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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Impacts of aircraft emissions on the air quality near the ground" *by* H. Lee et al.

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"Lee et al. present an interest study of the impacts of aviation emissions on air quality in the PBL. In particular, they address the influence of aviation emissions at various altitudes and explain that vertical mixing of directly emitted species is not the main mechanism under which aloft emissions affect air quality n the PBL. I find this paper is within the scope of ACP and recommend its final publication after the authors address several issues listed below."

We thank the anonymous reviewer for the careful reading and positive comments. As indicated in the following responses, we have incorporated all these comments into our new revision and added new references.

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General comments:

1. Aviation emissions will likely increase in the future (particularly in developing countries) if control measures are not enhanced. While it is critical to assess the influence of aviation emissions in current years, it is also important to discuss the potential changes in future emissions and implications for air quality. Also, I suspect that emissions in Asian countries are underestimated given the fast growth in the past decade. For example, total non-aviation anthropogenic emissions of NOx in China increase by about 30

→ We agree with the importance of the recent trend in aviation emissions. A recent study (Olsen et al., 2013) has shown the increase in fuel burn from commercial aircraft between 1992 and 2006. This is why we used two aviation emissions datasets in our study. Accordingly, sentences were revised as follows: Recently, Olsen et al. (2013) reported that the fuel burn from commercial aircraft increased by 71

2. The global model has a relatively low resolution and thus cannot simulate the nonlinear chemistry in the PBL very well. I suggest the authors to discuss the potential uncertainties due to model resolution, both horizontal (Lin et al., 2008) and vertical (Menut et al., 2013). Also, the impacts of LTO emissions should be significant near the airport. Therefore the paper should be clearer on the horizontal scale of the air quality being addressed, particularly when it concludes that aviation emissions only have insignificant impacts on air quality.

→ Thanks for the comment. We revised the introduction for clarification as follows: The main objective of this study is to evaluate effects of emissions from aircraft on air quality by comparing multiple simulations from a chemistry transport model with and without aircraft emissions. We evaluated the aviation-induced perturbations of gases and aerosols in the boundary layer. However, as discussed in Lin et al. (2008), our model's horizontal resolution is too coarse to simulate boundary layer ozone in some regions with large sub-gridcell heterogeneity. In addition, impacts of aviation emissions

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in sub-grid scale, such as highly concentrated ground emissions near major airports, are averaged over the entire grid cell area. Therefore, for this study we focused on the large-scale impacts of non-LTO aircraft emissions by analyzing ozone (O3), total odd-nitrogen (NOy) and PM-2.5 defined as the total mass mixing ratio of sulfate, ammonium nitrate (NH4NO3), organic carbon (OC), and black carbon (BC) particles.

3. The paper shows an interesting result that aviation emissions of NOx during cruise reduce, rather than enhance, NOy in the PBL in January. The authors also explain the seasonality of the magnitude of NOy perturbation by analyzing the heterogeneous reactions. It is unclear, however, why increased NOx emissions aloft would reduce NOy in the PBL.

→ We analyzed the unexpected NOy decrease in January. Because this is beyond the scope of our study, we decided not to include some detailed explanation. We are planning to publish another paper focusing on this. However, we have revised the manuscript to help understanding of reviewers and potential readers as follows: Above reactions are dominant at nighttime especially in winter due to the short lifetime of NO3 under sunlight. The net reaction of (R1) - (R3) becomes 2NO2 + O3 + H2O (s) → 2 HNO3 (R4) Clearly, (R4) can be a more efficient sink for NOx than O3 because of two NO2 molecules reacting with one O3 molecule. As shown later in Figure 6 and 7, the perturbation of O3 due to aviation emissions is larger than that of NOx in the boundary layer. As a result, the increased O3 caused by non-LTO emissions consumes background NO2 via (R4), i.e. background NOx is decreased but HNO3 is increased by the O3 perturbation propagating from the upper troposphere. However, this NOy decrease is ignorable in view of the air quality so it is beyond the scope of this study.

4. As the impact of air pollution on health is continuous (i.e., there is no 'threshold' below which amount pollutants do not affect health, as pointed out by the other reviewer), it appears inappropriate to completely disregard the impacts of aviation emissions on air quality just because the impacts are small.

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→ In section 3.2, we have added a paragraph supporting our conclusion based on careful review of previous studies in public health and PM 2.5 as follows: Analyses of mortality due to PM 2.5 in the previous studies have used different PM2.5 concentration-response functions but commonly considered only large changes in PM concentrations. For example, Schwartz et al. (2002) found that 10 μg m-3 and 20 μg m-3 of PM 2.5 concentration difference is associated with 1.5

Specific comments: P690, L9: better to specify the height.

→ The height information has been added as follows: We show that emissions near cruise altitudes (9 -11 km in altitude) rather than emissions during landing and take-off are responsible for most of the total odd-nitrogen (NOy), ozone (O3) and aerosol perturbations near the ground with a noticeable seasonal difference.

