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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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Specific Comments Although there is additional evaluation of the REMO-CTM system in the complementary JGR-paper, the reader can not really assess the ability of the modelling system to correctly describe AOT40 across India. The only control of the system’s ability to calculate surface AOT40 is given by the comparison with the data collected at a suburban site in Pune. The lack of relevant measurements over the Indo-Gangetic plains is a severe drawback in this and similar modelling studies. The authors should, nevertheless, explore additional ways to evaluate the performance of the model. Optimally, of course, by comparing with real-world AOT40 data collected at rural location across India during 2003. Other methods include comparing other ozone measures, which may be more readily available or AOT40 generated by other models operated over India. Two such studies are already mentioned in the paper.

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Answer: We have incorporated referee’s suggestion as far as possible. We have responded to almost similar kind of comment in the answers of reviwer-1 (first comment and partially the 2nd comment) and discussed the above issue in the paper as advised by reviewer-1. I appreciate referee’s understanding about the fact that the lack of relevant regular measurements over the Indo-Gangetic plains (IGP) is a drawback in this and similar modelling studies as far as AOT40 is concerned. However, we did provide a detailed modeling work and discussed various processes responsible for the distinct variability and high gradient over the IGP-region (Beig and Ali, 2006) which is also captured by the present model as discussed in our complementary JGR paper (Roy et al., 2008). However, as far as AOT40 model studies are concerned for IGP or many other regions of India, we need to make a beginning some where and the present paper is a sincere effort in this direction. In Roy et al. (2008), we have also compared the model simulated seasonal cycles of ozone for the year 2003 with observed data at four monitoring stations spread over India. The qualitative agreement was found to be of reasonable extent and there were few quantitative disagreements due to certain reasons which have been discussed therein [Roy et al., 2008]. In addition the model has been able to capture the gradient in ozone concentrations (which determines AOT40) between the Indo-gangetic areas and the remaining parts of India with higher values over the IGP region as reported earlier in several observational and modeling studies [Beig and Ali, 2006; Ali et al., 2004]. Although there are quite a few measurements of ozone reported from India, none of them have reported the AOT40 assessment. Such kind of calculation requires data in much more detailed form than reported by them and we do not have access to any of them in such a detail and hence could perform the AOT40 calculations using observations only for Pune.

However, we could follow the suggestion of the referee mentioned at the end of his/her comment related to comparison of AOT40 with other model results published earlier. The AOT40 generated over the Indian region by other models like HANK [Mittal et. al.,2007] and MATCH [Engardt, 2008] has not been compared with observational data. Mittal et. al. (2007) present a gridded distribution of monthly AOT40 values over India

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for few months from February’2000 to May’2000 and Engardt (2008) provides 3-monthly AOT40 plots over south Asia for the year 2000. We have added a discussion in the paper for the comparison of our model calculated monthly and 3-monthly AOT40 values over India, with those presented in the above mentioned two published model studies as suggested by the referee although they are for different years.

The quality and accuracy of the emissions inventory utilized for the present study is also difficult to asses. There is no information given about the temporal or vertical spread of the emissions in the model domain. There is no information on how biogenic isoprene emissions are treated. Again a comparison of the present emission inventory with other, recent, emission inventories generated for India would be helpful for the reader to assess the uncertainty in previous and present emission inventories for India.

Answer: The model accounts for emissions of several species like CO, NOx, VOC’s etc which are provided to the model for the surface level on monthly basis. The emissions of all the species other than CO and NOx have been obtained from the widely used standard database of Reanalysis of the Tropospheric chemical composition (RETRO) data which provides 0.50 Œ0.50 emission data set [Olivier et al., 2003]. The emissions for CO and NOx are taken from the recent high-resolution estimates of the new Indian inventory, [Beig and Brasseur, 2006; Dalvi et al., 2006] with subsequent downscaling to 0.50Œ0.50 using the GIS based statistical methodology [Dalvi et al., 2006] involving necessary activity data. The new region specific Indian national inventory accounts for the rapid temporal variability and small-scale geographical variations and are found to be different from the coarser estimates given by the global inventories like EDGAR and POET. The differences and similarities are discussed in details in our earlier paper [Beig and Brasseur, 2006] which is cited here now and hence not repeated. The standard natural emissions have been considered as part of the emission inputs which are fed to the model and biogenic isoprene emissions is one amongst them. The uncertainties in the simulated (absolute) concentrations which

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crop up due to the uncertainties in emissions are difficult to estimate but likely to be within the range of 2-5% as discussed in Beig and Brasseur (2006).

Give co-ordinates of the site in Pune where the ozone measurements were collected. Discuss the surroundings of the monitoring station, being a >suburban station< (p.4149, l. 6-7) located within the bounds of a city with more than 5 million inhabitants. How well is such a station suited for verifying a regional model operating across India.

Answer: The co-ordinates of the chosen receptor site in Pune is 18.540 N and 73.810 E (now included in the paper) along with discussion about the surrounding of this site as advised by the reviewer. The detail of this site is also given in detail at our earlier paper (Beig te al., 2007). The monitoring station is located at the northwestern parts of the Pune city which is a well industrialized semi urban city of India at an altitude of around 550m. Surrounded mostly by hilly areas the site is at a considerable distance from the major traffic junctions and hence defined as semi-urban rather than urban.

