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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Lightning NO_x emissions over the USA investigated using TES, NLDN, LRLDN, IONS data and the GEOS-Chem model" *by* L. Jourdain et al.

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Major comments:

1) The impact of the stratosphere:

In this paper, we used Sstrat as a part of a sensitivity study to show that ozone mixing ratios in the upper troposphere in GEOS-Chem are very sensitive to the treatment of the flux from the stratosphere. We do not use Sstrat as the baseline in the paper because we think that this setting presents some drawbacks and did not want the GEOS-Chem users to think that we have fixed the stratosphere in the GEOS-Chem model.

Indeed, the GEOS-Chem simulation with the treatment of the stratosphere like in Sstrat has too much ozone (relatively to the sondes measurements) in the uppermost troposphere and lower stratosphere as shown in the Figure_review1.pdf (available at ftp://lpce.cnrs-orleans.fr/users/Line_JOURDAIN/pub/). In this figure, we present the mean difference: between the GEOS-Chem profiles (Sbase, Sstrat and Sbase_ini, Sstrat_ini) and IONS profiles, between TES profiles and IONS profiles, between TES a priori profiles and IONS profiles. Sbase_ini and Strat_ini (solid lines) lines represent the raw GEOS-Chem profiles. These profiles were not modified to take into account the sensitivity of TES (not like Sbase and Sstrat).We see that Sstrat_ini overestimates the ozone in the uppermost troposphere-lowermost stratosphere compared to the sondes. This is why we do not consider this simulation as a good baseline simulation.

The difference between Sbase and Sbase_ini or Sstrat and Strat_ini becomes large in the uppermost troposphere and lower stratosphere because we use TES profile as the true profile (in the formula 1 of section 2.1) above the tropopause to calculate the modified GEOS-Chem profiles (Sbase and Sstrat). This approach is also taken in other works in particular in Zhang et al. (GRL, 2006) where it is explicitly mentioned. This is done because GEOS-Chem does not have a predictive capability in the stratosphere. With this setting (taking TES as the true GEOS-Chem profile above the tropopopause), Sstrat does not show an overestimation of the ozone in the uppermost troposphere-lowermost stratosphere like in the real GEOS-Chem simulation Sstrat ini.

Sbase and Sbase_ini are also different. But, it is important to note that the setting we used do not affect the profiles below 200 hPa. So it does not affect our analysis that mainly focused on the level 300hPa. We also checked that all the features seen in the UT in Sbase was also in Sbase_ini and does not come from TES nor from the TES a priori.

In addition in the previous figure 7 (Fig7_old.pdf available at ftp://lpce.cnrs-orleans.fr/users/Line_JOURDAIN/pub/), we see that the correlation at 300 hPa between GEOS-Chem and TES is lower for the simulation Sstrat than for the other simula-

tions, in particular at high latitudes (triangles) where the contribution of the stratosphere is higher. So even if the ozone in Sstrat agrees better in mean with TES, at 300 hPa the correlation between TES and Sstrat is less good than the correlation between TES and Sbase.

To conclude, the comments of the reviewer helped us understand that showing the results of Sstrat is leading to confusion. Therefore, we decided to remove this simulation from the paper for clarity and now just infer a problem with the stratospheric ozone contribution because the bias between GEOS-Chem ozone and measurements increases with altitude (comparison with IONS ozonesondes in section 2.4) and also with latitude in the upper troposphere (comparison with TES in section 3.1.2).

Please note that we removed the results for the simulation Sstrat in figures 3 and 7 and changed the text accordingly.

Concerning the impact on our conclusions, the main conclusions of the paper remain that:

- TES has enough sensitivity to ozone variability in the troposphere that it can observe ozone enhanced layers downwind of convective events over the USA in July 2006. Thus this dataset can be used to test and constrain the parameterisation of the NOx produced by lightning.

- GEOS-Chem with the parameterisation of Price and Rind (1992) can reproduce the ozone enhancements layers seen by TES and confirm the influence of LNOx on the enhancements. But the model GEOS-Chem underestimates the intensities of the ozone enhancements.

- The model's ability to reproduce the location of the enhancements is due to the fact that this model reproduces the pattern of the convective events occurrence on a daily basis during the summer of 2006 over the USA, even though it does not well represent the relative distribution of lightning intensities.