Abstract: please emphasize the spatial scale of the findings. i.e., small-scale influence near the airports is not simulated here.

→ Both abstract and introduction were revised as follows:. The large-scale effects of current levels of aircraft emissions were studied through comparison of multiple simulations allowing for the separated effects of aviation emissions occurring in the low, middle and upper troposphere.

P691, L15: please define the height of non-LTO. → We revised the manuscript as follows:. Tarrason et al. (2004) found that the emission by aircraft during climb/descent and during cruise, the so called non-LTO emissions occurring above 1 km in altitude, can have a larger impact than LTO emissions on air quality in Europe because of the relatively large amount of non-LTO emissions compared to LTO emissions.

P692, L22: what is ‘N’?

→ CAM-chem defines NOy as the sum of all reactive nitrogen compounds by default. N is atomic nitrogen.

P693, L9: Emissions of NH3 from soil and waste are affected by temperature and other

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met conditions.

→ This is a good point. We cited Nowak et al. (2010) to highlight the importance of NH3 concentrations under similar meteorological conditions. The text has been revised as follows: Although the equilibrium state and equilibrium constant to produce aerosols are also determined by the local temperature and relative humidity, the concentration of NH3 is the most important key factor under similar meteorological conditions (Nowak et al., 2010).

P693, L14: 'his'should be 'this'

→ We corrected it

P693, L20: emission dataset here and even the FAA dataset later do not account for the recent rapid growth in developing countries (like China). Please comment.

→ We addressed this issue by citing Olsen et al. (2013). Please refer to our answers for the general comments 1.

P693, last paragraph: please discuss the diurnal cycle of emissions. Aircrafts fly mostly during the daytime. In the later paragraph the authors suggest uncertainties are not important for the 'hydrophilic' assumption for BC and for emission indices. It will be helpful to indicate the point here.

→ We agree with this and revised the text as follows: For simplicity, all black carbon and organic carbon aerosols from aircraft were assumed to be hydrophilic. We will validate this assumption later. In addition, we used annual average emissions as input to our simulations. The diurnal cycle and seasonal variation of aviation emissions are ignored in our approach. So any difference shown in our results between different seasons is caused by seasonally varying dynamics and chemical environment.

P695, L26: how about the thickness of the three layers?

→ The thickness depends on local temperatures. The reference pressure is different

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from actual pressure depending on topography. As mentioned, the use of these three layers does not make any considerable difference in our analyses.

P696, L9: 'surface'or 'PBL'? Also, the sentence is difficult to understand. It is better to briefly mention here the cause of reduced NOy in the PBL.

→ It should have been 'in the boundary layer' not 'at the surface'. The phrase has been corrected. We hope that our answer for the general comment 3 resolved this.

P698, L3: which case is the result for?

→ It is from the baseline simulation 'CTRL'. We have added this to the sentence.

P698, L26: the sentence is unclear.

→ The sentence has been revised as follows: To further examine the downward propagation of NOx and O3 perturbations, we carried out two additional simulations. We added cruise altitude emissions to the model run 'CTRL' as forcing for 30 days from the beginning of January and the beginning of July.

P700, L9: do you mean PM in the PBL?

→ Yes, we should have been more specific about this. The sentence was revised as follows: In the wintertime boundary layer, the increased HNO3 that has longer lifetime than NOx determines the effects of the non-LTO emissions on the boundary layer PM-2.5, rather than directly emitted aerosols from aircraft.

P700, L10: HNO3 has a longer lifetime than NOx?

→ Mean life time of HNO3 in the boundary layer and upper troposphere are about 5 days and 2-3 weeks respectively (Balkanski et al., 1993) whereas one of NOx is several hours.

P702 formulae: what is x?

→ The x is random variable in PDFs. The sentence was revised as follows: The

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Hellinger distance between two probability density functions f(x) and g(x), for a random variable x, is defined as

P703, L11: how about p-value of 0.87 in Dec?

→ 87

P703, L23: how about E. Asia for the >50 ppbm case? The number of gridpoint-day increases from 39 to 43, an increase by 10

→ We agree with the reviewer's comment. It is needed to consider the rapid increase of aviation emissions over Asia with updated emission database and a model with higher resolution. For this, we briefly mentioned it in the revised conclusion. When we compared the frequency of PM 2.5 higher than 35 μg m-3, we found the negligible difference (467 vs. 464). For the 50 ppbm case, frequency of 39 to the total case is just 39/(294*31)=0.00428. This small increase does not change shape of the overall probability distribution in Asia.

P704, L29: As NOy are decreased in the PBL in January, it suggests that the increased formation of NH4NO3 is the cause of reduction in NOy.

→ Please refer to our above response to general comment 3.

References:

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