The choice of a monitoring station for the assessment of model data was limited by the availability of sufficient amount of consistent observational data for the year 2003 over the Indian region. So although the model calculates the cumulative ozone exposure indices like AOT40 throughout the Indian region we have selected Pune as the receptor site where adequate observational data was available to us over India for the said time period. However, as mentioned above (answer to comment-1), we have compared model ability to validate the ozone variability with the results of 4 different observational stations spread over India. In addition, the meteorological as well as some trace gas data obtained by satellite measurements are compared with model data for whole of the Indian geographical region (Roy et al., 2008). We have shown in Roy et al. (2008) that model is able to capture the seasonal and geographical gradient in ozone over India and the higher values of ozone over the Indo-Gangetic plain region are clearly distinct wrt the remaining parts of India in model results. This is probably enough to have confidence in model results given the constraints.

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The maps of Fig. 3 show AOT40 accumulated during one month only. Personally I would much rather have seen 3-month AOT40, for which there are (at least for Europe) established dose-response relationships for crops. If 1-months maps are retained, the reason for not forming (the traditional) 3- or 6- month AOT40 needs to be clarified in the text. Also, there are three panels but two different colour-legends. It is impossible to judge which legend that goes with which figure(s). Please use one legend for all three panels.

Answer: As per the referee’s suggestion we have included the 3-monthly AOT40 plots in the paper. We have retained the 1-month AOT40 figures with identical color-legend and scale for all the graphs following the reviewer’s advice.

On page 4147 and 4148 reduced solar radiation following the cloudy conditions during the rainy season is mentioned several times as one of the main reasons for the lower concentration of O3 during this period. Is there really any evidence for this statement? How do we know it is not caused by reduced precursor concentrations or different circulation or mixing patterns?

Answer: We agree that we have overemphasized the word ‘cloudy” by using it in several places. Usage of this repetition is reduced in the revised version. This is one among a few reasons for lower ozone during monsoon season and certainly not a main reason. In the monsoon season, the southwest monsoon circulation drives pristine air mass from the oceanic regions towards the land areas which results in a reduction in precursor concentrations over the Indian region and hence the ozone as correctly hinted by referee and we have included a discussion to this effect. The reduced solar radiation following cloudy conditions during the monsoon period is an additional reason which can help in lowering the concentrations of ozone during this period since, in general frequent cloudy conditions prevail during the monsoon time over the monitoring station Pune.

On page 4148, lines 16-21 a number of -emission sources scattered over the entire IG

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region-. Shall one interpret this as these sources not occurring elsewhere or that they occur in far higher numbers here?

Answer: This should be interpreted that IGP region is one among the high frequency source region. The densely populated Indo-Gangetic plains have a substantial level of rural population as well as industries. This makes the IGP-region prone to anthropogenic emissions. But the reasons for high concentration of ozone are both photochemical production as well as prevailing dynamics (Beig and Ali, 2006, Roy et al., 2008). Relevant sentences are reframed.

Although it is never claimed that the model covers the whole country of India it appears from the maps presented that the whole nation is not included (a number of north easterly states seem to be omitted), is that a correct observation?

Answer: The model domain extends from 0-400N and 600-900E. The referee is right in his observation that exactly the whole nation is not included in the model domain and a small portion of north easterly states are missing due to above limitation.

Technical corrections

p. 4142, l. 16: -November and April- should probably read -November to April

Answer: Yes, we agree. Correction is made.

p. 4143, l. 27-28: Engardt (2008) use an Asian (not global) emission inventory (TRACE-P, Streets et al. 2003, doi: 10.1029/2002JD003093).

Answer: True. We have made the appropriate correction and also the above mentioned reference is added.

p. 4144, l. 1-2: Dalvi et al., 2006 and Beig and Brasseur, 2006 are both missing in the reference list.

Answer: We are sorry that we missed our own references. These missing references have been added in the revised version.

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p. 4144, l. 19: -0 to 10 hpa-. Should probably be -0 m to 10 hPa-, or -surface to 10 hPa-.

Answer: Following We have changed the text to “surface to 10 hPa” as advised.

p. 4145, l. 26-27: -we present daily AOT40 values, daily 8 h average and the daily maximum ozone levels over the Indian region-. Actually these values are only presented for the model grid-cell encompassing Pune.

Answer: The model calculates the daily AOT40 values, daily 8 h average and the daily maximum ozone levels over the Indian region for the given grid for the year 2003. In this respect we have mentioned that we present daily AOT40 values, daily 8 h average and the daily maximum ozone levels over the Indian region. However depending on the adequacy of observational data over India for the said time period we have chosen the monitoring station Pune for an assessment of the modeled data where the values have actually been presented in the paper.

p. 4146, l 12-13: -between November 2003 and May- never really happens. Id recommend formulating it as -during Jan-May 2003 and Nov-Dec 2003- or skip the year and write -between November and May-;

Answer: As per the referee’s suggestion we have skipped the year and changed the text.

p. 4148, l 1: -monsoon season- Maybe better to spell out the months in question. Some authors have defined Summer- and Winter- (or South-West, North-East) Monsoon. Also the period is not unambiguously defined across all India.

Answer: Following the reviewer’s suggestion we have specified months corresponding to the monsoon season and the text has been updated from “monsoon season” to “southwest monsoon season comprising the months from June to September”.

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