- New updated values of LNOx for midlatitudes given by recent studies seem to improve the comparison between the GEOS-Chem model and TES (reduction of the bias by 40%).

- This latter conclusion is limited by the fact that the bias between GEOS-Chem simulations and ozonesondes increases with altitude and latitude, suggesting the stratospheric contribution to tropospheric ozone is underestimated in the model.

We now emphasize these points in the abstract and in the "Conclusions" section.

2) Vertical profile of LNOx :

In our paper, we use the vertical distribution of NOx produced by lightning given by Pickering et al. (1998). More recently, Ott et al. (2009) used a 3-D cloud scale chemical transport model that includes a parameterized source of lightning NOx source based on observed flash rates to simulate six midlatitudes and subtropical thunderstorms. The new results suggest that our model using Pickering et al (1998) may place at midlatitudes too much NOx near the surface and upper troposphere and too little in the middle troposphere. The authors calculate the impact on the tropospheric ozone at the global scale using the GMI (Global Modeling Initiative) model and they show that it leads to a decrease of the ozone in the upper troposphere of 5-10 ppbv in midlatitudes in summer. In conclusion, implementing the new profiles would lead to an additional small negative bias for ozone in the uppermost troposphere. This is now mentioned in the section 3.2.2 and in the "Conclusions".

Minor comments:

Abstract lines 12-17: the sentence is now shorter.

1125, 3-5: We remove the first part of the sentence mentioning the non-linearity of the ozone production.

1129,6: changed as suggested

1130,10: We agree that it would have been better to use the geographic distribution of the ratio values of IC/CG of Boccippio et al. (2001). For technical reasons, we could not get the data shown in Boccippio et al. (2001). But we show in the section 3.2.1 that the agreement between observed and simulated ozone is due to the fact that this model reproduces the pattern of the occurrence of the convective events and their associated lightning on a daily basis during the summer of 2006, even though it does not well represent the relative distribution of lightning flash intensities.

1130, 14 changed as suggested

1129-1130: The simulation SNLDN has the same flash rates as the simulation Sbase except over the United States and few hundred kilometres off the coast of the United States. There are more flashes in NLDN than in OTD/LIS over the United States as shown in Fig. 2, but the production of NOx per flash in SNLDN is the same as in Sbase (ie: 260 mol/flash). So therefore, over North America midlatitudes (25-50N), LNOx in SNLDN (0.14 TgN) is higher than in Sbase (0.1 TgN). Over the midlatitudes, LNOx in Slighx2 is 2 times LNOX in SNLDN, so it results that LNOx in Slighx2 totals 0.28 TgN.

To clarify, we have added a sentence in section 2.3 to mention the point that LNOx in SNLDN is higher than Sbase because more lightning are observed in July 2006 in NLDN and LRLDN than in OTD/LIS climatology .

Fig.2 bottom left: The flashes are regionally scaled to match OTD/LIS on a monthly basis. We did not perform a scaling gridbox by gridbox, which is why the distributions from OTD/LIS and from the model after the scaling are not similar. In particular, we cannot reproduce a maximum in a region if this maximum does not exist in GEOS-Chem. The scaling was done to correct the relative importance of the regions, which was at first very far from being realistic as shown by the figure 2 top left. But for our study, we focus on the United States, for which we could use NDLN and LRLDN data ,for July 2006, that have a better spatial and temporal resolution. In this case, we performed a scaling gridbox by gridbox on a daily basis.

Fig. 2 bottom right: The simulation SNLDN has the same flash rates as the simulation Sbase except where we have NLDN and LRLDN data, that is, over the United States (NLDN) and up to few hundred kilometres off the coasts and borders of the United States (LRLDN). This latter information is added in 2.3 when presenting SNLDN. Note also that LRLDN does not include data over Canada in July 2006.

We changed the caption of figure 2 to mention the two following points

- GEOS-Chem is regionally scaled to OTD/LIS.

- GEOS-Chem is scaled gridbox by gridbox to NLDN and LRLDN observations over North America. This latter information is also added more explicitly when presenting SNLDN in section 2.3.

Fig. 3: the curves corresponding to Sstrat have been removed.

Fig. 4: The caption has been updated as suggested.

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