Interactive comment on "Northern Hemisphere Contrail Properties Derived from Terra and Aqua MODIS Data for 2006 and 2012" *by* David P. Duda et al.

Anonymous Referee #2

Received and published: 16 November 2018

We thank reviewer #2 for their review and comments. They have helped to improve our manuscript.

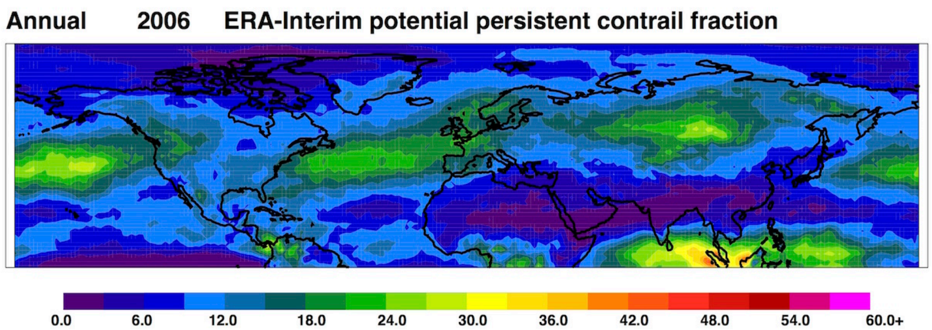
The study involves a very relevant comparison of satellite contrail retrieval outputs by contrasting annual averages from two years in terms of differences in traffic, coverage, optical depth, and particle size. Nevertheless, this comparison is confounded by differences in altitude, meteorology and background characterisation techniques. I would strongly suggest that all comparisons in the study are performed separately for each variable, while keeping all others constant. I believe that this should be easily done with the data already available in the study, as this would greatly expand the applicability of the results to a wider community.

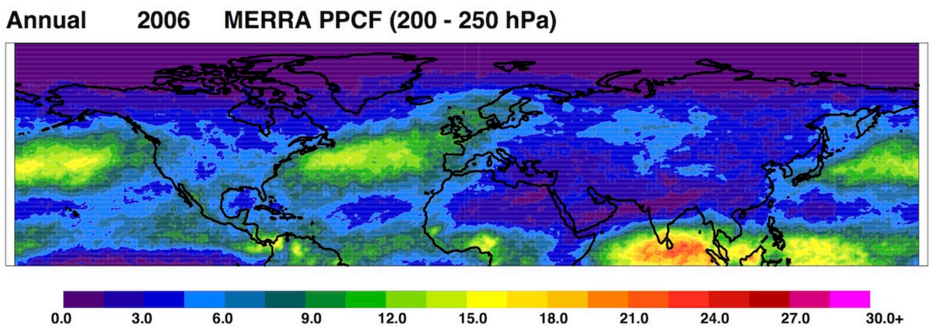
The title of the article should reflect the fact that this is a comparison of two years of contrail retrievals with respect to variables not necessarily linked to "interannual variability", as it is the case for traffic and altitude changes between the two years. I would make the following specific suggestions:

Following the suggestion of anonymous referee #1, we have already revised the title of the paper to "Northern Hemisphere Contrail Properties Derived from Terra and Aqua MODIS Data for 2006 and 2012".

a) Provide an estimate of the uncertainties and differences in the calculated potential contrail coverage between the ECMWF and MERRA data. This will allow modellers to inform their choice of data base and help to quantify the uncertainties linked to the calculated contrail coverage. It would be useful to give these differences in PPCF from the ECMWF and MERRA as maps and latitudinal and global averages. Depending on the temporal pattern of the differences, the results might need to be presented as seasonal or monthly averages.

Currently, any estimate of linear contrail coverage using the PPCF from the two meteorological re-analyses and air traffic would be very uncertain. Although the annually-averaged spatial patterns of PPCF calculated from ERA-Interim and MERRA are generally similar, the absolute values differ by nearly a factor of two. (Notice the difference in the scale in the following annual means.)





It would complicate an already long manuscript to present maps of the monthly or seasonally varying PPCF in the paper. However, we agree that a comparison of the year-to-year variation of seasonal PPCF from both re-analyses with the corresponding changes in contrail coverage would be valuable. To simplify the analysis, we computed the two-year relative change [(2012 – 2006)/2006×100%] in seasonal [DJF, MAM, JJA, SON] screened and unscreened contrail coverage versus the corresponding seasonal two-year absolute (2012 - 2006) change in PPCF computed from both MERRA and ERA-Interim data. The year-to-year changes in coverage were calculated for each season in each of the nine high air traffic regions plus the NH and plotted versus the corresponding changes in PPCF.

