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Atmospheric Measurement Techniques Discussions

Interactive comment on "Comparison of RO tropopause height based on different tropopause determination methods" *by* Ziyan Liu et al.

Ziyan Liu et al.

1243913856@qq.com

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Dear Anonymous Referee 2 and editor Thanks for reading our manuscript and providing comments and suggestions, which are really helpful for us. We have carefully read your comments and gave the following responses. Massive revisions are done, and thus we upload the revised manuscript in supplement file. We also uploaded this reply in PDF format in supplement file.

For general comments: 1. * Using RO data from two missions introduces a complication to this study. I see two issues here: First, I think it would help the paper to keep its focus on the comparison of the two tropopause determination methods, instead of also comparing two missions. Secondly, and more importantly, the data of these missions

are from two different processing centers and I suppose that they are not consistently processed. Metop data are processed by ROMSAF, and information about the processing of FY3C is missing in the paper. It has been shown in the literature that only for the same processor and processing version profiles from different RO missions can be mixed together. Applying the tropopause determination algorithms on inconsistently processed proïňĄles will most probably result in a systematic bias. I would strongly recommend to only use data from one processing to avoid this additional complication, or to first validate that no bias is introduced.

Our reply: Thanks for your advice. Using only one RO mission's data can avoid systematic bias, which is better for comparing two methods. However, the data profile obtained by GNSS RO is globally random distributed, and now, and only few RO missions are capable for long term stable operational running, mainly including FY3, Metop, COSMIC (equipment aging) and COSMIC2 (launched recently), and the amount of their daily data profile is still limited. To study tropopause and other global scale atmospheric researches based on GNSS RO data, the best way is to assimilate all RO missions' data. Thus, studying the consistency between different RO missions' data and the bias characteristic of different RO missions' data is the first step to achieve the inter-mission data assimilation. Our article focuses on the tropopause, and shows the bias characteristic of tropopause derived from different RO mission's data (FY3C/Metop), and it is the major objective of our article. BesidesïijŇthe other purpose of this article is to promote FY3 atmosphere products. FY3C has already be in orbit for 6 years, and data from FY3C is prepared to be used in long term atmospheric research. Thus, bias comparison between FY3C and Metop as well as ECMWF operational data is quite meaningful for the participation of FY3C in RO international cooperation in the future and also helpful for the further quality improvement of FY3 products. Based on this reason, we used two RO missions in our study. In spite of this, in our results, we provided comparison results of two methods based on only one RO mission data (ie. Fig. 11 and 12 in manuscript). Also, for the bias between RO and ECMWF, if you are only interested in seasonal bias of Metop, you can only focus on the solid line in Fig. 4 and 6 in manuscript, as well as

Fig. 9 and 10 in manuscript. If we add figures for seasonal bias between single RO mission and ECMWF, the results may seem repetitive. The systematic error caused by different processor will affect the comparison results. Data of FY3 is processed by China Meteorological Administration (we add this in line 27 in revised manuscript) and the part of processing software (from Level 1b (bending angle/impact parameter/orbit parameters. . .etc) to Level 2 (temperature/pressure/humidity. . .etc)) of FY3 is based on ROPP, which is similar with Metop (line 18), besides, the local solar time of FY3C and Metop is similar (line 18), and it is the reason why we choose FY3C and Metop in our study. ROMSAF website provide local solar time and global statistics of bending angle/refractivity of many RO missions, including FY3C and Metop. The following figures give local solar time comparison and the one-day global statistic for bending angle from Metop-a, Metop-b and FY3C respectively (we just provide an example, you can find it on https://www.romsaf.org/monitoring/index.php).

(There are some problems about uploading figures via this system, and thus we upload these 5 figures in the supplement file. However, we suggest you reading the pdf format reply in supplement file directly.)

Those results are quite same. However, global statistic may cannot reflect the results in some certain area, and it is impossible to show global distribution of bending angle/refractive/temperature, and thus in our RO tropopause results, some regional biases are shown and it is meaningful for the validation and the further development of FY3.

