

Comments on “Predicting Aviation Contrail Occurrence Using Bayesian Population Statistics From Reanalysis Data” by Daniel A. Williams, Cyril J. Morcrette, and James M. Haywood
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This study aims to develop a statistical tool that can predict the likelihood of contrail formation based on the relative humidity present at certain flight levels. This tool is intended as an alternative to highly parameterised methods and machine learning techniques. The method uses human-flagged contrail observations from satellite data, which are combined in the OpenContrails dataset. A Bayesian approach is used to statistically relate contrail occurrence and meteorological conditions.

The manuscript briefly describes the data sets and methods used, before deriving the statistical relations. The model is then tested on the validation dataset using binary classification metrics (confusion matrix), and subsequently the results are presented.

I have tried to avoid repeating comments that have already been mentioned by previous reviewers. However, I do have several comments, both major and minor, which are listed below. Once the authors have adequately addressed these, the manuscript may be considered for publication in ACP.

Major comments:

- The statistical method has been trained on data from the US region only. This is very limited in terms of latitude. While I agree that there is a lot of air traffic across the contiguous United States, there is also traffic above and below the US, as well as across the Atlantic. As I understood it, the dataset also contains contrails from other regions. Why did you not use them? Could you elaborate?

The point I want to make is: Is there a chance of latitudinal and longitudinal dependence in contrail formation, particularly with regard to pressure level? Or are there seasonal variations induced by factors such as solar zenith angle and sunshine duration, and their effect on global circulations? Did the authors perform tests in this regard?

Can the authors comment on the applicability of the model? Can it be applied to ERA5 data outside the latitudinal and longitudinal region used for training?

- On page 15, in the conclusion section and on line 306, the authors mention that it has been demonstrated that the method is resilient to biases. I apologise if I have missed that, but I cannot find a proper discussion of that.
Further, the possibility of bias in ERA5 relative humidity (RH) is also not discussed. Various studies have indicated that RH is biased in ERA5, though the direction of the bias depends on the study. This should be discussed more, or at least made clearer.
Furthermore, the authors trained and tested the method with ERA5 data, which is fine. However, it should be noted that applying the trained model across different numerical weather prediction (NWP) models may not work because the biases in the model output used for training are inherent in the trained prediction model. Therefore, the trained model could not simply be applied to ECMWF or ICON model output. While this may be clear to the authors, it should be mentioned. Retraining is therefore required for each NWP.
- In many cases, only the term 'relative humidity' is used. It is necessary to be more specific, indicating whether this is relative humidity with respect to ice or liquid water. Please make the necessary adjustments throughout the text. Also, be aware that the definition of RH in ERA5 depends on the temperature (ice or liquid water).

- L67-68: It is worth mentioning the difficulties involved in simulating RH and ice supersaturation in models.
- Isn't the model biased towards current flight altitudes? Since aircraft typically fly along specific airways, the method is biased towards this altitude region, as no information about potential contrail formation is gained from levels above or below the typical flight paths. Therefore, the method would be less suited to vertical flight re-routing. Could the authors comment on this, please?

Minor comments:

L32: "At present, the majority of aviation ERF comes from non-CO₂ effects; the contribution from which will only increase as the sector decarbonises and places an increasing reliance upon SAFs ". This will depend on the time scales. Please specify whether you mean instantaneous or integrated over a longer period.

L43: "...exceeds the local saturation vapour pressure" Please specify whether this is with respect to liquid water or ice.

L111: What is a "real" flight path?

L114-116: How did the authors select the training and validation datasets? Was the validation set chosen at random by the authors or already provided in the data set?

L115: When counting multiple contrails within one image (and its associated meteorological condition), is only one contrail considered, or are they all considered? This could introduce bias into the statistics. While the presence of many contrails in an image can indicate favourable conditions for contrail formation, the image may also simply depict a region with high air traffic. You mention this in the text, but could the authors elaborate further?

L128: Related to the previous comment, "(each mask contains a single contrail)". Does this mean there is a maximum of one contrail, or a minimum of one contrail?

L130: Is it useful to provide the full name of DBSCAN, even though it maybe generally known?

L137-138: Please check the grammar of this sentence.

L150--152: How have the stochastic samples been sampled? Along the same flight track, but at different times of day, on different days, in different months and/or years? Please specify.

L155: 'By drawing biased and...' I wouldn't say the statistic is biased with respect to contrails. This creates the impression that contrails cause higher humidity/supersaturation, but it is actually the other way around. In other places, too, it reads as though contrails are the cause and not the effect. For example, see L225-235: 'contrail-biased' or L242: '...by the contribution from contrails...' and L244: instead of 'oversampling', 'higher humidity is more likely'. This is just a suggestion.

L245–246: 'Stochastically sampled' instead of 'climatology'? This would be more consistent with your methodology section.

L255: Mention that -40°C is the threshold for homogeneous freezing.

L261: "When the flat prior is used,...."

L261: Write "..., nearly all combinations of pressure and humidity...."? This is just a suggestion.

L271: "As noted earlier in Section 2.1..." I cannot find a statement in this regard in Section 2.1, so please check.

L320: "Whilst efforts have been made to consider various sources ..." Could the authors please explicitly mention the sources to be more precise?

L324: Maybe I missed it, but I don't think the larger bounding box was defined. But please correct me if I'm wrong.

L329-330: "These scenarios could lead to the oversampling of dry conditions in the lower atmosphere in the contrail-sampled extractions, however this should be a less important when considering the upper atmosphere where aircraft typically cruise"

What about the influence of deep convection?

L330: " Opportunities will arise in **the** future to..." Missing "the"?

L334-end: This reads a little like an introduction. You could skip it or put it at the beginning of the conclusion.

Figure 3: Subfigure titles: Please be consistent and decide whether to use RH or relative humidity.