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Atmospheric Chemistry and Physics Discussions

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

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Replies to the Referee #1 comments/suggestions

The paper is well written and the abstract well summarizes the paper and the title is adequate. The authors describe the impact of tropical cyclone into the tropopause parameters (altitude, temperature and humidity) in the Indian Ocean. They selected 16 tropical cyclones and studied the tropopause variation within 2000 km of radius from the center of the cyclone by using GPS radio occultation profiles.

Reply: First of all we wish to thank the reviewer for going through the manuscript care-

fully, 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.

Major comment I have 2 major concerns about the analysis: 1) I am afraid that 2000 km of radius is too large working at tropical latitudes. As known the tropopause has large variation approximately between 30âŰę and 40âŰę and the variation that the authors attribute to the cyclone could easily due to the latitudinal effect. I strongly suggest reducing the area of interest at no more than 1000 km from the cyclone center.

Reply: We completely agree with the reviewers concern for considering the larger area (2000km) as the latitudinal effect may arise. After considering the reviewers concern we have restricted the discussion to within 1000 km from the cyclone centre.

2) The authors did a cumulative analysis without considering the intensity of the cyclone. According to its intensity, the storm/cyclone can reach different altitudes and can affect the tropopause characteristics in different ways. Doing a cumulative analysis much information is lost so I strongly suggest to separate the study by selecting the storms according to the intensity

Reply: Kindly note that we already mentioned in the manuscript that we did analysis based on cyclone intensity wise. Later we have clubbed the tropopause parameters that do not shown significant variations. Note that in Figure 4 we showed tropopause parameters for CS (combined results of CS and SCS) only. This aspect is clearly mentioned in the revised manuscript.

Comments section by section Introduction Lines 1-20: I suggest adding some references in the first paragraph. Almost each sentence of this paragraph needs a citation.

Reply: We have added relevant references for the said text as suggested.

Database page 13047 Line 5: the authors should write here, where the data are coming from, I guess they have used the COSMIC Data Analysis and Archive Center (CDAAC)

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website (http://cosmic-io.cosmic.ucar.edu/cdaac/index.html)

Reply: We added the data source website in the revised manuscript as suggested.

Line 13: the authors should specify here the type of data that have used, atmospheric profiles (atmPrf).

Reply: Mentioned.

Page 13048 Line 6: the authors should explain here how they selected the 16 TCs out of 44. Here they just wrote ". . . based on life time . . ." but we need to arrive at the section Summary and conclusions to know that the selection criterion is that the cyclone lasted at least 4 days.

Reply: Selection procedure adopted for 16 cyclones out of 44 cyclones is mentioned at the desired place in the text as suggested.

Line 2: what is the cyclone intensity number (CI T-number)?

Reply: T-number is related to the Dvorak technique which is widely used system to estimate TC intensity (which includes tropical depression, tropical storm, and hurricane/typhoon/intense tropical cyclone intensities) based solely on visible and infrared satellite images. Cyclone Intensity (CI) number is commonly used for TC intensity for over North Indian Ocean (India Meteorological Department).

Line 11: what is the grade? Line 14: Table 1 is introduced here for the first time. Going to read the table, the reader do not know what is the grade, and what the acronyms mean (i.e. CS, SUCS, VSCS, SCS). The cyclone intensity number is neither described. The authors should add these information into the Table caption and describe the grade, cyclone intensity number and acronyms in this section.

Reply: We have provided details of the acronyms used in the table 1 at section 3.2. In order to avoid repetition, we have not mentioned in the table caption. Details of the grade, cyclone intensity number can be found in IMD website.

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Classification of the TCs Page 13049 Lines 17-21: what TC classification is this? Why they did not uses the common classification Saffir-xxxx with the 5 cyclone intensity category?

Reply: This classification is commonly used over North Indian Ocean (IMD) and we have provided the TC information (as mentioned in table 1) based on this classification only. The source for this definition is cited in the revised manuscript.

Tropopause parameters observed during VSCS Nargis Page13051 Line 1-9: it is hard to follow the description without any reference to the Figure. They should report step by step what panel they are referring to.