2. *Lewis 2009 showed comparisons of bending angle-based tropopauses to lapse rate tropopauses latitudinally resolved, and included comparisons to collocated radiosondes. Schmidt et al. 2010 used 8 years of RO data from various missions and ECMWF analysis data and showed latitudinally and seasonally resolved differences between bending angle- and dry temperature-based tropopauses. They also compared differences in tropopause height trends between these methods. Apart from the comparison between FY3C and Metop (see above), I am not sure how the new finding of this study

in light of the existing ones can be summarized. I think the main results and conclusions of this study need to be discussed in more detail, going beyond the existing results. If the main finding are the differences between Metop and FY3C, then the different processing needs to be addressed (see above), and some attempt to explain those differences need to be made. If the focus stays on the difference between LRT and BAT, the details of Figs. 11 and 12 are worth to be looked at in more detail and additional work should be performed to understand these differences better (with the existing work as background). Our response: RO tropopause is not a new topic, which has been studied since the launch of GPS-MET experiment. For the tropopause results, we just provide these comparison results derived from FY3C and Metop to show the bias characteristic for others who use these data or de relative research to take reference. Also, the part of our purpose, as we noted above, is to promote and improve FY3 series data. For example, although the global statistic of bending angle of two RO missions are similar, FY3C shows higher BAT than Metop, especially over Antarctic during DJF and over 45N during JJA. The LRT of two RO missions show different over mid latitude region. These point out the problem that need to be investigated. However, these are more relative to the data processing instead of tropopause. The FY3C data is not completely processed by us and the inner process of retrieval from RO raw data to temperature is complex, and thus we cannot answer the reason of these difference exactly, now. This need further study.

For specific comments: 1. * The global map plots (Figs. 3, 5, 7, 8) are hard to read for several reasons. For the difference plots (bottom row), please use a diverging color scale so that one can distinguish positive and negative values. Secondly, the resolution of the bitmaps is too low. And thirdly, I do not understand where the white stripes pattern in these plots comes from? They do not represent the RO event distribution, and seem to be related to the underlying map. I find these patterns quite distracting. Our response: We have renewed the figures in revised manuscript. Each color point represents a tropopause height derived from a bending angle/atmosphere profile. The white stripes indicate that there is no data in this area. These figures illustrate the data

distribution, indicating that data of FY3C and Metop has the similar distribution.

2. * The paper needs heavy editing with respect to English language. I am (obviously) not a native speaker myself, and strongly recommend to use an English proofreading service. Our response: We have asked language edit service to polish our manuscript. The revised manuscript and the language edit certificate is uploaded in supplement file.

3. * You write that you use "ECMWF reanalysis data"; I guess you actually use ECMWF operational analysis data? Our response: We made a mistake here, and we have corrected it as “operational analysis data”.

4. * In Fig. 6, and also Fig. 4, the presented bias structures of Metop and FY3C are very different. Do you have an explanation for this? I think this is quite surprising, and I would guess that this is related to the different data processings (see above). Largest differences can be found in mid latitudes, where the occurrence of double tropopauses make the detection of the first tropopause more demanding. If the paper keeps the comparison between the two missions, these differences need to be discussed and analyzed in more detail (e.g. single proïňĄle comparisons, and so on). As shown in a number of publications, RO measurements from different missions can be usually combined as long as they are processed consistently, such systematic differences between two missions are therefore surprising to the reader and need explanation.

Our response: Although multi-tropopause usually occurs in mid-latitude, we do not think the different bias in Fig. 4 and 6 is caused by multi-tropopause. The reasons are as follow: LRT is determined according to WMO criterion (scan tropopause from bottom to top). The multi-tropopause may cause the first tropopause not obvious, but it is still data problem that one always find the first tropopause while the other always find the second tropopause (if so). On the contrary, in Fig. 11a and 12a, the BAT is higher than LRT over tropics and polar region, but they are similar over mid-latitude. we think it may be caused by multi-tropopause, for BAT is to find the strongest tropopause, but

LRT is to find the lowest tropopause. The difference in Fig. 4 and 6 are more likely caused by the data itself, in other words, the inner processing of data. As we noted above, FY3C and Metop have the same local time and the same processing software. We try to avoid systematic bias and thus we choose FY3C and Metop, but the results are still different. Thus, to find out the answer, it needs to look over each step of data retrieval. It needs further study, and we cannot give the answer right now in this article. For the data combination, actually we did not combine data from two RO missions. Results of FY3C is just based FY3C data and results of Metop is just based on Metop data.

