

## ***Interactive comment on “Winter 2018 major sudden stratospheric warming impact on midlatitude mesosphere from microwave radiometer measurements” by Yuke Wang et al.***

**Yuke Wang et al.**

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Reply to Referee #1

Ref: Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2018-1361-RC1>, Apr 04, 2019 Title: “Winter 2018 major sudden stratospheric warming impact on midlatitude mesosphere from microwave radiometer measurements” by Yuke Wang et al.

We thank Referee #1 for useful comments, discussion and proposals for corrections. We made corrections and changed the text according to the suggestions. Our revisions and reply to Referee #1 comment are below. Line numbers of the revised manuscript

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are indicated.

Referee Comment: RC Authors Comment: AC

RC: GENERAL COMMENTS

The topic of ground-based mesospheric carbon dioxide observations is interesting and fits into the scope of ACP. The local microwave radiometer observations over Kharkiv during the major warming event in 2018 are valuable, but they need to be validated and explained adequately. In this sense I suggest the authors to add stratospheric carbon dioxide and mesospheric temperature data for a solid discussion of horizontal and vertical transports. If this information is provided in a concentrated form during a \*major revision\*, the paper would gain further value.

AC: CO and mesospheric temperature data horizontal and vertical transports are included in new Sect. 4.1 and 4.3: 4.1 CO variability 4.3 Temperature changes.

RC: SPECIFIC COMMENTS

RC: 1) Validation: A validation of the reported CO observations is required. For this purpose satellite observations could be used 1) to compare the CO in the 60-90 km range and 2) to extend the profiles will into the stratosphere. This would allow the qualification of downward transport during the 2018 major warming event in comparison with other events. Note, that the shown changes remain in the 70-80 km range while Funke et al. (2009) reports on effects down to 30 km for the 2004 major warming event. Such a three-dimensional picture would allow to place the local observations into a global context.

AC: Comparison with MLS data is now included (Figure 3). This shows good agreement. We extend CO profiles into the stratosphere (see new Figure 3).

RC: 2) Explanation: The present explanation of the observed mesospheric is highly speculative. It uses analysis data for the stratosphere which does not directly imply a clear picture of the mesosphere. So you can not use the presence of stratospheric

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planetary waves to explain oscillations in the mesosphere on the daily basis. For such a link mesospheric data are required, which exist with satellites.

AC: Satellite mesospheric data from MLS is now included for explanation in a new text in Sect. 4.1, 4.3, 4.4 and Supplement.

In this sense, you give some information on MLS-derived temperatures in figures 2.a and 7, but the latter is very noisy and not very helpful. The presentation of maps at selected levels would considerably help the interpretation of local CO and T observations in terms of three-dimensional transports.

AC: Maps of the CO distribution at selected level have been created and they are described in new Sect. 4.1 (Figure 4, Figure S1 and Figure S2). Along with CO profiles (Figure 3) they are used for the CO motion analysis in terms of horizontal and vertical transports.

RC: 3) Concentration: In some points the discussion of stratospheric dynamics is distracting the reader. Given the aim of the paper to present and understand the local mesospheric CO behavior, the detailed presentation of stratospheric circulation patterns in figures 3, 5 and 6 and related texts does not help this understanding and should be erased in favor of a concise discussion of joint stratosphere-mesosphere data in the sense of the comment above.

AC: Figures 3, 5 and 6, and the discussion of stratospheric dynamics has been erased.

RC: TECHNICAL CORRECTIONS

L19: Change "was" to "is" for present tense. AC: Corrected L23: Change "have been" to "are". AC: Corrected L42: Change "happened" to "happens". AC: Corrected L45: Change "The" to "A". AC: Corrected L51: Insert "is" after "database". AC: Corrected in L53. L56: Replace "waves" by "activity" and "propagate" by "propagates" AC: Corrected in L60. L58: What do you mean with "upward transfer of the momentum and heat"? The EP flux is the flux of wave activity, which is much upward and equatorward

