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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on “The effect of lightning NO_x production on surface ozone in the continental United States” *by* B. Kaynak et al.

B. Kaynak et al.

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First we would like to thank Anonymous Referee 2 for his/her constructive comments and suggestions. Here are our answers to his/her questions shown in italic.

This is an interesting model study of the sensitivity of surface ozone to NOx produced by lightning. The conclusion, that on average the contribution is relatively minor, has policy implications because it implies that the background O3 (which cannot be regulated) is not much enhanced by lightning. The paper is suitable for publication, but could benefit by additional discussion of several topics.

1. The uncertainties in lightning NOx emissions are very large, especially for intracloud (IC) flashes. The factor of 3 correction for unmeasured number of IC flashes is obviously a rough estimate, as is the new IC/CG ratio of 1 vs. older value of 0.1 for NO

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Interactive Discussion

Discussion Paper

production. Figure 2 shows that the new vertical profile of NOx emission is essentially zero in the boundary layer, compared to the older parameterization which maximized at the lowest altitudes. While a very detailed statistical analysis is presented on the results with the new parameterization, only one paragraph (bottom of p. 5069, top of p. 5070) is devoted to describing the results from the old parameterization. There, it is argued that allocating more NOx to the boundary layer actually leads to less O3 because the convection occurs in late afternoons and evenings, with lower photolysis and O3 titration by fresh NO. However, this is not obvious, because values of O3 late in the day are usually not the ones that are measured by 1-hr or even 8-hr maxima, and one might expect significant carryover of NOx into the photochemically active hours of the next day. More generally, given the large uncertainties in both the total lightning NOx and its vertical profile, more discussion of the sensitivities might be warranted.

According to our simulation results and ambient monitoring (e.g., http://www.air.dnr.state.ga.us/), 8-h maximum ozone typically occurs in the late afternoon (around 18:00) which actually coincides with convective events. Additional NOx coming from lightning has a titration effect and can result in a decrease in ozone concentrations. Further, the reduced photolysis during storms leads to an environment where additional NO emissions typically lead to reduced ozone.

More discussion on the sensitivity simulation is added to the appropriate parts of the manuscript as follows:

”The maximum difference in the 4th highest values is 23 ppbv whereas it is 35 ppbv for the 1st highest 8-h O3. 1-h O3 follows a similar pattern as 8-h O3 and the maximum difference in the 4th highest values is 33 ppbv versus 46 ppbv for 1st highest value. There are also significant decreases in ozone with the addition of lightning by up to -20 ppbv. Overall, the net additional exceedance from lightning with the older lightning NOx distribution profile is -1.8% for 8-h. The highest 8-hr ozone level also had the highest reduction with -3.6%, showing a negative sensitivity.”

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2. While the O3 changes from lightning NOx may be small when averaged over the entire domain, they might be quite important at some specific locations, e.g. from Fig. 10 in Florida, Salt Lake City, or Denver, all of which have significant populations. It might be interesting to explore these exceptional areas in more detail.

Additional information and discussion on specific locations is added to the appropriate parts of the manuscript as follows:

”The greatest differences in 8-h O3 are in Ocala and Panama City, FL (more than 20 ppbv), Salt Lake City, UT (up to 14ppbv) and Denver, CO (up to 16ppbv). Florida, being the region with the most intense lightning during this period, is expected to have the highest impacts. Even though the other two cities do not have high biogenic emissions, the sensitivity of ozone to NOx emissions from our simulations is positive, indicating increase in ozone with additional NOx emissions. The high altitude of those two cities, which results in high photolysis rates, increases radical production and allows more effective use of additional NOx.”

3. It is not fully clear how lightning is distributed into CMAQ layers. Looking at Fig. 2, CMAQ has several layers below 1 km, but only one lighting point is shown.

As explained on p5067/l14-16, the vertical profile (going up to 16 km), is scaled to the cloud top height obtained from MM5, and the emissions are allocated, proportionally, to the below cloud-top cells. For example, if the cloud top is 5 km in a specific grid, the emissions are placed in the cells below 5 km, using the, though vertically compacted, distribution shown. For example, the emissions that were in the bottom 1 km using the 16 km profile are now placed in the cells containing the lowest 5/16 of a km.

4. It is stated (p. 5070) that O3 production efficiency (OPE) is decreased by lightning NOx, while the actual values reported (OPE = 5.47 for basecase and 5.66 for lightning) indicate the opposite. The reason given, that ozone is decreased by late afternoon NOx injections, has the same problems as mentioned above. However, it is typically true that OPE decreases at higher NOx. Some clarification is needed.

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We have checked Fig. 10, and there is a mismatch in the color coding of regression equations. As can be noticed from the trend lines, the higher slope (OPE) and lower y-intercept (Background O3) belong to basecase, not lightning case. This mismatch is corrected both in Fig.1 and the corresponding text. Thank you for pointing out this issue.

Technical Comments:

5063/18: replace 'to' with 'in'.

done

5063/19: insert: and 'a' recent.

done

5064/5,6: not clear 'these cases would not compromise the current 80 ppbv...'

The reason is lower ozone values in the spring. That part is removed from the sentence.

5064/17 and 5065/13: citation (2008b) should be (EPA, 2008b); also need to correct in reference list.

done

Fig.1 suggests more than 2ppb change in MNB lightning is added.

For clarification, Fig. 1 shows the model evaluation for 8-hr O3 for all measurements (AIRS, CASTNET, SEARCH), not only AIRS stations. And the unit in the y-axis is percentage, not ppbv.

On the other hand, Fig. 6 is the difference between 2 simulations (daily 1-hr and 8-hr maximum O3 for the grids w/ AIRS stations. The 8-hr O3 (model evaluation) have more data and may be affected differently than max 8-hr O3 (lightning-base comparison).

The caption of Fig.1 and Fig.6 are modified for clarity.

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Interactive Comment

5066/9: replace 'that' with 'those'.

done

5066/17: replace 'on' with 'in'.

done

5066/20: replace 'of widely' with 'of a widely'.

done

5067/1: what is lighting 'mass'?

changed to lightning produced NOx

5067/4: using 'results' from De-Caria....

done

5069/5: replace 'narrows' with 'narrow'

done

5069/8: replace 'is infrequent' with 'are infrequent'.

done

5069/19-20: Denver and Salt Lake City don't have high biogenic emissions, yet show large effects.

We checked the sensitivity of ozone to NOx emissions in those two cities and found it is positive even though they do not have high biogenic emissions. Factors leading to this response include the high altitude, which results in high photolysis rates, intensifying radical production and increasing the production of ozone. The more intense radical production pushes the atmosphere away from being radical-limited, which is often associated with being NOx-rich/VOC-limited.

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Interactive Comment

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 5061, 2008.