The following figures (Y and Z) have been added to the manuscript. Figure Y(a) shows a scatter plot of the relative difference in seasonal unscreened contrail coverage between 2012 and 2006 determined from *Terra* MODIS data for each of the high air traffic regions versus the corresponding 2012 minus 2006 absolute difference in PPCF computed for each season and each air traffic region from the MERRA re-analysis data. Figure Y(b) shows the same scatter plot with the linear regressions for each of the air traffic regions. Note two outlier plots: the red crosses represent the North Atlantic region while the brown triangle regression with the anti-correlation between coverage and PPCF represents the NE Pacific region. In Figures Y(c) and Y(d), the screened coverage and MERRA PPCF are essentially uncorrelated due to the additional outlier relationships between screened coverage and PPCF (red triangles represent Europe/Latin America corridor; green triangles represent HI/CONUS corridor). Figure Z shows similar relationships between the seasonal *Terra* MODIS-derived contrail coverage and

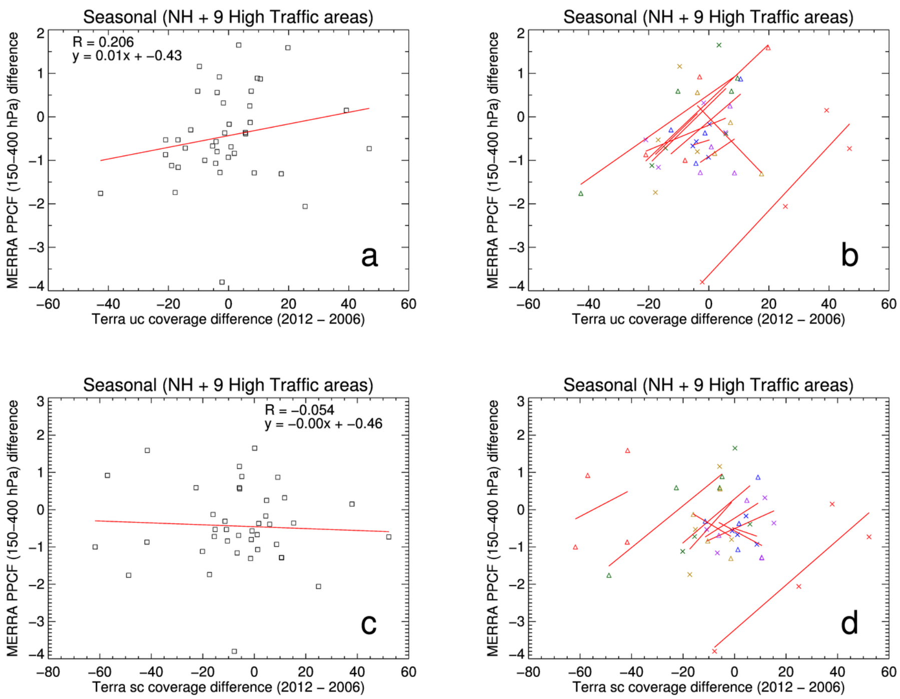


Figure Y: Scatter plots of *Terra* MODIS-derived contrail coverage versus PPCF computed from MERRA re-analyses of the upper troposphere (150 – 400 hPa).