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in the case of SSWs. Please, reformulate. AC: Old Figure 2 and corresponding text have been removed. L61: Insert "its" after "is". AC: Corrected in L64. L65: Change "atmosphere" to "atmospheric". AC: Corrected in L68. L84: Replace "in" with "associated with", for example. AC: Replaced in L94. L143: Replace "are" with "is" because it refers to "data set" (singular). AC: Corrected in L152. L156: Insert a comma after "snow". AC: Inserted in L166. L160: Why not use "CO" for "carbon dioxide" (here and elsewhere)? AC: Corrected in L169 and hereinafter. L161: Are these validation tests published and documented? Please, provide a reference. AC: Reference provided in L170. L162: Why not use "MWR" for "microwave radiometer" (here and elsewhere)? AC: Corrected in L174 and hereinafter. L166: Above you wrote "sideband" - please, unify. AC: Corrected in L174. L167: Replace "The first" with "At first". AC: L175: Corrected to "Firstly" as proposed by Referee #2. L169: Replace "The second" with "At second". AC: L177: Corrected to "Secondly" as proposed by Referee #2. L175: Which of the two methods were used for this article? AC: Explained in L182–184. In this article, the both methods were used with averaging the values of the zonal wind speed for altitudes of 70–85 km. Time interval January 1 – March 31, 2018 including the SSW 2018 event is considered. L178: What do you mean with "similar"? Rüfenachts instrument is for ozone at 30-79 km - please, specify yours. AC: This paragraph has been removed. L185: Insert "and" before "have". AC: Inserted in L191. L200: Shorten subtitle to "3 Northern hemisphere SSW effects" in the same style as for section 4. AC: Shortened, L210. L202: Begin with "The general" and insert "a" after "is". AC: Sentence rephrased in L212. L204: Insert "a" before "sequence". AC: Inserted and rephrased in L214. L212: Why not use "SSW" for "sudden stratospheric warming" (here and elsewhere)? AC: We use "SSW" in L227 and below. L225: Replace "in the" with "into". AC: Sentence rephrased in L229–230. L233: See comment for L58. AC: The text corrected. The EP-flux discussion removed. L238: Replace "since" with "after". AC: The text removed. L242: "QBO" appears only once in the text, so it does not indeed to be abbreviated. AC: The text removed. L244: Insert "less likely" after "latitudes". AC: The text removed. L256: Correct "WMR" to "VMR". AC: Corrected in

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L256. L376: Insert "The" before "Elevation". AC: This paragraph has been removed. L377: Insert "A" before "Similar". AC: This paragraph has been removed. L437: The paragraph should be shifted to where first reference to Fig. 4 is made. AC: This paragraph has been removed. Fig.2: Please, mark "10 Feb" in (a) as in (b),(c), and (d). AC: Corrected in all Figures. Fig. 4: Please, indicate height ranges in (a) and (b) as in (c) and (d). AC: Corrected, indicated in new Figure 3. Fig. 7: Please, indicate "10 Feb" as in Fig. 2. AC: Corrected in all Figures.

Reply to Referee #2

Ref: Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2018-1361-RC2>, Mar 16, 2019 Title: "Winter 2018 major sudden stratospheric warming impact on midlatitude mesosphere from microwave radiometer measurements" by Yuke Wang et al.

We thank Referee #2 for useful comments, discussion and proposals for corrections. We made corrections and changed the text according suggestions. Our revisions and reply to Referee #2 comments are below. RC (AC) is Referee (Authors) comments. Line numbers of the revised manuscript are indicated.

Referee #2 Comments: General comment:

RC: This study used the reanalysis and microwave radiometer measurements to investigate the February 2018 SSW event and its impact on the midlatitude mesosphere from an in-situ site. Given that the application of radiometers measurements into the SSW studies is still lack, this manuscript is suitable for the Atmospheric Chemistry and Physics journal. However, I have a concern about the novelty of the paper. The SSW events, their impacts, and predictions have been widely explored in literature, but this study shows little review on the previous studies (e.g., Charlton et al. 2007JC; Hu, Ren, et al. 2014JAS; Taguchi 2018JGR; Rao et al. 2018JGR; Tripathi et al. 2016MWR; Karpechko et al. 2018GRL; Rao et al. 2019AAS). By comparing the previous studies and this one, the novelty of this study can be well stressed in the introduction and discussion sections. The authors are responsible for their investigating the latest publi-

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cations about this topic on their own. In addition, some typos and description errors still exist in the manuscript. The structure of this version can be further improved. Therefore, I recommend a major-plus revision. If those problems are well solved, the ACP journal can consider its publication. Please see my specific comments below.

