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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Structure, dynamics, and trace gases variability within the Asian summer monsoon anticyclone in extreme El Niño of 2015–16" *by* Saginela Ravindra Babu et al.

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Replies to Referee #2 Comments/Suggestions

Anonymous Referee #2 This a very interesting and well-structured paper that should be published by ACP. It shows how a strong boreal summer ENSO event like that in 2015 significantly weakens the strength of the Asian summer monsoon anticyclone (ASMA). Typically, ENSO events happen during the boreal winter, so summer events, which are rather rare, may be important in a changing climate. The paper shows how the composition of air within the ASMA around the UTLS is strongly influenced by such a summer El Nino, with less tropospheric (CO, WV) and more stratospheric

(ozone) signatures (all these quantities are derived from the MLS observations). Also the warming of the tropopause (lapse rate and cold point) within the ASMA as derived from the COSMIC data is very convincing. Thus, I would like to recommend this paper for publishing in ACP by taking into account the following critical points. There are also few important formulation issues listed in the minor comments.

Reply: First of all, we wish to thank the reviewer for going through the manuscript carefully, appreciating actual content of the manuscript and offering potential solutions to improve the manuscript content further. We have revised the manuscript while considering both the reviewer's comments/suggestions.

Major points

In Figs 6-9, I would recommend to show which differences are statistically significant by comparing the difference with the standard deviation σ of the calculated mean value. Typically, hatched areas (e.g. by black dots) are used to show which differences are larger than 2σ.

Reply: Thanks for the valuable suggestion. As for the reviewer suggestion, we have done a statistical analysis for the obtained anomalies for trace gases and the tropopause temperatures. Further, we compared the obtained anomalies with the $\pm 2\sigma$ standard deviation of background long term mean. We have highlighted the values which are greater than the $\pm 2\sigma$ standard deviation in Figures 7 to 10 in the revised manuscript.

Minor comments: Abstract, P1 L13 In your abstract, you talk about the extreme El Nino 2015-16 event, so my impression was that you will discuss the winter part of this event...however your topic is much more the unusual summer start of this event...maybe you should reformulate your abstract, maybe something like this: A weak 2014/15 El Nino developed in 2015 to a strong boreal summer event which continued and even enhanced during the following winter. In this work, the detailed changes in the structure, dynamics and trace gases within the Asian summer monsoon anticy-

clone (ASMA) is delineated by using Aura Microwave Limb Sounder (MLS) measurements, COSMIC Radio Occultation (RO) temperature, and NCEP reanalysis products. Our analysis concentrates only on the summer months of July and August 2015 when Nino3.4 index started to exceed 1.5 values. The results show that the ASMA structure was quite different in summer 2015 as compared....

Reply: Authors thanks to the reviewer for a nice suggestion. We have modified the abstract in the revised manuscript as suggested by the reviewer.

Abstract, P2 L29-31 ...and further supports... During a “normal” El Nino which typically maximizes during the boreal winter, there is a shift of convection from the Western to the Eastern Pacific, so something similar has to be expected for the summer El Nino...so this is for me one of the main reasons for the warming of the tropopause in the ASM region. Of course, changes in ozone you recognized follow this shift in convective patterns and also influence the tropopause temperature...

Reply: Yes. The well-known Walker circulation reversal during the El Niño events suppresses the convection over the ASM region. We agree with the reviewer that shift in the convection during El Niño is also one of the plausible reasons for the observed tropopause warming in 2015. The enhanced ozone (heating due to O3) alone might be not the reason for the tropopause warming. Apart from ENSO induced convection, other factors also can influence the tropopause temperature, such as stratospheric QBO, and atmospheric waves. We have discussed these things in the results section in the revised manuscript. However, to avoid confusion, we have removed this sentence from the abstract in the revised manuscript.

P2 L36 boreal summer, centered at 25N and extending....

Reply: Corrected as per suggestion.

P2 L42 Santee et al., 2017).

Reply: Corrected as per suggestion.

P2 64 ....Das and Suneeth, 2020). Most of the water vapor enters the stratosphere through.... P2 68-71 ....about the causative mechanism...???? ....is mainly controlled by the advection and tropopause altitude... I think that the cold point tropopause mainly dominates the WV concentrations in the lower stratosphere. I would recommend to reformulate all statements related to Das and Suneeth publication.

Reply: We have reformulated all statements related to ‘Das and Suneeth publication’ in the revised manuscript. We have revised the sentences as follows: ‘Recently, Das and Suneeth (2020) reported about the distributions of WV in the UTLS over the ASMA during summer using thirteen years of Aura Microwave Limb Sounder observations. They concluded that WV in the UTLS region inside the central part of ASMA is mostly controlled by horizontal advection and very less from the local process and tropopause temperature in both summer and winter’.

P4 L78-105, Tweedy et al., 2018 versus Yan et al., 2018 Maybe you should make more clear, even in the introduction, how to classify the 2015-2016 El Nino event: In my understanding there was a weak El Nino during the 2014/15 boreal winter which developed to strong boreal summer ENSO event (following the definition discussed in Tweedy et al., 2018). This summer ENSO event continued and even enhanced until the winter 2015/16. Thus, following the definition given in Yan et al., 2018, it was a long-lasting El Niño event because it lasted over two consecutive winters.

