Responses to Referee#1 Darrel Baumgardner

We thank all reviewers for their helpful advices and constructive comments about our paper. Their suggestions and criticism have led to a strongly revised and restructured version of our manuscript where we concentrated on two goals: (1) we develop a new method to identify microphysical properties of contrails, contrail cirrus and natural cirrus in the same meteorological conditions from in situ measurements, (2) radiative forcing of contrail cirrus and natural cirrus are derived by satellite observations based radiative transfer modeling in air traffic region favorable for contrails evolution. To this end, we have modified pictures and removed some of them, made the text more concise, added a supplement and wrote clearer explanations.

We thank Darrel Baumgardner for his helpful advices regarding our manuscript acp-2022-537: ***Observations of microphysical properties and radiative effects of contrail cirrus and natural cirrus over the North Atlantic***.

In the following we number the referee comments (RC) and give replies (R) to each of them.

RC1: This research study, while a worthy topic for investigation, fall far short of its intended goal, i.e. to improve our understanding of the radiative forcing by contrails, contrail cirrus and cirrus by using satellite measurements validated by in situ observations.

R1: We thank the reviewer for this comment. We reshaped the focus of our study and now more clearly formulate and address our goals: Based on airborne in-situ and lidar measurements on HALO together with satellite data we identified an ideal contrail cirrus outbreak event in the North Atlantic Region (NAR). With this method we investigated the effective radii that are characteristic of contrails, contrail cirrus and natural cirrus under the given meteorological conditions. We then developed a new method using satellite data and radiative transfer modelling to derive the temporal evolution of the radiative forcing of the contrail cirrus outbreak event and find warming contrail cirrus in the early morning hours and cooling contrail cirrus during the day. We hope that this approach improved the red line of the manuscript. We also changed the title in order to avoid the impression of a systematic study to: ***Observations of microphysical properties and radiative effects of a contrail cirrus outbreak over the North Atlantic***

RC2: Although the authors have devoted a fair amount of effort to analyze the satellite observations to identify contrails and contrail cirrus, they conclude in the end that it is impossible, so instead they take three passes from in situ measurements and three passes from airborne lidar to conclude, and this is my paraphrasing, "We can't identify contrails or contrail cirrus from the satellite measurements in the region where the aircraft measurements were made, but since we think we might have identified contrails and contrail cirrus with the airborne measurements, we will generalize and assume that there must also be such clouds observed by the satellites". This is not convincing.

R2: We didn't state that it is impossible to identify contrails and contrail cirrus in the satellite data and the investigation based on the in situ measurements was not meant to be an alternative to that. Although contrails are visible both in the RGBs and in part in the brightness temperature difference (BTD) plots, it is well known that automated contrail identification in satellite data is a difficult task and only the linear shape of contrails combined with the presence of small ice crystals that induce large BTDs can be used for that task. However, the reviewer's comments show that our arguments were not clear, so we restructured the paper to make its red line much more evident and convey clear conclusions. We agree with the reviewer and removed the discussion on the intercomparison of satellite and in-situ data. Instead we now use the different instruments and methods to identify the dedicated contrail cirrus outbreak event unambiguously from all available data sources. We also follow the suggestion and produced satellite images with the high spatial resolution, and we clearly find contrail cirrus from satellite, in the same area as the in-situ and lidar observations during the flights as shown in the new figure 2. We derived a new radiative forcing estimate using satellite data and microphysical information from the collocated in situ cirrus measurements in the radiative transfer calculations. We then used this information to derive the RF of the contrail cirrus outbreak as a whole and we investigated the evolution of the contrail cirrus outbreak over a time span of 8 hours from satellite data. This method allows to investigate night and day effects of contrail cirrus, not covered by the airborne data.

RC3: I am unconvinced by the arguments that are made by the authors. Whereas case studies are an acceptable means for studying cloud microphysical processes when the data sets are limited and hard to obtain, this study does not fall in that category. There must be thousands of measurements by the DLR Falcon and Halo in contrails and contrail cirrus that could be used and yet the authors have chosen one day with only three passes, with no justification for why this day was chosen.

