Dear Dr. Christopher Hoyle,

We have revised our manuscript according to Dr. Schumann's comments. Specifically, we have modified the abstract to precisely reflect that the 1 cooling effect is due to contrails and aviation aerosols only. We have also followed Dr. Schumann's recommendation to obtain an estimate of the 2050 CO_2 radiative forcing based on Sausen and Schumann (2000). Finally, we have also done further analysis on the factor 7 increase for the global contrail radiative forcing in 2050 from the 2006 level and can confirm that it is not an error. Based on our contrail parameterization, there are two sources for contrail ice mass: 1) aviation water vapor emission, and 2) ambient water vapor uptake. The second part can be easily overlooked and thus we have added a sentence in the manuscript to remind readers its importance in extrapolating future contrail radiative forcing. Dr. Schumann also raised a valid point with regard to the factor 6.1 increase in contrail radiative in East Asia, well below the global increase. This is mainly due to how averaging is done. In our definition of East Asia, the blue box in Fig. 6c, it includes area where very light air traffic takes place. If we only include grid cells with heavy air traffic in this region for the regional average calculation, the projected increase in contrail radiative forcing will be significantly higher. A more detailed explanation regarding this concern is included in the response to Dr. Schumann.

Thank you for your acceptance of our manuscript for publication.

Regards,

Chih-Chieh Chen and Andrew Gettelman

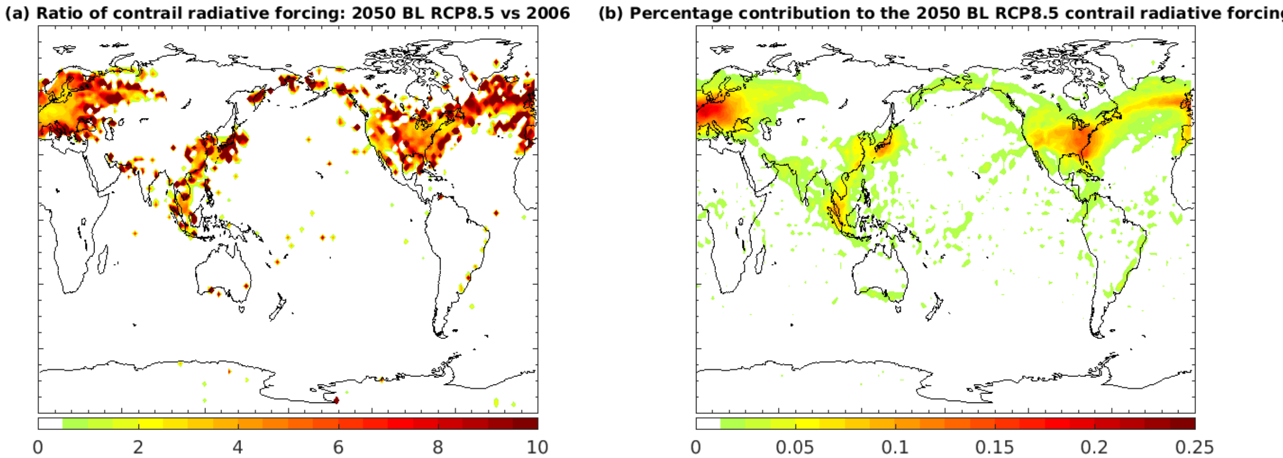
Dear Dr. Schumann,

We appreciate your careful review on our manuscript. We have revised our manuscript according to your suggestion. We believe that this has greatly enhanced the clarity of the manuscript. Here are our response to the points you raised:

1. We have revised the abstract according to your recommendation and added the request caveats.
2. We have revised the text according to your suggestion and cite Gierens et. al (1999) and Marquart et al. (2003) in the section on future aviation emission scenarios.
3. The uncertainty estimates have been added to the text.
4. We have checked our calculations and the factor 7 increase of contrail radiative forcing in 2050 is not an error. Based on our contrail parameterization, there are two sources for contrail ice mass upon the formation of contrails: 1) aviation water vapor emission, and 2) ambient water vapor above ice supersaturation within the initial volume of contrails (which is proportional to flight distance). As stated in lines 340–353 of the manuscript, there is minimal spread in contrail radiative forcing between BL and SC1 even though the fuel consumption is reduced by nearly 50% in SC1. This implies that the uptake of background water vapor is an important portion of the contrail ice mass. Therefore, it is essential to take into account the effects of the increase in fuel consumption and flight distance when attempting to estimate the increase of contrail radiative forcing.

   As stated in lines 332–339, the most pronounced increase in contrail radiative forcing in 2050 is in East Asia which is consistent with the projected fuel consumption and flight distance increases. Under the BL scenario in 2050, the fuel consumption is projected to increase by a factor of 7.5 and the flight distance is projected to increase by a factor of 6.2 in East Asia. The contrail radiative forcing in 2050 under the BL scenario within this region, defined in Fig. 6c, is estimated to increase by a factor of 6.1, below the factor 7 for the global increase. Note that the formation of contrails in this region in 2050 under RCP8.5 is substantially suppressed due to the reduction in the frequency of persistent contrail (Fig. 2f). However, within the blue box in Fig. 6c as our definition for East Asia, it includes areas where very light air traffic takes place. If we only include grid cells with heavy air in this region, the projected increase in contrail radiative forcing could be significantly higher than 6.1.

   To illustrate this, we include a figure which illustrates the percentage increase in contrail radiative forcing in 2050 from the 2006 level (panel (a)), and the percentage contribution to the 2050 contrail radiative forcing (panel (b)) for each grid cell, under the BL scenario and RCP8.5. From panel (b), it is clear that the contrail contrail radiative forcing in Central Europe, E. US, the flight corridor over N. Atlantic, Japan, and Indonesia makes the biggest contribution to the global average. It is also seen, in panel (a), that the increase in contrail radiative forcing in 2050 from the 2006 level can exceed a factor of 10 over the flight corridor in N. Atlantic, Japan, and Indonesia. Thus, the radiative forcing in these regions are responsible for the factor 7 increase of the global contrail radiative forcing in 2050.
5. We have followed the methodology of Sausen and Schumann (2000) to obtain an estimate of 2050 CO_2 radiative forcing. The manuscript has been revised accordingly.



Regards,

Chih-Chieh Chen and Andrew Gettelman