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Atmospheric Chemistry and Physics Discussions



# *Interactive comment on* "Exposure-plant response of ambient ozone over the tropical Indian region" *by* S. Roy et al.

**S. Roy et al.**

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In the introduction (p 4143; l 22) authors have missed out references by saying that valid and long term measurement of ozone in India are very small. I agree with the fact that there are no reports of AOT40 over Indian region. But if you have systematic, valid (means published), and long term measurements then deriving AOT 40 is merely mathematical formulation. Hence authors are requested to do additional literature review or remove sentence that “Number of measurement sites in India having valid and long term representative measurements of surface ozone is too small”. There are at least following valid (published) long term ozone measurements: Khemani et al., 1995 at Pune; Debaje et al., 2003 at Tranquebar; Lal et al., 2000 at Ahmedabad ; Naja et al., 2002, 2003 at Mt Abu, Gadanki ; Jain et al., 2005 at Delhi., Srivastav et al., 2001 at Agra; Taneja et al., 2004 at Agra; Pulikesi et al., 2006 at Chennai; Reddy et al.,

2008 at Anantpur; Singh et al., 2008 at Darjeeling; Kuniyal et al., at Himalayan region; Chand et al., 2004 and some other. In addition I would requests authors to extract the ozone measurements from few of the literatures and try to derive and compare AOT 40 values with their standards. This will rather strengthen their claims about model study.

Answer: I agree that the sentence has created some confusion and I have reframed the sentence to convey the real message. I agree that there are quite a few measurements of ozone in India and majority of these references /work which you mentioned are cited in our recent paper provided that they are published in globally accessible journals (Roy et al., JGR, 2008). We have also compared our model results of ozone with the observed data from 4 Indian stations in the above paper. This reference (Roy et al., 2008) is already cited in the present manuscript and now we have mentioned it while discussing above mentioned sentences. However, I will still argue that even these 6-8 stations will also be called “a few” for a big geographical region like India and obviously some of these measurements are not continuous and reported only incremental analysis and some are made using K-I techniques which I do not trust that it is reliable and should be viewed with extreme caution. However, without going into the detailed argument, we have reframed the sentence and made it clear that although there are quite a few measurements of ozone reported from India, none of them have reported the AOT40 assessment as also mentioned by referee. The regional distribution of AOT40 to assess the potential for ozone induced damage on crop growth for any station requires much more detailed level of data than reported by them and the we do not have access to any of them in such a detail and hence, we could perform the AOT40 calculations using observations and comparison only for our own data of Pune. However, we did discuss about the comparison of our AOT40 model results with other published AOT40 model results in view of the comments made by referee-2.

Using a REMO-CTM 3-D regional, offline model authors have tried to simulate first the ozone concentration and then derived AOT 40 values over the Indian region as



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AOT 40 can not directly be simulated by the present model. Authors have tried to validate the model in Roy et al., 2008 JGR paper by comparing model results with observed precipitation and other trace gases obtained from in-situ measurements (only for one observational site) and remote sensing techniques. However, such derivation and comparison for ozone and subsequently for AOT 40 does not make much sense at least for the reasons pointed out by reviewer 1. In view of this authors should try to evaluate their model by comparing with real time AOT 40 data for rural site. As I have already mentioned scores of valid measurements are available over rural part (where most of the crops are harvested) of India, authors can try one of the stated sites. One can not compare oranges with apples just because they are growing in same soil. The comparison with rural site is of additional importance when observational site in the present study is of urban category and while addressing issue of AOT 40. Again as rightly pointed out by reviewer 1 one month AOT 40 values or time series of AOT 40 values does not make any sense as far as vegetation exposure response of ozone is concerned. Before and since I saw present paper I did not see the time series or seasonal description of the AOT 40 values (references are welcome from authors). Instead try to consider showing frequency distribution plot of AOT 40 values.

Answer: Part of this comment is same as the earlier one and we answered. We have also now posted the answers to both the anonymous reviewer’s comments and hence in a way some of the above comments are answered. The time series of seasonal distribution of AOT40 is included and discussed in the paper in detail in response to comments of reviewer-1 and as per your suggestion. Regarding validation of the model, above reviewer probably could not go in details of our earlier paper (Roy et al., 2008). In that paper, we have compared model results of ozone with the results of 4 different observational stations spread over India. In addition, the meteorological as well as trace gas data obtained by satellite measurements are compared with model data for whole of the Indian geographical region and NOT for one observational site as understood by the above reviewer. As far as AOT40 calculations using observations are concerned, we are constrained due to unavailability of the systematic data to us



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as mentioned above but we are confident that model will certainly be able to validate the AOT40 for other regions of India, specially IGP region because model is able to resolve quite well the gradient in ozone and other trace gases distribution over India and higher values (hot spots) in IGP region (Roy et al., 2008). The detailed scientific interpretations for such a gradient in IGP region for all the seasons are discussed by us earlier (Beig and Ali, 2006). This point is discussed in the answer to reviewer-1 as well as in the manuscript as desired by reviewer-1.