AC: We (i) added new results in the revised manuscript (Fig. 3, Fig. 4, Figs. 6–9 and Supplemental Material), (ii) better structured Sections of the results and discussion, (iii) highlighted the novelty and (iv) corrected typos and errors.

Major comments: RC1. The English language needs to be further improved. Many weird expressions can be found in this manuscript. I will list all of them in the minor comments one by one. I found some English speakers in the coauthors. Send this manuscript to all of them and well polish the language and correct all typos.

AC1: We have improved the grammar in the manuscript and corrected errors.

RC2. The organization of the manuscript is disappointing. I found many data links in the main body of the "paper" (Lines 236, 243, 415, 741, 743, 748, 779 : : : :). Why not introduce all the datasets in the method section? Or present a table to list all the data sources the authors used. The random placement of any dataset largely diminishes the general quality of the manuscript. The authors are writing a scientific article, not a diary.

AC2: We have moved description of the data sets to sub-Section 2.2 and, partially, to Supplement.

RC3. The discussion section seems to be a replication of the former sections, not a real discussion at all. The authors need to compare their result with others (e.g., Taguchi 2018; Karpechko et al. 2018; Rao et al. 2019: : : : ) to put an emphasis on the new finding of the study. Another concern is about the discussion on the stratopause elevation, descent, and disappearance, which are not shown in any figure. If the stratopause is drawn in relevant figures (Figs. 2, 4 and 6), their description will

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be more easily understood.

AC3: We have improved the structure of the discussion (new sub-Sections 5.1–5.3 have been introduced) and conclusions as suggested.

RC4. Some low-level mistakes should be avoided as much as possible. For example, it is well known that the ERA Interim has 37 levels from 1000 hPa to 1 hPa (Dee et al, 2011), but the authors can extend this reanalysis to 0.01 hPa (Line 188) and 0.1 hPa (Line 196). They did not refer to ERA Interim website for accurate introduction, but did to the second-hand data source (Line 197). Where is the 60-layer ERA Interim (Line 196) dataset from? Similar problems can also be found in other data sources. Please carefully check, check and recheck, and search, search and re-search. The authors should make sure that they present a real research.

AC4: We have corrected the specific errors and omissions noted above, and made other improvements for consistency. Details of the pressure level ranges are described in Supplemental Section “The description of the data used for analysis”.

Minor comments: RC1. L22: ERA Interim, NCEP/NCAR, and other second-hand datasets that have been processed by others. Right? AC1: L22 corrected to “Data from the ERA-Interim and MERRA-2 reanalyses,...”. Other data sources are described in Section 2.2. RC2. L23: reanalyzes => reanalyses. AC2: Corrected in L22. RC3. L42: Awkward expression for “the event of SSW” => the SSW event. AC3: L42 Corrected to “Major sudden stratospheric warming (SSW) events which happen roughly...”. RC4. L46, L49: Weird phrase for “eastward”, “westward”=> westerlies, easterlies. AC4: Corrected throughout the manuscript. RC5. L51: The citations are not exhaustive. Other studies should be well reviewed. AC5: Other studies cited in L47–53. RC6. L52-55: Weird transition for the topics. What is the “usefull tool”? Can you provide more information for readers? AC6: More information is provided in L57–59. RC7. L58-59: The explanation is wrong. The upward propagations of waves do not denote the upward propagation of momentum and heat. The EP flux components are nearly proportional

