

## ***Interactive comment on “Effect of tropical cyclones on the tropical tropopause parameters observed using COSMIC GPS RO data” by S. Ravindra Babu et al.***

**S. Ravindra Babu et al.**

vratnam@narl.gov.in

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Replies to the Referee #2 comments/suggestions

Comments of the manuscript entitled, 'Effect of tropical cyclones on the tropical tropopause parameters observed using COSMIC GPS RO data' by Babu et al., submitted to plausible publication in ACP. This paper deals with the effects of tropical cyclone on tropopause characteristics. The authors have presented a detail analysis of the tropopause characteristics using seven years of COSMIC data. The variation of tropopause height and temperature during the passage of the tropical cyclone from the

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climatological mean is presented in this paper. This study is very important, in principle, since detail knowledge of the tropopause characteristics during the passage of tropical cyclone is very crucial for understanding the water vapour budget of the lower stratosphere, which have significant effects on global warming. The article is well written and contains significant original material. I recommend for publication in ACP with some minor revision

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 reviewers comments/suggestions.

General Comments : (1)The tropopause height/temperature derived during the passage of tropical cyclone is subtracted from the climatological mean tropopause height to show the variability associated with cyclone. How do author account for the day to-day variability of the tropopause? Authors can mention in their manuscript. I also suggest taking the mean tropopause height for 5-6 days, one week before and after the passage of cyclone and then subtract it from the tropopause height/temperature obtained during cyclone in order to understand the variability.

Reply: We subtracted the tropopause parameters during TC period with the specific monthly mean climatology (calculated using GPS RO data from 2002-2013). There could be day-to-day variability even during cyclone period, however, since the cyclone system is synoptic in nature sustaining for few days, one may not expect large day-to-day variability. Since large data (14 years) has gone through the monthly mean climatology, we assume variability less than solar cycle is nullified, if not removed completely. We also did analysis based on before 5 days and after 5 days method and are attached as supplementary figures.

(2)During tropical cyclone, enormous amount of water vapour is pumped from lower troposphere to the upper troposphere, even up to the lower stratosphere. The temper-

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ature derived in COSMIC has assumption of water vapour profile from model. During cyclonic condition, how accurate is the temperature derived in COSMIC data? It can be discussed in the manuscript.

Reply: We completely agree with the reviewers concern in using the RO measured T at tropopause during cyclone activity which is expected to bias T measurements with assumption of dry atmosphere. However, note that we could notice similar change in N which is combination of T and WV. In the simulations reported in Rao et al., TAO, 2009 paper, one can notice that change in the T is not that sensitive when compared to Pressure and Water Vapour. Since, the changes are found to be up to 4-5 K, we expect these are meaningful even after considering expected larger bias during disturbed weather conditions. This aspect is clearly mentioned in the revised manuscript. More details of COSMIC temperature during Cyclone period was given by Biondi et al 2011.

Specific Comments : Page-2 L-4/8 : 'In the present study, high verti-. . . . .'  
Authors can mention the value of 'high vertical resolution' (is it 100 m or 200 m) and accuracy of temperature measurements.

Reply: In the present study we used 200 m vertical resolution atmPrf temperature profiles from COSMIC GPS RO data.

L-12/14 : 'From all the TCs events, we generate the mean cyclone. . . . .'  
Mean tropopause height can be mentioned. How author accounted for the inter-annual variability?

Reply: Corrected. We calculated the monthly mean tropopause parameters from 2002-2013 GPS RO data and we used these monthly mean tropopause parameters for different TCs for subtracting the tropopause parameters during TC period. For example, we used April month mean tropopause parameters for Nargis TC that was occurred in the month of April 2008. Since large data (14 years) has gone through it, we assume variability less than solar cycle is nullified if not removed completely.

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L-17/18 : 'However, as the distance from cyclone eye. . . . .'  
Author can mention the distance in km instead of degree (5 $\sigma$ ) throughout the manuscript.

Reply: Corrected.

L-19 : 'Lowering of CPH (0.6 km) and LRH (0.4 km) values with coldest CPT and LRT (2-3 K). . . . .'  
Since authors mentioned that CPH is lower by 0.6 km and LRH by 0.4 km, it is essential to provide the vertical resolution and accuracy of the COMIC measurement.

Reply: We provided the vertical resolution and accuracies of GPS RO measurements in the revised manuscript as suggested.

L-23/25 : 'These changes in the tropopause parameters are expected to influence the water. . . . .'  
Change in the tropopause characteristics can influence UTLS region much more than mentioned in this abstract. Here a general statement is enough to convey the message (Holten et al., 1995)

Reply: Considered in the revised manuscript as suggested.

Page-3 L-14/15 : 'This will change the thermal and chemical structure of. . . . .'  
This sentence is repeated. Delete this sentence.

Reply: Removed.

L-18 'There is a possibility that TCs lift and cool the tropopause more than other meso scale. . . . .'. I do not agree with this statement. Is there any study reported so far that TC lift and cool the tropopause more than MCS? If so, please provide reference in the manuscript.

