Reply to Reviewer #1
(Referee comment on "Distribution and morphology of non-persistent and persistent contrail formation areas in ERA5" by K. Wolf et al. (egusphere-2023-3086), https://doi.org/10.5194/egusphere-2023-3086-RC1, 2024)

We thank the Reviewer for the time she/he spent on the manuscript, and for the useful comments. Addressing the comments has improved the manuscript.

For better legibility, the Reviewer's comments are highlighted in **bold** and changes in the manuscript are in *italics*.

This is a most impressive, comprehensive article, characterizing the potential persistent contrail (PC) formation conditions as a function of time of year, temperature, relative humidity, pressure, and wind speed. The region considered is from the North Atlantic flight corridor from the East coast of North America to central Europe and between 30◦N and 70◦N, using data from 2015 to 2021. The modified Schmidt-Appleman criteria are used to identify the PC regions, using a combination of In-service Aircraft for a Global Observing System (IAGOS) data and ERA5 re-analysis products. Most interestingly, the dimensions of individual PC formation regions was determined by applying the python image processing tool scikit-image Python. Some takeaways that I got from the article. Most commercial aircraft are currently flying at altitudes that are most prone to PC formation, thus, shifting to probably lower altitudes would decrease PC formation, but this is not practical. Also, that the position of highest wind speed might be used as a proxy for potential PC occurrence. It's interesting, using the angle between the elongated PC regions and latitude that lateral flight diversion would reduce the time spent inside the PC zone with limited additional fuel consumption.
Some quality controls were used in the analysis. A 2023 study noted by Wolf et al. evaluated the IAGOS observations, with directly measured temperature and relative humidity with a Vaisala sensor from commercial aircraft, to evaluate ERA5 performance. They found a dry bias and applied a correction to those data. My comments appear below. I recommend publication of the article subject to minor revision.

We thank the Reviewer for the positive appreciation of our manuscript.

Main Comments
The Vaisala Humicap sensor is used for the relative humidity measurements for IAGOS. I assume the sensor is similar to a Vaisala RS80H (Humicap) sensor. A study by Verver et al. (2006) found a significant wet bias in RH from +2% to +5% in the RS80H profiles in the upper troposphere when compared with a very advanced humidity sensor. Please comment on this as it may have effected the dry bias found in the ERA5 data. Verver, G., M. Fujiwara, P. Dolmans, C. Becker, P. Fortuin, and L. Miloshevich, 2006: Performance of the Vaisala RS80A/H and RS90 Humicap Sensors and the Meteolabor "Snow White" Chilled-Mirror Hygrometer in Paramaribo, Suriname. J. Atmos. Oceanic Technol., 23, 1506–1518

Verver et al. (2006) investigated the performance of several Vaisala radiosondes, among others, of types RS80A, RS80H, and RS90H. Those were compared with a chilled-mirror hygrometer. RS80H and RS90H are both equipped with a Vaisvala Humicap-H sensor that

the Reviewer is referring to.
Verver et al. (2006) did not make any specific remarks about biases above 7 km altitude, which makes it difficult to compare with IAGOS measurements. Verver et al. (2006) only stated a good correlation between the radiosonde observations and the chilled-mirror hygrometer. Radiosonde measurements further require corrections to consider for, among other factors, for sensor time lag / response time and potential insolation (e.g., Miloshevich et al. (2004) and Heymsfield et al. (1998)). These can cause potential biases. In addition, transferring the measurement performance of radiosonde equipment to aircraft measurements is difficult as they operate under different technical constraints and operational conditions. The corrections for aircraft measurements of relative humidity are different as thermodynamic effects, due to the high wind velocity around the sensor inlet, have to be considered (e.g., Neis et al. (2015) and Petzold et al. (2017)).
However, we acknowledge that IAGOS might be subject to a humidity bias of some kind. In this regard we refer to the comparison study by Petzold et al. (2020), who showed good statistical agreement between IAGOS measurements and dedicated humidity measurements.