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to the eddy momentum flux and eddy heat flux, so the poleward eddy heat flux favors the polar warming. It is wrong to stress the upward transfer of heat. AC7: L62–63, the text corrected to “The enhanced wave activity results in the rapid warming of the polar stratosphere and the breakdown of the stratospheric polar vortex...”. RC8. L61: “: : : is impact : : :” => is its impact . AC: Corrected in L64. RC9. L63: “during the weeks or even month” =>in weeks or even more than one month AC9: L66, corrected to “during the following weeks to month”. RC10. L72: upward displacements or downward displacements? AC10: Detailed in L75–80. RC11. L89-90: Are you sure de la Torre et al. (2012) developed the WACCM and Shepherd et al. (2014) developed the CMAM. If they are the model users, please rephrase. AC11: L98–100, The text rewritten. RC12. L92: for example=> e.g. AC12: Corrected in L102. RC13. L99: exchange in stratosphere-mesosphere coupling => exchange between the stratosphere and the mesosphere? AC13: Corrected in L108–109. RC14. L101: the => a AC14: Corrected in L110. RC15. L111-112: Use the past tense. AC15: Corrected in L119–120. RC16. L127: change “sub-vortices” to “sister vortices.” AC16: Changed in L136. RC17. L128: Few articles use “eastward” and “westward” to denote the zonal wind direction. The wind direction refers to where the wind comes from, not where the wind will go. Did the authors learn some lessons like an introduction to meteorology? AC17: Corrected to “westerly” and “easterly” throughout the text. RC18. L130-L132: It is not true. Rao et al. (2018) first reported the February 2018 SSW, followed by Karpechko et al. (2018), right? AC18: Corrected to (Rao et al., 2018; Karpechko et al., 2018; Vargin and Kiryushov, 2019) in L138. RC19. L133: Use the present tense. AC19: Corrected, L143. RC20. L143: in the 2017/18 winter? AC20: Corrected, L153. RC21: L144: Weird expression. Consider? Please rephrase. AC21: Rephrased, L152–153. RC22. L145: What does “this” refer to? AC22: Removed, L153. RC23. L152: You think mid-latitudes are in Kharkiv? It will be better to change to “Kharkiv in midlatitudes”. AC23: Changed, L162. RC24. L159: Please check the ACP citation format. “Pidyachiy et al. 2010; Pidyachiy et al. 2017”=> Pidyachiy et al. 2010, 2017 AC24: Corrected, L168. RC25. L160: Delete “observations”. AC25: Rewritten, L169. RC26. L162: Wrong cita-

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tion format. AC26: Corrected, L170. RC27. L167, 169: The first, the second=> Firstly, secondly. AC27: Corrected, L175, L177. RC28. L168: by search : : :=> by searching AC28: Corrected, L176. RC29. L178: similar to=> consistent with AC29: Rewritten, 182–184. RC30. L188, L196: 0.01hPa? 0.1hPa? 60 layers? AC30: Detailed in Supplement, page 1. RC31. L190-191: Rephrase this sentence. AC31: Changed in revised Section 2.2. RC32. L202: What do you mean by "general tendency"? AC32: L 212–214, corrected to: "Descending air masses are observed throughout the mesosphere and stratosphere of the winter polar region (Orsolini et al., 2010; Chandran and Collins, 2014; Limpasuvan et al., 2016; Zülicke et al., 2018)." RC33. L205: in the 2017/18 winter. AC33: Corrected, L215. RC34. L207: Why is it "enhanced warming"? It will mislead readers that the warming is enhanced. Similar problems can be also seen in Line 211. AC34: Removed in both cases, L215–217. RC35. L212: Use the present tense. Reverse=> reversal AC35: Corrected, L229. RC36. L219-220, 226: Rao et al. (2018) also studied the January 2009 SSW. AC36: Corrected, L236. RC37. L225-226: You can just say: "the SSW in February 2018 is mainly forced by wave 2" AC37: Rewritten, L229–230. RC38. L227: The description is not clear. Maybe you can describe something like this: The domination of planetary waves changes from wave 1 in January to wave 2 in February. AC38: Description improved L232–234. RC39. L230-231: This conclusion contradicts with the 2018 February SSW type. The vortex split SSW events are mainly caused by the wave 2. If you diagnose the poleward eddy heat flux at 100 hPa, you will not reach such conclusion. AC39: This fragment has been removed. RC40. L232: Delete "vector". AC40: This paragraph has been removed. RC41. L233-234: This expression is wrong. The EP flux is parallel to the planetary wave propagation, but cannot measure the upward transfer of heat flux and momentum flux. The eddy heat flux ( $[T'v']$ ) and eddy momentum fluxes ( $[u'v']$ ) are a good measure of meridional transport, NOT VERTICAL transport. AC41: This paragraph has been removed. The detailed study of EP flux behavior during the event left for future consideration. RC42. L235: The EP flux is a second-hand product based on NCEP/NCAR reanalysis and redistributed by ESRL. The data should be introduced

