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Interactive Comment

Interactive comment on "Simulated radiative forcing from contrails and contrail cirrus" *by* C.-C. Chen and A. Gettelman

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We would like to thank the reviewer for the very careful review and very useful suggestions. We have revised the manuscript accordingly. Please see the attached file for the revised manuscript. Our response to the reviewer's concerns is as follows:

(A) Main concerns

1. We believe that a much representation of the diurnal cycle can only be achieved by obtaining hourly output instead of 6-hourly output. Furthermore, plotting the results in local time would also accurately reflect the influence of solar zenith angle which is a key factor in the shortwave forcing. As a result, we have re-done the first set of simulations to obtain hourly output. Unfortunately, the version of the model we used our previous

results did not run on our new super-computer. We had to use a slightly newer version of CAM5. Thus, the numbers have changed slightly. Nevertheless, the revised figure (Fig. 2) can deliver a much cleaner message. However, we would like to clarify that since there does not exist a distinct cloud type for contrails in CAM5, we are not able to track the subsequent development of contrails once they are formed. As a result, the lag effect discussed in Newinger and Burkhardt (2012) and Schumann and Graf (2013) cannot be captured in our model.

2. We have revised the manuscript based on the suggestions of the reviewer.

(B) Minor remarks

1. We have dropped the terms “instantaneous” and “integrated” effects in the abstract.

2. fixed, but adding “long-term average” to the text.

3. the references added to the text.

4. sensitivity due to shape and size of ice crystals mentioned in Section 2.2 and the discussion on uncertainties in Section 3.2 has been expanded to include these factors.

5. revised, the addition cloud fraction is computed as contrail ice mass, from both aircraft water vapor emissions and ambient humidity, divided by the empirical in-cloud ice water content.

6. findings by Schumann and Graf (2013) added to the text.

7. we appreciate the comment by the reviewer.

8. The first set of simulations, as stated in the text, is a diagnostic calculation at each time step, aviation emissions and contrails are assumed to have no impact on the model state. The forcing obtained in these calculations represent an instantaneous forcing. On the other hand, since the “integrated” effect is the difference between two simulations, it is important to ensure the forcing exceeds the internal variability of the model.

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9. Since there does not exist a distinct cloud type for contrails in CAM5, it is not possible for us to obtain a “true” estimate for linear contrail radiative forcing. As aforementioned, when contrails form they immediately become part of the ice clouds in the model. In other words, the model is not capable in distinguishing contrails, linear contrails or contrail cirrus, from natural cirrus. Therefore, we made very strict assumptions in the first set of simulations to yield our best estimate for linear contrail radiative forcing, since all contrails are assumed to vanish at the end of each time step. Strictly speaking, it is truly an “instantaneous” effect.

10. Fig. 2 is indeed for linear contrails and extra description has been added to the figure caption.

11. With the new hourly output and local time representation, using daily or monthly emissions yeild almost identical forcing.

12. One possibility is that the daily variation of air traffic within each month is not very high, and thus the daily or monthly emissions are nearly identical.

13. The suggestion has been added to the text.

14. this part of the manuscript has been removed to the new representation of Fig. 2.

15. Here is our clarification: the energy balance at the top of the atmosphere (RESTOM) is equal to the shortwave fluxes (FSNT) and the longwave fluxes (FLNT) at the top of the atmosphere, i.e. RESTOM = FSNT + FLNT. Cloud forcing is slightly different from radiative fluxes at the top of the atmosphere since it only takes into account the impact of the presence of clouds while holding all other atmospheric states the same, i.e. total cloud forcing (CF) is equal the sum of shortwave cloud forcing (SWCF) and longwave cloud forcing (LWCF). The usage of Δ represents the impact of aviation emissions and additional cloud cover due to contrails over a base state atmosphere, i.e. the control simulation without aircraft emissions has non-zero FSNT, FLNT, SWCF, and LWCF. The aviation impact is defined as the difference from

the base state.

16. text revised, the diurnal cycle for contrail cirrus radiative forcing is similar as shown in Newinger and Burkhardt (2012), i.e. it does not possess a very definite-looking cycle as presented in Fig. 2, so we chose not to show it.

17. references cited in Section 3.2.

18. One major reason for our lower forcing for linear contrails is due to the very restrictive life-time (30 minutes). The definition of young contrails by Burkhardt and Karcher 2011 is contrails formed within 5 hours. Clearly, our estimate is going to fall on the lower end.

19. results from these recent studies are now included

20. Our simulated ice water path and optical depth associated with contrail cirrus is added to the manuscript. Indeed, compared to previous studies, our simulated optical depth is lower which explains the lower radiative forcing that we obtained. This has been added to the end of Section 3.3.

21. This refers to the aviation CO2 forcing, but not for contrails.

22. fixed

23. caption for Fig. 2 revised.

24. fixed

25. extra comment: As aforementioned, RESTOM = FSNT + FLNT. CF = SWCF+LWCF. RESTOM is not equal to the sum of SWCF and LWCF.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/13/C3793/2013/acpd-13-C3793-2013-supplement.pdf

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