Reply: Corrected in the revised manuscript as suggested.

Line 8: ". . . can be partly attributed to the latitudinal change itself . . ." this is one of my main concerns about the results. According to Table 1, we are talking about TCs centered at latitudes between 11âŮę and 23.5âŮę and the analysis is done in a radius of 2000 km from the TC center which approximately means 20âŮę. The tropopause altitudes between 30âŮę and 40âŮę has a big variation and the large area considered in this analysis mostly falls in this latitude range. I suggest reducing the area of interest at maximum 1000 km so that the results are not affected by the latitudinal variation.

Reply: As mentioned in reply for the main comment 1, we agree with this aspect and we have discussed in the text related to within 1000 km from the cyclone centre.

Spatial variation of tropopause parameters from the centre of TC Page 13052 Line24-25: the authors, describing Figure 5, says that they did the analyses irrespective of the TC intensity. In this paper they also refer a few times to Biondi et al., 2015 which shows that the atmospheric thermal structure is strongly related to the intensity of the storm/cyclone. Looking at Biondi et al., 2015 in the Indian Ocean the cloud top altitudes (and related tropopause uplift) could change by 1.5/2 km depending on the storm intensity. This means that analyzing the data irrespective to the intensity could

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lead to wrong results. I suggest to improve this part and re-do the analyses according to the different intensities.

Reply: We already mentioned in the manuscript that we did analysis based on cyclone intensity wise first and later clubbed if there is no big change between different stages. In Figure 4 we showed tropopause parameters for CS (combined results of CS and SCS). This aspect is clearly mentioned in the revised manuscript.

Spatial variation of water vapor from the centre of TC Page 13054 Lines 1-9: I0m afraid that the humidity in the layer 10-15 km of altitude is mostly coming from the model and not from the RO measurement. The enhancement of water vapor by 30-50 ppmv cannot be visible by the ROs since they are not sensitive to such a small variation.

Reply: Kindly note that we have presented relative humidity (RH) but not the water vapour. 50-60% of RH in the upper troposphere is very high and it is quite expected to pump large humidity to upper troposphere during cyclone system. Further, note that the wetprf are estimated using 1-D variation method by feeding model T as an initial guess. After a few iterations, the estimated RH from RO measurements is independent of initial guess and accurate enough to investigate the same.

Vertical thermal structure of UTLS within 500 km from TC centre Page 13055 Line 27: ". . . Multiple tropopause structures . . ." Double tropopauses were already seen by Corti et al., 2008, Biondi et al., 2011, Davis et al., 2014, I suggest citing them here.

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

Are the multiple tropopauses evident just at 1âŰę distance from the TC centre or is this visible just in this case due to the small number of averaged profiles, as reported by Biondi et al., 2015?

Reply: This may be due to less number of occultations within 100 km from TC centre. But this multiple tropopause structures are regularly observed only within the 100 km profiles while analysing individual cyclones. This aspect is clearly mentioned in the

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revised manuscript.

Corti, T., Luo, B. P., deReus, M., Brunner, D., Cairo, F., Mahoney, M. J., Matucci, G., Matthey, R., Mitev, V., dos Santos, F. H., Schiller, C., Shur, G., Sitnikov, N. M., Spelten, N., Vossing, H. J., Borrmann, S., and Peter, T.: Unprecedented evidence for overshooting convection hydrating the tropical stratosphere, Geophys. Res. Lett., 35, L10810, doi:10.1029/2008GL033641, 2008.

Biondi, R., Neubert, T., Syndergaard, S., and Nielsen, J. K.: Radio occultation bending angle anomalies during tropical cyclones, Atmos. Meas. Tech., 4, 1053–1060, doi:10.5194/amt-4-1053-2011, 2011.

Davis, C. A., Ahijevych, D. A., Haggerty, J. A., and Mahoney, M. J.: Observations of Temperature in the Upper Troposphere and Lower Stratosphere of Tropical Weather Disturbances, J. Atmos. Sci., 71, 1593–1608, doi:10.1175/JAS-D-13-0278.1, 2014.

Reply: We have included these additional references in the revised manuscript.

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