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in the method section. If the authors calculate the EP flux themselves, the procedure should also be described. AC42: This paragraph has been removed. RC43. L241: I draw the QBO evolution based on NCEP/NCAR reanalysis and do not find the same conclusion as the authors obtained. Moreover, if the QBO is in its easterly phase, the equatorward transport of waves is suppressed (Holton and Tan 1980). The authors are responsible for their correct explanation of their results. AC43: The results related to EP-flux have been removed. RC44. L260: What does the 6-ppmb level mean? I guess the authors mean the 6-ppmb contour. Moreover, the figure caption does not depict the white contour. Add the caption for the white contours and delete "(thin parts : : : : )" AC44: Corrected, L260, L263. Figure 3 caption updated, "thin parts..." deleted. RC45. L265: Change the citation format. It will be better to revise to "[Fig. 4 in Koo et al. (2017); Fig. 5 in Rayan et al. (2017)]" AC45: Corrected, L267–268. RC46. L269: I can not understand why the authors used weird phase like "eastward direction". What if you just use "westerly winds"? AC46: Corrected to "westerly wind" throughout the manuscript. RC47. L278: Have you compared the effects of the February 2018 SSW event in different regions? If not, how can you get such conclusion? AC47: Corrected, L253–255, and Fig. 4 is introduced for illustration. RC48. L284: What is "this Z"? Do you have "that Z"? Revised to "The Z : : ." AC48: This fragment has been removed. RC49. L285: What do you mean by "that"? AC49: This paragraph has been deleted. RC50. L291-294: This long sentence is not easy to understand. Please split and rephrase. AC50: This paragraph has been deleted RC51. L299-300: Did you perform a power spectra analysis? The authors mentioned the "5-8 days period". AC51: Spectral analysis provided and results included in new Section 4.4. RC53. L302: What are the atmospheric normal modes? AC53: This paragraph has been removed. RC54. L308: the easterly winds. AC54: This paragraph has been removed. RC55. L313: What are the "reverse process"? AC55: This paragraph has been removed. RC56. L316: What are the "meridional tendency"? AC56: This paragraph has been removed. RC57. L328: I found that the authors did not know where they should put the adverb "also". Please shift it after "are". Revise throughout the manuscript. AC57: Corrected.

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RC58. L334: Relative to what the influence weakens? AC58: Old Fig. 6 and related text have been removed. RC59. Section 5: This section is result indeed, not a real discussion. Please add more discussion on the differences between this study and previous studies (Rao et al. 2018JGR; Karpechko et al. 2018GRL : : : :). Emphasize the novelty of your work. AC59. Discussion has been updated; see new Section 5 and sub-Sections 5.1–5.3. RC60. L341: westward : : : wind => mesospheric easterly winds AC60: Corrected and rewritten in L433, see AC61. RC61. L342: Only wind speed? I don't think so. AC61: The CO altitude profiles in the mesosphere have been measured by the MWR with one day time resolution. Using the CO molecule as tracer, the wind speed has been retrieved from the Doppler shift of the CO 115.3 GHz emission and the mesospheric winds reverse from westerly to easterly below the winter mesopause region (70–85 km) has been detected. L431-434 RC62. L345-346: Replicate the method. Is there any new information? AC62: Sentence rephrased in L431–434. RC63. L348: Reanalyzes (verb) => reanalyses (noun) AC63: Corrected in L438. RC64. L355, L456: The stratopause variation was not explored at all. How did the authors come to the conclusion on "stratopause disappearance"? AC64: The stratopause variations are described in new Section 4.3. RC65. L357: Ambiguous phrase "increase in winter season". AC65: Deleted. RC66. L369: What is "the similar processes"? Rather ambiguous. AC66: Removed. RC67. L372: "This Z" => "The : : ::" AC67: Removed. RC68. L378: Who noted this? Could you add a citation? AC68: Removed. RC69. L387: Delete "meridian". AC69: Deleted. The changes in the CO field are illustrated in new Fig. 4, Fig. S1 and S2 and are described in related text. RC70. L389: Did you show this? AC70: The results to confirm this are included in new Section 4.1 and are discussed in Section 5.1. RC71. L400: Did you mean the blocking high? AC71: Removed. Analysis is focused on the CO re-distribution at different pressure levels in the context of the wave effects (Sections 4.1 and 5.1). RC72. L404-406: Rephrase this sentence. AC72: Removed. RC73. L407: again? How many replacements of warming by cooling happened? AC73: Rephrased in L522–523. RC74. L414: What are the large-scale process? The authors seemed to hide some useful