R3: We now give the motivation for the choice of this case study: the cold and humid meteorological situation and the air traffic over the North Atlantic, a region with a relevant impact of air traffic on clouds and radiation (Graf and Schumann, 2012, Duda et al. 2013, Spangenberg et al. 2013, Vázquez-Navarro et al., 2015, Teoh et al. 2022a, b), lead to a contrail cirrus outbreak in a thin cirrus over the open ocean. This day was the “golden day” for contrail cirrus measurements during the ML-CIRRUS campaign. It was predicted three days in advance by the weather and contrail models (see Fig. 4 in Voigt et al., BAMS, 2017), and therefore invited for a case study.

From in situ measurements, the opportunity to identify microphysical properties of contrails, contrail cirrus and natural cirrus in similar meteorological conditions in the Norther Atlantic flight Corridor (NAF) with ordered flight tracks is ideal. Also, with respect to flight operations this flight was unique, in later campaigns regulatory restrictions prevented research flights in the NAF and we were not allowed any more to fly within the NAF perpendicular to the flight tracks of passenger traffic in order to perform in-situ contrail cirrus measurements.

From satellite remote sensing, the condition with contrail cirrus over an open ocean with only a few low-level water clouds and the relative homogeneity of the oceanic background in the solar range and thermal IR increases the ability to retrieve the impact of cirrus on TOA radiation, therefore we selected this day. The computation of contrail cirrus and natural cirrus radiative forcing (Duda et al., 2019) using radiative transfer model calculations in air traffic in high relative humidity regions is a powerful tool (Minnis et al., 2004).

RC4: In addition, the lengthy descriptions of the data are overly detailed with unnecessary discussions of irrelevant features. Every sentence has to be written with information that coveys succinctly the point the authors wish the reader to see and understand. There are too much speculations, i.e. "might be", "could be", possibly", with little concrete data that the reader can use to understand what the authors are trying to convey.

R4: We thank the referee for this comment, we removed speculations from the manuscript, we shortened the manuscript significantly in order to focus on information which is most relevant for the manuscript. We think that we now more clearly address and convey the messages given by our study.

RC5: There are many other aspects of this manuscript that fall short of my expectations, but rather than address them in this review, I will wait for what I hope is a more comprehensive (and convincing) study that has more in situ measurements in co-located satellite measurements. I will also expect to see a detailed discussion of how the in situ measurements were processed, including an engineering error propagation that includes the expected uncertainties in derived quantities, time offsets in the cloud, NO and RH measurements. quantification of the polarization ratio (not perpendicular to forward but perpendicular to sum of perpendicular and parallel), etc.

R5: Our study combines in-situ and remote sensing data to identify a contrail cirrus outbreak situation in the NAF. We then use a new method to derive the RF of contrail cirrus and cirrus based on data from in situ and lidar observations from aircraft and satellite remote sensing used in radiative transfer simulations. We selected this case study on purpose in order to test the proposed methodology. Contrail cirrus in the NAF have been investigated in previous studies (Graf and Schumann., 2012; Duda et al., 2013; Spangenberg et al. 2013, Vázquez-Navarro et al., 2015; Teoh et al. 2022a, b), showing that the NAF is an area of interest and with high variability in contrail cirrus cover and radiative impact.

After testing the methodology in the case study, we will apply it to a more climatological oriented study with a larger dataset to investigate the radiative effects of cirrus and contrail cirrus using RTM simulations involving cloud top height CTH and ice optical thickness IOT from satellite, effect radii R_{eff} from in situ values, and cloud bottom height CBH and cloud thickness from lidar.

In the revised manuscript we give more information on instruments, data evaluation and uncertainties from in-situ and lidar measurements as well as from satellite observations. We give this information in a depth which is required for the manuscript and in a similar detail for all instruments used in this study. We refer to previous publications in the references for deeper insight in instrument issues. In addition, we had to remove results of the polarization ratio from in-situ cloud probes. Here, the reviewer is right, the method and the evaluation of polarization data from the cloud probes needs an in-depth discussion in an independent paper, which is out of the scope of this multi-instrument study.

We have addressed all important points raised by the reviewer in the revised version of the manuscript.

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