

Interactive comment on “Influence of tropical cyclones on tropospheric ozone: possible implication” by S. S. Das et al.

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Response to Referee #2's Comments

The paper “Influence of tropical cyclones on tropospheric ozone: possible implication” by Das. S. S. et al. discusses the role tropical cyclones may play in controlling tropospheric ozone level. The paper is based on the analysis of ozone and humidity measurements in the vicinity of two tropical cyclones which occurred in the Bay of Bengal in 2012 and 2013. The paper also takes advantage of a series of WRF simulations which describes the dynamical field in the vicinity of the cyclones. Understanding the role of tropical convection in the stratosphere to troposphere exchange is certainly a scientific question which falls well within the scope of ACP. This is made even more interesting

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by the impact these processes could have on near surface conditions. Although studies of this kind are not new the authors present results of two cyclones which could potentially add relevant information on these exchange processes. Das S. et Al. also appear to reach quite substantial conclusions by the end of the paper (pages 19315 lines 4-9920) but these don't seem to be fully supported by the evidences presented in the paper. In particular I don't think the paper demonstrates to a sufficient level:

Response : We would like to sincerely thank Dr.C.Buontempo for reviewing the manuscript and for his constructive comments/suggestion and accepting the conceptual view.

Point-by-point responses on how we have addressed each recommendations/suggestions are given below. Please note that manuscript is also altered in view of reviewer - 1 and 3's comments and suggestion.

1) that the ozone enhancement is attributable entirely to a stratospheric intrusion and not to local source (e.g. lightning), tropospheric advection, or anthropogenic origin.

Response : During the period of observations, the sky was fully cloudy, raining and the possibility of anthropogenic activities are negligible during rain event. Moreover, the enhancement observed in ozone is at much higher height i.e. middle and upper troposphere.

There were lightning event all around the Indian region not specifically over the cyclone area as observed from satellite measurements. However, we agree with referee that we cannot fully rule out the thunderstorm.

There may be possibility of advection which is already discussed and also attributed due to cyclone. Now we have modified / revised the manuscript accordingly.

2)that the intrusion in the troposphere would add as a significant stratospheric sink as suggested in line 7-10 on page 19307

Response : Yes, we agree with the referee but the amount is too low as that of strato-

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spheric ozone which cannot be traceable.

3) how significant such exchange process is for the overall ozone budget of the troposphere and what its possible impact on the living organisms could be (page 19307 line 27 and page 19308 line 15-19).

Response : Ozone budget and its impact on living organism are now discussed in the revised manuscript.

4) whether the tropical cyclones in the bay of Bengal could be considered representative of the tropical cyclones in other part of the tropics.

Response : Probably yes. We have come across few latest literatures which proved that thunderstorms enhance tropospheric ozone [Pan et al., 2014]. More discussion is made in the revised manuscript with references. There are few studies which clearly proven the enhancement of surface ozone due to intrusion of stratospheric into the troposphere associated with severe weather condition (Stohl et al., 2000; Jiang et al., 2015)

5) what is the extent of the area for which the ozone enhancement area has been recorded.

Response : It is very difficult to say the extent of the area as there is no much observational (ozonesonde) evidence and satellite passes are very limited in time and space. However, with the numerical simulations it is found that the entire band of the cyclone participated in the exchange process, i.e. 50 km x 250 km.

6) how significant the enhancement of surface ozone detected during the passage of the cyclones is when compared to the normal level of variability at the station.

Response : The variability at the station depends on the synoptic meteorological condition in addition to changes in local anthropogenic activity. The variability (i.e. 1-sigma standard deviation) is ~ 9.5 ppbv during the month of October. Thus, observed enhancement is of the order of normal variability at the station. Thus, it is possible that

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observed enhancement could be due to surface reaching intrusion effect but possibility of local/anthropogenic activity could not be fully ruled out.

7) how well the WRF-ARW is able to describe the dynamical field around the cyclone cyclones that exists.

Response : We have used different Physics schemes using WRF-ARW simulation and found one scheme (Please see Das et al., 2011 for more detail) is compared well with the observation of zonal, meridional and vertical winds.

I would think the paper would become significantly stronger if an estimate of the overall ozone mass exchange through cyclones would be attempted by the authors on the basis of the measurements they acquired and the number of tropical

Response : We agree with the referee but we have only two cases of tropical cyclone where we have few ozonesonde observations. In near future we will definitely estimate of the overall ozone mass exchange with more number of cyclone cases and simultaneous observations of ozonesonde at different locations. We thank referee for the suggestion.

Detailed comments: Page 19306 Line 18 : at least one of the many references should be mentioned here.

Response : Now reference is included.

Page 19306 Line 18 : I would think the property of Ozone as GHG don't depend so much on its location in the atmosphere

Response : Corrected.

Page 19306 Line 24 : I don't think that categories such as "bad" and "good" are particularly useful for the discussion here especially because it is not clear to whom such change would be good or bad.

Response : Following the reviewer's comments, entire sentence is removed in the

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revised manuscript.

Page 19308 lines 9-10: at least at the first order the amount of radiation that reach the surface should not depend on the specific vertical profile of ozone as much as on its total column amount.

Response : Sentence is modified in the revised manuscript.

Page 19313 line 14: I don't think it can be safely assumed that tropical cyclones have no lightning for example: <http://journals.ametsoc.org/doi/abs/10.1175/MWR-D-11-00236.1>

Response : We thank referee for raising this important point. Now we have revised the statements in this version of manuscript.

Page 19314 line 24: I think the provides only once piece of evidence in support of the thesis the authors suggest rather than a demonstration similarly I would be more cautious in the conclusion c.

Response : Now we have elaborated the discussion in this context.

Page 19315 lines 11-14: I don't think this statement is fully supported by the evidences presented by the authors. The enhancements the authors suggest (which I assume can only be local) is probably offset by a slow ascent happening on the large scale. Understanding the balance between these two competing processes would be the only way to the long-term impact tropical cyclones may have on the ozone concentration of the troposphere.

Response : With the limited observations of ozonesonde along with numerical simulation we have tried to established the stratospheric intrusion associated with the passage of tropical cyclone. Now we have also included vertical velocity profiles observed from MST radar as supporting evidence.

References : Pan, L.L. et al., 2015.: Thunderstorms enhance tropospheric ozone by

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