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information. Another data link appears. The organization of the manuscript needs to be improved. AC74: Removed. Zonal wave spectra are presented and discussed in new Sections 4.4 and 5.3. RC75. L419: What do the previous studies refer to? Add the citations directly. AC75: Citation added in L572–575. RC76. L435: Add a comma after "(2012)" and after "(2014)". AC76: This paragraph has been rephrased in L501–509. RC77. L450: registered? Revised to "documented". AC77: Corrected, L603. RC78. L466: Add "is" after "which". AC78: Corrected in L635.

Proposed references added and discussed.

References: Rao, J., R.-C. Ren, H. Chen, X. Liu, Y. Yu, and Y. Yang, 2019: Subseasonal to seasonal hindcasts of stratospheric sudden warming by BCC\_CSM1.1(m): A comparison with ECMWF. *Adv. Atmos. Sci.*, accepted. doi: 10.1007/s00376-018-8165-8. Charlton, A. J., and L. M. Polvani, 2007: A new look at stratospheric sudden warmings. Part I: Climatology and modeling benchmarks. *Journal of Climate*, 20, 449-469. Hu, J., Ren, R., & Xu, H. (2014). Occurrence of winter stratospheric sudden warming events and the seasonal timing of spring stratospheric final warming. *Journal of the Atmospheric Sciences*, 71(7), 2319-2334, doi:10.1175/JAS-D-13-0349.1. Rao, J., R. Ren, H. Chen, Y. Yu, and Y. Zhou, 2018: The Stratospheric Sudden Warming Event in February 2018 and its Prediction by a Climate System Model. *J. Geophys. Res. Atmos.*, 123(23), 13332-13345, doi: 10.1029/2018JD028908. Taguchi, M., 2018: Comparison of Subseasonal-to-Seasonal Model Forecasts for Major Stratospheric Sudden Warmings. *Journal of Geophysical Research: Atmospheres*, 123, 10,231-210,247, doi:10.1029/2018jd028755. Karpechko, A. Y., A. Charlton&YAR&G Perez, M. Balmaseda, N. Tyrrell, and F. Vitart, 2018: Predicting Sudden Stratospheric Warming 2018 and its Climate Impacts with a Multi&YAR&GModel Ensemble. *Geophysical Research Letters*, 45, 13,538-513,546, doi:10.1029/2018gl081091. Tripathi, O. P., Baldwin, M., Charlton-Perez, A., Charron, M., Cheung, J. C. H., Eckermann, S. D., Gerber, E., Jackson, D.R., Kuroda, Yu., Lang, A., McLay, J., Mizuta, R., Reynolds, C., Roff, G., Sigmond, M., Son, S.-W., and Stockdale, T. 2016. Examining the Pre-

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dictability of the Stratospheric Sudden Warming of January 2013 Using Multiple NWP Systems. Monthly Weather Review, 144, 1935-1960, doi:10.1175/mwr-d-15-0010.1.

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Our reply to Referee #1 and Referee #2 comments, the new text of the manuscript in the blue colored text and new figures, and the Supplement to the manuscript are given in the supplement below.

Please also note the supplement to this comment:

<https://www.atmos-chem-phys-discuss.net/acp-2018-1361/acp-2018-1361-AC1-supplement.pdf>

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Interactive comment on Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2018-1361>, 2019.