

Interactive comment on “High ozone at rural sites in India” by D. Chand and S. Lal

D. Chand and S. Lal

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Reply to Referee #1

We thank the referee#1 for his/her valuable comments. We would like to make the following responses.

1. This paper presents first such results of surface ozone over a rural site at Khambat in the down wind flow from the industrial area of Ahmedabad-Baroda region. However, eventhough the measurements were made for a short period of about a week each time but these were made in two successive winters.
2. The Khambat measurements were made continuously in a stationary position. This was a fixed station and represents the main results. We have already not included the results when the vehicle was in motion on main roads except for Bhavnagar city. The

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change in ozone while crossing this city is in good match with other changes.

3. Khambhat is not only in downwind of the urban Gujarat but also one of the entry points of the pollution to the Arabian Sea. Observations at Khambhat are important for the marine environments of the Arabian Sea and the Indian Ocean.

4. The Khambhat measurements are compared with simultaneous or near simultaneous measurements made at Ahmedabad and Mt. Abu. The published results for Ahmedabad (Lal et al., 2000) and Mt. Abu earlier (Naja et al., 2003) represents measurements for these two sites only and not for Khambhat.

5. We have tried to show that significantly higher levels of surface ozone can be found at remote sites and not necessarily at bigger cities. This seems to have been observed in US/Europe but these are first such measurements from an Indian site.

6. We would have done further analysis but unfortunately the data are limited to ozone only as pointed out. We would very much like to have other related measurements also. But at the same time we would like to publish these very clear results on surface ozone. We also wish to point out that eventhough rural site shows higher levels of ozone than at Ahmedabad, but we do not find very high ozone even crossing 120 ppb which has been observed often over many US sites. This is also to be noted that this is the region of stronger photochemical activity.

7. We agree fully with the comments of the referee for the limitation of the data. Not withstanding this limitation, we wish to publish these limited results to emphasise the above mentioned points to the world community.

Reply to Referee #2

First of all we thank the reviewer for meticulously going through the manuscript. The constructive and valuable comments of the reviewer have certainly improved the quality of our article. We also thank the reviewer for appreciating our work.

Our replies to the comments of the referees are given below:

General comments: The paper deals with the interesting topic of high boundary layer ozone levels at rural sites in India. It demonstrates the occurrence of large-scale photochemical ozone production downwind of major urban and industrial areas in the region, based on carefully planned field measurements. The paper merits publication also because few available ozone measurements at rural sites in the Indian subcontinent exist so far.

Specific comments: 1. In 2.1 Monitoring sites. Some general information containing the size and the emission characteristics of the urban and industrial centers in the area would be helpful for the better understanding of the conditions leading to such high levels of ozone photochemical formation.

We have added some information on the type and number of vehicles in Ahmedabad. But unfortunately we do not have much record of the emission inventories from industries in Gujarat state. So, at present, it is not possible to say much on the emission characteristics.

2. In 2.3 Meteorology. In addition to the wind pattern, some information on temperature and sunshine duration would be helpful for the readers not familiar with the region to understand better that during the mid-winter period in India the prevailing meteorological conditions, comparable to spring/summer conditions at mid-latitudes, might favor substantial ozone photochemical production.

We have added the sunshine duration and temperature variations in the observational season.

3. In Table 1. The difference at the morning minimum urban ozone levels at Ahmedabad, could be due to the different urban NO_x levels between the two campaign periods, which consume ozone very rapidly in urban centers.

Yes, it is most likely due to different levels of NO_x or may be due to change in the

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meteorological parameter during the two years. Now we have added one sentence in the first paragraph of page 3366.

4. Also in Fig. 3d, the ozone decrease in the urban area of Bhavnagar should be primarily due to the ozone titration by fresh NO emissions from the nearby car exhausts. The last paragraph of the page 3366 should be modified accordingly.

Now the paragraph is modified. Some text is added to support the results.

Corrections/Modifications in the MS as suggested by referee#2.

P 3362 Line 16-17 Add the following sentences after completion of the sentence (...locations are above mean sea level.)

Ahmedabad is among highest polluted cities of India (CPCB, 2003). The sources of most of the pollutants are emissions from the vehicular traffic in this city. Ahmedabad accounts about 2% of the number of total vehicles in India (CPCB, 2003, annual reports). The dominant sources of the vehicles are two wheelers which account about 77% of the total vehicles in Ahmedabad.

P 3365 Line 01 Add the following sentences after completion of the sentence (...range of 2-6 m/s.)

The lowest and highest temperature at Khambat was observed to be 15 C and 31 C respectively. The sunshine duration in month of January taken from Mt Abu observations is about 10.5 hours (sunrise 07:30 hrs, sunset 1800 hrs (IST)).

P 3366 Line 10-11 Add the following sentence after completion of the sentence (...similar for the years.)

The difference in average ozone levels at Ahmedabad in night hours during the two years may be due to different levels of NO_x or some changes in the meteorological parameters.

P 3366 Line 26-27 Add the following sentence after completion of the sentence (...inside the city was around 26 ppbv.)

The ozone loss in the urban area of Bhavnagar is attributed primarily to the ozone titration by fresh NO emissions from the nearby vehicle exhausts.

P 3371 Add the following reference in reference list.

CPCB (Central Pollution Control Board of India) annual report-2003. See the annual reports at web '<http://www.cpcb.delhi.nic.in/annual.htm>'.

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 3359, 2004.

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