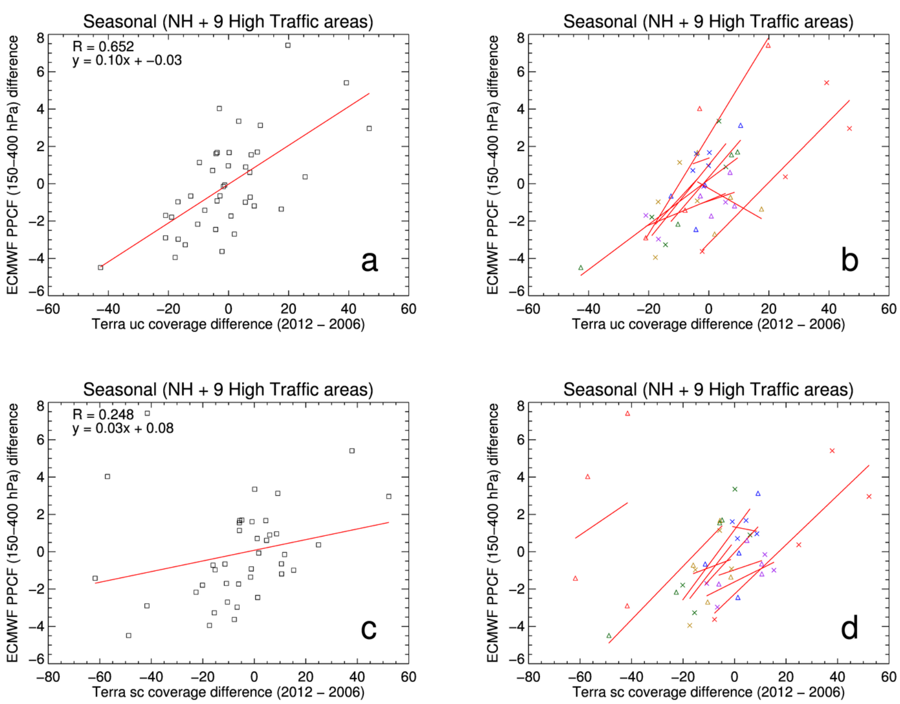


Figure Z: Scatter plots of *Terra* MODIS-derived contrail coverage versus PPCF computed from ECMWF re-analyses of the upper troposphere (150 – 400 hPa).

the ERA-Interim-based PPCF, although the correlations are stronger than for the MERRA data. Overall, the correlations are better for the PPCFs computed from the ERA-Interim re-analyses, and for the unscreened coverage. The differences between the unscreened coverage and the screened coverage scatter plots suggest that the nature of the air traffic data between 2006 and 2012 may have changed for the Europe/Latin America and the HI/CONUS air routes. The North Atlantic air route appears to be an outlier from the other air traffic regions in both the screened and unscreened contrail coverage scatter plots. Because very few unscreened contrails in the North Atlantic region are screened out by the flight track screening, the similarity between the unscreened and screened results would be expected. The shift of the North Atlantic regression to the right of the other regions suggests that contrails might have been more easily detected in the North Atlantic during 2012. The standard deviation of the background 12-µm brightness temperature, which is known to affect the detectability of linear contrails by the CDA, decreased by about 10% in 2012 compared to 2006 in the North Atlantic region, which may account for some of the discrepancy. (In contrast, however, the HI/CONUS region had a decrease in the 12-µm BT variability of 11 – 15% between 2006 and 2012, but the unscreened coverage changes are in more agreement with the other air traffic regions. The other air traffic regions generally had background heterogeneity changes of less than 5% between the two years.) In addition, the magnitude of the discrepancy between the North Atlantic and the other air traffic regions is noticeably larger in the MERRA-based plots. It appears that there is greater uncertainty between the MERRA- and ECMWF- derived PPCF in this region between 2006 and 2012 than in other regions.

b) It would be useful to complement Table 2 with maps of temperature and PPCF, but in this case contrasting the differences between 2006 and 2012. This will make it easier to understand the latitudinal dependence of PPCF on temperature changes and validate them by screened CC retrievals. The maps, again, should probably correspond to representative seasons or months, depending on their variability between the two years.

Please note that the contrail temperatures used in the contrail property retrievals are based on annual means that relate the average contrail altitude/pressure height with temperature. Thus, the inclusion of monthly or seasonal maps of temperature changes is detail beyond what we intended for this study.

c) In order to explain the differences between the two years in terms of the change in altitude, it should be easy with your available data to perform PPCF calculations using the actual altitudes and present them in a map together with traffic differences and their resulting CC. This will provide an observational measure of the relative dependence of CC on altitude. The comparisons will require to first keep traffic volume constant in order to assess the altitude dependence only, and then assess the contribution from traffic volume differences.

I believe that this altitude-dependence assessment will provide extremely useful information to link model outputs and climatological data on how the optical depth and De can be prescribed in terms of ambient temperature, please do not exclude this section from the manuscript.

The determination of how CC relates to altitude/pressure is not clear from the data. When we plotted the two-year differences in contrail coverage (both screened and unscreened) for each season and each air traffic region with the corresponding two-year change in PPCF *at each pressure level*, none of the plots showed a strong correlation between CC and (one pressure level) PPCF. A stronger correlation was only evident when we used the two-year change in PPCF computed throughout the upper troposphere (150 – 400 hPa). This result at least shows that the relation between satellite-observed CC and re-analysis-derived PPCF with altitude is complicated and the topic of another study.

d) It is not clear to me how contrail radiative forcing was calculated, this should be appropriately described in the manuscript.

Text has been added to section 2.3 to describe the calculation of the contrail radiative forcing.

e) The suggested analyses should provide a way to discriminate the sources of the differences in retrieved CC between the two years. For these analyses the background characterisation must therefore be somehow be kept constant so it does not affect the conclusions.

I believe that with these additions the paper will make a much more significant contribution to the way in which we understand contrail retrievals from satellites and guide the use of retrieved atmospheric and contrail data in contrail models.

It is not clear what the reviewer is requesting here in terms of "background characterization". We agree that the reviewer's suggestions are helpful in minimizing the unavoidable effects that result from having to use some different data sets in the two years of analysis.

Pg 2 ln 28, delete "and"

The extra "and" has been deleted.