Response to Reviewer #2

We thank Reviewer #2 for the positive assessment of our manuscript. The comments provided valuable clarifications and have helped improve both the content and presentation of the article. All comments have been carefully addressed. Below, we reproduce the comments from Reviewer 2 in *italics*.

In this study, the authors build up a hybrid machine learning model to correct bias of relative humidity over ice in ERA5 in the UTLS over North Atlantic. The model consists of a XGBoost regressor in dry conditions and an ANN in more humid regions, with the threshold of 85% RHi. In the test data, the model can reduce the dry bias of ERA5, and increase the number of correctly predicted ISSRs.

The paper is well written, with a clear presentation of technical details. The figures and tables effectively illustrate the comparisons.

I have a few additional comments that should be clarified as part of a minor revision before the study is published.

We are grateful to Reviewer #2 for the careful reading and comments. We address the additional comments below.

In Sect 2.3 or Fig 2, the ERA5 variables are linearly interpolated to match the mean altitude of the IAGOS data points. This is a reasonable approach to reduce discrepancies between model level and pressure level input data. However, I am thinking if log-pressure linear interpolation—as used in tools like pycontrails—might be more appropriate, since it better represents the vertical structure of the atmosphere.

Reviewer #2 is raising a good point about the linear interpolation of ERA5 variables to match the altitude of the IAGOS data points, as did Reviewer #1. We indeed performed a linear interpolation using pressure as a coordinate for T and q to map the ERA5 pressure levels to the aircraft altitude. We experimented with polynomial interpolation but the resulting datapoints did not match the IAGOS observations as closely as the linear approach. We did not try a log-pressure linear interpolation as done in pycontrail python module. This may indeed be a better vertical interpolation. We add the following sentence at line 116:
"Future work should test log-pressure linear interpolation to reflect the atmosphere's vertical structure."

In Table A1, in addition to XGBoost, LightGBM also performs well in predicting RHi, particularly in terms of MAE and ETS. It would be helpful to include a sentence or two explaining the choice of XGBoost over LightGBM, or whether the results could be generalized to gradient boosting decision trees as a class of models.

The performance of several machine-learning models is reported in Table A1. XGBoost and LightGBM indeed achieve a similar MAE. However, we selected XGBoost as it offered better classification performance. While LightGBM achieved a slightly lower Test MAE (11.55% vs. 11.56%), XGBoost outperformed LightGBM in the ETS (0.35 vs. 0.32). The two models use Gradient Boosting Decision

Trees, explaining the very similar results. Since our dataset size is limited, the computational speed offered by LightGBM was not a limiting factor, allowing us to prioritize the model giving the best balance over all evaluation metrics (MAE, R^2 and ETS). We acknowledge that LightGBM can be considered in the Hybrid Architecture especially when using a significantly larger dataset (millions of samples), or when dealing with very limited computational resources.

Other comments:

The definition of contrail formation and persistence could be clarified. Contrails form when hot and humid jet engine exhaust mixes with the cold ambient atmosphere, resulting in local liquid saturation within the plume. Contrails persist when the surrounding air is ISSRs, allowing the ice crystals to grow and spread into contrail-induced cirrus. This clarification relates to the first sentence of the abstract and Lines 35–36.

We have modified the sentence at line 35-36 to address the Reviewer's remark on contrail formation and persistence as follows:

> "The largest contributor to non-CO2 effective radiative forcing (ERF) is the radiative forcing from condensation trails---contrails---which are linear ice clouds formed behind aircrafts as hot exhaust gases mix with cold ambient air. The physical processes governing contrail formation are well understood (Schmidt, 1941; Appleman, 1953; Schumann, 1996)."

We think that the first sentence of the abstract is not misleading as we are speaking about persistent contrail cirrus, and not just contrails.

The description of Fig 4a as the baseline ERA5 reanalysis could be introduced earlier

We add the following sentence at line 120:

"A comparison between observed RHi from IAGOS and RHi predictions from ERA5 reanalysis is shown in Fig. 4a."

Lines 26: full name of MOZAIC

We now give the full name of the acronym MOZAIC.

Line 70: the measurements of RHi are not direct; they are calculated from temperature and water vapor measurements

Indeed, RHi is estimated from the temperature and the relative humidity by IAGOS. We have modified the manuscript as follows:

> "Combining these datasets enables a supervised learning approach where the ERA5 features serve as model inputs, while the estimation of RHi from IAGOS from temperature and relative humidity measurements serve as the target variable."

Sincerely,

Jérémie Juvin-Quarroz, on the behalf of the authors