Reply: In the paper entitled 'Overshooting convection in tropical cyclones' Romps and Kuang (2009) pointed out, that there is the possibility that TCs lift and cool the tropopause more than other mesoscale systems. We added this reference in the revised manuscript as suggested.

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L-23/24 : 'Most of these exchanges take. . . . . ' The sentence is not clearly conveying the meaning.

Reply: We have re-written this statement with better clarity.

Page-4 L-2/5 : 'However, the availability of Global. . . . . ' There are many studies on tropopause characteristics using COSMIC. Provide few references in the manuscript.

Reply: We added some more references in the revised manuscript as suggested.

Page-5 L-5/10 : 'COSMIC GPS RO is a constellation of six microsattellites. . . . . ' Which set of COSMIC data were downloaded?

Reply: We have provided the source of the COSMIC data in the revised manuscript.

L-18/19 : 'The vertical resolution. . . . . ' I have a doubt on 200 m vertical resolution. Because there are many new algorithms implemented on GPS RO techniques which provide better vertical resolution (e.g. Full spectral inversion, See Kuo et al., 2004).

Reply: There are different vertical resolutions available but for the present study we used 200 m resolution temperature (atmPrf) profiles available at CDAAC website only which is freely available for the public use.

Page-7 L-10/13 : 'In order to estimate the effect of TCs on the tropopause. . . . . ' It will be better to provide the climatological map of tropopause similar to that of Fig.2b.

Reply: We have provided climatological map as Fig.2c as suggested.

L-17 : 'It is named as low pressure when. . . . . ' Write once the equivalent of knots in m/s.

Reply: Mentioned in kmph.

Page-9 L-2/3 'Though it is difficult to draw. . . . . ' CPH/LHR is higher/lower relative to what? It should be mentioned.

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Reply: Mentioned.

Page-10 L-7/11 : ' These different variations. . . . . ' There may be equal contribution from wind shear associated with tropical cyclone (e.g. Das et al., 2012). How authors accounted the wind shear during the interpretation of results?

Reply: Strong wind shear usually generated during cyclone activity will alter mainly the convection to the south side of the cyclone which is already mentioned as first reason for the observed variability.

Page-11 L-20/22 : 'Cyclone centered – composite of averaged. . . . . ' How accurate is the water vapour measurement during cyclonic disturbances when humidity is very high and thermal structure changes significantly? These aspects can be discussed in the manuscript.

Reply: We do not have any information on the accuracies of the GPS RO measurements during disturbed conditions. However, in the simulations reported in Rao et al., (2009), one can notice that change in the T is not that sensitive when compared to pressure and water vapour. Since, the changes are found to be 50-60% in RH in upper troposphere, we expect these are meaningful even after considering expected larger bias during disturbed weather conditions. This aspect is clearly mentioned in the revised manuscript.

References:

Kuo, Y.H., et al., 2004, Inversion and Error Estimation of GPS Radio Occultation Data, J. Meteo. Soc. Japan, 82. 1B, 507-531.

Das, S. S., K. N. Uma, and S. K. Das (2012), MST radar observations of short-period gravity wave during overhead tropical cyclone, Radio Sci., 47, RS2019, doi:10.1029/2011RS004840.

Reply: We have already included Kuo et al., (2004) reference and other reference is out of scope of the present study as it is related to gravity waves.

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

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Interactive comment on Atmos. Chem. Phys. Discuss., 15, 13043, 2015.

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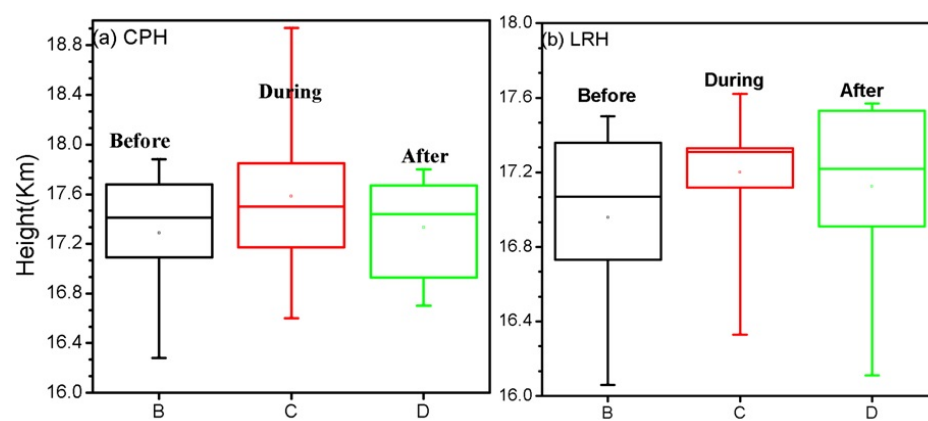


Fig. 1.

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