Line 143. How are the time-averages calculated? Is it from the current point to 19.4 seconds ahead of the aircraft?

To be clearer this section has been extended and rephrased to the following:

"The IAGOS measurements are averaged by applying a Gaussian filter. The standard deviation σ of the Gaussian filter is approximated with:
$\sigma = (k - 1) / 6,$
where k is the window length of the smoothing filter. To average over 19 km, we set σ = 3, based on an assumed average cruise speed of around 240 m s^{-1} *and a resulting segment length (distance between two measurements) of around 1 km."*

Do NPC satisfy the SAc criteria but not rh>rhi? I assume that's the case but I suggest stating it.

We followed the suggestion of the Reviewer and made the paragraph clearer.

"Within this study we use the revised version of the SAc following Schumann (1996) and Rap et al. (2010). General details on the SAc and equations required to calculate T_{crit} *and* r_{crit} *can be found in Rap et al. (2010) or Wolf et al. (2023a). Within the present study the same definitions and nomenclature as in Wolf et al. (2023a) are used, and data points are categorized for non-persistent contrails (NPC), persistent contrails (PC), and reservoir (R) conditions. Data points that are flagged for NPC fulfill the SAc, but the ambient air is sub-saturated with respect to ice (100 % < rice). Samples that are flagged for PC fulfill the SAc and are saturated with respect to ice (*r_{ice} *> 100 %). Data points that are flagged for reservoir conditions fulfill the criteria for ice-supersaturation but fail the SAc. Discussion on the Reservoir category can be found in Wolf et al. (2023a). All data points that are not assigned to one of the groups are labeled as non-contrail (NoC)."*

A schematic showing the different path lengths for IAGOS and EROS would be helpful, and showing the distances for time-averaged values.
We appreciate the Reviewer's comment and we would like to make the paper more readable. However, it is not clear to us what the Reviewer wants to be displayed, i.e., what she / he means with different path lengths / segment length. The paths length is a distance

and the distribution of crossing length for NPC, PC, and reservoir conditions are presented in a Fig.1.

Figure 6. This is a most interesting and important figure. Years ago, there was a program called GHOST (Global HOrizontal Sounding Technique), which used constant pressure balloons to measure ambient temperature and relative humidity. Also, more recently, the CNES new super pressure balloon system deployed for Strateole-2 program. Would such systems potentially aid in evaluating the ERA5 data in the future?

Yes, additional in-situ measurements by balloons would be beneficial, particularly when the observations cover a longer time period like it seems to be the case for the Strateole-2 program. In-situ observations in the upper troposphere and lower stratosphere are sparse. Available measurements typically stem from dedicated measurement campaigns that target specific regions or atmospheric features for a limited period of time. Remote sensing observations, e.g., from satellite or ground, rely on assumptions for their retrieval products that introduce uncertainties. However, the sampling by individual balloons might be too limited to provide a strong constraint on numerical weather forecasting systems.

Minor Comments

138. "fixed grid resolution" is repeated in this line
The doubled part of the sentence has been removed.

167. allows us
“us” has been added to the sentence.

249: could you define "all grid boxes"

To be more specific, the sentence has been rephrased to the following:

“P is calculated for each p-level as the ratio of PC flagged grid-boxes in relation to the total number of grid boxes in the investigated domain and is then averaged over time steps and months.”

250. for pressure

The Reviewer is right and the word was exchanged:

“For p-levels below 225 hPa the distributions are dispersed suggesting a larger seasonal variability. ”

362. Further more>Furthermore
The typo has been corrected.

Heymsfield, A. J. / Miloshevich, L. M. / Twohy, C. / Sachse, G. / Oltmans, S., Upper-tropospheric relative humidity observations and implications for cirrus ice nucleation, 1998, Geophys. Res. Let. , Vol. 25, No. 9, p. 1343-1346

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