5. * p.1 l30: "variation trend"? Probably you mean "trend in tropopause height"? Our response: We use ‘changes in the tropopause’ in revised manuscript.

6. * p.2 l33: "direct sounding technic" => "in-situ measurements" Our response: We corrected this according to your suggestion.

7. * p.3 l65: "Bending angle proïňĄle is level-1 data but dry temperature proïňĄle is level-2 data, and thus we only discuss the tropopause height (TPH)" I do not understand this sentence. Our response: We noticed that level-1, level-2 is not an official terminology, which are just used in RO retrieval, and thus we delete this sentence.

8. * Fig. 1: "Temperature" is misspelled. Our response: We have corrected this mistake.

9. * p.6 l117: GPS, BDS: Introduce acronyms Our response: We add the full name of the acronyms.

10. * p.6, l121: "Wegner" => "Wegener" Our response: We have corrected this mistake.

11. * p.6, l124: Which processing is used? Our response: We add “The data processing of FY3 is undertaken by China Meteorological Administration (CMA)”. The processing software is also ROPP, which is noted in line 118.

12. *p.7l141-142: Supposing that these are ECMWF operational analysis, are these

numbers correct? To my knowledge analysis resolution close to the surface is better than the stated 200 m, and at 20 km it should be around 400 m (and not 300 m), but I might be wrong.

Our response: Yes, it is ECMWF operational analysis, and we have corrected this in revised manuscript. The first level is 0.02 km and the second level is 0.04 km. Until 2km, the interval is 200 m. The 90th level is 19.83 km and 91th level is 20.22 km. At 17 km, the interval is about 300m, and tropopause seldom higher than 17 km. From 200 m at 0 km to 300 m at 20 km is not accurate, but if we say 20m-400m, it may still lead misunderstanding because the interval variation is not homogenous. We corrected as “from 200 m at 2 km to 300 m at 17 km (tropopause is seldom higher than 17 km) and 400 m at 20 km.”

13. * p.7 l144: "bias regulation": Not sure what this means. Maybe "bias characteristics"? This term occurs several times in the manuscript. Our response: We correct it as “latitudinal bias”. We also correct this term in later section.

14. * p.7 l149: "spatial interval with" => "spatial distance to" Our response: We corrected this according to your suggestion.

15. * p.8 l169: "opposite trend" => "opposite behavior" ("trend" is misleading). Our response: We corrected this according to your suggestion.

16. * p.9 l176: "totally different": This is overstated, I think they look overall quite similar. Our response: There indeed has some difference, and we delete the “totally”.

17. * p.12 l215: "bias trends": No trends involved here. Our response: We delete the “trends” here.

18. * p.12 l216: "RMSE trend": No trends involved here. Our response: We use “curve”, instead of “trend”.

19. * p.13 l238: "variation trends": No trends involved here. Our response: We delete the “trends” here.

20. * Figs. 11, 12: "Summer" and "Winter" are ambiguous. Please use "DJF" and "JJA". Our response: We have renewed the figures

21. * p.15 l252: "To detect the global tropopause" => "To detect the global tropopause with RO" Our response: We corrected this according to your suggestion.

22. * p.16 l262: No trend involved here. Our response: We delete the “trends” here.

23. * p.16 l262: "availability" is not the correct word. Maybe "reliability" or "usability"? Our response: We use reliability here.

If you have any question, please do not hesitate to contact us. We are hoping for hearing from you.

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2019-379/amt-2019-379-AC4-supplement.zip

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