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Atmospheric Chemistry and Physics Discussions

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

S. S. Das et al.

dassiddhu@yahoo.com

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Response to Referee #1's Comments

Influence of tropical cyclones on tropospheric ozone: possible implication By Das et al. This paper presents ozonesonde observations in southern India for two tropical cyclonecases. For both cases, 5-6 ozonesonde profiles during 5-9 days show an ozoneenhanced layer that (seems to have) descended from the upper troposphere to lowertroposphere during the observation period at the rate of about 1 km/day. As additionalsources of information, numerical simulations using the WRF model and microwavesatellite tropospheric humidity data are also presented. The authors conclude that theenhanced ozone layer was originated from the stratosphere in association with

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thetropical cyclone activity.The ozone observation results are very interesting, and the hypothesis that the observed ozone layer was associated with the tropical cyclone activity is also very interesting.However, I think that the authors need more data analysis to confirm that theirconclusions are really supported by all the available data and information. I do notthink that in the current manuscript, the hypothesis has been proved correct.

Response : We would like to sincerely thank the anonymous referee for very positive evaluation and constructive comments/suggestion for the improvement of the manuscript.

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 - 2 and 3's comments and suggestions.

In thefollowing, I write the key questions. (1) In Introduction, the authors just cite some papers that discuss possible roles of tropicalcyclones in the stratosphere-troposphere exchange. Add more specific discussion,based on previous works (including those discussing the dynamical and thermodynamicalstructure of tropical cyclones), how tropical cyclones could work for transport oflower stratospheric air into the troposphere. What is a horizontal scale of such a transport?At the core (or the eye) of the tropical cyclones, there might exist a net downwardtransport. But, what the ozone observations showed might be of much larger horizontalscale, including the outer region of a tropical cyclone, and thus related to other flowstructures of the tropical cyclones. Also, does the descent rate of 1 km/day correspondto, for example, the subsidence in non-convective tropical region by radiative cooling? Response : Introduction is elaborated in view of (i) dynamical and thermodynamical structure of tropical cyclone with references (ii) Mechanism for transport of lower stratospheric air into the troposphere (iii) We do not have many observations to comments on its horizontal scale. However, using simulation it was found that the horizontal scale is about 50 km X 250 km (Das et al., 2011). (iv) We do not have observations of stratospheric intrusion during non-convective days for

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estimating descend rate.

(2) Reanalysis data and numerical simulation data can be used to make trajectorycalculations. I think that trajectory calculations are necessary to show the origin ofthe ozone enhanced layer and to prove that the layers at different altitudes in differentsoundings are actually an identical layer.

Response : We thank referee for the suggestion. We have tried to do the back trajectories (ARL/NOAA HYSPLIT) analysis but could not able to capture event. This may be due to the poor temporal and spatial resolution of the reanalysis data (input).

(3) It seems to me that the dates of the numerical simulation results shown in Figure 3 and of the satellite humidity data shown in Figure 4 do not correspond well to those for ozonesonde observations shown in Figure 2. For example, for the Nilam case in 2012,ozonesonde data are from 30 October to 7 November, while the numerical simulationresults are on 30 October for a snapshot and from 27 October to 2 November for the time series. The satellite data are shown on 25 October, with the time series for15 October to 10 November. I am puzzled at the choice of these dates. Therefore, the question about whether the layers at different altitudes in different soundings areactually an identical layer or not cannot be readily answered.

Response : The ozonesonde observation for Nilam is from 30 October to 7 November 2012. The time-series for Nilam showing in (right panel) Fig.3(c) and 3 (d) (RH) is from 27 October to 2 November 2012, which is well within the observations. To minimized the number of similar figure, we have only shown one set of figure (Figure 3(a) and 3(b)) on 30 October 2012 over the ozonesonde observation site (Trivandrum).

Similarly, the ozonesonde observations for Phailin are from 11-15 October 2013. The time-series for Phailin in shown in Figure 4(c) and 4(d) are from 7-12 October 2013, which is well within the observation period. In addition we have shown one example of height-latitude cross-section on 10 October 2013 over Trivandrum.

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Similar methodology is adapted for satellite observations. To avoid the confusion, we have split the Fig.3 and 4 (old manuscript) in two different parts.

(4) The surface ozone actually showed a step-like change in the behavior in Figure 2.However, there are several factors that control the surface ozone (as the authors haveacknowledged), and I think that more discussion is needed to attribute the elevatednight-time ozone and elevated daytime ozone to the ozone transport from the above.For example, after the passage of a tropical cyclone, stronger sunshine and higherhuman activities might lead to elevated daytime surface ozone, and prevailing oceanicair-mass following the cyclone might lead to weaker destruction of surface ozone atnight-time. I think there are several previous publications that discuss diurnal variationsof surface ozone around the tropical coastal regions, which would be helpful for the interpretation of the current results.

Response : Thank you for the suggestions. We have discussed the changes in sunshine in the revised manuscript. Along with the surface-ozone variation, we have show the time series of ground-reaching total solar radiation (Please see the Figure below). This shows that there was not much change in the radiation among the days 11-13 and 14-17 October 2013. Thus, this indicates that the observed enhancement was not due to change in sunshine. At the Thumba station, ozone remains to its daytime value even after evening hours until the onset of land-breeze (David and Nair, 2011) and do not increase in the evening hours. Interestingly, the enhancement observed on 14 October is during evening hours (16-17 hours) where solar radiation is very low or even zero. (Discussion with the reference including the diurnal variability of surface ozone is made in the revised manuscript). Over the site, land-breeze prevails during night-time. The change in night-time ozone depends on the precursor gas (e.g. NO) concentration in land-breeze, which has dependency on local precursor gas emission/human activity. Though there was cyclone, but Thumba was unaffected by rain and change in human activity during 11-17 October would not have happened considerably. However, the possibility of change of human activity cannot be denied fully. This is because the

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observed 10 ppbv of enhancement fall under the day to day variability (i.e. 1-sigma standard deviation over October is ∼9.5 ppbv). Thus, in nutshell, the effect of intrusion of ozone would have reached upto the surface causing ∼10 ppbv of enhancement in surface ozone, however, other possibility of this enhancement cannot be fully ruled out.

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).

Minor comments. Technical description is also necessary for the IMD's ozonesonde. Also, are there any intercomparison results between the ECC ozonesonde and IMD ozonesonde?

Response : We thank referee for the suggestion. Now we have incorporated in the revised manuscript.

For the WRF simulations, is the domain for 60 km horizontal resolution from 1S to 25N and 60E to 100E? How about the domain for 20 km horizontal resolution? Also, is the 20 km horizontal resolution appropriate for a tropical cyclone simulation? Cite some papers to discuss the ability and limitation with this setting for a tropical cyclone simulation.

Response : The model domain has been configured with two nested domains of 60 and 20 km horizontal resolution. The inner domain is 20 km and thus it is the horizontal resolution for 1oS to 25oN and 60oE to 100oE. To see the gross-features, 20 km horizontal resolution is appropriate. We have earlier carried out with two nested domains of 81 km and 27 km (Das et al., 2011).

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