO at 100 hPa obtained from MLS satellite observations and (e) ASR

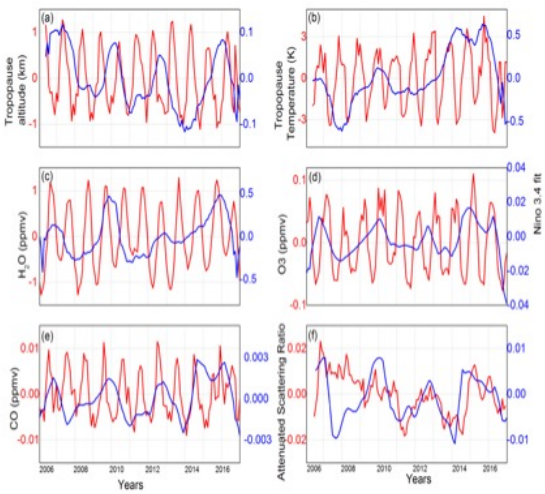

Fig. 2. Figure 6. Time series anomalies of (a) tropopause altitude, (b) tropopause temperature obtained from COSMIC, (c) WV, (d) O3, (e) CO at 100 hPa obtained from MLS satellite observations and (e) ASR