Reply: Thanks for the suggestion. We have modified the text as suggested.

We have revised the sentences as follows: ‘It was started as a weak El Niño during 2014-15 boreal winter and it developed as a strong boreal summer El Niño event in 2015 (Tweedy et al., 2018). Further, this strong boreal summer event continued and significantly enhanced until the boreal winter of 2015-16’.

P8 L180 In a similar manner, we....

Reply: Corrected in the revised manuscript.

P10 L194-195 ...in August if compared to July.

Reply: Corrected in the revised manuscript.

P10 L195 ...over the northwestern Pacific...(see also L406)

Reply: Corrected in the revised manuscript.

P10 L206 ...as well as at 150 hPa...

Reply: Corrected in the revised manuscript.

P12 L232 ...of the westerlies.

Reply: Corrected in the revised manuscript.

P12 L242 Western Pacific (use large letters for geographic names)

Reply: Corrected in the revised manuscript.

P14 Figure 5, caption please write correctly the PV units.

Reply: Corrected in the revised manuscript.

P15 L277 ...penetration....has started

Reply: Corrected in the revised manuscript.

Figure 6 and Figure 7, captions please mention that PV is from ERA-Interim in Figure 6 and ozone from MLS in Figure 7

Reply: Mentioned in the revised manuscript.

General Sometimes you write O3 and sometimes O3....

Reply: We make it consistent throughout the manuscript.

P16 L289 Further, we quantify the change in O3, CO and WV concentration...within the ASM during 2015 caused by the dynamical effects....and we do not need the last

sentence, I think.

Reply: Modified as per suggestion.

P16 L295 It is well-documented that the ASMA contains low (high)...

Reply: Corrected as per suggestion.

P16 L298 Differences of the trace gases within and outside of the ASMA are attributed to...

Reply: Corrected in the revised manuscript.

P16 L301 two times “strongly”

Reply: Corrected in the revised manuscript.

P16 L303 ...(Yan et al., 2018...)

Reply: Corrected in the revised manuscript.

P17-19 L314-351 There are few repetition in the text...you should also explain the strong negative values in Fig 7 probably related to a stronger upwelling in the BD circulation during this summer El Nino (see also Diallo et al., 2018). The sentence in L346 does not contain any verb....The sentence in L349-351 is confusing...

Reply: We have taken care most of the things in the revised manuscript.

P20, Figure 8 + text There is also a considerable year-to-year variability of the CO sources (biamass burning) which may be also the reason for the CO anomaly in 2015, see e.g. Santee et al.,JGR, 2017....maybe you would like to discuss this point.

Reply: The authors fully agree with the reviewer that there is a considerable year-to-year variability of the CO sources. Apart from this, a weak vertical transport from the boundary layer to the UTLS region over the ASM region is generally observed during El Niño period (Fadnavis et al., 2019). We have discussed about this in the revised manuscript as suggested by the reviewer.

P21 Figure 9 There is a significant enhancement of WV in the tropics, probably related to warmer tropical temperatures following EL Nino. For the typical winter El Nino a positive water anomaly is expected in the tropical tropopause region (see Randel et al. 2009 or Konopka et al., 2016), so something similar can be expected for a summer El Nino

Reply: Yes. The authors fully agree with the reviewer that there is a significant enhancement of WV particularly at 146 hPa in July and 100 hPa in August months. We have discussed about this in the revised manuscript as suggested by the reviewer.

P22 L389 ...we tried to...please reformulate

Reply: Modified in the revised manuscript as suggested.

P22 L395-96 It is well-documented that...are occur (?) This sentence is confusing

Reply: Apologies for confusion. We have modified entire sentence in the revised manuscript.

P22 L401 Kindly noticed...please reformulate

Reply: Modified in the revised manuscript as suggested.

P22 L406 Nortwestern Pacific

Reply: Corrected in the revised manuscript.

P23 L415-416 During winter El Nino, there is a shift of convection from the Western to the Eastern Pacific, something similar has to be expected for the summer El Nino...so this is for me one of the main reasons for the warming of the tropopause in the ASM region (less convection). Of course, changes in ozone you recognized follow this shift in convective patterns and also influence the tropopause temperature

Reply: We agree with the reviewer that the shift in the convection during El Niño is also one of the plausible reasons for the observed tropopause warming in 2015. As

mentioned earlier, the enhanced ozone (heating due to O3) alone might be not the reasons for the tropopause warming. Apart from ENSO induced convection, other factors also can influence the tropopause temperature, such as stratospheric QBO and atmospheric waves. We have discussed this thing in the results section in the revised manuscript.

P24 438 in the stratospheric tracer (O3) within the ASMA..

Reply: Corrected in the revised manuscript as suggested.

We once again thank the reviewer for going through the manuscript carefully and offering potential solutions which made us to improve the manuscript content further.

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