

## ***Interactive comment on “Simulated 2050 aviation radiative forcing” by C.-C. Chen and A. Gettelman***

### **Anonymous Referee #2**

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This paper describes the radiative forcing from aviation for 2050, differentiating between contrail cirrus and aerosol effects. Different scenarios are used prescribing the amount of air traffic and changes in emissions due to increases in engine efficiency or alternative fuels. Aircraft emissions are found to have the largest impact due to sulfuric acid aerosols changing the liquid water path of clouds and therefore causing radiative cooling in particular over the oceans. If sulfur emissions are cut then nearly all the radiative forcing is due to contrail cirrus.

The paper is an extension of the authors' work on simulating the impact of contrail cirrus and aviation aerosol emissions on climate differing mainly in the inventories used. The paper is interesting and worth publication after major revisions. In particular, more information about the simulation and the parameterizations of the aviation effects needs to be given, significance tests need to be performed and the decrease in cloud coverage when simulating only the impact of contrail cirrus needs to be explained. More

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critical discussion of the uncertainty of the results and of the single components would be important. Do the authors judge the uncertainty of the aerosol effect to be of the same size as that one due to contrail cirrus?

Comments:

1. You distinguish between H<sub>2</sub>O effects when talking about contrail cirrus and BC and SO<sub>4</sub> effects when showing aerosol effects, neglecting the fact that contrail cirrus ice crystals form to a large degree on aviation aerosols and that contrail cirrus properties are dependent on the aviation aerosol emissions. You do not discuss this effect which likely means that you do not simulate the impact of soot emissions on contrail cirrus. Furthermore, it is not clear to me whether you take into account that aerosols that form contrail ice crystals may not be available for cloud indirect effects. In areas that are frequently ice supersaturated this could have a large impact on the results.

2. Throughout the paper you compare indirect aviation aerosol effects with contrail cirrus but do not discuss whether you believe the level of confidence connected with the two estimates to be similar. The uncertainty should not only consider the variability that you find within your simulations (and that you probably plot in figure 3) but also the assumptions that you make within the model such as nucleation thresholds and fraction of efficient ice nuclei. In the caption of figure 3 you should explain what kind of uncertainty you are plotting (vertical bars).

3. You seem not to adapt the Schmidt-Appleman criterion to the aviation scenarios. It is well known that a change in water vapor emissions, such as prescribed in scenario 3, or a change in fuel efficiency, that is connected with a change in propulsion efficiency, mainly impact contrail cirrus due to the change in the Schmidt-Appleman criterion and not due to a change in the water emissions. If you do adapt the criterion when prescribing different emissions, then please clearly state this.

4. When discussing the spread of contrail cirrus radiative forcing for different aviation scenarios it should be mentioned that the spread is underestimated due to the fact that

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the effect of aviation aerosol emissions on contrail cirrus properties and changes in the Schmidt-Appleman criterion due to changes in water emissions and fuel efficiency are (probably) neglected (see above).

5. Could you please comment on the size of the reduction of aerosol radiative forcing between the BL case and Scenario 1 given that fuel consumption was reduced by only 2%. How can we understand this large effect?

6. In figures 4 and 5 you do not discuss your results regarding changes in total cloud cover. I do not understand why total cloud cover (fig 4d) is decreased in the northern mid latitudes when looking at 'H<sub>2</sub>O-effects' only. Shouldn't we see here the increase in total cloud cover due to contrail cirrus? Likewise in figure 5d for scenario 2 we see a reduction in total cloud cover even though in this scenario the aerosol effects are small. This needs to be analyzed and discussed in more detail.

7. Most of the figures show differences between two simulations but no significance testing is applied. This limits the information content of the figures significantly. Just to give an example, can we really expect the by far largest change in ice water path due to the indirect effect of aviation aerosols in 2050 over northern Australia during northern winter or is this signal maybe not significant (fig. 9f)? OR Do we really expect a cooling over most of Southern America resulting from changes in cloudiness in 2050 (fig. 6d)?

8. The initialization of contrails with a diameter of 10  $\mu$ m is very extreme. Schroder et al. found 10-11 (7-8)  $\mu$ m as an effective (mass) diameter for contrails older 30 minutes. The mass based diameter for young contrails is 2  $\mu$ m. Please comment on the impact on contrail cirrus ice crystal numbers and optical properties.

9. The amount of sulfur in aviation fuel varies strongly. Could you please state how much sulfur is emitted when using the base fuel.

10. When you compare the results of different simulations regarding contrail cirrus radiative forcing you should mention the base year for which contrail cirrus RF was

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estimated. Part of the spread can be explained by the fact that inventories for the year 2002 and 2006 were used.

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