

Comments on “Investigating the limiting aircraft design-dependent and environmental factors of persistent contrail formation” by Liam Megill and Volker Grewe (<https://doi.org/10.5194/egusphere-2024-3398>)

The manuscript investigates the influence of potential future aircraft-engine designs on the formation of condensation trails (contrails). The authors identify three main constraints on contrail formation: persistence (supersaturation), droplet formation, and droplet freezing. These factors are then set into context to aircraft-dependent designs determined by the type of propulsion system and fuel used. As the authors point out, alternative fuels such as hydrogen can cause more persistent contrails, while other technologies such as water enhanced turbofan engines can reduce persistent contrail formation compared to conventional kerosene jet engines.

The three limiting factors for persistent contrail formation and their combinations are identified on a global scale, but also weighted with future scenarios of air traffic in 2050, thus projecting into the future and showcasing contrail formation using future jet engines.

The statistical analysis is based on 10 years of three-dimensional ERA5 data, primarily using temperature and relative humidity fields. The ERA5 data are used to determine the location and frequency of occurrence of ice supersaturated regions (ISSR) and how often one or more of the above limiting factors restrict contrail formation. Limitations of the ERA5 data itself – underestimation of ISSR – are discussed and partially corrected for by the use of scaling factors. The result section further elaborates about the “spatial variability of persistent contrail formation” and “climatological potential persistent contrail formation”.

The authors cite latest and relevant literature in the motivation / introduction. The presented results are also compared and set into context with current literature.

The manuscript is generally very well written and structured, with clear and readable figures. The manuscript fits into the scope of ACP and I recommend this manuscript for publication after the authors have satisfactorily addressed the major and minor comments listed below.

Major comments:

- (1) The authors investigate and discuss the formation potential of persistent contrails in time and space using alternative engine types and fuels instead of today's kerosene jet engines. As shown in this manuscript and in previous studies, the use of hydrogen is expected to increase the number of persistent contrails. However, contrails exert a radiative forcing on short time scales of minutes to days, if they form at all. In contrast, fossil fuels and the release of carbon dioxide causes a radiative forcing on time scales of several decades and longer. The summary gives the impression that hydrogen powered aircraft have a generally negative impact on the climate. While it may be beyond the scope of the manuscript to calculate the actual radiative forcing, the authors should mention in the summary that “green” hydrogen, which is not sourced from fossil fuels, would cause more persistent contrails, but without the negative effect of CO₂ emissions, and is therefore likely to be more environmentally friendly compared to conventional jet engines.
- (2) One comment concerns the use of the supplementary material. In the manuscript the authors often refer to figures in the supplement. The authors might consider including the frequently and therefore seemingly relevant figures in the appendix or in the main text. Often

referenced figures are Figures 4, 5, and 6 from the supplement. These figures could be exchanged with Table 2, which provides detailed numbers but is not necessarily needed directly in the main text and could be shifted in the appendix or the supplement. Table 2 is partly redundant as the important numbers are also given and discussed in the main text.

- (3) Regardless of comment 2 and where the figures are eventually located, ambiguity in the referenced figures could be avoided. For example, the authors refer to Figure 6 in the text and to Figure 6 in the supplement in one sentence. It would be clearer if the authors use: Figure 6 for figures in the main text, Figure A6 for figures in the appendix, and S6 for figures in the supplement.

Minor comments:

L16: Please explain CO₂ at first appearance.

L21: Why use of capital letters for “Effective Radiative Forcing”? Is the abbreviation / acronym missing?

L60: Please explain “H/C ratio”.

L69: Please add a space between the unit and “(kerosene)” as well as “(hydrogen)”.

L103: Could you introduce the abbreviation “CON” earlier, at the first occurrence?

L106: Please check for consistent use of the serial/oxford comma. It was not used before and after, but here in this line.

L113: Abbreviations and symbols should be avoided at the beginning of a sentence.

L122: Do you mean “...we define $\text{mean}\{c_p\}$ to be..”?

L123 and 124: Please check for grammar. Abbreviations and symbols at the beginning of a sentence should be avoided. This also applies to later occurrences in the text.

L138: Why is homogeneous freezing required? If ice nucleating particles are present, contrails could also form at temperatures above 235K? For example, in the triangle formed by the 235 K line, the G-line, and the water vapor saturation curve? The Schmidt-Appleman criterion requires homogeneous freezing, but in reality this would mean that contrails can form at higher ambient temperatures?

L144: Please explain “nvPM”.

Table 1: Please explain (E) and (K) in row 3, column 7.

L161-162: Please explain 0.5 and 1.0 V, even though it can be guessed from the next sentence.

L168: “altitudes higher than 217 hPa” could be confusing. Suggest to re-write, e.g.: At pressure levels lesser than 217 hPa. This also applies to later occurrences in the text.

L187: Could you specify where you selected 2160 hours from. It implies that DEPA 2050 is an inventory of simulated flight tracks. The DEPA 2050 data could also be some kind of a weighting function. You might briefly mention the type of info of DEPA2050 data in section 2.3.

L208: You are interested in regions with supersaturation where $RH_i > 1$, correct? Why are you focusing on $RH_i < 1$?

L305 to 307: The sentence “Since the horizontal...”. What is meant with the word “aligned”? Spatially or statistically? A short explanation would be helpful.

Figure 4 y-axis label: “limfact”. Even though the meaning could be guessed it would be good to write the full word in the label or to use an abbreviation that is explained in the figure caption.

L351: Please explain what is meant by “...*conservatively* regrid...”

L368: “north” instead of “above”?

L369: “south” instead of “below”?

L375: “aim” instead of “wish”?

L376: *G* already introduced