

Reply to the reviewers comments on the manuscript “The subtleties of three-dimensional radiative effects in contrails and cirrus clouds” by Carles et al.

The authors would like to thank the reviewers for reading the manuscript and for their insightful comments that helped improve it. The following document provides answers to the comments in blue.

The line numbers given in this document correspond to the latest submitted version. All changes brought to the new manuscript version are noted in the track changes file provided.

Response to reviewer #2, comment RC2 :

General comments

The study by Carles et al. is a sensitivity analysis of optically thin ice clouds radiative effects (CRE) to their geometrical dimensions and optical thickness investigating also the importance of the 3D effects on these estimations. By using Monte Carlo radiative transfer simulations for both 1D and 3D configurations, the authors derived useful insights for CREs (SW, LW and net) in terms of clouds geometry, their optical thickness and the relative position of the sun, highlighting when the 3D effects are important. To put into perspective their results in terms of the importance of including the 3D effects in estimating cirrus and contrails radiative effects and forcing, CRE estimates integrated for selected days at different latitudes were also calculated and discussed. The objectives of the study are quite straightforward and are addressed by thorough analysis. I consider the topic and results of this manuscript to fit the scope of ACP.

I have some general and minor comments which should be addressed prior to publication.

- It would increase the value of manuscript to elaborate in the introduction which was the gaps identified in previous studies which motivated the objectives of the current study.

We thank the reviewer for this comment. We reformulated and added framing in the introduction, l. 28 to 36, (l. 31 to 39 in the track changes file): “The three-dimensional effects of radiation are not taken into account in contrail studies based on climate modelling (Bickel et al., 2020) or simplified process-models (Teoh et al., 2020, 2024). However, they have previously been demonstrated to be non negligible in the radiative effect of contrails and cirrus (Gounou and Hogan, 2007; Forster et al., 2012). These few pioneering studies are not yet sufficient to quantify 3D effects on a global scale, e.g. to know in which situations they are most significant, whether they always have the same sign, or whether they could be at least partially compensated when considering temporal (diurnal, seasonal cycle) or spatial averages (along a flight trajectory). Thus, the objective of our study is twofold : firstly, to quantify the 3D effects of radiation in contrails and identify the behavior specific to a range of low optical depths representative of these clouds and secondly to explore the importance of the 3D effects when integrated on idealised larger time or space scales”.

- There is an extensive part dedicated to CRE 1D results and to simple analytical models of CRE in relation to cloud optical depth. Apart from explaining the results in a more intuitive way, please provide the added values of this analysis.

Following this comment and a similar comment from reviewer #1, we have re-organized section 3.1.1 on 1D CRE and moved some text to Appendix C1. This has allowed us to shorten this section and put more emphasis on the 3D sections. Always with the aim of shortening 1D sections, we have removed a paragraph in section 3.1.3 on 1D net CRE (l. 220 to 226 in the track changes file). See also the conclusion, l. 401 to 404 (l. 428 to 431 in the track changes file).

- There is a very short discussion in Lines 428-431 comparing the results of the present study with previous studies. I suggest placing at the relevant sections the differences and similarities that are briefly mentioned in the conclusions section.

We thank the reviewer for this comment. We decided not to move this paragraph, as no pre existing section was thought to be relevant (for instance, section 4.3 is about sensitivity to cloud shape and not a comparison between previous studies and our results), and we did not want to create a new section for this short discussion.

Specific comments

Table 1. L hasn't been introduced yet.

We corrected this in the table 1.

Line 154: I cannot see the vertical line mentioned here in Fig. 2b

We corrected Fig. 2.

Line 168: Please, be more specific instead of "cf"

Corrected in the text l.173 (l. 185 in the track changes file)

Figure 4: Fig 4b should have the colored light shadowing? I was expecting something more like Fig. 4c. In addition, "Blue" are black lines right?

We precised the legend: the shadowings in panel (b) correspond to the range of 3D effects. We also corrected "blue" by "black".

Technical corrections

Figure 3: (a) in the SW, (b) in the LW instead of "(a) in the LW, (b) in the SW"

We thank the reviewer for their attention, we have corrected the legend.