Specific Comments:

There is something indistinct in figure 1 and figure 2a. A careful look at figure 2a indicates two possibilities 1. Observational data is missing from approximately 75th day (meaning mid of March) till 135th day (meaning mid of May) with few data points around 120th day (meaning end of April). If data is missing for the month of April and possibly for March and May as well, then how come figure 1 shows the observational data? 2. A detailed look at figure 2a for model values (blue line) shows a consistent red background line between 75th and 135th day (if we consider data is not missing) a one-to-one agreement between observed and simulated values is noticed. If it is a case then why there is significant difference in observed and modeled values for the months of March, April, and May in figure 1? May authors can consider using different colors to avoid the confusion.

Answer: We thank the referee for pointing out this discrepancy which has cropped up due to a problem in plotting the data for the daily time series for the figures 2a-c. Following the referee’s comment we have re-plotted these figures (from 2a-c) with the required data fitted in the missing gaps. We are sorry for such a confusion /mistake and oversight.

In figure 2b and 2c authors have shown a time series of daily 8 h average of ozone concentration and daily maximum ozone concentration (averaging time is not mentioned in the caption, but assumed over 1 hr) respectively. I would like to request authors to



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double check the 8 hr ozone concentration values (or mention for clarity that how 8 h average ozone was calculated) as there is no significant difference in 8 h average and 1 h average values specifically during winter season. On the contrary a significant difference is expected in 1 h and 8 h averaged ozone concentration for this particular observational site.

Answer: There is no averaging involved in the calculation of the daily maximum ozone concentration. It is maximum value of the day. The daily 8 hr average has been calculated by averaging 8 data points obtained each hour during 11-18 hours. The PATTERN of the time series for the daily 8 hr average and the daily ozone maximum may appear to be similar but there is a difference in the magnitude. The 8-hourly average has to be smaller than the maximum value of the day which is clear. However, it is true that the difference is not as high in the modeled data, as obtained in the observed data for winter season because the regional model has to some extent underestimated the ozone levels during this time due to the reason stated in the answer to the next comment.

Figure 2b and 2 c: Why model underestimates 8 h and 1 h average ozone during winter and summer and overestimates 8 h and 1 h average ozone during monsoon? This needs to be explained since present model is regional model which is competent of confining the local phenomenon.

Answer: Yes, we agree that such issue need to be discussed in the paper and we have done it now. As mentioned above the model has underestimated the ozone values during the winter/spring months of higher concentration. The observational site is situated in the northwestern side of the Pune city (18.54 N, 73.81E). Major industries are located in the northeastern and eastern side of the site around 20-25 km away. During the winter time since the predominant wind pattern is northeasterly so the pollutants emitted from these industries can enhance the level of ozone precursors and hence the ozone at the receptor site. Since the regional model has the coarser resolution (0.5o x 0.5o), the effect of above mentioned local emission sources in the locality of the receptor site (which is on a subgrid scale) can not be captured by the model. This may have



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resulted in the underestimation of the modeled ozone levels during the winter period.

Although the model is able to capture the overall variability in the precipitation pattern over India (larger than 0.5o x 0.5o scale) to a reasonable extent it was unable to capture any sudden, localized excess rainfall event (much smaller than the model resolution) which has happened during the monsoon months of the year 2003 as per the rainfall records (IMD-report, 2003). This will obviously result in reduction of observed ozone but there will not be any manifestation of the same on the modeled results due to coarser resolution.

So in conclusion we wish to mention that some small differences are unavoidable due to the above reasons but, in general, model is able to capture distinct seasonal pattern very well as discussed in detail elsewhere (Roy et al 2008).

As mentioned kindly reconsider figure 3 with one month AOT 40 values (even if they are just a representation of model output they do not make any sense) as it does not implicate any significant information.

Answer: As per the suggestion of the referee we have added the 3-monthly plots for AOT40 over India for the year 2003 in the paper. However along with this we have retained the monthly AOT40 figures replotted with the same color scale and color legend. I would like to suggest authors to cite following references:

References : Girgzediene and Bycenkiene, Environ Monit Ass, 2007 Tuovien, Environ Pollution, 2000 Tuovien, Environ Pollution, 2002 Fuhrer et al., Environ Pollution, 1997 Interactive comment on Atmos. Chem. Phys. Discuss., 9, 4141, 2009.

Answer: We have cited the above reference.

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